Sutter, Matthias und Strassmair, Christina:

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Munich Discussion Paper No. 2007-28

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Volkswirtschaftliche Fakultät
Ludwig-Maximilians-Universität München

Online at https://doi.org/10.5282/ubm/epub.2016

Communication, cooperation and collusion in team tournaments – An experimental study*

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Abstract

We study the effects of communication in an experimental tournament between teams. When teams, rather than individuals, compete for a prize there is a need for intra-team coordination in order to win the inter-team competition. Introducing communication in such situations may have ambiguous effects on effort choices. Communication within teams may promote higher efforts by mitigating the internal free-rider problem. Communication between competing teams may lead to collusion, thereby reducing efforts. In our experiment we control the channels of communication by letting subjects communicate through an electronic chat. We find, indeed, that communication within teams increases efforts and communication between teams reduces efforts. We use team members' dialogues to explain these effects of communication, and check the robustness of our results.

JEL-classification: C92, J33

Keywords: Tournament, Team decision making, Communication, Collusion, Free-riding, Experiment

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* We would like to thank Gary Bornstein, Dennis Dittrich, Martin Kocher, Sandra Ludwig, Wolfgang Luhan, Wieland Müller, Klaus Schmidt, two anonymous referees and an associate editor for very helpful comments and suggestions. Cornelia Horn, Torben Krüger, Julia Neudorfer and Felix Oettl provided valuable research assistance. Financial support from the Center of Experimental Economics at the University of Innsbruck (sponsored by *Raiffeisen Landesbank Tirol*), the Austrian Science Foundation (FWF-Project P16617), the Tiroler Wissenschaftsfonds and the ENABLE *Marie Curie Research Training Network*, funded under the 6th Framework Programme of the European Union, is gratefully acknowledged.

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1. Introduction

Tournaments between teams are a useful tool to motivate team members to elicit high levels of efforts. Team tournaments can be implemented both within a given company, but also across companies. An example for the within-company case might be a competition of different units within an advertising agency to put forward the best proposal for a large advertising campaign contract, which is then rewarded with a large bonus and additional resources for the members of the successful unit. Likewise, large automobile companies sometimes rely on the competition between several working groups to develop the design of a new car. An example for a team tournament between different companies is a research contest where teams of researchers compete for being the first to innovate or deliver a pre-specified 'product', which is then rewarded by a large prize. There are numerous examples for research tournaments, like the contest to select an engine for the first-ever passenger line between two British cities, which was sponsored by Liverpool and Manchester Railway in 1829 (see Fullerton and McAfee, 1999, for more details) or the "Golden Carrot Contest" in the early 1990ies when electric utilities offered a 30 million dollar reward for the first company to build a better refrigerator with lower electricity demand and no chlorofluorocarbons (see New York Times, 1992). Though such research contests have been analyzed from different angles[1], an important limitation of this specific literature is the assumption that the actors in research contests are modeled as unitary players, as if research teams were individuals. Any kind of internal conflict within teams is ruled out in such a setting. Yet, it seems important and much more realistic to consider the effects arising from the possibility of shirking within teams (as highlighted by Holmstrom, 1982) or the opportunity for collusion between teams. Allowing for communication within and between competing teams may limit the former (shirking), but facilitate the latter (collusion), depending on the precise communication infrastructure available in the tournament.

We are going to present an experimental study where we have carefully controlled and varied the available communication infrastructure within and between competing teams. Our design shall provide answers to the following questions: (1) Which effects has communication on the degree of intra-team cooperation and/or inter-team collusion in team tournaments and how do these effects depend on the available communication channels within and between teams? (2) Why does communication have any effects, i.e. what kind of arguments are invoked in communication and how do they affect behavior? We deem the answers to both

[1] See, e.g., Taylor (1995) or Fullerton and McAfee (1999), which show that free entry into such tournaments is not optimal for efficiency.

questions interesting for two reasons. First, they address important issues in organizational economics, as the precise structure of communication channels may affect employees' efforts at work. As a consequence, a better understanding of how communication affects behavior will have an impact on the optimal organization of companies. Second, examining the effects of communication in strategic interaction is of general interest for economics (see Crawford, 1998), as communication – though typically considered "cheap talk" – may be informative and may thus lead to behavior that is different from interaction without communication. Team tournaments provide a much richer source for investigating communication effects than strategic games between individuals do, because team tournaments allow for several variations concerning the possible addressees of communication (within and/or across teams).

Team tournaments have already received some attention in recent years. Nalbantian and Schotter (1997) and van Dijk et al. (2001) present a model of a team tournament where teams with several members compete against each other for a given prize, with the latter being shared equally among the winning team's members.[2] Both in their models and in the associated experiments, Nalbantian and Schotter (1997) and van Dijk et al. (2001) show that competition between teams increases individuals' efforts and mitigates the internal free-rider problem, compared to other incentive schemes like piece rates or (intra-team) revenue sharing. Yet, both papers have examined the behavior in team tournaments under the condition of *no* communication within and between teams. Whereas the assumption of no communication *between* teams may be appropriate for research and other team-based contests – where teams often don't know (all) other competitors – communication *within* teams will typically be possible in these cases. Communication may even take place *between* competing teams when team tournaments are run within a given company, for example when members of competing units meet at the coffee machine.

The effects of communication on behavior in tournaments between *individuals* have been examined by Harbring (2006). She has implemented an experimental tournament between two persons who have to choose a costly effort, with the person choosing the higher effort receiving a fixed prize. When these two persons can exchange e-mail messages before deciding on their effort, they choose only about one quarter of the effort which prevails under

[2] Stein and Rapoport (2004) present a different, two-stage type of (Tullock-like) tournament between teams where the prize is not split equally among the members of the winning team, but where the prize is allocated only to a single member of the winning team. The tournament has two stages, where the winning team is determined in one stage and the winning individual (in the winning team) in another stage. In both stages, the probability of winning is proportional to the effort invested. We do not consider such a two-stage type of tournament with proportional winning probabilities. Rather we focus on equal rewards of team production, which creates simultaneously the within-team free-rider problem and the between-teams competition in which we are interested.

no communication. Hence, the possibility to communicate leads to a very high degree of collusion, which is inefficient for the principal. Since Harbring (2006) studies only tournaments among individuals, it remains unclear whether her findings apply to team tournaments which have the additional feature of *intra*-team interaction. Furthermore, Harbring's study cannot address the issue whether different restrictions on communication within and between teams produce different results.

In our experiment, we implement a 2×2 design by combining the two factors (a) within-team communication, and (b) between-teams communication. If within-team communication is possible, members of a team can exchange messages, but there is no chance of transmitting messages from one team to the other team. If between-teams communication applies, sending a message to the other team is possible. The case where neither channel is available constitutes the control-condition without communication. If both factors apply, communication is fully encompassing in the sense that all messages are public information for all members of the competing teams. Additionally, we consider a situation where team members can choose endogenously whether their messages are transmitted only to members of their own team or whether a message shall also be public for members of the competing team. This endogenous treatment shall reveal subjects' preferences for explicit collusion by choosing the between-teams communication channel.

We have chosen an experimental approach for studying the effects of communication in team tournaments because experimental economics allows a systematic and controlled variation of different conditions for communication within and between teams, holding all other conditions constant. In the laboratory, it is easily possible to vary the range of communication that is available for a specific set of actors, while at the same time confronting them with identical tasks. This is much harder, if not impossible, in field studies, which nevertheless provide important and novel insights into the influence of communication on behavior. The paper by Genesove and Mullin (2001), for instance, is related to our research interests on how communication affects behavior. Genesove and Mullin (2001) have analyzed the written protocols of the Sugar Institute cartel meetings in the U.S. in the interwar-period, showing how communication among the relevant market suppliers led to collusion by specifying and homogenizing business practices rather than fixing prices. Our context is different from the one by Genesove and Mullin (2001), though, because they do not consider a tournament design and since they do not address the possible conflicts of interest *within* single cartel members, but only those *between* the cartel members. Our team tournament captures both features of *intra*- and *inter*-team conflict at the same time and in our experimental design we compare behavior under various communication infrastructures, contrary to Genesove and Mullin's (2001) case study on the specific conditions of the Sugar Institute case.

The rest of the paper is organized as follows: Section 2 contains the basic tournament model. The experimental design and the treatments are introduced in section 3. Section 4 derives our hypotheses. Section 5 presents the experimental results, focusing first on effort choices in the tournament and then analyzing the contents of communication and its relation to effort choices. We conclude section 5 by reporting several robustness checks with respect to the parameterization of our model. Section 6 summarizes the main findings and their possible implications.

2. The model

Our tournament setup is based on Nalbantian and Schotter (1997). In the following we present already the precise parameters used in the experimental study in order to avoid a repetition of the model in the section on the experimental design.

Consider a group of six workers indexed i = 1, 2, …, 6. The six workers are split into two teams, with workers {1, 2, 3} in team T_1, and workers {4, 5, 6} in team T_2. Each worker can independently choose an effort level $e_i \in [0, 100]$. Effort costs are $C(e_i) = e_i^2/100$. The output Y of team T_j is given by

$$Y_j = \sum_{i \in T_j} e_i + \varepsilon_j . \tag{1}$$

The random variable $\varepsilon_j \in$ [L, H], with L = –40 and H = +40, is uniformly distributed and can be interpreted as a random shock in production or as the degree of (positive or negative) synergy created in the team production process. Team T_j's output is then multiplied by a factor f = 1.5 to generate the team's revenue.[3] This revenue is shared equally among all team members. Competition in the tournament is implemented by allocating a transfer TR = 90 to the team with the higher output, where the transfer has to be paid by the team with the lower output.[4] Benefits and costs from transfers are also shared equally within teams. In total, the expected payoff π of member i in team T_j is then given as

[3] In the original paper by Nalbantian and Schotter (1997), the factor f is interpreted as the price of the output that is sold on a competitive market. Hence, it is assumed that workers get an equal share from the revenue generated from producing the output.

[4] This zero-sum implementation of the tournament is in principal equivalent to a situation where the prize (TR here) is provided by an external source.

$$E(\pi_i) = \frac{fE(Y_j)}{3} - \frac{e_i^2}{100} + P\frac{TR}{3} - (1-P)\frac{TR}{3}. \quad (2)$$

The first term on the right-hand side represents member *i*'s share of his team's revenue. The second term captures member *i*'s costs of providing (individual) effort. The third and fourth term show the expected benefits, respectively costs, from winning or losing the tournament, with *P* denoting the probability of winning the tournament.

As is shown in full detail in Appendix B, this model of a team tournament has a unique (and symmetric) Nash-equilibrium where all team members choose the following effort e_i^*:

$$e_i^* = \frac{50f(H-L) + 100TR}{3(H-L)} = 62.5. \quad (3)$$

3. Experimental design

3.1. Information conditions

The tournament is repeated for 10 rounds with a partner matching, meaning that the same three subjects stay within a given team and are paired with a competing team of three other fixed members for the whole experiment. Parameters are specified as introduced in the previous section. The number of repetitions was common knowledge (see the experimental instructions in Appendix A). Hence, the only subgame perfect Nash equilibrium coincides with the Nash equilibrium of the stage game ($e_i^* = 62.5$).

In all treatments subjects face the same parameters and have to enter their decision on their effort level individually and independently on a computer screen. At the end of each round, subjects are informed about (i) the effort level that each member of their own team has chosen, (ii) the random shock of their team, (iii) the output of their team, (iv) the output of the competing team (but not the individual effort or the random shock in the competing team) and (v) whether their team has won the tournament or not. Finally, subjects get to know (vi) their payoff in the respective round. At the end of the experiment, subjects are asked to fill out a questionnaire concerning their behavior in the experiment (see Appendix A for details).

3.2. Experimental treatments

The experimental treatments are based on a 2×2 design that is complemented by one treatment with an endogenous choice of the communication channel. The treatments differ with respect to the communication infrastructure within and between teams.

1. ***NOCOMM***: Subjects can not communicate with each other. This treatment serves as the control condition without any communication.
2. ***INTRA***: Members of a team can exchange messages *within* the team, but it is impossible to send messages to members of the competing team.
3. ***INTER***: Communication between teams is possible, but not within teams. In order to avoid the latter, we set up three pairs where always one member of team T_1 can communicate with one member of team T_2. This procedure ensures that we can separate the effects of within-team communication (in *INTRA*) from those of between-teams communication (in *INTER*).[5]
4. ***INTRA+INTER***: Every message is public for members of *both* competing teams. It is not possible to restrict one's message to members of the own team only. This treatment combines the options from *INTRA* and *INTER*, but leaves subjects with no choice as to which channel to use (contrary to the next treatment).
5. ***ENDOGENOUS***: Here subjects can choose themselves whether they want to send a message to the members of their *own* team only (intra-chat) or to all members of *both* teams (inter-chat). Subjects can use both types of chats at any time according to their wishes. The endogenous choice of which communication channel to use will provide insights into subjects' preferences and the effects of endogeneity.

In all treatments except *NOCOMM* subjects could exchange e-mail messages in real-time via a chat program *before* entering their decision.[6] The time to exchange messages was 8 minutes in the first two rounds and 4 minutes in rounds 3 to 10. When sending messages participants were free to discuss anything except their seat number or anything else that could reveal their identity. Furthermore, making threats or arranging side-payments after the experiment was also forbidden.

3.3. Experimental procedure

The experimental sessions were run computerized (using zTree by Fischbacher, 2007) in October 2003, June 2004 and January 2007 at the University of Innsbruck. 408 students participated in the experiment. Subjects were randomly assigned to treatments and could only

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[5] We would like to thank one referee for suggesting this treatment which we had not considered initially.

[6] By using e-mail messages as medium for communication it is possible to exclude the influence of physical attributes like attractiveness, resulting sympathies and everything else that might affect behavior in addition to the transfer of linguistic messages (Schweitzer and Solnick, 1999, for instance, document the existence of a 'beauty-premium' in face-to-face ultimatum bargaining). For some differences between electronic communication (via electronic chat or e-mail) and face-to-face communication see Frohlich and Oppenheimer (1998) or Kocher and Sutter (2007). Given that using electronic communication is very widespread in companies and since we were predominantly interested in the consequences of communication and the exchange of messages, we opted for using an electronic chat instead of face-to-face discussion.

take part in one session. Sessions lasted about 60 minutes, with subjects earning on average € 13.7.

4. Hypotheses

Since communication does not change the basic payoff structure of the game (see equation (2)), the Nash equilibrium (with $e_i^* = 62.5$) might be considered a reasonable benchmark for behavior in all treatments. However, there are good reasons both from economics and psychology why the Nash equilibrium might fail as a good predictor for behavior in the treatments *with* communication.

Even in cases where communication is 'cheap talk' in the sense that players' messages have no direct payoff implications, economic theory has shown that communication has a large potential to increase the cooperation of interacting players (see, e.g., Rabin, 1994; Farrell, 1995; Farrell and Rabin, 1996; Crawford, 1998). This is mainly due to messages conveying useful information to other players, e.g. about other players' types, intentions and strategies or about their expectations of other players' strategies. Compared to a no-communication setting, the possibility to communicate makes cooperation and coordination of players' actions easier to establish and more likely.[7]

Social psychology has shown that the higher levels of cooperation with communication (than without it) can be explained by two main factors: first, the opportunity to make commitments (even when they are not enforceable) and, second, the possibility to increase the degree of group identity through communication (Brickman, 1987; Orbell et al., 1988; Dawes et al., 1990; Kerr and Kaufman-Gilliland, 1994). Elster (1986, pp. 112-113), for instance, has suggested that it is "pragmatically impossible to argue that a given solution should be chosen just because it is good for oneself. By the very act of engaging in a public debate … one has ruled out the possibility of invoking such reasons. To engage in discussion can in fact be seen as one kind of self-censorship, a pre-commitment to the idea of rational decision." By rational decision, however, Elster (1986) refers to decisions which are advantageous for the *group* (of communicating subjects) as a whole, but (possibly) contrary to egoistic preferences. Hence, communication may change the individuals' reference point for optimization. Instead of maximizing own payoffs, individuals may consider the joint payoff (or welfare) of those

[7] Communication may also promote the coordination of actions (and thus reducing their variance between teams) by establishing a common understanding of the game (e.g., through correcting possible errors or through one member demonstrating optimal strategies).

engaged in the discussion as the appropriate target for optimization.[8] In the following we derive the optimal efforts for different targets. The stated efforts shall serve as a benchmark for the behavior in the different treatments with communication. The following predictions are based on the assumption that subjects do not only consider their individual payoff for maximization, but the sum of their own payoff and of the payoffs of all subjects that they can communicate with. Note that none of the predicted efforts constitutes an equilibrium choice if a subject wants to maximize his own payoff.

If communication within a team is possible (in *INTRA*) and a team member i wants to maximize the joint payoff π_{T_j} of his team T_j, equation (4) states the expected payoff:

$$E(\pi_{T_j}) = fE\left(Y_j\right) - \frac{\sum_{i \in T_j} e_i^2}{100} + P*TR - (1-P)*TR \tag{4}$$

Maximizing equation (4) with respect to e_i yields e_i^{INTRA} as optimal for the *own team's* sum of payoffs (under the assumption that also all other workers are maximizing their own team's payoff):

$$e_i^{INTRA} = \frac{50f(H-L)+100TR}{(H-L)} = 187.5\,. \tag{5}$$

Given that e_i is restricted to the interval [0, 100] in the experiment, the individually optimal effort for the own team as a whole is then given by $e_i^{INTRA} = 100$.

If a subject i can only communicate with one member k of the competing team, but not with members of his own team (in *INTER*), maximizing the joint payoff of members i and k requires equation (6) to be maximized:

$$E(\pi_i + \pi_k) = \frac{fE\left(Y_1 + Y_2\right)}{3} - \frac{e_i^2 + e_k^2}{100}\,. \tag{6}$$

Note that (6) is not affected by the transfer or the winning probability, since in any state of the world one of both individuals will be part of the winning team while the other one will be part of the losing team. The resulting optimal effort level corresponds to the one that prevails when no tournament is implemented at all.

$$e_i^{INTER} = \frac{100f}{6} = 25\,. \tag{7}$$

[8] This kind of reasoning is, of course, different from the economic approach, where communication may enhance cooperation and coordination even though individuals only care for their own well-being. Yet, both the economic and the psychological approach acknowledge that 'cheap talk' can affect behavior despite its (typically given) irrelevance for payoffs. Note for our team tournament that even if communication changes a subject's expectations about the other players' efforts, an individual's incentive for free-riding within the team is not removed. Consequently, communication need not increase optimal efforts as long as individual payoffs remain a subject's sole concern.

If communication includes both teams (in *INTRA+INTER*) then the socially optimal effort choice that maximizes the joint payoffs across both teams follows from equation (8):

$$E(\pi_{T_1+T_2}) = fE(Y_1+Y_2) - \frac{\sum_{i\in T_1} e_i^2 + \sum_{k\in T_2} e_k^2}{100} \qquad (8)$$

Again, the transfer need not be considered in (8) because the transfer from the losing team to the winning team is a zero-sum transaction. Hence, the socially optimal effort $e_i^{INTRA+INTER}$ is given as:

$$e_i^{INTRA+INTER} = \frac{100f}{2} = 75. \qquad (9)$$

These considerations provide a set of testable hypotheses about the effects of the various communication infrastructures.

Hypothesis 1. In *NOCOMM* we expect Nash equilibrium behavior ($e_i^* = 62.5$).

Hypothesis 2. In *INTRA* subjects maximize their own team's joint payoff. Hence, we expect the maximum effort $e_i^{INTRA} = 100$.

Hypothesis 3. In *INTER* subjects maximize the sum of their own payoff and the payoff of one member of the competing team. This yields as a prediction $e_i^{INTER} = 25$.

Hypothesis 4. In *INTRA+INTER* subjects maximize the joint payoff for *both* teams. This is achieved by choosing the collectively optimal effort $e_i^{INTER} = 75$.

Hypothesis 5. Efforts in *ENDOGENOUS* can be expected to lie in between those in *INTRA* and *INTRA+INTER*, yielding $e_i^{ENDOGENOUS} \in [75, 100]$.

Hypothesis 6. From Hypotheses 1 to 5 we expect the efforts in the different treatments to be ordered as follows: *INTRA* ≥ *ENDOGENOUS* ≥ *INTRA+INTER* > *NOCOMM* > *INTER*.

5. Results

5.1. Behavior in the tournament

5.1.1. Effort levels

Table 1 provides an overview about the average effort levels, the average standard deviation within teams and the average profits. The average efforts are very close to the predictions in treatments *NOCOMM* (58.13) and *INTRA+INTER* (75.79). As expected, the efforts in *ENDOGENOUS* (81.34) are in the range [75, 100], and in particular between those in *INTRA+INTER* and those in *INTRA* (89.32). Although efforts in *INTRA* fall short of the predicted maximum of 100, Figure 1 shows a clear upward rising trend of efforts in *INTRA*, with average efforts reaching 97 in round 9. The efforts in *INTER* (59.69) are far above the predicted level of 25. In fact, average efforts in *INTER* and *NOCOMM* are not significantly different from each other (Mann-Whitney U-test[9]; see also Figure 1 for an illustration that efforts in *NOCOMM* and *INTER* are very similar). This finding implies that the opportunity to communicate with a member of the competing team (when communication *within* teams is *im*possible) does not have any effect on effort levels. However, in all treatments where communication within teams *is* possible (*INTRA+INTER, INTRA, ENDOGENOUS*) the efforts are clearly higher than in *NOCOMM* (see the estimations in Table 2 and the discussion of it below). The standard deviations of efforts show a similar pattern as efforts. They are significantly higher in *NOCOMM* and *INTER* than in the other treatments ($p < 0.05$ in any pairwise comparisons; Mann-Whitney U-tests), indicating that communication within teams makes effort choices more homogeneous. Pooling the treatments with within-team communication (*INTRA, INTRA+INTER* and *ENDOGENOUS*) and those without within-team communication (*INTER* and *NOCOMM*) we find that the average profits are significantly higher with within-team communication than without ($p < 0.05$; Mann-Whitney U-test; $N = 68$). This shows again that communication with members of the own team has a systematic impact on behavior.

Tables 1 and 2 and Figure 1 about here

In Table 2 we report the results of a linear cross-sectional time-series model with random effects using feasible generalized least squares (FGLS). This method allows estimations in the presence of heteroscedasticity across panels. We take the individual effort of a given round as dependent variable, and regress it on the round number, on its square, on dummies for the different treatments, taking *INTRA* as the benchmark, and on interaction terms of treatment and round.[10]

Efforts increase at the beginning of the experiment, but exhibit an inverted U-shape across the whole 10 rounds (see the coefficients for "Round" and "Round²"). Compared to *INTRA*, all other treatments have significantly lower efforts. Contrary to Hypothesis 6, the

[9] For the Mann-Whitney U-tests reported in this chapter we consider each group of six subjects as one independent observation by taking the average of the dependent variable across all six subjects.

[10] Taking the average efforts in a group of six subjects (i.e. of both teams) as unit of observation would have yielded the same qualitative results.

efforts are not significantly different between *NOCOMM* and *INTER* (Wald test on treatment dummies). However, the order of efforts in the other treatments is in line with Hypothesis 6, implying *INTRA* > *ENDOGENOUS* > *INTRA+INTER* > *NOCOMM* ($p < 0.05$; Jonckheere test).

Result 1: Communication *within* teams increases efforts and profits and reduces the standard deviation of efforts on average. The order of observed efforts is largely in line with Hypothesis 6 that had expected the highest efforts when only communication within teams is possible and lower efforts when communication between teams is added.

5.1.2. Distribution of efforts

Figure 2 shows that the distribution of actually chosen efforts (over all 10 rounds) is typically not heavily centered on the point predictions, even in the treatments where the overall average efforts are close to the predicted ones. In *NOCOMM* 9% of choices satisfy 62.5 ± 2.5; in *INTRA+INTER* 8% satisfy 75 ± 2.5; in *INTER* 1.4% satisfy 25 ± 2.5. Only in *INTRA* we find that 56% of actual choices are $e_i = 100$, as predicted by Hypothesis 2. The maximum effort of $e_i = 100$ is also the modal choice in *INTRA+INTER* (with 31%). Even though this choice is optimal for the own team, it is detrimental for the joint payoff of both teams together. The relatively high frequency of choosing 100 in *INTRA+INTER* can thus be interpreted as a partial failure to collude. The next most frequent effort choices in *INTRA+INTER* are 80 (close to the optimal choice in case of collusion), 50, and 60 (close to the Nash equilibrium). The frequencies of efforts in *ENDOGENOUS* are in most effort ranges in the middle between *INTRA+INTER* and *INTRA*, indicating that behavior in *ENDOGENOUS* is driven by factors stemming from both *INTRA* and *INTRA+INTER*. Effort choices in *NOCOMM* are rather symmetrically distributed, and even more so in *INTER*, with peaks in the middle in both treatments.

Result 2: The distribution of actual efforts fits the point predictions of our hypotheses rather poorly, even though the average efforts are close to the point predictions except for *INTER*.

Figure 2 about here

5.1.3. Reaction to winning or losing the tournament

In Table 3 we report the results of a panel probit regression that examines how winning or losing the tournament in round *t*-1 affects an individual's efforts in round *t*. Since team members were informed about the other team members' efforts and the competing team's output at the end of each round, they had an opportunity to react to this information in the next round. In order to measure these effects we regressed the binary variable *increase* (1 if individual effort strictly increased from round *t*-1 to round *t*, 0 otherwise) on the following independent variables: treatment dummies, *Round*, *Round²*, *Winlast* (1 if team won in round *t*-1, 0 otherwise), *C_Output* (output of the matched team in the previous round), *Max* (1 if individual's effort is the strict maximum within the own team in round *t*-1, 0 otherwise), *Min* (1 if individual's effort is the strict minimum within team in round *t*-1, 0 otherwise), and interaction terms.

Table 3 about here

Compared to *INTRA* (as the benchmark treatment) we find significantly negative treatment effects for *NOCOMM, INTER,* and *ENDOGENOUS* on the likelihood of strictly increasing an individual's effort from round *t-1* to round *t*. Table 3 also shows a significantly negative effect of winning the tournament in the previous round on the probability of an individual to increase the effort. In other words, the likelihood that members of losing teams increase their efforts in the next round is ceteris paribus significantly higher. Note, however, that this effect is noticeably reduced – though not full offset – in treatments *NOCOMM* and *INTER*. The latter interaction effects document again that the effects of the tournament on efforts are lowest in *NOCOMM* and *INTER*, hence in the treatments without communication within teams. The output of the competing team in the previous round (*C_Output*) has, in general, a negative effect, which means that the higher the competing team's output, the less likely is an individual to increase his efforts. Being the team member with the highest contribution in round *t-1* makes an increase in efforts less likely in *NOCOMM* and *INTER* (see the interaction terms of *Max* with these treatments). Being the team member with the lowest contribution in round *t-1* induces an individual to increase his efforts, probably to adjust to the effort levels of the other team members. This effort increasing effect is partly offset in treatments *NOCOMM*, *INTER*, and *INTRA+INTER*.

Result 3: Losing the tournament typically increases the likelihood of increasing the efforts in the next round. Hence, tournaments are an effective means of raising efforts, though least effectively in *NOCOMM* and *INTER*.

5.2. Analysis of communication

The messages sent in the treatments with communication provide a rich source of information for studying why communication has any impact on effort choices, respectively what kind of arguments are invoked and how they affect behavior. To analyze the messages we have developed 11 categories for different types of statements as follows: First the authors read independently through parts of the electronic chat protocols[11] and established a preliminary set of categories, i.e. statements and arguments. These categories were then reconciled. Subsequently, two undergraduate research assistants independently did the coding for each single team and round, assigning the value of "one" if a statement or argument showed up in a given round and chat, and the value "zero" otherwise. The two independent sets of coding had an average cross-coder correlation of 0.57 for the 11 categories.[12] We then let the two coders discuss all the discrepancies in coding and agree on a single decision for coding. This final coding was used for the analysis to be reported in the following.

Table 4 about here

Table 4 lists the categories for coding, their description and the relative frequency with which a specific category was coded as present (value "one"). The proposal to choose identical efforts (category C1 and also category C11 if communication between teams is possible) is by far the most frequent category that dominates the electronic communication in all treatments except for *INTER*. Note that the contents of communication in *INTER* is markedly different from the other treatments, as the exchanged messages are in most cases rather uninformative for behavior (by most frequently using the chat to complain about the other member in one's own team, see category C5), and the exchanged messages not affect behavior (as the discussion of Table 5 will show). We therefore focus in the following discussion on the treatments *INTRA*, *INTRA+INTER*, and *ENDOGENOUS*.

[11] These protocols add up to about 400 pages of (German) communication. Electronic files of the communication are available upon request.

[12] An average cross-coder correlation of around 0.6 (as in our case) is well accepted in social psychology (see, e.g., Orbell et al., 1988). In economics, the analysis of verbal protocols through coding is very rare. One recent exception is found in Cooper and Kagel (2005) who report an average cross-coder correlation of 0.39.

In about 85% of cases where the topic of coordination (C1) is mentioned, team members actually agree on it. Such agreements are subsequently only broken in about 10% of cases. Hence, defection from agreements is rare, and most often found in the 10th round of the experiment, when there is no future interaction. Obviously, before round 10, most team members feel committed to what they agree upon in the chat and because defection can be easily detected. These findings suggest that one of the consequences of communication is to turn the stage game into a (though finitely) repeated game. This makes cooperation more attractive, and we will see below that proposals to cooperate on identical efforts increase the actually chosen efforts.

In about 6% to 11% of observations we find the argument to choose unequal efforts within teams (category C2), for example two members choosing rather high efforts and one member choosing a rather low one.[13] The proposals C1, C2 and C11 are sometimes backed up by arguments concerning fairness and loyalty (see categories C3 and C4). If agreements are reached, but broken, team members sometimes insult the respective member by calling him a free-rider or sucker (category C5). The competitive goal of beating the competing team is explicitly stated in only 3% to 9% of cases (category C6).

Categories C7 to C11 address some specific aspects of behavior towards the competing team. The issue of keeping the own team's strategy secret, for instance, is more often mentioned than we would have expected. About 9% of observations in *INTRA+INTER* are classified under the respective category C7, and about 2% of observations in *ENDOGENOUS*. But note the fundamental difference between these two treatments: In *ENDOGENOUS*, the issue of secrecy is always raised in the *intra*-chat, that is in the messages received only by members of the own team.[14] In *INTRA+INTER*, all messages are public for members of both teams, but nevertheless secrecy is advocated with statements such as "*We must not announce which numbers we want to choose because the other group can read what we discuss.*" Similar to the issue of keeping the own team's strategy secret is the proposal to lie to the other team (category C8), which is made in 8% of observations in *ENDOGENOUS*.

Categories C9, C10 and C11 contain statements that we expect to foster collusion. It is either an appeal to members of both teams not to compete, because that raises effort costs for members of both teams (C9), a proposal to let teams take turns in winning the tournament

[13] In order for asymmetric efforts to be 'fair', such proposals are typically associated with the suggestion to use a rotation scheme such that each member chooses a low effort every third round (thereby benefiting from the high efforts of the other two members in a given round).

[14] In fact, the *inter*-chat is only used in 46% of rounds in *ENDOGENOUS* (and in many of these rounds for non-substantive talk like saying hello), whereas the *intra*-chat is used in each single round.

(C10), or a proposal to choose identical efforts in order to have the independently drawn random shock determine the winning team (C11).

Table 5 about here

In Table 5 we report a panel regression where we regress the individual effort in a given round on the categories of communication introduced above. In addition to the communication categories we included a variable for the round and its square and the difference between the own team's and the competing team's output in the previous round (in order to control for the outcome of the tournament in the previous round and for dependencies with the behavior of the matched team).

We find in the *INTRA*-treatment that proposals for identical efforts of all team members (C1) increase members' efforts significantly. Suggestions to coordinate on the same action typically find an agreement.[15] As a consequence, higher commitments lead to higher efforts. The goal to beat the other team (C6) induces higher efforts, but proposing unequal efforts within a team drives down efforts (C2).

In *INTRA+INTER* the proposal to choose identical efforts (C1) increases efforts significantly. If teams want to beat the other team (C6) or try to keep their strategy secret (C7), efforts get higher. A significantly negative effect on efforts is found for appeals to fairness (C3), insults against deviating members (C5), an appeal not to compete (C9), and proposals to take turns in winning (C10). The latter category is a sign of collusion, as it is backed up by the argument that taking turns saves on effort costs by avoiding an unproductive race to the top of feasible efforts.[16] The negative influence of insulting defecting members (C5) can be explained by insults either bringing 'effort-busters' (with higher than agreed upon efforts) back in line or by creating a bad atmosphere and leading single members to cheat on the others.

In *ENDOGENOUS* we find a strongly positive effect of category C1 (proposal to choose identical efforts within teams) and of an attempt to deceive the other team (C8). However, if collusive arguments arise, like e. g. taking turns within (C2) and across teams (C10) or choosing identical efforts across both teams (C11), this leads to significantly lower efforts.

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[15] It seems interesting to mention that we found in no treatment a significant relation between the magnitude of the proposed identical effort and the relative frequency with which teams agree on an identical effort. This is due to the high frequency (of about 90%) of reaching an agreement once coordination on the same effort is mentioned.

[16] Kaplan and Ruffle (2006) show that taking turns is a welcome means of cooperation in two-player games.

In *INTER* we see that no category has a significant impact on efforts. They are either too infrequent to be relevant or do not have a significant influence.

Result 4: The most important behavioral effect of communication originates from proposals to choose identical efforts within the own team, thus increasing efforts. Taking turns in winning is a strong collusive argument that drives down efforts.

5.3. Post-experimental questionnaire

After the experiment subjects had to answer individually several questions which were ordered in three different sets. Table 6 lists all questions and their mean answers. Please note from Table 6 that not all sets of questions were used in all treatments. In the following discussion we restrict ourselves to the questions we deem most interesting.

Table 6 about here

The answers to question 1 (Q1) reveal that participants in *INTRA* and *ENDOGENOUS* consider their individual profits significantly *less* important in comparison to the sum of profits within their own team than participants both in treatments *NOCOMM* and *INTRA+INTER* ($p < 0.05$; pairwise Mann-Whitney U-tests).[17] This result suggests that pure *intra*-team communication (available in *INTRA* and *ENDOGENOUS*) changes the reference point for the maximization calculus of subjects, as was the presumption for the formulation of our hypotheses in section 4.

Concerning Q2 on the attempt to cooperate with the competing team, the relative frequency of subjects answering “Yes” ranges from 36% in *ENDOGENOUS* to 80% in *INTRA+INTER*. Considering all treatments and correlating the answer to this question with a subject’s average effort level, we find a significantly negative relationship (Spearman rank correlation coefficient of –0.15; $p < 0.05$). Hence, subjects who try to cooperate with the competing team typically choose smaller efforts.

Regarding the questions in set 2, we deem Q7 and Q8 most important. The answers to Q7 can be taken as a (rough) proxy for group identity. Between 73% and 81% of subjects describe the atmosphere within their team as “good” (coding “1”), and there are no significant differences in the rating between treatments (Mann-Whitney U-test). Rather, we find a significantly positive correlation between an individual’s average effort and his assessment of

[17] In this subsection we use individual data as units of observation. Taking groups of six subjects (i.e. two related teams) as independent units of observation yields basically the same results (and they are available upon request).

the atmosphere within the team in each single treatment. The Spearman rank correlation coefficients are 0.35 in *INTRA*, 0.26 in *INTRA+INTER* and 0.33 in *ENDOGENOUS* ($p < 0.05$ in all treatments).

The answers to Q8 on the relationship with the competing team indicate very clearly that subjects in *INTRA+INTER* perceived this relationship as significantly *less* competitive than subjects in either *INTRA* or *ENDOGENOUS*, where competition is assessed as stronger ($p < 0.05$; Mann-Whitney U-test). The fact that all messages are public for members of the competing teams in *INTRA+INTER* creates a rather cooperative feeling and reduces the degree of 'felt' competition, which ultimately also drives down efforts. It is no surprise that this is not the case in *ENDOGENOUS*, where subjects were not forced to send messages also to members of the competing team.

Result 5: *Intra*-team communication increases the relative importance of the team's joint payoffs in comparison to a subject's own payoff. A better atmosphere in the team is correlated with higher efforts, and making messages public across competing teams reduces the perceived intensity of competition.

5.4. Robustness checks

In this section we would like to present two robustness checks concerning (i) the magnitude of the possible influence of communication within teams (in *INTRA*) and (ii) the relation between the effort-increasing effect of communication within teams and the effort-reducing effect of communication between teams (in *INTRA+INTER*). These checks are intended to address the following possible concerns with our parameterization from section 3.[18] First, one might argue that the effort-increasing effect of within-team communication can not be fully demonstrated in the parameterization of *INTRA* because the predicted effort level for joint team payoff maximization was outside the feasible effort range ($e_i^{INTRA} = 187.5 > 100$). Therefore, it seems reasonable to examine whether chosen efforts fall below or above the predicted effort in a parameterization that satisfies $e_i^{INTRA} < 100$. Second, the effort-reducing effect of communication across teams (in *INTRA+INTER*) might be more convincingly demonstrated for a parameterization which yields $e_i^{INTRA+INTER} < e_i^* < e_i^{INTRA}$. The latter ordering would provide a test whether the effort-reducing effect of communication across teams can outweigh the effort-increasing effect of communication within teams.

[18] We would like to thank both referees and the responsible editor for the suggestion to address both concerns by running additional treatments.

Unfortunately, it is not possible to find a parameterization that satisfies $e_i^{INTRA+INTER} < e_i^* < e_i^{INTRA} < 100$, without at the same time yielding negative expected payoffs in the *INTRA*-treatment (see Appendix C for a proof). Since we wanted to avoid expected losses for methodological reasons (see Friedman and Sunder, 1994, for why the expectation of negative earnings may have undesirable side-effects), we have decided to address both possible concerns in separate robustness checks where the expected payoffs are positive, at least for the hypothesized equilibria.[19] A total of 156 subjects participated in the sessions for the robustness checks, with none of these subjects having participated in any other session reported in this paper. In order to save on subjects and on our research budget (and also to check the robustness of the model for a different team size) we have decided to use teams of two subjects each (instead of setting up teams with three subjects as in the previous sessions). The sessions were run in January 2007 at the University of Innsbruck, and they took about 60 minutes.

5.4.1. Robustness check r1: $e_i^* < e_i^{INTRA} < 100$

In the upper half of Table 7 we present the parameters and the main results of robustness check *r1*. In one treatment with these parameters subjects had no opportunity to communicate (*NOCOMM-r1*, with expected effort e_i^*), and in the other treatment communication within the team was possible (*INTRA-r1*, with expected effort e_i^{INTRA})[20]. The observed average efforts in *INTRA-r1* (66.6) fall below the predicted level (85, if team members want to maximize the joint profit of their team), but they are clearly higher than in *NOCOMM-r1* (with average efforts of 51.3, compared to a predicted level of 42.5). Figure 3 illustrates that the efforts in *INTRA-r1* are increasing over rounds, and are always larger than in *NOCOMM-r1*. The upper half of Table 8 reports an FGLS-estimation where the treatment dummy "*INTRA-r1*" and the interaction term "Round × *INTRA-r1*" show that efforts in *INTRA-r1* are significantly higher than in *NOCOMM-r1*, and the difference is increasing over rounds. The average profits are not statistically different (Mann-Whitney U-test) between both treatments (which is largely due to the concavity of the payoff function and the relatively high standard deviation of efforts in *NOCOMM-r1*).

[19] For reasons of succinctness we dispense with an analysis of communication in the robustness checks and with a presentation of the data from the post-experimental questionnaire. The instructions used in the robustness checks-treatments are identical to those in Appendix B, except that the relevant parameters (see Table 7) have been changed.

[20] The derivation of predictions in this subsection is analogous to those in Appendix B. Details are available upon request from the authors.

Result 6: Communication within teams increases efforts in comparison to a situation without communication. However, the efforts stay below those predicted for the case when team members want to maximize the joint profit of the team.

Tables 7 and 8 and Figure 3 about here

5.4.2. Robustness check r2: $e_i^{INTRA+INTER} < e_i^* < 100$.[21]

In the lower half of Table 7 we present the parameters and the main results of robustness check *r2* where we compare a treatment without communication (*NOCOMM-r2*) to one with communication within and between teams (*INTRA+INTER-r2*). The actual efforts in *INTRA+INTER-r2* are only slightly below those in *NOCOMM-r2* (44.0 vs. 46.8), even though the maximization of both teams' sum of payoffs would predict an optimal effort of $e_i^{INTRA+INTER} = 29$ (with $e_i^* = 42.6$ in *NOCOMM-r2*). However, as Figure 4 and the lower half of Table 8 show, average efforts in *INTRA+INTER-r2* are indeed lower in the first half of the experiment, meaning that the effort-reducing effect of communication across teams can, in fact, dominate the effort-increasing effect of communication within teams (which is the novel insight from robustness check 2). The lower efforts and the smaller standard deviation also lead to significantly higher profits in *INTRA+INTER-r2* than in *NOCOMM-r2* ($p < 0.05$; Mann-Whitney U-test).

Result 7: The effort-reducing effect of communication across teams can dominate the effort-increasing effect of communication within teams. However, in our robustness check 2 we only find temporary evidence for this possibility.

Figure 4 about here

6. Conclusion

We have studied the effects of communication in an experimental tournament between two competing teams. Our results have shown that it matters substantially whether communication is restricted to the own team or also covers the competing team. If only communication within teams is possible, efforts rise significantly, even though they do not reach the level that would prevail if team members wanted to maximize the sum of their team

[21] Note that the parameters in *NOCOMM-r2* in robustness check 2 are different from those in *NOCOMM-r1*.

members' profits. If communication across competing teams complements the communication within teams efforts go down significantly. Though the overall effect of communication (when adding the effort-increasing effect of communication within teams and the effort-reducing effect of communication across teams) is ambiguous and depending on the prevailing parameters, the direction of the influence of communication within teams or communication across teams on efforts is unequivocal.

Generally speaking, communication facilitates the coordination of actions. Yet, coordination can have different consequences. When communication within teams is possible communication is an efficient means to coordinate team members' efforts at higher levels and to reduce the free-rider problem within teams. This aspect of our results is in line with previous research on the effects of communication. From public goods games we know that communication limits the degree of free-riding and thus increases contributions (Ledyard, 1995; Brosig et al., 2003). In coordination games, like the battle of the sexes game or market entry games, cheap talk has been shown to increase the frequency of equilibrium play (Cooper et al., 1989, 1992; Farrell, 1987; Park, 2002). In two-person bargaining games, like the dictator or the ultimatum game, communication makes 'fair' divisions of the pie more frequent and decreases the frequency of inefficient disagreements (Camerer, 2003). It is noteworthy that these previous studies have implemented (or modeled) communication always in the form that *all* interacting subjects communicate with each other. Therefore, these studies have not been able to disentangle the possible effects of communication depending upon whether all interacting subjects or only a *subset* of actors can communicate. In our context of a tournament setting, the restriction of communication to a subset of actors, i.e. the members of a given team (in *INTRA*), has been shown to be most efficient in raising efforts.

If communication encompasses all interacting actors within and across competing teams it leads to collusion and thus to significantly *lower* efforts than in case of communication within teams only. The latter result is similar to the findings of McCutcheon (1997) or Kandori and Matsushima (1998) who have shown that communication may have socially undesirable effects by fostering collusion among incumbent competitors in a market. Likewise, Aoyagi (2007) has shown that communication may promote collusion in auctions. Yet, these studies have not considered the possibility of internal conflicts within competing firms or bidders, contrary to our framework which has captured both the competition between companies, but also the free-riding incentives within companies.[22]

[22] In social psychology, there is some evidence on so-called 'team-games' where competition between teams is associated with a free-rider problem within teams. These team-games have the structure of a binary prisoner's dilemma game where the team with more cooperating members wins a prize. Bornstein (1992, 2003) has shown

Checking the contents of communication we have found that the main reason for increasing cooperation is the commitment that team members make for specific actions. In fact, most subjects feel obliged to align their decisions with their (cheap-talk) verbal commitments and therefore match their words with their deeds in about 90% of cases.[23] In the *INTRA*-treatment commitment is typically on identical and very high efforts, whereas in *INTRA+INTER* subjects more often commit to intermediate efforts (in order to save jointly on effort costs). The strength of commitment is supported by the opportunity to monitor other team members or the output of the competing team. If commitments or agreements are broken – which can be easily detected (without any costs) – free-riders are frequently exposed to social disapproval by calling them cheaters or free-riders. It is these kinds of (non-monetary) social sanctions which seem to be important to uphold cooperation within and across teams.[24]

One noteworthy feature of the effects of communication is the fact that it is not the mere possibility to exchange messages between teams that automatically leads to cooperation in the form of collusion. The most convincing evidence for this statement stems from our *ENDOGENOUS* treatment where subjects can choose themselves whether to use the *intra*-team chat or the *inter*-team chat. The latter is used in less than 50% of cases. However, the mere frequency of sending messages (or the number of lines written) in the *inter*-chat has no significant influence on overall efforts.[25] Rather it is the contents of the *inter*-chat messages that matters. Only when members of competing teams invoke specific arguments (like taking turns or committing to identical efforts across teams) then one can find a (negative) effect on efforts. For instance, if competing teams use the *inter*-chat to *agree* on joint actions, then average efforts are 70.0 and thus close to the collusive outcome, whereas efforts are significantly higher with 84.2 on average in the absence of any agreements.

In sum, our results seem to support the following general policy implication. From the viewpoint of a company that relies on internal team tournaments to induce high efforts of its work teams or departments, it seems a wise policy to provide good communication facilities

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that communication within teams increases the relative frequency of cooperative choices, but that communication between teams decreases cooperation. These results seem to be compatible with our findings in the more general setting of a tournament with (practically) continuous effort choices.

[23] Duffy and Feltovich (2006) have shown in a series of three different two-person games (prisoners' dilemma, stag hunt and chicken game) that messages about one's intended actions have a very high predictive power for actual decisions. Analyzing data from a TV-show that has the structure of a prisoner's dilemma game, Belot et al. (2006) also find that a player's promise to cooperate is a very good predictor for his actual cooperation.

[24] In the context of public goods games (without any *inter*-team competition), Masclet et al. (2003) or Rege and Telle (2004) have found a positive effect of non-monetary (and non-verbal) sanctions on the level of cooperation within groups.

[25] The same holds true for the *INTER* treatment where subjects could only communicate with a member of the competing team, but not with members of their own team. Communication in this treatment does not seem to have any impact on efforts compared to the control condition *NOCOMM*.

within teams to promote cooperation, but to restrict communication between competing teams to prevent collusion. The Sony Music group provides an example for the latter. Sony Music has several labels under which it sells its music (Columbia Records, Epic Records, Legacy Music, Nonesuch, Sony Classical, …). These labels compete for larger market shares with within-company (as well as outside-company) competitors. The prize for single labels within the Sony Music group is, then, to receive more funds to finance future projects and recordings. The promotion departments of Sony's labels usually have a telephone conference once a week in which the department's 6 to 12 members discuss and agree on particular strategies for promoting the label's products. Interestingly enough, these conferences are typically set by Sony Music headquarters at exactly the same date and time. This might be interpreted as an attempt to limit the degree of communication (and the scope for collusion in marketing activities) between its labels when it comes to making important decisions. To say the least, our experimental results support such a kind of policy.

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Tables

Table 1. Efforts and profits

Treatment	Average efforts	Average standard deviation of efforts within team and round	Average profit
INTER – between teams (*N* = 72)*	59.69	12.08	46.54
NOCOMM – no communication (*N* = 90)	58.13	12.84	46.42
INTRA+INTER – between and within teams (*N* = 90)	75.79	5.46	50.44
ENDOGENOUS – selective communication *(N* = 72*)*	81.34	4.06	49.36
INTRA – within teams (*N* = 84)	89.32	3.61	50.08

* Six subjects form one set of two teams á three members.

Table 2. Treatment and round effects on effort (FGLS-estimation)

Dependent variable: Individual effort Independent variables:	*Coefficient*
Intercept	76.79**
NOCOMM	-34.14**
INTRA+INTER	-20.70**
ENDOGENOUS	-12.89**
INTER	-33.18**
Round	5.54**
Round²	-0.37**
Round × NOCOMM	-0.41
Round × INTRA+INTER	0.48*
Round × ENDOGENOUS	0.96**
Round × INTER	-0.12

Number of observations: 4080.

** significant at the 1%-level

* significant at the 5%-level

Table 3. Effects of winning the tournament on efforts (Panel probit regression)

Dependent variable: *Increase*♣	
Independent variables:	*Coefficient*
Intercept	2.218**
NOCOMM	-1.354**
INTRA+INTER	-0.501
ENDOGENOUS	-1.198*
INTER	-1.573**
Round	-0.123*
Round²	0.003
Round × NOCOMM	-0.031
Round × INTRA+INTER	0.102**
Round × ENDOGENOUS	0.075*
Round × INTER	-0.054
Winlast♣♣	-1.116**
Winlast × NOCOMM	0.566**
Winlast × INTRA+INTER	0.025
Winlast × ENDOGENOUS	-0.215
Winlast × INTER	0.596**
C_Output♣♣♣	-0.007**
C_Output × NOCOMM	0.007**
C_Output × INTRA+INTER	-0.000
C_Output × ENDOGENOUS	0.004*
C_Output × INTER	0.009**
Max♣♣♣♣	0.080
Max × NOCOMM	-1.053**
Max × INTRA+INTER	-0.277
Max × ENDOGENOUS	-0.239
Max × INTER	-0.851**
Min♣♣♣♣♣	1.679**
Min × NOCOMM	-0.819**
Min × INTRA+INTER	-0.830*
Min × ENDOGENOUS	-0.334
Min × INTER	-0.775*

Number of observations: 3672.

* significant at the 5%-level

** significant at the 1%-level

♣ 1 if individual effort strictly increased from round *t*-1 to round *t*, 0 otherwise

♣♣ 1 if own team won in the previous round, 0 otherwise

♣♣♣ C_Output is the output of the competing team in the previous round

♣♣♣♣ 1 if individual effort is the strict maximum of all individual efforts within the team in the previous round

♣♣♣♣♣ 1 if individual effort is the strict minimum of all individual efforts within the team in the previous round

Table 4. Categories for coding messages

Category	Description	Relative frequency of coding "1"			
		INTRA	*INTRA+INTER*	*ENDOGENOUS*	*INTER*
C1	Proposal to choose identical efforts within team	0.78	0.55	0.88	0.03
C2	Proposal to choose unequal efforts within team (e.g. 2 members high, 1 member low)	0.08	0.11	0.06	0.00
C3	Appeal to fairness within team ("It is fair, if all members of the group choose the same effort")	0.06	0.11	0.05	0.03
C4	Appeal to loyalty ("Let's stick to what we have agreed on.")	0.02	0.09	0.03	0.003
C5	Insult of defecting members	0.01	0.07	0.01	0.13
C6	Goal to beat the other (competing) team	0.03	0.04	0.09	0.01
C7	Secrecy of strategy ("Do not reveal chosen efforts to members of other team.")	n.a.	0.09	0.02	0.01
C8	Lying towards the other team about own intended choices	n.a.	0.003	0.08	0.00
C9	Appeal not to compete with other team	n.a.	0.14	0.004	0.003
C10	Proposal to take turns in winning the tournament (each team wins every second round)	n.a.	0.15	0.05	0.00
C11	Proposal that members of both teams choose identical effort to make winning random	n.a.	0.24	0.05	0.01

n.a. not applicable in *INTRA*-treatment, because competing teams could not communicate with each other

Table 5. Effects of the communication categories on team efforts (FGLS-estimation)

Dependent variable: Individual effort				
Independent variables:	*INTRA*	*INTRA+INTER*	*ENDOGENOUS*	*INTER*
Intercept	79.15**	59.47**	56.15**	37.14**
Round	3.11**	3.38**	6.53**	8.63**
Round²	-0.20**	-0.14	-0.41**	-0.66**
Difference between output own team and other team in previous round	0.01*	-0.04**	0.04**	0.05**
C1 (Identical effort within team)	7.15**	6.68**	13.45**	5.08
C2 (Unequal efforts within team)	-11.38**	2.38	-10.98**	-♣
C3 (Appeal to fairness)	3.64	-15.58**	-2.60	1.96
C4 (Appeal to loyalty)	2.56	9.69**	8.59*	-37.23
C5 (Insult of defecting members)	-3.69	-11.96**	-19.08	0.50
C6 (Goal to beat other team)	6.41**	10.59**	-3.24	5.44
C7 (Secrecy)	-	9.97**	9.56	-6.28
C8 (Lying to other group)	-	17.76	10.04**	-♣
C9 (Appeal not to compete)	-	-3.86*	-♣	-23.00
C10 (Take turns in winning)	-	-9.07**	-35.52**	-♣
C11 (Identical efforts in both teams)	-	5.24**	-21.71**	0.01
Number of observations	756	810	648	648

** significant at the 1%-level

* significant at the 5%-level

♣ Argument at most mentioned once overall (therefore not considered in the panel regression)

Table 6. Post-experimental questionnaire

Question [coding in squared brackets]	*Mean values*				
	NOCOMM (N = 90)	*INTRA* (N = 84)	*INTRA+ INTER* (N = 90)	*ENDO-GENOUS* (N = 72)	*INTER* (N = 72)
Set 1 (all treatments)					
Q1. Have you considered your individual profit as more important for your decision on the effort than the sum of payoffs of your own team? [+1 = "More important"; 0 = "Equally important"; -1 = "Less important"]	0.13[a, c]	-0.08[a, e]	0.21[e, h]	-0.08[c, h]	0.04
Q2. Have you tried to cooperate with the matched team (as far as possible)? [1 = "Yes"; 0 = "No"]	0.61[b, c]	0.56[e, f]	0.80[b, e, h, i]	0.36[c, f, h, j]	0.61[i, j]
Q3. Would you wish to switch to a different team if the game were repeated another 10 rounds? [1 = "Yes"; 0 = "No"]	0.32[a, c]	0.18[a, g]	0.20[i]	0.14[c, j]	0.39[g, i, j]
Set 2 (*INTRA, INTRA+INTER* and *ENDOGENOUS*)					
Q4. Have you tried to coordinate with members of your team concerning the efforts to choose? [1 = "Yes"; 0 = "No"]	-	1.00	0.97	0.99	-
Q5. Have you felt cheated or betrayed with respect to the chosen efforts by another member in your team? [1 = "Yes"; 0 = "No"]	-	0.17[e]	0.38[e]	0.24	-
Q6. Have you cheated or betrayed anyone in your team concerning your chosen effort? [1 = "Yes"; 0 = "No"]	-	0.10[e]	0.28[e]	0.15	-
Q7. How would you describe the atmosphere within your team? [1 = "Good"; 0 = "Neutral"; -1 = "Bad"]	-	0.77	0.64	0.72	-
Q8. How would you describe the relationship with the matched team? [1 = "Rather cooperative"; 0 = "Neutral"; -1 = " Rather competitive"]	-	-0.49[e]	-0.01[e, h]	-0.31[h]	-
Set 3 (*INTRA+INTER; ENDOGENOUS* and *INTER*)					
Q9. Have you tried to coordinate with members of the matched team concerning the efforts to choose? [1 = "Yes"; 0 = "No"]	-	-	0.70[h]	0.24[h, j]	0.61[j]
Q10. Have you felt cheated or betrayed by another member in the matched team? [1 = "Yes"; 0 = "No"]	-	-	0.26	0.19	0.17
Q11. Have you cheated or betrayed anyone in the other team? [1 = "Yes"; 0 = "No"]	-	-	0.22	0.19	0.22

Significantly different ($p < 0.05$; Mann-Whitney U-tests for Q1, Q7 and Q8; χ^2-tests for others) in pairwise comparisons
([a]) NOCOMM vs. INTRA, ([b]) NOCOMM vs. INTRA+INTER, ([c]) NOCOMM vs. ENDOGENOUS,
([d]) NOCOMM vs. INTER ([e]) INTRA vs. INTRA+INTER, ([f]) INTRA vs. ENDOGENOUS, ([g]) INTRA vs. INTER,
([h]) INTRA+INTER vs. ENDOGENOUS, ([i]) INTRA+INTER vs. INTER, ([j]) ENDOGENOUS vs. INTER

Table 7. Parameters and main results in the robustness checks

	Predicted Efforts	Average efforts	Average standard deviation of efforts (per team and round)	Average profit
Robustness check 1:				
Teams á 2 subjects. $f = 5.5$. $C(e_i) = e_i^2/20$. $e_i \in [0,100]$. $L = -30$, $H = 30$. $TR = 90$.				
NOCOMM-r1 – no communication ($N = 40$)	$e_i^* = 42.5$	51.27	6.73	113.46[#]
INTRA-r1 – within team ($N = 36$)	$e_i^{INTRA} = 85$	66.58	1.36	113.59[#]
Robustness check 2:				
Teams á 2 subjects. $f = 2.9$. $C(e_i) = e_i^2/20$. $e_i \in [0,100]$. $L = -16$, $H = 16$. $TR = 90$.				
NOCOMM-r2 – no communication ($N = 40$)	$e_i^* = 42.6$	46.77	6.83	08.51[§]
INTRA+INTER-r2 – between teams ($N = 40$)	$e_i^{INTRA+INTER} = 29$	44.04	3.80	22.27[§]

[#] Exchange rate: 100 points = 1 Euro.

[§] Exchange rate: 40 points = 1 Euro.

Table 8. Treatment and round effects on effort in robustness checks (FGLS-estimation)

Robustness check 1 ($N = 760$)	
Dependent variable:Individual effort level	
Independent variables:	*Coefficient*
Intercept	48.12**
INTRA-r1	5.54**
Round	1.60**
Round²	-0.16**
Round × INTRA-r1	1.91**
Robustness check 2($N = 800$)	
Intercept	50.54**
INTRA+INTER-r2	-10.52**
Round	0.19
Round²	-0.08*
Round × INTRA+INTER-r2	1.35**

** significant at the 1%-level

* significant at the 5%-level

Figures

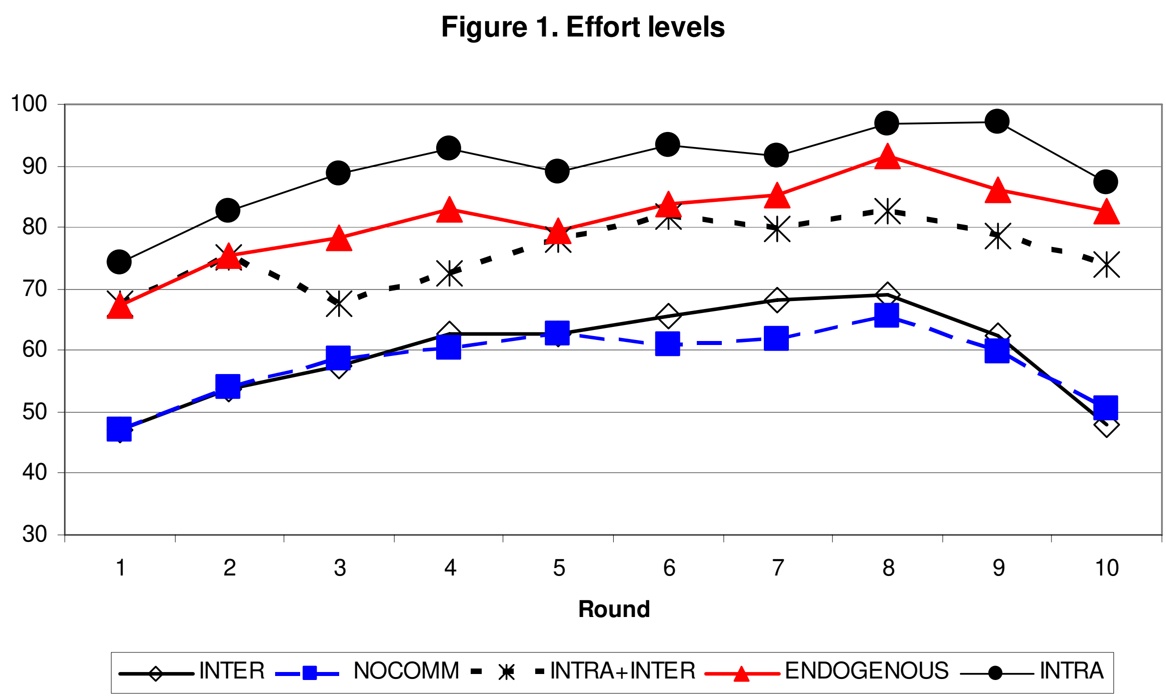


Figure 1. Effort levels
100
90
80
70
60
50
40
30
1
2
3
4
5
6
7
8
9
10
Round
INTER
NOCOMM
INTRA+INTER
ENDOGENOUS
INTRA

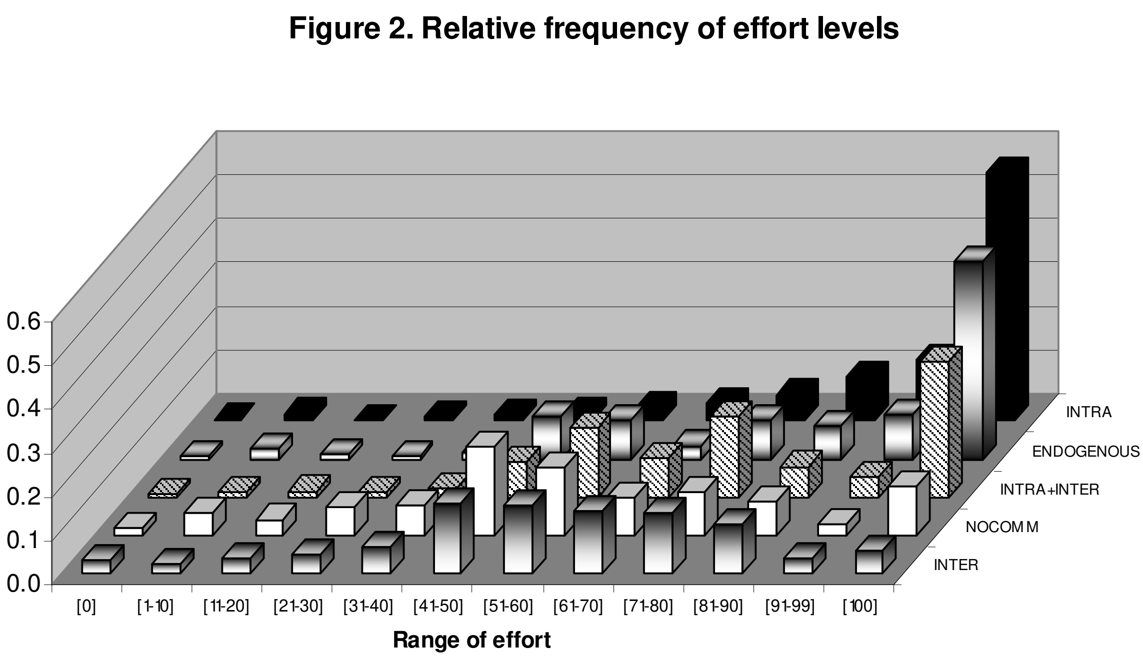


Figure 2. Relative frequency of effort levels
0.6
0.5
0.4
0.3
0.2
0.1
0.0
[0]
[1-10]
[11-20]
[21-30]
[31-40]
[41-50]
[51-60]
[61-70]
[71-80]
[81-90]
[91-99]
[100]
Range of effort
INTRA
ENDOGENOUS
INTRA+INTER
NOCOMM
INTER

Figure 3. Effort levels in robustness check 1

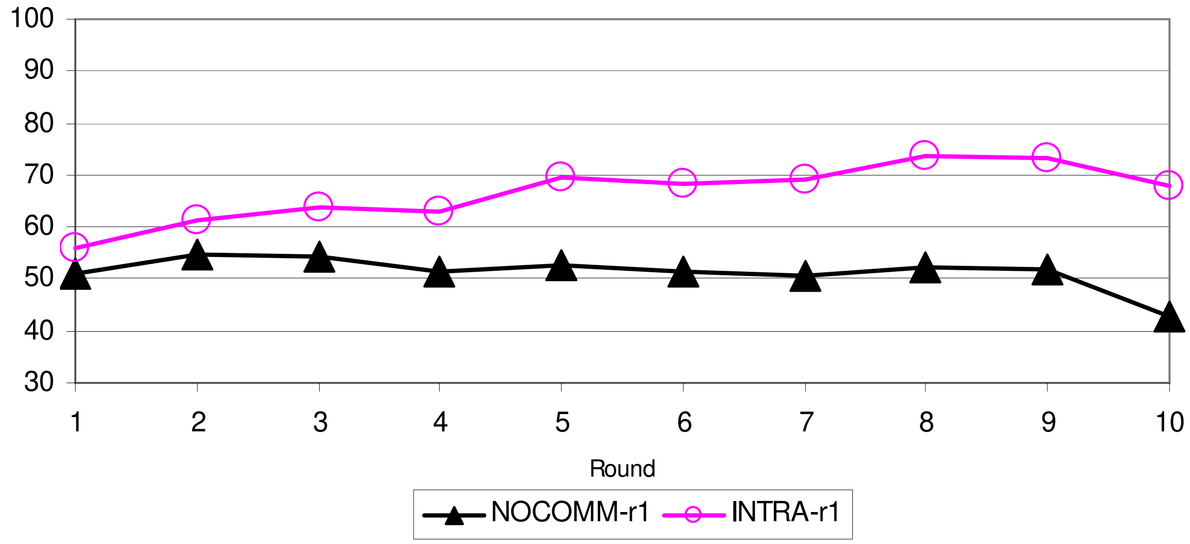
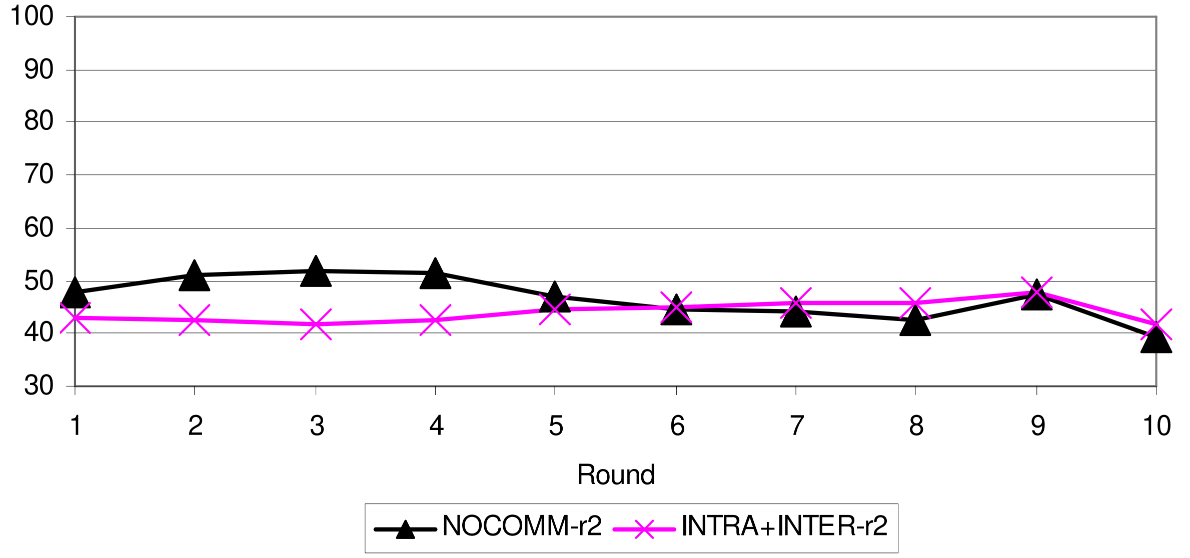


Figure 4. Effort levels in robustness check 2



Appendix A (not necessarily for publication)

Experimental instructions

These instructions are for the NOCOMM-treatment.

Modifications for the INTRA-treatment are added in `Courier` *and squared brackets.*

Modifications for the INTRA+INTER-treatment are given in italics and parenthesis.

Modifications for the ENDOGENOUS-treatment are given in Arial *and parenthesis.*

Modifications for the INTER-treatment are added in ***Forte*** *and curly brackets.*

Welcome to the experiment. Please do not speak to other participants until the experiment is completely over. If you face any difficulties, questions, or problems, please raise your hand and an instructor will come to your desk. In this experiment, we want to study decision making of subjects. Your decisions as well as the decisions of other participants will remain anonymous. You will be paid at the end of the experiment according to the rules introduced below. `[In addition, you will receive a show-up fee of 4 €.]` *(In addition, you will receive a show-up fee of 4 €.)* (In addition, you will receive a show-up fee of 4 €.) ***{In addition, you will receive a show-up fee of 4 €.}***

2 groups of 3 subjects each – 10 rounds

In this experiment, we will randomly assign you to a group of 3 subjects. In addition, your group will be randomly matched with another group of 3 subjects. The composition of your group and the matched group will remain fixed throughout the whole experiment, which will last for 10 rounds. Hence the decisions of the members of the other group, those of your group members and that of your own affect the result of the game and consequently your payment.

Structure of each round

In each round your task is to choose an integer number from the closed interval [0, 100].

`[Before your decision on the number you have the opportunity to chat electronically with the members of your own group via an anonymous chat forum. You will have 8 minutes to chat with each other in the first two rounds and 4 minutes in the following rounds. You are forbidden to make threats or to reveal your identity, seat number or anything that might uncover your anonymity. The content of your discussion has no binding impact on the course of the experiment.]`

(Before your decision on the number you have the opportunity to chat electronically with the members of your own group as well as with those of the matched group via an anonymous chat forum. You will have 8 minutes to chat with each other in the first two rounds and 4 minutes in the following rounds. You are forbidden to make threats or to reveal your identity, seat number or anything that might uncover your anonymity. The content of your discussion has no binding impact on the course of the experiment.)

(Before your decision on the number you have the opportunity to chat electronically with the members of your own group as well as with those of the matched group via anonymous chat forums. If you want to send a message to members of your own group only, please use the window at the top of your screen. If you want to send a message both to the members of your own team and to the members of the competing team, please use the window at the bottom of your screen. You will have 8 minutes to chat with each other in the first two rounds and 4 minutes in the following rounds. You are forbidden to make threats or to reveal your identity, seat number or anything that might uncover your anonymity. The content of your discussion has no binding impact on the course of the experiment.)

{Before your decision on the number you have the opportunity to chat electronically with a member of the other group via an anonymous chat forum. Neither you nor this other person can chat with other participants of the experiment. Each member of your own group can chat with a member of the other group only. You will have 8 minutes to chat with each other in the first two rounds and 4 minutes in the following rounds. You are forbidden to make threats or to reveal your identity, seat number or anything that might uncover your anonymity. The content of your discussion has no binding impact on the course of the experiment.}

After members of your group and the matched group have entered their number, you are informed about the numbers chosen by members of your group. All numbers of your group are then summed up and a uniformly distributed random number from the closed interval [-40, 40] is added to the sum of numbers in your group, which yields your **group result**.

Payment for the group result

The group result is multiplied by 1.5, which generates the **group revenue**. The group revenue is shared equally among all members of your group.

> A fictitious example:
> Member 1 chooses 46. Member 2 chooses 76. Member 3 chooses 10.
> → group sum = 46 + 76 + 10 = 132
> → random shock (for example): – 4
> → group result = 132 – 4 = 128
> → group revenue = 128 * 1.5 = 192
> → individual share of group revenue = 192 / 3 = 64

Choosing a number has costs of the form:

$$\text{Costs} = (\text{number})^2/100.$$

> In the previous fictitious example:

→ each member has to bear his costs:

- costs for member 1: $46^2/100 = 21.16$
- costs for member 2: $76^2/100 = 57.76$
- costs for member 3: $10^2/100 = 1$.

→ these costs are deducted from each member's share of group revenue:

- payment for the group result for member 1: 64 – 21.16 = 42.84
- payment for the group result for member 2: 64 – 57.76 = 6.24
- payment for the group result for member 3: 64 – 1 = 63.00

Additional payment for the relative group result

At the end of each round your group's result is compared to the result of the matched group. The group with the higher result obtains a **bonus** of 90 points, whereas the group with the lower result has to suffer a **reduction** of 90 points. Bonuses as well as reductions are divided equally among the members of a group.

You will always be informed about the result of the matched group and whether your group gets the bonus or the reduction. However, you will not be informed about further details in the matched group (such as numbers chosen by individual members in the matched group or the random number in the matched group).

> If in the above fictitious example the matched group had a result of 210, your group with a group result of 128 would have to bear the reduction. That means that each member of your group (including yourself) would lose 30 points.

Summary of total payment

In each round, your payment consists of **your share of the revenue of your group minus your individual costs plus or minus the equal share of the bonus or the reduction**:

$$Payment = \frac{1.5*(group\ revenue)}{3} - \frac{number^2}{100} + / - \frac{90}{3}$$

Your payments in single rounds are summed up at the end of the experiment and paid in cash.

Exchange rate: 1 € = 60 Points

(or 10 Points = approximately 17 Cent)

At the beginning of the experiment, you receive an additional endowment of 150 points as initial endowment.

Post-experimental questionnaire

Questions 1.) to 3.) were asked in all treatments. (Coding for statistical analysis is given in parenthesis.)

1.) Have you considered your individual profit as more important for your decisions than the sum of payoffs of your own group?
   - More important *(+1)*
   - Equally important *(0)*
   - Less important *(-1)*

2.) Have you tried to cooperate with the matched group (as far as possible)?
   - Yes *(1)*
   - No *(0)*

3.) Would you wish to switch to a different group, if the game were repeated another 10 rounds?
   - Yes *(1)*
   - No *(0)*

Questions 4.) to 8.) were answered by participants in INTRA and INTRA+INTER and ENDOGENOUS.

4.) Have you tried to coordinate with members of your group concerning the numbers to choose?
   - Yes *(1)*
   - No *(0)*

5.) Have you felt cheated or betrayed with respect to the chosen number by another member in your group?
   - Yes *(1)*
   - No *(0)*

6.) Have you cheated or betrayed anyone in your group concerning your chosen number?
   - Yes *(1)*
   - No *(0)*

7.) How would you describe the atmosphere within your group?
   - Bad *(-1)*
   - Neutral *(0)*
   - Good *(1)*

8.) How would you describe the relationship with the matched group?
   - Rather competitive *(-1)*
   - Neutral *(0)*
   - Rather cooperative *(1)*

Questions 9.) to 11.) were answered by participants in treatments INTER, INTRA+INTER and ENDOGENOUS.

9.) Have you tried to coordinate with members of the matched group concerning the numbers to choose?
   - Yes *(1)*
   - No *(0)*

10.) Have you felt cheated or betrayed by anybody of the other group?
   - Yes *(1)*
   - No *(0)*

11.) Have you cheated or betrayed anyone in the other group?
   - Yes *(1)*
   - No *(0)*

Appendix B (not necessarily for publication)

Proof of the unique and symmetric Nash Equilibrium (for referees' convenience, not intended for publication)

Maximizing function (2) from section 2 with respect to a subject's strategic choice variable e_i yields:

$$\frac{\partial E(\pi_i)}{\partial e_i} = \frac{f}{3} - \frac{2e_i}{100} + \frac{2TR}{3} * \frac{\partial P_j}{\partial e_i} = 0.$$

In order to solve this equation one needs to know the first derivation of P_j (the winning probability of team j) with respect to e_i. In the following, we present, first, a graphical analysis of the winning probability. Second, we will show analytically how to derive the winning probability.

Figure A1 shows on its x-axis the difference between the output of the other team *k* and team *k*'s effort, which must always equal team *k*'s random shock ε_k. The y-axis measures the difference between the output of the own team *j* and the competing team *k*'s effort. Only in case of identical effort sums in both teams is the vertical axis indicating team *j*'s random shock ε_j. Because Figure A1 implies a simple comparison of the outputs of both teams minus an identical amount (i.e. team *k*'s effort), the 45° line determines the winner of the tournament (this also applies to figures A2 to A5). All realizations above this line indicate that team *j*'s output exceeds that of team *k*, hence team *j* wins the tournament. Consequently, points above the 45° line can be regarded as team *j*'s winning area.

To pin down the winning probability one has to, first of all, take into account that the values of the x-axis can only vary in the range of team *k*'s random shock, whereas the realization of y-values depends of team *j*'s random shock *and* the difference between both teams' efforts Δ, with $\Delta = \Sigma e_j - \Sigma e_k = (Y_j - \varepsilon_j) - (Y_k - \varepsilon_k)$.

In case of identical team efforts (Δ = 0) – as is assumed in Figure A1 – the possible y-values can only vary in the interval of *j*'s random shock. Hence the set of all points that can be realized in Figure A1 (with Δ = 0) can be marked as the square with the corners (L, L), (H, L), (H, H) and (L, H), whose area equals $(H-L)^2$. This square of possible outcomes in the experiment will be denoted "*possible square*" in the following.

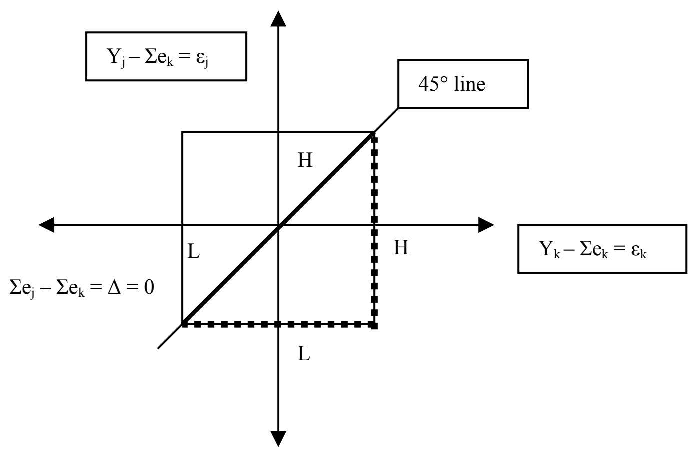


Figure A1. Δ = 0

With the help of the 45° line and the "possible square" set one can define the probability with which a given team is winning. This is due to the uniform distribution of the random shock. For instance, the relation of the area in the "possible square" which is below the 45° line to the total area of the "possible square" defines team *k*'s winning probability. In Figure A1 the respective area in which team *k* wins is limited by the two dotted lines and the 45° line.

In a more general case like in Figure A2, in which Δ > 0, the "possible square" is shifted upwards by the amount of Δ because the possible range of x-values remains the same.

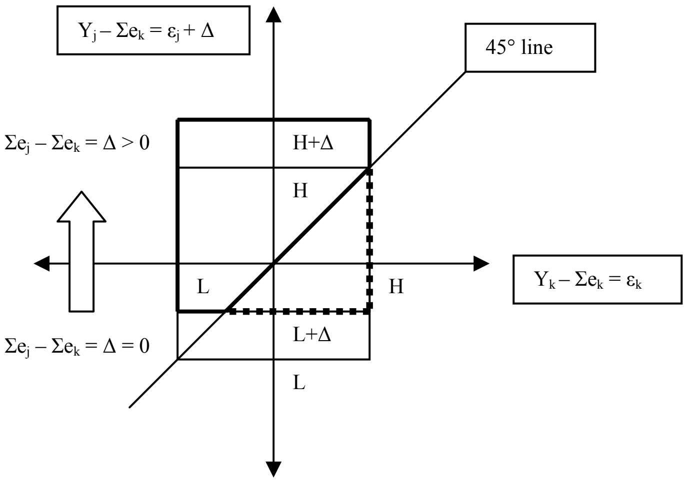


Figure A2. Δ > 0

The higher Δ, the smaller the area where the other team *k* is possibly winning and the higher team *j*'s winning area limited by the bold lines in Figure A2.

Due to the uniform distribution of the random shocks within the interval [L, H], every point within the "possible square" is equally likely. Hence the probability of winning is determined by the relation of the area of advantageous outcomes (those above the 45° line for team *j*) to the area of the "possible square", with the latter being defined as $(H-L)^2$. Then one can arrive at the following winning probabilities for team *j* (P_j) and team *k* (P_k).

$$P_k = \begin{cases} 0 & \forall\, \Delta \geq (H-L) & Case\ 1 \\ \dfrac{(H-L-\Delta)^2}{2*(H-L)^2} & \forall\, 0 \leq \Delta \leq (H-L) & Case\ 2 \\ 1-\dfrac{(H-L+\Delta)^2}{2*(H-L)^2} & \forall\, (L-H) \leq \Delta \leq 0 & Case\ 3 \\ 1 & \forall\, \Delta \leq (L-H) & Case\ 4 \end{cases}$$

$$P_j = 1 - P_k$$

In the following, these four cases are represented graphically. After that we are going to examine the derivation of P_j with respect to e_i.

<u>*Case 1*</u>

The effort of the own team j exceeds the one of the other team k with an amount larger than the range of the random shock. Thus $P_j = 1$.

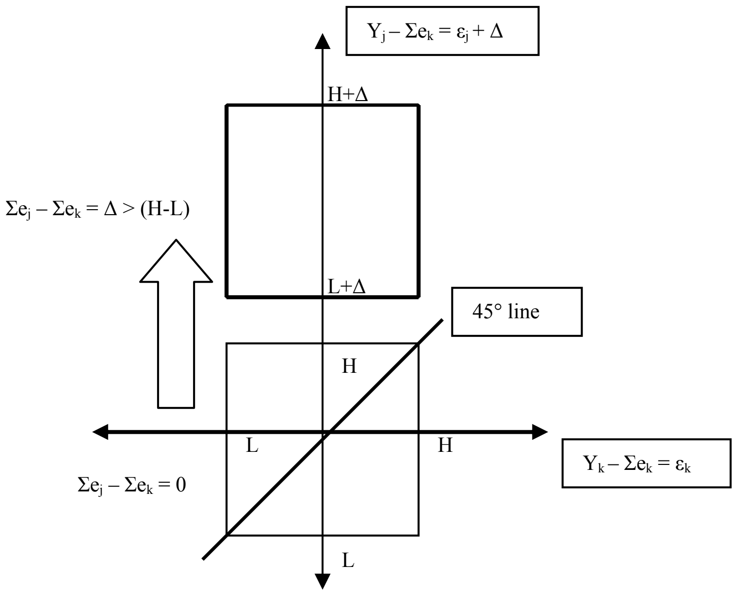


Figure A3. Δ > (H-L)

<u>*Case 2*</u>

The effort of the own team j exceeds the one of the other team k by less than the range of the random shock (see Figure A2).

<u>*Case 3*</u>

The effort of the other team k exceeds the one of the own team j by less than the range of the random shock.

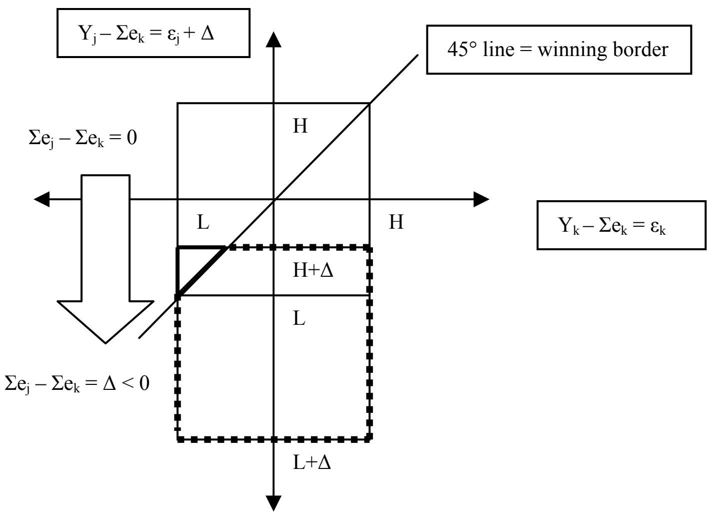


Figure A4. Δ < 0

<u>*Case 4*</u>

The effort of the other team k exceeds the one of the own team j by more than the range of the random variable. Hence $P_j = 0$.

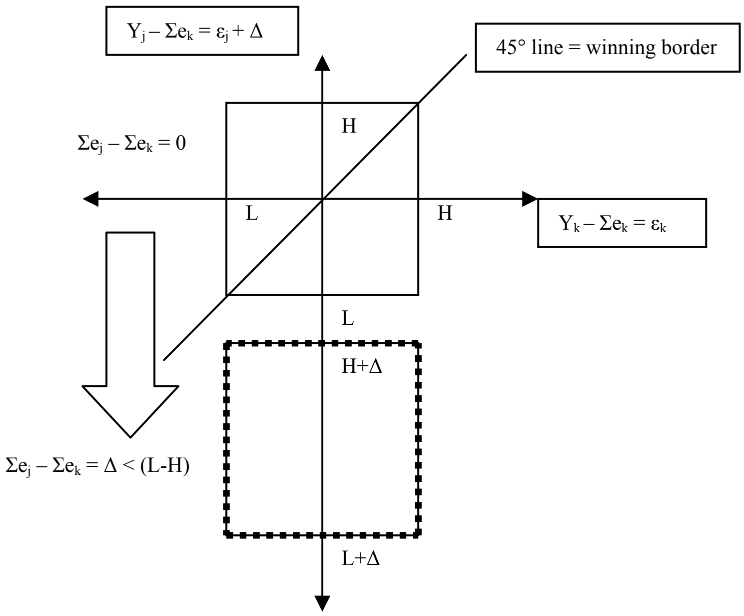


Figure A5. Δ < (L-H)

From the viewpoint of the own team *j* one can rewrite the winning probability P_j as follows (separating for the moment the four different cases illustrated above):

$$P_j = \begin{cases} 1 & \forall\ \Delta \geq (H-L) \quad \textit{Case } 1 \\ \frac{1}{2} + \frac{\Delta}{(H-L)} - \frac{\Delta^2}{2*(H-L)^2} & \forall\ 0 \leq \Delta \leq (H-L) \quad \textit{Case } 2 \\ \frac{1}{2} + \frac{\Delta}{(H-L)} + \frac{\Delta^2}{2*(H-L)^2} & \forall\ (L-H) \leq \Delta \leq 0 \quad \textit{Case } 3 \\ 0 & \forall\ \Delta \leq (L-H) \quad \textit{Case } 4 \end{cases}.$$

The graph of this function looks as follows:

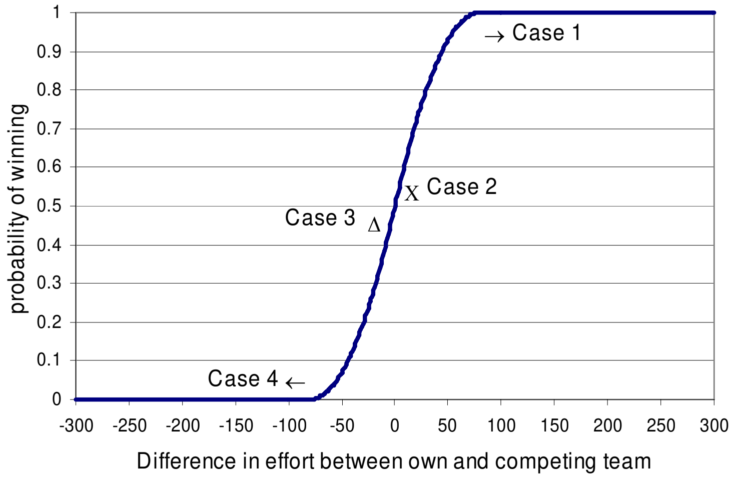


Figure A6. Graph of winning probability

The first partial derivations of all 4 cases can be written as:

$$\frac{\partial Pj}{\partial \Delta} = \begin{cases} 0 & \forall\, \Delta \geq (H-L) \quad \text{Case } 1 \\ \frac{1}{(H-L)} - \frac{\Delta}{(H-L)^2} & \forall\, 0 \leq \Delta \leq (H-L) \quad \text{Case } 2 \\ \frac{1}{(H-L)} + \frac{\Delta}{(H-L)^2} & \forall\, (L-H) \leq \Delta \leq 0 \quad \text{Case } 3 \\ 0 & \forall\, \Delta \leq (L-H) \quad \text{Case } 4 \end{cases}$$

In the symmetric case ($\Delta = 0$) the slope of the winning probability function is $\frac{1}{(H-L)}$. Substituting Δ^2 with $\Delta*|\Delta|$ or $\Delta*\sqrt{\Delta^2}$ one can summarize cases 2 and 3 which yields the following function:

$$P_j = \begin{cases} 1 & \forall\, \Delta \geq (H-L) \quad \text{Case } 1 \\ \frac{1}{2} + \frac{\Delta}{(H-L)} - \frac{\Delta*\sqrt{(\Delta^2)}}{2*(H-L)^2} & \forall\, (L-H) \leq \Delta \leq (H-L) \quad \text{Cases } 2 \text{ and } 3 \\ 0 & \forall\, \Delta \leq (L-H) \quad \text{Case } 4 \end{cases}$$

The first derivations with respect to Δ are:

$$\frac{\partial Pj}{\partial \Delta} = \begin{cases} 0 & \forall\, \Delta \geq (H-L) \quad \text{Case } 1 \\ \frac{1}{(H-L)} - \frac{\sqrt{\Delta^2}}{(H-L)^2} & \forall\, (L-H) \leq \Delta \leq (H-L) \quad \text{Cases } 2 \text{ and } 3. \\ 0 & \forall\, \Delta \leq (L-H) \quad \text{Case } 4 \end{cases}$$

With the help of further transformation one can generate a function to capture all 4 cases:

$$P_j = \left(\frac{1}{8} + \frac{\Delta}{4*(H-L)} - \frac{\Delta*\sqrt{\Delta^2}}{8*(H-L)^2}\right)*\left(1+\frac{\Delta+(H-L)}{\sqrt{(\Delta+(H-L))^2}}\right)*\left(1-\frac{\Delta-(H-L)}{\sqrt{(\Delta-(H-L))^2}}\right)+\frac{\Delta-(H-L)}{2*\sqrt{(\Delta-(H-L))^2}}+\frac{1}{2}.$$

Its first derivation with respect to Δ is:

$$\frac{\partial P_j}{\partial \Delta} = \left(\frac{(H-L)-\sqrt{\Delta^2}}{4*(H-L)^2}\right)*\left(1+\frac{\Delta+(H-L)}{\sqrt{(\Delta+(H-L))^2}}\right)*\left(1-\frac{\Delta-(H-L)}{\sqrt{(\Delta-(H-L))^2}}\right).$$

This function generates also a slope of $\frac{1}{(H-L)}$ in point of $\Delta = 0$.

After differentiating the probability function with respect to Δ, we need to calculate the first partial derivation concerning the player's strategic decision variable e_i:

$$\frac{\partial P_j}{\partial e_i} = \frac{\partial P_j}{\partial \Delta} * \frac{\partial \Delta}{\partial e_i}$$

Due to $\frac{\partial \Delta}{\partial e_i} = 1$ the two derivations yield identical results.

Finally one can insert the first partial derivation of the winning probability in the first order condition derived at the beginning of this mathematical proof. Assuming that all 6 players maximize their expected profits in the same manner one can derive 6 first order conditions. Solving them yields equation (3) of section 2.

Similarly, one can derive the solutions for the cases in which single players maximize not their own payoff, but their own team's payoff (see equation (5)) or the total payoff of both teams (see equation (7)).

Appendix C (not necessarily for publication)

Explanation of why two robustness checks are needed

Considering a team tournament setting with four workers grouped into two teams, where the effort costs are given by $C(e_i) = e_i^2 / x$, the restriction $e_i^{INTRA+INTER} < e_i^*$ can be formulated as follows

$$e_i^{INTRA+INTER} = \frac{fx}{2} < \frac{x}{2} * \left(\frac{f}{2} + \frac{TR}{(H-L)} \right) = e_i^* . \quad \text{(C1)}$$

This is equivalent to

$$\frac{f}{2} < \frac{TR}{(H-L)} . \quad \text{(C2)}$$

Implementing the restriction $e_i^{INTRA} \leq 100$ in our experimental setting requires a non-negativity constraint of equilibrium payoffs in the INTRA treatment.

$$E\left(\pi_i^{INTRA}\left(e_i^{INTRA}\right)\right) = f\left(\frac{fx}{2} + \frac{TRx}{(H-L)}\right) - \frac{\left(\frac{fx}{2} + \frac{TRx}{(H-L)}\right)^2}{x} \geq 0 \quad \text{(C3)}$$

Condition (C3) can be rewritten as

$$\frac{f}{2} \geq \frac{TR}{(H-L)} , \quad \text{(C4)}$$

for $\left(\frac{f}{2} + \frac{TR}{(H-L)}\right) x \geq 0$. Obviously, conditions (C2) and (C4) cannot hold at the same time. Therefore, it is necessary to implement the two different restrictions in two separate settings.