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Not all Group Members are created Equal: Heterogeneous Abilities in Inter-group Contests

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Not all Group Members are created Equal: Heterogeneous Abilities in Inter-group Contests[1]

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Abstract:
Competition between groups is ubiquitous in social and economic life, and groups are typically not created equal. Here we experimentally investigate the implications of this general observation on the unfolding of symmetric and asymmetric competition between groups that are either homogeneous or heterogeneous in the ability of their members to contribute to the success of the group. Our main finding is that, in contrast with a number of theoretical predictions, efforts in contests involving heterogeneous groups are higher than in contests involving only homogeneous groups, leading to reduced earnings (to contest participants) and increased inequality. This effect is particularly pronounced in asymmetric contests, where both homogeneous and heterogeneous groups increase their efforts. We find that asymmetry between groups changes the way group members condition their efforts on those of their peers. Implications for contest designers are discussed.

Keywords: Contests, groups, abilities, heterogeneity, experiments

JEL: C72, D72, C92, H4

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1. Introduction

Many situations in social and economic life are characterized by rivalry and conflict between two or more competing parties. Warfare, socio-political conflicts, political elections, lobbying, R&D competitions, and promotion tournaments, are all examples of inter-group conflicts in which groups spend scarce and costly resources in order to gain an advantage over other groups. Within each competing group, group members may differ with respect to a variety of characteristics such as preferences, resources, wealth, productivity, or motivation, which, in turn, can affect their ability and willingness to compete. Acknowledging that such within-group heterogeneity is the rule rather than the exception, a straightforward implication is that competing groups are rarely identical, and contests are typically not symmetric.

Examples abound. For instance, countries competing for access to natural resources or geopolitical influence will typically (if not always) differ with regard to the degree of diversity in society, such as the distribution of income, education, or other sociodemographic characteristics. In the domain of organizations, firms often rely on interfirm alliances to compete with other firms or alliances (for example in the context of developing new products). Such alliances can be *cross-function* when partners contribute diverse and complementary resources, or *same-function* when firms have similar competencies (Amaldoss and Staelin, 2010). The resulting competition can then be either symmetric (between two cross-function alliances or two same-function alliances) or asymmetric (between a cross-function and a same-function alliance). Within firms, asymmetric contests between heterogeneous teams can occur in the context of performance-contingent payment schemes, such as paying bonuses to the best performing team(s) in order to increase productivity (Nalbantian and Schotter, 1997; Bandiera et al., 2013). Within-team heterogeneity in such settings is only natural, as team members can have different skills or abilities. It follows that the competing teams themselves are also not necessarily similar, resulting in an asymmetric competition.[2]

Despite these rather natural applications, the behavioral literature on group competition has largely focused on situations in which symmetrical agents or teams compete against each other (see Dechenaux et al., 2015 and Sheremeta, 2017, for overviews). Whether the insights from this

[2] The effect of heterogeneity on effort when individuals rather than groups compete for a reward has been analyzed by Chen et al. (2011) and Orrison et al. (2004), and the behavioural consequences of heterogeneity in team production by Hamilton et al. (2003) and Brandts et al. (2007, 2016).

literature translate into more complex situations, however, is far from obvious as heterogeneity can affect conflict behavior in non-trivial ways. For example, while it has long been argued that belonging to a group can cause individuals to develop a feeling of group identity (Sherif et al., 1961; Tajfel and Turner, 1979), the salience of this group identity might be mitigated if group members are unequal. Furthermore, while team diversity is often thought of as creating positive synergy effects (Cox and Blake, 1991; Horwitz and Horwitz, 2007), heterogeneity within groups might also backfire as it can lead to a plurality of potentially conflicting behavioral rules and norms, which, in turn, may dampen coordination and collaboration (Reuben and Riedl, 2009).[3] In sum, "… the direction and magnitude of effects of team diversity on team outcomes have been an important question that is still not fully understood" (Horwitz and Horwitz, 2007, p. 988).

In the current paper, we systematically analyze and test how heterogeneity, both within and between groups, affects competition between groups. For ease of exposition, we will use the terms *homogeneous* and *heterogeneous* to describe within-group structures (i.e., whether group members are similar or not), and *symmetric* and *asymmetric* to capture the relationship between the groups (i.e., whether competing groups are similar or not). In particular, we are interested in how heterogeneity with regard to players' abilities to contribute to the group effort affects competition between groups. In our setting, a high-ability person is more efficient in converting her effort to a contribution to the group than a low-ability person, i.e., for each unit of invested effort, the former contributes more to the group than the latter. Heterogeneity in this respect is only natural, as some group members may be stronger, smarter, or wealthier than others. As an illustration, think of a team of salespersons, with one member that is more talented, experienced, or is endowed with a more densely populated sales territory, than the others. The high ability individual has a higher marginal productivity in the sense that even if all team members exert the same effort (in terms of, e.g., hours worked or energy expenditure), she will contribute more to the team's success than her less able peers.

We investigate the role of ability heterogeneity within and between groups with the help of a laboratory experiment. The major advantage of using a laboratory experiment is that it allows us to tightly distinguish between a player's ability and her effort choice, something that is almost impossible to achieve in the field, where one can typically only observe performance, which is a

[3] However, as shown by Chatman and Flynn (2001), these effects may be mitigated by learning and experience.

function of both effort and ability (and noise). It further allows us to exogenously manipulate the composition of players within groups, which circumvents complicating factors such as self-selection that emerge in most real-world situations where groups form endogenously. As a workhorse for studying group contests, we use an experimental version of Tullock's contest game (Tullock, 1980) in which two groups compete for a prize that is divided equally among all members of the winning group (see Konrad, 2009). Each group member decides how much of a given endowment to invest into the group's joint production and how much to keep for herself. The contribution of each individual to the group is deterministic (determined by the effort and the ability), and contributions by each group member are perfect substitutes. The group's probability of winning the contest is equal to the proportion of its total contributions out of the total contributions by both groups.

We study this basic decision situation in three different treatments. In the first treatment, we study the commonly explored symmetric contest between two homogeneous groups, in which all group members in both groups are equally able to compete. To study the pure effect of within-group heterogeneity, in the second treatment both competing groups are (equally) heterogeneous. In particular, each group consists of one low-ability, one medium-ability, and one high-ability player, while holding the average ability of group members constant compared to homogeneous groups (consisting of three medium-ability players). In the third treatment, we focus on the most interesting and natural situation in which the two competing groups differ from each other. To provide a clean comparison to the first two treatments, we examine an asymmetric contest between a homogeneous group and a heterogeneous group.

We establish three distinct theoretical benchmarks (see Section 2), assuming that individuals strive to maximize either their individual payoff (standard equilibrium), their team's joint earning (Joint payoff maximization, as in Leibbrandt and Sääksvuori, 2012), or the difference between their team and the other (parochial altruism, as in Abbink et al., 2012). Our results reveal that effort levels in contests involving heterogeneous groups are higher than in contests involving only homogeneous groups, and that this effect is particularly pronounced in asymmetric contests, where both homogeneous and heterogeneous groups increase their effort relative to the symmetric cases.[4]

[4] This result resembles the finding of Hamilton et al. (2003) who find that heterogeneous teams are more productive than homogeneous teams using field data from a manufacturing firm.

While overall effort levels are well captured by the joint payoff maximization predictions (efforts are significantly higher than the standard selfish prediction and significantly lower than the levels predicted by parochial altruism), none of the models capture the comparative statics we observe across treatments. Furthermore, in heterogeneous groups we find that—in contrast to all theoretical predictions, which agree in stating that only high-ability players should contribute, while low- and medium-ability players should free-ride, but in line with a notion of fairness—players of all ability levels contribute almost equally to the success of the group.

Intra- and inter-group dynamics—the way individuals condition their behavior on the past behavior of others—help explain these results. We find that individual choices are driven by a hierarchy of conditional behavior: individuals react to their own previous effort, their own group's effort, and the effort exerted by the other group, in that order. Interestingly, asymmetric competition exacerbates the sensitivity of homogeneous group members to the previous contributions of their group members, but there is no such effect for heterogeneous groups. Within heterogeneous teams, players of different abilities condition their effort on that of their 'relevant' peer, as in Croson et al. (2005, 2015) or Kölle (2015). Low- and medium- ability players—in both symmetric and asymmetric contests—mostly react to each other's past behavior, but not to that of high ability players. High players are sensitive to the behavior or their medium-ability group member, but only in symmetric contests; when the contest is asymmetric they become unconditional cooperators, as their contribution is not driven by the effort levels of their group members.

Finally, we show that asymmetric contests are not only more intense, but also more volatile, suggesting that facing a group that is different from your own can lead to an increase in strategic uncertainty. From a managerial perspective, the main policy lesson from our data is that asymmetric contests outperform symmetric ones, as group outcome is significantly higher. If managers are free to assign individuals to teams, and match groups with each other, our results suggest that asymmetric competition generates more overall output. Our design also allows us to quantify the risks of asymmetric contests. In particular, we find that from the perspective of the individuals who take part in the contest, asymmetric contests have two detrimental effects: they decrease individual earnings and they increase inequality within groups. To the extent that individuals who take part in the contest care about these aspects, there could be detrimental effects on the organization as a whole due to increased dissatisfaction (and, in turn, increased adverse behavior or higher turnover rates). Taken together, our results show that heterogeneity in abilities significantly affects contest behavior, and that these effects are strongest in the most natural setting where heterogeneity exists both within and between groups.

We contribute to the literature on inter-group contests by focusing on how heterogeneity in abilities affects the unfolding of competition. Previous studies primarily investigated symmetric contests between homogeneous groups, but a respectable (and growing) number of studies have looked into the effects of asymmetries in group size (Abbink et al., 2010; Ahn et al., 2011), endowments (Rapoport et al., 1989; Hargreaves Heap et al., 2015), costs (Ryvkin, 2013; Bhattacharya, 2016), prize evaluation (Sheremeta, 2011b; Chowdhury et al., 2013), communication (Cason et al., 2017), punishment (Sääksvuori et al.; 2011), and profit sharing rules (Kurschilgen et al., 2017), on the unraveling of competition between groups. However, none of these studies have investigated the role of heterogeneous abilities, and, in contrast to the current paper, most only investigated asymmetries either within or between groups, but not in conjunction.

A number of papers are of particular relevance to ours. Our general experimental design is reminiscent to that of Sheremeta (2011b), who analyzes symmetric and asymmetric contests under different contest rules between groups whose members differ in their evaluation of the prize. In line with our results, heterogeneous groups share labor much more equally than predicted by theory. In contrast to our findings, increasing heterogeneity does not lead to an intensification of conflict. Note, however, that Sheremeta (2011b) studies heterogeneity with respect to prize valuations, not in abilities, as we do in the current work. As shown by Kölle (2015) in a slightly different setting without competition between groups, heterogeneity in valuations can lead to very different behavioral reactions than heterogeneity in abilities as payoff consequences are very different between these two. Chen and Lim (2017) compare the effectiveness of homogeneous and heterogeneous sales teams under different contest rules. They find that while heterogeneity in abilities has no effect when the winner is determined by the average team effort, it does have detrimental effects when the winner is determined by the minimum or maximum effort level within each team. Note, however, that in Chen and Lim (2017) effort and ability are substitutes, while in our case a player’s ability determines her marginal productivity of exerting effort, i.e., effort and ability are complements. Our paper is further related to the studies by Ryvkin (2011) and Brookins et al. (2015) who analyze the effects of heterogeneity in players' cost of effort (which could be seen as another way to operationalize heterogeneity in abilities) on sorting into teams. In line with the theoretical predictions of Ryvkin (2011), Brookins et al. (2015) find that efforts are higher in balanced contests, where the average ability is held equal between the two groups, than in unbalanced contests, where the average ability in one group is higher than in the other. In contrast to our setup, they do not study the natural benchmark, featured in the bulk of the literature, of contests involving completely homogeneous groups.

The rest of the paper is organized as follows. Section 2 presents the general setup of our group contests as well as theoretical predictions. In Section 3 we describe our experimental design and procedures in more detail. Section 4 summarizes our results. Section 5 concludes.

2. Model and Predictions

Consider the following inter-group contests for public goods by Katz et al. (1990). Let there be $n = 2$ groups of $m \geq 1$ risk-neutral players each, competing to win a prize mV. All group members are endowed with the same amount of resources (e.g., time) w, which they can either use to help the own group win the contest, or they can use it for themselves (e.g., for an alternative private activity). Let $e_{i,j} \geq 0$ represent the effort (resources) spent by player i in group j. Importantly, players may differ in their ability to contribute to their group activity; a high-ability player is better able than a low-ability player in converting her effort to an actual contribution to the group. That is, her contribution to the group output is given by $x_{i,j} = e_{i,j} \cdot \alpha_{i,j}$, where $\alpha_{i,j}$ is the ability of player i in group j determining her marginal productivity of effort. We assume that individual group members' efforts are perfect substitutes, i.e., total effort of group j is given by $E_j = \sum_{i=1}^{m} e_{i,j}$ and the total contribution of group j is given by $X_j = \sum_{i=1}^{m} \alpha_{i,j} e_{i,j}$. Following Tullock (1980), the probability of group j winning the contest and securing the prize is given by the following contest success function:

$$p_j(X_1, X_2) = \begin{cases} \dfrac{X_j}{X_1 + X_2} & if\ X_1 + X_2 > 0 \\ \dfrac{1}{2} & otherwise. \end{cases}$$

When a group wins, each member of the winning group receives an equal share of the prize, V.[5] The expected payoff of player *i* in group *j* is then given by

$$\pi_{i,j}(x_{i,j}, X_1, X_2) = w - x_{i,j} + \frac{X_j}{X_1+X_2}V.$$

In our experiment (see Section 3), we consider two different type of groups, which can be either homogeneous or heterogeneous in the composition of the ability of their members. If follows that three types of inter-group contests can arise: two symmetric contests where both groups share the same internal composition in ability of their members (either homogeneous or heterogeneous), and one asymmetric contest with a homogeneous group competing with a heterogeneous one. The different contests may lead to different predicted outcomes. We describe below the resulting equilibria predicted under three distinct assumptions: players maximize either their own earnings; the joint-profit of the group; or the difference in earnings between their own and the competing group.

Under the standard assumption of purely *self-interested* individuals, following Konrad (2009), if all players in all groups are equally able to contribute to the group output, i.e., $\alpha_{i,j}$ is the same for all players (*symmetric homogeneous contest*), there is a unique equilibrium prediction for the total group effort that is the same as in a two-player contest and equal to $E_1 = E_2 = \frac{V}{4}$. Theory, however, remains silent about the behavior of individual group members: any combination of efforts that add up to $\frac{V}{4}$ constitutes an equilibrium. When both groups are heterogeneous but identical (*symmetric heterogeneous contest*), the prediction about the group effort level does not change, but there is a clear-cut prediction for the individual efforts. As contributions to the group are perfect substitutes and costs of effort are linear, in equilibrium only the member with the highest ability in each group should exert effort, while the other group members should free ride (see Baik, 2008, for a similar result when group members differ with regard to the evaluation of the prize).

When groups differ with respect to the most able group member (*asymmetric contests*), the group contest reduces to an asymmetric contest between the most able group members in each group. In

[5] Equal sharing rules are a common way to distribute bonuses within teams, e.g., in sports competitions, especially when efforts are not fully observable or not verifiable (see Kurschilgen et al., 2017, for a study on the effect of sharing rules in inter-group competition).

the following, we denote the ability of the most able member within each group by $\bar{\alpha}_j$. The solution is then given by simultaneously solving the two reaction functions of the optimal efforts of the two players, yielding $E_1 = \frac{(\bar{\alpha}_1\bar{\alpha}_2E_2V)^{\frac{1}{2}} - \bar{\alpha}_2E_2}{\bar{\alpha}_1}$ and $E_2 = \frac{(\bar{\alpha}_1\bar{\alpha}_2E_1V)^{\frac{1}{2}} - \bar{\alpha}_1E_1}{\bar{\alpha}_2}$. By denoting $\alpha = \bar{\alpha}_1/\bar{\alpha}_2$ as the relative ability between the most able player of both groups, the resulting unique symmetric Nash Equilibrium is given by $E_1 = E_2 = \frac{\alpha V}{(1+\alpha)^2}$, which for $\alpha \neq 1$ is strictly smaller than $\frac{V}{4}$. As a result, effort is predicted to be lower in asymmetric than in symmetric contests (see also Fonseca, 2009, for a similar result investigating heterogeneity between players in individual contests).

Experimental evidence from group contests typically shows a departure from standard predictions, with a general tendency of over-dissipation (see Sheremeta, 2017, for an overview). Possible explanations that have been put forward to explain such over-investments by groups are joint profit maximization (i.e., striving to maximize the sum of payoffs within the own group; Leibbrandt and Sääksvuori, 2012) or parochial altruism (i.e., the display of altruism towards in-group members along with hostility towards out-group members; Bernhard et al., 2006, Choi and Bowles, 2007; Abbink et al., 2012). When applying these concepts to our setting, compared to the standard predictions from above, the following qualitative predictions across treatments can be derived.

When players try to *maximize joint payoffs*, the objective function is given by $mw + \frac{X_j}{X_1+X_2}mV - E_j$. In this case, in symmetric contests the predicted effort is equal to $E_1 = E_2 = \frac{mV}{4}$, while in asymmetric contests aggregate effort is predicted to be $E_1 = E_2 = \frac{\alpha mV}{(1+\alpha)^2}$. Hence, while compared to the standard prediction of purely selfish players effort levels are predicted to be higher, it still holds that effort should be lower in asymmetric than in symmetric contests, and that in heterogeneous groups only high ability players should exert any effort.

If, instead, group members are motivated by *parochial altruism*, they strive to maximize the difference between their own and the other groups' payoff, $(\frac{X_1}{X_1+X_2}mV - E_1) - (\frac{X_2}{X_1+X_2}mV - E_2)$. In this case, the total effort exerted by each group in symmetric contests will be $E_1 = E_2 = \frac{mV}{2}$, which is higher than predicted efforts in asymmetric contests, given by $E_1 = E_2 = \frac{2\alpha mV}{(1+\alpha)^2}$. Both of these effort levels are higher than the ones predicted under the assumption of pure self-interest and joint payoff maximization. Yet, as before it holds that in heterogeneous groups only high ability players should be active, while in homogeneous groups any combination of efforts leading to the predicted aggregated effort is an equilibrium.

To summarize, while the three different assumptions about subjects' objective function lead to differences in absolute predicted total effort levels, they all share some common qualitative characteristics. First, irrespective of the type of contest (symmetric or asymmetric) homogeneous and heterogeneous groups are predicted to exert the same level of aggregate effort. Second, within heterogeneous groups only the member with the highest ability should exert any positive effort (the others should free ride), while in homogeneous groups there is a continuum of optimal effort combinations. Third, total effort is predicted to be lower in symmetric compared to asymmetric contests.

In our experiment (see below) we empirically test each of these predictions. With regard to the predicted effort levels within heterogeneous groups, we expect behavior to deviate from theory as it predicts an extreme distribution of labor, which, in turn, creates substantial inequality within groups. There is now ample evidence from a variety of contexts that many people care about the relative distribution of outcomes (see e.g., Fehr and Schmidt, 1999; Bolton and Ockenfels, 2000; Sobel, 2005; Fehr and Schmidt, 2006). Applied to our context, if players dislike inequality within groups they have an incentive to match their group members' efforts, as payoff equality can only be obtained if all group members exert the same level of effort, irrespective of their ability. For heterogeneous groups, this is in stark contrast to the theoretical predictions above which state that only the high ability player should contribute. Hence, if players are also motivated by fairness considerations within groups, we should expect a more equal distribution of labor in heterogeneous groups.[6]

[6] See Kölle et al. (2016) for a formal analysis of these effects in a related setting. One caveat with this analysis is that it makes it hard to derive any unique behavioural predictions. The reason is that when agents are inequity averse, this leads to a multiplicity of equilibria as in this case agents face a coordination problem in which they try to match each other's effort (in order to avoid inequality).

3. The Experiment

Our experimental game is based on the model described above. Subjects were randomly divided into three-person groups (m = 3). Each group was then matched with another, randomly selected, group (n = 2), to repeatedly compete for a prize for 45 consecutive periods using a *partner-matching protocol*. The prize was worth 300 points, to be shared equally among the members of the winning group (i.e., for each member V = 100). In each period, each group member received an endowment of 100 tokens (w = 100), which they could either use for their own private consumption or use to exert effort $e_i \in [0, 100]$ to increase the probability of the group winning the contest. There were three types of players, *low-ability*, *medium-ability*, and *high-ability*, which differed in the effectiveness of their effort. Homogeneous groups consisted of three *medium-ability* players, while heterogeneous groups consisted of one *low-ability* player, one *medium-ability* player, and one *high-ability* player.[7] Each token spent by a *low-ability* player yielded a contribution of one for the group ($\alpha_{low,j} = 1$); each token spent by a *medium-ability* player yielded a contribution of two for the group ($\alpha_{medium,j} = 2$); and each token spent by a *high-ability* player yielded a contribution of three for the group ($\alpha_{high,j} = 3$). Player types were assigned randomly and remained constant throughout the whole experiment. Importantly, both homogeneous and heterogeneous groups have the same total endowment (300 tokens) and the same strategy space (contributions between 0-600). Cross matching these two group types yields two symmetric contests and one asymmetric contest, for a total of three experimental treatments: *Symmetric-homogeneous*, *Symmetric-heterogeneous*, and *Asymmetric.*

The Experiment was conducted at LabSi (University of Siena) using z-Tree (Fischbacher, 2007). A total of 258 subjects were recruited for 15 sessions (13 with 18 subjects and 2 with 12 subjects each) resulting in 15 independent observations in symmetric homogeneous contests, 14 in symmetric heterogeneous contests, and 14 in asymmetric contests. At the beginning of each session, written instructions were handed out to participants and read aloud by the experimenter. After that, and before the start of the experiment, subjects had to correctly answer a set of control questions to ensure correct understanding of the incentives and structure of the game. At the end

[7] In the instructions given to participants we avoided loaded terms like ability. Instead, low-, medium-, and high-ability players were given the labels Blue, Red, and Green, respectively. For an English translation of the instructions, see Appendix B.

of the experiment, participants were paid their earnings in cash. Sessions lasted between 50 and 60 minutes, and subjects earned on average around €8.50.

Table 1 summarizes our experimental design as well as the theoretical predictions for each of the three conditions. Note, that the predictions for parochial altruism (players try to maximize the payoff difference between both groups) slightly differ from those derived in Section 2, because effort levels of players were capped at a maximum equal to individuals' endowment (*w = 100),* while in Section 2 there was no such constraint. While this cap does not change the prediction that in heterogeneous groups only the high-ability player should exert any effort, predicted group efforts in asymmetric contests are no longer the same for homogeneous and heterogeneous groups.

4. Results

We divide the presentation of our results into four subsections. In Section 4.1 we provide an overview of the main treatment differences. In Sections 4.2 and 4.3 we focus in more detail on individual, type- and group-specific behavior. Finally, in Section 4.4 we discuss the implications of the observed behavior on efficiency and inequality.

4.1. The effects of contest type on the degree of competition

Figure 1 summarizes the contest behavior in all three treatments, *Symmetric homogeneous*, *Symmetric heterogeneous*, and *Asymmetric.* The left panel depicts the development of group efforts over time (divided into 5-period blocks). The right panel shows the total average group efforts over all periods. The results reveal a clear pattern. We observe the lowest effort levels in symmetric-homogeneous contests in which two homogeneous groups compete against each other. Aggregated over all periods, group efforts amount to 67.2 tokens on average. When both groups are heterogeneous (symmetric-heterogeneous contest), group efforts increase by about 19% to 79.8 tokens. Surprisingly, in asymmetric contests with one homogeneous and one heterogeneous group, competition further intensifies. On average, group efforts increase to 93.3 tokens, which is 39% higher compared to the symmetric-homogeneous contest and 17% higher compared to the symmetric-heterogeneous contest.

Table 1: Summary of treatments and equilibrium predictions

	Effort [Group contributions] (winning probability)					
Treatments # Subjects [Contests]	*Selfish*		*Joint payoff maximization*		*Payoff difference*	
	Homogeneous group(s)	Heterogeneous group(s)	Homogeneous group(s)	Heterogeneous group(s)	Homogeneous group(s)	Heterogeneous group(s)
Symmetric homogeneous *N = 90 [15]*	$\sum_{i=1}^{3} e_{i,j}$=25 $[X_j = 50]$ $(p_j = 0.5)$	- - -	$\sum_{i=1}^{3} e_{i,j}$=75 $[X_j = 150]$ $(p_j = 0.5)$	- - -	$\sum_{i=1}^{3} e_{i,j}$=150 $[X_j = 300]$ $(p_j = 0.5)$	- - -
Symmetric heterogeneous *N = 84 [14]*	- - -	$e_{low,j} = 0$ $e_{medium,j} = 0$ $e_{high,j} = 25$ $[X_j = 75]$ $(p_j = 0.5)$	- - -	$e_{low,j} = 0$ $e_{medium,j} = 0$ $e_{high,j} = 75$ $[X_j = 225]$ $(p_j = 0.5)$	- - -	$e_{low,j} = 0$ $e_{medium,j} = 0$ $e_{high,j} = 100^*$ $[X_j = 300]^*$ $(p_j = 0.5)$
Asymmetric *N = 84 [14]*	$\sum_{i=1}^{3} e_{i,j}$=24 $[X_j = 48]$ $(p_j = 0.4)$	$e_{low,j} = 0$ $e_{medium,j} = 0$ $e_{high,j} = 24$ $[X_j = 72]$ $(p_j = 0.6)$	$\sum_{i=1}^{3} e_{i,j}$=72 $[X_j = 144]$ $(p_j = 0.4)$	$e_{low,j} = 0$ $e_{medium,j} = 0$ $e_{high,j} = 72$ $[X_j = 216]$ $(p_j = 0.6)$	$\sum_{i=1}^{3} e_{i,j}$=150* $[X_j = 300]^*$ $(p_j = 0.5)^*$	$e_{low,j} = 0$ $e_{medium,j} = 0$ $e_{high,j} = 100^*$ $[X_j = 300]^*$ $(p_j = 0.5)^*$

Note: Homogenous groups consist of three players who all have a medium ability of $\alpha_{i,j} = 2$. *Heterogeneous groups consist of three players with abilities* $\alpha_{low,j} = 1$, $\alpha_{medium,j} = 2$, *and* $\alpha_{high,j} = 3$. *These predictions are altered by the fact that in our experiment players' endowment was capped at w = 100.*

To test the significance of these results, we run multilevel linear mixed-effects regressions that take into account the inter-dependency of observations (repeated observations of individuals that are nested within a contest of two competing groups). The results are shown in Table 2. Model (1) reveals that while the differences between *Symmetric homogeneous* and *Symmetric heterogeneous* and between *Symmetric heterogeneous* and *Asymmetric* are not significant (p = 0.283 and p = 0.267, respectively), the equality of group efforts between *Symmetric homogeneous* and *Asymmetric* can be rejected at the 5% level (p = 0.028).[8]

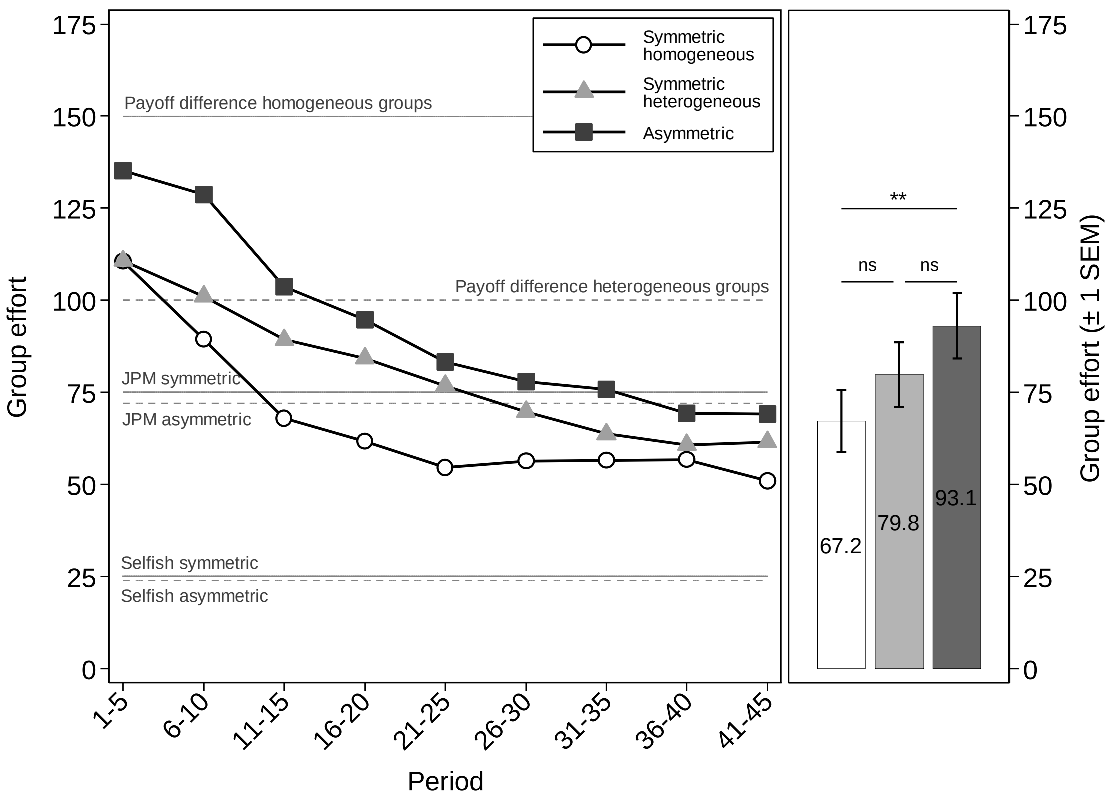

Figure 1: Group effort over time (left panel) and average group effort over all periods (right panel) across treatments. Reference lines in the left panel correspond to the theoretical predictions summarized in Table 1.

As is apparent from the left panel of Figure 1, these differences are robust over time and already present in the early stages of the repeated interaction (compare also model (2) in Table 2). Additionally, in line with previous results (e.g., Abbink et al., 2010, Sheremeta, 2010, 2011a;

[12] Using non-parametric tests yields very similar results.

Fallucchi et al., 2013; Brookins & Ryvkin, 2014), we observe that efforts significantly decrease over time in all treatments. This decay is thereby somewhat more pronounced in the asymmetric contest as indicated by the significant negative coefficient of the *Asymmetric* × *Period* interaction term in model (2) in Table 2 (see also Table A1 in Appendix A), suggesting that treatment differences slightly reduce over time. We summarize these findings in our first result:

> **Result 1**: *Compared to two homogeneous groups competing in a fully symmetric contest, heterogeneity in abilities within and in particular between groups leads to an intensification of competition.*

Table 2: Group effort by treatment.

Dependent variable: Group Effort	(1)	(2)
Symmetric-heterogeneous	12.612	14.079
1 if Treatment = Symmetric-heterogeneous, 0 otherwise	(11.758)	(11.842)
Asymmetric	25.895**	37.180***
1 if Treatment = Asymmetric, 0 otherwise	(11.758)	(11.842)
Period		-1.221***
		(0.042)
Period x Symmetric-heterogeneous		-0.064
		(0.061)
Period x Asymmetric		-0.491***
		(0.061)
Constant	67.191***	95.278***
	(8.170)	(8.228)
Test: Symmetric-heterogeneous = Asymmetric	*p = 0.267*	*p = 0.055*
Random intercepts:		
Contest	Yes	Yes
Group	Yes	Yes
Subject	Yes	Yes
Observations	11610	11610

Notes: Multilevel linear mixed-effects models using random intercepts for matching groups (a contest between two groups), groups, and individuals. Numbers in parentheses indicate standard errors. Significance levels * p < 0.1, ** p < 0.05, *** p < 0.01.

To what extent can these findings be explained by our theoretical predictions in Section 2? The left panel of Figure 1 shows the predictions of the different models as references lines. In line with results from previous studies on group lottery contests (see Sheremeta, 2017, for an overview), we find that effort levels in all treatments are way above the standard selfish equilibrium prediction (+169% symmetric-homogeneous contests, +219% in symmetric-heterogeneous contests, and +288% in asymmetric contests; Signrank tests, all $p < 0.002$). The predictions based on the assumption of parochial altruism, on the contrary, are above what we observe in our data. Relative to this benchmark, group efforts in *Symmetric homogeneous*, *Symmetric heterogeneous*, and *Asymmetric* amount to only 45%, 80%, and 75%, respectively, of the predicted level (Signrank tests, $p < 0.001$, $p = 0.006$, and $p = 0.041$, respectively).[9] It instead seems that our aggregate results are best captured by the predictions of joint payoff maximization. The deviations from the predicted levels are small and not significant (*Symmetric homogeneous:* -10%, $p = 0.281$; *Symmetric heterogeneous:* +6%, $p = 0.730$; *Asymmetric:* +29%, $p = 0.084$). Note, however, that none of these models can capture the comparative statics we observe across treatments, i.e., they cannot explain why effort increases when the contest involves heterogeneous groups.

In addition to the effect on the overall level of competition intensity, the type of contest—symmetric or asymmetric—also has an effect on the *volatility* of competition, both between and within groups. To measure between-group volatility, we calculate the absolute distance in group efforts between the two competing groups in a given period. We find that in asymmetric contests the average absolute difference in group efforts is substantially and significantly higher than in symmetric contests (47.2 vs. 37.4 (+26%); Mann Whitney U-test, $p = 0.047$). No such difference is observed between the two symmetric contest treatments (*Symmetric-homogeneous*: 38.0, *Symmetric-heterogeneous:* 36.9; Mann Whitney U-test, $p = 0.541$). To measure within-group volatility, we calculate how much groups change their efforts (in absolute terms) from one period to the other. We find that in symmetric contests, groups change their effort on average by 25.6 tokens between two consecutive periods, with no differences between symmetric-homogeneous and symmetric-heterogeneous contests (26.3 and 24.8, respectively; Mann Whitney U-test, $p = 0.513$). In asymmetric contests, in contrast, this measure amounts to 32.4 tokens, significantly more than in symmetric contests (+27%, Mann Whitney U-test, $p = 0.017$). Overall, these results suggest a substantially increased degree of volatility when contests are asymmetric. A possible reason for this result is that when facing a group different from your own, it becomes harder to put

[9] Note again that in this case, predictions for heterogeneous are limited by the high-ability player's endowment of 100.

oneself into the shoes of others and, hence, predict the opponent's behavior. As a consequence, strategic uncertainty increases, and behavior is less stable. We summarize these findings in our second result:

> **Result 2**: *When the contest is asymmetric, there is a substantial increase in the volatility of competition, both within and between groups.*

4.2. Group- and type-specific behavior

To understand what drives our treatment differences, we now zoom into group- and type-specific behavior. Panel A of Figure 2 depicts the average group efforts of homogeneous and heterogeneous groups, conditional on the type of contest (symmetric or asymmetric). It shows that both homogeneous and heterogeneous groups compete more aggressively in asymmetric contests, i.e., when faced with a group different from their own. This effect is particularly pronounced for homogeneous groups, who significantly increase their efforts from 67.2 to 97.5 tokens (+45%, linear mixed effects model, p = 0.023; see model (1) in Table A2 in Appendix A). For heterogeneous groups, effort also increases but this effect is much less pronounced (+11%, from 79.8 to 88.7 tokens) and not statistically significant (linear mixed effects model, p = 0.452; see model (2) in Table A2).

When comparing the behavior of the two different group types, we find that in contrast to our findings from the symmetric contests where heterogeneous groups exert more effort than homogeneous groups (compare Figure 1), in asymmetric contests we observe the opposite pattern. In this case, homogeneous groups exert more effort than heterogeneous groups (97.5 vs. 88.7). Strikingly, they even outperform heterogeneous groups in terms of actual contributions (effort × ability; 195.0 vs. 183.3), although neither of these effects is significant (linear mixed effects models, p = 0.313 and p = 0.531, respectively). As a result, heterogeneous groups do not utilize their comparative advantage over homogeneous groups as the latter win the contest in 49.8% of the cases, significantly more often than the 40% predicted by standard theory (Wilcoxon Signrank test, p = 0.022).

Next, we take a closer look at the type-specific behavior. Recall that heterogeneous groups consist of players of different abilities—one low-, one medium-, and one high-ability player—and that all theories considered in Section 2 predict that only the high-ability player exerts effort, while the other players are predicted to completely free ride. Our empirical results are in stark contrast to these predictions. In symmetric contests, the efforts of low-, medium-, and high-ability players are practically identical, accounting for 33%, 34%, and 33%, respectively, of the group's overall effort. This suggests that other motivations such as inequality concerns within the group matter for individual behavior, too. In asymmetric contests, the picture slightly changes. The efforts of low-, medium-, and high-ability players now account for 30%, 33%, and 37%, respectively, of the group's overall effort. This indicates that in asymmetric contests high-ability players take over a leading role by exerting more effort, an observation we will come back to in the next section.

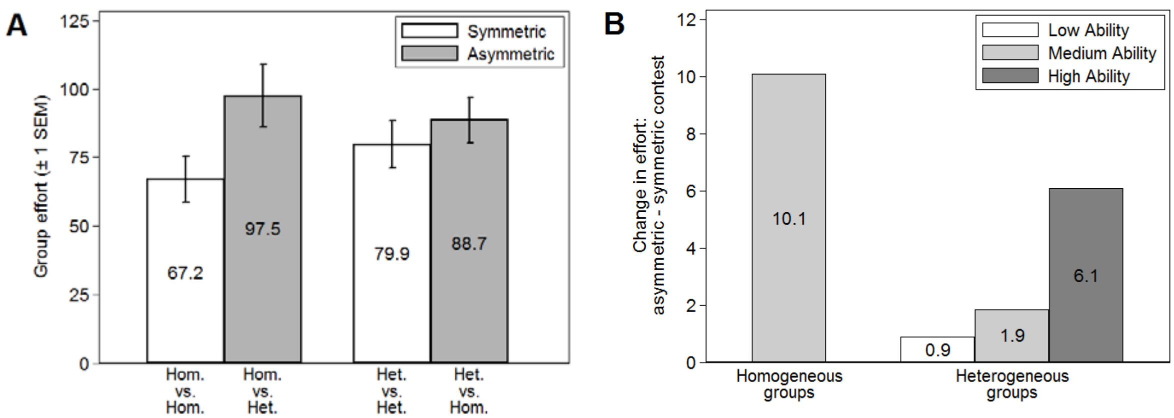

Figure 2: Group efforts depending group and contest type (Panel A). Change in individual efforts in asymmetric contests compared to symmetric contest by player's type (Panel B).

To better illustrate how the different player types react to a change in the opponent's group type, Panel B of Figure 2 depicts the difference in individual efforts between asymmetric and symmetric contests, separately for low-, medium-, and high-ability players. As can be seen, while all types increase their effort levels in asymmetric contests, the magnitude of this effect varies across types. In particular, in heterogeneous groups the difference is much more pronounced for high-ability players, who increase their effort by 6.1 tokens on average, accounting for 69% of the total group increase. Low- and medium-ability players, in contrast, increase their efforts by only 0.9 and 1.8 tokens, respectively. Yet, despite these asymmetric reactions, the distribution of efforts is still very far from the theoretical predictions that only high ability players should exert any effort. We summarize these findings in our third result:

Result 3:
(i) Both homogeneous and heterogeneous groups increase their efforts in asymmetric compared to symmetric contests, but only in the former case this effect is significant.
(ii) In heterogeneous groups, the different player types tend to share the burden of exerting effort much more equally than predicted by theory. In asymmetric contests, high-ability players start exerting higher efforts than their lower ability group members.

4.3. Conditional cooperation and the inter-dependency of effort within and between groups

To better understand these effects, in the following section we provide a more detailed account of individual behavior by investigating the group dynamics of effort provision. In particular, we explore to what extent individual behavior is contingent on the lagged efforts of the other players—both within their own and the opponent group—as well as on the type of contest.

To answer these questions, we run a set of multilevel mixed-effects regressions that explicitly take into account the inter-dependency of individual observations within a given (6-person) contest. As the dependent variable, we use an individual's effort choice in period *t*. The main explanatory variables are the lagged average efforts of the two other members of the own group (*Ingroup effort t-1),* and the lagged average efforts of the opponent group (*Outgroup effort t-1*). To see whether behavior differs depending on the type of contest, we include interaction terms with an *Asymmetric* dummy which takes the value 1 if the contest is asymmetric, and 0 otherwise. For clarity and ease of interpretation, we use separate models for homogeneous (Model 1) and heterogeneous groups (Models 2). Because in heterogeneous groups different ability types might display different behavioral patterns, we run three additional regression models in which we distinguish between low-, medium-, and high-ability players (Models 3-5). To investigate whether effort contingencies also depend on the other player's type, instead of using the lagged average efforts of all own group members, we include player specific lagged efforts (*Low-ability effort t-1*, *Medium-ability effort t-1*, *High-ability effort t-1*). In all regressions we include a *Period* variable to capture learning/general time trends, as well as lagged individual efforts (*Own effort t-1*) to capture individual path dependency.

Table 3: Determinants of individual efforts by group and player type

Dependent variable: Effort in period *t*	**Homogeneous groups**	**Heterogeneous Groups**			
		All	Low	Medium	High
	(1)	(2)	(3)	(4)	(5)
Own effort *t-1*	0.245*** (0.013)	0.221*** (0.013)	0.100*** (0.023)	0.290*** (0.022)	0.278*** (0.022)
Ingroup effort *t-1*	0.100*** (0.022)	0.109*** (0.023)			
Ingroup effort *t-1* × Asymmetric	0.062* (0.033)	-0.027 (0.034)			
Low-ability effort *t-1*				0.074*** (0.027)	0.014 (0.027)
Low-ability effort *t-1* × Asymmetric				0.012 (0.042)	0.006 (0.043)
Medium-ability effort *t-1*			0.096*** (0.032)		0.106*** (0.029)
Medium-ability effort *t-1* × Asymmetric			-0.026 (0.048)		-0.153*** (0.045)
High-ability effort *t-1*			0.014 (0.032)	0.047 (0.030)	
High-ability effort *t-1* × Asymmetric			0.029 (0.045)	0.028 (0.042)	
Outgroup effort *t-1*	0.058*** (0.009)	0.069*** (0.009)	0.052*** (0.016)	0.075*** (0.014)	0.072*** (0.015)
Outgroup effort *t-1* × Asymmetric	-0.007 (0.013)	-0.021* (0.012)	-0.021 (0.022)	-0.036* (0.020)	0.001 (0.021)
Period	-0.223*** (0.023)	-0.230*** (0.022)	-0.381*** (0.040)	-0.129*** (0.038)	-0.194*** (0.038)
Asymmetric *1 if contest is asymmetric, 0 otherwise*	4.094 (2.617)	3.571 (2.479)	1.279 (4.181)	1.837 (3.850)	7.172* (4.122)
Constant	15.677*** (1.776)	17.448*** (1.758)	24.951*** (3.004)	13.023*** (2.810)	14.486*** (3.050)
Random intercepts:					
Contest	Yes	Yes	Yes	Yes	Yes
Group	Yes	Yes	No	No	No
Subject	Yes	Yes	Yes	Yes	Yes
Observations	5808	5544	1848	1848	1848

Notes: Multilevel linear mixed-effects models using random intercepts for matching groups (a contest between two groups), groups, and individuals. Numbers in parentheses indicate standard errors. Significance levels * p < 0.1, ** p < 0.05, *** p < 0.01.

The regression results are reported in Table 3. We start by discussing the results from our first two models investigating aggregate behavior in homogeneous and heterogeneous groups. In both cases, we find a positive and significant *Own effort t-1* coefficient, indicating evidence for individual path dependency as found in many previous studies (e.g., Abbink et al., 2010; Brookins et al., 2015; Chowdhury et al., 2016). Furthermore, players in both types of groups condition their effort provision on that of their own group members (*Ingroup effort t-1*) as well as on the behavior of their opponent (*Outgroup effort t-1*). Both of these effects are highly significant. While in symmetric contests, the magnitude of these effects is very similar across homogeneous and heterogeneous groups, it seems that when the contest becomes asymmetric, the two group types adjust behavior differently. In particular, in homogeneous groups, facing a heterogeneous group as an opponent leads to strengthened collaboration within groups as indicated by the significant *Ingroup effort t-1* × *Asymmetric* interaction term. Contrary to that, in heterogeneous groups we observe a diminished degree of interdependency of efforts as indicated by the negative coefficients of the *Ingroup effort t-1* × *Asymmetric* and *Outgroup effort t-1*× *Asymmetric* interaction terms, although only the latter effect is significant.

To better understand these asymmetric reactions of homogeneous and heterogeneous groups, we now turn to the results of models 3-5 investigating type-specific behavior in heterogeneous groups. The results reveal several interesting patterns. In particular, they show that while low-ability and medium-ability group members condition their effort on each other's past behavior (with the magnitude being comparable to the one observed in homogeneous groups), they both largely ignore the efforts of their high-ability group member. The high-ability player, in contrast, responds to the effort of the medium-ability player when the contest is symmetric (as indicated by the positive and significant *Medium-ability effort t-1* coefficient), but does not do so when the contest is asymmetric (as indicated by the negative and significant *Medium-ability effort t-1* × *Asymmetric* coefficient). In this case, he instead starts to increase his effort unconditionally as indicated by the significant *Asymmetric* dummy. In neither case he relates his decision to the one made by the low-ability player.

Taken together, these results suggest that the different players react very differently to other's effort depending on the other player's type, and that these effects seem to be contest-specific. This highlights that, as in Reuben and Riedl (2013), heterogeneity within groups can lead to a multiplicity of (potentially conflicting) behavioral norms and rules that, as we show here, might additionally depend on situational factors such as the opponent's type in a contest. We summarize these findings in our fourth result:

> **Result 4**: *In symmetric contests, members of homogeneous and heterogeneous groups react very similarly to effort exerted by their own and the opponent group. In homogeneous groups, players become more responsive towards their group members' efforts when competing in an asymmetric contest. No such effect is observed for heterogeneous groups. This is due to (i) high-ability players, who in asymmetric contests contribute independently of both other group members, and (ii) low- and medium-ability players, who in both types of contests largely ignore the efforts by the high ability group member but only condition their behavior on each other's effort.*

4.4. Efficiency and inequality

It this section, we investigate the consequences of the observed behavior on overall welfare. We distinguish between the perspective of the contest participants and that of the contest designer. Given the structure of the Tullock contest, higher efforts are inevitably associated with lower earnings for the contest participants. From their point of view, the social optimum is reached when neither group invests anything into the contest (in this case the winner is determined by a coin flip). Contest designers, in contrast, are interested in maximizing overall output and, hence, have an interest in high levels of effort by all players. A second important dimension besides individual or firm efficiency is how the gains from competition are distributed. While contests designers may not care about inequality between agents per se (as long as it does not hamper output), results from many previous papers show that many people care about relative earnings. In our setting, group members in all treatments always receive an equal share of the winning prize independent of their own effort. Because marginal costs of effort are also identical for all players, equality in individual earnings can only be reached when all group members exert the same level of effort. Yet, given the different abilities (and hence different marginal productivities) of players in heterogeneous groups, theory predicts some amount of inequality in equilibrium as only high-ability players are predicted to exert any effort. For homogeneous groups, on the other hand, theory remains silent on the degree of inequality, as it only makes predictions on the aggregate level of contributions, but not on the division of labor within groups.

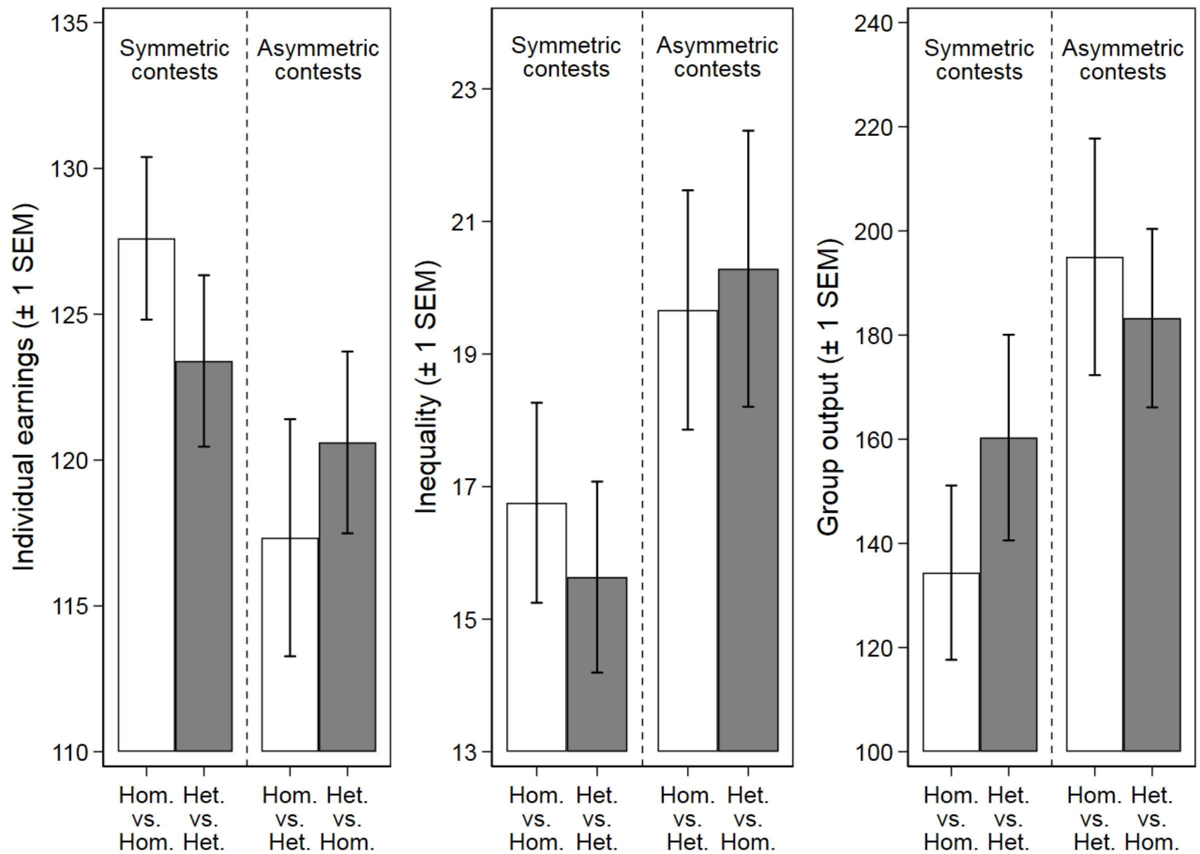

Figure 3: Earnings, inequality, and group output by group and contest type. White bars show homogeneous groups, grey bars show heterogeneous groups.

Figure 3 shows, for each group and contest type, the average individual earnings (left panel), the average degree of inequality as measured by the standard deviation of individual earnings within a group in a given period (middle panel), and the average group output, measured as the sum of contributions (effort × ability) within a group (right panel). Surprisingly, despite the different group structure and distribution of ability types, when comparing homogeneous (light bars) and heterogeneous groups (grey bars) we find very similar levels of earnings, inequality, and group output at the aggregate level (earnings: 124.3 vs. 122.5, p = 0.901; inequality: 17.7 vs. 17.2, p = 0.866; group output 153.7 vs. 168.0, p = 0.965), as well as when comparing both group types separately for symmetric and asymmetric contests (all $p > 0.281$, linear mixed effects models, see Table A3 in Appendix A).

The type of contest, in contrast, has a strong impact on both efficiency and the distribution of wealth. In particular, compared to the case in which two identical groups compete against each other (symmetric contests), asymmetric contests not only have detrimental effects on individual earnings (due to the increased efforts as highlighted in Section 4.1), but also on inequality. While earnings significantly decrease on average by about 5% from 125.6 to 119.0 tokens (linear mixed effects model, $p = 0.058$, see Table A4 in Appendix A), inequality significantly increases by 23% from 16.2 to 20.0 ($p = 0.036$). As shown by Figure 3, while these effects occur in both types of groups, the effect of decreased earnings is particularly pronounced for homogeneous groups (-8% ($p = 0.026$) compared to -2% ($p = 0.524$) in heterogeneous groups), and the effect of increased inequality is particularly pronounced in heterogeneous groups (+30% ($p = 0.049$) compared to +17% ($p = 0.226$) in homogeneous groups; see also Table A4 in Appendix A).

Yet, in heterogeneous groups the level of inequality is still much lower than what would be observed if only the high-ability player contributes (as predicted by theory). In the following, we calculate how much resources heterogeneous groups forgo by adopting an equal rather than optimal sharing rule. The amount is substantial. In symmetric contests, heterogeneous groups invest on average 79.8 tokens, leading to contributions (*effort* × *ability*) of 160.3 tokens. The same amount of contributions, however, could have also been achieved if the high-ability player invested only 53.4 tokens. Heterogeneous groups thus could have spent about a third less of what they actually did without changing the overall group contributions. Of course, this would have led to a considerable increase in within-group inequality. Similar amounts are observed in asymmetric contests, where they use 45% more resources than would have been optimal.

Finally, given that in a Tullock contest the interests of a contest designer are opposite to the ones of the participants, it is clear that the former prefers asymmetric contests. For example, our results indicate that if a contest designer can decide on the matching between two homogeneous and two heterogeneous groups, she can increase group output by about 29% by creating two asymmetric rather than two symmetric contests (linear mixed effects model, $p = 0.051$, see Table A4 in Appendix A). We summarize these findings in our fifth result:

Result 5: *Compared to the case in which two groups of the same type compete against each other (symmetric contests), introducing an asymmetry between groups decreases individual earnings and increases inequality within groups. Still, in heterogeneous groups inequality levels are much lower than predicted by theory and players forgo a substantial amount of wealth by sharing labor equally rather than optimally. For contest designers, in contrast, asymmetric contests are favorable as total output is highest in this case.*

5. Conclusion

Some people are stronger, smarter, or wealthier than others. An obvious consequence is that the ability to perform particular tasks is not identical for everyone. In this light, research on contests that presupposes identical abilities is rather idiosyncratic. To address this issue, the current work investigates the effects of within-group heterogeneity in abilities on behavior in inter-group contests. We compare the commonly explored symmetric contests between homogeneous groups—in which the ability is identical for all group members in both groups—to symmetric contests between two heterogeneous groups, and to asymmetric contests between a homogeneous and heterogeneous group.

Our main result is that, in contrast with a number of theoretical equilibrium predictions, efforts in contests involving heterogeneous teams are higher than in contests involving only homogeneous teams. The effect is particularly pronounced in asymmetric contests, where both homogeneous and heterogeneous teams increase their efforts. As a result, heterogeneous groups do not utilize their comparative advantage when competing against homogeneous groups, as both groups win the contest equally often. At the individual level, we find that players in heterogeneous groups divide the labor much more equally than predicted by theory, which states that only the highest ability group members should exert effort, while all others free ride. This effect is particularly pronounced in symmetric contests in which efforts of low-, medium-, and high-ability players are practically identical. In line with a notion of fairness or inequity concerns, it seems that high-ability players are not willing to accept the relatively lower payoffs that are inevitably associated with exerting more effort than the other group members, nor do the less able group members expect them to do so.[10] Such equal sharing of labor is attenuated, however, when heterogeneous groups compete against homogeneous groups in asymmetric contests. In this case, high-ability players invest more effort despite their less able peers not willing to match these increased contributions. It thus seems that in asymmetric contests high-ability players understand the comparative advantage they have and are willing to accept the responsibility that comes with being the most able member of the group. Interestingly, while in heterogeneous groups we observe a weaker interdependency of efforts between group members when the contest becomes asymmetric, the opposite pattern is observed in homogeneous teams where conditional cooperation is increased when the opponent team is different from the own. The latter effect might be due to an increased sense of identity that is triggered by facing a different group (Chowdhury et al., 2016), or due to an increased sense of threat triggered by the presence of a high-ability member in the opposing team.

Our findings have some important policy implications. For example, when knowing that workers are heterogeneous in their ability, managers in firms can construct groups that are either homogeneous or heterogeneous and organize contests that are either symmetric or asymmetric. A clear hierarchy of the amount of effort that these settings extract from the workers emerges from our data; efforts are highest in asymmetric contests and lowest in symmetric homogeneous contests. Hence, a manager who is only interested in maximizing group output should opt for the former. However, asymmetric contest may also have several drawbacks. For example, as highlighted by our experiment, the increased overall output comes at the cost of increased volatility in participants' behavior, which might be due to an increase in strategic uncertainty that arises when facing a group that is different from the own and whose behavior is more difficult to predict. Such volatility might be undesirable for the manager as it makes the reliability and security of his planning more difficult. Furthermore, insofar as the manager also cares (at least to some extent) about the well-being of his employees, asymmetric contests might have negative side effects as they reduce the workers' overall welfare due to a decrease in earnings and an increase in inequality. But even if the manager does not care about the well-being of the employees per se, it might be optimal to refrain from asymmetric contests because in the long-run they can lead to dissatisfaction in the workforce, which, in turn, may increase adverse behavior or turnover rates.

[10] These results are in line with evidence from public goods experiments, which also find a high degree of interdependency between contributions of group members of different abilities (Kölle, 2015).

Future research should address these questions by studying how teams are formed endogenously in these type of contexts, both in situations in which managers can determine the group composition as well as in situations in which agents can self-select into different teams. Furthermore, while our laboratory experiment provided only a minimal environment for analyzing the effects of heterogeneity in symmetric and asymmetric contest, we believe that more research is needed in order to test the robustness of our results in more complex and rich environments, like in natural field settings. A different interesting avenue for future research is to investigate whether common institutions such as communication, leadership, or punishment, which have been found to be effective in increasing cooperation in homogeneous teams (e.g., Abbink et al. 2010; Leibbrandt and Sääksvuori, 2012; Cason et al., 2012; Eisenkopf 2014), are similarly effective in heterogeneous teams.

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Appendix A: Additional Analyses

Table A1: Average individual efforts by treatment and group type.

Treatment	**Rounds 1-15**	**Rounds 16-30**	**Rounds 31-45**	**All Rounds**
Symmetric homogeneous	29.8	19.2	18.3	22.4
	(12.0)	(12.5)	(10.1)	(10.8)
Symmetric heterogeneous	33.5	25.7	20.7	26.6
	(12.7)	(12.0)	(9.8)	(11.0)
Asymmetric	40.8	28.4	23.8	31.1
	(11.9)	(13.4)	(10.5)	(11.0)
- *homogeneous group*	43.0	30.1	24.4	32.5
	(14.8)	(16.2)	(14.4)	(14.2)
- *heterogeneous group*	38.7	26.7	23.3	29.6
	(13.3)	(11.3)	(9.0)	(10.3)

Notes: Numbers in parentheses are standard deviations using a contest between two competing groups as the unit of observation.

Table A2: Group effort by group and contest type.

Dependent variable: Group Effort	Homogeneous Groups (1)	Heterogeneous Groups (2)	Asymmetric Contest (3)
Asymmetric contest	30.320**	8.857	
1 if contest is asymmetric, 0 otherwise	(13.312)	(11.775)	
Homogeneous group			8.851
1 if group is homogeneous, 0 otherwise			(8.764)
Constant	67.191***	79.803***	88.660***
	(8.828)	(8.007)	(9.575)
Random intercepts:			
Contest	Yes	Yes	Yes
Group	Yes	Yes	Yes
Subject	Yes	Yes	Yes
Observations	5940	5670	3780

Notes: Multilevel linear mixed-effects models using random intercepts for matching groups (a contest between two groups), groups, and individuals. Numbers in parentheses indicate standard errors. Model (1) uses only data from homogeneous groups and Model (2) uses only data from heterogeneous groups. Model (3) compares behaviour from homogeneous and heterogeneous groups in the asymmetric contest. Significance levels * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A3: Earnings, inequality, and group effort by group type.

Dependent variable:	Individual Earnings			Inequality			Group output		
	Symmetric contest	Asymmetric contest	Combined	Symmetric contest	Asymmetric contest	Combined	Symmetric contest	Asymmetric contest	Combined
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Homogeneous group	4.204	-3.268	0.355	1.121	-0.622	0.265	-25.936	11.768	0.603
1 if group is homogeneous,0 otherwise	(3.907)	(4.061)	(2.845)	(2.019)	(2.244)	(1.572)	(24.853)	(18.802)	(13.890)
Constant	123.399***	120.605***	123.242***	15.635***	20.286***	17.304***	160.318***	183.254***	160.345***
	(2.810)	(3.490)	(2.233)	(1.452)	(1.878)	(1.194)	(17.874)	(19.386)	(12.767)
Random intercepts:									
Contest	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Group	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Subject	Yes	Yes	Yes	No	No	No	No	No	No
Observations	7830	3780	11610	2610	1260	3870	2610	1260	3870

Notes: Multilevel linear mixed-effects models using random intercepts for matching groups (a contest between two groups), groups, and individuals. Models (4) – (9) only use contest and group random effects as the dependent variable is calculated at the group level. Models (1), (4), and (7) only use data from symmetric contests, and Models (2), (5), and (8) only use data from asymmetric contests. Models (3), (6), and (9) uses all data. Numbers in parentheses indicate standard errors. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A4: Earnings, inequality, and group effort by contest type.

Dependent variable:	**Individual Earnings**			**Inequality**			**Group output**		
	Homo-geneous	Hetero-geneous	Combined	Homo-geneous	Hetero-geneous	Combined	Homo-geneous	Hetero-geneous	Combined
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Asymmetric contest	-10.265**	-2.794	-6.602*	2.908	4.651**	3.761*	60.640**	22.936	42.235*
1 if contest is asymmetric,0 otherwise	(4.620)	(4.383)	(3.478)	(2.402)	(2.366)	(1.796)	(26.624)	(25.611)	(13.890)
Constant	127.603***	123.399***	125.573***	16.756***	15.635***	16.215***	134.382***	160.318***	146.903***
	(3.080)	(2.641)	(1.985)	(1.386)	(1.556)	(1.025)	(17.656)	(17.398)	(12.374)
Random intercepts:									
Contest	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Group	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Subject	Yes	Yes	Yes	No	No	No	No	No	No
Observations	7830	3780	11610	2610	1260	3870	2610	1260	3870

Notes: Multilevel linear mixed-effects models using random intercepts for matching groups (a contest between two groups), groups, and individuals. Models (4) – (9) only use contest and group random effects as the dependent variable is calculated at the group level. Models (1), (4), and (7) only use data from homogeneous groups, and Models (2), (5), and (8) only use data from heterogeneous groups. Models (3), (6), and (9) uses all data. Numbers in parentheses indicate standard errors. * p < 0.10, ** p < 0.05, *** p < 0.01

Appendix B: Experimental Instructions (translated from Italian)

Instructions

Welcome! You are about to take part in an experiment about decision-making. It is important that you do not talk to any of the other participants until the experiment is over. If you have a question at any time please raise your hand and an experimenter will come to your desk to answer it.

During the experiment you will have the chance to earn points, which will be converted into cash using an exchange rate of # points = 10p. At the end of today's session, you will be paid in private and in cash. The amount you earn will depend on your decisions, so please follow the instructions carefully.

At the beginning of the experiment, you will be matched with two other people to form a **team of three**. These people will be randomly selected from the participants in this room. The composition of the team will stay the same throughout the experiment, i.e., you will form a group with the same two other participants during the whole experiment. Your team will be matched with another team. This other team will be randomly selected at the beginning of the experiment, and will stay the same throughout the whole experiment.

Note that you will not know the identity of members of your team or the other team, neither during nor after today's session. Likewise, other participants will not know your identity.

Decision task

The experiment will consist of **45 rounds**, and in each round your team and the other team will compete for a prize, as will now be explained.

Each round has the same structure. At the beginning of each round each person will be given an endowment of **100 tokens. There are three types of tokens: BLUE tokens, RED tokens, and GREEN tokens**. Each person will be endowed with tokens of one colour only.

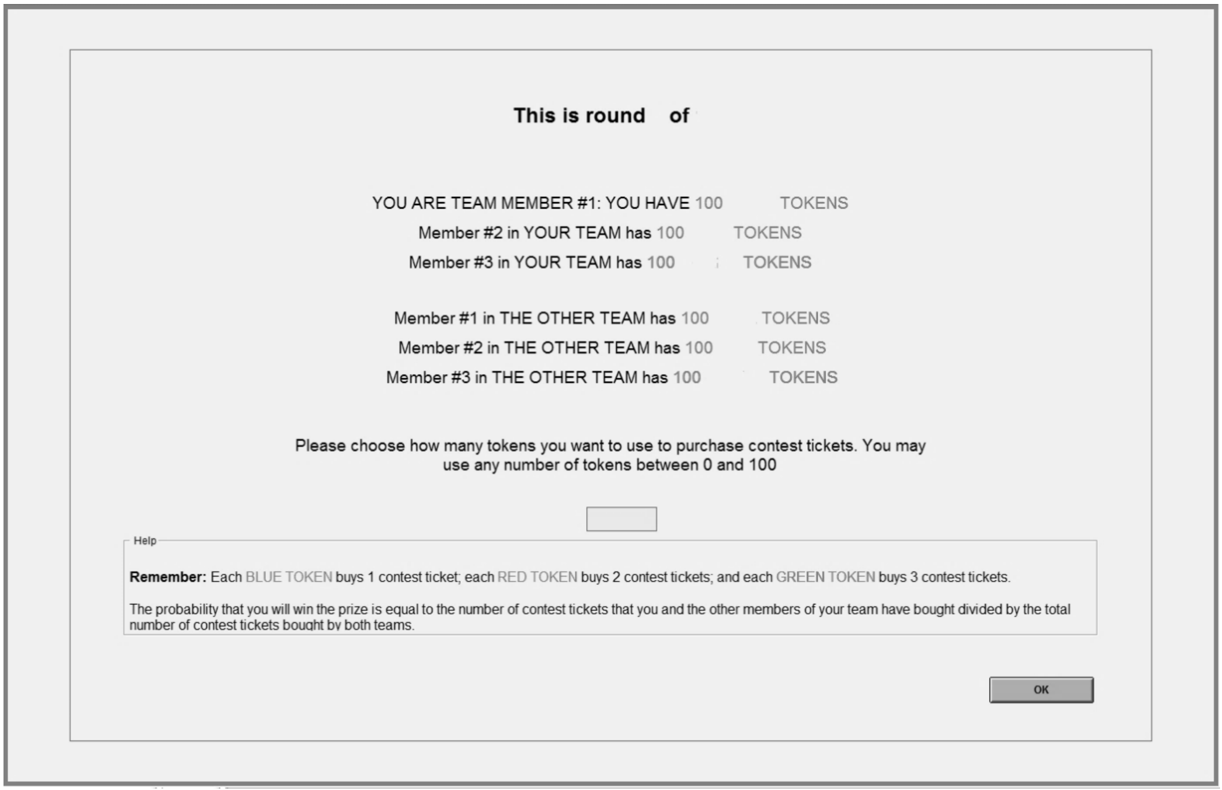
Each person can keep his/her tokens for himself/herself, or use them to buy "contest tickets". Each BLUE token buys 1 contest ticket. Each RED token buys 2 contest tickets; and each GREEN ticket buys three contest tickets.

In other words, if you received 100 BLUE tokens you can buy between 0 and 100 contest tickets; if you received 100 RED tokens you can buy between 0 and 200 contest tickets; and if you received 100 GREEN tokens you can buy between 0 and 300 contest tickets.

The type of tokens each person receives in each round remains constant throughout the experiment. For example, if someone receives BLUE tokens in the first round, that person will receive BLUE tokens throughout the experiment. You will learn which type of tokens you receive, which type of tokens the other members of your group receive, and which type of tokens each member of the other group receives.

Tokens that are not used to buy contest tickets are worth 1 point per token, regardless of the colour. These points will be added to the respective person's point balance.

In each round each person must decide how many tokens to use to buy contest tickets. Each participant will enter his or her decision via the computer. An example screenshot is shown below.



Determining the Winning Team

After each round, as soon as everybody has made a decision, the computer will calculate the total number of contest tickets purchased by each team and determine which team wins the prize. The prize is worth **300 points**, which are divided equally between the three members of the winning team, so each team member receives **100 points**. The chance that your team wins the prize depends on the number of contest tickets bought by your team, and the number of contest tokens bought by the other team. In general, the more contest tickets your team purchases, the higher your chance of winning the contest; the less contest tickets your team purchases, the lower your chances of winning the contest. The same applies for the other team

The exact chance of winning the contest is given by the number of contest tickets bought by your team, divided by the total number of contest tickets bought by both teams. If your team buys X contest tickets and the other team buys Y contest tickets, then your team's chance of winning the prize is $\frac{X}{X+Y}$, and the other team's chance of winning is $\frac{Y}{X+Y}$.

Example:

1. If your team purchases 300 contest tickets and the other team purchases 300 contest tickets, then the total number of contest tickets is 600, and your team's chance of winning is $\frac{300}{600} = \frac{1}{2} = 50\%$. The other team's chance is $\frac{300}{600} = \frac{1}{2} = 50\%$.
2. If your team purchases 300 contest tickets and the other team purchases 100 contest tickets, then the total number of contest tickets is 400, and your team's chance of winning is $\frac{300}{400} = \frac{3}{4} = 75\%$. The other team's chance is $\frac{100}{400} = \frac{1}{4} = 25\%$.
3. If your team purchases 100 contest tickets and the other team purchases 300 contest tickets, then the total number of contest tickets is 400, and your team's chance of winning is $\frac{100}{400} = \frac{1}{4} = 25\%$. The other team's chance is $\frac{300}{400} = \frac{3}{4} = 75\%$.

Note that if one of the teams doesn't buy any contest tickets, the other team wins the prize with certainty. If both teams do not buy any contest tickets, no lottery takes place and the prize is lost.

Determining Payoffs

If your team wins the contest: you will earn points from the tokens you kept for yourself, and your share from the team prize.

$$Earnings = 100 - number\ of\ tokens\ used\ to\ purchase\ contest\ tickets + share\ in\ the\ prize$$

If your team does not win the contest: you will only earn points from the tokens you kept for yourself.

$$Earnings = 100 - number\ of\ tokens\ used\ to\ purchase\ contest\ tickets$$

Example:

Suppose you

- Receive 100 RED tokens
- Keep 80 tokens for yourself

- Use 20 tokens to purchase 40 contest tickets (at a price of 2 tickets per token)

<u>Suppose further that the second member in your team</u>

- Receives 100 BLUE tokens
- Keeps 80 tokens for him/herself
- Uses 20 tokens to purchase 20 contest tickets (at a price of 1 tickets per token)

<u>And that the third member in your team</u>

- Receives 100 GREEN tokens
- Keeps 90 tokens for him/herself
- Uses 10 tokens to purchase 30 contest tickets (at a price of 3 tickets per token)

This means that your team purchased 90 (40+20+30) contest tickets in total. Suppose that the other team purchased a total of 210 contest tickets.

<u>Then, the chance that</u>

- your team wins is $\frac{90}{90+210} = \frac{90}{300} = 0.30 = 30\%$
- and the chance that the other team wins is $\frac{210}{90+210} = \frac{210}{300} = 0.70 = 70\%$

<u>Payoff</u>

If your team wins the contest:

You will earn 80 points from the 80 RED tokens you kept for yourself, and 100 points from your share of the team prize, for a total of 180 points in the round.

$$Your\ payoff = 100 - 20 + 100 = 180$$

The second member in your group will earn 80 points from the 80 BLUE tokens he/she kept for him/herself, and 100 points from his/her share of the team prize, for a total of 180 points in the round.

$$Second\ member\ payoff = 100 - 20 + 100 = 180$$

The third member in your group will earn 90 points from the 90 GREEN tokens he/she kept for him/herself, and 100 points form his/her share of the team prize, for a total of 190 points in the round.

$$Third\ member\ payoff = 100 - 10 + 100 = 190$$

If your team does not win the contest:

You will earn 80 points from the 80 RED tokens you kept for yourself, and nothing from the prize.

$$Your\ payoff = 100 - 20 = 80$$

The second member in your group will earn 80 points from the 80 BLUE tokens he/she kept for him/herself, and nothing from the prize

$$Second\ member\ payoff = 100 - 20 = 80$$

The second member in your group will earn 90 points from the 90 GREEN tokens he/she kept for him/herself, and nothing from the prize

$$Second\ member\ payoff = 100 - 10 = 90$$

End of each period

After all participants have made a decision, a feedback screen will appear showing the results from the current round. Each participant will receive the following summary of the period:

- Number of contest tickets purchased by his/her team
- Number of contest tickets purchases by other team
- Which team won the competition

As well as the following information about him/herself and each of his/her two group members:

- Initial number of tokens
- Type (color) of tokens
- Number of tokens kept
- Number of tokens used to purchase contest tickets
- Number of contest tickets purchased
- Earnings from the contest
- Total earnings in the period

The information is sorted by the number of contest tickets purchased in descending order (with the participant who purchased most contest tickets listed first). Thus, a participant's information may be listed on different rows in different rounds.

An example feedback screen:

The points you earn in each round will be added to the points you earned in the previous rounds, and at the end of the session you will be paid based on your total point earnings from all 45 rounds.

Beginning the experiment

If you have any questions please raise your hand an experimenter will come to your desk to answer it.

Before starting the decision-making part of the experiment a set of questions will appear on your screen. These will help you to gain an understanding of the calculation of your earnings.

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