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Tournament Fever and the Perception of Strategic Uncertainty in Performance Contests*

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Abstract

As firms implement tournament bonus reward schemes, mainly the idea is to introduce competition amongst their agents in the order to promote their performance. Tournaments in which agents compete for a bonus by investing effort, are frequently applied, e.g., in development races, political contests, and promotion tournaments. The fallibility of evaluation processes and the inherent variability of competitors' effort choices introduce uncertainty to tournament settings with respect to the outcome. If heterogeneous agents interact in such a setting, experimental results suggest that increasing uncertainty leads to more excess of effort if compared to optimality (Avrahami et al., 2007). This paper experimentally investigates whether the observed over-performance in the tournament is similar to overbidding in auctions. Furthermore, it disentangles two possible sources of over-performance: either biased responses to, or wrong beliefs of, opponents' effort choices. We show that over-performance can be explained by "tournament fever": agents overreact to own beliefs, if compared to best responses, and mainly overestimate their opponents. Leveling uncertainty influences both overshooting and the precision of beliefs.

JEL Classification: J33, M42, M52, M55

Keywords: uncertainty, incentive effects, tournament fever, auction fever, all-pay auction

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1 Introduction

Bonus tournament settings are used in firms to motivate agents to induce (at least) a desired effort level (Lazear and Rosen, 1981). Firms differ in their production technologies and, thus, in the level of ascertainability of agents' effort investments. If there is any best practice effort assessment technology, it faces problems similar to all the others. On the one hand, performance varies due to intra-personal variance such as daily fluctuating work motivation, fatigue, or health concerns of agents. On the other hand, the assessment of performance itself can most often only be realized by inspecting work outcomes. Admittedly, that might be difficult or even impossible, e.g., due to cost restrictions or monitoring boundaries. Hence, the inspection reveals a working outcome that depends stochastically on the performance of an agent. This renders the assessment of the truly induced effort level vulnerable to errors, causing an impact on agents' work motivation. The way to assess agents' performance is therefore crucial for maintaining effort inspiring effects.

In tournaments human agents interact, imposing the need to consider strategic uncertainty about opponents' effort choices. This and the risk of the true performance revelation induce employers to face an overall uncertainty concerning the outcome of the bonus tournament. Cowen and Glazer (1996); Dubey and Haimanko (2003); Dubey and Wu (2001) show for heterogeneous agents that in situations where principals have full knowledge about the abilities of agents, tournaments reduce the incentives to invest effort. Approaching this obstacle, the authors theoretically demonstrate how reducing the principal's knowledge about agents' abilities by assessing their work outcomes less often restores incentive effects to invest effort. The motivating effects of less frequent outcome inspections, increasing the uncertainty about the outcome of the tournament, were experimentally shown by Kareev and Avrahami (2007). Avrahami et al. (2007) investigate how variations of uncertainty, as induced by changing the number of outcome inspections, affect the agents' choice behavior in comparison to equilibrium choices. For various experimental settings the authors found more over-optimal or fewer sub-optimal choices, respectively, with fewer outcome inspections. These rather systematic deviations from optimal behavior result in lower cost for each unit of effort with fewer working inspections. If, furthermore, the inspections are costly, a limitation of the level of control is advantageous for principals.

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Avrahami et al. (2007) suggest "tournament fever" as a driving force of the observed persistent short-run deviations from the equilibria. No further explanations are given of how it affects the agents and how it relates to variations of the overall uncertainty. In the paper at hand, we relate over-optimal effort choices to commonly observed overbidding behavior in auctions. We show that "tournament fever" is a valid explanatory concept for the obverved over-optimal choice behavior by manipulating rivalry as an arousal mediating factor, causing agents to lose sight of their actions. In order to investigate the effect of uncertainty on agents' choice behavior, we carefully disentangle possible origins of the observed deviations from equilibria by additionally eliciting beliefs about the choices of opponents. Whether the distortions originate in mislead beliefs about, or errant reactions to, opponent choices will shed light on how boundedly rational agents handle uncertainty. Hence, we approach the cognitive processes as being affected by variations of the overall uncertainty and explain why increasing the latter might be a reasonable choice in such tournament settings. To that end, we use - similar to the above study - a tournament setting where two agents compete for a bonus and an incentive structure to induce as-if risk neutral behavior of agents by sufficiently repeating and paying each choice situation.

We proceed by introducing the theoretical model, used by Avrahami et al. (2007), in section 2. A summary of their findings is subsequently presented in section 3. Section 4 asks why agents exert more effort than they should and where those deviations from theoretical benchmarks might originate. Our experimental setup is described in section 5. In section 6 we report and discuss our results, and conclude with a short discussion in section 7.

2 The model

In our setting, two agents $i = 1, 2$ work on a given project. They determine a desired effort level to spend on the project, once it starts. By choosing the effort level $p_i \in [0, 1]$, agents determine the probability with which the outcome of their project is evaluated, either as high (H with p_i) or as low (L with $1 - p_i$), with $0 \leq L < H$. The costs of agents (C_i) are given by

$$C_i(p_i) = \frac{c_i}{2} p_i^2 \;\; with \;\; c_i > B \quad for \quad i = 1, 2,$$

where c_i is a personal cost factor and costs are convex increasing in effort. To increase the work motivation of agents, i.e., their effort choices, a bonus scheme can be introduced. In our model, the two agents compete for a bonus B. To appoint the unique winner of the bonus, the principal needs to identify the better performing agent.

By observing the stochastic working outcome (H or L), the true effort choice might not be discovered. Clearly, the more often the principal checks the outcomes of the project, the better is the inference of the truly chosen effort level. For any control intensity (n) the observed work outcomes of the project are the realizations of n independent and identical chance moves according to the constant probabilities p_i chosen by the agents. Hence, for each agent i a sequence of length n of outcome observations - either high or low - is generated. The tournament is designed such that the outcome observations of both agents are compared and only the uniquely better performing agent will win the bonus. That is, only if one agent outperforms the other, the bonus is awarded to the winning contestant. This design prevents shirking cooperation among the agents trying to exploit the principal.

Hence, for $n \geq 1$ agent i's probability $P_i^n(p_i, p_j)$ to win the bonus is determined by combining two binominal distributions:

$$P_i^n(p_i, p_j) = \sum_{k=1}^{n} \left[\begin{pmatrix} n \\ k \end{pmatrix} p_i^k (1-p_i)^{n-k} * \sum_{e=0}^{k-1} \begin{pmatrix} n \\ e \end{pmatrix} p_j^e (1-p_j)^{n-e} \right].$$

For $i = 1, 2$, agent $i's$ expected payoff is thus given by

$$U_i(p_i, p_j) = F + \varepsilon p_i + B P_i^n(p_i, p_j) - \frac{c_i}{2} p_i^2,$$

where $F(\geq 0)$ is a flat fee and ε is a positive piece-rate payment. Note that ε is introduced to implement the idea of various levels of observability of the work for the principal, while agents remain uninformed about the exact choices of their opponents. High values of ε indicate piece-rate work such as productions on assembly lines, while low values are more applicable in less observable environments, e.g., office work.

Agents maximize their utility $U_i(p_i, p_j)$ subject to $0 \leq p_{i,j} \leq 1$. If there is only one inspection of the outcome ($n = 1$), $\varepsilon < c_j \left(\frac{c_i - B}{c_j - B} \right)$, and $\varepsilon < c_i \left(\frac{c_j - B}{c_i - B} \right)$, the second order

conditions are granted. The first order derivatives determine an interior equilibrium (p_i^*, p_j^*) by solving the equation system

$$\frac{\varepsilon}{c_i} + \frac{B}{c_i}(1 - p_j) = p_i \quad for \quad i, j = 1, 2.$$

Therefore, the equilibrium effort levels are given by

$$p_i^* = \frac{(B + \varepsilon)(B - c_j)}{B^2 - c_i c_j} \quad and \quad p_j^* = \frac{(B + \varepsilon)(B - c_i)}{B^2 - c_i c_j}.$$

As already shown in Avrahami et al. (2007), corner equilibria exist when personal costs (c_i and/or c_j) are very low or ε is large, rendering the piece-rate payment the driving force of effort choices. In this setting effort choices of agents are strategic substitutes. This should, in all likelihood, induce choice convergence to the equilibria. Hence, choices above the equilibria cannot be explained by a tendency of mutual surpassing.

If there are $n \geq 2$ working outcome investigations, complex polynomial equations have to be solved, and numerical approximation is used to determine the equilibria for the given parameter constellations.

Avrahami et al. (2007) examined how effort choices of agents reacted to variations in personal costs ($c_i = 11$ or $c_i = 22$), symmetric and asymmetric cost constellations ($c_i = c_j$ or $c_i \neq c_j$), piece-rate payment ($\varepsilon = 0.1$ or $\varepsilon = 10$), and two levels of outcome inspections ($n = 1$ or $n = 3$). In Table 1, the equilibrium choices for rational agents are listed also for a single-agent treatment, where competition is excluded.

Table 1: Equilibrium effort choices

	Tournament setting				Single agent		
	ε = 0.1		*ε = 10*		*ε = 0.1*		
Costs	**n = 1**	**n = 3**	**n = 1**	**n = 3**	**Costs**	**n = 1**	**n = 3**
$c_i = c_j = 11$	0.359	0.515	0.941	0.984	$c_i = 20$	0.345	0.047
$c_i = c_j = 22$	0.218	0.307	0.571	0.701	$c_j = 30$	0.277	0.031
$c_i = 11$ $c_j = 22$	0.474	0.525	1.000	1.000			
$c_i = 22$ $c_j = 11$	0.148	0.145	0.455	0.455			

If rational agents interact, they would mutually expect rationality, form their beliefs about the choices of opponents, and best reply to these beliefs. By forming best response functions and maximizing the own utility function, given the response function of the opponent, equilibrium choices are a reasonable assumption. In the tournament, the theoretical chances to win the bonus are higher and, correspondingly, the chances of a tie are smaller, the more outcome inspections there are, boosting equilibrium effort levels. In the single-agent setting, this pattern is reversed.

3 Previous findings and implications

As soon boundedly rational subject interact, strategic uncertainty together with the variance introduced by the number of control occasions to determine the better performing agent (n), sets the overall level of uncertainty. With more control occasions (increase in n), fewer errors in determining the winning agent are made; hence, the overall uncertainty is reduced. Avrahami et al. (2007) report subjects to be very sensitive to changes of personal cost, symmetry conditions, and the number of control occasions (subsequently refered to as the level of uncertainty): all parameters significantly affected effort choices with $p < 0.001$. While agents reacted in close correspondence to optimality ($Spearman's rho$=$0.675, p < 0.001$), the authors analyzed in more detail whether and how equilibrium deviations were affected by uncertainty. Indeed, Avrahami et al. found the exerted efforts relative to the equilibria to be sensitive to variations in the level of uncertainty (n). In the setting of $\varepsilon = 0.1$, the mean deviation from equilibrium was 0.091, with the 95% confidence interval of $[0.067, 0.114]$, at least a 95% chance to be larger than zero ($F(1, 191) = 58.668$, $p < 0.001$). The authors found overall significantly more overperformance for $n = 1$ rather than for $n = 3$ outcome observations ($F(1, 191) = 7.744$, $p = 0.006$). All interactions of uncertainty with the parameters significantly affected the equilibrium deviations.

For the setting of $\varepsilon = 10$, the mean deviation from equilibrium was 0.003 with a 95% confidence interval of $[-0.009, 0.0146]$, which is obviously not larger than zero ($F(1, 191) = .214$, $p = 0.644$). Still, the level of uncertainty significantly affected the deviations of effort choices from the equilibria in the various parameter settings ($F(1, 191) = 37.686$,

$p < 0.001$). As shown in Table 2, Avrahami et al. (2007) found significantly less under-performance for low cost agents in $n = 1$ than in $n = 3$. For high cost agents the authors observed significant over-performance in $n = 1$ but significant under-performance in $n = 3$. In the asymmetric cost constellations, the level of uncertainty did not significantly affect agents' choices.

Table 2: Previous experimental mean effort choices and 95% confidence interval

ε = 0.1, F=10, B=6

Costs	**n=1**			**n=3**		
	Mean effort - equilibrium	95% Confidence interval Lower bound	Upper bound	Mean effort - equilibrium	95% Confidence interval Lower bound	Upper bound
c_i=c_j=11	0.157	0.122	0.192	0.055	0.017	0.092
c_i=c_j=22	0.126	0.092	0.161	0.105	0.070	0.140
c_i=11	0.122	0.089	0.155	0.081	0.050	0.112
c_j=22	0.022	-0.009	0.052	0.058	0.026	0.090

ε = 10, F=10, B=6

Costs	**n=1**			**n=3**		
	Mean effort - equilibrium	95% Confidence interval Lower bound	Upper bound	Mean effort - equilibrium	95% Confidence interval Lower bound	Upper bound
c_i=c_j=11	-0.040	-0.057	-0.023	-0.073	-0.089	-0.056
c_i=c_j=22	0.086	0.063	0.110	-0.026	-0.051	-0.001
c_i=11	-0.057	-0.069	-0.045	-0.061	-0.075	-0.046
c_j=22	0.092	0.072	0.112	0.100	0.078	0.122

To summarize, the above study shows over-optimal effort choices affected by the variations of control occasions, with the main direction being more over-optimal or less sub-optimal choice behavior in $n = 1$ rather than in $n = 3$, respectively. Hence, more uncertainty leads to desirable results for principals, determined by less cost for each unit of effort in $n = 1$. If, furthermore, control is costly and decreases the work motivation (Aryee et al., 2002), principals may benefit from the reduction of control intensity. Applying a single-agent treatment, Avrahami et al. show that without any opponents a reduction of the outcome inspections increases equilibrium effort levels. Even though the variation of control occasions significantly affected ($F(1, 63) = 36.807$, $p < 0.001$) the choice behavior, over-performance was only found with $n = 3$ outcome inspections. Since without competition the motivating effect of uncertainty was not found, Avrahami et al. (2007) suggest that the competitive situation induced the deviations. Agents compensated their lack of certainty when estimating their winning probability with a kind of tournament fever, resulting in more overperformance or less underperformance, respectively.

Observing a different choice behavior without any rivals is not surprising: there is no element of strategic uncertainty. Hence, a slightly different notion of uncertainty is used which is based only on the variance of winning the bonus instead of the strategic aspect. Since the interactive situation is different, the comparison of the two settings seems rather ad hoc. Furthermore, Avrahami et al. (2007) remain unclear as to what the notion of tournament fever really defines. Which factors of the tournament actually induced the equilibrium deviations, and how did uncertainty cause the observed behavioral differences? The paper at hand elaborates on these questions and attempts to help us better understand what is "tournament fever."

4 Why are agents overshooting?

4.1 "Auction fever" in our tournament setting

In experimental auctions participants tend to overbid the true value of the object at stake (prize). This overbidding behavior is frequently found in experiments (Davis and Reilly, 1998; Schmitt et al., 2004). This overbidding grants auctioneers higher values due to the increased bids than the prize they would auction off. Overbidding is related to rent-seeking behavior of agents, benefitting auctioneers. Anderson et al. (1998) refer to such rent-seeking activities and suggest that rents, associated with the prize, are dissipated by the competitive process. Gneezy and Smorodinsky (2006) show that neither solution concepts, assuming fully rational subjects (Nash equilibrium), nor those assuming boundedly rational subjects (Logit equilibrium) fully account for the observed overbidding. This suggests that findings of over-optimal effort choices in tournaments may not be explainable by accounting for individual errors either.[1] As mentioned by Malhotra and Murninghan (2001), the systematic deviations are attributed to "auction fever." They suggest that competition and the salience of the ending auction create a state of competitive arousal in bidders, causing them to lose sight of their limits and bid more than what is optimal (Gilkeson and Reynolds, 2003). Heyman et al. (2004) argue that the competitive element incorporates excitement and joy of bidding, rendering the fact of winning and losing salient components of auctions.

[1] As, e.g., suggested by the quantal response equilibrium, where specifications of the error structure can be modeled, thus explaining deviations from best responses (McKelvey and Palfrey, 1995).

This allows agents to derive additional utility out of participating in potentially wasteful bidding wars. Similarly, Herschlag and Zwick (2000) describe thrills induced in bidders when winning contests, and the attraction of challenging rivals. Ku et al. (2005) define "auction fever" as the "...emotionally charged and frantic behavior of auction participants that can result in overbidding."

The reasoning behind "auction fever" requires a careful conceptualization of the influences of competition on behavioral reactions based upon emotions and induced arousal. It is argued that emotions increase the difficulties in processing information (Cannon-Bowers and Salas, 1998). However, there is is no unique definition of emotions (Russel, 2003). For clarification, Russel puts forward a framework that conceptualizes emotions without the need to invoke intentional objects of the emotion (e.g., in love *with* you, angry *at* you). To describe mood and emotionally charged events sufficiently, two object-free dimensions; valence (pleasure-displeasure) and arousal (activation-deactivation), are combined into the so-called "core-affect." This core-affect influences behavior and decision making and can itself be influenced and manipulated (Russel, 2003). If Ku et al. (2005) and Menon and Kahn (2002) report on "auction fever", or increased avoidance behavior, respectively, they refer to increased levels of feelings being stimulated, active, or alerted (arousal) as the driving force of the observed effects. Hence, the arousal dimension of the core-affect is affected by the competitive situation, giving us reason to assume impacts of such emotions on choice behavior.

Mano (1992) shows that with increasing levels of arousal subjects invested less time in deliberation on decision tasks, examined less relevant information, and used simpler strategies to make decisions. Mano relates this to stimuli, inducing an increased level of attention and more elaborate network encoding in memory. Ku et al. (2005) identify factors that induce arousal and therefore mediate effects on subjects' decision making, e.g., rivalry, social facilitation, time pressure, and the uniqueness of being first. Especially rivalry, as the emotional state of consciousness of a desire to win (Allport, 1924), is considered to increase the level of arousal.

If high levels of arousal account for overbidding behavior in auctions, this might explain over-performance in a principal-agent tournament, too. Avrahami et al. (2007) observe overshooting which even increases under uncertainty. This raises two questions. First, is our tournament setting similar to an auction, i.e., can the presence and impact of an

arousal mediating factor be verified? Second, how and where does uncertainty trigger behavioral differences in over-performance in this setting?

To approach the first question, similarities between auctions and our tournament settings need to be discussed. In the previous experiment, two agents compete for a bonus, preparing the ground for an increased arousal level. The agents independently bid effort levels and bear the costs for doing so. Subsequently, a bonus (prize) is awarded only to that contestant who exerted the highest effort. Following Tullock (1980), if the probability to win a prize is an increasing function of induced effort and the prize is awarded to the competitor who exerted the highest effort, this mechanism is called "all-pay auction" (see Anderson et al., 1998; Hörisch and Kirchkamp, 2007). Even though the unique determination of a winner is implemented in our tournament setting, other arousal inducing factors of auctions such as time pressure and social facilitation are missing. An obvious similarity is the rivalry of agents. If rivalry causes increased arousal levels in auctions ("auction fever"), it should similarly do so in tournaments. To reveal the affective power of rivalry in our tournament setting we vary the intensity of rivalry. In order to approach the arousal mediating factor rivalry, we substitute human rivals for computerized opponents. Blount (1995) suggests that the difference between human versus nonhuman opponents induces differences in the beliefs about an intentional causation of the outcome, affecting behavior. In this sense, following Ku et al. (2005), varying the intensity of rivalry is expected to vary the level of arousal, hence the overreactions of agents.

In order to tackle the second question of how and where uncertainty triggers behavioral differences in over-performance, we revisit the benchmark of choice deviations from equilibria as used in Avrahami et al. (2007). The equilibrium solutions rely on the assumption of two-sided rationality and its common knowledge. In the presence of boundedly rational agents, these assumptions seem rather strong. In order to understand the overshooting, we decompose the equilibrium deviations of choices. Since beliefs are detectable, best responses can be computed. Instead of equilibrium deviations, we use the comparison of choices to best responses to own beliefs as a benchmark. It assumes only one-sided rationality, hence relaxes the strong assumptions. The difference can be interpreted as a more robust proxy of individual rationality than choice deviations from equilibria. Our decomposition of overshooting into a belief and a choice part reveals a broader picture of the impact of uncertainty in the presence of different cost structures. It allows to disentangle possibly counterbalancing effects on beliefs and subsequent choices.

4.2 Sources of equilibrium deviations

To decompose equilibrium deviations from optimality, we use the conceptualization of the choice process of rational agents and introduce possible sources of deviations as depicted in Table 3. If the agents had held correct beliefs about their opponents and had reacted in an optimal way (situation a), no deviations from optimality would have occurred. Since the found significant deviations from optimality (up to 25 percentage points) are persistent in various experimental settings, we suggest that equilibrium deviations are no artifacts of the previous experiment. Subjects might have chosen an optimal answer to systematically wrong beliefs (situation b). Another explanation suggests that expectations about the opponent choices might have been correct, but the reactions turned out to systematically deviate from best response to the belief (situation c) nevertheless. Of course, deviations from optimality might also have originated from wrong beliefs and additional wrong responses (situation d).

Table 3: Decomposition of the choice deviations from equilibrium

	Correct beliefs $\tilde{p_i} = p_j$	Wrong beliefs $\tilde{p_i} \neq p_j$
$p_i = BR(\tilde{p_i})$ best response	Situation a	Situation b
$p_i \neq BR(\tilde{p_i})$ wrong response	Situation c	Situation d

By comparing beliefs ($\tilde{p_i}$) about the choices of opponents with their actual choices (p_j), we investigate the quality of belief deviations and the reactions to variations in uncertainty. For the sake of simplicity, we use the belief point predictions to compute best responses to each agent's belief ($BR(\tilde{p_i})$) and compare it to actual choices (p_i). This provides a simple benchmark of how rationally agents react to formed beliefs. Again, we analyze significant deviations from this benchmark and their correspondence to uncertainty variations.

5 Experimental design

The experiment comprises two constitutive settings. By varying the intensity of rivalry, we address the presence of arousal, indicating the extent of feverish behavior in our tournament

setting. In the first experimental setting, all subjects had human interaction partners (HI). In the subsequent second experimental setting all subjects faced computerized interaction (CI) partners. We used the data that was generated in the HI-setting to feed computerized interaction partners. In order to obtain the similarity between the HI- and the CI-setting, each subject in CI faced exactly the same effort choices that agents of the HI-setting experienced. That is, for each computerized opponent we programmed a vector that corresponded to human opponents' effort choices from the previous setting. We hypothesize that, ceteris paribus, the difference between human and computerized opponents leads to different behavior of agents.

All experiments were conducted in the computer laboratory of the Max Planck Institute of Economics in Jena, using z-Tree Fischbacher (2007). In total 256 undergraduate students of Jena University, with a background in the natural and social sciences, took part in the experiments; they were recruited by the use of ORSEE (Greiner, 2004). In each session 32 students participated, with pairing conducted randomly per round within groups of 8. Subjects were assigned to groups by letting them choose a cabin number. The instructions were made commonly known; whether they were understood was tested by a questionnaire.[2]

For each experimental setting we ran four sessions: two, where agents started with 24 choices under high uncertainty ($n = 1$) before proceeding to 24 choices under low uncertainty ($n = 3$), and another two sessions for the opposite case. We factorially manipulated agents' effort cost (low=11 or high=22) and cost symmetry in a within-subject design as depicted in Table 4. In each uncertainty setting, agents first experienced the symmetric cost situation and then proceeded to the asymmetric one, with half the participants first experiencing high and the other half low costs. For each combination of conditions six repetitions were conducted. Due to the equivalent parameter setting, the equilibrium effort levels remained the same as in Avrahami et al. (2007) and are displayed on the left-hand side of Table 1.

[2]The program and the instructions are based on those used by Avrahami et al. (2007). They were tested in a video pilot session. The observations enabled us to improve the instructions and to correct flaws in the programming. As the review of the videos revealed, the instructions were perceived as challenging but were nevertheless well understood. However, the data could not be handled since a minor programming mistake occurred.

Table 4: Parameter setting for the HI- and CI-treatments

Evaluated level of uncertainty	Costs to start with	Symmetric cost conditions		Asymmetric cost conditions	
		Low (high)	High (low)	Low (high)	High (low)
n=1	Low (high)	11,11 ; (22,22)	22,22 ; (11,11)	11,22 ; (22,11)	22,11 ; (11,22)
n=3	Low (high)	11,11 ; (22,22)	22,22 ; (11,11)	11,22 ; (22,11)	22,11 ; (11,22)

B=6, F=10, $\varepsilon = 0.1$

In our setting, we investigated the behavioral issues of the optimality deviations by eliciting not only choices but also beliefs of agents. We incentivized belief elicitation by paying subjects according to their deviations from the true effort choice of the opponent. In each round agents could earn

$$b * (a - (\tilde{p_i} - p_j)^2),$$

where $a = 1$ and $b = 11$. The maximum payoff was ensured when the belief was equivalent to the true choice. We informed CI participants about the similarity of HI and CI and explained how computerized agents chose effort choices likewise as stated above. Thus, we were also able to ask the subjects for their beliefs about the computerized opponents' effort choices.

In order to minimize portfolio selection among earnings of the bonus tournament rule and the belief elicitation, a random draw at the end of the experiment decided which of the earnings was paid out. Since each of the 48 effort choices and belief elicitations were payoff relevant, on the aggregate level risk neutrality could be assumed.[3]

To facilitate the understanding, we implemented a calculator that basically resembled the provided probability table to determine the chances to win the bonus. Having chosen a belief about the choice of the corresponding opponent, subjects entered their desired effort level. Subsequently, all subjects received feedback about their costs, whether they won the bonus, their profits, and overall earnings. After the six repetitions of actions in each cost condition the subjects were also informed about their earnings from the belief elicitation. An average session lasted approximately two hours, and subjects earned on average €15.75.[4]

[3]See Avrahami et al. (2007, p. 7).

[4]Note: the average hourly payment of a student in Jena amounted to €6.15.

6 Results

6.1 Differences between human and computerized opponents

To analyze the differences between the supposed high arousal HI- and supposed lower arousal CI-treatment, we refer to the effort choices and beliefs of agents. Subsequently, we compare these values to either optimality, best responses to beliefs, or the true effort choices of the opponents. All analyses are based on the means of the six repetitions of each cost condition. The values were submitted to an analysis of variances with repeated measurement. We controlled for all within-subject effects and the between-subject effect of the treatment condition, accounting also for interactions of the parameter. The averages of the values and the significance of occurring differences between the each treatment are shown in Table 5.

Table 5: Significant differences between the HI- and CI-treatments

		p_i		$p_i - p^*$		$p_i - BR(\tilde{p}_i)$		$\tilde{p}_i$		$\tilde{p}_i - p_j$	
		Human	PC	Human	PC	Human	PC	Human	PC	Human	PC
n=1	$c_i = c_j = 11$	0.541	0.493	0.183	0.135	0.315'	0.240	0.634*	0.552	0.094*	0.023
	$c_i = c_j = 22$	0.399	0.384	0.181	0.166	0.263	0.236	0.534*	0.473	0.135*	0.081
	$c_i = 11$	0.624*	0.547	0.150*	0.073	0.256	0.232	0.405	0.439	0.180	0.214
	$c_i = 22$	0.225'	0.279	0.077'	0.131	0.123	0.156	0.635*	0.563	0.011*	-0.060
n=3	$c_i = c_j = 11$	0.601*	0.540	0.086*	0.025	0.315*	0.205	0.634*	0.576	0.033*	-0.025
	$c_i = c_j = 22$	0.427	0.429	0.120	0.123	0.269	0.250	0.525*	0.485	0.098'	0.058
	$c_i = 11$	0.625*	0.549	0.100*	0.024	0.163	0.109	0.411*	0.471	0.165*	0.224
	$c_i = 22$	0.246	0.281	0.101	0.136	0.144	0.159	0.619*	0.579	-0.006'	-0.044
ANOVA between-subject effect		0.298		0.401		0.303		0.027		0.089	

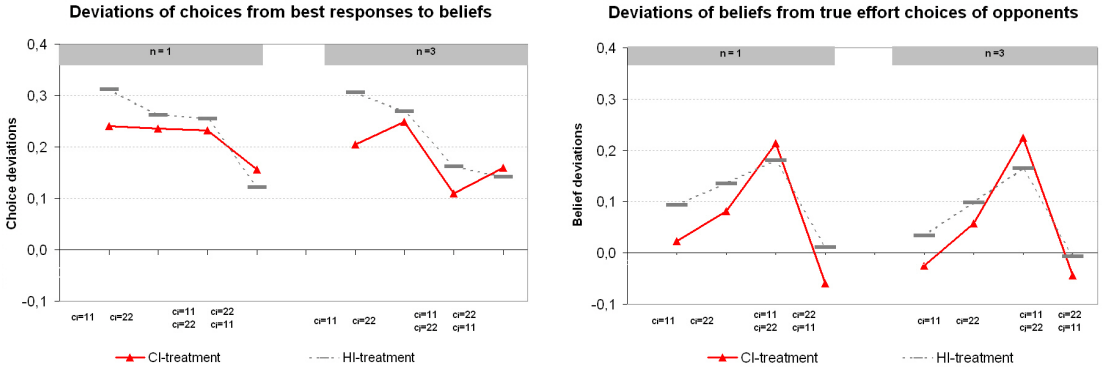
* significant at p<0.05, ' significant at p<0.1, t-test for equality of means for independent samples

Effort choices of agents in the HI-treatment (mean=0.461, std. error=0.016, $[0.430; 0.492]_{0.95}$) were slightly higher than effort choices of agents in the CI-treatment (mean=0.438, std. error=0.016 $[0.407; 0.469]_{0.95}$). Significant differences occurred in the interaction of the treatment and cost condition: the reduction of effort due to computerized rather than human rivals was significantly more intense with low rather than high costs ($F(1, 254) = 18.554$, $p < 0.001$). We observe a significant three-way interaction of cost, symmetry, and the treatment effect ($F(1, 254) = 6.088$, $p = 0.014$): with high costs the effect of substituted opponents is significantly more severe in asymmetry rather than in

symmetry. This implies that agents in the disadvantageous position of asymmetry choose less effort if they face human instead of computerized rivals. However, in the advantageous position and on equal level playing fields, the chosen effort levels are significantly higher, if there are human rather than computerized opponents.

Following Avrahami et al. (2007), we compared effort choices to theoretically optimal choice behavior, trying to capture the quality of agents' reactions to variations of the parameter setting. Differences in the equilibrium deviations of choices between the HI- and CI-treatment were revealed by the interaction of the treatment effect and the costs ($F(1, 254) = 18.445$, $p < 0.001$). The decrease of overreactions ($p_i - equilibria$)) due to computerized rather than human opponents was significantly more intense with low rather than high costs. Again, we observe a three-way interaction of symmetry, costs, and the differences due to rivalry ($F(1, 254) = 6.172$, $p = 0.014$): while, compared to the HI-treatment, overreactions are less intense in both symmetric cost settings of CI, in asymmetry, agents with high costs overreact significantly more in CI than in HI (see Table 5).

Figure 1: Choice deviations from best responses and precision of beliefs in the HI- and CI-treatments



Relaxing on the mutual rationality assumption, we compared choices to the one-sided best response to own beliefs about what either human or computerized opponent might have chosen. The treatment effect was significantly more pronounced in symmetry rather than in asymmetry ($F(1, 254) = 7.654$, $p = 0.006$), indicating fewer deviations from best responses in symmetry if agents competed against computerized opponents. We also find a significant interaction effect of the treatment condition the and costs ($F(1, 254) = 10.628$, $p < 0.001$).

The treatment effect is stronger for low rather than high costs and overshooting with low costs is significantly less intense with computerized opponents (see left-hand side of Figure 1).

This finding suggests differences in the belief formation process. Even though choice behavior of opponents was, by design, the same in HI and CI, agents anticipated a significantly different choice behavior. They expected human rivals to choose significantly higher effort levels than computerized opponents ($F(1, 254) = 4.955$, $p = 0.027$), implying a worse precision of beliefs if humans were the opponents. In interaction with the level of uncertainty, this treatment effect was significantly more pronounced with high rather than low uncertainty ($F(1, 254) = 4.091$, $p = 0.044$). The treatment condition interacted with symmetry ($F(1, 254) = 25.546$, $p < 0.001$): in symmetry the expected effort choices of human rivals are higher than the expected effort choices of computerized opponents. The treatment difference interacted also with costs ($F(1, 254) = 17.805$, $p < 0.001$): the decline in beliefs due to the substitution of opponents is more pronounced with high rather than with low costs. There is a significant three-way interaction of symmetry, costs, and the treatment effect ($F(1, 254) = 19.797$, $p < 0.001$): whereas with low costs the treatment condition affects beliefs significantly more in symmetry rather than in asymmetry, with high costs, the treatment affected beliefs similarly in symmetric and asymmetric settings. This implies the impact of asymmetry to be significantly more pronounced with human rather than computerized opponents and suggests relative positioning to have a larger impact on agents competing against human rivals.

On the right-hand side of Figure 1, the precision of the beliefs is depicted. With human rivals the precision of the beliefs is marginally worse than with computerized opponents ($F(1, 254) = 2.916$, $p = 0.089$). We observe a significant interaction of the symmetry condition and the treatment effect ($F(1, 254) = 11.142$, $p < 0.001$): the precision of beliefs in symmetry is significantly worse with human instead of computerized rivals. There is a significant interaction of the cost and treatment condition ($F(1, 254) = 8.999, p < 0.001$): the decline in over-estimation due to the substitution of human for computerized rivals is more pronounced with high rather than with low costs. Again, a three-way interaction between symmetry, costs, and the treatment effect ($F(1, 254) = 11.809$, $p < 0.001$) is observed: whereas in symmetry the precision of beliefs is always worse with human interaction partners, in asymmetry the precision is higher with human rather than computerized opponents.

Interpretation and discussion

Whether agents compete against human or computerized rivals has a significant impact on the choice behavior. As is commonly objected, the temptation to exert effort is stronger with low instead of high costs. This temptation, however, seems to diminish when computerized opponents are implemented. Yet, agents facing better-off opponents choose lower effort levels if the rival is human rather than computerized. Since agents give up their winning chances more easily with human rather than computerized opponents, the relative positioning appears to be perceived as less important with computerized rather than human rivals. We suggest that the relative positioning, especially with induced personal cost disadvantages, becomes less important with computerized rivals. Comparing the choices to optimality reveals that agents tend to over-perform less if they compete against computerized opponents, especially with low effort costs. This observation may be explained by less cognitive arousal, resulting in less overshooting in the CI-setting. However, while facing better-off agents, human rivalry leads to less instead of more over-performance. Again, relative positioning seems to render the fact of losing less important if the opponent is a computer rather than a human. Even by relaxing the mutual rationality assumption and common knowledge about it, treatment differences are revealed. Especially in the competition on an equal level playing field with low effort costs, agents deviate less from best responses if they face computerized opponents. Behavioral differences between human and computerized opponents are particularly apparent in the belief formation. Even though agents knew that their computerized opponents used effort levels of humans, it seems, beliefs were formed in a more cautious manner. Consequently, the precision of beliefs was higher with computerized opponents. Whether agents were less motivated to compete or benefitted from lower arousal remains, so far, unclear.

Rivalry is considered to be a mediating factor of arousal that affects overbidding in auction settings (Mano, 1992; Menon and Kahn, 2002). Having substituted human for computerized opponents we indeed observed rivalry to mediate behavioral effects in our tournament setting. As suggested by Ku et al. (2005) and Blount (1995), we find mainly higher choices, higher expected choices, more overreactions, and a lower belief precision with human interaction partners. With the same arousal mediating factor of "auction fever," revealing impact on behavior in our tournament, we suggest the overshooting choices to be similarly behaviorally based. Hence, the over-optimal choice behavior in our tournament can legitimately be described by the notion "tournament fever." In order to approach the question where and how uncertainty affects the behavior of agents, we analyze effort choices for the HI- and CI-setting in more detail.

6.2 Effects observed in the human opponent setting

Sensitivity to equilibrium

Similarly to the study of Avrahami et al. (2007), all parameters that determined the equilibria influenced the effort choices of agents: the level of uncertainty ($F(1,6136) = 13.141$, $p < 0.001$), the symmetry ($F(1,6136) = 65.843$, $p < 0.001$), and the costs ($F(1,6136) = 1289.72$, $p < 0.001$) significantly affected the chosen effort levels of agents. We observe significant interaction effects: the level of uncertainty interacts with symmetry ($F(1,6136) = 4.648$, $p = 0.031$), and the symmetry with costs ($F(1,6136) = 230.015$, $p < 0.001$). There is a marginal three-way interaction of uncertainty, symmetry, and costs ($F(1,6136) = 2.89$, $p = 0.089$). The correlation of effort choices and equilibria is considerably high ($Spearman's\ rho$ =.429, $p < 0.001$), and all main effects are found to be in the expected direction. Hence, the exerted effort beyond the equilibrium and its relation to uncertainty can be analyzed.

We concentrate on choice and belief deviations which are summarized in Table 6. To ease reading, the statistics of our analysis of variance with repeated measurements are shown in separate tables with hints in the corresponding text.

Table 6: HI-treatment: Overview of results

Source	Control	$c_i = c_j = 11$	$c_i = c_j = 22$	$c_i = 11$	$c_j = 22$
Mean effort choices	n=1	0.541	0.399	0.624	0.225
(p_i)	n=3	0.601	0.427	0.625	0.246
Mean effort - equilibrium	n=1	0.182*	0.181*	0.150*	0.077*
$p_i - p_i^*$	n=3	0.086*	0.120*	0.100*	0.101*
Mean belief	n=1	0.634	0.534	0.405	0.635
$(\tilde{p}_i)$	n=3	0.634	0.525	0.411	0.619
Best response to belief	n=1	0.229	0.137	0.369	0.103
$(\mathrm{BR}(\tilde{p}_i))$	n=3	0.295	0.158	0.464	0.104
Precision of belief	n=1	0.094*	0.135*	0.180*	0.011
$(\tilde{p}_i - p_j)$	n=3	0.033	0.098*	0.165*	-0.006
Choice deviation from best response to own belief	n=1	0.315*	0.263*	0.256*	0.123*
$(p_i - BR(\tilde{p}_i))$	n=3	0.315*	0.269*	0.163*	0.144*

$*$ significantly different from zero at $p < 0.05$, t-test for population means

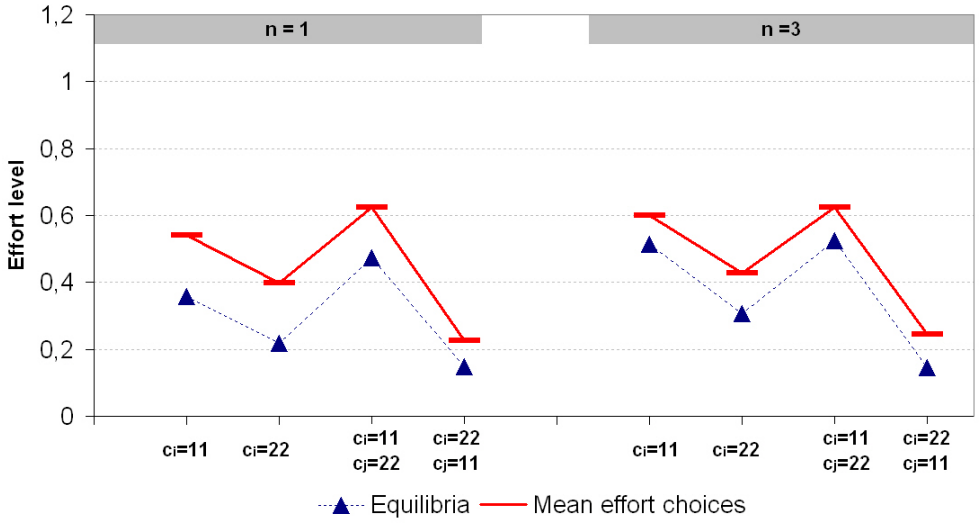
Choice deviations from optimality

The deviations of choices from the equilibria ($p_i - p^*$) were derived, and the mean of the six repetition of each agent in all parameter constellations were subsequently submitted to

an analysis of variance with repeated measurement. The level of uncertainty, costs, and symmetry were used as within-subject factors to explain the variance of choices of our setting. The experimental design controlled for order effects, and the pooling[5] suggested a balanced data set.

The mean deviation from the equilibrium is 0.125 (std.error=0.016, $[0.094, 0.155]_{0.95}$), and we find significantly more over-performance with $n = 1$ rather than with $n = 3$ control occasions, explaining 11.1% of the overall variance (see left-hand side of Table 7). In cost symmetry, over-performance is significantly higher than in the cost asymmetric condition, revealing 6.6% of the overall variance. Furthermore, we find significant interaction effects. The level of uncertainty interacts with symmetry: the decline in over-performance due to less uncertainty is more intense in symmetry rather than in asymmetry. Uncertainty and costs interacts such that the mentioned effect of uncertainty is more pronounced if agents hold low instead of high costs. Furthermore, we observe an interaction of symmetry and costs: the effect of cost on behavior is more severe in asymmetric than in symmetric settings (see Figure 2).

Figure 2: HI-treatment: Effort choices and equilibria



Choice deviations from best responses to stated beliefs

We asked each agent to state a belief about the opponent. For each agent the theoretically best response to the stated belief was calculated. The choices and best responses

[5]We checked for effects of the ordering of cost and scrutiny and found no overall significant between-subject effects.

to agents' beliefs can be seen in the left-hand side of Figure 3. Choices are significantly higher than best responses to beliefs, with the mean difference being 0.213 (std. error = 0.02, $[0.192, 0.270]_{0.95}$). This deviation has not been significantly affected by the main effect of uncertainty (see middle column of Table 7). However, the overreaction is significantly higher in symmetric compared to asymmetric settings, revealing 34.9% of the overall variance. Cost affects the choice deviations such that the overreaction is significantly more intense with low rather than high personal costs, accounting for 10.8% of the overall variance. The following significant interaction effects are observed: uncertainty interacts marginally with symmetry. The decline in overreactions due to less uncertainty is more intense in asymmetry rather than in symmetry. Uncertainty interacts with costs: we find a significantly stronger effect of uncertainty with low rather than high costs. Additionally, the choice deviations from best responses were affected by uncertainty via the interaction with costs and symmetry: while we observe no significant effect of uncertainty in both cost settings of the symmetric condition, the effect of uncertainty is significantly stronger in the advantageous rather than in the disadvantageous position of the asymmetric condition.

Table 7: HI-treatment: ANOVA results for choice deviations from equilibria and best responses, and for precision of beliefs

	$p_i - p_i^*$				$p_i - BR(\tilde{p}_i)$				$\tilde{p}_i - p_j$			
	df	F-value	p-value	η^2	df	F-value	p-value	η^2	df	F-value	p-value	η^2
Uncertainty	$F(1,127)=$	15.883	0.000	0.111	$F(1,127)=$	1.071	0.303	0.008	$F(1,127)=$	10.069	0.002	0.073
Symmetry	$F(1,127)=$	9.022	0.003	0.066	$F(1,127)=$	67.920	0.000	0.348	$F(1,127)=$	0.040	0.841	0.000
Cost	$F(1,127)=$	0.394	0.531	0.003	$F(1,127)=$	15.405	0.000	0.108	$F(1,127)=$	36.920	0.000	0.225
Uncertainty*Symmetry	$F(1,127)=$	12.170	0.001	0.087	$F(1,127)=$	3.319	0.071	0.025	$F(1,127)=$	2.954	0.088	0.023
Uncertainty*Cost	$F(1,127)=$	11.234	0.001	0.081	$F(1,127)=$	9.004	0.003	0.066	$F(1,127)=$	0.339	0.561	0.003
Symmetry*Cost	$F(1,127)=$	4.924	0.028	0.037	$F(1,127)=$	1.283	0.260	0.010	$F(1,127)=$	82.265	0.000	0.393
Uncertainty*Symmetry*Cost	$F(1,127)=$	1.885	0.172	0.015	$F(1,127)=$	10.805	0.001	0.078	$F(1,127)=$	0.522	0.471	0.004

Precision of beliefs

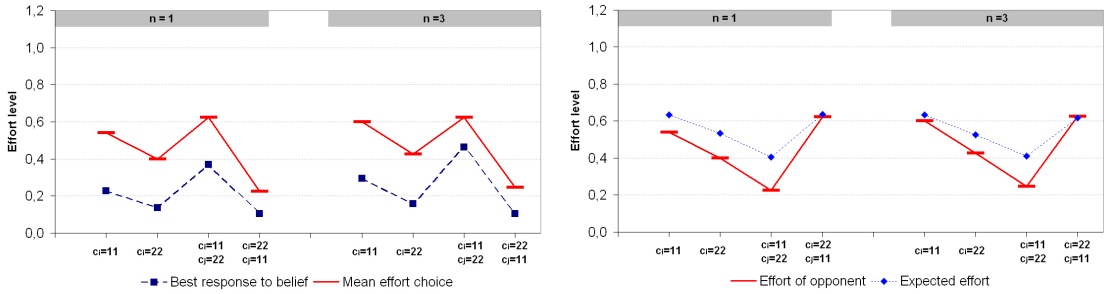
Before analyzing the quality of the stated beliefs, we controlled whether agents realized the situation they were interacting in. To this end, we compared the stated beliefs ($\tilde{p}_i$) to agents' own choices (p_i). The mean deviation of 0.088 (std. error=0.13, $[0.064, 0.114]_{0.95}$) indicates that agents perceived effort choices as strategic substitutes; if they expected high effort levels, they correctly chose lower effort levels themselves. In the advantageous position of the asymmetric cost condition, agents correctly anticipated their opponents choosing effort levels below their own effort levels. The mean deviation is -0.216 (std.

error=0.023, $[-0.262, -0.171]_{0.95}$). In the disadvantageous position agents expected opponents to choose much higher effort levels than the own effort level: the mean of the difference is 0.392 (std. error=0.021, $[0.350, 0.433]_{0.95}$).

To analyze the correspondence of beliefs ($\tilde{p}_i$) to opponents' actually chosen effort levels (p_j), we derived this difference at the individual level ($\tilde{p}_i - p_j$). The averages of the six interactions per cost situation were subsequently submitted to an ANOVA with repeated measurement, controlling for all interaction effects of the parameter setting (see right-hand column of Table 7).

As depicted on the right-hand side of Figure 3, beliefs significantly deviate from the choices of the opponents. Agents overestimated opponents by up to 8.8 percentage points (std. error= 0.013, $[0.064; 0.114]_{0.95}$). More importantly, this deviation is significantly larger with $n = 1$ rather than with $n = 3$. The level of uncertainty explains 7.35% of the overall variance. We find significantly higher belief deviations from opponent choices if agents hold low instead of high costs, accounting for 22.5% of the overall variance. Uncertainty marginally affected the precision of beliefs via the interaction with the symmetry condition: the decline in overestimation due to less uncertainty is stronger in symmetry rather than in asymmetry. The interaction of symmetry and costs significantly affected the belief deviations as well: in symmetry the precision of beliefs is worse, if agents hold high rather than low costs. By contrast, the precision is worse, if agents hold low costs in asymmetry, i.e., while facing opponents with high costs, overestimation is more pronounced than while facing opponents with low costs.

Figure 3: HI-treatment: Effort choices compared to best responses and beliefs compared to expectations



Interpretation and discussion

We replicated Avrahami et al. (2007) by finding significantly more over-optimal effort choices with high rather than low uncertainty. As initially stated, this questions where the persistent deviations originate and why there are more deviations for $n = 1$ rather than for $n = 3$. To elaborate on this, we disentangled choices and beliefs, allowing us to investigate whether agents make systematic errors by reacting to own beliefs, or by forming beliefs about opponents.

Our results show that agents tend to systematically overshoot, even if the benchmark uses best replies to beliefs instead of equilibrium effort levels. Agents' choices exceed rational best responses to own beliefs by on average 21.3 percentage points. A persistent deviation is found in all cost, symmetry, and uncertainty levels, contradicting the strategic substitute character of effort choices which suggested adjustments toward the equilibria. The observed deviations indicate that tournament fever took effect in the actual situation. Even though there is no significant main effect of uncertainty, it affects the choice deviations via the interaction with costs and symmetry. Increasing uncertainty induced agents to overreact by 7.17% more in $n = 1$ than in $n = 3$. Hence, leveling uncertainty triggers a behavioral consequence, with the main direction of the significant impact being more deviations with more uncertainty.

To understand the choice deviations, we elicited the beliefs of agents. Comparing the beliefs to truly chosen effort levels reveals agents to significantly overestimate their opponents by on average 8.9 percentage points. More interestingly, the overestimation of opponents increases by 43.8% with more uncertainty. Hence, the precision of beliefs is considerably worse with high rather than low uncertainty. This suggests that by controlling less often principals gain from agents' less precise formation of beliefs, driving their reactions to overshoot more with more uncertainty.

As will be mentioned in the conclusion the observations may be explained by the disappointment theory (Loomes and Sugden, 1986) or the decision affect theory (Mellers et al., 1997; Mellers and McGraw, 2001). This experiment was not designed to address the behavioral patterns of the belief deviations in detail; hence it cannot provide evidence for or against one of these competing behavioral explanations. However, the answer to where equilibrium deviations of choices originate is twofold. The deviations emerge from overreactions to best responses to own beliefs and additionally from the overestimation of opponents' effort choices. These deviations become more pronounced, if agents face more uncertainty. In other words, agents reveal a less feverish overreaction behavior, the more certain they are about the outcome of the competition.

6.3 Effects observed in the computerized opponent setting

Sensitivity to equilibrium

In our CI-treatment setting, all parameters that influenced the equilibria significantly affected the effort choices of agents: the level of uncertainty ($F(1, 6136) = 10.467$, $p = 0.001$), the symmetry condition ($F(1, 6136) = 41.985$, $p < 0.001$), and the cost structure ($F(1, 6136) = 663.251$, $p < 0.001$). There is a significant interaction effect of the level of uncertainty and symmetry ($F(1, 6136) = 8.983, p = 0.003$). Symmetry and cost interact significantly as well ($F(1, 6136) = 117.022$,$p < 0.001$). The choices correlate considerably with the equilibria ($Spearman's rho$ =0.334, $p < 0.001$), and all effects work in the expected direction. Hence, we proceed by approaching relevant deviations as usual.

The descriptive statistics dealing with examining this treatment are presented in Table 8. Similarly to the previous treatments, all analyses built upon individual agent data. Again, the means of six repetitions in each parameter constellation were submitted to an ANOVA with repeated measurement. The design of the experiment balanced out possible order effects such that the data could be pooled.[6]

Table 8: CI-treatment: Overview of results

Source	Control	$c_i = c_j = 11$	$c_i = c_j = 22$	$c_i = 11$	$c_j = 22$
Mean effort choices	n=1	0.493	0.384	0.547	0.279
p_i	n=3	0.540	0.430	0.549	0.281
Mean effort - equilibrium	n=1	0.135	0.166	0.073	0.131
$(p_i - p_i^*)$	n=3	0.025	0.122	0.024	0.136
Mean belief	n=1	0.552	0.473	0.439	0.563
$(\tilde{p_j})$	n=3	0.576	0.485	0.471	0.579
Best response to belief	n=1	0.253	0.148	0.315	0.124
$(\mathrm{BR}(\tilde{p_j}))$	n=3	0.336	0.180	0.440	0.122
Precision of belief	n=1	0.023	0.081*	0.214*	-0.06*
$(\tilde{p_j} - p_j)$	n=3	-0.025	0.058*	0.224**	-0.044*
Choice deviation from best response to belief	n=1	0.240*	0.236*	0.232*	0.156*
$(p_i - BR(\tilde{p_j})$	n=3	0.204*	0.249*	0.109*	0.159*

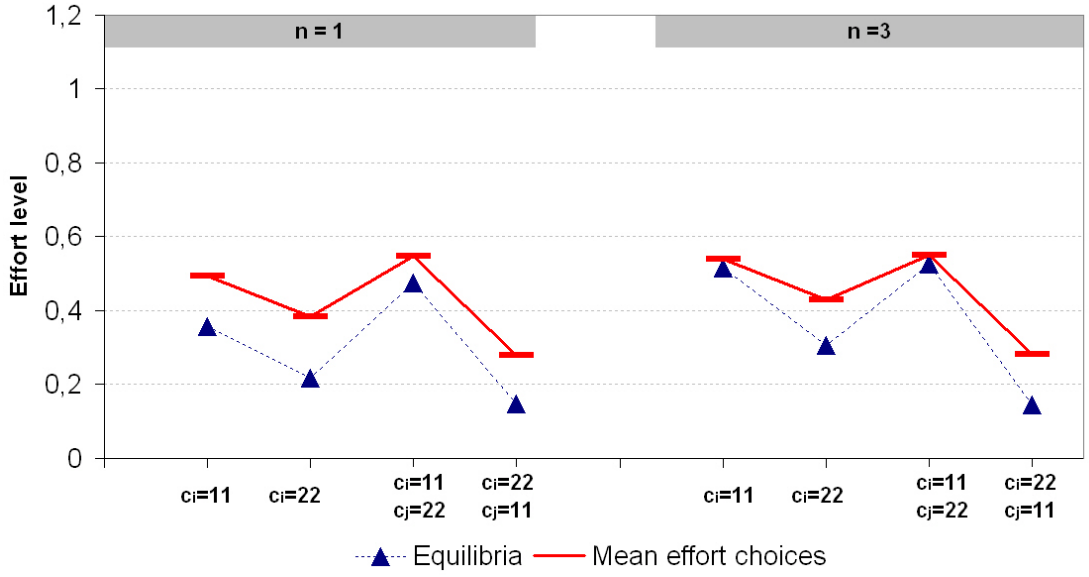
$*$ significantly different from zero at $p < 0.05$, t-test for population means

[6] However, we controlled for possible impacts of the ordering and observed no significant overall between-subject effects on choices and beliefs due to the order of costs or the level of uncertainty.

Choice deviations from optimality

Even with computerized opponents, choices deviate significantly from the equilibria: the mean deviation is 0.102 (std. error= 0.15, $[0.071; 0.133]_{.95}$). Again, we find significantly more over-optimal performance in $n = 1$ rather than in $n = 3$, explaining 8.6% of the overall variance of our findings. As depicted in Figure 4, we observe significantly larger choice deviations from optimality in symmetry rather than in asymmetry. The symmetry condition explains 4.1% of the overall variance in the experiment. The costs significantly affect the choice deviations from equilibrium, accounting for 23.7% of the overall variance: we find less over-performance if agents hold low instead of high costs. The interaction of uncertainty and the symmetry condition is found to be significant: the decline in over-performance due to less uncertainty was more pronounced in symmetry instead of asymmetry. The level of uncertainty also interacts with the costs: the effect of uncertainty is sigificantly stronger with low rather than high costs.

Figure 4: CI-treatment: Effort choices and equilibria



Choice deviations from best responses to stated beliefs

Again, we asked agents to state beliefs about their computerized opponents and computed the theoretically best response to it. The difference between the chosen effort level and best response reflects how rationally agents reacted to own beliefs. How our parameter setting affected the averaged difference is displayed in Table 9. With the overall mean being 0.198 (std. error=0.019 $[0.161; 0.235]_{.95}$), agents significantly overshoot if compared to

best responses to their own beliefs. The level of uncertainty significantly affected these deviations, accounting for 3.4% of the overall variance. Choice deviations from best responses were significantly higher in $n = 1$ rather than in $n = 3$. In symmetry we find significantly more choice deviations than in asymmetry, revealing 22% of the overall variance. We also observe a number of interaction effects. Uncertainty interacted with symmetry: the decline in overshooting due to less uncertainty is more severe in asymmetry rather than in symmetry. The level of uncertainty interacted with costs: the effect of uncertainty is more intense with low rather than high costs. We also find a significant three-way interaction of the level of uncertainty, costs, and symmetry: the effect of uncertainty is larger with low rather than high costs and significantly more intense in asymmetry rather than in symmetry (see left-hand side of Figure 5).

Table 9: CI-treatment: ANOVA results for choice deviations from equilibria and best responses, and precision of beliefs

	$p_i - p_i^*$				$p_i - BR(\tilde{p}_i)$				$\tilde{p}_i - p_j$			
	df	F-value	p-value	η^2	df	F-value	p-value	η^2	df	F-value	p-value	η^2
Uncertainty	$F(1,127)=$	11.931	0.001	0.086	$F(1,127)=$	4.452	0.037	0.034	$F(1,127)=$	0.892	0.347	0.007
Symmetry	$F(1,127)=$	5.492	0.021	0.041	$F(1,127)=$	35.846	0.000	0.220	$F(1,127)=$	25.067	<0.001	0.165
Cost	$F(1,127)=$	39.433	0.000	0.237	$F(1,127)=$	0.086	0.770	0.001	$F(1,127)=$	102.404	<0.001	0.446
Uncertainty*Symmetry	$F(1,127)=$	12.578	0.001	0.090	$F(1,127)=$	7.034	0.009	0.052	$F(1,127)=$	8.500	0.004	0.063
Uncertainty*Cost	$F(1,127)=$	11.746	0.001	0.085	$F(1,127)=$	16.834	0.000	0.117	$F(1,127)=$	0.776	0.38	0.006
Symmetry*Cost	$F(1,127)=$	1.378	0.243	0.011	$F(1,127)=$	3.477	0.065	0.027	$F(1,127)=$	200.649	<0.001	0.612
Uncertainty*Symmetry*Cost	$F(1,127)=$	0.234	0.630	0.002	$F(1,127)=$	4.679	0.032	0.036	$F(1,127)=$	0.228	0.634	0.002

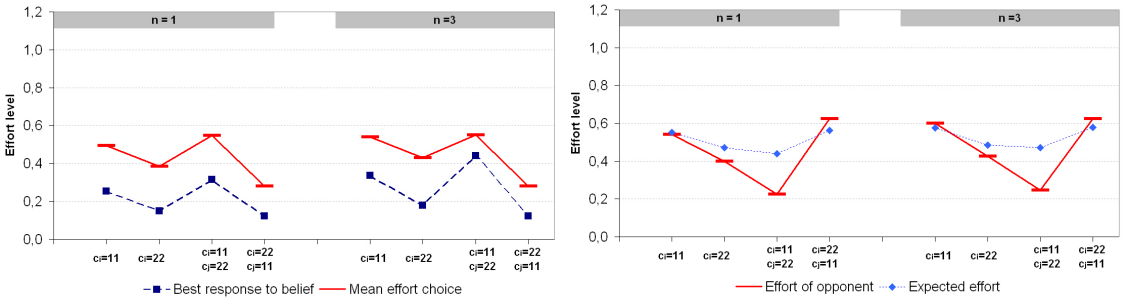
Precision of beliefs

To check the plausibility of our findings, we controlled whether agents correctly perceived the situation they were interacting in. Agents expected opponents to use higher effort levels than their own choices: the mean of 0.076 (std. error=0.015, $[0.045; 0.107]_{.95}$) is significantly larger than zero. In the advantageous position of asymmetry, agents correctly anticipated the effort choices of opponents being lower than own choices (mean=-0.093, std. error=0.021, $[-0.135; -0.052]_{0.95}$). By contrast, in the disadvantageous position they expect much higher opponent choices than own choices (mean=0.291, std. error=0.022, $[0.248; 0.333]_{0.95}$). Agents, it seemed, understood the situation they interacted in.

The precision of beliefs is captured by the difference between the expected and the preprogrammed effort levels. As can be seen on the right-hand side of Figure 5, agents slightly overestimated the effort choices of their computerized opponents. With the mean being

0.059 (std. error=0.012, $[0.034; 0.083]_{.95}$), this difference is significantly larger than zero. The main effect of the level of uncertainty did not influence the precision of the beliefs (see right-hand column of Table 9). The overestimation was affected by the symmetry condition: we find significantly larger deviations of beliefs from the preprogrammed effort levels in asymmetry rather than in symmetry, accounting for 16.5% of the overall variance in the setting. Cost affected the belief deviations: we observe more deviations with low rather than high personal costs, explaining 44.6% of the overall variance. Significant interaction effects are observed as well: the level of uncertainty interacts with the symmetry condition. The decline in overestimation due to less uncertainty was more pronounced in symmetry rather than in asymmetry. Costs interacted with symmetry: in symmetric settings the precision of beliefs is worse for high rather than low cost, while in asymmetry the precision is worse with low rather than high costs.

Figure 5: CI-treatment: Effort choices compared to best responses and beliefs compared to expectations



Interpretation and discussion

Also with computerized opponents, we observe significant over-optimal choice behavior which is more pronounced with more uncertainty. Using the less demanding benchmark of best responses to beliefs, we observe agents overshoot on best responses by up to 19.8 percentage points. Similarly as before, effort choices were strategic substitutes, what should induce convergence to the equilibria. The overshooting may be attributed to "tournament fever" since even with computerized opponents the competitiveness of the situations remained. Although its intensity of rivalry was less severe an increased arousal level seemed to have driven the emotional pursuit to participate in, and to win, a competition. Increasing uncertainty caused 20% more overshooting in $n = 1$ rather than in $n = 3$. This suggests less rational choice behavior of agents with more uncertainty. As to the precision

of beliefs, we find agents to overestimate their opponents by on average 5.9 percentage points. With more uncertainty overestimation increased by 20.75%. On an equal level playing field, agents tend to overestimate opponents more with more uncertainty, while in asymmetry the overestimation is not affected by the level of uncertainty. If agents are not aware of a priori differences between themselves, adding uncertainty increases the difficulties in forming correct beliefs.

Uncertainty obviously affects behavior by decreasing the precision of agents' beliefs. But even given these biased beliefs, agents consequently overshoot compared to their best responses. Hence, both overestimation and overshooting seem to drive agents' feverish choice behavior in our tournament setting.

7 Conclusion

Theoretical and experimental work suggests that increasing agents' uncertainty about the outcome of a tournament, e.g., by inspecting production outcomes less often, is beneficial for principals (Dubey and Haimanko, 2003; Dubey and Wu, 2001; Kareev and Avrahami, 2007; Avrahami et al., 2007). While competing for a bonus, agents in our tournament over-performed if compared to optimal choices. Avrahami et al. (2007) used choice deviations from optimality as a sensitive measure of the quality of agents' reactions to variations in uncertainty and cost conditions. The found over-performance of agents became more pronounced with more uncertainty and was prevalent in symmetric and asymmetric cost of effort conditions.

In our tournament we related over-performance to overbidding behavior in auctions. This overbidding behavior is mainly related to an increased level of cognitive arousal, driven by various mediating factors. Even though not all arousal mediating factors of auctions resided in our tournament setting, rivalry remained. With our experimental setting, we have revealed that substituting human rivals for computerized opponents has a significant impact on the choice behavior of agents. We suggest a different arousal level as the source of the differences and rivalry as the mediating factor. If rivalry pushes subjects to overbid in auctions, this is likely to induce over-performance in tournaments as well. Hence, the over-performance in our tournament can indeed be explained by a behavioral pattern similar to

overbidding in auctions. The observed over-optimality can be attributed to rivalry induced "tournament fever": an intense and emotionally charged behavior, driving agents to exert more effort than is optimal in order to win the competition.

While "tournament fever" explains substantial overreactions, the variation of uncertainty seems to operate the level of over-performance. By eliciting beliefs we saw that choice deviations from optimality emerged from overreactions to best responses to own beliefs and overestimations of opponents. Increasing uncertainty caused more overshooting and more overestimation. We observed that by increasing uncertainty the overestimation increased comparatively more than the overreaction to own beliefs. Hence, we suggest the effects of uncertainty on over-optimality to be mainly driven by the belief formation process.

Why uncertainty seems to affect the belief formation was not subject of this paper, however, we suggest two behavioral explanations. To protect themselves from disappointment, agents might have chosen to underestimate own winning chances by overestimating their opponents. This argumentation is in line with the disappointment theory (Loomes and Sugden, 1986) and may also explain differences between the levels of uncertainty. More uncertainty implies lower chances to win the bonus for that agent who invests more than the opponent. Anticipating more disappointment in $n = 1$ could lead to a stronger protective reaction, implying a higher overestimation of opponents in $n = 1$ than in $n = 3$. The same reactions may also be explained by the decision affect theory (Mellers et al., 1997; Mellers and McGraw, 2001): underestimating own winning chances increases the chance to be positively surprised, which is preferred by agents to unsurprising outcomes. Similarly, with more uncertainty unsurprising outcomes are perceived to be more likely; hence, with $n = 1$ agents overestimate their opponents more than with $n = 3$.

To identify and incorporate into our paper a comprehensive theory accounting for all our observations is beyond what would have been feasible here. This chapter was a first step to conceptualize "tournament fever" in a principal-agent setting. In order to better understand the mentioned observations, future research needs to tighten the relation to behavioral motivations such as disappointment aversion or decision affect theory. Upcoming studies should also elaborate on extensions of the competitive situation to more than two agents, broadening the floor for better applicability in firms. Furthermore, instead of comparing the observed over-optimal behavior to point predictions, intra-personal error may be assumed and incorporated in the calculation of the benchmark solutions. If still deviations from the benchmark are observed, the concept of "tournament fever" may gain further ground.

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