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# Risk Taking in Winner-Take-All Competition

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# Risk Taking in Winner-Take-All Competition*

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March, 2008

**Abstract**

We analyze a two-stage game between two heterogeneous players. At stage one, common risk is chosen by one of the players. At stage two, both players observe the given level of risk and simultaneously invest in a winner-take-all competition. The game is solved theoretically and then tested by using laboratory experiments. We find three effects that determine risk taking at stage one – an effort effect, a likelihood effect and a reversed likelihood effect. For the likelihood effect, risk taking and investments are clearly in line with theory. Pairwise comparison shows that the effort effect seems to be more relevant than the reversed likelihood effect when taking risk.

**Key Words:** Tournaments, Competition, Risk-Taking, Experiment

**JEL Classification:** M51, C91, D23

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# 1 Introduction

In many real-world situations, competition can be characterized as a winner-take-all contest or tournament. Typically, in sports contests there is only one winner who gets the high winner prize (Szymanski (2003)). When arranging a singing contest, only one participant wins the final round (Amegashie (2007)). In job-promotion tournaments, workers compete for a more attractive and better paid position at the next hierarchy level (Baker *et al.* (1994)). Firms and individuals invest in external or internal rent-seeking contests (Gibbons (2005)). In politics, individuals compete for being elected. Firms often compete in R&D (Loury (1979), Zhou (2006)) and invest resources for advertising to become the market leader (Schmalensee (1976), Schmalensee (1992)). Moreover, firms are involved in litigation contests for brand names or patent rights (Waerneryd (2000)). Finally, oligopolistic competition in new markets often looks like a tournament: only the firm that implements a new technical standard as a first-mover can realize substantial profits from network externalities (Besen and Farrell (1994)).

Most of the models on winner-take-all competition either build on the seminal work by Tullock (1980) or that by Lazear and Rosen (1981). These contest or tournament models usually focus on the effort or investment choices of the contestants: the higher the effort/investment of a single player relative to those of his opponents, the more likely he will win the tournament. However, in real tournaments, players also choose the risk of their strategic behavior. For example, politicians do not only invest resources during the election campaign, but also decide on the composition and, therefore, on the risk of their agenda. Athletes decide whether to switch to a new – and often more risky – training method or not. Prior to the choice of their advertising expenditures, firms have to decide on the introduction of a new product, which would be a more risky strategy than keeping the old product line. In many tournaments, contestants first have the choice between using a standard technique or solution (low risk) or switching to a new one (high risk); thereafter they decide on effort or, more generally, on input to win the tournament.

In our paper, we analyze such a two-stage tournament with risk taking at the first stage and effort or investment choices at the second stage. We consider an asymmetric tournament game[1] with discrete choices to derive several hypotheses which are tested in a laboratory experiment. In our tournament model, a more able player (the "favorite") competes against a less able one (the "underdog"). At first sight, one would expect that the favorite does not prefer a high risk which can jeopardize his favorable position, whereas the underdog strictly benefits from a high risk since he has nothing to lose but good luck may compensate for the lower ability. Our theoretical results show that this first guess is not necessarily true. Considering the risk choice of the favorite we can differentiate between three effects that determine risk taking: first, risk taking at stage 1 of the game may influence the equilibrium efforts at stage 2 (*effort effect*). According to this effect, both players prefer a high-risk strategy in order to minimize effort and, hence, effort costs at the second stage. Here, high risk serves as a commitment device for the players at the effort stage, leading to a kind of implicit collusion. Second, the choice of risk also influences the players' likelihood of winning. If equilibrium efforts do not react to risk taking the favorite will prefer a low-risk strategy to hold his predominant position (*likelihood effect*). Third, if equilibrium efforts do react to risk taking, the favorite may choose a high risk to maximize his winning probability (*reversed likelihood effect*). In this situation, high risk discourages the underdog at the effort stage since now the underdog can hardly influence the outcome of the tournament by his effort choice. Such discouragement is very attractive for the favorite when the gain of winning the tournament – as measured by the difference of winner and loser prize – is rather large.

[1] Note that we do not analyze a principal-agent model where the principal optimally designs the tournament game.

Our experimental analysis focuses on risk taking by the favorite and the subsequent effort choices by both players. For each effect we ran one treatment with two sessions – labeled reversed likelihood treatment, effort treatment, and likelihood treatment. Descriptive results indicate that, contrary to the reversed likelihood effect, both the effort effect and the likelihood effect are relevant for the subjects when choosing risk. The results from non-parametric tests and probit regressions reveal that the likelihood effect turns out to be very robust. The two other effects are not confirmed by a Binomial test, but a pairwise comparison of the treatments shows that the findings for the effort effect are more in line with theory than our results for the reversed likelihood effect. As theoretically predicted, favorites choose significantly more effort than underdogs in the reversed likelihood treatment and the likelihood treatment. In the effort treatment, players' behavior does not significantly differ given low risk, which follows theory, but for high risk underdogs exert clearly more effort than favorites, which contradicts theory. The subjects' effort choices as reactions to given risk are very often in line with theory. Again, the likelihood treatment offers very robust findings. Interestingly, in the two other treatments, favorites tend to react more sensitive to given risk than underdogs although subjects change their roles after each round.
Previous work on risk taking in tournaments either fully concentrates on the players' risk choices by skipping the effort stage, or considers symmetric effort choices within a two-stage game. The first strand of this literature better refers to risk behavior of mutual fund managers or other players that can only influence the outcome of a winner-take-all competition by choosing risk (see, for example, Gaba and Kalra (1999), Hvide and Kristiansen (2003) and Taylor (2003)). The second strand of the risk-taking literature is stronger related to our paper. Hvide (2002) and Kräkel and Sliwka (2004) consider a symmetric two-stage tournament with risk taking at stage 1 and subsequent effort choices at stage 2. However, symmetry of the equilibrium at the effort stage eliminates one of the three main effects of risk taking, namely the re-

versed likelihood effect. Nieken (2007) experimentally investigates the effort effect of the symmetric setting. On the one hand, her results show that subjects rationally reduce their efforts when risk increases. On the other hand, subjects do not behave according to the effort effect very well as only about 50% (instead of 100%) of the players choose high risk.

Our paper is most strongly related to Kräkel (forthcoming) who analyzes all three effects in an asymmetric two-stage tournament model. We simplify the analysis of Kräkel to make the theoretical findings testable in the laboratory. In particular, we assume that only one of the two players decides on risk at stage 1. Thereafter, both players observe the common risk and simultaneously decide on their effort choices. This simplification can be justified for at least two reasons. First, subjects in the lab seem to be overstrained in a more complex setting with simultaneous risk choices at stage 1 (see Nieken (2007)). Second, our simple model primarily serves to test the main topic addressed by Kräkel (forthcoming): given asymmetric competition, how relevant are the three theoretical effects of risk taking for real players? In our discrete model, we can clearly discriminate between these three effects by choosing certain parameter constellations. In a further step, these constellations have been tested in different experimental treatments.

The paper is organized as follows. The next section introduces the game and the corresponding solution. In Section 3, we point out the three main effects of risk taking – the effort effect, the likelihood effect, and the reversed likelihood effect. In Section 4, we describe the experiment. Our testable hypotheses are introduced in Section 5. The experimental results are presented in Section 6. We discuss three puzzling results in Section 7. Section 8 concludes.

## 2 The Game

We consider a two-stage tournament game with two risk neutral players. At the first stage (risk stage), one of the players chooses the variance of the underlying probability distribution that characterizes risk in the tournament. At the second stage (effort stage), both players observe the chosen risk and then decide simultaneously on their efforts. The player with the better relative performance is declared the winner of the tournament and receives the high prize $w_1$, whereas the other one gets the loser prize $w_2$ with $0 \leq w_2 < w_1$ and prize spread $\Delta w := w_1 - w_2$. Relative performance does not only depend on the effort choices but also on the realization of the common underlying noise term.

The two players are heterogeneous in ability. These ability differences are modeled via the players' effort costs. The more able player $F$ ("favorite") has low effort costs, whereas exerting effort entails rather high costs for player $U$ ("underdog"). In particular, both players can only choose between the two effort levels $e_i = e_L$ and $e_i = e_H > 0$ $(i = F, U)$ with $e_H > e_L$ and $\Delta e := e_H - e_L > 0$. The choice of $e_i = e_L$ leads to zero effort costs for player $i$, but choosing high effort $e_i = e_H$ involves positive costs $c_i$ $(i = F, U)$ with $c_U > c_F > 0$. Relative performance of player $i$ is described by

$$RP_i = e_i - e_j - \varepsilon \qquad (i, j = F, U; i \neq j) \tag{1}$$

with $\varepsilon$ as common noise term which follows a symmetric distribution around zero with cumulative distribution function $G(\varepsilon; \sigma^2)$ and variance $\sigma^2$. At the risk stage, the active player has to decide between two variances or risks. He can either choose a high risk $\sigma^2 = \sigma_H^2$ or a low risk $\sigma^2 = \sigma_L^2$ with $0 < \sigma_L^2 < \sigma_H^2$. Player $i$ is declared winner of the tournament if and only if $RP_i > 0$. Hence, his winning probability is given by

$$\text{prob}\{RP_i > 0\} = G\left(e_i - e_j; \sigma^2\right) = 1 - G\left(e_j - e_i; \sigma^2\right) \tag{2}$$

where the last equality follows from the symmetry of the distribution. In analogy, we obtain for player $j$'s winning probability:

$$\text{prob}\{RP_j > 0\} = 1 - G\left(e_i - e_j; \sigma^2\right) = G\left(e_j - e_i; \sigma^2\right). \tag{3}$$

The symmetry of the distribution has two implications: first, each player's winning probability will be $G(0; \sigma^2) = \frac{1}{2}$ if both choose the same effort level. Second, if both players choose different effort levels, the one with the higher effort has winning probability $G(\Delta e; \sigma^2) > \frac{1}{2}$, but the player choosing low effort only wins with probability $G(-\Delta e; \sigma^2) = 1 - G(\Delta e; \sigma^2) < \frac{1}{2}$. Let

$$\Delta G\left(\sigma^2\right) := G\left(\Delta e; \sigma^2\right) - \frac{1}{2} \tag{4}$$

denote the *additional winning probability* of the player with the higher effort level *compared to a situation with identical effort choices* by both players. Note that $\Delta G(\sigma^2) \in \left(0, \frac{1}{2}\right)$. We assume that increasing risk from $\sigma_L^2$ to $\sigma_H^2$ shifts probability mass from the mean to the tails so that $G(\Delta e; \sigma_L^2) > G(\Delta e; \sigma_H^2)$, implying

$$\Delta G\left(\sigma_L^2\right) > \Delta G\left(\sigma_H^2\right). \tag{5}$$

When looking for subgame-perfect equilibria by backward induction we start by considering the effort stage 2. Here, both players observe $\sigma^2 \in \{\sigma_L^2, \sigma_H^2\}$ and simultaneously choose their efforts according to the following matrix game:

| | $e_F = e_H$ | $e_F = e_L$ |
|---|---|---|
| $e_U = e_H$ | $\frac{\Delta w}{2} - c_U$ , $\frac{\Delta w}{2} - c_F$ | $\Delta w G(\Delta e; \sigma^2) - c_U$ , $\Delta w G(-\Delta e; \sigma^2)$ |
| $e_U = e_L$ | $\Delta w G(-\Delta e; \sigma^2)$ , $\Delta w G(\Delta e; \sigma^2) - c_F$ | $\frac{\Delta w}{2}$ , $\frac{\Delta w}{2}$ |

For brevity, we skipped the loser prize $w_2$ in each matrix cell for both players since strategic behavior only depends on the prize spread $\Delta w$.[2] The first (second) payoff in each cell refers to player $U$ ($F$) who chooses rows (columns).

Note that $(e_U, e_F) = (e_H, e_L)$ can never be an equilibrium at the effort stage since

$$\Delta w G\left(-\Delta e; \sigma^2\right) \geq \frac{\Delta w}{2} - c_F \Leftrightarrow c_F \geq \Delta w \left(\frac{1}{2} - G\left(-\Delta e; \sigma^2\right)\right)$$
$$\Leftrightarrow \quad c_F \geq \Delta w \left(\frac{1}{2} - \left[1 - G\left(\Delta e; \sigma^2\right)\right]\right) \Leftrightarrow c_F \geq \Delta G\left(\sigma^2\right) \Delta w$$

and

$$\Delta w G\left(\Delta e; \sigma^2\right) - c_U \geq \frac{\Delta w}{2} \Leftrightarrow \Delta G\left(\sigma^2\right) \Delta w \geq c_U$$

lead to a contradiction as $c_U > c_F$. Combination $(e_U, e_F) = (e_H, e_H)$ will be an equilibrium at the effort stage if and only if

$$\frac{\Delta w}{2} - c_i \geq \Delta w G\left(-\Delta e; \sigma^2\right) \Leftrightarrow \Delta G\left(\sigma^2\right) \Delta w \geq c_i$$

holds for player $i = F, U$. In words, each player will not deviate from the high effort level if and only if, compared to $e_i = e_L$, the additional expected gain $\Delta G\left(\sigma^2\right) \Delta w$ is at least as large as the additional costs $c_i$. Similar considerations for $(e_U, e_F) = (e_L, e_L)$ and $(e_U, e_F) = (e_L, e_H)$ yield the following result:

**Proposition 1** *At the effort stage, players $U$ and $F$ will choose*

$$\left(e_U^*, e_F^*\right) = \begin{cases} (e_H, e_H) & \text{if} \quad \Delta G\left(\sigma^2\right) \Delta w \geq c_U \\ (e_L, e_H) & \text{if} \quad c_U \geq \Delta G\left(\sigma^2\right) \Delta w \geq c_F \\ (e_L, e_L) & \text{if} \quad \Delta G\left(\sigma^2\right) \Delta w \leq c_F \end{cases} \tag{6}$$

[2] Note that, in any case, each player receives the lump sum $w_2$, either directly as loser prize or as part of the winner prize. Hence, only the additional prize money $\Delta w$ leads to incentives in the tournament.

Our findings are quite intuitive: the favorite chooses at least as much effort as the underdog because of higher ability and, hence, lower effort costs. If the additional expected gain $\Delta G(\sigma^2)\Delta w$ is sufficiently large, it will pay off for both players to choose a high effort level. However, for intermediate values of $\Delta G(\sigma^2)\Delta w$ only the favorite will prefer high effort, and for small values of $\Delta G(\sigma^2)\Delta w$ neither player exerts high effort.

At the risk stage 1, one of the two players is active and chooses common risk $\sigma^2$. Equations (2) and (3) show that risk taking directly influences the players' winning probabilities. Furthermore, Proposition 1 points out that risk also determines the players' effort choices at stage 2. We obtain the following proposition:

**Proposition 2** *(i) If $\Delta w \leq \frac{c_F}{\Delta G(\sigma_L^2)}$ or $\Delta w \geq \frac{c_U}{\Delta G(\sigma_H^2)}$, then both players will be indifferent between $\sigma^2 = \sigma_L^2$ and $\sigma^2 = \sigma_H^2$. (ii) Let $\Delta w \in \left(\frac{c_F}{\Delta G(\sigma_L^2)}, \frac{c_U}{\Delta G(\sigma_H^2)}\right)$. When $F$ is the active player at stage 1, he will choose $\sigma^2 = \sigma_L^2$ if $\Delta w < \frac{c_U}{\Delta G(\sigma_L^2)}$, and $\sigma^2 = \sigma_H^2$ otherwise. When $U$ is the active player at stage 1, he will always choose $\sigma^2 = \sigma_H^2$.*

**Proof:** See Appendix.

The result of Proposition 2(i) shows that risk taking becomes unimportant if the prize spread $\Delta w$ is very small or very large. In the first case, it never pays for the players to choose a high effort level, irrespective of the underlying risk. In the latter case, both players prefer to exert high effort for any risk level since winning the tournament is very attractive. Hence, the risk-taking decision is only interesting for moderate prize spreads that do not correspond to one of these extreme cases.

Proposition 2(ii) deals with the situation of a moderate prize spread. Here, the underdog always prefers the high risk. The intuition for this result comes from the fact that $U$ is in an inferior position at the effort stage according to Proposition 1, irrespective of the chosen risk level. Therefore, he has nothing to lose and unambiguously gains from choosing the high risk: in case of good luck, he may win the competition despite his inferior position; in case of bad luck, he will not really worsen his position as he has already a rather small winning probability. The favorite is in a completely different situation when being the active player at the risk stage. According to Proposition 1, he is the presumable winner of the tournament and does not want to jeopardize his favorable position. However, Proposition 2(ii) shows that $F$'s preference for low risk will only hold if the prize spread is smaller than a certain cut-off value. If $\Delta w$ is rather large, then it will pay for the favorite to choose high risk at stage 1. By this, he strictly gains from discouraging his rival $U$: given $\sigma^2 = \sigma_L^2$, we have $(e_U^*, e_F^*) = (e_H, e_H)$ at the effort stage, but $\sigma^2 = \sigma_H^2$ induces $(e_U^*, e_F^*) = (e_L, e_H)$.

# 3 Effort Effect, Likelihood Effect and Reversed Likelihood Effect

The results of Proposition 2 have shown that the behavior of player $U$ is rather uninteresting in this simple discrete setting as he has a (weakly) dominant strategy when being the active player at stage 1.[3] Therefore, the remainder of this paper focuses on the strategic risk taking of player $F$.

Recall that risk taking may influence both the players' effort choices and their winning probabilities. As already mentioned in the introduction, in particular three main effects determine a player's risk choice at stage 1. The first effect can be labeled *effort effect*. In our discrete setting, this effect will determine $F$'s risk choice if $\frac{c_U}{\Delta G(\sigma_L^2)} < \Delta w < \frac{c_F}{\Delta G(\sigma_H^2)}$.[4] In this situation, $\sigma^2 = \sigma_L^2$ leads to $(e_U^*, e_F^*) = (e_H, e_H)$ at stage 2, but $\sigma^2 = \sigma_H^2$ implies $(e_U^*, e_F^*) = (e_L, e_L)$. Hence, in any case the winning probability of either player will be $\frac{1}{2}$, but only under low risk each one has to bear positive effort costs. Consequently,

[3]In a model with continuous effort choices, there are also situations in which the underdog prefers low risk; see Kräkel (forthcoming).

[4]See the proof of Proposition 2 in the Appendix.

each player prefers high risk at stage 1 to commit himself (and his rival) to choose minimal effort at stage 2. Concerning the effort effect, both players' interests are perfectly aligned as each one prefers a kind of implicit collusion in the tournament, induced by high risk.

The second effect arises when $\frac{c_F}{\Delta G\left(\sigma_H^2\right)} < \Delta w < \frac{c_U}{\Delta G\left(\sigma_L^2\right)}$.[5] In this situation, the outcome at the effort stage is $(e_U^*, e_F^*) = (e_L, e_H)$, no matter which risk level has been chosen at stage 1. Here, risk taking only determines the players' likelihoods of winning so that this effect is called *likelihood effect.* If $F$ chooses risk, he will unambiguously prefer low risk $\sigma^2 = \sigma_L^2$. Higher risk taking would shift probability mass from the mean to the tails. This is detrimental for the favorite, since bad luck may jeopardize his favorable position at the effort stage. By choosing low risk, his winning probability becomes $G\left(\Delta e; \sigma_L^2\right)$ instead of $G\left(\Delta e; \sigma_H^2\right)$ $\left(< G\left(\Delta e; \sigma_L^2\right)\right)$. A technical intuition can be seen from Figure 1.

[Figure 1 about here]

There, the cumulative distribution function given high risk, $G\left(\cdot; \sigma_H^2\right)$, is obtained from the low-risk cdf , $G\left(\cdot; \sigma_L^2\right)$, by flattening and clockwise rotation in the point $\left(0, \frac{1}{2}\right)$. Note that at $\Delta e$ the cdf describes the winning probability of player $F$, whereas $U$'s likelihood of winning is computed at $-\Delta e$. Thus, by choosing low risk instead of high risk, the favorite maximizes his own winning probability and minimizes that of his opponent.

The third effect is called *reversed likelihood effect*: if $F$'s incentives to win the tournament are sufficiently strong, that is if $\Delta w > \max\left\{\frac{c_F}{\Delta G\left(\sigma_H^2\right)}, \frac{c_U}{\Delta G\left(\sigma_L^2\right)}\right\}$, he wants to deter $U$ from exerting high effort. Now the favorite's preference for low risk is just reversed. From the proof of Proposition 2, we know that low risk $\sigma_L^2$ leads to $(e_U^*, e_F^*) = (e_H, e_H)$, but high risk $\sigma_H^2$ induces $(e_U^*, e_F^*) = (e_L, e_H)$. Hence, when choosing high risk at stage 1, the favorite completely discourages his opponent and increases his winning probability

[5] See again the proof of Proposition 2.

by $G(\Delta e; \sigma_H^2) - \frac{1}{2} = \Delta G(\sigma_H^2)$, compared to low risk. This effect is shown in Figure 2.

[Figure 2 about here]

Low risk makes high effort attractive for both players since effort has still a real impact on the outcome of the tournament, resulting into a winning probability of $\frac{1}{2}$ for each player. Switching to a high-risk strategy $\sigma_H^2$ now increases the effort difference by $\Delta e$, which raises $F$'s likelihood of winning by $\Delta G(\sigma_H^2)$.

To sum up, the analysis of risk taking by the favorite points to three different effects at the risk stage of the game. These three effects were tested in a laboratory experiment which will be described in the next section. Thereafter, we will present the exact hypotheses to be tested and our experimental results.

# 4 Experimental Design and Procedure

We designed three different treatments corresponding to our three effects – the effort effect, the likelihood effect, and the reversed likelihood effect. For each treatment we conducted two sessions, each including 5 groups of 6 participants. Each session consisted of a testing phase and 5 rounds of the two-stage game. During each round, pairs of two players were matched anonymously within each group. After each round new pairs were matched in all groups. The game was repeated five times so that each player interacted with each other player exactly one time within a certain group. This perfect stranger matching was implemented to prevent reputation effects. Altogether, for each treatment we have 30 independent observations concerning the first round (15 pairs, 2 sessions) and 10 independent observations based on all rounds.

Before the 5 rounds of each session started, each participant got the chance to test the complete two-stage game of Section 2 for 10 rounds. Thus each participant had time to become familiar with the course of the experiment. During the testing phase, a single player had to make all decisions on his own so that he learned the role of the favorite as well as that of the underdog. Within the 5 rounds of the experiment the participants got alternate roles. Hence, each individual either played three rounds as a favorite and two rounds as an underdog or vice versa.

For each session, we used a uniformly distributed noise term $\varepsilon$ which was either distributed between $-2$ and 2 ("low risk"), or between $-4$ and 4 ("high risk").[6] Hence, we had $\Delta G\left(\sigma_L^2\right) = \frac{1}{4}$ and $\Delta G\left(\sigma_H^2\right) = \frac{1}{8}$. We also used the same tournament prizes ($w_2 = 0$ and $w_1 = 100$) and the same alternative effort levels ($e_L = 0$ and $e_H = 1$) for each session. However, we varied the effort costs between the treatments. In the *effort treatment* (testing the effort effect) we had $c_U = 24$ and $c_F = 22$, in the *likelihood treatment* (dealing with the likelihood effect) we had $c_U = 60$ and $c_F = 8$, and in the *reversed likelihood treatment* (focusing on the reversed likelihood effect) we used $c_U = 24$ and $c_F = 8$. It can easily be checked that these three different parameter constellations satisfy the three different conditions for the prize spread corresponding to the effort effect, the likelihood effect and the reversed likelihood effect, respectively.

The experiment was conducted at the Cologne Laboratory of Economic Research at the University of Cologne in January 2008. Altogether, 180 students participated in the experiment. All of them were enrolled in the Faculty of Management, Economics, and Social Sciences. The participants were recruited via the online recruitment system by Greiner (2003). The experiment was programmed and conducted with the software z-tree (Fischbacher (2007)). A session approximately lasted one hour and 15 minutes and subjects earned on average 13.82 Euro.

At the outset of a session the subjects were randomly assigned to a cubical where they took a seat in front of a computer terminal. The instructions

[6] Random draws were rounded off to two decimal places.

were handed out and read aloud by the experimenters.[7] Thereafter, the subjects had time to ask clarifying questions if they had any difficulties in understanding the instructions. Communication – other than with the experimental software – was not allowed. To check for their comprehension, subjects had to answer a short questionnaire. After each of the subjects correctly solved the questions, the experimental software was started.

At the beginning of each session, the players got 60 units of the fictitious currency "Taler". Each round of the experiment then proceeded according to the two-stage game described in Section 2. It started with player $F$'s risk choice at stage 1 of the game. He could either choose a random draw out of the interval $[-2, 2]$ ("low risk") or from the interval $[-4, 4]$ ("high risk"). When choosing risk, player $F$ knew the course of events at the next stage as well as both players' effort costs. At the beginning of stage 2, both players were informed about the alternative that had been chosen by player $F$ before. Then both players were asked about their beliefs concerning the effort choice of their respective opponent. Thereafter, each player $i$ ($i = U, F$) chose between score 0 (at zero costs) and score 1 (at costs $c_i$) as alternative effort levels. Next, the random draw was executed. The final score of player $F$ consisted of his initially chosen score 0 or 1 plus the realization of the random draw, whereas the final score of player $U$ was identical with his initially chosen score 0 or 1. The player with the higher final score got the winner prize $w_1 = 100$ and the other one $w_2 = 0$. Both players were informed about both final scores, whether the guess about the opponent's choice was correct, and about the realized payoffs. Then the next round began.

Each session ended after 5 rounds. At the end of the session, one of the 5 rounds was drawn by lot. For this round, each player got 15 Talers if his guess of the opponent's effort choice was correct and zero Talers otherwise. The winner of the selected round received $w_1 = 100$ Talers and the loser $w_2 = 0$ Talers. Each player had to pay zero or $c_i$ Talers for the chosen score

[7] The translated instructions can be found in the Appendix.

0 or 1, respectively. The sum of Talers was then converted into Euro by a previously known exchange rate of 1 Euro per 10 Talers. Additionally, each participant received a show up fee of 2.50 Euro independent of the outcome of the game. After the final round, the subjects were requested to complete a questionnaire including questions on gender, age, loss aversion and inequity aversion. Furthermore, the questionnaire contained questions concerning the risk attitude of the subjects. These questions were taken from the German Socio Economic Panel (GSOEP) and deal with the overall risk attitude of a subject.

The language was kept neutral at any time. For example, we did not use terms like "favorite" and "underdog", or "player $F$" and "player $U$", but instead spoke of "player $A$" and "player $B$". Moreover, we simply described the pure random draw out of the two alternative intervals without speaking of low or high risk. Instead favorites chose between "alternative 1" and "alternative 2".

# 5 Hypotheses

We tested seven hypotheses, six of them deal with the risk behavior and one of them with the players' behavior at the effort stage.

The first three hypotheses directly test the relevance of the reversed likelihood effect, the effort effect and the likelihood effect at stage 1 of the game. Since we designed three different constellations by changing one of the cost parameters, respectively, each effect could be separately analyzed in a single treatment. The effort treatment was obtained from the reversed likelihood treatment by increasing the favorite's cost parameter, whereas the design of the likelihood treatment results from increasing the underdog's cost parameter in the reversed likelihood treatment.

**Hypothesis 1:** *In the reversed likelihood treatment, (most of) the favorites choose the high risk.*

**Hypothesis 2:** *In the effort treatment, (most of) the favorites choose the high risk.*

**Hypothesis 3:** *In the likelihood treatment, (most of) the favorites choose the low risk.*

In a next step, we compared the risk choices in the different treatments. We expected that risk taking clearly differs among the three treatments. The corresponding behavioral hypotheses can be described as follows:

**Hypothesis 4:** *The favorites' risk taking in the effort treatment does not differ from that in the reversed likelihood treatment.*[8]

**Hypothesis 5:** *The favorites choose higher risk in the reversed likelihood treatment than in the likelihood treatment.*

**Hypothesis 6:** *The favorites choose higher risk in the effort treatment than in the likelihood treatment.*

Finally, we tested the players' effort choices at the second stage of the game. Since in any equilibrium at the effort stage the favorite does not choose less effort than the underdog, we have the following hypothesis:

**Hypothesis 7:** *The favorites choose at least as much effort as the underdogs.*[9]

[8] Of course, we cannot test whether risk taking is identical in both treatments, but we can test whether significant differences between the treatments do exist.

[9] Our hypotheses are stated in terms of "higher" risk and effort, but tests will deal with the frequency of the appearence of the two risk and effort levels. However, the interpretation does not change. If we observe, for example, that there is a significant higher proportion of favorites than underdogs choosing the high effort level, this also means that the average effort chosen by the favorites is higher.

# 6 Experimental Results

## 6.1 The Risk Stage

We tested the hypotheses with the data from our experiment, starting with Hypotheses $1-3$. Contrary to the reversed likelihood treatment, the findings on the favorites' risk choices in the effort and the likelihood treatments are in line with our theoretical predictions on average (see Figure A1 in the Appendix): favorites more often choose high risk (low risk) than low risk (high risk) in the effort treatment (likelihood treatment). However, when applying the one-tailed Binomial test we cannot reject the hypothesis that favorites randomly choose between high and low risk in the effort treatment in the first round. To check whether we can pool the data over all rounds, we ran different regressions (see Tables A1 to A3 in the Appendix). As the subjects play the game 5 times the observations are not independent from each other. Therefore, we computed robust standard errors clustered by subjects and checked for learning effects by including round dummies. We do not find any significant learning effects over time in all treatments since there is no significant influence of a certain round on risk taking. Additionally, we compared risk taking in round 1 with the risk taking of rounds $2-5$ for each treatment but did not find significant differences. We think that the relatively long testing phase of 10 rounds at the beginning of the experiment helped the subjects to study the consequences of different strategies. If there were any learning effects, these should only be relevant in the test phase. Thus, we pooled our data over the 5 rounds. In the following we present the results of the first round and additionally our results with pooled data.
The results of the one-tailed Binomial tests concerning Hypotheses 1 to 3 can be summarized as follows:[10]

[10] Table entries indicate the predicted risk choices.

| risk choice | reversed likelihood treatment | effort treatment | likelihood treatment |
|---|---|---|---|
| first round | high risk | high risk | low risk** |
| pooled data | high risk | high risk | low risk*** |

(*$0.05 < \alpha \leq 0.1$; **$0.01< \alpha \leq 0.05$; ***$\alpha \leq 0.01$)

**Table 1:** Results on risk taking (one-tailed Binomial tests)

**Observation on Hypotheses 1 to 3:** *Favorites more often choose low risk than high risk in the likelihood treatment, whereas the findings on high risk taking in the reversed likelihood and the effort treatments are not significant.*

In a next step, we pairwise compared the three treatments.

**Observation on Hypothesis 4:** *Favorites' risk taking in the effort treatment significantly differs from that in the reversed likelihood treatment* (Fisher test, two-tailed; first round: $\alpha \leq 0.01$; pooled data: $\alpha \leq 0.01$)

Whereas the Binomial test shows that favorites do not prefer high risk significantly more than low risk in the effort treatment, the relative comparison supports the initial impression from Figure A1: in the effort treatment, *t*he proportion of favorites choosing the high risk is higher than in the reversed likelihood treatment so that Hypothesis 4 can be clearly rejected. Therefore, the effort effect seems to be more relevant for subjects when choosing risk than the reversed likelihood effect. In addition, we ran a probit regression, using our pooled data set (see Table A1 in the Appendix). Here, the dummy variable for the effort treatment is highly significant which confirms our result from the Fisher test.

**Observation on Hypothesis 5:** *Favorites' risk taking in the reversed likelihood treatment is not significantly higher than that in the likelihood treatment* (one-tailed Fisher test).

The observation on Hypothesis 5 holds for the first round as well as for the pooled data set and is in line with our previous findings: in the likelihood treatment, favorites choose low risks as theoretically expected. Since, contrary to theory, they also often choose low risk in the reversed likelihood treatment, risk taking is not significantly higher in the reversed likelihood treatment. Again, we ran a probit regression with the pooled data, but did not find a significant result for the treatment dummy (see Table A2 in the Appendix).

**Observation on Hypothesis 6:** *Favorites' risk taking is significantly higher in the effort treatment than in the likelihood treatment* (Fisher test, one-tailed; first round: $0.01 < \alpha \leq 0.05$; pooled data: $\alpha \leq 0.01$)

Again, the Fisher test supports the general impression of Figure A1: favorites choose significantly higher risk in the effort treatment compared to the risk behavior in the likelihood treatment. Further confirmation comes from a respective probit regression (see Table A3 in the Appendix). Note that all three probit regressions show that risk aversion does not have a significant influence on the favorites' risk taking.

## 6.2 The Effort Stage

Given the favorite's risk choice at stage 1, the underdog and the favorite have to decide on their efforts at the second stage of the game. According to the subgame perfect equilibria, we would expect that the favorite chooses a higher effort level than the underdog in the reversed likelihood and the likelihood treatments, whereas both players' efforts should be the same in the effort treatment. Altogether, favorites should exert more effort than underdogs on average.[11]

Recall that in the reversed likelihood and the effort treatments different risk levels lead to different equilibria at the effort stage. Since both risk levels have been chosen at stage 1, we can test whether players rationally react to a given risk level. An overview on the aggregate effort choices is given by Figures A2 to A10 in the Appendix: in the reversed likelihood treatment, the favorite should always choose the large effort level independent of given risk, whereas the underdog should prefer small (large) effort if risk is high (low). Figures A2 to A4 show that the experimental findings are roughly in line with our theoretical predictions. For high risk, the subjects even perfectly react to given risk in round 5 – all underdogs choose low effort, but all favorites prefer the high effort level. In the effort treatment, theory predicts that both types of players choose small efforts under high risk, but large efforts under low risk. Figures A5 to A7 illustrate that subjects on average indeed react as predicted. Interestingly, favorites are more sensitive to risk than underdogs although subjects change their roles after each round. In the likelihood treatment, for both risk levels favorites (underdogs) should choose large (small) effort. As for the risk stage, in the likelihood treatment subjects' behavior seems to follow theoretical predictions also most closely when choosing effort, compared to the other treatments (see Figures A8 to A10).

Next, we used a one-tailed Binomial test to check if most of the subjects of a certain type choose the predicted effort level under a given risk against the hypothesis that subjects randomly decide between the two effort levels. Again, we can pool our data over the 5 rounds because regressions including round dummies (see Tables A4 to A6 in the Appendix) as well as tests comparing the effort in round 1 with the effort of rounds $2-5$ for a certain

[11] Uneven tournaments in the notion of O'Keeffe *et al.* (1984) were also considered in the experiments by Bull *et al.* (1987), Schotter and Weigelt (1992) and Harbring *et al.* (2007). In each experiment, favorites choose significantly higher effort levels than underdogs.

type and certain risk do not reveal any significant learning effects at the effort stage. The following table presents all first-round observations and the results for pooled data (a table entry illustrates the predicted effort level):

| | player: data | reversed likelihood treatment | effort treatment | likelihood treatment |
|---|---|---|---|---|
| high risk | $F$: 1st round | $e_F = 1$ | $e_F = 0^{**}$ | $e_F = 1$ |
| | $F$: pooled | $e_F = 1^{***}$ | $e_F = 0^{***}$ | $e_F = 1^{***}$ |
| | $U$: 1st round | $e_U = 0^{*}$ | $e_U = 0$ | $e_U = 0^{**}$ |
| | $U$: pooled | $e_U = 0^{***}$ | $e_U = 0$ | $e_U = 0^{***}$ |
| low risk | $F$: 1st round | $e_F = 1^{***}$ | $e_F = 1$ | $e_F = 1^{***}$ |
| | $F$: pooled | $e_F = 1^{***}$ | $e_F = 1^{***}$ | $e_F = 1^{***}$ |
| | $U$: 1st round | $e_U = 1$ | $e_U = 1^{*}$ | $e_U = 0^{*}$ |
| | $U$: pooled | $e_U = 1$ | $e_U = 1^{**}$ | $e_U = 0^{***}$ |

($^{*}0.05 < \alpha \leq 0.1$; $^{**}0.01 < \alpha \leq 0.05$; $^{***}\alpha \leq 0.01$)

**Table 2:** Results on effort choices (one-tailed Binomial tests)

The column corresponding to the reversed likelihood treatment reveals that favorites' reactions to risk taking is quite in line with theory as they choose high efforts for both risk levels. However, the underdogs' behavior is not significantly different from a random draw under low risk, but in line with the theoretical prediction under high risk. The column for the effort treatment confirms the initial impression from Figures A5 to A7. Whereas favorites react fairly well to different risk levels, the underdogs often choose high efforts even under high risk, which contradicts theory. The last column reports the findings for the likelihood treatment. Our results point out that subjects behave rationally at the effort stage with the exception of the favorites' effort choices in the first round given high risk.

Finally, we tested the favorites' effort choices against the underdogs' behavior. We either used a one-tailed Fisher test to check if the proportion of favorites choosing the high effort is significantly larger than that of the underdogs if theory predicts a higher effort level of the favorite ($e_F > e_U$), or a two-tailed Fisher test to check if there are any (unpredicted) differences between the proportion of types in the two effort categories. We have differentiated between three cases when comparing efforts – ignoring the given risk level (first panel of the table), only considering high-risk situations (second panel), only considering low-risk situations (third panel):

| | data | reversed likelihood treatment | effort treatment | likelihood treatment |
|---|---|---|---|---|
| both risks | $1^{st}$ round | one-tailed*** | two-tailed | one-tailed*** |
| | pooled | one-tailed*** | two-tailed | one-tailed*** |
| high risk | $1^{st}$ round | one-tailed* | two-tailed | one-tailed** |
| | pooled | one-tailed*** | two-tailed*** | one-tailed*** |
| low risk | $1^{st}$ round | two-tailed | two-tailed | one-tailed*** |
| | pooled | two-tailed*** | two-tailed | one-tailed*** |

(*$0.05 < \alpha \leq 0.1$; **$0.01 < \alpha \leq 0.05$; ***$\alpha \leq 0.01$)

**Table 3:** Results on effort comparisons (Fisher test)

Following the theoretical predictions, in the reversed likelihood treatment favorites should only exert more effort than underdogs if risk is high. The second panel of the table fits well with this prediction for the first round and pooled data, but according to the third panel subjects' behavior seems to be even different under low risk: considering the pooled data, favorites choose a significantly different effort than underdogs, thus contradicting theory. Inspecting the data reveals that the proportion of favorites choosing the high effort is even significantly higher than the respective proportion of underdogs under low risk. In both the effort treatment and the likelihood treatment, the effort difference $e_F - e_U$ should be independent of the risk level. $e_F - e_U$ should be zero under the effort treatment, but strictly positive under the likelihood treatment. Again, the findings for the likelihood treatment are pretty in line with theory. For the effort treatment, the second panel of the table shows that the different types of players choose significantly different effort levels under high risk (pooled data). Here, the underdogs exert clearly more effort than the favorites which is in line with our observations in Figures A5 and A7 and the findings for the Binomial test, but contrary to theory.

Finally, we ran probit regressions on the effort comparison between favorites and underdogs for the three different treatments (see Tables A4 to A6 in the Appendix). The regression results clearly support our findings for the Fisher test: whereas the player-type dummy is (highly) significant and in line with theory for the reversed likelihood and the likelihood treatments, it is not significant or even significantly different from theoretical predictions in the effort treatment. Furthermore, we checked if a player's risk attitude influences his behavior at the effort stage. However, only in 1 out of 6 regressions (reversed likelihood treatment under low risk) the risk aversion dummy is weakly significant and positive.

Altogether, we can summarize our findings for the effort stage as follows:

**Observation on Hypothesis 7:** *In the reversed likelihood treatment and the likelihood treatment, favorites choose significantly more effort than underdogs. In the effort treatment, players' behavior does not significantly differ given low risk, but for high risk underdogs exert clearly more effort than favorites.*

# 7 Discussion

The experimental results of Section 6 point to three puzzles, which should be discussed in the following: (1) favorites choose significantly more often the low risk than the high risk in the reversed likelihood treatment; (2) given low risk in the reversed likelihood treatment, favorites exert significantly more effort than underdogs; (3) given high risk in the effort treatment, underdogs choose significantly more effort than favorites.

Inspection of the players' beliefs concerning their opponents' efforts shows that puzzles (1) and (2) seem to be interrelated. It turns out that in the low-risk state of the reversed likelihood treatment, favorites' equilibrium beliefs differ from their reported beliefs in each of the five rounds of the repeated game. In the first and in the last round, 11 out of 23 favorites expect underdogs to choose a low effort level although theory predicts a high effort choice. The proportion of favorites with this belief is even higher in round 2 (10 out of 18), round 3 (10 out of 20) and round 4 (12 out of 21). Actually, about one half of the underdogs choose a low effort. Given that the favorites already had these beliefs when taking risk at stage 1, both puzzles (1) and (2) can be easily explained together: now, a favorite expecting a low effort by an underdog in both a low-risk and a high-risk state, should unambiguously prefer a high effort level in both states. The results of our Binomial test from Subsection 6.1 shows that indeed favorites highly significantly react in this way. This explains puzzle (2). When the favorites decide on risk taking at stage 1 and anticipate $(e_U, e_F) = (0, 1)$ under both risks, the underlying reversed likelihood problem turns into a perceived likelihood problem from the viewpoint of the favorites.[12] Given a perceived likelihood problem, the favorites should optimally choose a low risk in order to maximize their winning probability (see Figure 1), which explains puzzle (1).

Concerning puzzle (3), inspection of the players' beliefs does not lead to clear results. Similarly, controlling for risk aversion, loss aversion, inequity aversion and the history of the game does not yield new insights either. Most surprisingly seems to be the missing explanatory power of the players' history in the game: intuitively, subjects might react to the outcomes of

[12] See also the observation on Hypothesis 5 in Subsection 6.1.

former rounds when choosing effort in the actual round. However, our results do not show a clear impact of experienced success or failure in previous tournaments. Maybe, underdogs react too strongly to the close competition with the favorites. In the effort treatment, costs for exerting high effort were $c_U = 24$ and $c_F = 22$. Hence, the cost difference is rather small – in particular compared to the two other treatments –, and the underdogs might have chosen high efforts due to perceived homogeneity in the tournament. The underdogs' beliefs about the favorites' effort choices indicate that this effect might be relevant under high risk. In the first and third round, 7 (out of 18 and 15 respectively), and in the fourth round 8 (out of 19) underdogs expect favorites to choose high efforts, too.[13] However, in the concrete situation given $\sigma^2 = \sigma_H^2$ and $e_F = 1$, an underdog should prefer $e_U = 1$ to $e_U = 0$ if and only if $\frac{\Delta w}{2} - c_U > \Delta w G\left(-\Delta e; \sigma_H^2\right) \Leftrightarrow \Delta G\left(\sigma_H^2\right) \Delta w > c_U$, and for our chosen parameter values this condition (12.5 Talers > 24 Talers) is clearly violated.[14] To sum up, as we can see from Figures A5 and A6 underdogs reduce their efforts when risk increases, which is qualitatively in line with the effort effect, but it remains puzzling why underdogs do not react as strong as favorites to different risks although subjects change their roles after each round in the experiment.

# 8 Conclusion

In many winner-take-all situations, players first decide whether to use a more or less risky strategy and then choose their investments or efforts. In this case, risk taking at the first stage of the game determines both the optimal investment or effort levels at stage two and the players' likelihood of winning

[13] In the other two rounds the proportion of underdogs who believe the favorite to choose the high effort is somewhat lower: second round: 3 out of 13; last round: 4 out of 17.

[14] Note that in terms of converted money payments, subjects have to compare 1.25 Euro to 2.40 Euro. Given $e_F = 0$, high effort would only be rational for the underdog if 10 Euro > 19.20 Euro which is clearly not satisfied.

the competition. We find three effects that mainly determine risk taking – an effort effect, a likelihood effect, and a reversed likelihood effect. Our experimental findings point out that the impact of risk taking on the likelihood of winning (i.e. the likelihood effect) is very important for subjects at stage one. Moreover, also optimal investments for given risk are clearly in line with theory under the likelihood effect. Furthermore, in most of the rounds even the beliefs of the favorites seem to follow the theoretical beliefs in the likelihood treatment. Moreover, the beliefs of the underdogs are in line with the theory in all rounds. We obtain mixed results for the effort effect and the reversed likelihood effect, but pairwise comparison of treatments reveals that the effort effect seems to be more relevant for subjects than the reversed likelihood effect. Interestingly, the players very often react to given risk according to theory when investing into the winner-take-all competition. As a by-product, the results of our questionnaire point to an important finding on the concept of inequity aversion[15] as introduced by Fehr and Schmidt (1999) in the literature. Grund and Sliwka (2005) applied this concept to rank-order tournaments. If one player has a higher (lower) payoff than another player, the first (second) realizes a disutility from compassion (envy). In a tournament, players typically compare their relative payoffs and the tournament winner (loser) will feel some compassion (envy) when being inequity averse. Both Fehr-Schmidt and Grund-Sliwka assumed that envy is at least as strong as compassion. This assumption is central for the results in Grund and Sliwka (2005) since it directly implies that inequity averse contestants exert more effort than players who are not inequity averse. Using a sign test,[16] our findings point out that in each treatment subjects feel significantly more

[15]We used the same two games as Dannenberg *et al.* (2007) to measure the subjects' inequity preferences. In contrast to Dannenberg *et al.* (2007), not all subjects received a payoff for their decisions. After the subjects indicated their decisions, we randomly determined for which game and which row of that particular game two randomly selected subjects received a payoff according to their decisions. Furthermore, the respective player role of the selected subjects was randomly determined.

[16]Subjects with inconsistent behavior were excluded from the analysis.

compassion than envy (one-tailed, reversed likelihood treatment: $\alpha \leq 0.01$, effort treatment: $\alpha \leq 0.01$, likelihood treatment: $\alpha \leq 0.01$).[17] According to this result, inequity aversion would not lead to stronger competition in tournaments. On the contrary, competition would be weakened as any contestant anticipates to suffer from strong compassion in case of winning.

[17] A similar finding is made by Dannenberg *et al.* (2007) running experiments on public good games.

## Appendix

*Proof of Proposition 2:*

(i) We can rewrite (6) as

$$\left(e_U^*, e_F^*\right) = \begin{cases} (e_H, e_H) & \text{if} \quad \Delta w \geq \frac{c_U}{\Delta G(\sigma^2)} \\ (e_L, e_H) & \text{if} \quad \frac{c_U}{\Delta G(\sigma^2)} \geq \Delta w \geq \frac{c_F}{\Delta G(\sigma^2)} \\ (e_L, e_L) & \text{if} \quad \Delta w \leq \frac{c_F}{\Delta G(\sigma^2)}. \end{cases} \tag{6'}$$

Since we have two risk levels, $\sigma_L^2$ and $\sigma_H^2$, there are four cutoffs with $\frac{c_F}{\Delta G\left(\sigma_L^2\right)}$ being the smallest one and $\frac{c_U}{\Delta G\left(\sigma_H^2\right)}$ the largest one because of (5). Hence, both players will always (never) choose high effort levels if $\Delta w \geq \frac{c_U}{\Delta G\left(\sigma_H^2\right)}$ $\left(\Delta w \leq \frac{c_F}{\Delta G\left(\sigma_L^2\right)}\right)$, irrespective of risk taking in stage 1.

(ii) We have to differentiate between two possible rankings of the cutoffs:

$$\begin{array}{ll} \text{scenario 1:} & \dfrac{c_F}{\Delta G\left(\sigma_L^2\right)} < \dfrac{c_F}{\Delta G\left(\sigma_H^2\right)} < \dfrac{c_U}{\Delta G\left(\sigma_L^2\right)} < \dfrac{c_U}{\Delta G\left(\sigma_H^2\right)} \\ \text{scenario 2:} & \dfrac{c_F}{\Delta G\left(\sigma_L^2\right)} < \dfrac{c_U}{\Delta G\left(\sigma_L^2\right)} < \dfrac{c_F}{\Delta G\left(\sigma_H^2\right)} < \dfrac{c_U}{\Delta G\left(\sigma_H^2\right)}. \end{array}$$

If $\Delta w < \min\left\{\frac{c_F}{\Delta G\left(\sigma_H^2\right)}, \frac{c_U}{\Delta G\left(\sigma_L^2\right)}\right\}$, then in both scenarios the choice of $\sigma_L^2$ will imply $\left(e_U^*, e_F^*\right) = (e_L, e_H)$ at stage 2, whereas $\sigma^2 = \sigma_H^2$ will lead to $\left(e_U^*, e_F^*\right) = (e_L, e_L)$. In this situation, $F$ prefers $\sigma^2 = \sigma_L^2$ since

$$\Delta w G\left(\Delta e; \sigma_L^2\right) - c_F > \frac{\Delta w}{2} \Leftrightarrow \Delta w > \frac{c_F}{\Delta G\left(\sigma_L^2\right)}$$

is true. However, $U$ prefers $\sigma^2 = \sigma_H^2$ because of

$$\frac{\Delta w}{2} > \Delta w G\left(-\Delta e; \sigma_L^2\right).$$

If $\Delta w > \max\left\{\frac{c_F}{\Delta G\left(\sigma_H^2\right)}, \frac{c_U}{\Delta G\left(\sigma_L^2\right)}\right\}$, then in both scenarios the choice of $\sigma_L^2$

will result into $(e_U^*, e_F^*) = (e_H, e_H)$ at stage 2, but $\sigma^2 = \sigma_H^2$ will induce $(e_U^*, e_F^*) = (e_L, e_H)$. In this case, player $F$ prefers the high risk $\sigma_H^2$ since

$$\Delta w G\left(\Delta e; \sigma_H^2\right) - c_F > \frac{\Delta w}{2} - c_F.$$

Player $U$ has the same preference because

$$\Delta w G\left(-\Delta e; \sigma_H^2\right) > \frac{\Delta w}{2} - c_U \Leftrightarrow \frac{c_U}{\Delta G\left(\sigma_H^2\right)} > \Delta w$$

is true.

Two cases are still missing. Under scenario 1, we may have that

$$\frac{c_F}{\Delta G\left(\sigma_H^2\right)} < \Delta w < \frac{c_U}{\Delta G\left(\sigma_L^2\right)}.$$

Then any risk choice leads to $(e_U^*, e_F^*) = (e_L, e_H)$ at stage 2 and $F$ prefers $\sigma_L^2$ because of

$$\Delta w G\left(\Delta e; \sigma_L^2\right) - c_F > \Delta w G\left(\Delta e; \sigma_H^2\right) - c_F,$$

but $U$ favors $\sigma_H^2$ since

$$\Delta w G\left(-\Delta e; \sigma_H^2\right) > \Delta w G\left(-\Delta e; \sigma_L^2\right).$$

Under scenario 2, we may have that

$$\frac{c_U}{\Delta G\left(\sigma_L^2\right)} < \Delta w < \frac{c_F}{\Delta G\left(\sigma_H^2\right)}.$$

Here, low risk $\sigma_L^2$ implies $(e_U^*, e_F^*) = (e_H, e_H)$, but high risk $\sigma_H^2$ leads to $(e_U^*, e_F^*) = (e_L, e_L)$. Obviously, each player prefers the choice of high risk when being active at stage 1. Our findings are summarized in Proposition 2(ii).

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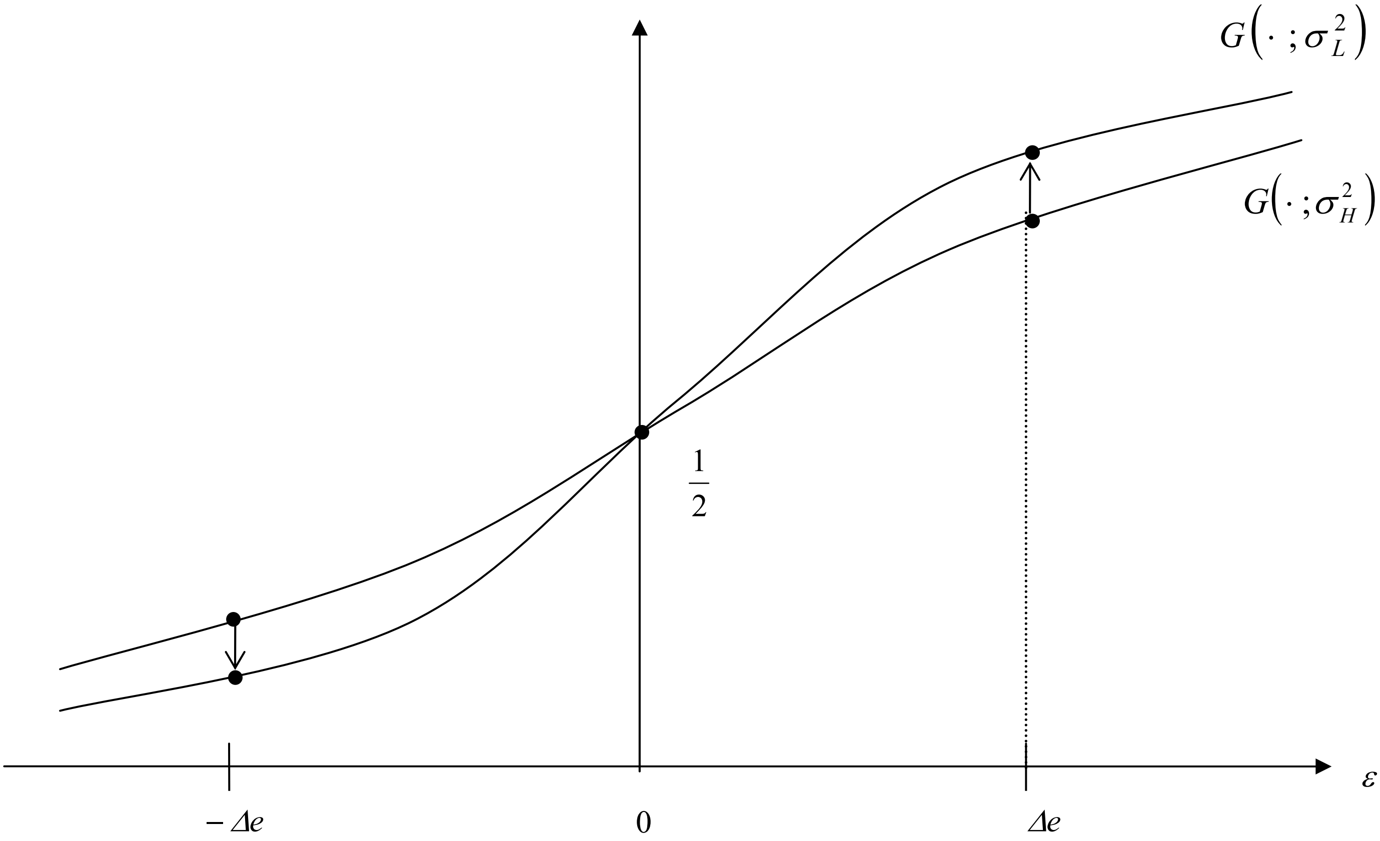



**Figure 1:** likelihood effect

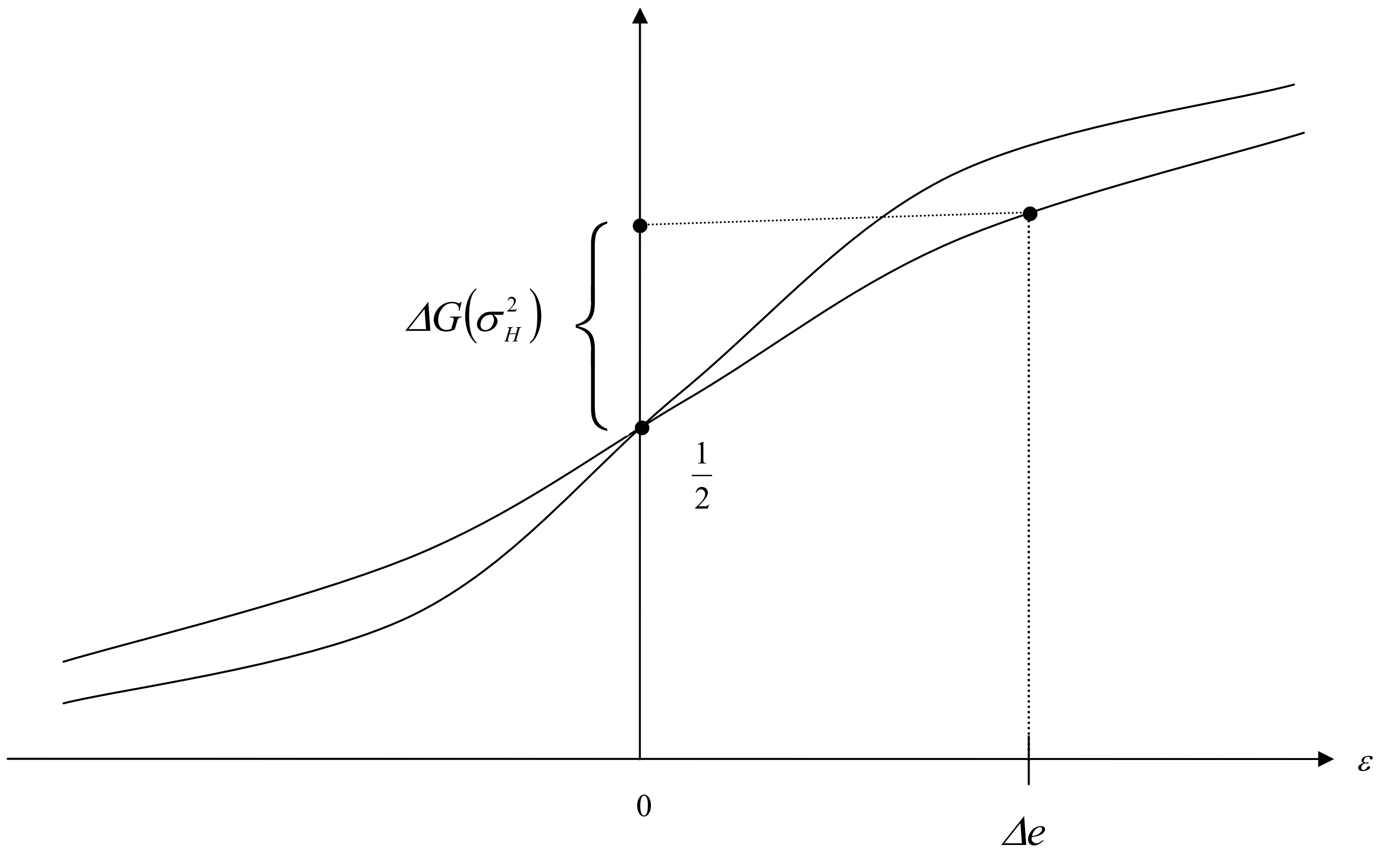
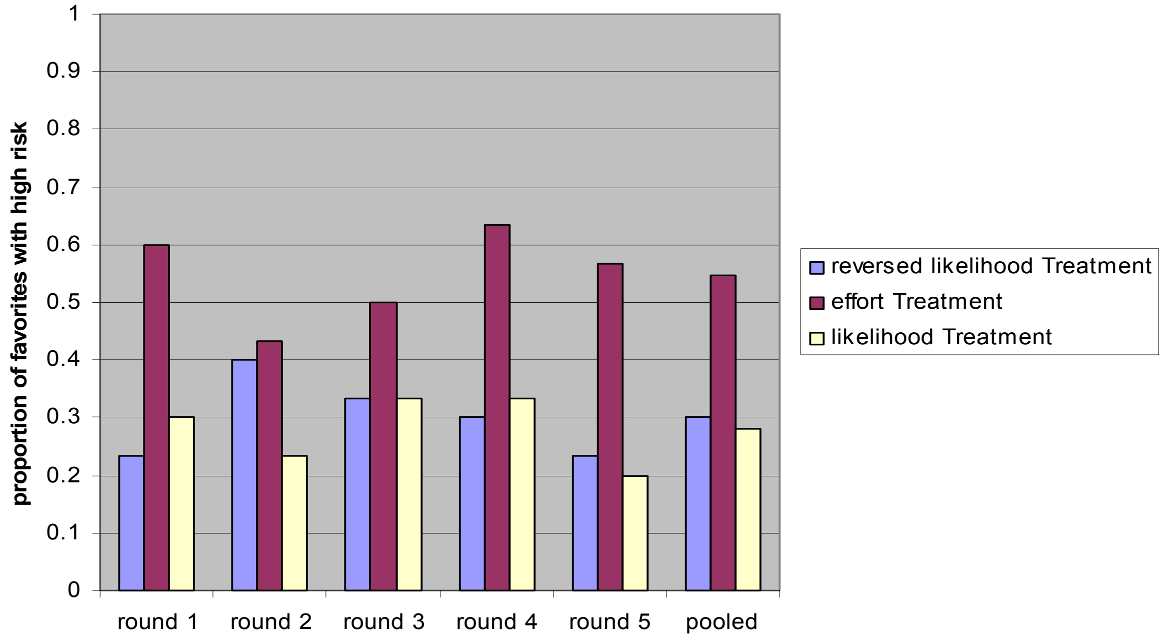



**Figure 2:** reversed likelihood effect




Number of favorites choosing the high risk

| | round 1 | round 2 | round 3 | round 4 | round 5 | pooled |
|---|---|---|---|---|---|---|
| reversed likelihood treatment | 7 out of 30 | 12 out of 30 | 10 out of 30 | 9 out of 30 | 7 out of 30 | 45 out of 150 |
| effort treatment | 18 out of 30 | 13 out of 30 | 15 out of 30 | 19 out of 30 | 17 out of 30 | 82 out of 150 |
| likelihood treatment | 9 out of 30 | 7 out of 30 | 10 out of 30 | 10 out of 30 | 6 out of 30 | 42 out of 150 |

**Figure A1:** Comparison of the favorite's risk choices over treatments

| | (1) | (2) |
|---|---|---|
| Dummy effort Treatment | 0.643*** | 0.621*** |
| | (0.20) | (0.20) |
| Dummy risk aversion | | -0.144 |
| | | (0.21) |
| Dummy Round 2 | 0.00849 | -0.00352 |
| | (0.24) | (0.24) |
| Dummy Round 3 | 0.00517 | 0.00442 |
| | (0.20) | (0.20) |
| Dummy Round 4 | 0.136 | 0.126 |
| | (0.17) | (0.17) |
| Dummy Round 5 | -0.0449 | -0.0494 |
| | (0.21) | (0.21) |
| Constant | -0.546*** | -0.473** |
| | (0.19) | (0.22) |
| Observations | 300 | 300 |
| Pseudo $R^2$ | 0.0479 | 0.0500 |
| Log Pseudolikelihood | -194.61582 | -194.1782 |

Robust standard errors in parentheses are calculated by clustering on subjects

*** p<0.01, ** p<0.05, * p<0.1

**Table A1:** Probit regression Hypothesis 4

| | (1) | (2) |
|---|---|---|
| Dummy likelihood Treatment | -0.0584 | -0.0580 |
| | (0.22) | (0.22) |
| Dummy risk aversion | | 0.0251 |
| | | (0.22) |
| Dummy Round 2 | 0.145 | 0.147 |
| | (0.24) | (0.24) |
| Dummy Round 3 | 0.192 | 0.192 |
| | (0.19) | (0.19) |
| Dummy Round 4 | 0.146 | 0.148 |
| | (0.19) | (0.19) |
| Dummy Round 5 | -0.161 | -0.161 |
| | (0.23) | (0.23) |
| Constant | -0.593*** | -0.606*** |
| | (0.20) | (0.23) |
| Observations | 300 | 300 |
| Pseudo $R^2$ | 0.0080 | 0.0081 |
| Log Pseudolikelihood | -179.19263 | -179.17939 |

Robust standard errors in parentheses are calculated by clustering on subjects

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

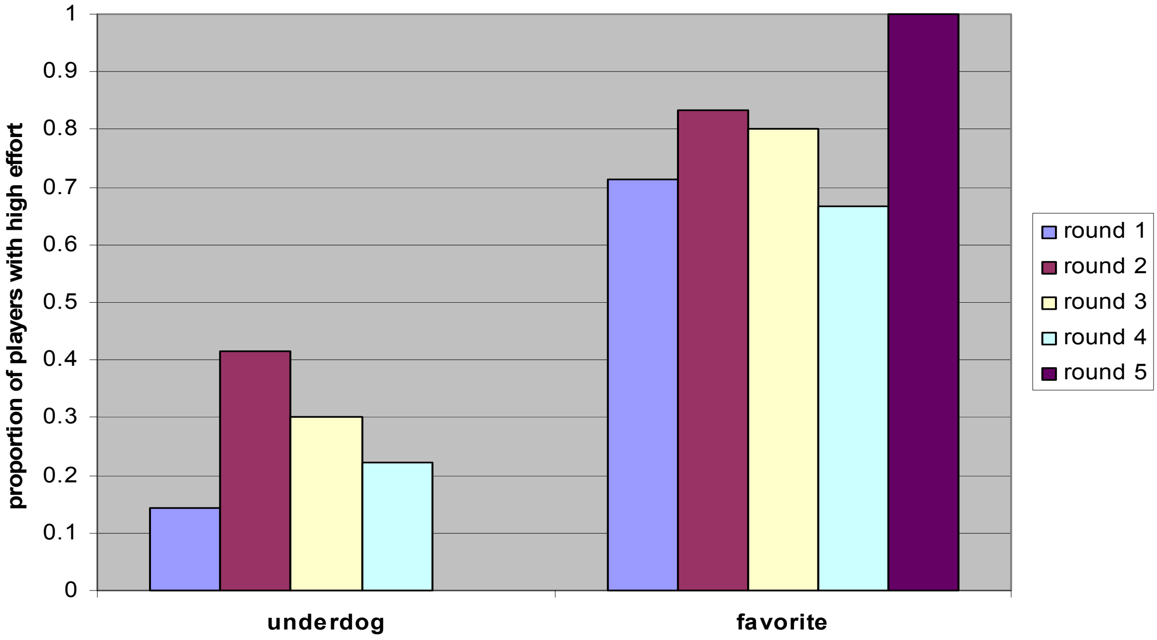
**Table A2:** Probit regression Hypothesis 5

| | (1) | (2) |
|---|---|---|
| Dummy effort Treatment | 0.707*** | 0.701*** |
| | (0.21) | (0.21) |
| Dummy risk aversion | | -0.0431 |
| | | (0.22) |
| Dummy Round 2 | -0.321 | -0.329 |
| | (0.24) | (0.25) |
| Dummy Round 3 | -0.0868 | -0.0902 |
| | (0.19) | (0.19) |
| Dummy Round 4 | 0.0896 | 0.0872 |
| | (0.17) | (0.17) |
| Dummy Round 5 | -0.186 | -0.191 |
| | (0.21) | (0.21) |
| Constant | -0.488** | -0.464** |
| | (0.20) | (0.23) |
| Observations | 300 | 300 |
| Pseudo $R^2$ | 0.0637 | 0.0639 |
| Log Pseudolikelihood | -190.44806 | -190.41028 |

Robust standard errors in parentheses are calculated by clustering on subjects

*** p<0.01, ** p<0.05, * p<0.1

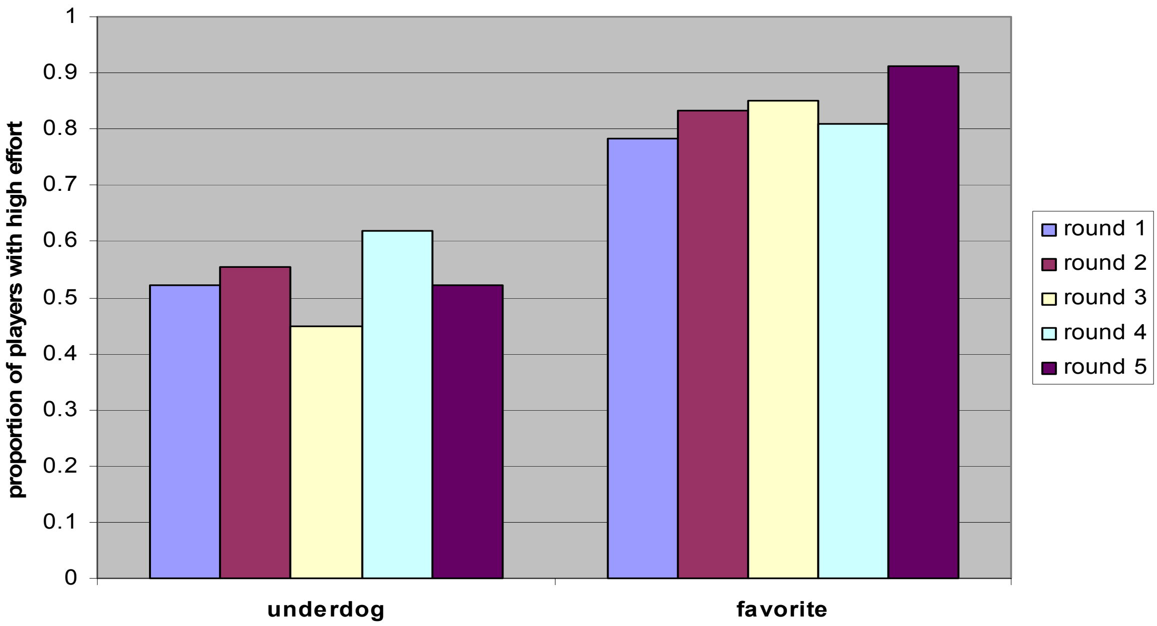
**Table A3:** Probit regression Hypothesis 6




Number of players choosing high effort

| | round 1 | round 2 | round 3 | round 4 | round 5 |
|---|---|---|---|---|---|
| underdog | 1 out of 7 | 5 out of 12 | 3 out of 10 | 2 out of 9 | 0 out of 7 |
| favorite | 5 out of 7 | 10 out of 12 | 8 out of 10 | 6 out of 9 | 7 out of 7 |

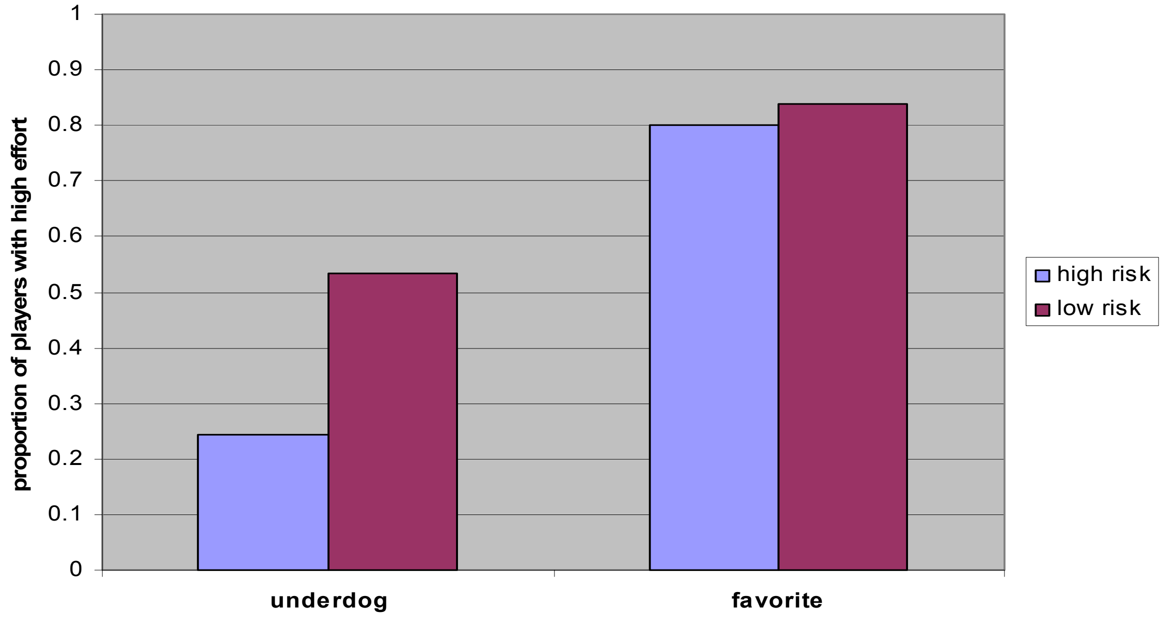
**Figure A2:** Effort choices in the reversed likelihood treatment with high risk




Number of players choosing high effort

| | round 1 | round 2 | round 3 | round 4 | round 5 |
|---|---|---|---|---|---|
| underdog | 12 out of 23 | 10 out of 18 | 9 out of 20 | 13 out of 21 | 12 out of 23 |
| favorite | 18 out of 23 | 15 out of 18 | 17 out of 20 | 17 out of 21 | 21 out of 23 |

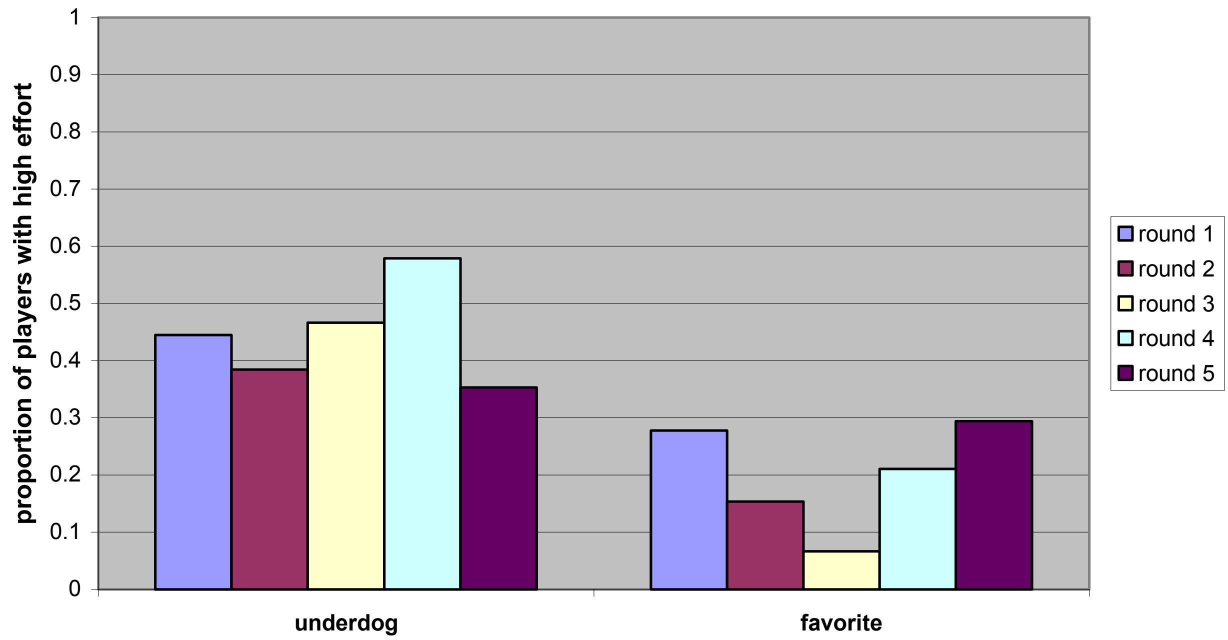
**Figure A3:** Effort choices in the reversed likelihood treatment with low risk




Number of players choosing high effort

| | high risk | low risk |
|---|---|---|
| underdog | 11 out of 45 | 56 out of 105 |
| favorite | 36 out of 45 | 88 out of 105 |

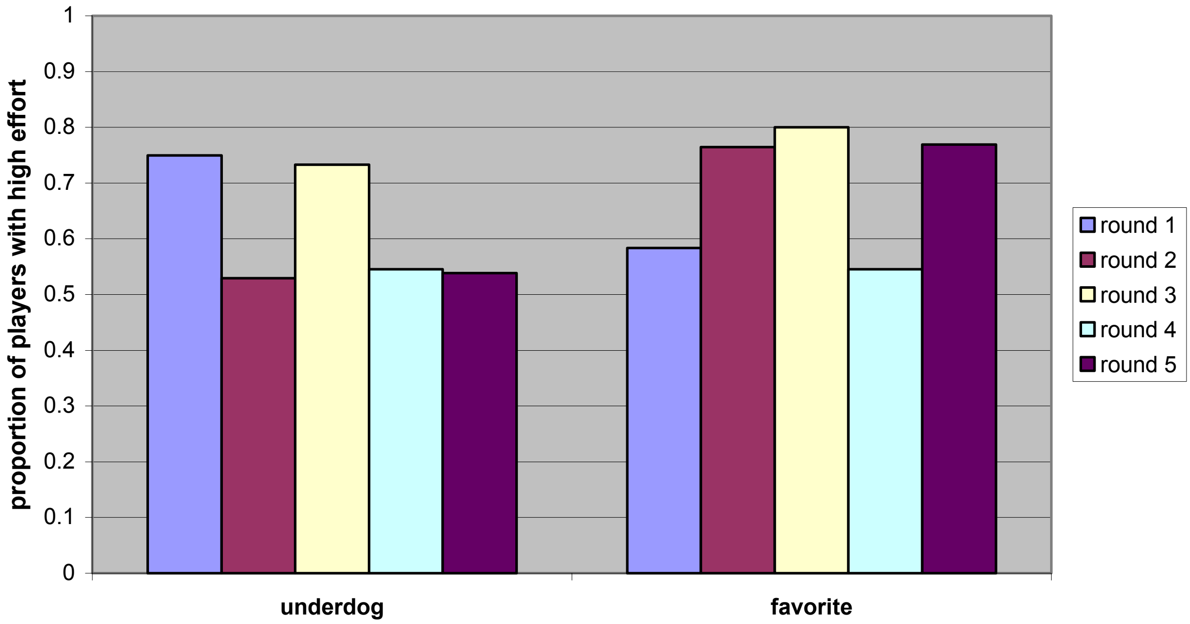
**Figure A4:** Effort choices in the reversed likelihood treatment with pooled data




Number of players choosing high effort

| | round 1 | round 2 | round 3 | round 4 | round 5 |
|---|---|---|---|---|---|
| underdog | 8 out of 18 | 5 out of 13 | 7 out of 15 | 11 out of 19 | 6 out of 17 |
| favorite | 5 out of 18 | 2 out of 13 | 1 out of 15 | 4 out of 19 | 5 out of 17 |

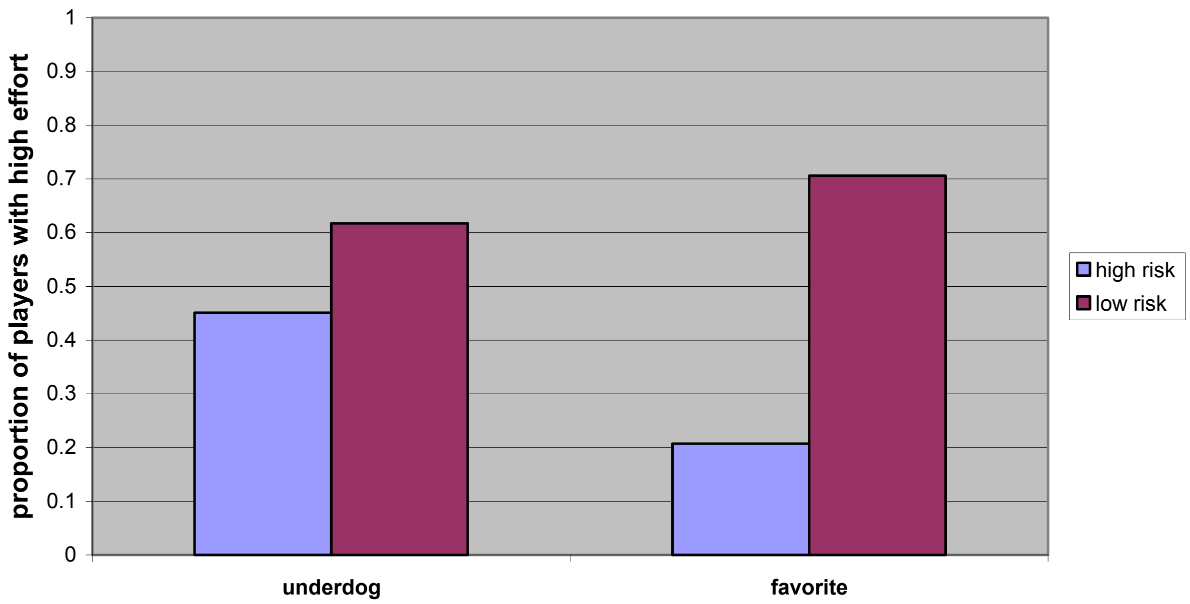
**Figure A5:** Effort choices in the effort treatment with high risk




Number of players choosing high effort

| | round 1 | round 2 | round 3 | round 4 | round 5 |
|---|---|---|---|---|---|
| underdog | 9 out of 12 | 9 out of 17 | 11 out of 15 | 6 out of 11 | 7 out of 13 |
| favorite | 7 out of 12 | 13 out of 17 | 12 out of 15 | 6 out of 11 | 10 out of 13 |

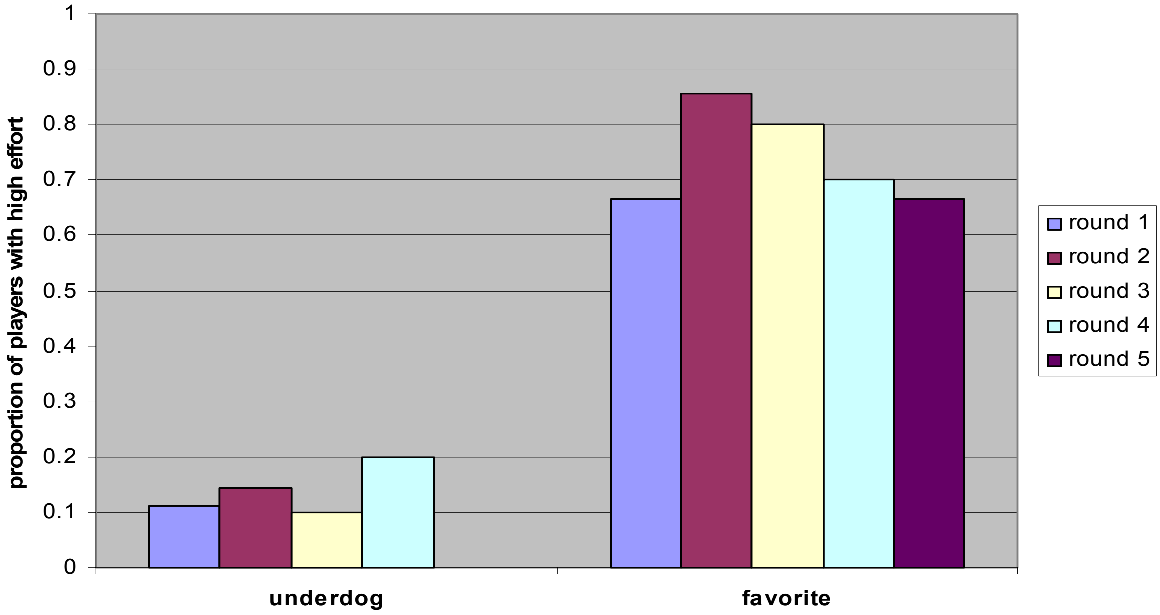
**Figure A6:** Effort choices in the effort treatment with low risk




Number of players choosing high effort

| | high risk | low risk |
|---|---|---|
| underdog | 37 out of 82 | 42 out of 68 |
| favorite | 17 out of 82 | 48 out of 68 |

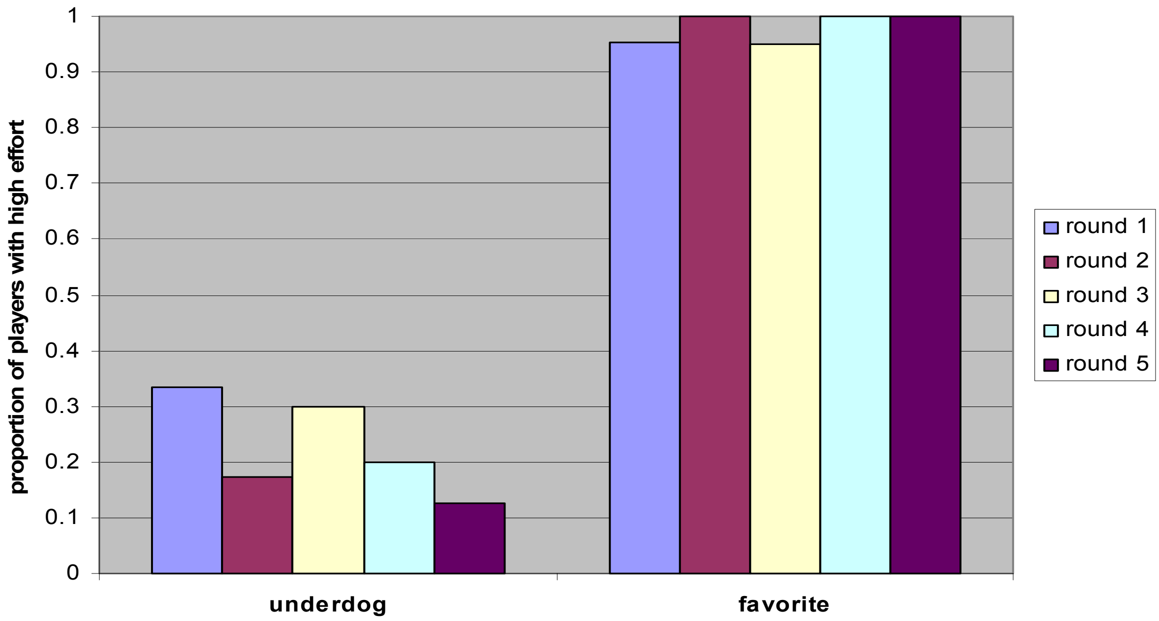
**Figure A7:** Effort choices in the effort treatment with pooled data




Number of players choosing high effort

| | round 1 | round 2 | round 3 | round 4 | round 5 |
|---|---|---|---|---|---|
| underdog | 1 out of 9 | 1 out of 7 | 1 out of 10 | 2 out of 10 | 0 out of 6 |
| favorite | 6 out of 9 | 6 out of 7 | 8 out of 10 | 7 out of 10 | 4 out of 6 |

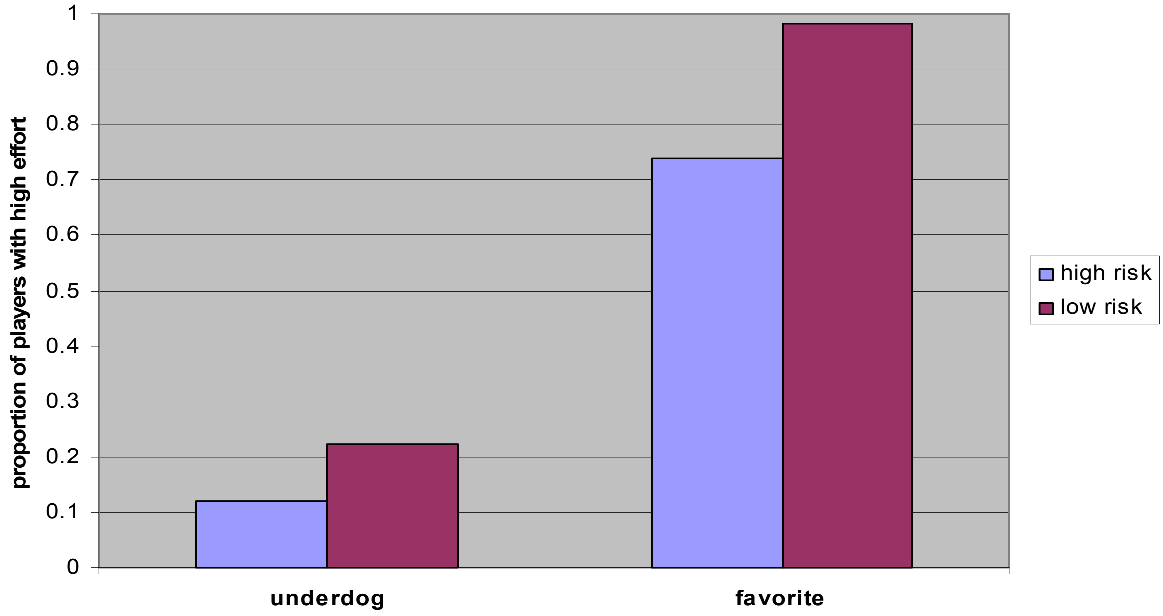
**Figure A8:** Effort choices in the likelihood treatment with high risk




Number of players choosing high effort

| | round 1 | round 2 | round 3 | round 4 | round 5 |
|---|---|---|---|---|---|
| underdog | 7 out of 21 | 4 out of 23 | 6 out of 20 | 4 out of 20 | 3 out of 24 |
| favorite | 20 out of 21 | 23 out of 23 | 19 out of 20 | 20 out of 20 | 24 out of 24 |

**Figure A9:** Effort choices in the likelihood treatment with low risk




Number of players choosing high effort

| | high risk | low risk |
|---|---|---|
| underdog | 5 out of 42 | 24 out of 108 |
| favorite | 31 out of 42 | 106 out of 108 |

**Figure A10:** Effort choices in the likelihood treatment with pooled data

| | High risk | High risk | Low risk | Low risk |
|---|---|---|---|---|
| Dummy Favorite | 1.580*** | 1.601*** | 0.907*** | 0.899*** |
| | (0.33) | (0.33) | (0.25) | (0.26) |
| Dummy risk aversion | | 0.173 | | 0.563* |
| | | (0.38) | | (0.31) |
| Dummy Round 2 | 0.664 | 0.660 | 0.132 | 0.155 |
| | (0.46) | (0.45) | (0.27) | (0.27) |
| Dummy Round 3 | 0.415 | 0.434 | 0.00406 | -0.0234 |
| | (0.39) | (0.40) | (0.21) | (0.21) |
| Dummy Round 4 | 0.0635 | 0.0722 | 0.186 | 0.179 |
| | (0.50) | (0.49) | (0.20) | (0.21) |
| Dummy Round 5 | 0.247 | 0.247 | 0.220 | 0.236 |
| | (0.40) | (0.40) | (0.23) | (0.24) |
| Constant | -1.037*** | -1.134** | -0.0249 | -0.257 |
| | (0.38) | (0.46) | (0.22) | (0.24) |
| Observations | 90 | 90 | 210 | 210 |
| Pseudo $R^2$ | 0.2600 | 0.2626 | 0.0931 | 0.1254 |
| Log Pseudolikelihood | -46.098419 | -45.936982 | -118.55264 | -114.33533 |

Robust standard errors in parentheses are calculated by clustering on subjects

*** p<0.01, ** p<0.05, * p<0.1

**Table A4:** Probit regression Hypothesis 7: reversed likelihood treatment

| | High risk | High risk | Low risk | Low risk |
|---|---|---|---|---|
| Dummy Favorite | -0.704*** | -0.706*** | 0.247 | 0.244 |
| | (0.20) | (0.21) | (0.23) | (0.22) |
| Dummy risk aversion | | 0.262 | | 0.396 |
| | | (0.34) | | (0.34) |
| Dummy Round 2 | -0.281 | -0.263 | -0.0463 | -0.0559 |
| | (0.30) | (0.31) | (0.31) | (0.32) |
| Dummy Round 3 | -0.306 | -0.311 | 0.304 | 0.341 |
| | (0.27) | (0.28) | (0.30) | (0.30) |
| Dummy Round 4 | 0.0858 | 0.0888 | -0.314 | -0.325 |
| | (0.22) | (0.22) | (0.34) | (0.34) |
| Dummy Round 5 | -0.101 | -0.0944 | -0.0278 | -0.0316 |
| | (0.27) | (0.27) | (0.28) | (0.29) |
| Constant | -0.0219 | -0.102 | 0.306 | 0.177 |
| | (0.25) | (0.27) | (0.26) | (0.27) |
| Observations | 164 | 164 | 136 | 136 |
| Pseudo $R^2$ | 0.0641 | 0.0704 | 0.0235 | 0.0389 |
| Log Pseudolikelihood | -97.256424 | -96.602822 | -84.97257 | -83.639756 |

Robust standard errors in parentheses are calculated by clustering on subjects

*** p<0.01, ** p<0.05, * p<0.1

**Table A5:** Probit regression Hypothesis 7: effort treatment

| | High risk | High risk | Low risk | Low risk |
|---|---|---|---|---|
| Dummy Favorite | 1.859*** | 1.877*** | 2.856*** | 2.856*** |
| | (0.35) | (0.35) | (0.36) | (0.35) |
| Dummy risk aversion | | -0.212 | | -0.00462 |
| | | (0.41) | | (0.32) |
| Dummy Round 2 | 0.422 | 0.479 | -0.236 | -0.235 |
| | (0.51) | (0.47) | (0.38) | (0.39) |
| Dummy Round 3 | 0.223 | 0.246 | -0.0915 | -0.0912 |
| | (0.44) | (0.42) | (0.35) | (0.35) |
| Dummy Round 4 | 0.240 | 0.274 | -0.160 | -0.160 |
| | (0.53) | (0.51) | (0.31) | (0.31) |
| Dummy Round 5 | -0.265 | -0.241 | -0.385 | -0.385 |
| | (0.45) | (0.43) | (0.40) | (0.40) |
| Constant | -1.352*** | -1.285*** | -0.592* | -0.590* |
| | (0.44) | (0.48) | (0.31) | (0.32) |
| Observations | 84 | 84 | 216 | 216 |
| Pseudo $R^2$ | 0.3259 | 0.3294 | 0.5415 | 0.5415 |
| Log Pseudolikelihood | -38.67116 | -38.466101 | -66.571261 | -66.571085 |

Robust standard errors in parentheses are calculated by clustering on subjects

*** p<0.01, ** p<0.05, * p<0.1

**Table A6:** Probit regression Hypothesis 7: likelihood treatment

**Instructions** (here: for the reversed likelihood treatment):

## Welcome to this experiment!

You are taking part in an economic decision making experiment. All decisions are anonymous, that means that none of the other participants gets to know the identity of someone having made a certain decision. The payment is also anonymous, that is none of the participants gets to know how much others have earned. Please read the instructions of the experiment carefully. If you do not understand something, look at the instructions again. If you are still having questions then give us a hand signal.

## Overview about the experiment

The experiment consists of 5 rounds. Before the experiment starts, you have the possibility to get familiar with it in ten sample rounds. These sample rounds have no influence on your payment and conduce to a better understanding of the experiment.
Each round consists of two stages: **Stage 1 and Stage 2**. In each round of the experiment you play together with a second person. All participants are divided into groups of 6 persons, out of which pairs for one round are chosen. If you have played together with a particular person in one round, you cannot meet this person in any further round again. Please notice that you are **only paid for one of the 5 rounds**. The computer randomly selects the round for which you are paid. Therefore please think carefully about your decisions because each round might be selected. Your decisions and the decisions of the other person with whom you play influence your payment. All payments resulting of the experiment are described in the fictitious currency Taler. The **exchange rate** is **1 Euro for 10 Talers**.

In the beginning of the experiment, an amount of 60 Talers will be credited to your experiment account. If you get further payments out of the randomly selected round, they will be added to your account and the whole sum will be paid out. If your payoff from the selected round is negative, it will be offset with your initial payment.

In the experiment there are 2 different player roles, **player role A** (player A in the following) and **player role B** (player B in the following). In the beginning, you are randomly assigned to one of these roles. In each round, you can be assigned to another role. You are then playing with a person who has the other player role. For both persons **a score is counted at the end of each round.** The player's score, depending on the player role, is influenced by several components which are presented in the following:

## <u>In case of player A</u>:

Your score at the end of a round (after stage 2) is calculated as following:

$$\boxed{\textbf{Score A} = \boldsymbol{Z_A + x}}$$

$\boldsymbol{Z_A}$ is a number that you select as player A in stage 2. You can choose between $\boldsymbol{Z_A = 0}$ and $\boldsymbol{Z_A = 1}$. The selected value will be taken into account for the calculation of your score. Dependent on the choice of $\boldsymbol{Z_A}$, several costs occur: If you choose $\boldsymbol{Z_A = 0,}$ this costs you nothing. If you choose $\boldsymbol{Z_A = 1,}$ this costs you $\mathbf{C_A = 8}$ Talers.

## <u>Influence of *x*:</u>

As **player A** you decide **between two alternatives** at **stage 1:**

**<u>Alternative 1</u>:**

If you choose **alternative 1**, *x* is randomly selected out of the interval from -2 to 2 (each value between -2 and 2 has the same probability). The randomly chosen *x* is specified on two decimal places.

**<u>Alternative 2</u>:**

If you choose **alternative 2**, *x* is randomly selected out the interval from -4 to 4 (each value between -4 and 4 has the same probability). The randomly chosen *x* is specified on two decimal places.

The randomly selected *x* influences your score at stage 2 (see above).

**<u>In case of player B</u>:**

If you act as player B, you do not make any decision in stage 1.

Your score at the end of stage 2 is calculated as following:

$$\boxed{\textbf{Score B} = \boldsymbol{Z_B}}$$

$\boldsymbol{Z_B}$ is a number that you select at stage 2. You can choose between $\boldsymbol{Z_B = 0}$ and $\boldsymbol{Z_B = 1}$. The selected value will be taken into account for the calculation of your score. If you choose $\boldsymbol{Z_B = 0}$**,** this costs you nothing. If you choose $\boldsymbol{Z_B = 1}$**,** this costs you $\mathbf{C_B = 24}$ Talers.

At the end of stage 2, the scores of both players are compared. The person with **the higher score** gets **100 Talers**. The other person gets **zero Talers**. If both persons have the same score, the higher one will be determined at random. In any case the costs of a chosen number will be subtracted from the already achieved Talers.

## Course of a round

**<u>Stage 1:</u>**

First you get the following **information**:

- which of the roles A and B is assigned to you
- in case of acting as **player A**: Information about your own costs $\mathbf{C_A}$ which occur if you choose $Z_A = 1$ at stage 2 and about the costs $\mathbf{C_B}$ of the other player that occur if he chooses $Z_B = 1$ at stage 2.
- in case of acting as **player B**: Information about your own costs $\mathbf{C_B}$ which occur if you choose $Z_B = 1$ at stage 2 and about the costs $\mathbf{C_A}$ **..** of the other player that occur if he chooses $Z_A = 1$ at stage 2.

If you act as **player A**, at stage 1 you will be asked which of **the alternatives 1 or 2** you want to choose. After you have selected one of the alternatives, stage 2 of the experiment begins.

**Stage 2:**

At stage 2, both players are **informed** about the chosen **alternative of player A.**

After that, you and the other player are asked what you think, which number Z the other one will choose. **If your guess is correct you will get 15 Talers, otherwise nothing.**

Then both players choose a **number Z**.

- in case of being **player A**, you can choose between $\boldsymbol{Z_A = 0}$ and $\boldsymbol{Z_A = 1}$. This influences your score. If you choose $\boldsymbol{Z_A = 1}$, costs of $\mathbf{C_A}$ occur.
- in case of being **player B**, you can choose between $\boldsymbol{Z_B = 0}$ and $\boldsymbol{Z_B = 1}$. This influences your score. If you choose $\boldsymbol{Z_B = 1}$, costs of $\mathbf{C_B}$ occur.

After that, you and the other player are informed about the decisions and the scores, $x$ is randomly selected and the player with the higher score is announced. In addition, you get informed how many Talers you would earn if this round were selected later. Hence, you get the following information:

**Your score:**
**Score of the other player:**

**The player with the higher score is player___.**
**Your guess was correct/false. Additionally, you would get ___ Talers.**
**Altogether, you would get ___ Talers in this round.**

Then the next round begins with the same procedure. Altogether you play 5 rounds. At the end of round 5, it is randomly chosen which round to be paid out. Thereafter, a questionnaire appears on the screen which you are to answer.

**<u>Overview about the possible payments</u>**:

| **Payment for the player with the higher score:** | **Payment for the player with the lower score:** |
|---|---|
| **100 Talers**<br>**- costs $C_A$ or $C_B$ respectively, if *Z* = 1 was chosen**<br>**+ 15 Talers for a correct guess of the other player's choice of *Z*** | **0 Talers**<br>**- costs $C_A$ or $C_B$ respectively, if *Z* = 1 was chosen**<br>**+ 15 Talers for a correct guess of the other player's choice of *Z*** |

The payments will be added to your experiment account. In addition you are paid 2.50 Euro for participating in our experiment.

Now please answer the comprehension questions below. As soon as all participants have answered them correctly, the 10 sample rounds will start.

Please stay on your seat at the end of the experiment until we invoke your cabin number. Bring this instruction and your cabin number to the front. Only then the payment for your score can begin.

## Thanks a lot for participating and good luck!