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ABSTRACT

Let's (Not) Escalate This! Leadership and Communication in a Group Contest

Economic and social situations where groups have to compete are ubiquitous. Such group contests create both a coordination problem within and between groups. Introducing leaders may help to mitigate these coordination problems. However, little is known about the effect of leadership in group contests. We conduct a group contest experiment, comparing two types of leadership—leading-by-example and transactional leadership—and investigating the effect of communication between leaders. We find that the introduction of leaders tends to increase contest investment, except for when leaders of competing groups can communicate. Transactional leaders increase followers' investment through the allocation of a relatively larger share of the prize to followers who have invested more. Communication between leaders decreases contest investments when there is leading-by-example but not when there is transactional leadership. Overall, leaders do not mitigate the over-investment problem in group contests.

JEL Classification: C92, D03, D72, D74
Keywords: rent-seeking, group contest, leadership

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1 Introduction

At various layers of society and with different degrees of hostility, competitive situations are ubiquitous in society. Be it the competition for publishing scientific papers, lobby groups vying for their interests, political campaigns competing for voter support, or rivalry on an inter-country level. What all these examples have in common is the considerable amount of unproductive resources spent in this rat race. Political campaigning, for instance, illustrates the intensity of competitive resource allocation, with U.S. federal election spending reaching $14.4 billion in 2020 (Evers-Hillstrom, 2021, in press). Additionally, in the EU, lobbying efforts by tech firms alone exceeded €113 million annually, with companies like Meta and Apple collectively spending over €15 million (Jones, 2023, in press). Another domain of high-stakes competition is research and development (R&D), where global spending has reached almost $1.7 trillion globally in 2021 (source: UNESCO), aiming to outpace competitors in innovation. These examples highlight how vast amounts of resources are directed towards gaining an advantage, often with limited productivity for society as a whole.[1]

While competition often manifests as individual rivalries, a significant portion of contests involves teams or groups vying against each other. In political lobbying, for example, corporate coalitions frequently form to exert collective influence on policy outcomes (Bertrand, Bombardini, & Trebbi, 2014). Similarly, in R&D, collaborative networks of firms and institutions engage in contests to secure patents or technological superiority (Fleming, King III, & Juda, 2007). These team-based contests often display unique dynamics, as groups pool resources and strategies to outperform competitors. However, empirical studies highlight that such contests can lead to resource over-expenditure and inefficiencies, similar to individual-level contests. For instance, Baye, Kovenock, and De Vries (2005) demonstrate how competitive dynamics in litigation, modeled using an auction-theoretic framework, can lead to excessive legal expenditures driven by parties attempting to influence trial outcomes.[2]

These findings align with experimental studies on contests, where over-contribution is a pervasive phenomenon. One of the most widespread models for (group) contests is the lottery game by Tullock (1980) or Katz, Nitzan, and Rosenberg (1990), where the winning probability increases with higher relative spending.[3] The vast majority of experiments on rent-seeking or contest games find contributions that are significantly higher than the Nash equilibrium prediction (Sheremeta, 2018, 2013; Dechenaux, Kovenock, & Sheremeta, 2015; Öncüler & Croson, 2005), causing rent over-dissipation and inefficiency. Sheremeta (2018) reviews the types of explanations that have been offered for this behavior: Most prominently, there is evidence for a motivational drive for coming out ahead of the other party.

[1] Consider also the global total military budget of $2.443 billion in 2023 (source: Stockholm International Peace Research Institute (SIPRI) Military Expenditure Database), equivalent to 2.3 percent of global gross domestic product (GDP), which is dedicated solely to being adequately equipped to face outside (or inside) challenges to the national interest.

[2] Inefficiencies can be further exacerbated by structural asymmetries between competitors, such as differences in resources or capabilities, which can trigger a "discouragement effect" among weaker contestants. Llorente-Saguer, Sheremeta, and Szech (2023) demonstrate this phenomenon in experimental studies, showing that greater heterogeneity between contestants reduces effort by the weaker party.

[3] See Konrad (2009) for a detailed discussion of this game concept.

Groups engaging in contests are often structured hierarchically, with leaders playing a crucial role in shaping group dynamics, particularly in managing coordination, motivation, and decision-making. Leadership can mitigate challenges such as over-investment, with leaders fostering trust, sanctioning free-riders, and attracting team-oriented participants to sustain collective action despite dilemmas like free-riding (Kosfeld, 2020). This study builds on these perspectives by exploring whether leadership can improve group welfare in contests for collective prizes. Previous research shows that in games where contributions are socially beneficial, such as public goods games, leaders help facilitate coordination and increase contribution levels and earnings (Kosfeld & Rustagi, 2015; Arbak & Villeval, 2013; van der Heijden, Potters, & Sefton, 2009; Potters, Sefton, & Vesterlund, 2007). For example, Rondeau and List (2008) find that leading donors can significantly increase following contributions in charitable donation contexts. [4] However, the impact of leadership in group contests remains less clear. Pittinsky and Simon (2007) highlight that strong leadership can foster ingroup cohesion but may also escalate intergroup conflict due to the ingroup/outgroup leadership trade-off.

Evidence on the effects of leadership in contest games is very limited. Loerakker and van Winden (2017) study leading-by-example and emotional leadership treatments, where leaders either only make their contribution first or also induce emotions in followers through video clips. However, they find no significant impact on contribution levels. Eisenkopf (2014) also examines leadership in a contest game where a manager provides advice but does not contribute herself. Despite varying the manager's incentives, the study finds no strong effect on behavior between different incentive schemes.

Another important factor influencing contest dynamics is communication, which has been shown to improve coordination in various experimental settings. Even "cheap talk" communication can help players align their strategies, increasing efficiency and reducing conflicts (e.g., Leibbrandt & Sääksvuori, 2012; Sutter & Strassmair, 2009; Blume & Ortmann, 2007; Van Huyck, Battalio, & Beil, 1993). In contest games, communication between groups can also be pivotal. Cason, Sheremeta, and Zhang (2012) presents a relevant example in the context of a weakest-link contest, where inter-group communication leads to lower efforts and higher payoffs, while within-group communication drives higher efforts but reduces payoffs. While our study only allows inter-group communication between leaders, the literature suggests that such communication can help mitigate excessive competition by allowing leaders to coordinate their strategies, potentially reducing over-expenditure.

Our experiment investigates two types of leadership in a group contest. In addition to a baseline treatment, which is a symmetric group contest game without a leader, we employ four experimental treatments with a group leader. In these treatments we vary the leadership style between pure *leading-by-example*, where the leader is only the first mover, and *transactional leadership* where the leader can also redistribute the prize in case the group wins the contest. In addition, we vary the communication possibilities between leaders of competing groups, who can either not communicate or can engage in free-form text communication.

Our results show that leadership largely tends to increase contest expenditures, driven by a strong positive correlation between leader and follower investments (contrary to theoretical predictions of a negative correlation). Moreover, transactional leaders tend to

[4]In games with negative externalities, such as public bad games, treatments with leaders also reduce negative externalities (Moxnes & van der Heijden, 2003; Vyrastekova & van Soest, 2003).

incentivize followers to increase investments, by allocating a larger share of the prize to those who invested more. However, importantly, intergroup communication via free-form chat between leaders mitigates excessive spending, as leaders coordinate to reduce conflict.

The remainder of the paper is structured as follows. Section 2 explains the setup of our study and the procedures, Section 3 discusses equilibrium strategies for the treatments and alternative hypotheses, Section 4 presents the results, followed by a short conclusion in Section 5.

2 Experimental Design

We implement a design with four experimental treatments, where we vary leadership styles and communication possibilities between leaders, and a control treatment (*Baseline*) without leaders and communication. Below we first describe the *Baseline* treatment, followed by a description of the four experimental treatments. In each treatment we vary exactly one aspect ensuring clean inferences. Table 1 provides an overview of the treatments.

2.1 *Baseline* Treatment

Participants are sorted into groups of four, with two groups competing for a fixed prize repeatedly for 15 periods. They interact with the same other players throughout the experiment (partner matching).

Each period consists of the following stages:

1. Each player receives an endowment of $E = 120$ tokens and decides how much of it to invest into lottery tickets. Each ticket costs one token. The investment of player k in group K and player m in group M are denoted by v_k and v_m, respectively. Tokens not spent on tickets are added to the player's private account.

2. The total number of lottery tickets invested by each of the competing groups determines the probability of winning the contest. Specifically, the winning probability, or contest success function (CSF), follows Tullock (1980) and Katz et al. (1990) and is given by:

$$p_K\left(\sum_{k\in K} v_k, \sum_{m\in M} v_m\right) = \begin{cases} \frac{\sum_{k\in K} v_k}{\sum_{k\in K} v_k + \sum_{m\in M} v_m} & \text{if } \max_{i\in K\cup M}\{v_i\} > 0 \\ 1/2 & \text{otherwise} \end{cases}.$$

   Here, p_K represents the probability that group K wins against group M, which is given by the sum of all lottery tickets of group K divided by the total lottery tickets bought by both groups. The winning group is determined by a lottery draw, where the chance of winning increases with the number of tickets invested.

At the end of each period, the investment of each player in a group are made public to their group members. The aggregated investment of the competing group is also revealed, along with the winning probability. The winning group receives a fixed prize of 1,920 tokens, which is evenly divided among its members (that is, $z = 480$ tokens for each group member). The losing group receives nothing.

2.2 Experimental Treatments

In the experimental treatments, pairs of groups compete in a contest game as just described. Different from the *Baseline* treatment, and common to all four experimental treatments, before the first period, one participant in each group is randomly selected to move first, thereby being the *leader*, for the duration of the experiment. The other group members, the *followers* know about the leader's role, but the term "leader" is not used in the instructions, or anywhere else in the experiment. Instead, the leader is referred to simply as "member 1".[5]

Thus, in all experimental treatments, the leader invests in lottery tickets first. Their investment is made public to their group members before the other group members decide simultaneously. The treatments differ (i) in the way the prize is distributed among the members of the winning group, and (ii) whether or not the leaders can communicate. These differences are detailed below.

Ingroup leading-by-example (*Ingroup lbe*). In this treatment, the winning group splits the prize equally ($z = 480$ per player), as in the *Baseline treatment.* There is no communication possible.

Ingroup transactional leader (*Ingroup trans*) Here, the leader of the winning group receives the whole prize ($4z = 1,920$) and may redistribute it among their group members in any way. The redistribution is made public to the leader's group but not to the competing group. There is no communication.

Intergroup leading-by-example (*Intergroup lbe*) This treatment is identical to the *Ingroup lbe* treatment, except that the leaders of competing groups can communicate privately for 45 seconds via a free-form chat window before making their investment decisions. Thereafter, the leaders of the competing groups decide independently and simultaneously on their investments.

Intergroup transactional leader (*Intergroup trans*) This treatment combines elements of the *Intergroup lbe* and *Ingroup trans* treatments. Leaders can privately chat before deciding their investments as in *Intergroup lbe*, and the leader of the winning group receives the whole prize ($4z = 1,920$) and may redistribute it among their group members as in *Ingroup trans.*

[5] We intentionally refrained from explicitly labeling the participant in the leader role as "leader" to avoid priming participants with expectations about the nature of the role, which could induce a demand effect. By using the neutral term "member 1," we sought to minimize any preconceived biases or behaviors associated with the leader role that might be triggered by the label. Previous research, including the Pygmalion effect, has shown that labels can activate stereotypes or role-specific expectations, influencing behavior in ways that could distort the dynamics of the experiment. For instance, higher expectations of performance can lead individuals to unconsciously fulfill those expectations, which might inadvertently affect the outcomes (Eden, 1992). By avoiding such priming effects, we aimed to ensure that participants' behavior was driven by the experimental context, rather than predefined role expectations, thus preserving the integrity of the treatment contrast (leader vs. non-leader).

Table 1: Treatment overview

	Leader moves first	Leader receives prize and may redistribute	Leaders communicate
Baseline			
Ingroup leading-by-example	✓		
Ingroup transactional leader	✓	✓	
Intergroup leading-by-example	✓		✓
Intergroup transactional leader	✓	✓	✓

2.3 Procedures

This experiment was conducted using z-Tree (Fischbacher, 2007), with participants recruited via ORSEE (Greiner, 2015). A total of 360 participants took part giving, nine independent pairs of groups per treatment. Each participant was seated in a private cubicle to ensure anonymity. The experiment consisted of three parts. In the first part individual risk preferences were elicited using the method introduced by Eckel and Grossman (2002) (see also Dave, Eckel, Johnson, & Rojas, 2010), in the second part individual social value orientation (SVO) was measured, following the approach by Murphy, Ackermann, and Handgraaf (2011), and in the final part the group contest was implemented. The latter was referred to as "part 3" in the participant instructions. Instructions for each part were distributed sequentially right at the beginning of the respective part.[6] Participants were required to answer comprehension questions correctly before proceeding. Following part 3, participants completed a questionnaire covering demographics, self-assessed risk preferences (Dohmen, Falk, Huffman, et al., 2011) and inclination to reciprocity (Dohmen, Falk, Huffman, & Sunde, 2009).

The sessions were conducted at the BEElab of Maastricht University and lasted about 80 minutes.[7] Average earnings were €11.75 across all treatments. Each participant received a financial compensation for each part of the game as follows. For the risk elicitation task, we paid out the results of the gamble that the player chose. For the SVO measure, we followed the payment procedures of Crosetto, Weisel, and Winter (2019)'s "RING matching" procedure. Participants $[i \dots I]$ were ordered on a virtual ring, where i is connected as sender to $i+1$, $i+1$ is connected as sender to $i+2$, and so on, with I being a sender to i, which makes everyone both a sender *and* a receiver. One choice *per participant* was randomly selected and paid out as a sender and one choice was paid out as receiver. For part 3, the sum of all earnings over all periods was paid out. Participants were informed about their earnings in part 1 and part 2 only after part 3 was finished. The payment procedures were publicly known among the participants.

[6] A copy of the instructions is provided in Appendix B. Screen shots from the experiment interface are provided in an online appendix.

[7] Due to technical problems, we shortened the game to eight periods for two group pairs in the *Intergroup lbe* treatment. This was clearly announced before the start and results are robust to dropping the data of this session.

3 Equilibrium Strategies and Hypotheses

We start with the *Baseline* treatment and discuss the experimental treatments thereafter. Assuming standard preferences and common knowledge of rationality, the sub-game perfect equilibrium of the single-shot game constitutes a benchmark. Under risk-neutrality each player i maximizes their individual expected earnings, which are given by

$$\pi_i\left(\sum_{k\in K} v_k, \sum_{m\in M} v_m\right) = E + \frac{v_i + \sum\limits_{k\in K\setminus i} v_k}{v_i + \sum\limits_{k\in K\setminus i} v_k + \sum\limits_{m\in M} v_m} \cdot z - v_i,$$

where K is player i's group, M the competing group, E the initial endowment, v_i the player's investment, $\sum_{k\in K\setminus i} v_k$ the total investment of the other three group members, $\sum_{m\in M} v_m$ the total investment of the other group, and z the prize to win.

For this type of group contest a unique equilibrium exists only with regard to the aggregate group investments, whereas at the individual level multiple equilibria exist (Abbink, Brandts, Herrmann, & Orzen, 2010; Konrad, 2009). The equilibrium investment level for each group is $\sum_{k\in K} v_k = z/4$.[8] In our experiment with $z = 480$, this results in 120 tokens per group, and all combinations of individual investments that add up to 120 tokens per group are equilibrium investments, constituting a coordination problem. As the game is symmetric, a reasonable selection criterion is that every player invests equally (cf. Katz et al., 1990). Given the group size of 4, this results in individual investments of $v_i = 120/4 = 30$. Thus, under symmetry, a risk neutral player is predicted to invest 25% of the endowment $E = 120$.[9]

In the experimental treatments, the set of subgame perfect equilibria is more restricted. The leader (l) in the *Ingroup lbe* treatment invests $v_l = 0$ in the subgame perfect Nash equilibrium. They can expect the followers to fully compensate for this and spend $\sum_{i\in K\setminus\{l\}} v_i = (z/4) - v_l$, which is $\sum_{i\in K\setminus\{l\}} v_i = 120$ in our implementation. Assuming symmetry among the followers, each of them invests equally, that is, $v_i = 120/3 = 40$.[10] In the *Ingroup transactional leader* treatment, a leader motivated only by their own earnings would not redistribute the prize, but keep it completely for themselves. Knowing this, followers would not invest in the contest. Thus, the leader is the sole investor and invests the group equilibrium amount of $v_l = 120$ tokens.[11] In both *Intergroup* treatments,

[8] See Appendix C.1 for the derivation of the equilibrium. In the repeated game the set of equilibria is larger and not restricted to sequences of single-shot equilibria.

[9] When loosening the assumption of risk-neutrality and assuming homogeneity of risk preferences, equilibrium investment to the contest decreases with increasing risk-aversion (see, Appendix C.2 for a discussion when using conventional functional forms, such as constant absolute risk aversion (CARA) and constant relative risk aversion (CRRA)). Katz et al. (1990) also show that for differing levels of risk aversion between groups, the group with a higher level of risk aversion invests less. Furthermore they show that for an individual player, the added expected utility gain from an additional unit of investment decreases with the level of risk aversion. In equilibrium, players with a relatively lower level of risk aversion would invest relatively more.

[10] If a risk-neutral leader is faced with risk averse followers, given (the leader's belief of) the followers' level of risk aversion, they would invest $v_l = 120 - \sum_{i\in K\setminus\{l\}} v_i$, where $\sum_{i\in K\setminus\{l\}} v_i$ decreases with the level of risk aversion of followers (see Appendix C.2 and Abbink et al., 2010; Katz et al., 1990). Also, v_l will be lower for higher levels of the leader's risk aversion.

[11] As before, under risk aversion, the leader's investment would decrease with their level of risk aversion. Followers, however, would still not invest anything as they would still expect that the leader keeps the whole amount if the prize is won.

communication between leaders is cheap talk and equilibrium predictions are the same as in the treatments without communication.

In summary, under standard assumptions and risk-neutrality, equilibrium investment at the group level is the same in all treatments and amounts to 120. In the (subgame perfect) Nash equilibrium of all treatments but the *Baseline*, the following holds: *a*) In the *leading-by-example* treatments without redistribution, the leader invests zero, whereas the followers invest up to the equilibrium group level amount, thus investing more than in the *Baseline* treatment. *b*) In the *transactional leader* treatments, the leader invests the whole equilibrium group level amount, whereas the followers invest zero.

Table 2 summarizes these equilibrium predictions. In addition, in the last column, it shows the investment level that would maximize total monetary welfare across groups, which is to invest nothing and each group having a 50% chance of winning (Social Opt.). Zero investment is socially optimal because investing in the contest only influences winning probabilities without any productive benefit.

Table 2: Overview of equilibrium investments and social optimal investment

	Group level	Leader	Followers tot.	Followers each if symmetric	Social Opt.
Baseline	120	–	120	30	0
Ingroup leading-by-example	120	0	120	40	0
Ingroup transactional leader	120	120	0	0	0
Intergroup leading-by-example	120	0	120	40	0
Intergroup transactional leader	120	120	0	0	0

Note: (Subgame perfect) Nash equilibrium predictions under standard assumptions and risk neutrality. The *Baseline* treatment has no leader.

3.1 Alternative Hypotheses

Leaders may pursue different objectives, influencing follower behavior in varying ways. Contests combine aspects of intra-group dilemmas with inter-group competition. Investments are inefficient from an inter-group perspective but provide incentives to invest from an intra-group perspective, and a coordination problem with social dilemma characteristics at the individual group level. The latter aspect is reminiscent of public goods problems where it has been shown that leaders can increase investments (Kosfeld & Rustagi, 2015; Arbak & Villeval, 2013; van der Heijden et al., 2009; Potters et al., 2007). We therefore expect that leaders may increase investments, at least when no communication is possible between leaders of competitive groups. This leads to our first hypothesis:

Hypothesis 1. *Investment in the* Ingroup *treatments will be at least as high as in the* Baseline *treatment.*

There exists a stream of literature showing that communication—even when just *cheap talk*—can improve coordination (e.g. Leibbrandt & Sääksvuori, 2012; Sutter & Strassmair, 2009; Blume & Ortmann, 2007; Van Huyck et al., 1993). Cason et al. (2012) is especially interesting as their experiment design is related to our set-up. In their experiment two groups are competing in a weakest-link contest and they allow for within-group and inter-group communication. The find that inter-group communication leads to significantly lower efforts in the weakest-link game. Thus, for our experiment, this literature suggests that communication between leaders may help to coordinate on more efficient investment levels. Accordingly, we formulate our next hypothesis:

Hypothesis 2. *Investment levels are lower in the* Intergroup *treatments than in the* Ingroup *treatments.*

The standard assumptions equilibrium investment levels predict that there is a strong negative correlation between leader and followers investments: depending on the treatment, either leaders invest the group equilibrium amount and followers nothing, or followers together invest this amount and leaders nothing (see Table 2). However, there is evidence that leader behavior can serve as a signal or sacrifice and that others follow the example (e.g., Hermalin, 1998; Potters, Sefton, & Vesterlund, 2005), for instance, out of reciprocity motives (e.g., Meidinger & Villeval, 2002). Accordingly, we expect that a high investment by the leader spurs followers to invest as well and that a low investment by the leader dissuades followers from investing. Thus, we expect:

Hypothesis 3. *In all treatments with leaders, there exists a positive relationship between leader and follower investment.*

Players may not only care about the monetary value of the prize, but winning as such may be a component of individual utility (e.g., Schmitt, Shupp, Swope, & Cadigan, 2004; Dohmen, Falk, Fliessbach, Sunde, & Weber, 2011).[12] In the *transactional leader* treatments, a leader may want to increase the chance of winning by using their investment as a signal and reward those followers more who invest more. In this case, leaders' redistribution behavior significantly deviates from the standard assumptions prediction of no redistribution. Specifically, a leader redistributes positive amounts to followers and distributes more to followers who behave according to the leader's benchmark.

Another motivation for prize redistribution is that leaders may be inequity averse and willing to incur material costs in order to reduce inequality (Fehr & Schmidt, 1999; Bolton & Ockenfels, 2000). Such leaders allocate a larger part of the prize to high investment followers, because higher investment levels make followers relatively poorer and leaders can close the earnings gap through the prize allocation.

Hypothesis 4. *In the* transactional leader *treatments, there exists a positive relationship between followers' investment levels and the prize redistributed towards them by the leader.*

[12] Sheremeta (2010) shows that more than 40% of experiment participants were willing to submit positive contest contributions to a contest with a prize value of $0.

4 Results

This section is divided into four parts. First we present general investment patterns and corresponding treatment differences, before turning to leaders' and followers' behavior, respectively, followed by an analysis of the leaders' communication pattern and its relation to contest investments.

We apply non-parametric methods for hypotheses testing: Mann-Whitney U (MWU) tests (Mann & Whitney, 1947) for independent sample tests and Wilcoxon signed-rank (WSR) tests (Wilcoxon, 1945) for paired tests. Furthermore, we use the Kruskal-Wallis (KW) test (Kruskal & Wallis, 1952) and Dunn's test (Dunn, 1964) with a false discovery rate (FDR) adjustment by Benjamini and Hochberg (1995) for tests involving more than two comparisons. To test for trends we use the non-parametric test developed by Cuzick (1985). If not stated otherwise, we use data on paired group level (eight players) as independent unit of observation and apply two-sided tests. For each treatment we have nine group pairs.

4.1 General Contest Investments

Figure 1 shows overall contest investments for all treatments. The dashed horizontal line at 120 represents the (risk neutral, standard preferences) Nash equilibrium benchmark as reference. In all treatments we observe strong over-investment with groups on average investing almost three times the risk neutral equilibrium prediction (WSR test: group invest = 120, $p < 0.001$). Results from a KW test indicate that there exist differences between treatments (KW test: $p = 0.023$). Pairwise comparisons using Dunn's tests show that investment levels in the *Baseline* treatment tend to be lower than in the *Ingroup trans* treatment ($p = 0.095$). Furthermore, investment levels in the *Intergroup lbe* treatment are lower than in all other treatments ($p \leq 0.032$), with the exception of *Baseline*, which is statistically not different ($p = 0.219$) (see Table 3). We summarize these comparisons in our first result.

Table 3: Pairwise comparison of group investment levels between treatments (Dunn's test with Benjamini-Hochberg FDR correction)

Column mean - row mean z test statistic (p-value)	Baseline	Ingroup lbe	Ingroup trans	Intergroup lbe
Ingroup lbe	−1.364 (0.144)			
Ingroup trans	−1.777 (0.095)	−0.413 (0.425)		
Intergroup lbe	1.023 (0.219)	2.387 (0.028)	2.800 (0.026)	
Intergroup trans	−1.472 (0.141)	−0.108 (0.457)	0.305 (0.422)	−2.495 (0.032)

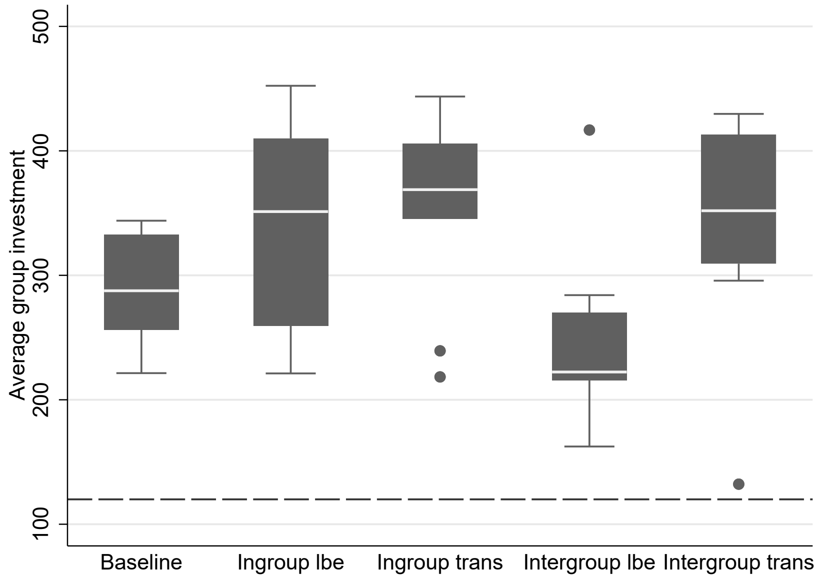

Figure 1: Investment in the contest. The white horizontal line indicates the median, boxes stretch from upper to lower quartile. Whiskers indicate largest and lowest value, excluding outliers, which are indicated by single dots.

Result 1. *(a) All contest investment levels are above the standard Nash equilibrium prediction. (b) In treatments with leaders but without communication (*Ingroup *treatments), contest investment levels are equal to or tend to be higher than investments in the* Baseline *treatment. (c) Leading by example with intergroup communication (*Intergroup lbe *treatment) leads to a decrease in contest investments.*

These results clearly reject the standard Nash equilibrium prediction regarding group level investments. The results also provide support for Hypothesis 1, and some evidence in favor of Hypothesis 2, but in the *intergroup lbe* treatment only. For the *intergroup trans* treatment, investment levels are on an equally high level as in the other treatments.

Looking into the dynamics of investments, Figure 2 depicts the average group investment to the contest over the periods per treatment. Again, the standard assumptions risk-neutral Nash equilibrium is indicated at a level of 120. Looking at group levels in period 1, we see that the *Intergroup lbe* treatment displays a significantly lower investment level than all other treatments (KW test using group level data, $p = 0.029$, $N = 75$).[13] In both *Intergroup* treatments there exists a significant time trend. While there is a positive trend for the *Intergroup trans* treatment (Cuzick test: $p = 0.072$), *Intergroup lbe* displays a decreasing investment level over time (Cuzick test: $p = 0.022$). The other three treatments display no trend (Cuzick tests, $p \geq 0.24$).

Result 2. *Investment levels decrease over time when leaders can communicate but cannot redistribute the prize (*Intergroup lbe*). In contrast, with communication between leaders and redistribution possibility (*Intergroup trans*) investment levels tend to increase over time.*

[13] See also Table A2 for pairwise comparisons using Dunn's tests.

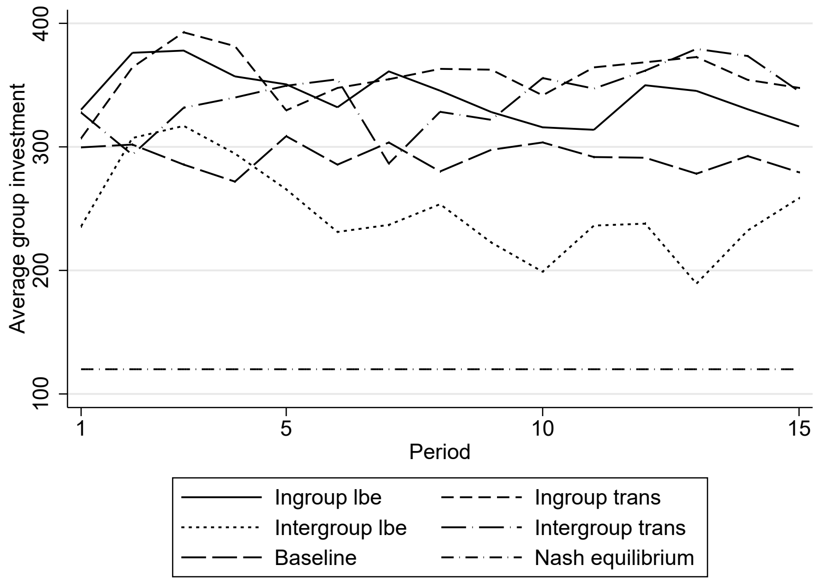

Figure 2: Investments in the Contest over the Periods

4.2 Leader Behavior

Figure 3 depicts leaders' investments in the leadership treatments aggregated over periods and shows that leaders invest at an overall comparable level, except for the *Intergroup lbe* treatment. However, statistical tests do not find significant differences across treatments (KW test: $p = 0.126$; pairwise comparisons using Dunn's test return $p \geq 0.062$, see Table A3).

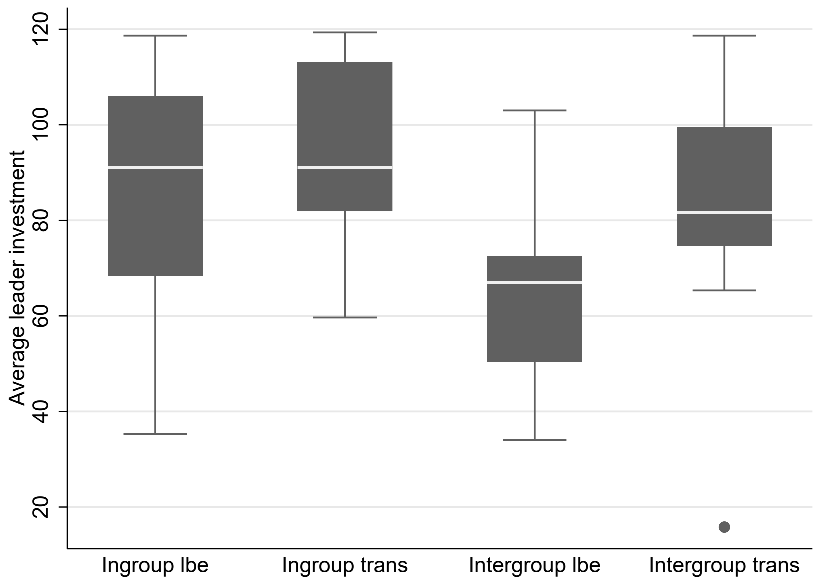

Figure 3: Leader investment in the contest. The white horizontal line indicates the median, boxes stretch from upper to lower quartile. Whiskers indicate largest and lowest value, excluding outliers, which are indicated by single dots.

Figure 4 shows average leader investment levels per period for each treatment with a leader. The left panel depicts *leading-by-example* treatments, in which the leader is merely a first mover in the game, whereas the right panel shows *transactional leader* treatments, in which the leader can also redistribute the prize. As reference, the dashed straight lines represents the respective Nash equilibrium. Notably, the different Nash equilibria for leaders' investments, seem not to have any effect on behavior. In terms of trend, we find some evidence for a difference between *leading-by-example* and *transactional* leaders. While leader investment levels for both *transactional* treatments show a positive trend (Cuzick tests at group pair level: *Ingroup trans* $p = 0.063$, *Intergroup trans* $p = 0.076$), the trends for the *leading-by-example* treatments tend to be negative (Cuzick test at group pair level: *Ingroup lbe* $p = 0.378$, *Intergroup lbe* $p = 0.083$). We summarize these results, which overall provide only weak partial evidence in favor of Hypothesis 2.

Result 3. *(i) Leaders in the* Intergoup lbe *treatment tend to invest less than in the other treatments. However, the effect is at best marginally significant. (ii) Over time, investment levels of leaders tend to decrease in* leading-by-example *treatments, but increase in* transactional leader *treatments.*

Next we examine potential determinants of leader behavior. Table 4 presents the results of GLS random-effects models with bootstrapped standard errors, analyzing the determinants of leader investment in period t. This panel data method accounts for both within- and between-individual variation, leveraging random effects to model the data structure efficiently. The random-effects approach allows us to explore how leader investment is influenced by other players' behaviors across treatments with leaders while accommodating potential correlation across observations within the same individual. Data from the *Baseline* treatment are excluded, as it does not involve leaders. We model leader behavior in period t to be potentially influenced by their on past investment, *Investment* $t-1$, the *Average follower investment* $t-1$, the *Other group's investment* $t-1$, and whether the leader's *Group won in* $t-1$. In addition, we allow for an influence of the time invariant factors of the leader's own social value orientation, *SVO angle* and own risk preferences, *Riskiness of Gamble Choice.*

The results from the regression analysis highlight some differences in the determinants

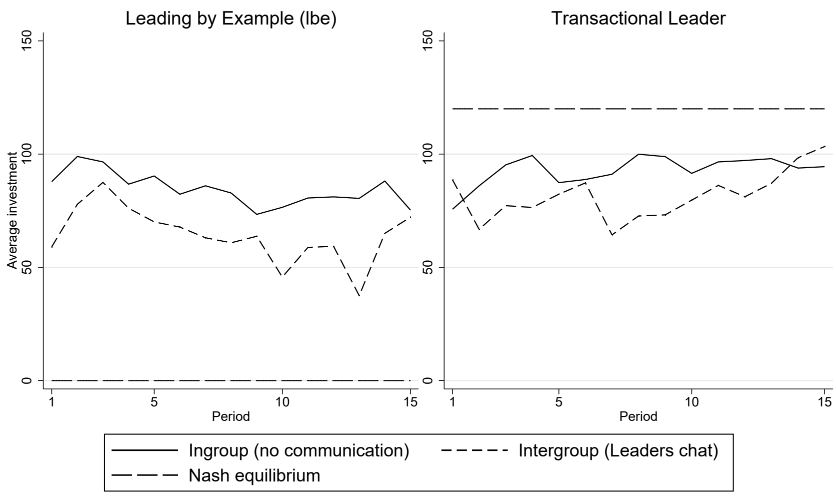

Figure 4: Investment to the Contest by Leaders only

Table 4: Determinants of leader investment in the leadership treatments

VARIABLES	(1) Ingroup lbe	(2) Ingroup trans	(3) Intergroup lbe	(4) Intergroup trans
	Leader investment in period t			
Investment $t-1$	0.583***	0.719***	0.336**	0.201
	(0.18)	(0.10)	(0.14)	(0.18)
Average follower	0.280	0.211*	0.102	0.113
investment $t-1$	(0.20)	(0.12)	(0.10)	(0.15)
Other group's	0.022	−0.015	0.031	0.119***
investment $t-1$	(0.02)	(0.01)	(0.02)	(0.02)
Group won in $t-1$	−6.695**	−0.814	−6.579	−16.346*
	(3.38)	(1.74)	(5.19)	(9.44)
SVO angle	−0.107	−0.176	−0.203	−0.241
	(0.23)	(0.17)	(0.58)	(0.29)
Riskiness of Gamble	0.446	−1.006	1.026	−1.523
Choice	(1.47)	(0.91)	(1.67)	(1.77)
Constant	5.331	24.902*	29.935	34.787
	(20.07)	(13.73)	(21.72)	(21.58)
Number of observations	252	252	224	252
Number of individuals	18	18	18	18
Within model R-squared	0.109	0.441	0.017	0.046
Between model R-squared	0.970	0.972	0.884	0.868
Overall R-squared	0.560	0.748	0.213	0.303

Note: GLS random-effects models; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Bootstrapped standard errors in parentheses. *Baseline* treatment omitted.

of leader behavior. While the own investment in $t-1$ has a significantly positive effect in both *Ingroup* treatments and the *Intergroup lbe* treatment, this is not the case for the *Intergroup trans* treatment. In the latter treatment, the other group's investment behavior exhibits a positive effect, in contrast to the other treatments where such an effect is absent. Interestingly, followers' investment in the previous period has only a small and mostly insignificant positive effect on leader investment. In all treatments, the effect of having won the contest in the previous period has a negative effect, but it is (marginally) significant only in treatments *Ingroup lbe* and *Intergroup trans.*

Result 4. *Leader investment behavior shows strong inertia in all treatments except for* Intergroup trans *where it is strongly positively related to the past investment of the competing group. In all treatments there is a trend that having won the contest in the past reduces leaders' investment levels.*

These findings provide little support for Hypothesis 3. Although the correlation between leader behavior and followers' past behavior is positive in all treatments it is marginally significant only in the *Ingroup trans* treatment.

In the transactional treatments, leaders have the ability to redistribute the prize. Figure 5 illustrates this relationship using a density-distribution sunflower plot (Dupont & Plummer, 2003), a method particularly effective for visualizing high-density bivariate data that might otherwise suffer from overstriking in a conventional scatterplot. The plot shows the relationship between the prize a follower receives ($\tilde{z}_i \in [0, 4z]$) and their investment relative to the leader's investment ($\tilde{v}_i = v_i - v_1 \in [-120, 120]$, where v_1 denotes the leader's investment and $i \neq 1$. The sign of $\tilde{v}_i$ indicates whether the follower contributes more ($\tilde{v}_i > 0$), less ($\tilde{v}_i < 0$), or an equal amount ($\tilde{v}_i = 0$) compared to the leader.

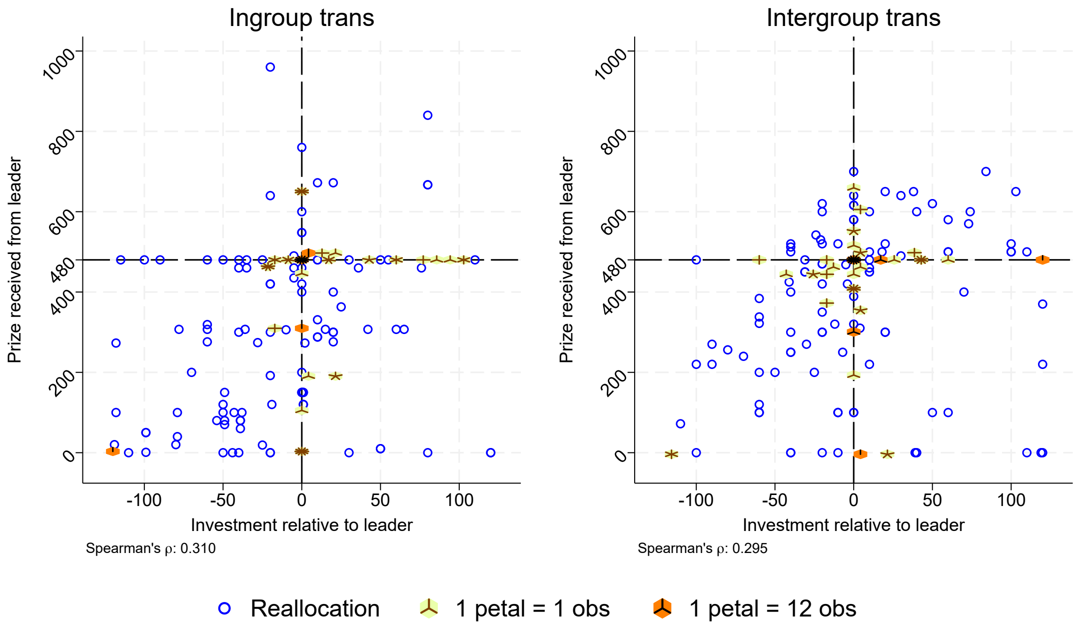

Figure 5: Reallocation of Prize by Transactional Leaders

The plot divides the x-y plane into 28 horizontal hexagonal bins, allowing a clear visualization of density across the range of investments.[14] Individual observations are plotted as small circles when there are fewer than l observations in a bin. Light sunflowers represent bins containing at least l but fewer than d observations, where each petal corresponds to a single observation. Dark sunflowers represent bins with d or more observations, with each petal corresponding to at least d observations. For this plot, $l = 3$ and $d = 13$. A dark sunflower with p petals represents between pd and $pd + d - 1$ observations. For instance: A dark sunflower with 1 petal represents between 13 and 25 observations. A dark sunflower with 2 petals represents between 26 and 38 observations. Thus, for a bin with exactly 14 observations, it would be depicted as a single-petaled dark sunflower.

Figure 5, also includes two reference lines for interpretation: (i) a horizontal line at 480, representing equal redistribution of the prize among all group members, and (ii), a vertical line at 0, where a follower invests at the same level as their leader. In the figure, two dominant strategic patterns can be recognized. First, followers tend to invest at the same level as the leader, which is illustrated by the high density of observations within the petal around a relative investment near zero ($\tilde{v}_i \in [-4.29, 4.29]$, comprising 55.9% of observations). Second, leaders reallocate an equal share of the prize, as evidenced by the accumulation of observations along the horizontal line at 480 ($\tilde{z}_i =\in [444.29, 515.71]$, which accounts for 60.1% of observations). These patterns create a cross, with approximately 78.4% of observations falling within this region.

[14] The bin size for the x-axis is 8.571, calculated for the range $[-120, 120]$ to create exactly 28 bins. See Dupont and Plummer (2003) for details on determining bin sizes.

Of the four regions outside this cross, the northwestern and northeastern quadrants contain few observations (7.7% of all observations, or 15.4% of observations outside the cross). This suggests that leaders generally do not reallocate more than an equal share, even to those who invest more than the leader. Observations outside the cross are predominantly located in the southwestern quadrant (61.1% of observations outside the cross). This area represents instances where leaders reallocate less than the equal share to followers with a negative relative investment. Additionally, for followers with extremely low relative investments ($\tilde{v}_i \leq -111.429$), we observe a clustering of 20 observations near zero redistribution ($\tilde{z}_i \leq 40$). This indicates that followers who fall far below their leader's benchmark receive close to nothing from the leader.

Regressions (1) and (2) in Table 5 examine the reallocation behavior of leaders, focusing on how they distribute prizes among followers. Using GLS random-effects models with bootstrapped standard errors, the analysis regresses a leader's prize allocation decisions in t on the relative investments of followers compared to the leader's own investment in t, *Investment relative to leader*, while controlling for the group's overall investment level in t, *Other followers' investment*, and the leader's own investment in t, *Leader investment*, as well the time-invariant variables *Riskiness of Gamble Choice* and *SVO angle*. Each leader forms a panel with three allocation decisions per period, corresponding to the three followers in their group.

Table 5: Determinants of leaders' redistribution decision in transactional leadership treatments

VARIABLES	(1) Ingroup trans Prize Allocated by Leader	(2) Intergroup trans Prize Allocated by Leader
Investment	1.814^{***}	1.259^{**}
relative to leader	(0.47)	(0.51)
Other followers'	−0.080	−0.232
investment	(0.34)	(0.27)
Leader investment	1.430^{**}	0.973^{**}
	(0.56)	(0.47)
Riskiness of Gamble	−15.519	−4.687
Choice	(12.28)	(6.06)
SVO angle	4.403^{**}	2.666
	(2.18)	(1.83)
Constant	265.497^{***}	358.390^{***}
	(74.29)	(64.72)
Number of observations	405	405
Number of individuals	18	18
Within model R-squared	0.182	0.078
Between model R-squared	0.453	0.229
Overall R-squared	0.279	0.112

Note: GLS random-effects models using data from followers in groups that have won in a given period.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Bootstrapped standard errors in parentheses.

Regression (1) shows the results for the *Ingroup trans* treatment and Regression (2) for the *Intergroup trans* treatment. In both treatments, the estimations reveal a strong positive effect of a follower's investment relative to the leader's investment. This supports the idea that leaders reward followers more who invest more. The investments of other followers in the group show no significant effect on prize allocation, indicating that leaders base their decisions on individual follower investments relative to themselves rather than group-level performance. Additionally, leaders who invest more themselves also allocate significantly more of the prize to their followers in both treatments, suggesting that leader investments are an indicator of their generosity or fairness. Consistent with intuition, leaders' social value orientation positively influences prize allocation, but it is significant only in the *Ingroup trans* treatment.

Together the findings show that leaders in transactional treatments show a concern for fairness in redistribution, but also reward higher investment and, thus, use prize allocations to incentivize higher investments. Overall, the results support Hypothesis 4. We summarize in our next result.

Result 5. *In* transactional *treatments, many leaders reallocate an equal share of the prize to followers. Furthermore, there is evidence for a positive relationship between follower investment levels and prize reallocation.*

4.3 Follower Behavior

Figure 6 shows contest investments of followers for all treatments with leaders, aggregated over periods. As for leaders, investment levels are lowest for the *Intergroup lbe* treatment. A KW test indicates that investments are different across treatments ($p = 0.047$), and pairwise

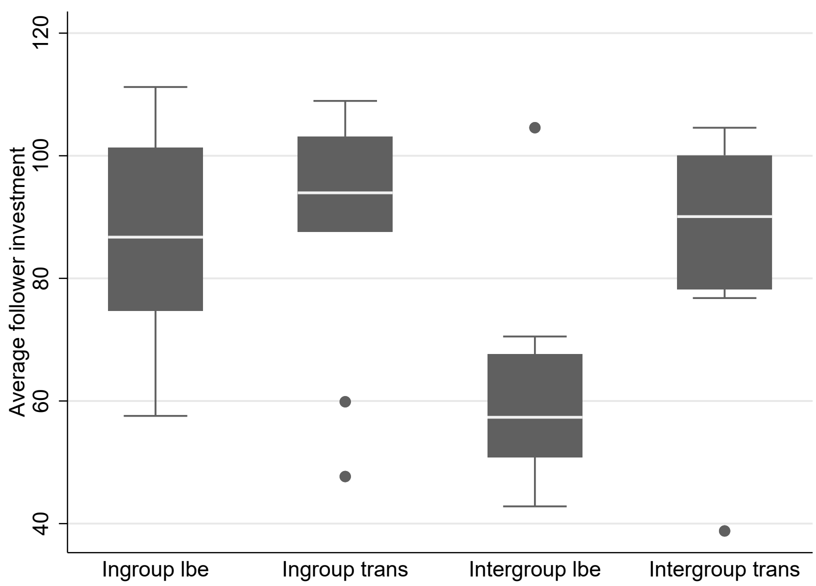

Figure 6: Follower investments in the contest. The white horizontal line indicates the median, boxes stretch from upper to lower quartile. Whiskers indicate largest and lowest value, excluding outliers, which are indicated by single dots.

comparisons show that follower investments in the *intergroup lbe* treatment are indeed lower than in any other treatment ($p \leq 0.039$). None of the other pairwise comparisons is significant ($p \geq 0.473$).[15]

Figure 7 shows average group investments for followers per period for each treatment with a leader. The left panel depicts *leading-by-example* treatments and the right panel depicts *transactional leader* treatments. The dashed straight lines represent the respective Nash equilibria for follower investment levels. As for leaders, the stark differences in the Nash equilibrium levels appear to have no effect on investment behavior. In line with the aggregate results, in each period, investment levels in the *intergroup lbe* treatment are lower than in all other treatments. Moreover, there is a significant negative trend in the *intergroup lbe* treatment (Cuzick test at group pair level, $p = 0.020$). In contrast, the trend tends to be positive for the *intergroup trans* treatment (Cuzick test at group pair level, $p = 0.092$) and insignificant for both ingroup treatments (Cuzick tests at group pair level, $p \geq 0.299$).

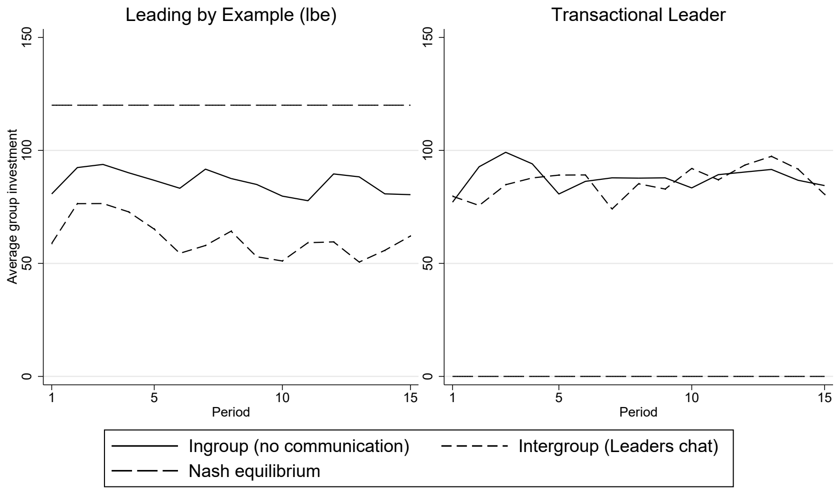

Figure 7: Investment in the Contest by Followers only.

We summarize these findings in the next result, which provides partial support for Hypothesis 2, as we find evidence in favor of it for the *Intergroup lbe*, but not the *Intergroup trans* treatment.

Result 6. *(i) Followers in the* Intergoup lbe *treatment invest significantly less than in the other treatments.(ii) Over time, investment levels of followers decrease in the* Intergroup lbe *treatment, but tend to increase or show no trend in the other treatments.*

Next we investigate potential determinants of follower behavior in the four leadership treatments. In Table 6, we present results of GLS random-effects models regressing a follower's investment in period t on a number of factors. Specifically, we allow follower investment in period t to depend on their own investment in the previous period, *Investment* $t-1$, *Leader investment* in the same period, the *Other group's investment* $t-1$, the investments of the other followers in the same group in the previous period, *Other followers' investment* $t-1$, and whether the own *Group won in* $t-1$ as well as the time-invariant

[15]Table A5 in the appendix reports all pairwise comparisons.

factors as the follower's risk preferences and social value orientation, measured by the *Riskiness of Gamble Choice* and *SVO angle*, respectively.

Table 6: Determinants of follower investment in the leadership treatments

	(1)	(2)	(3)	(4)
	Ingroup lbe	Ingroup trans	Intergroup lbe	Intergroup trans
VARIABLES	Follower investment in period t			
Investment $t-1$	0.363***	0.474***	0.254***	0.261***
	(0.07)	(0.06)	(0.04)	(0.06)
Leader investment	0.324***	0.220***	0.395***	0.513***
	(0.10)	(0.07)	(0.06)	(0.07)
Other group's	−0.017	0.007	−0.003	−0.007
investment $t-1$	(0.01)	(0.02)	(0.02)	(0.01)
Other followers'	0.065*	0.078**	0.058**	−0.018
investment $t-1$	(0.04)	(0.03)	(0.02)	(0.03)
Group won in $t-1$	1.836	−2.763	−6.050**	−1.706
	(1.95)	(3.12)	(2.70)	(2.59)
Riskiness of Gamble	0.049	−0.306	1.622**	−0.855
Choice	(0.50)	(0.78)	(0.69)	(0.99)
SVO angle	−0.036	0.517***	−0.000	0.110
	(0.10)	(0.15)	(0.18)	(0.16)
Constant	21.836**	3.837	7.500	32.817***
	(9.64)	(12.31)	(8.89)	(9.11)
Number of observations	756	756	672	756
Number of individuals	54	54	54	54
Within model R-squared	0.127	0.136	0.183	0.304
Between model R-squared	0.848	0.910	0.651	0.691
Overall R-squared	0.477	0.527	0.334	0.435

Note: GLS random-effects models; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Bootstrapped standard errors in parentheses. *Baseline* treatment omitted.

As for leaders, there is significant inertia in followers' behavior as their investment in the current period and their own investment in the previous period are highly correlated, in all treatments. Also common in all treatments, the leader's investment is a strong and significant predictor of follower investment. Other factors show mixed or limited effects. The investment of other followers in the group has a modest positive effect in the *Ingroup trans* and *Intergroup lbe* treatments but not in others. Investment levels of the competing group have no significant influence on follower behavior in any treatment. Winning the contest exhibits a negative effect in most treatments but is significantly only in the *Intergroup lbe* treatment. The same holds for the time-invariant factor of risk preferences, whereas the social value orientation is positively significant only in treatment *Ingroup trans*. We summarize the most robust findings of this regression analysis in the following result, which provides evidence in support of Hypothesis 3.

Result 7. *In all leadership treatments, follower investment behavior shows strong inertia and is strongly positively related with leader investment.*

Next we analyze in more detail the relationship between follower behavior and leader redistribution decisions in the *transactional leader* treatments. For this we focus on groups that won in $t-1$. Figure 8 employs a density-distribution sunflower plot to illustrate how a follower's willingness to invest (relative to the leader) relates to the leader's prize reallocation in the previous period. The plot shows the relationship between a follower's relative investment ($\tilde{v}_i$) and the prize they received from the leader in the previous period $\left(\tilde{z}_i^{t-1}\right)$.

We observe a clustering of followers investment at a level close to what the leader contributes ($\tilde{v}_i \in [-4.29, 4.29]$, representing 56.5% of the observations) and leaders reallocating the prize at an equal share level ($\tilde{z}_i^{t-1} \in [444.29, 515.71]$, comprising 33.2% of the observations). Altogether, 66% of all observations are concentrated near this cross. These dominant behavioral patterns define the boundaries for creating four domains in the graph.

The south-eastern domain remains nearly empty, with only three observations, all of which lie very close to the delimiters. This indicates that individuals who receive more than an equal split of the prize rarely invest less than the leader in the subsequent period. In contrast, a large number of observations outside the cross fall into the south-western domain (46.7% of the observations outside the cross), representing followers who received less than an equal share in the preceding period and who tend to invest less than the leader. The two northern domains also contain a significant proportion of observations outside the cross (52.1% of the observations outside the cross).

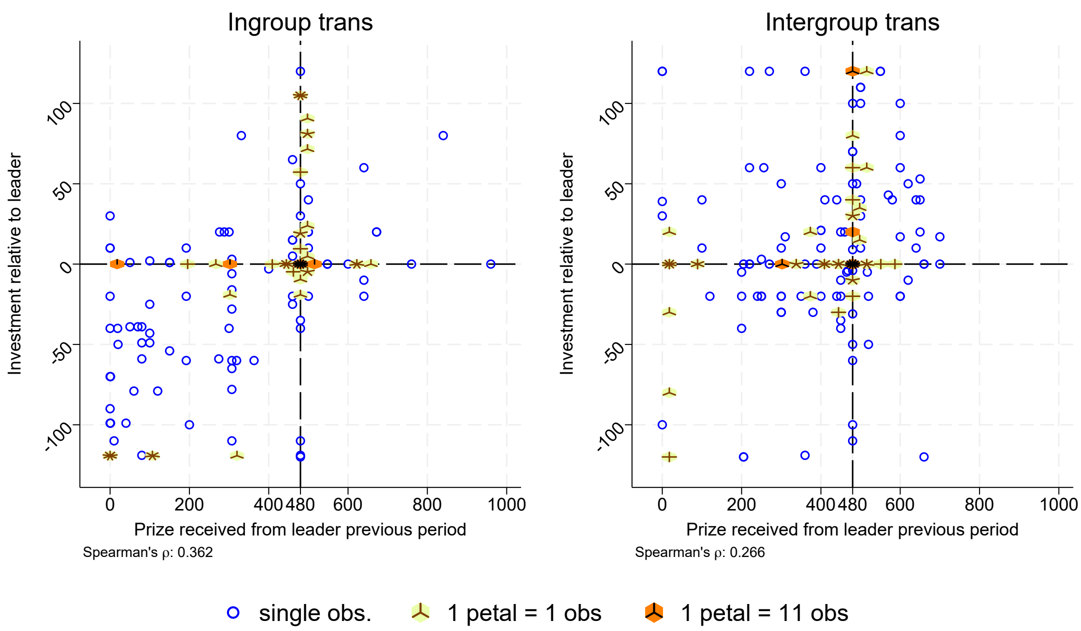

Figure 8: Followers' Relative Investment in Relation to the Prize they Received from the Leader in the Previous Period

Table 7 reports the results of GLS random-effects models investigating potential determinants of follower investment behavior in period t in groups that have won the contest in the previous period, $t-1$, for both *transactional leader* treatments. The explanatory variables are the *Share of the prize received from leader* $t-1$, the *Other followers' investment in* $t-1$, and the *Leader investment* t, as wells as risk preferences *Riskiness of Gamble* and social value orientation, *SVO angle*.

Table 7: Determinants of follower investment in in transactional leadership treatments for groups that won the contest in the previous period

VARIABLES	(1) Ingroup trans	(2) Intergroup trans
	Investment in period t	
Share of prize received	0.079^{***}	0.073^{***}
from leader $t-1$	(0.02)	(0.02)
Other followers'	0.095^{**}	0.050
investment $t-1$	(0.04)	(0.03)
Leader investment t	-0.767^{***}	-0.490^{***}
	(0.07)	(0.07)
SVO angle	0.599^{**}	-0.198
	(0.28)	(0.29)
Riskiness of Gamble	-0.653	-0.148
Choice	(1.22)	(1.37)
Constant	15.346	9.056
	(15.66)	(11.80)
Number of observations	378	378
Number of individuals	54	54
Within model R-squared	0.371	0.330
Between model R-squared	0.571	0.327
Overall R-squared	0.553	0.348

Note: GLS random-effects models; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Bootstrapped standard errors in parentheses.

In both treatments, receiving a higher share of the prize triggers significantly higher investments by followers. Interestingly, there is a significant negative relation between leader investment and follower investment indicating that followers in groups that won behave differently from followers in groups that lost (cf. Table 6). In addition, for the *Ingroup trans* treatment other followers' investment in the previous period and social value orientation have a positive effect on follower investments.

Result 8. *In groups that won the contest in the* transactional leadership *treatments there is a positive relation between followers investment and the share of the prize they received from the leader. In addition, in such groups higher leader investment reduces follower investment.*

The first part of this result indicates that also the inverse of the relationship discussed under Hypothesis 4 seems to hold: redistribution from the leader has a positive effect on followers' subsequent investment levels.

4.4 Intergroup Leadership: The chat contents

Prior to deciding on her investment level, each leader in the *Intergroup* treatments has the opportunity to communicate with the leader of the competing group via a chat window for 45 seconds each period. These conversations have been documented by the software and categorized by a research assistant who was not involved in this project in any other way. The assistant was not informed about the research question or about the hypotheses of this study. She read the entire chat history of all groups and sorted the messages according to categories, provided by us (see Table 8 for an overview of all categories). Messages can fall into multiple categories at a time. Figure 9 depicts the prevalence of messages fitting into the chat categories per treatment. We see that "low contribution" messages are being sent more frequently in the *Intergroup lbe* treatment than in the *Intergroup trans* treatment, while "bonding" or "small talk" are relatively less commonly used here.[16]

Table 8: Chat categories employed

Category	Criterion, i.e. "Conversation about..."
Low contribution	Investing an amount between 0-40 points
Medium contribution	Investing an amount between 41-80 points
High contribution	Investing an amount between 81-120 points
Alternate	Taking alternating turns in contributing
Bonding	Creating an emotional bond with each other
Small Talk	Non-game related casual conversations
Understanding	The rules of the game, clarifications
Efficiency	Deliberations about what would be the most "efficient" way to play
Followers' behavior	What the followers do / what they contribute
Give much to followers	Redistributing a significant sum of points to followers
Give little to followers	Redistributing only a minor sum of points to followers
Other	Any message that does not fall into any of the categories above

Using GLS random-effects models with bootstrapped standard errors, we examine how a leader's investment is influenced by the number and type of messages sent during a given period. Each message is categorized as described below. In addition, lagged values of the leader's own investment and a lagged group-win variable are included as controls. Table 9 presents the regression results for the *Intergroup lbe* treatment in Regression (1) and for the *Intergroup trans* treatment in Regression (2). This analysis is largely exploratory, and interpretations should be made cautiously.

First, messages discussing low contribution levels (e.g., 0–40 points) significantly reduce leaders' investment in both treatments. Messages emphasizing high contribution levels (e.g., 81–120 points) significantly increase investment, although the magnitude of this effect is higher in the *Intergroup lbe* treatment than in the *Intergroup trans* treatment. In contrast, discussions of medium contribution levels (e.g., 41–80 points) do not show significant effects in either treatment.

Alternate-turn strategies do not yield significant effects on investments, suggesting limited implementation of coordinated alternation strategies. Interestingly, bonding and small-talk messages significantly increase investment in the *Intergroup lbe* treatment. These messages, typically expected to foster emotional ties and reduce competitive spending, seem to escalate investment instead. This effect is not observed in the *Intergroup trans* treatment. Discussions categorized as "understanding" or "efficiency" do not have statistically significant effects on leader investment in either treatment. In the *Intergroup trans* treatment, leaders discussing giving little to followers significantly reduce their investment, while those expressing a preference to give much to followers significantly increase their investment.

[16] In the experiment we used the term "contribution" instead of "investment."

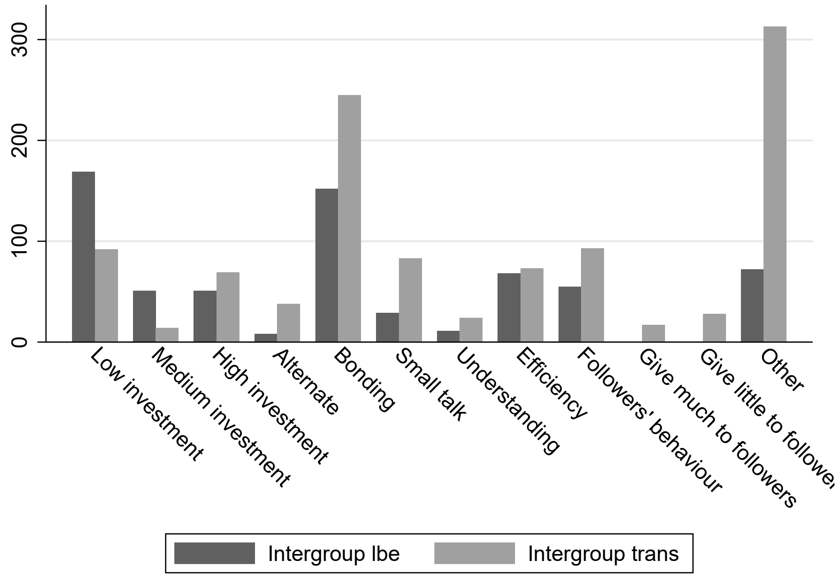

Figure 9: Prevalence of Chat Messages per Treatment

Regarding lagged effects, leaders' investment in the previous period $(t-1)$ are a strong positive predictor of current investment across both treatments, consistent with the other analysis of leader behavior. Also in line with previous analysis, the influence of winning the previous period $(t-1)$ differs between treatments: it significantly reduces investment in the *Intergroup trans* treatment but has no significant effect in the *Intergroup lbe* treatment.

The most interesting result of the chat analysis is the negative effect of the discussion of low investments. Together with the fact that such chats were most prevalent in the *Intergroup lbe* treatment (cf. Figure 9) this suggests an explanation why contest investments tend to be lowest in this treatment.

5 Conclusion

We investigate how leaders affect behavior in a group contest, complementing the studies by Loerakker and van Winden (2017) and Eisenkopf (2014). Specifically, we examine if leading-by-example, transactional leadership, and communication between leaders affect contest investments. Specifically, we are asking if the existence of leaders mitigates wasteful contest spending or escalates it.

Our results substantiate a pessimist view overall: Most leadership types do not reduce contest spending but rather tend to prompt an escalation of the contest, and transactional leaders tend to incentivize their group members to invest more resources in the competition. Importantly, communication between leaders of competing groups can have a mitigating effect on contest investment. However, this holds only when the leadership is not transactional but purely leading-by-example. The mitigating effect seems to come about because leaders talk about low investment levels and such talks are more prevalent when there is leading-by-example than when there is transactional leadership. However, even in the most

Table 9: Leader Investment as Function of Chat Contents

	(1)	(2)
	Intergroup lbe	Intergroup trans
VARIABLES	Leader Investment	
Low contribution	-13.579^{***}	-21.431^{***}
	(4.68)	(4.26)
Medium contribution	4.159	6.184
	(3.33)	(7.10)
High contribution	19.000^{***}	12.809^{**}
	(5.83)	(5.46)
Alternate	-2.695	-11.283
	(13.05)	(7.18)
Bonding	9.635^{***}	1.403
	(1.87)	(2.34)
Small talk	10.012^{***}	3.410
	(2.94)	(5.98)
Understanding	-0.007	7.106
	(19.07)	(7.78)
Efficiency	-1.540	-3.861
	(3.46)	(6.44)
Followers' behavior	5.348	5.110
	(4.09)	(3.44)
Give much to followers		11.839^{**}
		(5.95)
Give little to followers		-15.922^{**}
		(6.97)
Other	4.434	0.092
	(4.44)	(2.19)
Investment $t-1$	0.275^{***}	0.286^{***}
	(0.09)	(0.11)
Group won $t-1$	-6.016	-23.104^{***}
	(5.71)	(6.62)
Riskiness of Gamble Choice	1.130	-1.163
	(0.95)	(2.65)
SVO angle	0.039	-0.294
	(0.41)	(0.32)
Constant	38.272^{**}	82.265^{***}
	(15.40)	(16.85)
Number of observations	224	252
Number of individuals	18	18
Within model R-squared	0.179	0.154
Between model R-squared	0.824	0.842
Overall R-squared	0.402	0.369

Note: GLS random-effects models; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Bootstrapped standard errors in parentheses.

positive case general spending levels do not constitute a substantial improvement from the baseline level.

Our study only provides a starting point for research into the effect of leaders in contests. There are a number of possible avenues for future research. In our study we allow for communication between leaders of competing parties. One conceivable extension would be to consider also communication between leader and followers. Further, side-payments (as in Kimbrough & Sheremeta, 2013, 2014) or costly commitment (e.g. Kimbrough, Rubin, Sheremeta, & Shields, 2015) could constitute a promising vehicle for coordination between the groups. Prior research has employed these latter conflict resolution mechanisms for contests or other conflict models between individuals, only. The richer dynamics of a group setting with a leader could be an interesting and practically relevant extension of these studies.

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Appendix A Further Information on Parts 1 and 2

A.1 Measuring Risk Aversion

Prior to the group contest we take an individual risk preference measure. To this end we use an extended version of the method designed by Eckel and Grossman (2002). Players are confronted with a gamble choice as in Dave et al. (2010). They opt for one out of 11 gambles as presented in Table A1.[17] Each gamble has a 50:50 chance to either receive a low or a high payoff, respectively. While for Gamble 1 both payoffs are identical (representing the safe option), the alternatives gradually become more risky towards Gamble 11. At the same time, expected returns gradually increase from Gamble 1 to Gamble 9, with Gambles 9, 10 and 11 having an identical expected return. The gamble choice is designed such that risk averse players would choose a Gamble 1-8, a risk neutral player would go for Gamble 9 and a risk seeking player would opt for Gambles 10 or 11.

Table A1: Gamble choices

	Low Payoff	High Payoff	Expected Return	Standard Deviation	Implied CRRA Range
Option 1	28	28	28	0	$0.99 < r$
Option 2	26	32	29	3	$0.99 < r$
Option 3	24	36	30	6	$0.99 < r$
Option 4	22	40	31	9	$0.99 < r$
Option 5	20	44	32	12	$0.78 < r \leq 0.99$
Option 6	18	48	33	15	$0.64 < r \leq 0.78$
Option 7	16	52	34	18	$0.54 < r \leq 0.64$
Option 8	14	56	35	21	$0.46 < r \leq 0.54$
Option 9	12	60	36	24	$0 \leq r \leq 0.46$
Option 10	7	65	36	29	$r < 0$
Option 11	2	70	36	34	$r < 0$

This gamble choice method allows to elicit risk preferences in one step that is easy to understand and easy to implement. Furthermore, it allows for a parameter estimation giving an interval for the player's constant relative risk aversion (CRRA) of the form $u(x) = x^{1-r}$ with x being the wealth and r the coefficient of relative risk aversion (where $r < 0$ is risk seeking, $r = 0$ risk neutral and $r > 0$ risk averse). Dave et al. (2010) compare this method with other, more complex elicitation methods and find that it delivers a less noisy estimate for risk preferences.

A.2 Measuring Social Value Orientation

We take measures of individual social preferences. For this we make use of the SVO slider measure by Murphy et al. (2011).[18] Individuals set 15 sliders determining how to allocate tokens between themselves and another player, some of which are represented in Figure A1. This provides us with a measure for the most commonplace social orientations (for example

[17] The gambles were called "Option" in the experiment.
[18] Crosetto et al. (2019) provide a helpful tool for implementation.

altruistic, prosocial, individualistic, and competitive) and their relative weighing for the player.

The SVO slider measure constitutes a simplification and adjustment of the circle test employed by Brandts, Riedl, and van Winden (2009); Sonnemans, van Dijk, and van Winden (2006); Van Lange, De Bruin, Otten, and Joireman (1997). It has demonstrated reliable psychometric properties, yields scores for individuals at the ratio level and is quick and easy to implement (cf. Murphy & Ackermann, 2014).

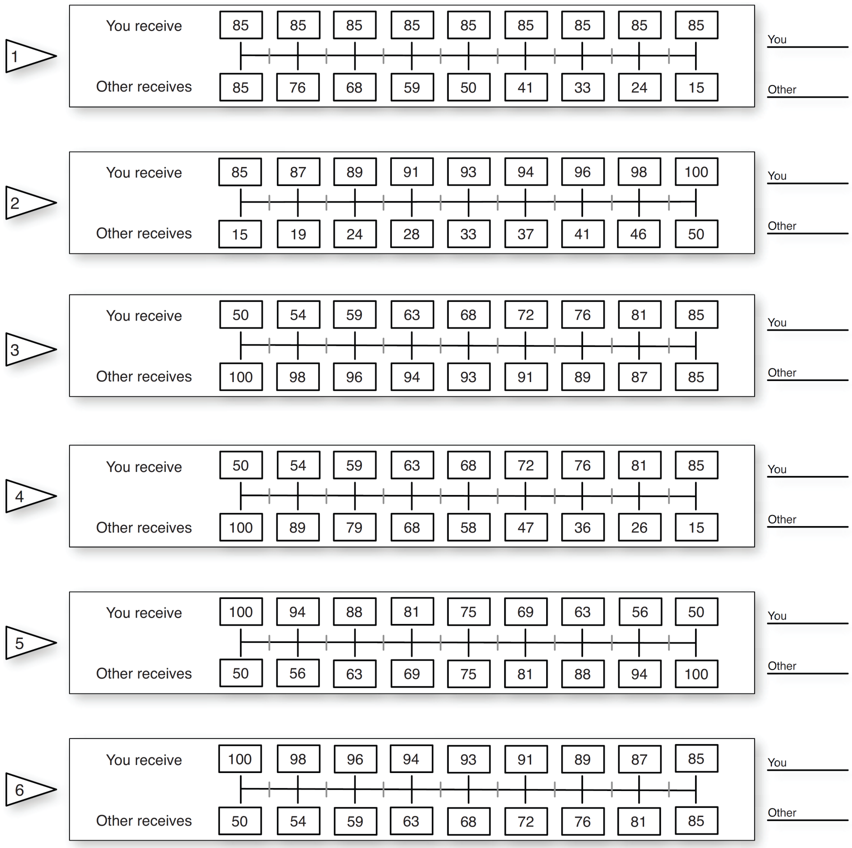

Figure A1: Examples for the slider questions as seen by the participants to measure Social Value Orientation.

Appendix B Instructions

The instructions consisted of three parts. Participants found part 1 with general information and introductions for the risk aversion measure[19] at their place when entering the laboratory. Once everyone was finished with this part of the experiment, the following set of instructions were distributed, which outlined the measurement of individual social value orientation.[20] After this part, participants received instructions for the main part of the experiment, which differed somewhat between the treatments, as outlined below. Paragraphs beginning with a treatment name in square brackets were only given to participants of that particular treatment.

[19] Find details in Appendix A.1

[20] see Appendix A.2

General Instructions

Welcome and thank you for participating in this experiment. In the experiment you can earn money with the decisions you make. Please read these instructions carefully. If you have any questions, please raise your hand and one of the experimenters will come to your cubicle to answer your question.

Talking or using mobile phones or any other electronic devices is strictly prohibited. Mobile phones and other electronic devices should be switched off. If you are found violating these rules, you will both forfeit any earnings from this experiment, and may be excluded from future experiments as well.

This is an experiment about decision making. The instructions are simple and if you follow them carefully you can earn a considerable amount of money which will be paid to you privately and in cash at the end of the experiment. The amount of money you earn will depend on your decisions, on other participants' decisions and on random events. You will never be asked to reveal your identity to anyone during the course of the experiment. Your name will never be associated with any of your decisions.

During the experiment you can earn points (the experimental money unit), which will be converted into cash at the end of the experiment, using an exchange rate of

40 points = 10 cent.

Thus, the more points you earn, the more cash you will receive at the end of the session.

This experiment consists of three parts. The following instructions explain part 1. After finishing that part, you will receive instructions for part 2 and after the end of part 2 you will receive instructions for part 3. None of your (or anyone else's) decisions for one part are affecting your (or anyone else's) earnings in the other parts.

All of your choices are completely confidential. You will learn your results of part 1 and part 2 after part 3 has finished. Points earned in each of the three parts will be added up to determine your total earnings.

Instructions part 1

This is an individual decision task and your choice will only affect you. You will be presented with six payoff options, of which you will have to choose one. Each option is associated with a low and a high payoff and both the high and low payoff are equally likely. At the end, after part 3 the computer will randomly pick either the low or the high payoff of the option you chose.

Instructions part 2

In this task you will be randomly paired with one other person in this room. You will make a series of decisions about allocating points between you and this other person.

One of your decisions will be picked randomly and you receive what you allocated to yourself and the other person receives what you allocated to her in this decision. Note that any of your decisions is equally likely to be chosen. Therefore you should treat each decision as if it is the one that counts.

One other person in the room will make such decision towards you. This is not the person you are randomly paired with.

Instructions part 3

In part 3, all participants are assigned to teams of four and your team will be randomly matched with another team. None of you will learn the identities of own team members or other team members. Part 3 will consist of 15 periods, and in each period you and the other participants can obtain a prize in the following way:

At the beginning of each period you will receive an endowment of 120 points. Then you can use none, parts or all of these points to buy lottery tickets for your team. Each lottery ticket costs 1 point. Any of your points not spent on lottery tickets will be accumulated in your private point balance. Likewise, each of your team members receives 120 points which they may use to buy lottery tickets for your team. Similarly, each member of the other team will receive 120 points and may buy tickets for their team in exactly the same way.

[Ingroup leading-by-example & Ingroup transactional leader] In your and the other group, one participant – member 1 – makes her / his decision before the others. Own team members will see, how many tickets this participant bought, before they make their decisions.

[Intergroup leading-by-example & Intergroup transactional leader] In your and the other group, one participant – member 1 – has been randomly selected to be able to communicate with one participant of the other group in private, via a chat window. This communication possibility will automatically expire after 45 seconds. Unless you are member 1, neither you nor any other participant will ever learn the contents of this communication. After that chat window has been closed, member 1 makes her / his decision. Own team members will see, how many tickets this participant bought, before they make their decisions.

After everybody has made the decision, a lottery will determine whether your team, or the team you are matched with, wins. The likelihood that a team wins depends in a proportional way on the total number of tickets, the team bought and on the total number of tickets, the other team bought. That is, if you and your team members bought in total X tickets, and the team members of the other team bought in total Y tickets, the likelihood that your team wins is $\frac{X}{X+Y}$ and the likelihood that the other team wins is $\frac{Y}{X+Y}$. Hence, the more tickets your (the other) team has, the higher is your (the other) team's chance of winning.

Examples: If your team and the other team have bought the same amount of tickets then each team is equally likely to win. If your team has bought three times as many tickets as the other team, then your team is three times more likely to win than the other team. If only one of the teams has bought tickets, then this team wins for sure. If neither your team nor the other team has bought any tickets, then each team is equally likely to win.

[Baseline, Ingroup leading-by-example & Intergroup leading-by-example] The winning team will receive a prize of 1,920 points in total, which will be split equally among group members. This delivers 480 points for each player of the winning group.

[Ingroup transactional leader & Intergroup transactional leader] The winning team will receive a prize of 1,920 points in total and member 1 will determine how the prize will be split among the group members. The losing team will receive nothing.

Summary: In part 3, your earnings in each period are determined as follows:

Winning team:

	Your Endowment (= 120)
-	Your tickets bought (between 0 and 120)
[Baseline, Ingroup leading-by-example & Intergroup leading-by-example]	
+	Prize (480)
[Ingroup transactional leader & Intergroup transactional leader]	
+	Share of the prize allocated by member 1 (between 0 and 1,920)
=	Your earnings

Losing team:

	Your Endowment (= 120)
-	Your tickets bought (between 0 and 120)
=	Your earnings

The points you earn in each period accumulate and your earnings in part 3 will be the total point earning from all 15 periods.

This part starts with a trial period in which you will be asked to answer some questions in order to check your understanding and to give you the opportunity to get acquainted with the setup. Points earned in this trial period will not be paid out.

Appendix C Standard Theoretical Predictions

C.1 Risk Neutral Equilibrium

Player i maximizes expected profit π_i by setting own investment $v_i = (v_i)_{i\in K}$. Investment of players $k \in K$ of own group K is labelled $\sum_{k\in K} v_k$, while players $m \in M$ in the other disjoint group M contribute $\sum_{m\in M} v_m$. Individual prize for winning a period is z. Solve individual optimisation problem for any period t, time indices are omitted.

$$\pi_i\left(\sum_{k\in K} v_k, \sum_{m\in M} v_m\right) = \frac{v_i + \sum\limits_{k\in K\setminus\{i\}} v_k}{v_i + \sum\limits_{k\in K\setminus\{i\}} v_k + \sum\limits_{m\in M} v_m} \cdot z - v_i$$

Deriving with respect to v_i delivers the best response function for any player i of group K:

$$\frac{\partial \pi_i\left(\sum_{k\in K} v_k, \sum_{m\in M} v_m\right)}{\partial v_i} = 0 \quad \Leftrightarrow \quad v_i = \sqrt{\sum_{m\in M} v_m \cdot z} - \sum_{m\in M} v_m - \sum_{k\in K\setminus\{i\}} v_k$$

Checking the second order condition confirms that we find a maximum:

$$\frac{\partial^2 \pi_i}{\partial v_i^2} = \frac{-\,2 \sum\limits_{m\in M} v_m \cdot z}{\left(\sum\limits_{k\in K} v_k + \sum\limits_{m\in M} v_m\right)^3} < 0$$

Using the first order condition of group M, we find a multiplicity of equilibria, characterized by $\sum_{m\in M} v_m = \frac{z}{4}$ and $\sum_{k\in K} v_k = \frac{z}{4}$. If we assume symmetry in own group: $v_i = \frac{z}{16}$.

C.2 Equilibrium with Risk Aversion

In this analysis we use techniques presented in Abbink et al. (2010); Katz et al. (1990). Let every agent maximize her individual concave utility function $u(\cdot)$, being identical for all players. For brevity, let $X = \sum_{k\in K} v_k$ and $Y = \sum_{m\in M} v_m$.

$$\frac{X}{X+Y} u(z + E - v_i) + \frac{Y}{X+Y} u(E - v_i) \tag{C.1}$$

As before, z is the individual prize to win, E is the individual endowment and v_i is a player's own investment. Differentiating (C.1) with respect to v_i and setting equal to zero:

$$\frac{Y}{X+Y}\left(u(z + E - v_i) - u(E - v_i)\right) = X u'(z + E - v_i) + Y u'(E - v_i) \tag{C.2}$$

For symmetric equilibria $X = Y$, so

$$\frac{u(z + E - v_i) - u(E - v_i)}{u'(z + E - v_i) + u'(E - v_i)} = 2X \tag{C.3}$$

CARA Under constant absolute risk aversion (i.e. exponential utility), let $u(\pi_i) = -e^{-\alpha\pi_i}$, with α being the measure of risk aversion. Set in to (C.3):

$$\frac{-e^{-\alpha(z+E-v_i)} + e^{-\alpha(E-v_i)}}{\alpha e^{-\alpha(z+E-v_i)} + \alpha e^{-\alpha(E-v_i)}} = 2X \tag{C.4}$$

We divide both numerator and denominator by $e^{-\alpha(E-v_i)}$ and rearrange:

$$X = \frac{1}{2\alpha} \cdot \frac{1-e^{-\alpha z}}{1+e^{-\alpha z}} \tag{C.5}$$

As shown in Abbink et al. (2010), $X = \frac{z}{4}$ if $\lim_{\alpha \to 0}$, which is the risk-neutral equilibrium. Deriving with respect to α delivers the slope of the function:

$$\frac{\partial X}{\partial \alpha} = \frac{ze^{-\alpha z}\left(2\alpha + 2\alpha e^{-\alpha z}\right) - \left(1-e^{-\alpha z}\right)\left(2+2e^{-\alpha z} - 2\alpha z e^{-\alpha z}\right)}{4\alpha\left(1+e^{\alpha z}\right)^2},$$

which simplifies to:

$$\frac{\partial X}{\partial \alpha} = \frac{e^{-2\alpha z} + 2\alpha z e^{-\alpha z} - 1}{2\alpha\left(1+e^{\alpha z}\right)^2} \tag{C.6}$$

Abbink et al. (2010) show that the slope is negative for all $\alpha > 0$ and $z > 0$. This means that departing from the risk neutral equilibrium at $\alpha = 0$ towards a higher level of risk aversion, equilibrium group investment decreases. To illustrate, Figure A2 depicts equilibrium group investment for specific α-values and $z = 480$.

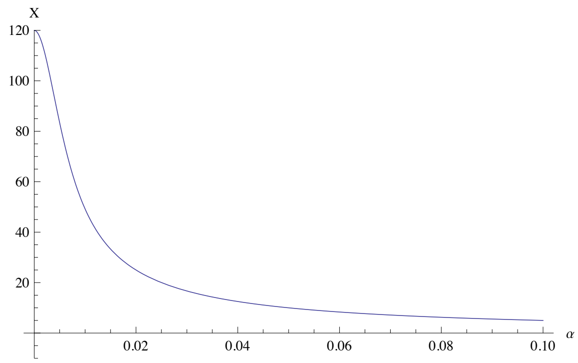

Figure A2: Equilibrium investment per contest group under CARA

CRRA We consider constant relative risk aversion, specified as $u(\pi_i) = \frac{\pi^{1-\rho}}{1-\rho}$, with ρ being the risk parameter. Set in to (C.3):

$$\frac{1}{1-\rho} \cdot \frac{(z+E-v_i)^{1-\rho} - (E-v_i)^{1-\rho}}{(z+E-v_i)^{-\rho} - (E-v_i)^{-\rho}} = 2X \tag{C.7}$$

Consider Figure A3 to see that investment for the contest decreases with risk aversion, under the assumption of symmetric behavior ($v_i = \frac{X}{4}$) and the parameters of the game ($z = 480, E = 120$).

Appendix D Dunn's Test Matrices

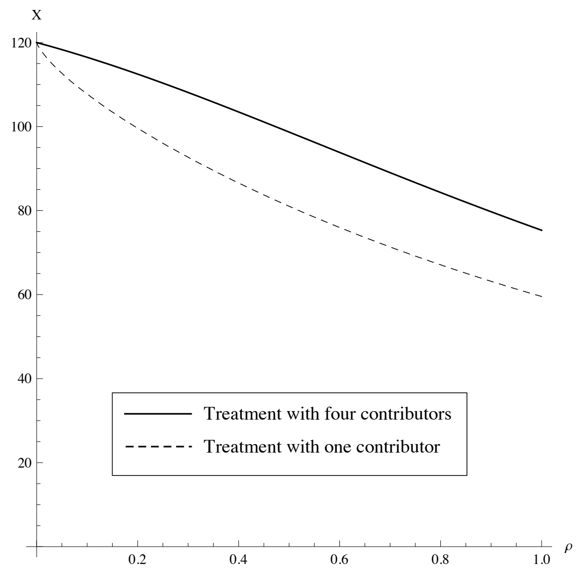

Figure A3: Equilibrium investment per contest group under CRRA

Table A2: Pairwise comparison of group investment in period 1 by treatment (Dunn's test with Benjamini-Hochberg FDR correction). Test at individual group level

Column mean - row mean z test statistic (p-value)	Baseline	Ingroup lbe	Ingroup trans	Intergroup lbe
Ingroup lbe	−1.082			
	(0.233)			
Ingroup trans	−0.399	0.683		
	(0.383)	(0.309)		
Intergroup lbe	1.691	2.773	2.09	
	(0.114)	(0.014)	(0.061)	
Intergroup trans	−1.184	−0.102	−0.785	-2.875^{**}
	(0.237)	(0.459)	(0.309)	(0.02)

Table A3: Pairwise comparison of leader investment by treatment (Dunn's test with Benjamini-Hochberg FDR correction). Test at group pair level.

Column mean - row mean z test statistic (p-value)	Ingroup lbe	Ingroup trans	Intergroup lbe
Ingroup trans	−0.671		
	(0.301)		
Intergroup lbe	1.645	2.316	
	(0.15)	(0.062)	
Intergroup trans	0.145	0.817	−1.499
	(0.442)	(0.311)	(0.134)

Table A4: Pairwise comparison of leader investment by treatment in period 1 (Dunn's test with Benjamini-Hochberg FDR correction). Test at individual group level.

Column mean - row mean z test statistic (p-value)	Ingroup lbe	Ingroup trans	Intergroup lbe
Ingroup trans	1.132		
	(0.193)		
Intergroup lbe	1.778	0.645	
	(0.113)	(0.3112)	
Intergroup trans	−0.057	−1.189	−1.834
	(0.477)	(0.234)	(0.2)

Table A5: Pairwise comparison of follower investment by treatment (Dunn's test with Benjamini-Hochberg FDR correction). Test at group pair level.

Column mean - row mean z test statistic (p-value)	Ingroup lbe	Ingroup trans	Intergroup lbe
Ingroup trans	−0.268		
	(0.473)		
Intergroup lbe	2.215	2.483	
	(0.04)	(0.039)	
Intergroup trans	0.067	0.336	−2.148
	(0.473)	(0.553)	(0.032)

Table A6: Pairwise comparison of follower investment by treatment in period 1 (Dunn's test with Benjamini-Hochberg FDR correction). Test at individual group level.

Column mean - row mean z test statistic (p-value)	Ingroup lbe	Ingroup trans	Intergroup lbe
Ingroup trans	0.068		
	(0.473)		
Intergroup lbe	4.683	4.615	
	(0.000)	(0.000)	
Intergroup trans	−0.226	−0.294	−4.909
	(0.493)	(0.577)	(0.000)