Knowing the Gap - Intermediate Information in Tournaments*

Sandra Ludwig[†] and Gabriele K. Lünser[‡]

July 15, 2008

Abstract

Intermediate information is often available to competitors in dynamic tournaments. We develop two simple tournament models with two stages: one with intermediate information on subjects' relative positions after the first stage, one without. In our models, equilibrium behavior in both stages is not changed by intermediate information. We test our formal analysis using data from laboratory experiments. We find no difference between average first and second stage efforts. With intermediate information, however, subjects adjust their effort to a higher extent. Subjects who lead tend to lower their second stage effort, subjects who lag still try to win the tournament. Overall, intermediate information does not endanger the effectiveness of rank-order tournaments: incentives do neither break down nor does a rat race arise. We also briefly investigate costly intermediate information.

Keywords: Tournament Design, Dynamic Tournaments, Intermediate Information, Feedback, Incentives, Experiment
JEL-Codes: C92, D01, D80, J30, M12

1 Introduction

Tournaments are often dynamic and competitors are able to gather information on their relative position during an ongoing contest. By nature such intermediate feedback allows

*We would like to thank Steffen Huck, Philipp Kircher, Eugen Kovac, Matthias Kräkel, Wieland Müller, and Christina Strassmair for helpful comments and discussions. We acknowledge financial support from the Bonn Graduate School of Economics. Lünser additionally acknowledges financial support from the Economic and Social Research Council (UK).

†University of Munich, Department of Economics, Ludwigstr. 28 (Rgb), 80539 Munich, Germany, e-mail: sandra.ludwig@lrz.uni-muenchen.de.

‡University College London, Department of Economics and ELSE, Gower Street, London WC1E 6BT, UK, e-mail: g.luenser@ucl.ac.uk.

for an adjustment of future actions. Consider, for instance, organizations which reveal information to their workers about how well they have performed in the past or workers who can observe their colleagues in situations where the relative performance is crucial for a promotion or bonus. Similarly, in sports contests like decathlon, distance events or soccer, it is possible to observe intermediate results of opponents. In patent races, signals about the relative position are sometimes made available. Static contests are, thus, not able to account for many real life situations. Hence, it is important to additionally investigate dynamic tournaments with multiple stages where the probability of winning depends on cumulative actions and in which subjects may gather *intermediate information* on their relative position. This paper theoretically and experimentally studies whether intermediate information in such competitive situations influences the agents' behavior.

We consider a simple two-stage rank-order tournament model with two symmetric agents who simultaneously choose their efforts in each stage. The contestants are able to observe each other's first-stage efforts – and thus their relative position – before entering the second stage. An agent's performance is stochastically related to the sum of efforts he has chosen in both stages. The agent with the higher overall performance wins the tournament and receives the winner prize, while the other agent receives the loser prize. In order to analyse the incentive effects of intermediate information, we also consider a baseline version of the tournament model in which agents gather no information after the first stage. Our models predict no difference in equilibrium behavior with and without intermediate information.

Based on these simple models, we investigate the effect of intermediate information on effort in an experiment. From a behavioral perspective there are two obvious – but opposing – explanations for deviations from the theoretical prediction that intermediate information does not change behavior: On the one hand, intermediate information on the relative position can enhance competition since agents are incited by the information. When agents know that they will receive information on their relative position they may try to out rival their opponent in the first stage. In the second stage, behavior then depends on the relative position. When agents lag they may try to win even harder or give up. When agents lead they may reduce their effort. On the other hand, collusive behavior might arise in the first stage. In the second stage, however, agents may misuse the signal they sent in the first stage and fiercely compete to win. Efforts reflect whether there is a tendency to enhanced competition or collusion in a single stage as well as in the entire tournament: More competition increases efforts while more collusion reduces efforts.

We mainly focus on the questions whether (i) intermediate information affects the effort choice in one stage or the total amount of effort, (ii) there is a tendency to collusion or enhanced competition in the first stage, (iii) subjects who are aware that they lead or lag adjust their second stage effort given this information.

In line with our theoretical predictions, our experimental results only show minor effects of intermediate information on an aggregate level. Thus, there is no overall tendency to enhanced competition or collusion. This does, however, not imply that there are no effects of intermediate information on an individual level. Indeed, we observe a significant difference in the subjects' adjustment of effort from the first to the second stage. When intermediate information is available, subjects adjust their effort to a greater extent across the first and second stage, hence they react to the information. More precisely, those subjects who lag tend to predominantly increase their second stage effort and those who lead tend to decrease it. Overall, intermediate information does not influence subjects' second stage effort choices by itself but conditional on being a favorite or a non-leader. Interestingly, subjects who lead always exert higher effort than those who lag – not only in the first stage but also in the second one. This might hint at different types of players: Those who choose relatively high effort and those who choose relatively low effort – independent of the information they receive. Regarding first stage efforts, it is remarkable that even though first stage effort does not significantly differ with and without intermediate information, subjects tend to successfully coordinate on a smaller difference between first stage efforts when intermediate information is available. Hence, intermediate information basically leads to a more "symmetric" (more balanced) tournament.

While in some situations intermediate information is very easy to obtain, in others some effort has to be made to identify one's relative position in an ongoing tournament. In an extension, we therefore investigate intermediate information which is costly. The theoretical prediction is that subjects do not buy the information and choose the same effort levels as with costless or no information. Indeed, we observe that subjects do not value intermediate information a lot. Even at a low cost, less than one-third of subjects buys the information. Additionally, those who buy the information do not behave differently from those who receive the information at no cost.

Overall, our study provides comforting news for the design of tournaments. It shows that intermediate information does not lead to a collapse of incentives, and at the same time does not lead to a rat race (Akerlof, 1976). Thus, intermediate information does not seem to endanger the effectiveness of rank-order tournaments. Therefore, in principle, when setting up a tournament the availability of intermediate information to contestants does not need to be prevented.

Our research question is complementary to the experimental studies by Schotter and Weigelt (1992) and by Weigelt et al. (1989). They consider "unfair" one-stage tournaments in which one contestant starts with a handicap. Thus, the tournament is comparable to the second stage of our tournament when agents learn whether they lead or lag. In contrast to our experiment, however, the handicap is exogenously imposed and does not arise endogenously. In line with our theoretical prediction, their prediction is that, with and without handicap, both agents exert the same effort. They find that (advantaged and disadvantaged) agents tend to oversupply effort compared to the theoretical prediction and that effort is lower than in a symmetric tournament without handicap. Unlike them, we observe that only favorites oversupply effort in the second stage. Moreover, in case the tournament endogenously turns out to be symmetric after the first stage, second stage effort is not higher than if the tournament turns out to be asymmetric. Hence, it makes a difference whether a handicap arises endogenously or is exogenously given.

There are some experimental studies that consider dynamic tournaments but with a different focus. Parco et al. (2004) consider a two-stage elimination contest in which only the winners of the first round compete in the second round. Players are resource-constrained in the sense that the more they invest in the first stage, the less they can invest in the second stage. Related to our analysis of intermediate information, Parco et al. compare two settings: In one resources of finalists are private knowledge and in the other one they are public knowledge, i.e. subjects know the maximum effort the opponent can choose in the final. Since players are resource-constrained, they cannot freely react to the information they have when resources are publicly known in the second stage. In line with their theoretical prediction (and similar to our predictions and observations), they observe no differences in effort choices between both information conditions. In both settings, however, they find over-expenditure in the first stage which is driven by the subjects' desire to make it to the final.

The studies by Gürtler and Harbring (2007) and Ederer and Fehr (2007) investigate dynamic tournaments in which the principal can provide feedback but has a commitment problem: The principal cannot only choose whether or not to reveal intermediate information but he can also misrepresent the information. Finally, Tong and Leung (2002) compare dynamic tournaments of certain and uncertain duration in which intermediate information is always provided. They do not theoretically solve the dynamic tournament model but test several heuristics that might apply against each other.[1]

Regarding the theoretical literature on tournaments, the main focus is on static mechanisms in which competing agents simultaneously choose an effort once, determining their performance and the winner.[2] There is a growing literature on sequential contests (going back to Dixit, 1987) in which one player moves before the other. When the second mover decides on his effort, he knows the first mover's decision. His decision resembles the second stage effort-choice in a tournament with intermediate information. A comparison between simultaneous and sequential contests like in Morgan (2003) or Ludwig (2006) is thus related to the issue of intermediate information. These studies show that as long as agents are symmetric (and this is common knowledge), equilibrium efforts are identical in simultaneous and sequential contests.[3]

Dynamic games in which effort is accumulated over rounds and all players play all rounds are analysed by Yildirim (2005) and Romano and Yildirim (2005). Here, players also ob-

---

[1]There is also a set of experimental papers studying dynamic oligopolies which one might see as related. For example, Huck et al. (2000) study four-firm oligopolies with product differentiation where subjects receive information about the opponents' actions in previous rounds. In contrast to our results, they observe that this intermediate information increases competition.

[2]For an overview on incentives in organizations see Gibbons (1998), Lazear (1999), and Prendergast (1999). See Konrad (2007) for an overview on contests in general.

[3]Weimann et al. (2000) conduct an experiment on sequential – but not on simultaneous – contests.

serve their opponents' effort after the first stage. In contrast to our model, the timing of actions does not matter for payoffs, only the cumulated effort, and therefore multiple equilibria exist. Aoyagi (2004) analyses the principal's optimal feedback policy in multi-stage tournaments. He investigates whether the principal, who receives a signal about the relative ranking, wants to (partly) reveal his signal to the agents. Other contributions on dynamic contests consider elimination contests (see e.g. Baik and Lee (2000) and Gradstein and Konrad (1999) for imperfectly discriminating contests and Moldovanu and Sela (2006) for a perfectly discriminating contest).

This paper is structured as follows. In Section 2 we present a simple two-stage tournament model with intermediate information and in Section 3 the baseline version without intermediate information. In Section 4 we describe the experimental design and procedures before we report our results in Section 5. In Section 6 we introduce costly intermediate information. We conclude in Section 7.

2 Tournament with Intermediate Information

We consider a two-person rank-order tournament with two stages $t = 1, 2$ (see Figure 1). In stage 1, two identical, risk neutral agents $i \in \{1, 2\}$ simultaneously choose an effort level $e_{i1} \in \left[0, \frac{a}{2}\right] \equiv \mathcal{I}$, where $a > 0$, and bear the corresponding cost $C(e_{i1}) = \frac{1}{c} e_i^2$ with $c > 0$. The cost function is convex, equal for both agents, and common knowledge. Before the agents enter stage 2, they observe the difference in effort levels which they exerted in stage 1. This difference is denoted by $k_{i1} := e_{-i1} - e_{i1}$. Thus, the agents can perfectly deduce the effort level the opponent has chosen in the first stage. Obviously, $k_{i1} < 0$ ($k_{i1} > 0$) means that agent i exerted a higher (lower) effort in the first stage than his opponent.

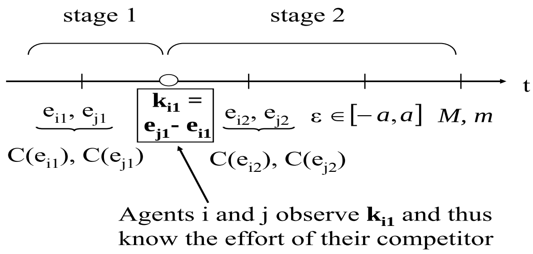
In stage 2, agents simultaneously choose an effort level $e_{i2} \in \left[0, \frac{a}{2}\right] \equiv \mathcal{I}$ again and bear the cost $C(e_{i2})$. At the end of stage 2, a noise term ϵ_i – which distorts the difference in the agent's total effort – is drawn from a uniform distribution over the interval $[-a, +a]$. The agent with the highest total output $y_i = e_{i1} + e_{i2} - \frac{\epsilon_i}{2}$ and $y_{-i} = e_{-i1} + e_{-i2} + \frac{\epsilon_{-i}}{2}$, respectively, where $\epsilon_{-i} \equiv \epsilon_i =: \epsilon$, wins the tournament. The winner receives the prize M and the loser receives the prize m with $0 < m < M$. The prize spread, i.e. the difference between the winner and the loser prize, is denoted by Δ. An agent's expected payoff in the tournament is

$$\pi_i = m + Pr(y_i > y_{-i})\Delta - C(e_{i2}) - C(e_{i1}).$$

By the intermediate information k_{i1} agents learn their current relative position in the ongoing tournament. If $k_{i1} < 0$, agent i enters stage 2 with a head start, whereas his competitor $-i$ lags and vice versa for $k_{i1} > 0$. We refer to the leading agent as *favorite* and to the one who lags as *underdog*.

In the following, we derive the subgame perfect equilibrium of the game. We restrict our analysis to pure strategies. Solving the game backward, we begin with stage 2. In stage

Figure 1: Two-stage Tournament with Intermediate Information



2, agents choose their effort levels to maximize their expected payoff considering the effort choices in stage 1 and e_{-i2} as given:

$$\max_{e_{i2}\in\mathcal{I}} \quad m + Pr(y_i > y_{-i})\Delta - C(e_{i2}).$$

$Pr(y_i > y_{-i})$ denotes agent i's probability to win the tournament, i.e. to additionally obtain Δ. The probability of winning for agent i is

$$Pr(y_i > y_{-i}) = Pr(e_{i1} + e_{i2} > e_{-i1} + e_{-i2} + \epsilon) = Pr(e_{i2} - e_{-i2} - k_{i1} > \epsilon)$$

$$= \begin{cases} 0 & \text{if } e_{i2} - e_{-i2} - k_{i1} < -a \\ \frac{1}{2} + \frac{e_{i2} - e_{-i2} - k_{i1}}{2a} & \text{if } e_{i2} - e_{-i2} - k_{i1} \in [-a, a] \\ 1 & \text{if } e_{i2} - e_{-i2} - k_{i1} > a \end{cases} \tag{1}$$

Note that since we restrict efforts to the interval $\mathcal{I}$, only the intermediate range of the probability of winning is relevant. Hence, according to Equation 1, agent i's probability of winning the tournament is given by

$$\Psi_{i2}(e_{i2}, e_{-i2}, k_{i1}) := \frac{1}{2} + \frac{e_{i2} - e_{-i2} - k_{i1}}{2a}$$

and the probability of winning the tournament of the opponent $-i$ equals $1 - \Psi_{i2}(e_{i2}, e_{j2}, k_{i1})$. The agents' maximization problems lead to the first order conditions[4]

$$\frac{\partial \Psi_{i2}(e_{i2}, e_{-i2}, k_{i1}))}{\partial e_{i2}}\Delta = \frac{2}{c}e_{i2} \Leftrightarrow \frac{c\Delta}{4a} = e_{i2}. \tag{2}$$

To make sure that the resulting effort choices lie indeed in the interval $\mathcal{I} \equiv \left[0, \frac{a}{2}\right]$, we assume that the cost function is sufficiently convex:

Assumption 1 $c \leq \frac{2a^2}{\Delta}$.

We see below that Assumption 1 is also a sufficient condition for equilibrium payoffs to be larger than the loser prize. This is important as otherwise an agent would have an incentive

[4]Since $-\frac{2}{c} < 0$ holds true by assumption, the first order conditions are also sufficient.

to exert no effort at all and thus receiving the loser prize at no cost.
From the first order condition (see Equation 2) it follows that agent i's effort choice in the second stage is *independent* of the opponent's choice e_{-i2} in the second stage. This means agents have a dominant effort choice in the second stage. Moreover, agent i's effort choice in the second stage is also independent of k_{i1} and thus, of the own and the opponent's first stage choices: In equilibrium, both agents – independent of whether they are the favorite or the underdog – exert equal effort in the second stage, which is $e^*_{i2} = \frac{c\Delta}{4a}$.[5] The reason is that the cost functions and the functions representing the marginal probability of winning are identical for any level of k_{i1}, e^*_{i2}, and e^*_{j2} for both agents. Hence, marginal costs equal marginal revenue at the same effort level – independent of an agent being the favorite or the underdog.
Now, we can solve the first stage. Here, the agents choose their efforts in order to maximize their expected payoff taking into account the optimal effort choices of stage 2:

$$\max_{e_{i1}\in\mathcal{I}} \quad m + Pr(y_i > y_{-i}|e^*_{i2}, e^*_{-i2})\Delta - C(e_{i1}) - C(e^*_{i2})$$

where $Pr(y_i > y_{-i}|e^*_{i2}, e^*_{-i2}) = Pr(e_{i1} + e^*_{i2} > e_{-i1} + e^*_{-i2} + \epsilon) = Pr(e_{i1} - e_{-i1} > \epsilon)$. Similar to above, we can define $\Psi_{i1}(e_{i1}, e_{-i1}) := \frac{1}{2} + \frac{e_{i1}-e_{-i1}}{2a}$ as the relevant probability of winning. The first order conditions for agents i (which are sufficient) are

$$\frac{\partial \Psi_{i1}(e_{i1}, e_{-i1})}{\partial e_{i1}}\Delta = \frac{2}{c}e_{i2} \Leftrightarrow \frac{c\Delta}{4a} = e_{i1}.$$

Assumption 1 guarantees that efforts lie in $\mathcal{I}$. Hence, the optimal effort levels in stage 1 are $e^*_{i1} = \frac{c\Delta}{4a}$ – identical to stage 2. Note that this implies the agents enter the second stage neck-and-neck as both agents choose the same effort in the first stage, which implies $k_{i1} = 0$. These are indeed the optimal effort choices since an agent's expected payoff is larger than m if and only if $c \leq \frac{4a^2}{\Delta}$, which holds true by Assumption 1. Hence, we have established the following proposition.

Proposition 1 *Let Assumption 1 be satisfied. In the tournament with intermediate information, a unique subgame perfect equilibrium exists. In this equilibrium,* $k_{i1} = 0$ *and* $e^*_{i1} = e^*_{i2} = \frac{c\Delta}{4a}$.

3 Baseline Tournament

The baseline tournament that we consider is identical to the tournament with intermediate information except for the fact that here agents receive no intermediate information. This means, they do not observe the difference in first stage effort levels. In the baseline tournament, the unique Nash-equilibrium outcome is identical to the tournament with intermediate

[5]Note that $\frac{c\Delta}{4a}$ is also the equilibrium effort in the corresponding symmetric one-stage tournament with two individuals.

information: Agents choose $e_{i1}^* = e_{i2}^* = \frac{c\Delta}{4a}$.[6]

The intuition for this result is simple: In the tournament with intermediate information, we have seen that *independent* of the opponent's and the own effort choice in the first stage, it is optimal to choose $e_{i2}^* = \frac{c\Delta}{4a}$. This means that whatever beliefs agents hold about k_{i1} in the tournament without intermediate information, it is optimal to choose $e_{i2}^* = \frac{c\Delta}{4a}$ in stage 2. Thus, beliefs do not matter at all at this point. What does this imply for the first stage? Agents know that their first stage behavior does not influence behavior in stage 2 as beliefs about k_{i1} do not matter. Hence, they know that it does not pay off to change the effort choice in the first stage just to influence beliefs of the opponent. When choosing their first stage efforts, agents simply maximize their payoffs given the (optimal) second stage efforts. This is exactly identical to the tournament with intermediate information.

Note that only the sum of an agent's effort determines his probability of winning. Because of the convex cost function it is always less costly for a player to split the total amount of total effort equally over both stages. Thus, we have the following proposition.

Proposition 2 *Let Assumption 1 be satisfied. In the baseline tournament, the unique Nash-equilibrium outcome is*

$$e_{i1}^* = e_{i2}^* = \frac{c\Delta}{4a}.$$

The proof is in the Appendix.

Obviously, equilibrium efforts are positive and under Assumption 1 they are smaller than $\frac{a}{2}$. Moreover, equilibrium payoffs are identical to before and thus larger than the loser prize as $c\Delta < 2a^2$.

Overall, with and without intermediate information, agents do neither care about the first stage effort of their opponent nor about their own. In addition, being or believing to be the favorite or the underdog does not matter for equilibrium efforts in stage 2.

4 Experimental Design and Procedures

Following our two simple two-stage tournament models, we conducted two straightforward treatments in order to investigate the influence of intermediate information on behavior. Across treatments we varied the subjects' feedback after the first stage: subjects did or did not receive information on the difference in effort levels. We denote these two treatments by *Info* and *NoInfo*. For each treatment we conducted two sessions consisting of 30 repetitions of the two-stage tournament. In each session, 18 subjects participated. They were randomly and anonymously matched into three subgroups of six. In each round, subjects of a subgroup were randomly re-matched into pairs. Hence, we collected six independent observations per treatment. The experiment was conducted in the *Laboratory for Experimental Research* at the University of Bonn. All sessions were computerized using the experimental software

[6]We again restrict efforts to be chosen from the interval $\mathcal{I}$ to ensure interior solutions.

Table 1: Design of the Experiment

	NoInfo	*Info*
Design		
# rounds	30	30
# participants	36	36
# independent observations	6	6
Parameters		
m	50	50
Δ	100	100
a	120	120
effort costs in each stage	$e_i^2/120$	$e_i^2/120$
Predictions		
effort of agent i in each stage	25	25

z-Tree (Fischbacher, 2007). Subjects were recruited over the internet with Greiner's (2004) ORSEE. Each subject was allowed to participate in one session only.

The design of the experiment is summarized in Table 1 which also shows the parameter specifications and equilibrium predictions for both treatments. We chose the parameters such that all aforementioned assumptions on them (see Section 2) are met. In the first and second stage each subject i chose an effort level e_i out of the integer set $e_i \in \{0, ..., 60\}$.[7] The random variable ϵ that distorts the total effort difference of agents was uniformly distributed over the integer interval $[-120, +120]$.

Before starting the experiment, the instructions were read to all participants.[8] We used neutral language, i.e. we avoided expressions like "tournament" or "effort". Instead subjects had to choose, e.g., a "number". In addition to the instructions we handed out cost tables which listed the costs induced by each possible choice of a "number". Participants had to calculate examples to demonstrate their understanding of the game.[9] During the experiment, participants were seated in cubicles and were not allowed to communicate with each other. In each round, subjects had to choose a number for the first and one for the second stage. In *Info*, subjects saw a feedback screen informing them about k_{i1} – the difference in first-stage effort levels – after the first stage. This screen displayed: "Your chosen number was by # units higher/lower than the number of the subject matched with you." After each round, the computer calculated the payoffs using the chosen numbers and each pair's

[7]These grids are considered to be fine enough for an approximation of the continuous choice problem.

[8]Original instructions were written in German. A translation is given in the Appendix.

[9]The numbers and the random number for these exercises had to be chosen by each participant herself *before* the introduction started. This procedure was used to keep possible suggestive influences as small as possible.

random number. Subjects received feedback about their own effort choices for the two respective stages, their effort cost in each stage, the achieved prize (winner or loser prize) and their payoff. Additionally, subjects were able to see their accumulated payoffs during the whole experiment. We provided no information regarding the decisions of the other subject or the actual random number. Sessions lasted for about eighty minutes including instruction time. During the experiment payoffs were given in the fictitious currency "taler". In the end payoffs were converted into Euro by a previously known exchange rate of 1 Euro per 220 taler. Average earnings of a subject were 9.90 Euros.

5 Experimental Results

We start by reporting average results in our two treatments. Then, we analyze the behavior of subjects under different information conditions in more detail. Our theoretical model predicts equal effort levels in the first stage of the tournament in *Info* and *NoInfo* as well as in the second stage of the tournament in *Info* and *NoInfo*. Table 2 shows in the left part average efforts, standard deviations of efforts over rounds, and also trends over rounds in the first and second stage as well as in both stages (horizontal sections) and treatments (columns). The right part reports Mann-Whitney U-tests (MWU tests) for significance of intermediate information. These MWU tests use group averages over all periods (i.e. 6 observations per treatment) as a unit of observation. Notice first the absent effect of intermediate information on average effort in the first and second stage: First stage average effort in *Info* is only 9.44% higher than in *NoInfo*. This percentage is even lower for the second stage (7.29%). The corresponding MWU tests indeed show that neither average effort in the first stage nor average effort in the second stage change when subjects are provided with intermediate information. This also holds true if one compares the total amount of effort exerted in the two-stage tournaments under both information conditions. Moreover, in both treatments and in both stages, average effort levels – which roughly lie between 34 and 38 – are above the equilibrium effort level of 25, possibly indicating an oversupply of effort. However, only effort in the second stage as well as total effort in *Info* are significantly higher than theory predicts (see Table 2 for details). We state as a first result:

Result 1 *Intermediate information does not have an influence on average effort in both stages.*

Figure 2 shows the average stage efforts over rounds in both treatments and visualizes our first result. Additionally, this figure suggests that over time efforts in *Info* and *NoInfo* diverge. To give this impression a statistical backing we calculated the Pearson correlation coefficients between rounds and average efforts for each independent observation for the first stage, the second stage and both stages, respectively. A Binomial test shows that the Pearson correlation coefficients in *Info* are significantly more often positive than negative (event probability $\alpha = 0.5$, see Table 2 for more detailed results). Thus, we observe an

Table 2: Overview of Average Results

	NoInfo	*Info*	**test values** *NoInfo* vs. *Info*
average effort in stage 1 (e_{i1})	34.31	37.55	0.197
	(19.68)	(17.91)	
trend of e_{i1} over rounds	0.0327	0.4043*	0.066
average effort in stage 2 (e_{i2})	35.08	37.64^{+}	0.469
	(19.20)	(18.83)	
trend of e_{i2} over rounds	0.0677	0.3655*	0.120
average total effort ($e_{i1} + e_{i2}$)	69.39	75.19^{+}	0.409
	(36.83)	(31.49)	
trend of $e_{i1} + e_{i2}$ over rounds	0.0658	0.4472*	0.155

Standard deviations of effort over rounds are given in parentheses and are based on all individual effort choices. The trend over rounds is indicated by the average Pearson correlation coefficient. Test values for treatment differences result from MWU tests (one-tailed).

By using Binomial tests (one-tailed, event probability $p = 0.5$) we indicate if the null hypothesis can be rejected in favor of the alternative hypothesis that the average values are more often above the equilibrium level than below or that the Pearson correlation coefficient is more often positive than negative:

$^{+}$*: significantly* $(0.01 < \alpha \leq 0.05)$ *above the equilibrium level of 25 (stage effort) or 50 (total effort)*

**: significantly* $(0.01 < \alpha \leq 0.05)$ *positive trend*

increasing trend of (first-stage, second-stage and total) effort over rounds in the tournament with intermediate information. The average Pearson correlation coefficients for the respective stages in *NoInfo* are, on the contrary, always astonishingly close to 0. Note, however, that the average efforts in the first and the second stage, respectively, do not differ significantly between *NoInfo* and *Info* even if one analyzes only the last ten rounds (MWU tests, first stage: $p = 0.197$; second stage: $p = 0.469$, one-tailed).

Our theoretical model further predicts that effort neither differs between the first and the second stage in *NoInfo* nor between the first and the second stage in *Info*. Indeed average efforts in both stages in *NoInfo* as well as in *Info* are quite similar (Wilcoxon Signed-Rank tests, *NoInfo*: $p = 0.500$; *Info*: $p = 0.281$, one-tailed). We additionally run (separately for each treatment) a simple tobit regression with clustering on matching groups where effort is the dependent variable and a stage dummy and rounds are explanatory variables. Table 3 shows these regressions and verifies that in both treatments there is no difference between first and second stage efforts as predicted by theory. In the regression for *Info* (and only there) the round variable is significant – confirming our earlier observation on increasing first and second stage efforts in *Info*. We summarize these observations in the following result:

Result 2 *Irrespective of the presence of intermediate information, average effort does not*

Figure 2: Average Effort over Rounds

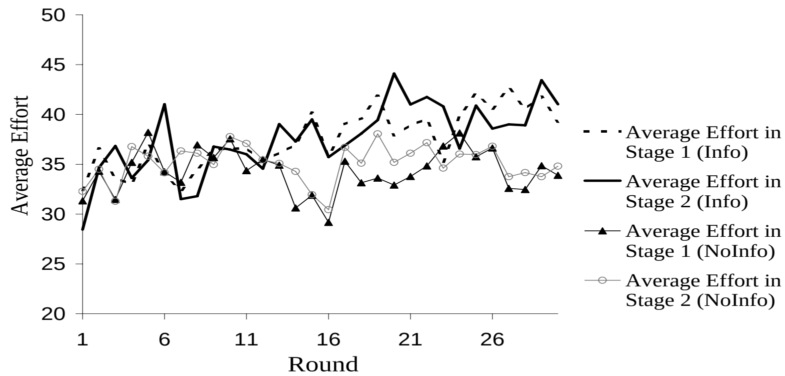


Table 3: Regression Results on Equal Effort in Both Stages

	NoInfo		*Info*	
effort in a stage	coef. (se)	$Pr > \|z\|$	coef. (se)	$Pr > \|z\|$
constant	35.5 (3.20)	0.000	34.11 (5.38)	0.000
round	-0.02 (0.19)	0.904	0.38 (0.13)	0.003
stage	1.31 (1.77)	0.459	-0.16 (3.00)	0.958
matching groups	6		6	
n	2160		2160	

Method: Tobit Regression with clustering on matching groups

change across stages within *a respective treatment.*

Even though we observe that intermediate information does not have a direct effect on average effort, it is premature to conclude that it does not have an effect at all. Some subjects might restrain effort in the first stage or, on the contrary, oversupply effort in order to deter their opponent when they know that intermediate information will be provided. Such bifurcated behavior might also occur in the second stage. Subjects who lag after the first stage, i.e. underdogs, could either give up or try to win the tournament even harder. Analogously, subjects who lead, i.e. favorites, could either play safe and exert a similar high effort in the second stage or put in less effort since they have already experienced a head start. Such counterbalancing effects might lead to no evident effect on the aggregate level. We therefore have a closer look at the data.

Figure 3: Cumulative Distribution of Effort Choices

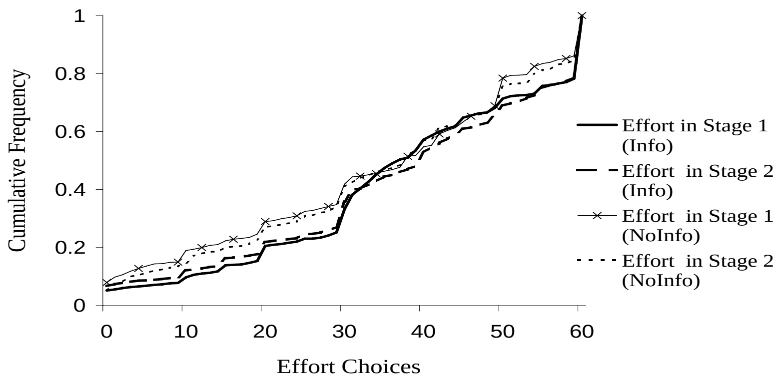


Figure 3 displays the cumulative distributions of all single effort choices in each stage in *NoInfo* and *Info*. The figure suggests that there is indeed some difference in behavior with and without intermediate information. The cumulative distributions of single effort choices in the first and the second stage in *NoInfo* lie above the ones in *Info* for effort levels roughly below 35 and above 50. This visually displays that with intermediate information less effort choices are made below 35. A huge jump in the cumulative distribution for effort levels between 30 and 35 in *Info* reunites the cumulative distributions, graphically representing the high frequency of those effort levels. A final difference in behavior is shown for effort levels above 50 when the cumulative distribution lines drift apart before merging again at 60. Thus, there are many more effort choices close to 60 in *Info*.

To further analyse whether subjects take the additional information into account, we next look at differences in effort levels with respect to two dimensions: *Individual* differences in effort levels across both stages and the difference in effort levels *between* subjects who compete against each other in both stages. Table 4 summarizes the results. As mentioned before, we do not observe a difference in average efforts across stages. We already reasoned that this might be due to bifurcated behavior of the subjects. Indeed, a comparison of the average change in effort from the first stage to the second stage in *NoInfo* (-0.77) and *Info* (-0.08) displays no significant difference. This does, however, not imply that there are no effort adjustments due to intermediate information: It might just be the case that decreases and increases offset each other. To see if subjects alter their effort at all, we calculated the *absolute value* of individual effort differences across first and second stage, i.e. we first take the absolute value of the individual effort difference across stages and then calculate the average. This measure integrates all changes between first and second stage effort *irrespective* of their direction. Considering absolute differences we now observe a clear significant effect

Table 4: Differences in Effort Levels

	NoInfo	*Info*	**Test values** *NoInfo - Info*
across stages for subject i			
$e_{i1} - e_{i2}$	-0.77	-0.08	0.294
absolute value of $e_{i1} - e_{i2}$	5.96	12.64	0.001
# equal split of total effort ($e_{i1} - e_{i2} = 0$)	595	305	0.008
across subjects $i \neq j$ **in one stage**			
($k_{i1} :=$) $e_j - e_i$ in 1^{st} stage	22.13	18.39	0.013
($k_{i2} :=$) $e_j - e_i$ in 2^{nd} stage	20.22	19.90	0.469
Wilcoxon test k_{i1} - k_{i2}	0.078	0.281	

Significance levels of differences between treatments result from MWU tests (one-tailed). Significance levels of differences within a treatment result from Wilcoxon Signed-Rank tests (one-tailed).

of intermediate information: Relative to the first stage subjects adjust – i.e. lower or increase – their second stage effort to a much greater extent in *Info* (12.64) than in *NoInfo* (5.96, compare upper part of Table 4). As Figure 4 shows this average absolute difference measure is systematically higher for *Info* than for *NoInfo* over all rounds. Moreover, the equal split of total effort among both stages (that is predicted by theory) is chosen significantly more often in *NoInfo* (595 times) than in *Info* (305 times).[10] While this provides additional evidence for modified behavior due to intermediate information, it also shows that subjects in *NoInfo* understand that given the convex cost function it is optimal to equally divide their effort between the first and second stage.

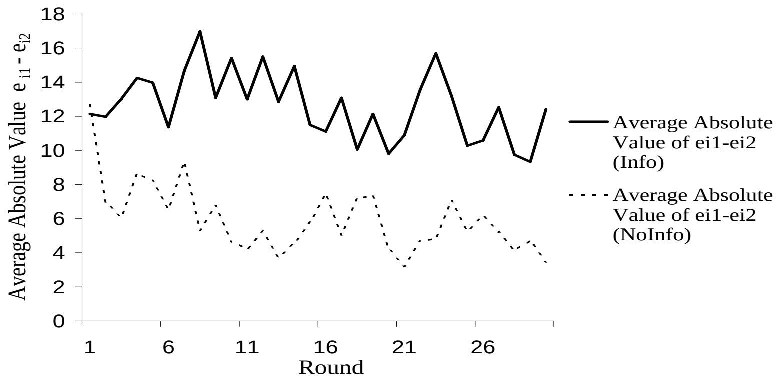
Result 3 *Subjects alter their second stage effort to a greater extent relative to their first stage effort when intermediate information is available.*

We now turn to *across* subject differences in effort levels within one stage (see lower part of Table 4). When considering the difference *across* matched subjects in the *first* stage, i.e. k_{i1}, we see that subjects in *Info* tend to successfully coordinate on a lower difference (18.39 vs. 22.13, lower part of Table 4, MWU test, $p = 0.013$, one-tailed). This is also supported by the observation that the standard deviation of all individual first stage efforts is significantly lower in *Info* than in *NoInfo* (see Table 2 for exact values, MWU test, $p = 0.021$, one-tailed). With 18.39, however, the difference in effort levels across subjects in the first stage in *Info* still remains quite large.[11] This hints at individual differences in first stage behavior.

[10] A glance at the (undisplayed) distribution of individual effort differences between the first and second stage in *Info* and *NoInfo* shows that distributions are quite symmetric and peak around zero in both treatments.

[11] Additionally, in *Info* about 24% of the realized k_{i1}-values are smaller than or equal to 5, whereas only 11% are above 35. In *NoInfo* these percentages are almost reversed with 15% and 22%, respectively (MWU

Figure 4: Absolute Value of Individual Differences in First and Second Stage Effort over Rounds



Similarly, we can consider *across* subject differences in *second* stage effort levels, i.e. $k_{i2} := e_{i2} - e_{-i2}$. Here, we do not find any difference across treatments (see Table 4). Moreover, k_{i1} and k_{i2} are roughly of the same size.

Result 4 *The effort difference across subjects in the first stage is lower when intermediate information is available.*

Up to now, we considered whether and how intermediate information affects behavior *on average*. We now ask whether and how it affects the behavior conditional on being the underdog or favorite in an ongoing tournament, i.e. conditional on lagging or leading. Basically, subjects might reduce or increase their effort relative to the first stage conditional on the intermediate information. Table 5 gives an overview on the effort change between first and second stage depending on the intermediate standing in *NoInfo* and *Info*. First, it informs about the number of peers, underdogs and favorites in each treatment. Furthermore, distinguishing between these three intermediate positions, it reports for each treatment the percentage of higher, equal and lower efforts in the second stage as well as the average effort change given a particular direction of the effort adjustment. The majority of subjects in *NoInfo* does not change their effort in the second stage relative to the first stage; so do subjects who have exerted the same amount of effort as their opponent in the first stage in *Info*. When subjects are aware of being the underdog in *Info*, however, 52% of subject increase their effort in the second stage, on average by as much as 20.74. Favorites on the other hand predominantly (48%) lower their effort in *Info* by on average 16.18. An across treatment comparison shows that more subjects adjust their effort in *Info* than in *NoInfo*.

test, k_{i1} in *Info* versus in *NoInfo*: lower range: p = 0.036 and upper range: p = 0.004, one-tailed).

Table 5: Effort Changes Between Stages Depending on Intermediate Standing ($k_{i1} \gtreqqless 0$)

	NoInfo			*Info*		
peers ($k_{i1} = 0$)	# = **28**			# = **98**		
% of higher/equal/lower effort in second stage	7 %	71 %	21 %	19%	59%	22 %
average change in effort between stages ($e_{i2} - e_{i1}$)	2.00	0.00	-21.50	12.26	0.00	-14.19
underdogs ($k_{i1} > 0$)	# = **526**			# = **491**		
% of higher/equal/lower effort in second stage	38 %	46 %	16 %	52%	21%	27%
average change in effort between stages ($e_{i2} - e_{i1}$)	13.88	0.00	-9.34	20.74	0.00	-20.69
favorites ($k_{i1} < 0$)	# = **526**			# = **491**		
% of higher/equal/lower effort in second stage	17 %	65 %	18 %	23%	29%	48 %
average change in effort between stages ($e_{i2} - e_{i1}$)	8.68	0.00	-19.55	11.46	0.00	-16.18

Most strikingly, (i) more underdogs increase their effort in *Info* than in *NoInfo* (52% vs. 38%) and additionally, this increase is much higher in *Info* (20.74 vs. 13.88); (ii) 27% of the underdogs in *Info* lower their second stage effort by as much as 20.69 (*NoInfo*: 16%, 9.34); (iii) many more favorites (48% vs. 18%) choose to lower their second stage effort in *Info*. The size of the lowering adjustment is not much less than in *NoInfo* (16.18 vs. 19.55).

Result 5 *With intermediate information underdogs (favorites) predominantly increase (lower) their second stage effort and do not give up (play safe).*

How do subjects choose their effort in the second stage? The Spearman rank order correlation coefficient between first and second stage efforts gives us a first idea: the coefficient is 0.79 in *NoInfo* and only 0.49 in *Info* (both: $p < 0.001$, $N = 1080$). This simple measure shows that in both treatments first and second stage efforts are positively correlated. Beyond, it also shows that in *Info* second stage effort is *less* correlated with first stage effort as subjects react to the intermediate information. To gain a deeper understanding how subjects choose their second stage effort, we run a simple tobit regression. We regress second stage effort on first stage effort, a favorite dummy (equal to one if $k_{i1} < 0$), an intermediate information dummy (equal to one in *Info*), and an interaction term of the last two variables. The regression results with clustering on the matching group level are shown in Table 6. The results indicate that second stage effort is highly dependent of first stage effort: The more effort a subject has

Table 6: Regression Results on Second Stage Efforts

second stage effort e_{i2}	coef. (se)	$Pr > \|z\|$
constant	7.20 (3.74)	0.054
effort in first stage	0.82 (0.09)	0.000
favorite	2.49 (2.27)	0.272
intermediate information	3.97 (4.22)	0.346
*favorite*intermediate information*	-7.81 (3.74)	0.037
matching groups	12	
# lower/ un-/upper censored	129/1634/397	

Method: Tobit Regression with clustering on matching groups

chosen in the first stage, the higher the effort in the second stage. Intermediate information and being a favorite by itself has no significant impact. Only when subjects are favorites and are given the feedback in *Info* that they are leading, they significantly reduce their effort (compared to non-leading subjects, i.e. underdogs and the ones that are neck-and-neck). Vice versa this means that subjects who do not lead significantly increase their effort when receiving the corresponding intermediate information in *Info*. This regression nicely shows that – depending on their standing in the ongoing tournament – subjects do indeed react to the intermediate information they receive in *Info*, even though there is no effect of the intermediate information by itself.

Result 6 *Intermediate information does not influence subjects' second stage effort by itself but only conditional on being a favorite or a non-leader.*

Taking a step back and looking at mere averages shows that, irrespective of the information condition, first stage effort, second stage effort as well as total effort of favorites are always considerably and significantly higher than the respective efforts of the underdogs.[12] Note additionally, that the favorite's effort in the two stages as well as their overall effort are significantly higher than predicted by theory. There is no significant difference with respect to the reported effort values between the treatments with and without information.[13]
Note that the previous results differ sharply from Schotter and Weigelt (1992) and Weigelt et al. (1989): with an exogenously given and known handicap they find an oversupply for all

[12]Average first stage effort (second stage effort/total effort): *NoInfo*-favorite: 45.47 (43.39/88.86), *NoInfo*-underdog: 22.72 (26.56/49.27), *Info*-favorite: 46.97 (41.80/88.76), *Info*-underdog: 26.47 (31.94/58.41). The p-values of Wilcoxon Signed-Rank tests (all one-tailed) between favorites and underdogs for the first stage, the second stage and total effort are always below 5%.

[13]MWU tests (all one-tailed): favorite – first stage effort (second stage effort/total effort): $p = 0.409$ ($p = 0.242/p = 0.469$); underdog – first stage effort (second stage effort/total effort): $p = 0.120$ ($p = 0.242/p = 0.242$).

subjects – not only for favorites – observing no difference between favorites and underdogs. Moreover, they find that in symmetric tournaments efforts are higher than in asymmetric ones. We observe, however, that the second stage efforts in a tournament that *endogenously* turns out to be symmetric are not higher than in one that turns out to be asymmetric (Wilcoxon Signed-Rank test, $p = 0.345$, one-tailed).
We also observe different effort adjustment behavior (across stages) of favorites and underdogs: Underdogs adjust their effort significantly more in both treatments (average absolute value $e_{i1} - e_{i2}$ in *Info*: favorites 4.94 / underdogs 9.63; *NoInfo:* favorites 7.06 / underdogs 16.42). Thus, an underdog reacts more to the information than a favorite. There is also a difference across treatments: For players in *Info*, the average absolute value of the effort difference is significantly larger than in *NoInfo* where subjects do not know whether they lag or not (MWU test, favorite: $p = 0.008$; underdog: $p = 0.002$, one-tailed).
Observing these differences between favorites and underdogs, one might ask whether it pays off to be a favorite. In *NoInfo* and *Info*, the favorite wins the tournament significantly more often than the underdog[14], indicating that favorites succeed in keeping their relative position throughout the tournament (average winning probability in *Info*: favorites 0.66 / underdogs 0.34; *NoInfo*: favorites 0.63 / underdogs 0.37). Moreover, there is a small but nevertheless significant difference between treatments with regard to the winning probability of favorites and underdogs, respectively. In the presence of intermediate information an underdog wins the tournament more often than an underdog who has no access to such information, for favorites, of course, the effect is reversed (MWU tests, favorites: $p = 0.013$; underdogs: $p = 0.032$, one-tailed). Note, however, that the average winning probability of underdogs only rises from 34 percent in *NoInfo* to 37 percent in *Info* and for favorites the probability decreases accordingly. Compared to the equilibrium prediction of a winning probability of 50 percent, favorites (underdogs) win significantly more (less) often in *Info* as well as in *NoInfo* (Binomial test, all $p = 0.016$). Expected payoffs of favorites are not higher than predicted by theory (Binomial test, $p = 0.109$ in *Info* and $p = 0.344$ in *NoInfo*) but for underdogs they are significantly lower (Binomial test, $p = 0.016$ for both treatments). Comparing the payoff of underdogs with the payoff of favorites, we find that it pays off to be a favorite (Wilcoxon Signed Rank test, $p = 0.028$, one-tailed, in *Info* and *NoInfo*).

6 Short Foray into Costly Intermediate Information

In the treatments described above, intermediate information is either provided at no cost or is not available. In this extension, we ask whether subjects value information on the effort gap in an ongoing tournament. Do they choose to receive intermediate information even if it is costly? To investigate this issue, we conducted a treatment in which subjects could buy the additional information at a (low) cost. We denote the new treatment by *InfoBuy*.

[14]To be precise, the probability of winning is higher – since there is still the random component. But *on average* a higher probability of winning leads to more success.

In practice, competitors not always receive information about their opponent without any action on their side, but might have to invest some effort or time in order to observe the other's behavior. In our experiment, this additional effort is represented by the cost to receive the information. Note that the cost is chosen to be small, not to completely change the strategic situation faced by subjects.

To analyse this issue, we implemented a two-stage tournament in which agents simultaneously decide on whether they want to receive the intermediate information (after the first stage) at a small cost before choosing first stage efforts. Agents are informed whether their opponent chose to buy the information before the tournament starts. Then, both agents simultaneously choose an effort and – according to their buying decision – possibly receive the information how much they lead or lag. Then agents choose their second stage efforts.

We already know that the effort choices are independent of the intermediate information in equilibrium (compare Propositions 1 and 2). As information is costly and does not change actions in the tournament, it can only be optimal *not* to buy the information. Hence, theory predicts that subjects will not buy the information in *InfoBuy* and exert the same effort as in *Info* or *NoInfo*:

Proposition 3 *Let Assumption 1 hold. In the tournament with costly intermediate information, there exists a unique symmetric subgame perfect Nash-equilibrium in which no subject buys the information and*

$$e_{i1}^* = e_{i2}^* = \frac{c\Delta}{4a}.$$

We kept the experimental design in *InfoBuy* as similar as possible to the other two treatments. We implemented 30 rounds of the two-stage tournament with 36 new subjects using the same matching procedure, collecting six independent observations. Additionally, when entering the first stage, subjects had to decide whether they want to buy the intermediate information. The cost was set at 10, i.e. only 6.67% of the winner prize.

Table 7 displays average efforts and the trend over rounds for the first stage, the second stage and both stages in *InfoBuy*, also distinguishing between buyers and non-buyers of the intermediate information. Only 29.96% of the subjects choose to buy the intermediate information.

Result 7 *Less than one-third of subjects buys the intermediate information.*

Not to add too much padding, according to MWU tests all average effort levels in *InfoBuy* do not differ from the ones in *Info* and *NoInfo*. Additionally, all buyers' average efforts do not differ from the average efforts in *Info*, and all non-buyers' average efforts do not differ from the average efforts in *NoInfo*.[15] Subjects in *InfoBuy*, however, oversupply effort in each stage compared to the equilibrium prediction of 25 – irrespective of whether one distinguishes

[15] Is there a relation between those players who buy (do not buy) the information and the favorites (underdogs)? In total, 63.61% (51.18%) of the buyers (non-buyers) are favorites or peers, i.e. $k_{i1} \leq 0$.

Table 7: Overview of Average Results in *InfoBuy*

	InfoBuy	*buyers* (*29.26%*)	*non-buyers* (*70.74%*)
first stage			
average e_{i1}	36.90^{+}	38.11^{+}	36.40^{+}
	(18.12)	(16.04)	(18.90)
trend of e_{i1} over rounds	0.1457	0.2691	0.0133
second stage			
average e_{i2}	38.68^{+}	40.18^{+}	38.05^{+}
	(17.91)	(17.35)	(18.10)
trend of e_{i2} over rounds	0.0035	0.0586	0.0359
both stages			
total effort $e_{i1} + e_{i2}$	75.57^{+}	75.89^{+}	74.65^{+}
	(32.92)	(25.50)	(34.86)
trend of $e_{i1} + e_{i2}$ over rounds	0.0907	0.1998	0.0245

Standard deviations of effort over rounds are given in parentheses and are based on all individual effort choices. The trend over rounds is indicated by the average Pearson correlation coefficient.
By using the Binomial test (one-tailed) we state the level of significance at which the null hypothesis can be rejected in favor of the alternative hypothesis that the average effort values are more often above the equilibrium level than below:
$^{+}$ *indicates that they are significantly above the equilibrium level with* $0.01 < \alpha \leq 0.05$.

between buyers and non-buyers.
Moreover, we observe no difference when comparing buyers' and non-buyers' behavior with respect to effort within one stage (Wilcoxon Signed-Rank test, first stage: $p = 0.218$; second stage: $p = 0.500$; both stages: $p = 0.500$, all one-tailed) as well as across stages (Wilcoxon Signed-Rank test, buyers: $p = 0.219$; non-buyers: $p = 0.109$, both one-tailed).
One observation which is surprising, but consistent across stages, is that subjects in *InfoBuy* who actually buy the intermediate information do not significantly increase their respective stage efforts as well as their overall effort over rounds any more.[16] For the second stage, even a significantly smaller Pearson correlation coefficient is observed in *InfoBuy* than in *Info*. Thus, receiving intermediate information at a cost keeps players from increasing their effort over rounds.
Does it nevertheless pay off to buy the intermediate information? We find that buying the information leads to a significant reduction in the subjects' payoff compared to non-buyers (59.79 vs. 71.19, Wilcoxon Signed-Rank test, $p = 0.027$, two-tailed), subjects in *Info* (59.79

[16]Remember that in *Info* there was a significant increasing trend over rounds for the first stage, the second stage as well as for the overall effort.

vs. 76.87, MWU test, $p = 0.006$, two-tailed) as well as subjects in *NoInfo* (59.79 vs. 78.94, MWU test, $p = 0.004$, two-tailed).[17]

Finally, in line with our results in *Info*, buyers of intermediate information show a greater absolute value of the effort difference between the first and second stage than non-buyers, since they receive the information on the effort gap in the ongoing tournament and can react to it (Wilcoxon Signed-Rank test, $p = 0.016$, one-tailed).

7 Conclusion

This study investigates the effect of intermediate information in competitive situations. We develop two simple two-stage rank-order tournament models with two symmetric agents who simultaneously choose their efforts in each stage. The models only differ with respect to the availability of intermediate information on the relative position of contestants after the first stage. Theoretically, there is no difference in equilibrium efforts irrespective of the information condition. We then experimentally investigate the effect of intermediate information on behavior in such two-stage tournaments.

In line with our theoretical prediction, we find that intermediate information makes no difference with respect to average efforts. A more profound data analysis reveals, however, that subjects adjust their second stage effort to a greater extent – in absolute values – compared to the first stage when intermediate information is available. Furthermore, subjects who lag (lead) tend to predominantly increase (lower) their second stage effort instead of giving up (playing safe). Thus, intermediate information does not influence the subjects' second stage effort choices by itself but only conditional on being a favorite or a non-leader.

In an extension, we investigate whether subjects acquire costly intermediate information. Our results provide another indicator that subjects do not value intermediate information a lot in the competitive situation we consider: more than two thirds of them restrain from buying intermediate information at a low cost.

Overall, this study indicates that intermediate information does not lead to a collapse of incentives. In the presence of intermediate information (i) subjects who lag behind still try to win the tournament rather than resign and (ii) subjects do not collude on lower effort levels in the first or second stage. Moreover, intermediate information does neither lead to a "rat race": The data does not hint at a persistent oversupply of effort, which would be inefficient.

One might conclude that rank-order tournaments are a highly appropriate device to provide incentives for competing agents and that the presence of intermediate information does not seem to endanger its effectiveness. Thus, in terms of effectiveness, there is no immediate need to restrict intermediate information from competing parties in a tournament.

[17] Even if we ignore the information costs of 10, buyers are not better off than non-buyers (Wilcoxon Signed-Rank test, $p = 0.463$, two-tailed) or subjects in *Info* or *NoInfo* (MWU test, $p = 0.109$ and $p = 0.150$, two-tailed).

References

[1] Akerlof, G. (1976), "The Economics of Caste and of the Rat Race and Other Woeful Tales," *Quarterly Journal of Economics* **90**, 599–617.

[2] Aoyagi, M. (2004), "Information Feedback in a Dynamic Tournament," ISER Discussion Paper Nr. 580.

[3] Baik, K. H. and S. Lee (2000), "Two-Stage Rent-Seeking with Carryovers," *Public Choice* **103**, 285–296.

[4] Dixit, A. (1987) "Strategic Behavior in Contests," *American Economic Review* **77**(5), 891–898.

[5] Ederer, F. and E. Fehr (2007), "Deception and Incentives. How Dishonesty Undermines Effort Provision," IZA Discussion Paper No.3200, Bonn.

[6] Fischbacher, U. (2007), "z-Tree: Zurich Toolbox for Ready-made Economic Experiments," *Experimental Economics* **10**, 171–178.

[7] Gibbons, R. (1998), "Incentives in Organizations", *Journal of Economic Perspectives* **12**(4), 115–32.

[8] Gradstein, M. and K. Konrad (1999), "Orchestrating Rent Seeking Contests," *Economic Journal* **109**, 536–545.

[9] Greiner, B. (2003), "An Online Recruitment System for Economic Experiments." Kurt Kremer, Volker Macho (eds.): Forschung und wissenschaftliches Rechnen 2003. GWDG Bericht 63. Ges. für Wiss. Datenverarbeitung, Göttingen, 79–93.

[10] Gürtler, O. and C. Harbring (2007), "Feedback in Tournaments under Commitment Problems: Theory and Experimental Evidence," IZA Discussion Paper No. 3111.

[11] Huck, S., H.-T. Normann, and J. Oechssler (2000), "Does Information About Competitors' Actions Increase or Decrease Competition in Experimental Oligopoly Markets?," *International Journal of Industrial Organization* **18**, 39–57.

[12] Konrad, K. (2007), "Strategy in Contests - an Introduction," Discussion Paper SP II 2007 - 01, Wissenschaftszentrum Berlin.

[13] Lazear, E. P. (1999), "Personnel Economics: Past Lessons and Future Directions - Presidential Address to the Society of Labor Economists," *Journal of Labor Economics* **17**(2), 1999–1236.

[14] Ludwig, S. (2006), "Private Information in Contests – Sequential versus Simultaneous Contests," mimeo, University of Munich.

[15] Moldovanu, B. and A. Sela (2006), "Contest Architecture," *Journal of Economic Theory* **126**(1), 70–97.

[16] Morgan. J. (2003), "Sequential Contests," *Public Choice* **116**, 1–18.

[17] Parco, J., W. Amaldoss, and A. Rapoport (2005), "Two-Stage Contests with Budget Constraints: An Experimental Study," *Journal of Mathematical Psychology* **49**, 320–338.

[18] Prendergast, C. (1999), "The Provision of Incentives in Firms," *Journal of Economic Literature*, **37** 1, 7 – 63.

[19] Romano, R. and H. Yildirim (2005), "On the Endogeneity of Cournot-Nash and Stackelberg Equilibria: Games of Accumulation," *Journal of Economic Theory* **120**, 73 – 107.

[20] Schotter, A. and K. Weigelt (1992), "Asymmetric Tournaments, Equal Opportunity Laws, and Affirmative Action: Some Experimental Results" *Quarterly Journal of Economics* **107**(2), 511 – 539.

[21] Tong, K. and K. Leung (2002), "Tournament as a Motivational Strategy: Extension to Dynamic Situations with Uncertain Duration," *Journal of Economic Psychology* **23**, 399–420.

[22] Weigelt, K., J. Dukerich, and A. Schotter (1989), "Reactions to Discrimination in an Incentive Pay Compensation Scheme: A Game-Theoretic Approach," *Organizational Behavior and Human Decision Processes* **44**, 26–44.

[23] Weimann, J., C.-L. Yang, and C. Vogt (2000), "An Experiment on Sequential Rent-Seeking," *Journal of Economic Behavior and Organization* **41**, 405–426.

[24] Yildirim, H. (2005), "Contests with Multiple Rounds," *Games and Economic Behavior* **51**, 213–227.

Appendix – Proof of Proposition 2.

In a Nash-equilibrium of the baseline tournament without intermediate information, a player maximizes his expected payoff with respect to his first and second stage effort given the other player's actions. Hence, the first order conditions are

$$\frac{\partial \pi_i}{\partial e_{i1}} = \frac{1}{2a}\Delta - C'(e_{i1}) \stackrel{!}{=} 0,$$

$$\frac{\partial \pi_i}{\partial e_{i2}} = \frac{1}{2a}\Delta - C'(e_{i2}) \stackrel{!}{=} 0.$$

The first order conditions are also sufficient as the cost function is convex. Thus, $e_{i1} = e_{i2} = \frac{c\Delta}{4a}$. Exactly like in the tournament with intermediate information, equilibrium efforts lie in $\mathcal{I}$ if Assumption 1 holds and as in the tournament with intermediate information Assumption 1 is also sufficient for expected payoffs to be larger than the loser prize. This establishes Proposition 2.

Appendix – Instructions (*NoInfo* and *Info*)

(Original instructions were in German. They are available from the authors upon request.)

At the beginning of the experiment participants will be randomly divided into **3 subgroups with 6 members each**. In each round, each member will be randomly **matched with one other member of his subgroup**.
During the whole experiment you will only interact with people of your own subgroup. You will not be informed about the identity of the participant matched with you.

The experiment consists of **30 rounds**. Each round consists of **2 stages**. Costs and payoffs are given in the fictitious currency “taler”.

Procedure of a round
At the beginning of a round, you will be informed whether you are **player A** or **player B**. If you are player A, the player matched with you is a player B and vice versa. Player A and B have to take identical actions. The differentiation is only important for the illustration of the results (see below).

Stage 1

- You choose an **integer from 0 to 60** and enter this number into the designated field. The number you choose at this stage causes a certain cost. (A detailed explanation concerning these costs follows later.)
- **Treatment Info:** [You learn by how much your chosen number in stage 1 is higher or lower compared to the number chosen in stage 1 by the player matched with you.]

Stage 2

- You again choose an **integer between 0 and 60** and enter this number into the designated field. The number you choose at this stage also causes a certain cost.
- A **random number** is drawn from the set **{–120, ..., +120}**, where each number has the same probability of being drawn. You and the player matched with you do not learn this random number.

Calculation of the round payoff
The computer calculates the round payoff on the basis of the numbers chosen by you, the ones chosen by the participant matched with you, and the random number. This happens as follows:
First of all, the result for **player A** and **player B** is calculated. The result for player

A [B] is the sum of the numbers chosen by him in both stages plus [minus] half of the random number:

Result player A	**= chosen number in stage 1**
	+ chosen number in stage 2
	+ 0.5 x random number
Result player B	**= chosen number in stage 1**
	+ chosen number in stage 2
	— 0.5 x random number

The **payment** of each player depends on who has the higher result. The player with the higher result receives a high payment and the player with the lower result receives a low payment. The high payment is 150 taler and the low payment is 50 taler.
In case of a tie a fair random move decides who receives the high payment.

Your round payoff is equal to your payment minus the costs of your chosen numbers in each stage:

Round payoff	**=payment**
	— cost of chosen number in stage 1
	— cost of chosen number in stage 2

The **cost** for each number can be found in the **cost table**. There you find all costs for the numbers from 0 to 60. All participants receive the same cost table.

- At the end of each round, you learn whether you received the high or the low payment and which round payoff you achieved.
  Moreover, the numbers you have chosen in stage 1 and stage 2, as well as the corresponding costs are displayed to you.
  <u>**Treatment Info:**</u> [You also see by how much your number in stage 1 was higher or lower than the number in stage 1 of the participant matched with you.]
- The next round starts.

Your total payoff from the experiment is the sum of all individual 30 round payoffs. At the end of the experiment this amount in taler is exchanged at an exchange rate of 1 Euro per 220 taler.

Please note:
During the whole experiment no communication with other participants is permitted. If you have any questions, please raise your hand out of the cubicle. All decisions are

made anonymously. Also the payout is anonymous, which means that no participant will learn the payout of another participant.

number	**cost for number**	**number**	**cost for number**
0	0.00		
1	0.01	**31**	8.01
2	0.03	**32**	8.53
3	0.08	**33**	9.08
4	0.13	**34**	9.63
5	0.21	**35**	10.21
6	0.30	**36**	10.80
7	0.41	**37**	11.41
8	0.53	**38**	12.03
9	0.68	**39**	12.68
10	0.83	**40**	13.33
11	1.01	**41**	14.01
12	1.20	**42**	14.70
13	1.41	**43**	15.41
14	1.63	**44**	16.13
15	1.88	**45**	16.88
16	2.13	**46**	17.63
17	2.41	**47**	18.41
18	2.70	**48**	19.20
19	3.01	**49**	20.01
20	3.33	**50**	20.83
21	3.68	**51**	21.68
22	4.03	**52**	22.53
23	4.41	**53**	23.41
24	4.80	**54**	24.30
25	5.21	**55**	25.21
26	5.63	**56**	26.13
27	6.08	**57**	27.08
28	6.53	**58**	28.03
29	7.01	**59**	29.01
30	7.50	**60**	30.00