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An experimental study on the information structure in teams*

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Abstract

Is free-riding in teams reduced when one member receives a signal on his colleague's performance? And how does free-riding depend on the signal's type? We address these questions in experimental teams in which two agents sequentially exert effort to contribute to the team output. We vary the type of information the second mover receives prior to his effort choice and find that agents work more when signals are available. Overall, behavior differs from predictions of standard theory. Signals that are predicted to have no effect are, in fact, influential and signals that are predicted to have an effect are redundant.

Keywords: Team production, Free-riding, Experiment, Information, Signal
JEL Classification: C92, J30, M50, D82

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1 Introduction

Team members often work inefficiently little as their rewards are related to the team output but the costs of contributing to the team output accrue to the individual member only. In this paper we address the question whether team members are stimulated to work more when one member receives a signal on his colleague's performance prior to his effort choice. Furthermore, we analyze how the signal's type affects behavior.

In many situations agents of a team act sequentially and the second mover observes some signal on the first mover's performance. The signal may affect the second mover's incentives. Consider, for example, the case where individual contributions to the team output are substitutes (i.e. the more one agent contributes, the lower are the incentives for the other agent to work hard) and the second mover can perfectly observe the first mover's contribution. If all agents are self-interested, it is optimal for the first mover to work little in order to induce the second mover to work hard. However, if agents are concerned about fairness or reciprocity, the first mover may face incentives to work hard in order to induce his fellow worker to work hard as well. Furthermore, the signal's type may play an important role: The second mover may observe how hard the first mover worked for the team project or how much value he added to the team output. Take, for example, the development of a new product consisting of a design and a construction phase. The constructor may observe the effort the designer devoted to designing the product (e.g. if their offices are situated closely together), or the quality of the design (e.g. results of a customer test series), or both. If the constructor's and the designer's wages depend only on the quality of the product, a selfish constructor focuses on the information on the quality of the design, whereas a fair-minded constructor also takes the designer's effort into account. This raises the question how the information structure in teams affects behavior.

In order to put this question to a test, we conduct a series of laboratory experiments in which two team members work sequentially. We observe that on average both agents work more when the second mover receives an informative signal on the first mover's performance. Especially the first mover's effort turns out to be a stimulating signal.

In our experiment a team consists of two agents who sequentially decide on their effort to contribute to the team output. Prior to the second mover's effort choice he observes a signal on the first mover's performance. The higher an agent's effort, the higher is the probability that his contribution to the team output is high rather than low. An agent's payoff equals his wage minus his effort costs. Both agents receive the same wage that positively depends on the team output. The wage scheme is given exogenously, e.g. by a principal or a market that is not modeled in the game.

As we focus on the pure incentive effect of different information structures, we vary the signal across treatments, while we keep everything else constant. Our treatments are defined according to the degree of information the signal provides about the first mover's contribution – the only performance variable of the first mover that is directly payoff relevant for the second mover. Given the first mover's contribution, the second mover's payoff does not depend on the first mover's effort. In our benchmark treatment there is no signal at all, while in the other treatments the signal is either the first mover's effort (i.e. an imperfect signal), or the first mover's contribution (i.e. a perfect signal), or both. Observing both does, however, not provide more information on the first mover's contribution than observing his contribution only. Still, the effort provides additional information about the first mover's payoff.

We implement a wage scheme such that agents' contributions are substitutes. In this case standard theory predicts for all treatments with an informative signal that the second mover's effort is negatively related to the signal[1] and the first mover works less than in the benchmark treatment. We observe, however, that on average the first mover works more when informative signals are available and the second mover positively reacts to the signals. Even if the second mover observes the first mover's contribution and effort, the second mover's effort increases in the first mover's effort. This contradicts standard theory since in this case the first mover's effort is payoff irrelevant for the second mover. Overall, both agents work more on average when informative signals are available.

In an extension we test whether these results are robust to the strategic context. By varying the wage scheme we implement a setting where agents' contributions are complements, i.e. the more one agent contributes to the team output, the higher are the incentives for the other agent to work hard. In this case standard theory predicts for all treatments with an informative signal that the second mover's effort is positively related to the signal and the first mover works more than in the benchmark treatment. Similar to before – but more consistent with standard theory – we find that the first mover works more in the presence of informative signals and

[1] If the first mover's effort and contribution are observable, the second mover only reacts to the first mover's contribution.

the second mover's effort increases in the first mover's effort. The positive relation to the first mover's effort is again inconsistent with standard theory when both the first mover's effort and contribution are observable. As for substitutes, both agents work more when informative signals are available.

Overall, our results indicate that standard theory fails to explain how team members behave when informative signals are available. A simple model of inequity aversion, however, can largely explain our results. Taking into account that agents care about payoff inequalities, the information on the first mover's effort becomes directly relevant for the second mover's utility: The first mover's effort determines the first mover's effort costs and, thereby, payoff inequalities.

The issue of team production when agents can observe signals on a team mate's performance has been addressed in theoretical papers relying on standard preferences by Goldfayn (2006), Winter (2006a, b), and Ludwig (2008). They find mixed results on whether sequentially working teams outperform simultaneously working teams in which no signals are observable. Their results crucially depend on the team's production function and the strategic nature of the game. Moreover, the theoretical paper by Huck and Rey Biel (2006) shows that sequentially working teams outperform simultaneously working teams when agents dislike effort inequalities between team mates. This indicates that also social comparison is crucial in team settings where signals are available. In our empirical analysis we can address the role of the strategic nature of the game, different signals, and social preferences.

Some empirical studies investigate the effect of signals in settings where the agents' payments are completely independent of those agents' actions on whom they receive the signal: Falk and Ichino (2006) study the performance in a real-effort task when individuals work either separately or in a shared room. Sausgruber (2009) investigates behavior in a public good experiment when individuals receive information on the overall contribution of *another* group of individuals. Both studies find that individuals work or contribute more when signals are available.

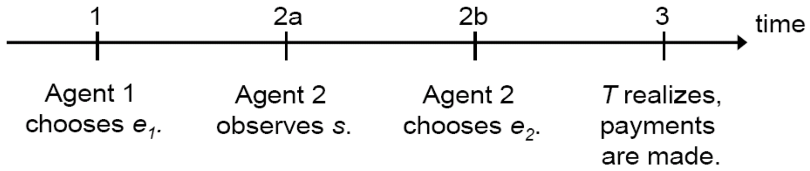
Mohnen et al. (2008), in contrast, consider signals in dynamic teams where the agents' payments directly depend on those agents' actions on whom they receive the signal. Nevertheless, agents' actions in their setting are strategically independent according to standard theory since agents have a dominant strategy. Hence, standard theory predicts that signals on the other agent's action have no effect. They conduct a real-effort experiment in which two agents work simultaneously in two consecutive stages. After the first stage agents either mutually observe their performance or observe nothing. They find that agents work harder in the first stage and also achieve a better aggregate team performance when receiving interim information. While in their study both agents send and receive a signal, in our study one agent is the sender and the other one the receiver. Therefore, full commitment of the sender and a reaction without strategic uncertainty of the receiver are only possible in our study.

Similar to Mohnen et al. (2008), the literature on sequential contributions to public goods considers signals within groups. The signal in these settings is equal to one or several predecessors' contributions. In the standard (linear) public good game agents' actions are again strategically independent. Consequently, standard theory predicts no difference between sequential and simultaneous contributions. Standard public good experiments find that a sequential structure alone does not or only slightly increase the contributions to the public good, e.g. Güth et al. (2007), Levati et al. (2007), Potters et al. (2007), Gächter et al. (2008), and Rivas and Sutter (2008). These studies observe, however, that many individuals are conditional cooperators (Fischbacher et al., 2001), i.e. they contribute if others do so but they do not if others do not contribute. In contrast to the aforementioned studies, Gächter et al. (2009) implement a non-standard public good experiment in which actions are strategic substitutes. In line with their theoretical predictions, sequential contributions result in lower overall provision than simultaneous contributions. Nevertheless, there is evidence for conditional cooperation. In contrast to our setup, an agent's investment is deterministically related to his contribution and, in addition, the signal's type does not vary in all these public good experiments.

Huck and Müller (2000) vary the noisiness of the signal a second mover receives on the first mover's action. Their experimental setup considerably differs from a voluntary contribution game: Its payoffs resemble those of a market with quantity competition and are designed such that fairness considerations do not play a major role. They find that behavior converges to the subgame perfect outcome, irrespective of the signal's noise. While their signals differ in the degree of information, our signals differ in the type of information: The first mover's contribution directly affects both agents' wages, the first mover's effort directly affects his effort costs.

The paper proceeds as follows. In Section 2 we present the experimental design and procedure, and in Section 3 the behavioral predictions and hypotheses. We summarize our results in Section 4. In Section 5 we extend our analysis to the case of complements. We discuss our results in Section 6 and conclude in Section 7.

Figure 1: Timeline of the game



2 Experimental design and procedure

We consider a team of two agents, agent 1 and agent 2, that generates a team output T. Agents sequentially exert effort: First, agent 1 exerts effort $e_1 \geq 0$. Second, agent 2 observes a signal s and, then, exerts effort $e_2 \geq 0$. Agent i's effort e_i, with $i \in \{1, 2\}$, does not directly influence the team output T but the probability that agent i's contribution to T is high ($b_i = 1$) rather than low ($b_i = 0$), $Pr\left(b_i = 1|e_i\right) = p\left(e_i\right)$ with $p'\left(e_i\right) > 0$. The probability that agent i's contribution to T is low equals $Pr\left(b_i = 0|e_i\right) = 1 - p\left(e_i\right)$. $p\left(e_i\right)$ is independent of e_j. The sum of both agents' contributions generates the team output $T := b_1 + b_2$. Each agent receives a high wage w_H if $T = 2$, i.e. if the contributions of both agents are high, an intermediate wage w_M if $T = 1$, i.e. if the contribution of only one agent is high, and a low wage w_L if $T = 0$, i.e. if the contributions of both agents are low, with $w_H > w_M > w_L = 0$. If agent i exerts effort e_i, he incurs private costs $c(e_i)$ with $c(0) = 0$, $c'(e_i) \geq 0$, and $c''(e_i) > 0$. Agent i's expected payoff is his expected wage minus his effort costs. Figure 1 illustrates the timing of the game.

For our experimental design we choose the following parameters. Agent $i \in \{1, 2\}$ could choose effort $e_i \in \{0, 1, ..., 80\}$ with corresponding effort costs $c(e_i) = \frac{e_i^2}{80}$. An effort of e_i yields a high contribution ($b_i = 1$) with probability $p\left(e_i\right) = 0.1 + 0.01 \cdot e_i$. The agents' wages conditional on the team output are $w_H = 280$, $w_M = 172$, and $w_L = 0$.

In this experimental study we focus on the question how the availability of different signals affects team mates' behavior. Hence, we vary s across treatments and keep everything else constant. Table 1 presents our four treatments.

As agent 1's contribution – in contrast to his effort – directly affects agent 2's payoff, we define our treatments according to the degree of information the signal provides about agent 1's contribution. In treatment T-NO, our benchmark treatment, there is **no** signal at all, i.e. $s = \{\}$. Hence, agent 1's and agent 2's decision problems are theoretically identical and so agents behave as if they had to decide

Table 1: Treatments

Treatment	Signal	Number of participants
T-NO	no signal	18
T-IMP	e_1	34
T-P	b_1	36
T-PPlus	e_1 and b_1	30

simultaneously.[2] In treatment T-IMP $s = e_1$ which is an imperfect signal on b_1. In treatment T-P $s = b_1$, i.e. agent 2 receives a perfect signal on b_1. In T-PPlus agent 2 receives $s = (e_1, b_1)$ and is again perfectly informed on b_1. Observing e_1 in addition to b_1 does, however, not provide more information on agent 1's contribution.

In each of our experimental sessions the team production setting was played for 14 rounds. Individuals' roles as well as the treatment conditions were fixed for all rounds. The matching of agents, in contrast, was random such that individuals were not able to distinguish whether their current team mate had already been matched with them in a previous round or not. After each round individuals received feedback concerning e_1, e_2, b_1, b_2, and both agents' payoffs of the past round. Therefore, treatment differences cannot be explained by shame. Only one randomly determined round was paid for all participants of a session. At the end of the 14^{th} round individuals were informed which round is paid. All this was told the participants in the instructions that were handed out at the beginning of the experiment and were framed as a team work setting.[3] In a post-experimental questionnaire we elicited data on the participants' sex, subject of studies and risk attitude[4].

Our experimental sessions were run at the Munich Experimental Laboratory for Economic and Social Sciences (MELESSA) in Germany in 2008. 118 individuals participated in the experiment. They were randomly assigned to sessions and could

[2] Empirically, the mere knowledge about the physical timing of moves may affect behavior even if the informational condition is equivalent to a simultaneous setting: Duffy et al. (2007), for instance, find that the timing itself matters in a dynamic public good experiment, whereas Masclet et al. (2007) find that it has no effect in a standard public good experiment.

[3] See the appendix for a more detailed description of the procedure of a session and translated instructions. Original instructions are written in German and are available upon request.

[4] Individuals indicated on a scale ranging from 0 to 10 whether they are willing to take risks (or try to avoid risks). 0 represented a very weak willingness to take risks, while 10 represented a strong willingness to take risks. Dohmen et al. (2005) show that this general risk question is a good predictor of actual risk-taking behavior.

take part in one session only. For the recruitment we used the software ORSEE by Greiner (2004). The experiment was programmed and conducted with the experimental software z-Tree by Fischbacher (2007). The sessions lasted about 1 hour. Individuals earned on average 12.6 € (at the time of the experiment 1 € ≈ 1.57 USD), including a show-up fee of 7 €[5].

3 Behavioral predictions and hypotheses

In this section we derive behavioral predictions on how agents in a team react when one member receives a signal on his colleague's performance. As a benchmark, we consider the standard neoclassical approach.

3.1 Behavioral predictions of a self-interest model

The standard neoclassical approach assumes that all individuals are selfish, i.e. their utility depends only on their own material payoff and increases in this payoff. Furthermore, we assume that all individuals maximize their expected utility and are risk-neutral.

T-NO

If there is no signal at all, we solve for the Nash equilibrium of the simultaneous move game. Agent i's expected payoff given agent j chooses e_j, with $i, j \in \{1, 2\}$ and $j \neq i$, and $w_L = 0$ is

$$U_i\left(e_i, e_j\right) = w_H \cdot p\left(e_i\right) \cdot p\left(e_j\right) + w_M \cdot \left[p\left(e_i\right) \cdot \left(1 - p\left(e_j\right)\right) + \left(1 - p\left(e_i\right)\right) \cdot p\left(e_j\right)\right] - \frac{e_i^2}{80}.$$

Maximizing $U_i\left(e_i, e_j\right)$ with respect to e_i, agent i's reaction function is

$$e_i^*(e_j) = 0.4 \cdot \left[w_M + (0.1 + 0.01 \cdot e_j) \cdot (w_H - 2 \cdot w_M)\right].$$

$e_i^*(e_j)$ strictly increases in e_j if $w_H > 2 \cdot w_M$, while it strictly decreases if $w_H < 2 \cdot w_M$. Hence, efforts are strategic complements if $w_H > 2 \cdot w_M$, while they are strategic substitutes in our setting as $w_H < 2 \cdot w_M$. Solving for the intersection of both agents' reaction functions and substituting $w_H = 280$ and $w_M = 172$, we derive the unique Nash equilibrium in which $e_1^* = e_2^* = \frac{165.6}{3.14} \approx 52.74$.

[5] We chose a relatively high show-up fee as losses were deducted from the show-up fee. This was applied for about 10 % of the participants.

T-IMP

In T-IMP agent 2 receives the signal $s = e_1$ and we solve for the subgame perfect Nash equilibrium given $s = e_1$. Agent 2's reaction to $s = e_1$ is equivalent to his reaction function in T-NO, i.e.

$$e_2^*(s) = 0.4 \cdot [w_M + (0.1 + 0.01 \cdot s) \cdot (w_H - 2 \cdot w_M)].$$

Equivalently to above, $e_2^*(s)$ strictly increases (decreases) in $s = e_1$ if $w_H >(<) 2 \cdot w_M$. $e_2^*(s) = e_2^*(e_1)$ maximizes agent 2's expected payoff $U_2(e_2, s)$ given $s = e_1$. Agent 1 anticipates agent 2's reaction to s and maximizes his own expected payoff

$$U_1(e_1, e_2^*(e_1)) =$$
$$w_H \cdot p(e_1) \cdot p(e_2^*(e_1)) + w_M \cdot [p(e_1) \cdot (1 - p(e_2^*(e_1))) + (1 - p(e_1)) \cdot p(e_2^*(e_1))] - \tfrac{e_1^2}{80}$$

with respect to e_1. Agent 1's expected payoff is maximized at $e_1 = \frac{1.616256}{0.0434464} \approx 37.20$. Consequently, in the unique subgame perfect Nash equilibrium $e_1^* = s \approx 37.20$ and $e_2^* = \frac{2.464128}{0.0434464} \approx 56.72$ according to agent 2's reaction ($e_2^*(e_1) = 66.24 - 0.256 \cdot e_1$).

T-P

In T-P we solve for the unique Nash equilibrium given $s = b_1$. Agent 2's expected payoff given agent 1's contribution is high, i.e. $s = b_1 = 1$, is

$$U_2(e_2, b_1 = 1) = w_H \cdot p(e_2) + w_M \cdot (1 - p(e_2)) - \frac{e_2^2}{80}. \tag{1}$$

$U_2(e_2, b_1 = 1)$ is maximized at $e_2^*(b_1 = 1) = 0.4 \cdot (w_H - w_M) = 43.20$. Agent 2's expected payoff given agent 1's contribution is low, i.e. $s = b_1 = 0$, is

$$U_2(e_2, b_1 = 0) = w_M \cdot p(e_2) - \frac{e_2^2}{80}. \tag{2}$$

$U_2(e_2, b_1 = 0)$ is maximized at $e_2^*(b_1 = 0) = 0.4 \cdot w_M = 68.80$. Note that $e_2^*(b_1 = 1) >(<) e_2^*(b_1 = 0)$ if $w_H >(<) 2 \cdot w_M$. Agent 1 anticipates agent 2's reaction to s and maximizes his own expected payoff

$$U_1(e_1, e_2^*(b_1)) = w_H \cdot p(e_1) \cdot p(e_2^*(b_1 = 1)) + w_M \cdot$$
$$[p(e_1) \cdot (1 - p(e_2^*(b_1 = 1))) + (1 - p(e_1)) \cdot p(e_2^*(b_1 = 0))] - \tfrac{e_1^2}{80}$$

with respect to e_1. $e_1 = 37.568$ maximizes $U_1(e_1, e_2^*(b_1))$. Hence, in the unique Nash equilibrium $e_1^* = 37.568$, $e_2^*(b_1 = 1) = 43.20$, and $e_2^*(b_1 = 0) = 68.80$.

T-PPlus

In T-PPlus agent 2 also observes agent 1's effort (in addition to his contribution). This additional piece of information does, however, neither influence agent 2's expected payoff nor his reaction to s in comparison to T-P since agent 2's expected payoff is independent of e_1 given b_1 (cf. Equations 1 and 2). Consequently, agent 1's decision problem is the same as in T-P. Thus, in the unique Nash equilibrium $e_1^* = 37.568$, $e_2^*(b_1 = 1) = 43.20$, and $e_2^*(b_1 = 0) = 68.80$.

Table 2 summarizes the predictions of the standard self-interest model. In all treatments agents work inefficiently little since an effort of 80 always maximizes the sum of payoffs.

Table 2: Behavioral predictions

Treatment	e_1	e_2
T-NO	52.74	52.74
T-IMP	37.20	66.24 - 0.256 * e_1 = 56.72
T-P	37.57	43.20 if b_1 = 1
		68.80 if b_1 = 0
T-PPlus	37.57	43.20 if b_1 = 1
		68.80 if b_1 = 0

The predictions are rounded to two digits after the decimal point.

3.2 Hypotheses

Based on the predictions of the self-interest model, we formulate the following hypotheses.

Hypothesis 1 *Decreasing reaction of the second mover to informative signals:*

(i) In T-IMP the second mover exerts less effort the higher the first mover's effort.

(ii) In T-P and T-PPlus the second mover exerts less effort when the first mover's contribution is high than when it is low.

If $w_H < 2 \cdot w_M$, the second mover faces higher incentives to work when either the first mover works less in T-IMP, or when the first mover's contribution is low rather than high in T-P and T-PPlus.

Hypothesis 2 *Less effort of the first mover when signals are informative: The first mover's effort is smaller in T-IMP, T-P, and T-PPlus than in T-NO.*

If $w_H < 2 \cdot w_M$, the first mover leans back when signals are informative. This is due to the first mover's anticipation that the second mover works more the smaller the informative signal. Hence, by working less he can shift work load to the second mover and save effort costs.

Hypothesis 3 *No additional information by the first mover's effort when the first mover's contribution is known: Efforts in T-P and T-PPlus are the same.*

As individuals only care about their own expected payoff, the information on the first mover's effort in addition to the information on the first mover's contribution does not alter the second mover's maximization problem. Therefore, both agents' decisions are identical in T-P and T-PPlus.

4 Results

First, we focus on the second mover's behavior and analyze how it is affected by different signals. Then, we consider the first mover's behavior.

4.1 The second mover's behavior

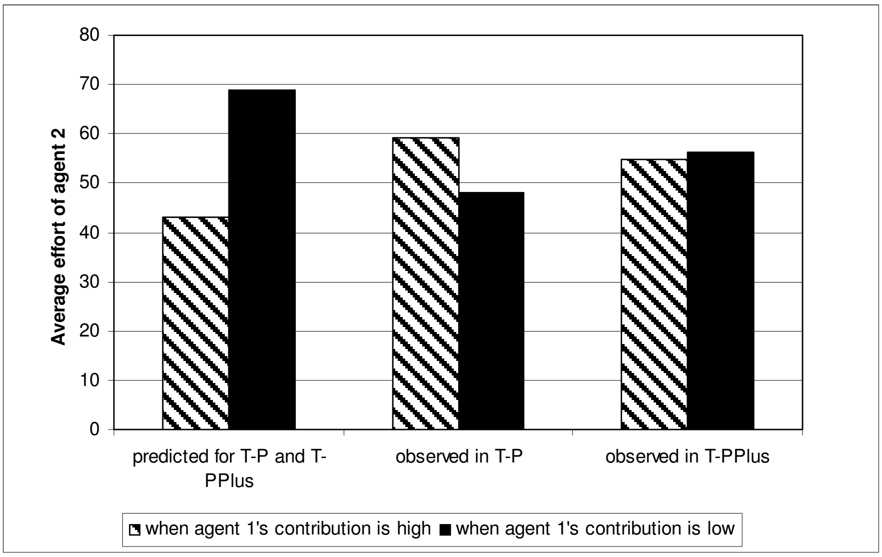
Table 3 reports for each treatment the mean and the standard deviation of the second mover's effort across individuals and all rounds.

Table 3: Mean and standard deviation of e_2

Treatment	Mean	Standard deviation	Number of observations
T-NO	50.29	13.23	126
T-NO*	49.07	14.21	252
T-IMP	53.49	23.98	238
T-P	54.25	23.72	252
T-PPlus	55.26	18.34	210

*: e_1 and e_2 are considered.

Figure 2: The second mover's average reaction in T-P and T-PPlus



In T-NO the second mover's average effort is around 50 (with or without the decisions of the first movers)[6] which is close to our prediction of 52.74. If, in contrast, an informative signal is available for the second mover, the second mover works more on average. This may be caused by the signal's realized value the second mover observes in these treatments. In the following we, therefore, illustrate how the second mover reacts to the signals. The second mover's average reaction to the first mover's contribution is considerably different than predicted: In T-P the second mover works more when the first mover's contribution is high rather than low, and in T-PPlus the second mover's average effort does not vary in the first mover's contribution. Figure 2 reports the second mover's average effort conditional on the first mover's contribution in T-P and T-PPlus.

If we consider the second mover's reaction to the first mover's effort in T-IMP and T-PPlus, we find that the second mover's effort is positively correlated with the first mover's effort: In T-IMP and in T-PPlus the correlation coefficient is equal to 0.24 and 0.12, respectively. The self-interest model, in contrast, predicts a negative correlation in T-IMP and no correlation in T-PPlus.

In order to analyze the second mover's behavior more closely and to test our hypotheses regarding the second mover, we regress the second mover's effort[7] on

[6] As in T-NO the second mover does not receive a signal prior to his decision, the first mover's decision problem is theoretically identical to the second mover's decision problem. Therefore, both agents' decisions of T-NO may be considered in the analysis of the second mover's behavior.

[7] In our regressions we also consider the first mover's decisions in T-NO. Our results do not

treatment dummies, the interactions of treatments dummies with available signals, and control variables such as sex and risk aversion[8]. In the first two columns of Table 4 we report the results of two random effects panel regressions where one (Tobit) captures that our dependent variable is (weakly) between 0 and 80.

Table 4: Regression results on e_2 and e_1

Dependent variable:	e_2 Panel (re)	e_2 Panel (re) (Tobit)	e_1 Panel (re)	e_1 Panel (re) (Tobit)
Intercept	+47.30	+46.73	+45.58	+44.65
	(0.000)	(0.000)	(0.000)	(0.000)
T-IMP	- 09.72	- 13.17	+07.49	+07.72)
	(0.066)	(0.045)	(0.092)	(0.124)
T-P	- 01.44	- 01.73	+02.54	+01.88
	(0.737)	(0.752)	(0.568)	(0.707)
T-PPlus	- 05.46	- 05.65	+10.66	+12.17
	(0.432)	(0.496)	(0.020)	(0.019)
T-IMP * e_1	+00.24	+00.34		
	(0.000)	(0.000)		
T-PPlus * e_1	+00.25	+00.27		
	(0.008)	(0.014)		
T-P * b_1	+12.56	+16.01		
	(0.000)	(0.000)		
T-PPlus * b_1	- 02.88	- 03.03		
	(0.275)	(0.313)		
Sex	+05.65	+08.05	+06.85	+08.54
(1 if male, 0 else)	(0.059)	(0.035)	(0.040)	(0.023)
Risk aversion	- 01.65	- 02.88	- 02.53	- 01.92
(1 if risk averse, 0 else)	(0.582)	(0.453)	(0.454)	(0.617)
Number of observations	952	952	952	952
(Pseudo) R-squared	0.069		0.089	

(re): random effects
In all four regressions e_1 and e_2 in T-NO are considered.
Numbers in brackets represent the p-values of the coefficients.

change qualitatively when we only consider the second mover's decisions.

[8] We create the variable for risk aversion from our measure of risk attitude that we elicited in the post-experimental questionnaire.

When only the first mover's effort is observable (T-IMP), the second mover's effort significantly increases in the first mover's effort. When only the first mover's contribution is observable (T-P), the second mover's effort significantly increases in the first mover's contribution. When both the first mover's effort and contribution are observable (T-PPlus), the second mover's effort significantly increases in the first mover's effort. We do, however, not find a significant effect of the first mover's contribution on the second mover's effort in T-PPlus. These results confirm our previous observations from Figure 2 and from the correlation coefficients in T-IMP and T-PPlus: In contrast to our predictions, the second mover positively reacts to informative signals – in T-PPlus at least to the first mover's effort. The first mover's effort seems to be an especially stimulating signal as it even affects the second mover's effort in T-PPlus. Consequently, we reject Hypotheses 1(i) and 1(ii). We also reject Hypothesis 3 since the second mover's behavior in T-PPlus varies with the first mover's effort and, therefore, does not equal the second mover's behavior in T-P.

We summarize our findings on the second mover's behavior in the following three results:

Result 1 *Higher average effort of the second mover in T-IMP, T-P, and T-PPlus than in T-NO: On average the second mover exerts more effort when informative signals are available for the second mover.*

Result 2 *Increasing reaction of the second mover in T-IMP, T-P, and T-PPlus: In contrast to Hypotheses 1(i) and 1(ii), the second mover exerts more effort, the higher the first mover's effort in T-IMP and T-PPlus, or the higher the first mover's contribution in T-P.*

Result 3 *Effect of the first mover's effort on the second mover's behavior when the first mover's contribution is observable: In contrast to Hypothesis 3, the second mover's effort increases in the first mover's effort in T-PPlus.*

4.2 The first mover's behavior

We now turn to the first mover. Our theoretical predictions of the first mover's behavior are based on the fact that the first mover expects the second mover to react as predicted by the self-interest model. Yet, the second mover's behavior systematically deviates from the predictions. The first mover may anticipate the second mover's actual behavior and, therefore, behave differently than hypothesized even if he maximizes his own material payoff. Table 5 reports for each treatment the mean and the standard deviation of the first mover's effort across individuals and rounds. Similar to the second mover's behavior in T-NO, the first mover's average

Table 5: Mean and standard deviation of e_1

Treatment	Mean	Standard deviation	Number of observations
T-NO	47.84	15.08	126
T-NO*	49.07	14.21	252
T-IMP	55.26	17.74	238
T-P	49.28	24.15	252
T-PPlus	58.43	13.34	210

*: e_1 and e_2 are considered.

effort in T-NO is about 50 which is relatively close to the prediction of 52.74. In all treatments with an informative signal the first mover works more on average than in T-NO and considerably more than predicted. Thus, the first mover does on average not lean back when the second mover receives an informative signal. One can show that – given the actual behavior of the second movers – it paid off for first movers to work more when informative signals are available.

In order to test our hypotheses regarding the first mover, we regress the first mover's effort on treatment dummies and control variables such as sex and risk aversion.[9] In the third and fourth column of Table 4 we report the results of two random effects panel regression where one (Tobit) captures that our dependent variable is (weakly) between 0 and 80.

When the second mover only observes the first mover's effort (T-IMP), the first mover works (marginally) significantly more compared to T-NO. When the second mover observes only the first mover's contribution (T-P), the first mover neither works significantly more nor less compared to T-NO. When the second mover observes both the first mover's effort and contribution (T-PPlus), the first mover works significantly more than in T-NO. Thus, the availability of signals (weakly) increases the first mover's effort. Especially the observability of his effort stimulates the first mover to work more. The reason may be that the second mover positively reacts

[9] In our regressions we also consider the second mover's decisions in T-NO. Our results do not change qualitatively when we only consider the first mover's decisions.

to the first mover's effort and the first mover anticipates this. Although the second mover positively reacts to the first mover's contribution in T-P, the first mover does not work significantly more in T-P than in T-NO. The reason may be that the first mover's effort does not directly map into his contribution. On the basis of these results, we reject Hypothesis 2. We also reject Hypothesis 3 since the coefficient of T-PPlus is significantly larger than the one of T-P in both regressions. These findings are summarized in the following two results:

Result 4 *No decreasing effect of informative signals on the first mover's effort: On average, the first mover works more in T-IMP, T-P, and T-PPlus than in T-NO. In T-IMP and T-PPlus, in which the first mover's effort is observable, the first mover works (marginally) significantly more than in T-NO.*

Result 5 *Effect of the first mover's effort on his behavior when the first mover's contribution is observable: In contrast to Hypothesis 3, the first mover exerts more effort when the second mover can observe the first mover's effort in addition to his contribution.*

Our results show that both the first and the second mover's behavior systematically differ from the predictions of the self-interest model when informative signals on the first mover's performance are available. The second mover positively reacts to informative signals, especially to the first mover's effort, and on average both agents work more.

Finally, we test whether the sum of the first and the second mover's effort is higher when informative signals are available. Table 6 presents the results of two random effects panel regressions where we regress the sum of the first and the second mover's effort on treatment dummies. In one of these regressions (Tobit) we capture that the sum of the first mover's and the second mover's effort is (weakly) between 0 and 160. When informative signals are available, the sum of efforts is at least as high as in T-NO. When the first mover's effort is available for the second mover (T-IMP or T-PPlus), the sum of efforts is even significantly larger.

Table 6: Regression results on the sum of e_1 and e_2

Dependent variable:	$e_1 + e_2$ Panel (re)	$e_1 + e_2$ Panel (re) (Tobit)
Intercept	+98.13	+98.13
	(0.000)	(0.000)
T-IMP	+10.61	+10.81
	(0.082)	(0.070)
T-P	+05.39	+05.49
	(0.372)	(0.353)
T-PPlus	+15.56	+15.53
	(0.013)	(0.011)
Number of observations	826	826
(Pseudo) R-squared	0.031	

(re): random effects
Numbers in brackets represent the p-values of the coefficients.

5 Extension

So far, we have focused on the case of substitutes in which $w_H < 2 \cdot w_M$. In this section we vary the strategic setting and consider the opposite case, i.e. $w_H > 2 \cdot w_M$, to check whether the observed behavioral patterns remain unchanged. We invited 130 additional individuals in order to run our four treatments with $w_M = 110$ instead of $w_M = 172$. All other parameters of the game remained the same. Table 7 presents our additional treatments that are indicated by ^{X}.

Table 7: Additional treatments

Treatment	Signal	Number of participants
T-NO^X	no signal	18
T-IMP^X	e_1	36
T-P^X	b_1	38
T-PPlus^X	e_1 and b_1	38

As described in Section 3, efforts are strategic complements in T-NO^X and the second mover's reaction is predicted to increase in the signals in T-IMP^X, T-P^X, and T-PPlus^X.[10] Furthermore, the self-interest model predicts the first mover to not work less but more when informative signals are available. Similar to the case of substitutes, no treatment differences are predicted between T-P^X and T-PPlus^X. Table 8 summarizes the predictions of the self-interest model for our additional treatments.[11]

Table 8: Behavioral predictions for the additional treatments

Treatment	e_1	e_2
T-NO^X	61.05	61.05
T-IMP^X	77.61	46.40 + 0.240 * e_1 = 65.02
T-P^X	73.28	68.00 if b_1 = 1
		44.00 if b_1 = 0
T-PPlus^X	73.28	68.00 if b_1 = 1
		44.00 if b_1 = 0

The predictions are rounded to two digits after the decimal point.

Based on these predictions we formulate the following hypotheses.

Hypothesis 4 *Increasing reaction of the second mover when signals are informative and $w_M = 110$:*

(i) In T-IMP^X the second mover exerts more effort the higher the first mover's effort.

(ii) In T-P^X and T-PPlus^X the second mover exerts more effort when the first mover's contribution is high than when it is low.

If $w_H > 2 \cdot w_M$, the second mover faces higher incentives to work when the first mover works more in T-IMP^X or when the first mover's contribution is high rather than low in T-P^X, and T-PPlus^X.

Hypothesis 5 *Higher effort of the first mover when signals are informative and $w_M = 110$: The first mover's effort is higher in T-IMP^X, T-P^X, and T-PPlus^X than in T-NO^X.*

[10] In T-PPlus^X the increasing reaction only refers to the first mover's contribution and not to his effort. This is analogous to T-PPlus.

[11] The derivation of these predictions is analogue to the one in Section 3.

The first mover anticipates that the second mover positively reacts to the informative signals and that he can, therefore, induce the second mover to exert a high effort by working a lot in T-IMP^X, T-P^X and T-PPlus^X.

Hypothesis 6 *No effect of the additional information on the first mover's effort when the first mover's contribution is known and* $w_M = 110$*: Efforts in T-P*^{X} *and T-PPlus*^{X} *are the same.*

Table 9 reports the average behavior of both agents in our additional treatments.

Table 9: Mean of e_1 and e_2 in the additional treatments

Treatment	Mean of e_1	Mean of e_2	Number of observations
T-NO^X	45.37	46.53	126
T-NO^X*	45.95	45.95	252
T-IMP^X	62.27	59.67	252
T-P^X	61.05	61.88	266
if $b_1 = 1$		61.60	199
if $b_1 = 0$		62.70	67
T-PPlus^X	55.54	55.82	266
if $b_1 = 1$		62.94	155
if $b_1 = 0$		45.88	111

*: e_1 and e_2 are considered.

In T-NO^X agents work on average about 46 which is lower than the prediction of 61.05. As w_M is smaller than in the case of substitutes (and w_H and w_L remained the same), agents may be less motivated to exert effort. Similar to the previous section, both agents work more on average when the second mover receives an informative signal. The second mover's reaction to the first mover's contribution differs, however, compared to what we observed for substitutes: In T-P^X the second mover's average effort does not vary with the first mover's contribution, while in T-PPlus^X the second mover works more on average when the first mover's contribution is high than when it is low.

In order to analyze behavior more closely and to test our hypotheses for the additional treatments, we regress the second mover's effort on treatment dummies, interactions of treatments dummies with available signals, and control variables and we regress the first mover's effort on treatment dummies, and control variables.[12] Table 10 reports our regression results.

Table 10: Regression results on e_2 and e_1 in the additional treatments

Dependent variable:	e_2 Panel (re)	e_2 Panel (re) (Tobit)	e_1 Panel (re)	e_1 Panel (re) (Tobit)
Intercept	+46.08	+44.79	+43.52	+42.56
	(0.000)	(0.000)	(0.000)	(0.000)
T-IMP^X	- 09.85	- 13.09	+17.23	+20.58
	(0.083)	(0.076)	(0.001)	(0.001)
T-P^X	+14.96	+20.67	+14.08	+19.09
	(0.000)	(0.000)	(0.005)	(0.003)
T-PPlus^X	- 12.64	- 14.38	+09.15	+11.75
	(0.003)	(0.010)	(0.066)	(0.064)
T-IMP^X * e_1	+00.37	+00.48		
	(0.000)	(0.000)		
T-PPlus^X * e_1	+00.30	+00.34		
	(0.000)	(0.000)		
T-P^X * b_1	+00.41	+00.72		
	(0.863)	(0.814)		
T-PPlus^X * b_1	+09.22	+11.08		
	(0.000)	(0.000)		
Sex	+01.02	+02.73	+05.46	+06.48
(1 if male, 0 else)	(0.680)	(0.421)	(0.133)	(0.162)
Number of observations	1036	1036	1036	1036
(Pseudo) R-squared	0.173		0.106	

(re): random effects
In all four regressions e_1 and e_2 in T-NO^X are considered.
Numbers in brackets represent the p-values of the coefficients.

Similar to the results for substitutes, the second mover's effort significantly increases in the first mover's effort in T-IMP^X. The coefficient of the interaction of T-IMP^X with the first mover's effort is even significantly larger than the predicted 0.24. In contrast to Hypothesis 4(ii) and the results for substitutes, the

[12]In our regressions we again consider the first and the second mover's decisions in T-NO^X. Our results do not change qualitatively if we separately consider the first mover's and the second mover's decisions in T-NO^X.

second mover's effort does not increase in the first mover's contribution in T-P^X. In T-PPlus^X, however, the second mover's effort significantly increases in both the first mover's effort and his contribution. Hence, the first mover's effort, again, is a very stimulating signal for the second mover, while the first mover's contribution significantly affects the second mover's effort only if also the first mover's effort is observable. With respect to the first mover's behavior we find that in all treatments with informative signals the first mover works significantly more than in our benchmark treatment. On the basis of these results, we reject Hypothesis 4(ii) with respect to T-P^X. We also reject Hypothesis 6 regarding the second mover's behavior as his effort in T-PPlus^X varies with the first mover's effort and contribution, while it is independent of both in T-P^X. We summarize our findings in the following results.

Result 6 *Higher average effort in T-IMP^X, T-P^X, and T-PPlus^X than in T-NO^X: On average the first and the second mover exert more effort when informative signals are available.*

Result 7 *Increasing reaction of the second mover in T-IMP^X and T-PPlus^X: In line with Hypotheses 4(i) and 4(ii), the second mover works more the higher the first mover's effort in T-IMP^X, and the higher the first mover's contribution in T-PPlus^X. In T-P^X the first mover's contribution does not significantly affect the second mover's effort.*

Result 8 *Increasing effect of informative signals on the first mover's effort when $w_M = 110$: The first mover works significantly more in T-IMP^X, T-P^X, and T-PPlus^X than in T-NO^X.*

Result 9 *Effect of the additional information on the first mover's effort on the second mover's behavior when $w_M = 110$: In contrast to Hypothesis 6, the second mover's effort increases in the first mover's effort in T-PPlus^X. The first mover's behavior does, however, not differ between T-P^X and T-PPlus^X.*

6 Discussion

Our results of both the case of substitutes and complements show that (i) the second mover positively reacts to the first mover's effort when the first mover's effort is the only available signal, (ii) the second mover (weakly) positively reacts to the first mover's contribution when the first mover's contribution is the only available signal, (iii) the second mover positively reacts to the first mover's effort when the first mover's effort and contribution are observable, and (iv) the first mover does not lean back but (weakly) forward when informative signals are available. These observations are inconsistent with the predictions of the self-interest model.

We try to explain our data with an alternative model that considers elements of social comparison. If individuals compare their payoff with their team mate's payoff, the information on the team mate's effort becomes crucial – even if the information on the team mate's contribution is given. This is because the team mate receives the same wage and his payoff may only differ due to a different effort level. In order to make a converse assumption to the self-interest model, we make the extreme assumption that all individuals are inequity averse. We choose the inequity aversion model by Fehr and Schmidt (1999) as it has proved to explain human behavior in series of different games and is comparably simple.[13] Inequity averse agents dislike payoff inequalities which implies for our team setting that they dislike effort inequalities (as they receive the same wage).

We summarize the main predictions of our alternative model as follows:[14] If only the first mover's effort is observable (in T-IMP and T-IMP^X), the second mover's effort increases in the first mover's effort[15], and the first mover works at least as much as if no informative signal is available (in T-NO and T-NO^X). If only the first mover's contribution is observable (in T-P and T-P^X), the second mover does not react to the first mover's contribution, and the range of the first mover's equilibrium effort is about the same as if no informative signal is available. If the first mover's effort and contribution are observable (in T-PPlus and T-PPlus^X), the second mover's effort increases in the first mover's effort and is constant in the first mover's contribution[16], and the first mover works at least as much as if no informative signal is available.

In T-IMP and T-IMP^X our observations are in line with the predictions of the

[13]Bolton and Ockenfels (2000) also model inequity aversion. For the sake of simplicity, however, we focus on the model of Fehr and Schmidt (1999). In particular, we assume that the parameter of aversion to disadvantageous inequity is $\alpha = 2$ and the parameter of the aversion to advantageous inequity is $\beta = 0.6$. These values were also assumed in Fehr et al. (2007, 2008) for inequity averse individuals in order to explain observed behavior.

[14]The detailed predictions and their derivations are in the appendix.

[15]In T-IMP the second mover's reaction decreases for $e_1 < \frac{66.24}{3.256} \approx 20.34$. Yet, more than 95 % of our observations of e_1 are strictly larger than 20.34.

[16]In T-PPlus (T-PPlus^X) this holds for $e_1 > \frac{68.8}{3} \approx 22.93$ ($\frac{68}{3} \approx$22.67). Yet, more than 99 % (84 %) of our observations of e_1 are strictly larger than 22.93 (22.67).

model of inequity aversion for both agents: The corresponding coefficients are significantly positive (cf. Tables 4 and 10).

For T-P and T-P^X the model of inequity aversion predicts that the second mover chooses the same effort independent of the first mover's contribution. In equilibrium the second mover knows the first mover's effort. Therefore, the signal b_1 does not give any additional information on the first mover's effort. If the second mover is inequity averse, he tries to match the first mover's effort independent of b_1. In T-P we observe that the second mover exerts more effort if the first mover's contribution is high (cf. Table 4), which is inconsistent with the predictions of the model of inequity aversion and also the self-interest model. In line with the model of inequity aversion, we observe in T-P^X that the second mover does not react to the first mover's contribution (cf. Table 10). As the model of inequity aversion predicts multiple equilibria for T-P and T-P^X, it is not clear for the second mover which effort the first mover has chosen. Thus, one may argue that the signal b_1 provides some information to the second mover whether the first mover's effort was rather high or low. As a low contribution rather indicates a low effort, the second mover's behavior in T-P could be interpreted as a punishment of the first mover for choosing a low effort. Why does this argument not hold for T-P^X? Figure 2 and Table 9 show that the second mover's effort after a high contribution is similar in T-P as in T-P^X, but after a low contribution the second mover's effort is lower in T-P than in T-P^X. Hence, there seems to be no such punishment in T-P^X. This observation could be related to the fact that in T-P^X the second mover ex ante has a second mover advantage in terms of material payoffs, while in T-P there is a first mover advantage. If an agent faces an ex ante advantage, he may hesitate to punish his team mate in an environment where effort is unobservable and he cannot be sure whether his team mate, indeed, exerted a low effort. Regarding the first mover's behavior in T-P and T-P^X, we observe that he works at least as much as if no informative signal is available. This does not contradict the prediction of the inequity aversion model.

In T-PPlus and T-PPlus^X the second mover positively reacts to the first mover's effort, and the first mover works at least as much as if no informative signal is available (cf. Tables 4 and 10). Furthermore, the second mover does not react to the first mover's contribution in T-PPlus. These results are in line with the model of inequity aversion. We observe that the second mover positively reacts to the first mover's contribution in T-PPlus^X, which is in line with the self-interest model but only in line with the inequity aversion model for a small range of e_1 (cf. Footnote 16).

Overall, our model of inequity aversion with the extreme assumption that all individuals are inequity averse largely explains our results. Nevertheless, our simple parameterization, in particular that all individuals are inequity averse with the corresponding parameters, does not comply with all of our observations. This concerns especially the exact point predictions. Anyhow, our results suggest that social comparison plays a crucial role in teams and shapes behavior: The reaction to signals may be contrary to the predictions of the self-interest model and signals that are predicted to have no effect may, in fact, be influential.

7 Conclusion

We have presented an experimental study on teams in which one team member receives a signal on his colleague's performance prior to his own decision. We observe that both the first and the second mover tend to work more on average when informative signals are available. This holds when agents' contributions are substitutes as well as when they are complements. Especially the first mover's effort seems to be a stimulating signal: If the first mover's effort is observable, the second mover works more the higher the first mover's effort, and the first mover chooses a higher effort. This observation is independent of whether the first mover's contribution is observable or not. If the first mover's contribution is the only observable signal, the second mover reacts (weakly) positively and the first mover works (weakly) more. If the first mover's contribution is observable in addition to his effort, the second mover does not react to the contribution in the case of substitutes and positively reacts to it in the case of complements.

Overall, the self-interest model fails to capture our results, while a simple model of inequity aversion largely explains behavior. Therefore, we conclude that social comparison plays a crucial role in teams in which informative signals are available. Agents' behavior may not only be contrary to the predictions of the self-interest model but also signals that are predicted to have no effect may, in fact, be influential and signals that are predicted to have an effect may be redundant.

Our results suggest that signals in teams may reduce free-riding irrespective of the strategic context. Providing information on effort seems to be an effective way to achieve more efficient outcomes. With regard to the organization of teams it seems particularly promising if agents work closely together: In this case they are not only able to observe their colleagues' efforts but also social comparison may be very pronounced.

Appendix

Experimental sessions

The order of events during each experimental session was the following: Individuals were welcomed and randomly assigned a cubicle in the laboratory where they took their decisions in complete anonymity from the other participants. The random allocation to a cubicle also determined an individual's role. Individuals were handed out the instructions for the experiment and the experimenter read them aloud. Then, individuals had time to go through the instructions on their own and ask questions. After all individuals had finished going through the instructions and all remaining questions had been answered, we proceeded to the decision stages. After the 14^{th} round individuals were informed about which of the 14 rounds is paid for all participants of the session, and their payment. We finished each experimental session by letting individuals answer a questionnaire that asked for demographic characteristics such as sex, subject of studies, and risk attitude. We also asked individuals to describe how they came to their decisions.

Instructions, the program, and the questionnaire were originally written in German. In the following we give a translation of the instructions for T-NO. Instructions for the other treatments are as similar to T-NO as possible, with the difference being the description of what worker 2 knows when choosing his effort.

Translated instructions for T-NO

Instructions for the experiment

Welcome to this experiment. You and the other participants are asked to make decisions. **At the end of the experiment you will be paid in cash according to your decisions and the decisions of the other participants.** In addition, you receive a payment of 7 Euro.

During the whole experiment you are not allowed to speak to other participants, to use cell phones, or to start any other program on the computer. If you have questions, please raise your hand. An instructor of the experiment will then come to your seat to answer your questions.

During the experiment we do not speak of Euros but of points. Your payment will initially be calculated in points. At the end of the experiment your actual amount of total points will be converted into Euro according to the following exchange rate:

1 point = 4 Eurocents.

In this experiment there are participants in the role of **worker 1** and participants in the role of **worker 2**. One worker 1 and one worker 2 form a work team. When the experiment starts, you will be informed whether you are in the role of worker 1 or worker 2. The roles are assigned randomly. During the whole experiment that consists of 14 rounds you keep your assigned role. At the beginning of each round it will be determined anew which workers 1 and workers 2 form work groups. This assignment is random and anonymous. No participant receives any information about the identity of his matched participants.

The procedure of a round

One worker 1 and one worker 2 form a work group that has to complete two tasks. Each task can be completed with either high or low quality. Whether a task is completed with high or low quality, depends on a worker's effort and on chance.
At the beginning of each round worker 1 chooses his effort X1. X1 is an integer between 0 and 80 (including 0 and 80). The effort chosen by worker 1 influences the probability that the first task is completed with high quality and, therefore, also the probability that the first task is completed with low quality. The probability that the first task is completed with high quality is (10 + effort of worker 1) percent. Accordingly, the probability that the first task is completed with low quality is (90 – effort of worker 1) percent.

Probability that the first task is completed with high quality $= (10 + X1)\ \%$

Probability that the first task is completed with low quality $= (90 - X1)\ \%$

Examples: If worker 1 chooses an effort of 17, the first task will be completed with high quality with a probability of 27 % and with low quality with a probability of 73 %. If worker 1 chooses an effort of 72, the first task is completed with high quality with a probability of 82 % and with low quality with a probability of 18 %.
After worker 1 has chosen his effort X1, worker 2 chooses his effort X2. At this point in time worker 2 is neither informed about the effort of worker 1 nor about the quality with which first task is completed. Worker 2 chooses an effort that is an integer between 0 and 80 (including 0 and 80). The chosen effort of worker 2 influences the probability that the second task is completed with high quality and,

therefore, also the probability that the second task is completed with low quality. The probability that the second task is completed with high quality is (10 + effort of worker 2) percent. Accordingly, the probability that the second task is completed with low quality is (90 - effort of worker 2) percent.

Probability that the second task is completed with high quality $= (10 + X2)\ \%$

Probability that the second task is completed with low quality $= (90 - X2)\ \%$

Examples: If worker 2 chooses an effort of 17, the second task will be completed with high quality with a probability of 27 % and with low quality with a probability of 73 %. If worker 2 chooses an effort of 72, the second task is completed with high quality with a probability of 82 % and with low quality with a probability of 18 %. The **wage** of the workers in a work group depends on the quality with which both tasks are completed:

- If both tasks are completed with high quality, **both** workers receive a wage of **280 points** each.
- If one task is completed with high and the other task with low quality, **both** workers receive a wage of **172 points** each.
- If both tasks are completed with low quality, **both** workers receive a wage of **0 points** each.

Each worker bears the **effort costs** for **his** effort. The effort costs depend on the chosen effort of a worker and are the following:

$$\text{effort costs} = \frac{(\text{chosen effort of a worker})^2}{80}$$

The table at the end of the instructions indicates the effort costs for all possible effort levels of a worker.

A worker's payoff for a round is his wage minus his effort costs:

$$\text{profit of a round} = \text{wage - effort costs}$$

After worker 1 and worker 2 have chosen their effort, both workers are informed about the effort of both workers in their work group, the quality with which the first and the second task are completed, and each worker's profits in this round.

Number of rounds

The experiment consists of 14 repetitions of the procedure described above. This results in 14 constituent rounds. Each participant keeps his role as worker 1 or worker 2 throughout all 14 rounds. At the beginning of each round the work groups are randomly formed anew. No worker is able to distinguish whether his matched worker has already been assigned to him in one of the preceding rounds or not.

Payment of the experiment

In this experiment not all 14 rounds are paid. **One** randomly determined round is paid for all participants. Which of the 14 rounds is paid out, will be told all participants after the 14^{th} round. All participants are paid according to their profit in the randomly chosen round. If your profit in this round is negative, this amount is deducted from the 7 Euro mentioned at the beginning of the instructions.

Table of costs

Effort	Effort costs	Effort	Effort costs
0	0.00	40	20.00
1	0.01	41	21.01
2	0.05	42	22.05
3	0.11	43	23.11
4	0.20	44	24.20
5	0.31	45	25.31
6	0.45	46	26.45
7	0.61	47	27.61
8	0.80	48	28.80
9	1.01	49	30.01
10	1.25	50	31.25
11	1.51	51	32.51
12	1.80	52	33.80
13	2.11	53	35.11
14	2.45	54	36.45
15	2.81	55	37.81
16	3.20	56	39.20
17	3.61	57	40.61
18	4.05	58	42.05
19	4.51	59	43.51
20	5.00	60	45.00
21	5.51	61	46.51
22	6.05	62	48.05
23	6.61	63	49.61
24	7.20	64	51.20
25	7.81	65	52.81
26	8.45	66	54.45
27	9.11	67	56.11
28	9.80	68	57.80
29	10.51	69	59.51
30	11.25	70	61.25
31	12.01	71	63.01
32	12.80	72	64.80
33	13.61	73	66.61
34	14.45	74	68.45
35	15.31	75	70.31
36	16.20	76	72.20
37	17.11	77	74.11
38	18.05	78	76.05
39	19.01	79	78.01
		80	80.00

Numbers are rounded to two digits after the decimal point.

Behavioral predictions of a model of inequity aversion

In this subsection we derive behavioral predictions for our treatments from a model of inequity aversion. In contrast to the self-interest model, an individual's utility does no longer only depend on his own material payoff but also on other individuals' payoffs. We use the assumptions from the model by Fehr and Schmidt (1999) in order to capture the notion of inequity aversion. For the case of two players, individual i's utility function is

$$u_i(e_i, e_j) =$$
$$\pi_i(e_i, e_j) - \alpha \cdot \max\{\pi_j(e_i, e_j) - \pi_i(e_i, e_j), 0\} - \beta \cdot \max\{\pi_i(e_i, e_j) - \pi_j(e_i, e_j), 0\},$$

where $\pi_j(e_i, e_j)$ denotes individual j's payoff given he chooses e_j and individual $i \neq j$ chooses e_i. α measures the aversion to disadvantageous inequity, and β the aversion to advantageous inequity.

In stark contrast to the self-interest model, in which $\alpha = \beta = 0$ for all individuals, we now assume $\alpha = 2$ and $\beta = 0.6$ for all individuals. Furthermore, we assume that individuals maximize their expected utility.

The case of substitutes

T-NO

If there is no signal at all, we solve for the Nash equilibrium of the simultaneous move game. In a first step, we derive agent i's reaction to any possible strategy of agent $j \neq i$, with $i, j \in \{1, 2\}$.

Given agent j chooses $e_j = \frac{165.6}{3.14} \approx 52.74$, the unique prediction of the self-interest model, agent i chooses $e_i = 66.24 - 0.256 \cdot e_j = \frac{165.6}{3.14}$ as a best response. This maximizes agent i's expected payoff, which is shown in the derivation of the predictions of the self-interest model, and minimizes the inequity of payoffs as $e_i = e_j$. Thus, it maximizes agent i's expected utility.

Given agent j chooses $e_j > \frac{165.6}{3.14}$, $e_i = 66.24 - 0.256 \cdot e_j$ maximizes agent i's expected payoff but not his utility as it generates advantageous inequity since $66.24 - 0.256 \cdot e_j < \frac{165.6}{3.14}$ for $e_j > \frac{165.6}{3.14}$. Therefore, agent i's optimal response is larger than $66.24 - 0.256 \cdot e_j$ (but smaller than e_j). It equals $\min\left\{\frac{66.24 - 0.256 \cdot e_j}{1-\beta}, e_j\right\}$, which is derived by maximizing agent i's expected utility for the case of advantageous inequity with respect to e_i. For $\beta = 0.6$ and $e_j \leq 80$ the minimum is equal to e_j.

Given agent j chooses $e_j < \frac{165.6}{3.14}$, again $e_i = 66.24 - 0.256 \cdot e_j$ maximizes agent i's expected payoff but not his expected utility as it generates disadvantageous inequity since $66.24 - 0.256 \cdot e_j > \frac{165.6}{3.14}$ for $e_j < \frac{165.6}{3.14}$. Therefore, agent i's optimal response is smaller (but larger than e_j). It equals $\max\left\{\frac{66.24 - 0.256 \cdot e_j}{1+\alpha}, e_j\right\}$, which is derived analogously to above. For $\alpha = 2$ the maximum is equal to e_j if and only if $e_j \geq \frac{66.24}{3.256}$.

We summarize agent i's reaction function for $\alpha = 2$, $\beta = 0.6$ and $e_j \in [0, 80]$ as follows

$$e_i^*(e_j) = \begin{cases} e_j & \text{if} \quad e_j \geq \frac{66.24}{3.256} \\ \frac{66.24 - 0.256 \cdot e_j}{3} & \text{if} \quad e_j < \frac{66.24}{3.256} \end{cases}.$$

In a next step, we solve for the intersections of both agents' reaction functions.

If $e_j \in \left[\frac{66.24}{3.256}, 80\right]$, all strategy combinations with $e_j = e_i \in \left[\frac{66.24}{3.256}, 80\right]$ are intersections.

If $e_j \in \left[0, \frac{66.24}{3.256}\right)$, there is no intersection. To see this, suppose, to the contrary, there was at least one intersection. Then $e_i = \frac{66.24-0.256\cdot e_j}{3}$ and $e_i < \frac{66.24}{3.256}$, as otherwise $e_j = e_i \geq \frac{66.24}{3.256}$ which was a contradiction. As $e_i < \frac{66.24}{3.256}$, $e_j = \frac{66.24-0.256\cdot e_i}{3}$. Yet, the two equalities can only hold if $e_j = e_i = \frac{66.24}{3.256}$. Since $\frac{66.24}{3.256} \notin \left[0, \frac{66.24}{3.256}\right)$, there cannot be an intersection.

Thus, the set of Nash equilibria is equal to the set of all strategy combinations with $e_j = e_i \in \left[\frac{66.24}{3.256}, 80\right]$.

T-IMP

In T-IMP agent 2 receives the signal $s = e_1$. We solve for the subgame perfect Nash equilibrium given $s = e_1$. Agent 2's reaction to $s = e_1$ is equivalent to his reaction function in T-NO as derived before. Agent 1 anticipates agent 2's reaction to s and maximizes his own expected utility[17]

$$U_1\left(e_1, e_2^*(e_1)\right) = w_H \cdot p\left(e_1\right) \cdot p\left(e_2^*(e_1)\right) + w_M \cdot \left[p\left(e_1\right) \cdot \left(1 - p\left(e_2^*(e_1)\right)\right) + \left(1 - p\left(e_1\right)\right) \cdot p\left(e_2^*(e_1)\right)\right] - \frac{e_1^2}{80} - \beta \cdot \left(\frac{e_2^*(e_1)^2}{80} - \frac{e_1^2}{80}\right).$$

with respect to e_1. For $e_1 \in \left[\frac{66.24}{3.256}, 80\right]$, $e_2^*(e_1) = e_1$ and agent 1's expected utility is maximized at $e_1 = 80$.[18] For $e_1 \in \left[0, \frac{66.24}{3.256}\right]$, $e_2^*(e_1) = \frac{66.24-0.256\cdot e_1}{3} \geq e_1$ and agent 1's expected utility is maximized at $e_1 = \frac{66.24}{3.256}$.[19] As $e_1 = \frac{66.24}{3.256}$ is agent 1's best choice out of the range $e_1 \in \left[0, \frac{66.24}{3.256}\right]$, and $e_1 = 80$ is agent 1's best choice out of the range $e_1 \in \left[\frac{66.24}{3.256}, 80\right]$, which includes $e_1 = \frac{66.24}{3.256}$, agent 1's best choice for the whole range of $e_1 \in [0, 80]$ is $e_1 = 80$. Consequently, in the unique subgame perfect Nash equilibrium $e_1 = s = 80$ and $e_2 = 80$ according to agent 2's reaction $e_2^*(e_1) = e_1$ for $e_1 \geq \frac{66.24}{3.256}$.

T-P

In T-P we solve for Nash equilibria given $s = b_1$. In a first step, we derive agent 2's reaction to any combination of e_1 and b_1. Consider $b_1 = 1$. What is agent 2's best response in this case?

[17] Here we use the fact that agent 1 either faces no payoff inequality because agent 2 perfectly matches his effort $\left(\text{for } e_1 \geq \frac{66.24}{3.256}\right)$ or advantageous inequality because agent 2 chooses more effort $\left(\text{for } e_1 < \frac{66.24}{3.256}\right)$.

[18] This function's maximum is attained at $e_1 > 80$. As the function is concave, it increases in e_1 for the whole range of $e_1 \in \left[\frac{66.24}{3.256}, 80\right]$. Hence, $e_1 = 80$ is the maximum for $e_1 \in \left[\frac{66.24}{3.256}, 80\right]$.

[19] Out of the range $e_1 \in \left[0, \frac{66.24}{3.256}\right]$, $e_1 = \frac{66.24}{3.256}$ yields the highest material payoff for agent 1 and avoids payoff inequalities since $e_2^*(e_1) = \frac{66.24-0.256\cdot e_1}{3} = e_1$ for $e_1 = \frac{66.24}{3.256}$.

Given agent 1 chooses $e_1 = 43.20$, which is agent 2's equilibrium effort in the self-interest model as derived in Section 3, agent 2 chooses $e_2 = 43.20$ as a best response. This maximizes agent 2's expected payoff, which is shown in the derivation of the predictions of the self-interest model, and minimizes the inequity of payoffs as $e_2 = e_1$.

Given agent 1 chooses $e_1 > 43.20$, $e_2 = 43.20$ maximizes agent 2's expected payoff (as the payoff maximizing effort is independent of e_1). This choice, however, generates advantageous inequity. Therefore, agent 2's utility maximizing response is larger than 43.20 (but smaller than e_1). It equals $\min\left\{\frac{43.20}{1-\beta}, e_1\right\}$, which is derived by maximizing agent 2's utility for the case of advantageous inequity with respect to e_2. For $\beta = 0.6$ and $e_1 \leq 80$ the minimum equals e_1.

Given agent 1 chooses $e_1 < 43.20$, $e_2 = 43.20$ again maximizes agent 2's expected payoff. This time, however, it generates disadvantageous inequity. Therefore, agent 2's optimal response is smaller (but larger than e_1). It equals $\max\left\{\frac{43.20}{1+\alpha}, e_1\right\}$, which is derived analogously to above. For $\alpha = 2$, the maximum equals e_1 if and only if $e_1 \geq 14.4$.

We summarize agent 2's reaction for $b_1 = 1$, $\alpha = 2$, $\beta = 0.6$ and $e_1 \in [0, 80]$ as follows

$$e_2^*(e_1|b_1 = 1) = \begin{cases} e_1 & \text{if } e_1 \geq 14.4 \\ 14.4 & \text{if } e_1 < 14.4 \end{cases}.$$

Equivalently, we can derive agent 2's reaction for $b_1 = 0$, $\alpha = 2$, $\beta = 0.6$ and $e_1 \in [0, 80]$ that is the following

$$e_2^*(e_1|b_1 = 0) = \begin{cases} e_1 & \text{if } e_1 \geq \frac{68.80}{3} \\ \frac{68.80}{3} & \text{if } e_1 < \frac{68.80}{3} \end{cases}.$$

Note that for $e_1 \geq \frac{68.80}{3}$ agent 2's reaction is $e_2 = e_1$ independent of b_1.

In a next step, we solve for the intersections of both agents' reaction functions, i.e. we search for strategy combinations $(e_1, (e_2(b_1 = 1), e_2(b_1 = 0)))$ in which e_1 is a best response to $(e_2(b_1 = 1), e_2(b_1 = 0))$ and $(e_2(b_1 = 1), e_2(b_1 = 0))$ is a best response to e_1.

Given $e_1 = \frac{165.6}{3.14}$, the equilibrium effort of T-NO in the self-interest model, agent 2's best response is $\left(\frac{165.6}{3.14}, \frac{165.6}{3.14}\right)$ since $e_1 \geq \frac{68.80}{3}$. Given agent 2 chooses $\frac{165.6}{3.14}$ independent of b_1, agent 1's best response is to choose $e_1 = \frac{165.6}{3.14}$. This maximizes agent 1's expected payoff, which is shown in the derivation of the predictions of the self-interest model, and minimizes the inequity of payoffs as $e_1 = e_2(b_1 = 1) = e_2(b_1 = 0)$. Hence, this strategy combination is a Nash equilibrium.

Given $e_1 = x \in \left(\frac{165.6}{3.14}, 80\right]$, agent 2's best response is (x, x) as $e_1 \geq \frac{68.80}{3}$. Given agent 2 chooses $x \in \left(\frac{165.6}{3.14}, 80\right]$ independent of b_1, agent 1's best response is to choose x as it is shown by the reaction function derived in T-NO for the model of inequity aversion. Thus, all strategy combinations with $e_1 = e_2(b_1 = 1) = e_2(b_1 = 0) \in \left(\frac{165.6}{3.14}, 80\right]$ are Nash equilibria.

Given $e_1 = x \in \left[\frac{68.80}{3}, \frac{165.6}{3.14}\right)$, agent 2's best response is (x, x). Given agent 2 chooses $x \in \left[\frac{68.80}{3}, \frac{165.6}{3.14}\right)$ independent of b_1, agent 1's best response is to choose x, as it is shown by the reaction function derived in T-NO for the model of inequity aversion. Consequently, all strategy combinations with $e_1 = e_2(b_1 = 1) = e_2(b_1 = 0) \in \left[\frac{68.80}{3}, \frac{165.6}{3.14}\right)$ are Nash equilibria.

Given $e_1 = x \in \left[14.4, \frac{68.80}{3}\right)$, agent 2's best response is $\left(x, \frac{68.80}{3}\right)$. Given agent 2 chooses x if $b_1 = 1$ and $\frac{68.80}{3}$ if $b_1 = 0$, agent 1's best response is not x. It can be shown that $e_1 = \frac{68.80}{3}$, for instance, yields a strictly higher expected utility than $e_1 = x \in \left[14.4, \frac{68.80}{3}\right)$. Consequently, there is no Nash equilibrium with $e_1 \in \left[14.4, \frac{68.80}{3}\right)$.

Given $e_1 = x \in [0, 14.4)$, agent 2's best response is $\left(14.4, \frac{68.80}{3}\right)$. Given agent 2 chooses 14.4 if $b_1 = 1$ and $\frac{68.80}{3}$ if $b_1 = 0$, agent 1's best response is not x. Choosing $e_1 = 14.4$, for instance, yields a strictly higher expected payoff and causes less payoff inequalities than $e_1 = x \in [0, 14.4)$. Hence, there is no Nash equilibrium with $e_1 \in [0, 14.4)$.

Thus, the set of Nash equilibria is equal to the set of all strategy combinations with $e_1 = e_2(b_1 = 1) = e_2(b_1 = 0) \in \left[\frac{68.80}{3}, 80\right]$.

T-PPlus

In T-PPlus agent 2 observes agent 1's effort in addition to his contribution. We solve for the subgame perfect Nash equilibrium given $s = (e_1, b_1)$. Agent 2's reaction to $s = (e_1, b_1)$ is equivalent to his best response in T-P as derived before. Agent 1 anticipates agent 2's reaction to s and maximizes his own expected utility[20]

$$U_1\left(e_1, e_2^*(e_1|b_1 = 1), e_2^*(e_1|b_1 = 0)\right) = w_H \cdot p\left(e_1\right) \cdot p\left(e_2^*(e_1|b_1 = 1)\right) + w_M \cdot \left(p\left(e_1\right) \cdot \left(1 - p\left(e_2^*(e_1|b_1 = 1)\right)\right) + \left(1 - p\left(e_1\right)\right) \cdot p\left(e_2^*(e_1|b_1 = 0)\right)\right) - \frac{e_1^2}{80} - \beta \cdot p\left(e_1\right) \cdot \left(\frac{e_2^*(e_1|b_1=1)^2}{80} - \frac{e_1^2}{80}\right) - \beta \cdot \left(1 - p\left(e_1\right)\right) \cdot \left(\frac{e_2^*(e_1|b_1=0)^2}{80} - \frac{e_1^2}{80}\right).$$

with respect to e_1. It can be shown that $e_1 = 14.4$ is agent 1's best choice out of the range $e_1 \in [0, 14.4]$, $e_1 = \frac{68.8}{3}$ out of the range $e_1 \in \left[14.4, \frac{68.8}{3}\right]$, and $e_1 = 80$ out of the range $e_1 \in \left[\frac{68.8}{3}, 80\right]$. Hence, agent 1's expected utility is maximized at $e_1 = 80$.

[20] Note that agent 2's reaction implies that agent 2's effort is at least as high as e_1. Thus, agent 1 faces either no or advantageous payoff inequality.

Therefore, in the unique subgame perfect Nash equilibrium $e_1 = 80$ and $e_2 = 80$, according to agent 2's reaction $e_2^*(e_1|b_1 = 1) = e_2^*(e_1|b_1 = 0) = e_1$ for $e_1 \geq \frac{68.80}{3}$.

The case of complements

T-NO^X

If there is no signal at all, we solve for the Nash equilibrium of the simultaneous move game. In a first step, we derive agent i's reaction function to any possible strategy of agent $j \neq i$, with $i, j \in \{1, 2\}$. We proceed analogously to T-NO but start with the unique Nash equilibrium prediction of the self-interest model that is $e_j = \frac{116}{1.9} \approx 61.05$.

For $\alpha = 2$, $\beta = 0.6$ and $e_j \in [0, 80]$ agent i's reaction function is

$$e_i^*(e_j) = \begin{cases} e_j & \text{if} \quad e_j \geq \frac{46.40}{2.760} \\ \frac{46.40+0.240 \cdot e_j}{3} & \text{if} \quad e_j < \frac{46.40}{2.760} \end{cases}.$$

In a next step, we solve for the intersections of both agents' reaction functions. It can be shown that the set of Nash equilibria is equal to the set of all strategy combinations with $e_j = e_i \in \left[\frac{46.40}{2.760}, 80\right]$.

T-IMP^X

In T-IMP^X we solve for the subgame perfect Nash equilibrium given $s = e_1$ using agent 2's reaction function of T-NO^X. Agent 1 anticipates agent 2's reaction to s and maximizes his own expected utility with respect to e_1. Analogously to T-IMP, it can be shown that agent 1's expected utility is maximized at $e_1 = 80$. Consequently, in the unique subgame perfect Nash equilibrium $e_1 = s = 80$ and $e_2 = 80$, according to agent 2's reaction $e_2^*(e_1) = e_1$ for $e_1 \geq \frac{46.40}{2.760}$.

T-P^X

In T-P^X we solve for the Nash equilibrium given $s = b_1$. To derive agent 2's best response to e_1 if $b_1 = 1$, we proceed analogously to T-P and start with agent 2's equilibrium effort of the self-interest model $e_1 = 68$. Agent 2's reaction for $b_1 = 1$, $\alpha = 2$, $\beta = 0.6$ and $e_1 \in [0, 80]$ is as follows

$$e_2^*(e_1|b_1 = 1) = \begin{cases} e_1 & \text{if} \quad e_1 \geq \frac{68}{3} \\ \frac{68}{3} & \text{if} \quad e_1 < \frac{68}{3} \end{cases}.$$

Equivalently, we can derive agent 2's best response for $b_1 = 0$ that is the following

$$e_2^*(e_1|b_1 = 0) = \begin{cases} e_1 & \text{if} \quad e_1 \geq \frac{44}{3} \\ \frac{44}{3} & \text{if} \quad e_1 < \frac{44}{3} \end{cases}.$$

By solving for the intersections of both agents' reaction functions we derive all Nash equilibria of T-P^X. Proceeding in an equivalent way to T-P and starting with $e_1 = \frac{116}{1.9}$, the equilibrium effort in T-NO^X in the self-interest model, we can show that the set of Nash equilibria is equal to the set of all strategy combinations with $e_1 = e_2(b_1 = 1) = e_2(b_1 = 0) \in \left[\frac{68}{3}, 80\right]$.

T-PPlus^X

In T-PPlus^X we solve for the subgame perfect Nash equilibrium given $s = (e_1, b_1)$. Agent 2's reaction to $s = (e_1, b_1)$ is equivalent to his best response in T-P^X. Agent 1 anticipates agent 2's reaction to s and maximizes his own expected utility with respect to e_1. It can be shown that agent 1's expected utility is maximized at $e_1 = 80$. Consequently, in the unique subgame perfect Nash equilibrium $e_1 = 80$ and $e_2 = 80$, according to agent 2's reaction $e_2^*(e_1|b_1 = 1) = e_2^*(e_1|b_1 = 0) = e_1$ for $e_1 \geq \frac{68}{3}$.

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