Optimal and Fair Prizing in Sequential Round-Robin Tournaments: Experimental Evidence

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Abstract

We experimentally investigate how the prize structure affects the intensity, fairness, and dynamic behavior in sequential round-robin tournaments with three players. We compare tournaments with a second prize equal to either 0%, 50%, or 100% of the first prize. While theory predicts the 50%-treatment to be most intense, we find that aggregate effort is highest in the 0%-treatment. In contrast, our evidence supports the predictions that the 50%-treatment is fairest (though not perfectly fair), whereas the late mover is advantaged in the 100%-treatment and disadvantaged in the 0%-treatment. Also in line with the theory, we identify a strategic (reverse) momentum: after winning the first match, a player increases (decreases) effort in the second match of the 0%-treatment (100%-treatment). Additional findings suggest that dynamic behavior is also subject to a psychological momentum.

Keywords: Sequential Round-Robin Tournament; All-pay Auction; Fairness; Intensity; Strategic Momentum; Experiment

JEL classification: C72, C91, D72, Z20

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1 Introduction

The goals of contest design are diverse. The organizer of a contest often targets at intensity: she may want to maximize productive effort, either on an aggregate level (like in sports or sales contests) or on an individual level (like in R&D races), or minimize wasteful effort (like in rent-seeking). Other frequent objectives are fairness and competitive balance: while contestants with similar characteristics should have similar prospects of success, contests between unequal participants are sometimes required to level the playing field in order to overcome selection biases (like in promotion contests) or increase the interest of third parties (like that of spectators and sponsors of sports, music, and arts competitions). For dynamic battles, which are composed of a sequence of component contests, this also includes the requirement that, e.g., a sports tournament should not be decided before its final match to maintain suspense.

One of the most important features in contest design is the allocation of prizes. While other elements like the contest success function or the dynamic structure are often fixed by the natural or legal environment, the organizer of a contest can frequently allocate prizes from a given pool at her own discretion. The prize structure shapes an incentive scheme that determines the contestants' decisions on entry and effort. It is thus decisive for individual and aggregate investment levels. Moreover, in dynamic contests, like elimination tournaments or races, the allocation of prizes also affects the intertemporal effort decisions and, thereby, the fairness and competitive balance.

One particular form of a dynamic contest is the round-robin tournament, in which participants compete against each other in a sequence of pairwise matches and are ranked according to the number of matches won. Round-robin tournaments are widely used to organize competitions in sports: entire championships, such as the major national football leagues in Europe with up to 20 teams (like in the English Premier League), but also small components of larger tournaments, such as the early rounds (group stages) of the Olympic wrestling tournaments (2000 and 2004) or the second stage of the FIFA World Cup in Spain (1982) with only three contestants per group. While in both of these examples only the first-ranked contestants advanced to the next stage, from 2026 on, the initial group stage of the FIFA World Cups will be organized in the form of round-robin tournaments with three teams per group two of which qualify for the next stage. As a winner of one group will always be matched with a runner-up of a different group at the next stage, ranking first may, however, be more valuable than ranking second. More generally, organizers of round-robin tournaments often employ several rank-dependent prizes.

Despite their frequent use in practice, a formal analysis of round-robin tournaments that accounts for the strategic effects of their dynamics has been neglected until recently. The main theoretical results from the related literature can be summarized as follows. Sequential round-robin tournaments with a *single prize* for the player ranked first are not fair: depending on their position in the sequence of matches, the players have differing ex-ante winning probabilities and expected payoffs (Krumer et al., 2017; Sahm, 2019). The reason is a discouragement effect of trailing players that implies a strategic momentum (see, e.g., Mago et al., 2013) and has been identified in many forms of dynamic contests (Konrad, 2009, Chapter 8). Allowing for *multiple prizes*, Laica et al. (2021) show that no rank-dependent prize structure exists for which sequential round-robin tournaments with more than three players are fair, and round-robin tournaments with three players are fair if and only if the second prize equals half of the first prize. Only in this case, the participant's intertemporal effort decisions are not distorted either: in each single match, they only depend on the players' characteristics but not on the position of the match in the schedule of the tournament. Moreover, in a round-robin tournament with three symmetric players, a second prize equal to half of the first prize will also maximize expected aggregate effort if the discriminatory power of the contest success function that shapes competition on the match-level is sufficiently high.

In this article, we present a laboratory experiment to test how the prize structure influences the intensity, fairness, and dynamics of effort decisions in a sequential round-robin tournament. Three homogeneous players compete against each other in an exogenous sequence of pairwise matches by choosing effort from a given budget. Each single match is organized as an all-pay auction. The players are ranked according to the number of matches won and receive rank-dependent prizes. The third prize is normalized to zero. We compare three different treatments: tournaments with a second prize equal to either 0%, 50%, or 100% of the first prize.

While theory predicts the 50%-tournament (0%-tournament) to be most (least) intense, we find that aggregate effort is highest in the 0%-tournament. The main reason is that the observed discouragement effect for the late mover (player 3) in the 0%-tournament is much weaker than predicted (see also Mago and Sheremeta, 2017, 2019). This result is surprising because previous experimental studies of contest environments, in which multiple prizes are predicted to elicit more aggregate effort than a single prize, mostly support these predictions (see, e.g., Lim et al., 2009; Müller and Schotter, 2010; Freeman and Gelber, 2010). In line with the theory, aggregate effort is lower in the 100%-tournament than in the 50%-tournament, which can be explained by lean-back effects (Laica et al., 2021): if the second prize equals the first prize, a player who has won her first match will lose much of her incentives to provide additional effort in her second match.

We consider three notions of fairness: a tournament induces i) fair payoffs if the players have the same ex ante expected payoffs, ii) a fair ranking if they have the same ex ante expected winnings,[1] and iii) fair matches if they have the same winning probabilities of 1/2 in each single match. Theory predicts that the 50%-treatment is fair on all three accounts, while the late mover (player 3) has a considerable advantage in the 100% treatment, and a disadvantage in the 0% treatment. By and large, we confirm these predictions for the late mover. In contrast, we find that the 50%-tournament is not perfectly fair, as the late mover (player 3) wins less and the first mover (player 1) earns more than the other players and not all matches are fair.

Considering the players' dynamic effort choices, we identify a strategic momentum in the 0%-tournament: after winning (losing) her first match, a player increases (decreases) effort in her second match. Similarly, we observe a reverse strategic momentum in the 100%-tournament: after winning (losing) her first match, a player decreases (increases) effort in her second match. These observations can be explained by the dynamic incentives implied by the respective prize structure. On the other hand, we find mixed evidence on choice dynamics in the 50%-treatment in which strategic effects are absent. While there seems to be a reverse momentum, the changes of effort levels between the first and the second match are below what would be expected from mixed strategy play. We provide complementary analyses to identify the psychological driving forces of these findings. The results point towards a reverse psychological momentum.

[1] This is defined as the sum of the ex ante probabilities to rank first, second, or third multiplied by the first, second, and third prize, respectively, and sometimes referred to as the *weighted qualification probability (WQP)*

The remainder of this article is structured as follows. Section 2 surveys the related literature. Section 3 provides the theoretical foundations. We explain our experimental design and procedures in Section 4 and present our results in Section 5. Section 6 concludes. The online supplementary material contains complementary statistical results and the experimental instructions.

2 Related Literature

Many authors have studied the role of the prize structure in static and dynamic contests. Sisak (2009) and Chowdhury et al. (2020, Chapter 4.4) provide surveys of the related literature. Here, we focus on the most closely related articles with comparable assumptions.

Barut and Kovenock (1998) show that for static all-pay auctions with an arbitrary number of symmetric risk-neutral players, linear costs of effort, and the sum of prize money fixed, all prize structures with a last prize (for the worst performer) of zero yield the same expected aggregate effort. Although this theoretical neutrality result implies, in particular, that a single prize is sufficient to maximize expected aggregate effort, Harbring and Irlenbusch (2003) provide experimental evidence that average effort increases (and the number of zero-bidders decreases) in the number of winner prizes. Moldovanu and Sela (2001) show that a winner-take-all prize structure is also optimal in static all-pay auctions with linear effort costs if players have private information about their (symmetrically distributed) valuations and Müller and Schotter (2010) provide experimental evidence supporting this result.[2] By contrast, if players are ex-ante asymmetric (in their valuations), multiple prizes may be optimal even if effort costs are linear (Glazer and Hassin, 1988; Clark and Riis, 1998; Cohen and Sela, 2008; Dahm, 2018). These findings for static contests already suggest that multiple prizes may be optimal in dynamic contests if the sequential structure implies (ex-interim) asymmetric continuation values, as is the case in sequential round-robin tournaments.

One persistent phenomenon in many forms of dynamic contests is the so-called discouragement effect (Konrad, 2009, Chapter 8): low continuation values undermine the players' incentives to provide effort in early stages. The effect may stem from (ex-interim) asymmetries like, e.g., in races when one player is ahead of the other (Harris and Vickers, 1985). But it may also arise in symmetric structures due to the anticipation that an initial win will only lead to further battles in which much of the rent will be dissipated like, e.g., in elimination contests (Rosen, 1986). It is a stable finding in the theory of dynamic contests that multiple prizes may be suitable to mitigate such discouragement effects. This holds for both, additional prizes or penalties on the level of single component contests in races (see, e.g., Konrad and Kovenock, 2009; Gelder, 2014; Sela and Tsahi, 2020) or multi-stage battles (see, e.g., Sela, 2012; Feng and Lu, 2018; Clark and Nilssen, 2018a,b, 2020, 2021) as well as rank-dependent prizes in elimination tournaments (see, e.g., Rosen, 1986) and round-robin tournaments (see below). There is also some experimental evidence for the predicted impact of different prize structures in races (Mago et al., 2013; Mago and Sheremeta, 2017; Gelder and Kovenock, 2017) and elimination contests (Stracke et al., 2014; Delfgaauw et al., 2015). To the best of our knowledge, however, the role of the prize structure in round-robin tournaments has not yet been investigated in a controlled experiment.

[2]Instead, multiple prizes may be optimal if effort costs are convex or players are risk averse; see, e.g., Fang et al. (2020) and Kalra and Shi (2001).

The reason may be that, despite their frequent use in practice, a formal analysis of round-robin tournaments that accounts for the strategic effects of their dynamics has been neglected until recently. Krumer et al. (2017) and Sahm (2019) consider sequential round-robin tournaments with three or four symmetric players, which are ranked according to the number of matches won, and a single-prize for the player ranked first. Krumer et al. (2017) assume that each single match is organized as an all-pay auction and show that such tournaments are not fair: depending on their position in the sequence of matches, the players have differing ex-ante winning probabilities and expected payoffs.[3] Sahm (2019) assumes that each match is organized as a general Tullock contest (including the perfectly discriminating all-pay auction as a limit case) and shows that the extent and direction of discrimination in the round-robin tournament depend crucially on the discriminatory power of the contest success function that shapes competition on the match level. For round-robin tournaments with three symmetric players and matches organized as all-pay auctions, Krumer et al. (2017) compare two discrete prize structures: if the sequence of matches is exogenous (endogenous), two identical prizes generate more (less) expected aggregate effort than a single prize. Krumer et al. (2020) illustrate that in round-robin tournaments with four players, matches organized as all-pay auctions, and two identical prizes a player may even have adverse ex-interim incentives in the sense that he may prefer losing over winning some match depending on the course of the tournament. Laica et al. (2021) extend the analysis to sequential round-robin tournaments with an arbitrary number of heterogeneous players, matches organized as general Tullock contests, and multiple arbitrary rank-dependent prizes. They show that a tournament with three players is fair if and only if the second prize equals half of the first prize;[4] this prize structure also maximizes expected aggregate effort if matches are organized as all-pay auctions. By contrast, with more than three players, no prize structure exists for which a tournament with a fully sequential exogenous match schedule is fair.[5] Our experimental design allows us to test the main theoretical predictions by Laica et al. (2021) for round-robin tournaments with three players.

Most experimental and empirical studies of behavior in dynamic contests try to identify a so-called momentum. They distinguish between a strategic momentum and a psychological momentum. A strategic momentum arises due to different effort incentives as a result of asymmetric continuation values in component contests. The discouragement effect is an example for a strategic momentum. In contrast, a psychological momentum considers past performance to be causal for the players subsequent behavior. In other words, how a stage was actually reached changes a player's perception as it has a direct effect on confidence, motivation, competitiveness and, thus, effort provision (see, e.g., Meier et al., 2020).

Evidence for a strategic momentum is mixed. In single-prize laboratory experiments with best-of-n races and single matches organized as lottery contests, Mago and Razzolini (2019) and Mago and Sheremeta (2019) find evidence for a strategic momentum. However, in best-of-three races where matches are organized as all-pay auctions, Mago and Sheremeta (2017) find no significant discouragement of a first match loser in the sec-

[3]Based on sports data from mega-events, Krumer and Lechner (2017) provide empirical evidence for such non-fairness results.

[4]Dagaev and Zubanov (2017) show that such a prize structure is capable to entail a fair tournament also if players have no real effort costs but just decide how to split their given resources between their two matches.

[5]As Caglayan et al. (2020) show, though, round-robin tournaments with four players and three rounds, in each of which two matches (organized as lottery contests) take place simultaneously, are ex ante fair.

ond match. Empirical studies on tennis confirm the existence of a strategic momentum (Malueg and Yates, 2010; Gauriot and Page, 2019), whereas Ferrall and Smith Jr. (1999) only find negligible strategic effects in best-of-n races in basketball, baseball, and hockey. When intermediate prizes are introduced, Mago et al. (2013) confirm the existence of a strategic momentum for a first match winner in a best-of-three laboratory experiment where matches are organized as lottery contests. Iqbal and Krumer (2019) empirically investigate best-of-five tennis competitions of nations that include several combinations of pairwise matches and find that intermediate prizes mitigate discouragement effects of trailing nations. We contribute to this literature by identifying a (reverse) strategic momentum also in sequential round-robin tournaments.

A psychological momentum is usually considered as bi-directional affecting both, winners and losers, and as equal-directional meaning that the tendency of an outcome is more likely to be confirmed subsequently: "success breeds success" (see, e.g. Mago et al., 2013; Cohen-Zada et al., 2017; Gauriot and Page, 2018, 2019; Mago and Razzolini, 2019; Meier et al., 2020). In their laboratory experiments, Mago et al. (2013) and Mago and Razzolini (2019) find no evidence for a psychological momentum in best-of-n races where matches are organized as lottery contests. In their empirical studies on basketball and tennis, Gilovich et al. (1985), Morgulev et al. (2019), and Gauriot and Page (2018) find no support for a psychological momentum either. By contrast, Cohen-Zada et al. (2017) and Meier et al. (2020) provide empirical evidence for a psychological momentum in judo and tennis.

Contrary to the "success breeds success" pattern, the opposite effect that falling behind incentivizes laggards is also observed, both in experiments (Eriksson et al., 2009; Gelder and Kovenock, 2017) and field studies (Berger and Pope, 2011). Based on their laboratory experiments, Tong and Leung (2002, p.404) even suggest a "hare-tortoise" decision heuristic for dynamic contests which is in line with reference-dependent objectives in prospect theory (Kahnemann and Tversky, 1979). It can be understood as a reverse psychological momentum in the sense that the trailing player will exert more effort to catch up whereas the leading player slacks off. Similar effects arise in other (field) experiments (Casas-Arce and Martínez-Jerez, 2009; Kuhnen and Tymula, 2012). Fu et al. (2015) find support for this heuristic in a real-effort laboratory experiment on single-prize best-of-three races between two parties.[6] Our experimental findings suggest that the dynamic behavior in sequential round-robin tournaments is also subject to such a reverse psychological momentum.

3 Theoretical Model

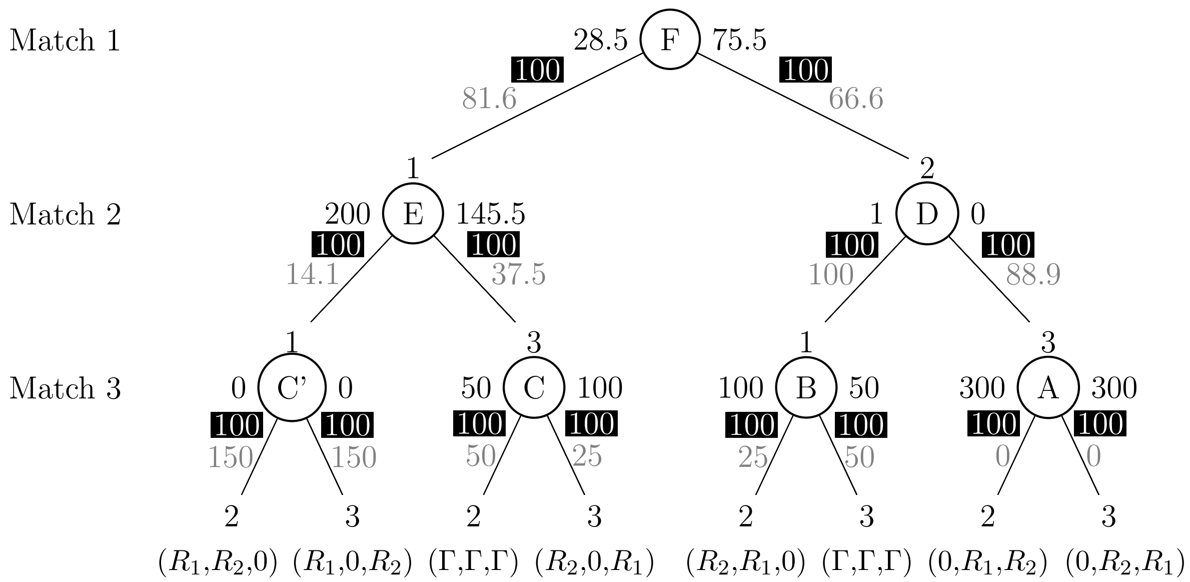
We consider round-robin tournaments with three symmetric, risk-neutral players and an exogenous sequence in which player 1 is matched with player 2 in the first match, player 1 is matched with player 3 in the second match, and player 2 is matched with player 3 in the third match.[7] We abstract from draws: in each match, one player wins and the other player loses. At the end of the tournament, players are ranked in descending order according to the number of matches won and receive rank-dependent prizes (R_j) where

[6] In contrast to the theoretical predictions, they observe that the race is not more likely to end after two than three matches because losers (winners) of the first match increase (decrease) their effort in the second match.

[7] Apart from renaming players, this exogenous sequence is unique. Laica et al. (2021) show that the use of endogenous sequences in which the outcome of the first match determines the order of the two remaining matches leads to similar results.

$R_1 \geq R_2 \geq R_3$. If all three players have won one match, each player receives one of the prizes R_1, R_2, R_3 with probability 1/3 (random tie breaking)[8], which yields an expected payoff of $\Gamma := \sum_j R_j/3$. In our experiment, we have that $R_3 = 0$ and $R_1 + R_2 = 600$ in each tournament of each treatment. Treatments differ by the ratio $a = R_2/R_1 \leq 1$ of the second and third prize.

The structure of the tournament with its $2^3 = 8$ potential courses is depicted in Figure 1. The seven nodes $k \in \{A, \ldots, F\}$ represent all combinations for which the ranking of the tournament has not yet been determined when the respective match starts.



Note: black $\triangleq$ $(a = 0)$; black box $\triangleq$ $(a = 1/2)$; light gray $\triangleq$ $(a = 1)$; $\Gamma := \frac{\sum_j R_J}{3}$.

Figure 1: Tournament Structure and Expected Efforts

Each match of the tournament is organized as an all-pay auction between two players, A and B, with linear costs of effort, see e.g. Konrad (2009, Chapter 2.1). More specifically, player i's probability of winning match k against player j is

$$p_i^k = \begin{cases} 0 & \text{if } x_i^k < x_j^k, \\ 1/2 & \text{if } x_i^k = x_j^k, \\ 1 & \text{if } x_i^k > x_j^k, \end{cases}$$

where x_i^k denotes the effort of player $i \in \{1, 2, 3\}$ in match k. Player i chooses x_i^k in order to maximize his expected payoff

$$E\pi_i^k = p_i^k \left(w_i^k - x_i^k\right) + \left(1 - p_i^k\right)\left(\ell_i^k - x_i^k\right), \tag{1}$$

where w_i^k (ℓ_i^k) denotes player i's expected continuation payoff from winning (losing) match k with $w_i^k \geq \ell_i^k \geq 0$. If $w_i^k > \ell_i^k$ for both players $i, j \in \{1, 2, 3\}$, $i \neq j$ involved in match k, a Nash equilibrium (in mixed strategies) exists and has the following properties (Krumer et al., 2017, 2019; Laica et al., 2021):[9] For $i, j \in \{1, 2, 3\}$ with $i \neq j$ and $w_i^k - \ell_i^k \leq w_j^k - \ell_j^k$,

[8]For risk-neutral players, the tie breaking rule is equivalent to the assumption that the aggregate prize money $1 + a$ is shared equally among the three players.

[9]Baye et al. (1996) provide a comprehensive analysis of all-pay auctions.

the expected equilibrium efforts are

$$Ex_i^k = \frac{(w_i^k - \ell_i^k)^2}{2(w_j^k - \ell_j^k)} \quad \text{and} \quad Ex_j^k = \frac{w_i^k - \ell_i^k}{2}, \tag{2}$$

the equilibrium winning probabilities are

$$p_i^k = \frac{w_i^k - \ell_i^k}{2(w_j^k - \ell_j^k)} \quad \text{and} \quad p_j^k = 1 - p_i^k, \tag{3}$$

and the expected equilibrium payoffs are

$$E\pi_i^k = \ell_i^k \quad \text{and} \quad E\pi_j^k = w_j^k - (w_i^k - \ell_i^k). \tag{4}$$

If instead $w_i^k = \ell_i^k$ for some player $i \in \{1, 2, 3\}$ in some match k, player i's optimal effort choice is $x_i^k = 0$ for any effort level $x_j^k \geq 0$ of player $j \in \{1, 2, 3\}, j \neq i$ involved in match k. Thus, for a positive continuation payoff, player j will have no best reply unless there is a smallest monetary unit $\varepsilon > 0$; the best reply is then $x_j^k = \varepsilon$. As $\varepsilon \to 0$, in the limit, $x_j^k \to 0$ and $p_j^k \to 1$.[10]

The tournament represents a sequential game that can be solved by backward induction for its subgame perfect equilibrium (SPE), making repeatedly use of equations (2)–(4). The details of this procedure have been provided by Krumer et al. (2017) for $a = 0$, by Krumer et al. (2019) for $a = 1$, and by Laica et al. (2021) for $a = 1/2$. The solutions provide theoretical predictions about both, the ex ante expected outcome of the tournament and the players' dynamic behavior.

Table 1 displays the players' ex ante expected overall efforts ($EX_i = \sum_k Ex_i^k$), winnings ($EW_i = \sum_k p_i^k R_k$), and payoffs ($E\pi_i = \sum_k E\pi_i^k$) for the three different prize structures in our experiment. Figure 1 provides the expected efforts along the course of the tournament.

Table 1: Ex Ante Expected SPE-Values

	Efforts (EX_i)			Winnings (EW_i)			Payoffs ($E\pi_i$)		
	$a=1$	$a=\frac{1}{2}$	$a=0$	$a=1$	$a=\frac{1}{2}$	$a=0$	$a=1$	$a=\frac{1}{2}$	$a=0$
Player 1	130.7	200	67.1	192.5	200	116.1	61.8	0	49
Player 2	112.9	200	160.1	194.2	200	409.1	81.3	0	249
Player 3	98.5	200	74.9	213.3	200	74.9	114.8	0	0
$\sum_i z_i$	342.1	600	302.0	600	600	600	257.9	0	298
RSD	0.116	0	0.418	0.047	0	0.744	0.255	0	1.084

Note: RSD$\triangleq$ relative standard deviation

Only the prize structure for which the second prize equals half of the first prize ($a = 1/2$) leads to symmetric continuation payoffs in each and every match (Laica et al., 2021). It thus induces not only a fair tournament in the sense that the players have identical ex ante expected payoffs and winnings, and winning probabilities of 1/2 in each single match. It also maximizes the intensity of the tournament, measured by ex ante expected aggregate effort per unit of prize money. By contrast, any other prize structure entails

[10] As an alternative tie breaking rule, introducing an additional (marginal) prize on the match level has the same implications (Laica et al., 2021).

asymmetric continuation payoffs in some of the matches reducing investment incentives and provoking discrimination. Intuitively, if only the player ranking first receives a prize ($a = 0$), a *discouragement effect* occurs which reduces the investment incentives of trailing players and thus disadvantages the late mover (player 3). If instead the second prize equals the first prize ($a = 1$), a player who has won her first match will lose much of her incentives to provide additional effort in her second match. Such *lean-back effects* favor the late mover (player 3).

We summarize our theoretical predictions in the following hypotheses.

Hypothesis 1. *The tournament is most (least)* intense*, if $a = 0.5$ ($a = 0$).*

Hypothesis 2. *The tournament is most (least)* fair*, if $a = 0.5$ ($a = 0$).*

Hypothesis 3. *A prize structure with $a = 0.5$ induces (a) a fair ranking, (b) fair payoffs, and (c) fair matches.*

Hypothesis 4. *The late moving player 3 will be*

(a) advantaged, if $a = 1$,

(b) disadvantaged, if $a = 0$.

The solutions of the subgame perfect equilibrium also allow predictions about the dynamics of players' behavior depending on the course of the tournament. Figure 1 displays the players' expected equilibrium efforts in each single match. In particular, we observe a *strategic momentum* for the early movers (players 1 and 2), if the second prize equals zero (discouragement effect) and a *reverse strategic momentum*, if it equals the first prize (lean-back effect); more precisely:

Hypothesis 5. *After winning the first match,*

(a) each player will decrease effort in her second match, if $a = 1$,

(b) players 1 and 2 will increase effort in their second match, if $a = 0$.

4 Experimental Design and Procedure

We test the hypotheses outlined in Section 3 with the help of a laboratory experiment. This enables us to investigate the impact of the prize structure on intensity, fairness and dynamics in sequential round-robin tournaments with three players under controlled conditions. In this section, we describe the design and procedures of the experiment. The experimental results are presented in Section 5.

4.1 Design

We conduct an experiment with three treatments in a between-subject design. Irrespective of the treatment, an experimental session is split into three parts. In part 1, we elicit risk-preferences following the multiple price list format of Holt and Laury (2002).[11], and in part 3 we implement a cognitive reflection test (CRT) similar to Frederick (2005).

[11]Each subject is presented with a table of ten ordered decisions between a safe amount of 180 points and a risky lottery which offers either 400 points or 0 points. Across the table, the likelihood of receiving the 400 points increases from 0.1 in the first row to 1.0 in the last row in steps of 0.1 (hence, the probability

The main part of interest is part 2 where subjects play 20 repetitions (*periods* henceforth) of a sequential three-player round-robin tournament with matches organized as all-pay auctions. Subjects are randomly and anonymously assigned player numbers at the beginning of the part which are fixed across periods to provide player-specific learning opportunities. In each period, each subject is randomly matched with two other subjects assigned a different player number than herself and asked to play the tournament in the fixed sequential sequence according to which players 1 and 2 meet in match 1, players 1 and 3 meet in match 2, and players 2 and 3 meet in match 3. While we fix the total prize money at $R_1 + R_2 = 600$ points across treatments, treatments differ with respect to the value of the second prize. Concretely, we conduct a treatment for each value of $a \in \{0, 0.5, 1\}$, and we refer to them as the 0%-, 50%-, and 100%-treatment, respectively. This implies that the first and second prize (in points) are given by $(R_1^0, R_2^0) = (600, 0)$ in the 0%-treatment, $(R_1^{0.5}, R_2^{0.5}) = (400, 200)$ in the 50%-treatment, and $(R_1^{100}, R_2^{100}) = (300, 300)$ in the 100%-treatment.

For each round-robin tournament in part 2, each subject receives an initial endowment of $I = 600$ points which he can use to invest in his two matches to gain a prize.[12] Hence, in his first match a subject can invest any number of integer points $x_i^1 \in [0, 600]$ and in his second match any number of the remaining integer points $x_i^2 \in [0, 600 - x_i^1]$. The winner of a single match is determined by an all-pay auction meaning that the subject who chooses more points wins the match. In case both subjects choose the same amount of points, the computer randomly selects the winner by coin flip. While at the end of a match the winner is announced to all players of the particular round-robin tournament, only the players who actually participate in a match are informed about the points chosen in that particular match.[13] During the tournament, subjects are briefed on their current account of points, results of matches and all points chosen in each match they participated, and the current standings. Player number, match plan and prize values are continuously displayed.

At the end of a tournament, a prize is awarded according to the final ranking. The subjects with two wins in her matches will rank first and receive the prize R_1, and the subject with one win in her matches will rank second and receive the prize R_2. In case all players win one match, the round-robin tournament ranks are randomly determined by the computer such that every player has the same chances to rank first, second or third. The final payoffs of a subject are $I - x_i^1 - x_i^2 + R_1$ in case she ranks first, $I - x_i^1 - x_i^2 + R_2$ in case she ranks second, and $I - x_i^1 - x_i^2$ otherwise. At the end of a tournament, each subject learns her final payoffs and whether her rank has been determined unequivocally by the number of her wins or by a random draw.

of receiving the 400 points in row k equals $k/10$). Subjects are required to select one of the options in each row (we did not allow for indifference). For a subject who maximises expected utility and has a strictly increasing utility function, there exists a unique row such that the subject chooses the risky lottery in this and all subsequent rows and the safe amount in all previous rows. The subject's risk preferences may thus be summarised by the number of times he chooses the safe lottery. In the experimental instructions, probabilities are explained in terms of throws of a ten-sided dice.

[12] An initial endowment is supposed to, although collectively decreasing or increasing the average level of subjects' effort choices, not account for significant individual distortions in each subject's effort choices and thus, be independent for the determination of a contest winner (Sheremeta, 2011).

[13] That way we prevent players from exploiting budget constraints of other players. Otherwise it should not influence effort choices in the equilibrium anyhow. In practice, although there are measures indicating the intensity of a match, some intensity is never observable and perceived only as a participant.

4.2 Procedure

Four sessions were conducted for the 0%-treatment and three sessions were conducted for each, the 50%- and the 100%-treatment. The former proceeded from November to December 2016 whereas the latter between May and July 2019. All the sessions took place at the experimental laboratory of the department of social sciences at the University of Bamberg ("BLER"). Participants were invited via the ORSEE recruitment system (Greiner, 2015). Either 15 or 18 subject participated in a session which lasted on average 90 minutes. In total 174 subjects participated and earned on average an amount of EUR 14.42 per subject. The experimental sessions were computerized by using the software zTree (Fischbacher, 2007).

5 Results

We present our results in five steps: First, we analyze the evolution of effort choice decisions across the course of the experiment. We then discuss intensity and fairness, respectively. Fourth, we examine the treatments for dynamic effects within a tournament. Finally, we provide a complementary analysis on dynamics across tournaments where single matches are organized as all-pay auctions and within tournaments where single matches are organized as lottery contests.

5.1 Adaptation to the Choice Environment

To reliably test our theory which is based on the subgame perfect equilibrium concept, we have to ensure that behavior has stabilized. Figure 2 shows the evolution of the average total effort levels in a tournament across the periods of the experiment, separately for each player type.[14] The upper (middle, lower) panels contain the results for the 100%- (50%-, 0%-) treatment, where subjects compete for a first prize of size $R_1^{100} = 300$ ($R_1^{0.5} = 400$, $R_1^0 = 600$) and a second prize of size $R_2^{100} = 300$ ($R_2^{50} = 200$, $R_2^0 = 0$). In each figure, the black solid (dotted; dashed) line depicts the average total effort for player 1 (2; 3), and the gray line of the same shape depicts the corresponding theoretical benchmark.

Additionally, we find that some subjects seem to not have understood the task as they (almost) always invest their entire endowment across the two matches. Concretely, six subjects invest their entire endowment in at least 19 out of 20 periods.[15] These subjects seem to view the task as one of optimally splitting the endowment between their two matches, rather than investing into a tournament of all-pay auctions. The right panel of Figure 2 shows the evolution of the total average effort levels when those subjects are excluded, whereas the left panel includes all subjects.

Figure 2 clearly shows that in each treatment and irrespective of the sample, total tournament efforts markedly decrease across the first periods. For example, in the 100%-treatment the average subject in the role of player 1 decreases her tournament effort from 107.4 across the first seven periods (*F7* henceforth) to 92.4 across the last 13 periods (*L13* henceforth). Similarly, the average tournament effort of subjects in the role of player 2 (3) decreases from 219.0 (138.3) in F7 to 155.4 (112.0) in L13. Table 2 contains the corresponding numbers for the other two treatments. It shows that the average tournament

[14] An analogous analysis that separates each player's choice evolutions for his first and second match is provided in the appendix.

[15] This comprises four subjects (with IDs 9, 15, 17, and 21) in the 0%-treatment, and one subject each in the 50%-treatment (ID=149) and the 100%-treatment (ID=233).

Note: Gray lines depict the theoretical benchmarks.

Figure 2: Average effort per Tournament

effort is at least ten points lower in L13 compared to F7 for almost all treatments and player types. The sole exception is player 3 in the 0%-treatment for which the average tournament effort shows no clear trend across periods.

Figure 2 also reveals that – unsurprisingly – focusing on subjects who did understand the task reduces the average tournament effort for the affected player types. Concretely, the average tournament effort of player 2 is around 25 points lower in the reduced sample in both two-prize treatments, and all players' average tournament efforts are lower in the reduced sample in the 0%-treatment (by 14 to 29 points). On the other hand, reducing the sample does not change our conclusions regarding the dynamics of tournament efforts across periods.

Table 2: Average total effort per player type

Sample	Player	100%-treatment F7	L13	T	50%-treatment F7	L13	T	0%-treatment F7	L13	T
	1	107.4	92.1	130.7	124.1	114.0	200	351.5	237.5	65.6
Full	2	219.0	155.4	113.0	195.0	167.4	200	207.2	196.9	159.7
	3	138.3	112.0	90.5	181.7	134.5	200	291.3	290.4	74.7
	1	107.4	92.1	130.7	124.1	114.0	200	341.5	221.0	65.6
Reduced	2	195.2	127.6	113.0	171.1	142.0	200	189.4	178.6	159.7
	3	138.3	112.0	90.5	181.7	134.5	200	261.9	260.9	74.7

Note: F7 $\hat{=}$ first 7 periods; L13 $\hat{=}$ last 13 periods; T $\hat{=}$ equilibrium predictions

We estimate panel regression models with the chosen effort levels per subject and tournament as dependent variable to provide statistical evidence for the reported effects. The models include as explanatory variables (i) dummies for the player number fully interacted with treatment dummies, and (ii) the inverse of the period number fully interacted with both sets of dummies. Further specifications also include subject-specific control variables.[16] In addition, we include subject-specific random effects (RE) to account for the multiple decisions made by a subject, and we estimate robust standard errors clustered at the session level and corrected for the finite number of clusters (ten) to account for possible dependence within sessions. The results are presented in Table 3.

In all models we find clear evidence for a significant decrease of total tournament efforts across periods for at least one player type in each treatment, irrespective of the sample. Concretely, the decrease is rather small and insignificant for players 2 and 3 in the 0%-treatment and for player 1 in the 100%-treatment. For all other treatments and player roles, tournament efforts decrease, at least in the initial periods. The results also indicate that efforts seem to be lower in the 50%- and 100% treatment compared to the 0%-treatment.

To assess how fast behavior stabilizes, we re-estimate the models and gradually exclude the first periods. The results are available from the authors upon request. Once we exclude the first six periods, the period trend becomes insignificant for all players in all treatments with the exception of player 1 in the 0%-treatment. Furthermore, the impact of the period becomes marginally significant for this player once we also exclude period seven.

Taking these results into account, we focus subsequently on decisions made in the last thirteen periods (L13), and we exclude the decisions of players who almost always invest their entire endowment in the tournament. Results for the full sample of decisions and including all periods are presented in the online supplementary material.

5.2 Intensity

Table 4 is the empirical counterpart of table 1: It summarizes for each treatment and each player role the average total effort, winnings, and payoffs (net of endowments) across the last 13 periods (L13). Additionally, the sum across players ($\sum_i z_i$) and the relative standard deviation (RSD) are reported for each variable and each treatment.

[16]Specifically, we control for (i) risk aversion via the number of safe choices in the first part of the experiment, (ii) cognitive reflection via the number of correct answers in the third part of the experiment, (iii) the demographic variables age, gender, field of studies, and number of siblings, and (iv) responses to

Table 3: Panel estimations for changes of efforts across periods

Dep. Variable	Total Effort			
Sample	Full Sample		Reduced Sample	
Model	(1)	(2)	(3)	(4)
Constant	244.06***	232.87**	226.93***	176.68**
	(46.778)	(79.664)	(35.136)	(67.384)
Player 2	-55.26	-17.35	-56.81	-9.69
	(57.376)	(47.664)	(32.775)	(29.285)
Player 3	43.69	58.16**	31.09	55.89**
	(42.994)	(18.077)	(35.856)	(19.162)
50%-Treatment × Player 1	-140.55**	-97.67	-123.41***	-74.57
	(47.848)	(55.845)	(36.549)	(49.699)
50%-Treatment × Player 2	-88.72	-65.61	-97.73**	-55.93
	(51.890)	(59.815)	(38.565)	(51.334)
50%-Treatment × Player 3	-113.68**	-83.56	-96.54**	-69.52
	(47.131)	(46.602)	(35.605)	(41.346)
100%-Treatment × Player 1	-154.57**	-112.28*	-137.43***	-100.74*
	(48.177)	(52.610)	(36.979)	(48.788)
100%-Treatment × Player 2	-97.92	-87.04	-109.15**	-105.79*
	(57.266)	(62.070)	(40.020)	(49.490)
100%-Treatment × Player 3	-141.20**	-81.08	-124.06***	-65.89
	(47.504)	(45.225)	(36.098)	(41.043)
$(1/Period)\times$				
0%-Treatment × Player 1	185.23***	185.37***	201.51***	201.49***
	(47.213)	(47.081)	(34.293)	(34.266)
0%-Treatment × Player 2	64.96	65.21	67.91	67.89
	(44.643)	(44.822)	(47.111)	(47.201)
0%-Treatment × Player 3	16.51	16.80	18.09	18.06
	(67.834)	(67.747)	(74.731)	(74.742)
50%-Treatment × Player 1	77.99**	77.99**	77.99**	77.99**
	(24.868)	(24.911)	(24.870)	(24.914)
50%-Treatment × Player 2	120.63***	120.63***	127.73***	127.73***
	(28.132)	(28.180)	(33.452)	(33.512)
50%-Treatment × Player 3	114.93**	114.93**	114.93**	114.93**
	(40.820)	(40.891)	(40.824)	(40.897)
100%-Treatment × Player 1	44.39	44.39	44.39	44.39
	(30.671)	(30.724)	(30.674)	(30.729)
100%-Treatment × Player 2	175.16***	175.16***	186.11***	186.11***
	(23.298)	(23.339)	(34.494)	(34.556)
100%-Treatment × Player 3	102.01***	102.01***	102.01***	102.01***
	(29.340)	(29.391)	(29.343)	(29.396)
Control Variables	No	Yes	No	Yes
Observations	3,480	3,480	3,360	3,360
Subjects	174	174	168	168
R^2	0.137	0.299	0.129	0.314

Note: Robust standard errors in parentheses, clustered at the session level and corrected for the finite number of clusters. All models include a subject-specific random effects error structure. Significance level: *** (1%), ** (5%), * (10%)

Table 4: Overview of Experimental Results (Averages)

	Total Effort			Winnings			Payoffs		
	$a=1$	$a=\frac{1}{2}$	$a=0$	$a=1$	$a=\frac{1}{2}$	$a=0$	$a=1$	$a=\frac{1}{2}$	$a=0$
Player 1	92.1	114.0	221.0	168.3	197.4	222.4	76.2	83.4	1.4
Player 2	127.6	142.0	178.6	204.8	203.6	167.8	77.2	61.7	-10.7
Player 3	112.0	134.5	260.9	221.3	194.9	178.0	109.2	60.3	-82.9
$\sum_i z_i$	331.8	390.5	660.5	594.4	595.9	568.2	262.6	205.4	-92.2
RSD	0.131	0.091	0.153	0.112	0.018	0.125	0.175	0.155	1.210

Note: RSD$\triangleq$ relative standard deviation

Intensity measured by the average total effort in L13 deviates from theoretical predictions in different degrees dependent on the treatment. Compared to the theoretical benchmark, players substantially underinvest in the 50%-treatment, they are close to predictions in the 100%-treatment, and they substantially overinvest in the 0%-treatment. As a consequence, intensity is decreasing in a and thus largest in the 0%-treatment rather than inverse U-shaped, as predicted. Turning to the different players, we find that player 1 underbids the most in the 50%-treatment, also underbids in the 100%-treatment, and substantially overbids in the 0%-treatment. Player 3 overbids the most in the 0%-treatment and also overbids slightly in the 100%-treatment. Finally, player 2 is close to the theoretical predictions in all three treatments.

To formally test Hypothesis 1, we estimate panel regression models of the total tournament effort with subject-specific random effects and treatment dummies as explanatory variables. In line with the hypothesis, we pick the 50%-treatment as a baseline. In further specifications, we also include the player role fully interacted with the treatment as well as various control variables, e.g., for risk aversion and cognitive reflection. The results are presented in table 5.

We find that effort in the 50%-treatment is about 20 points higher than in the 100%-treatment, but 90 points lower than in the 0%-treatment. The difference to the 0%-treatment is significant, even if we add control variables. Our estimations also reveal that the difference between the 50%- and the 0%-treatment is mainly driven by player 3 who invests substantially and significantly more in the latter treatment. Players 1 and 2 also invest more in the 0%-treatment, but the differences are not significant. On the other hand, player 2 invests significantly less in the 100%- than the 50%-treatment, player 1 invests insignificantly less, and player 3 invests approximately the same in both treatments.[17]

Result 1. *The tournament is most (least) intense if the second prize equals zero (the first prize).*

How can the observed ranking of treatments with respect to intensity be explained? To investigate reasons for the differences in over- and underbidding of players, figure 3 shows the average efforts of players for each match and each possible course of the tournament. The figure is, thus, the empirical counterpart of figure 1.

our final questionnaire.

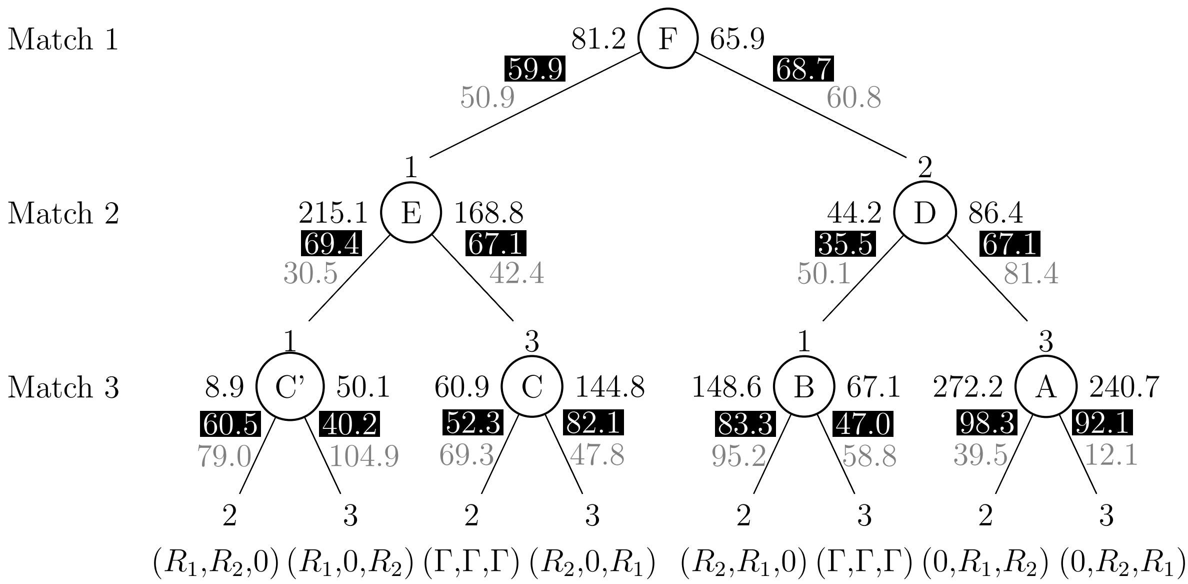
[17]Additionally, we find that subjects who are less risk averse, more generous or more ambitious, female subjects, and subjects who assign a higher importance to winning a tournament invest more. In contrast, subjects who assign a higher importance to the final payment invest less.

Table 5: Panel Estimations for Intensity

Dep. Variable	Total Effort			
Model	(1)	(2)	(3)	(4)
Constant	129.95***	77.20	114.01***	75.83
	(9.679)	(46.369)	(10.261)	(50.068)
0%-Treatment	89.58**	73.55*	106.98**	63.12
	(33.330)	(38.381)	(34.031)	(45.079)
100%-Treatment	-19.70	-25.53	-21.87	-34.57
	(13.290)	(16.601)	(13.051)	(21.706)
Player 2			27.94	22.71*
			(16.143)	(12.135)
× 0%-Treatm.			-70.38*	-24.55
			(33.784)	(22.565)
× 100%-Treatm.			7.50	-14.63
			(22.839)	(15.192)
Player 3			20.53***	-2.14
			(5.302)	(12.534)
× 0%-Treatm.			19.42	62.83**
			(39.307)	(22.745)
× 100%-Treatm.			-0.63	39.13**
			(13.297)	(13.112)
Control Variables	No	Yes	No	Yes
Observations	2,184	2,184	2,184	2,184
Subjects	168	168	168	168
R^2	0.089	0.267	0.109	0.282

Note: Robust standard errors in parentheses, clustered at the session level and corrected for the finite number of clusters. All models include a subject-specific random effects error structure.
Significance level: *** (1%), ** (5%), * (10%)

We note first that players never bid zero or almost zero when they should. This holds for nodes D and C' in the 0%-treatment as well as for node A in the 100%-treatment. This is well in line with the finding in various studies that subjects seem to derive a utility or joy of winning itself, regardless of the monetary outcome (see e.g. Sheremeta, 2010, 2011, 2013). Indeed, joy of winning may also explain why our subjects overbid in nodes B, C, and E in the 0%- and the 100%-treatment: In each of these cases, at least one of the players can secure the first rank in the tournament by winning the current match. Hence, in addition to a joy of winning the match, winning may also entail an additional joy of winning the entire tournament. While a joy of winning may therefore explain all but one instance of overbidding in the 0%- and 100%-treatment (the exception is player 1 in node F of the 0%-treatment), it remains an open question why these effects do not lead to overbidding (on average) in the 50%-treatment for any player at any of the nodes. While puzzling, this finding does not imply that joy of winning is not present in the 50%-treatment. Indeed, we observe rather asymmetric efforts in nodes B and C for this treatment (contrary to predictions), and they are in both cases higher for the player who is able to achieve the first rank.



Note: black $\triangleq$ 0%-treatment; black box $\triangleq$ 50%-treatment; light gray $\triangleq$ 100%-treatment; $\Gamma := \frac{\sum_j R_J}{3}$.

Figure 3: Average Efforts Along the Course of the Tournament

5.3 Fairness

We assess the fairness of the tournament by the differences of players in the average winnings and payoffs. Table 4 contains the results by player role and treatment.

In both two-prize treatments, winnings are qualitatively and quantitatively close to the theoretical predictions. As predicted, player 3 has the highest and player 1 the lowest average winnings in the 100%-treatment, whereas winnings of all three players are very similar in the 50%-treatment. The 100%-treatment also reflects the theoretical predictions in terms of payoffs: Player 3 clearly achieves the largest average payoff, only slightly below the payoff she could expect ex ante in the SPE. On the other hand, there is no difference in the average payoffs of players 1 and 2 which is why the dispersion of the average payoffs is below the predicted dispersion. In the 50%-treatment, player 1 earns substantially more than the other two players which contradicts the prediction of equal payoffs and yields a strictly positive rather than a zero dispersion.

In contrast, the average winnings and payoffs differ substantially from their theoretical counterparts in the 0%-treatment. First, player 2 wins the least rather than the most on average, and player 1 (player 3) wins almost (more than) twice as much as she should expect ex ante based on the SPE. Winnings are thus considerably less dispersed than predicted. Second, payoffs are lower than predicted for all players, and even negative for players 2 and 3 for whom the deviation is the largest.

Overall and in line with predictions, our results still suggest that the tournament is most (least) fair in the 50%-treatment (0%-treatment) as winnings and payoffs are least (most) dispersed.

To formally test Hypothesis 2, we conduct t-tests of session averages. Concretely, we calculate for each session the average winnings and payoffs of each player and the relative standard deviation (RSD) of these averages across players. As negative values pose a problem for the calculation of the RSD, we use payoffs inclusive of endowments. The average RSD of the average winnings per session is $\overline{RSD}_{0\%}\left(\bar{W}_i\right) = 0.372$ in the 0%-

treatment and thus significantly higher than in the 50%-treatment ($\overline{RSD}_{50\%}\left(\bar{W}_i\right) = 0.056$, p=0.004) and in the 100%-treatment ($\overline{RSD}_{100\%}\left(\bar{W}_i\right) = 0.138$, p=0.01). The difference between the two-price treatments is also significant (p=0.025). Moreover, the average RSD of the average payoffs per session is significantly larger in the 0%-treatment ($\overline{RSD}_{0\%}\left(\bar{\pi}_i\right) = 0.098$) than in the 50%-treatment ($\overline{RSD}_{50\%}\left(\bar{\pi}_i\right) = 0.021$, p=0.005) and in the 100%-treatment ($\overline{RSD}_{100\%}\left(\bar{\pi}_i\right) = 0.033$, p=0.009). While the difference between the two-price treatment is not significant in this case, this is likely due to the small sample sizes (three independent observations per treatment) and the small predicted effect.[18] Hence, we find clear support for Hypothesis 2.

Result 2. *The distribution of average winnings and payoffs is most (least) fair in the 50%-treatment (0%-treatment), if fairness is measured by the average RSD of the session-averages per player.*

Statistical evidence for hypotheses 3 and 4 is provided by panel regression models of players' winnings and payoffs. All models include as explanatory variables dummies for the player number fully interacted with treatment dummies. In line with the hypotheses, we pick the 50%-treatment and player 3 as the base categories. In addition, we include subject-specific random effects (RE) and we estimate robust standard errors clustered at the session level and corrected for the finite number of clusters (ten). Further specification also incorporate our control variables. The results are provided in Table 6.

Hypothesis 3 is rejected. First, although players win almost the same on average in the 50%-treatment, we find that winnings of player 3 are significantly lower than of the other two players once controls are added (part a). Second, player 3 also earns significantly less than player 1, although the significance is marginal (part b).

Third, table 7 lists the winning probabilities in the different matches for, respectively, player 1 (in nodes F, E, and D) or 2 (in nodes, A, B, C, and C') as well as the p-values of binomial tests. We focus on matches in which both players are part of the reduced sample. The table shows that the empirical winning probabilities differ by at least ten percentage points from the SPE prediction of 0.5 at four out of seven nodes, and the difference is significant in each of those cases. Hence, we also reject the prediction of fair matches (part c of hypothesis 3).

Result 3. *The 50%-tournament is not perfectly fair:*

(a) Player 3 wins significantly less than players 1 and 2.

(b) Player 1 earns (significantly) more than player 2 (player 3).

(c) Only the matches in nodes F, E, and A are fair.

In contrast, the panel estimation results (table 6) lend support to Hypothesis 4. In the 100%-treatment, player 3 wins and earns significantly more on average than players 1 and 2, as predicted (part a). In the 0%-treatment, the differences in players' average winnings are not significant, but player 3 earns significantly less on average than players 1 and 2 (part b).

Result 4. *The late moving player 3 is advantaged (in terms of winnings and payoffs) in the 100%-treatment, and disadvantaged (in terms of payoffs) in the 0%-treatment.*

[18] Taking into account the endowment yields a predicted RSD of the ex ante expected payoffs per player of 0.154 in the 0%-treatment, 0 in the 50%-treatment, and 0.032 in the 100%-treatment.

Table 6: Panel Estimations for Winnings and Payoffs

Dep. Variable	Winnings		Payoffs	
Model	(1)	(2)	(3)	(4)
Constant	194.87***	116.82**	660.33***	643.29***
	(6.75)	(45.09)	(11.41)	(35.71)
0%-Treatment	-16.85	-3.19	-143.24***	-129.68***
	(29.70)	(31.20)	(37.45)	(30.64)
100%-Treatment	26.40***	51.57***	48.89***	46.45***
	(7.24)	(7.51)	(13.44)	(13.15)
0%-Treatment × Player 1	44.36	4.16	84.30***	64.75***
	(33.06)	(17.78)	(14.92)	(6.78)
0%-Treatment × Player 2	-10.19	6.81	72.19**	69.08**
	(55.05)	(54.30)	(31.64)	(29.50)
50%-Treatment × Player 1	2.56	19.19**	23.09*	17.08*
	(7.66)	(8.45)	(11.97)	(7.78)
50%-Treatment × Player 2	8.75	23.88*	1.33	-1.51
	(15.83)	(11.57)	(2.71)	(11.28)
100%-Treatment × Player 1	-52.94***	-62.50**	-33.05**	-25.29**
	(2.77)	(21.15)	(14.29)	(10.02)
100%-Treatment × Player 2	-16.46**	-66.30***	-32.00*	-38.03**
	(5.55)	(9.40)	(14.55)	(12.74)
Control Variables	No	Yes	No	Yes
Observations	2,184	2,184	2,184	2,184
Subjects	168	168	168	168
R^2	0.009	0.095	0.092	0.114

Note: Robust standard errors in parentheses, clustered at the session level and corrected for the finite number of clusters. All models include a subject-specific random effects error structure. Significance level: *** (1%), ** (5%), * (10%)

Table 7: Match results in the 50%-treatment

Node	F	E	D	C'	C	B	A
# Observations	221	128	106	59	59	39	64
Considered player	1	1	1	2	2	2	2
Fraction of Wins	0.534	0.500	0.377	0.627	0.322	0.718	0.563
p(binomial test)	> 0.1	> 0.1	$= 0.01$	$= 0.07$	< 0.01	< 0.01	> 0.1

As a final remark, our panel estimations also reveal that subjects who are less risk averse or assign a higher importance to winning win more, whereas male subjects and subjects who assign a higher importance to their final payoff earn more.

5.4 Choice Dynamics

To test our final hypothesis, we analyze the dynamics of effort choices within tournaments. Concretely, we investigate how subjects change their efforts between their first and their second match in response to the outcome of the first match. For this purpose, we compare for each treatment and each match along each potential course of the tournament the average effort choices of players to the theoretical predictions. Table 8 provides the average effort choices of players in their first and their second match, separated by choice situation, i.e. by the nodes in figure 1. Notice that we condition the average choice in the first match on the outcome of the match, i.e. we provide average choices of winners and losers separately.

Table 8: Average Efforts in the First and Second Match

	Nodes		Result	0%-Treatment		50%-Treatment		100%-Treatment	
Pl.	1st	2nd	Match 1	$\bar{x}_i^1$	$\bar{x}_i^2$	$\bar{x}_i^1$	$\bar{x}_i^2$	$\bar{x}_i^1$	$\bar{x}_i^2$
1	F	E	Win	122.2	215.1	82.5	69.4	76.0	30.5
1	F	D	Loss	29.1	44.2	32.7	35.5	30.2	50.1
2	F	B	Win	126.9	148.6	112.9	83.3	86.2	95.2
2	F	A	Win	126.9	272.2	112.9	98.3	86.2	39.5
2	F	C'	Loss	25.5	8.9	30.0	60.5	29.4	79.0
2	F	C	Loss	25.5	60.9	30.0	52.3	29.4	69.3
3	E	C	Win	314.3	144.8	108.3	82.1	59.6	47.8
3	D	A	Win	112.0	240.7	96.1	92.1	111.2	12.1
3	E	C'	Loss	98.1	50.1	25.9	40.2	15.4	104.9
3	D	B	Loss	23.3	67.1	19.1	47.0	34.5	58.8

Note: $\bar{x}_i^m \triangleq$ Average effort of player i subjects in her mth match.

The table indicates three regularities: First, in line with predictions players 1 and 2 seem to exhibit a strategic momentum after winning in the 0%-treatment: In all three situations, the average subject increases her effort after winning in the first match. This also holds for player 3 after a win in node D, but not after a win in node E. In contrast, there is no clear regularity in the change of efforts after a loss.

Second, we detect lean-back effects after winning in the 100%-treatment: In four out of five cases, the average effort is lower in the second match after a win in the first match. The sole exception is the behavior of player 2 after winning the first match and meeting the losing player 3 in the second match (node B). Conversely, the average effort always increases after a loss in the first match.

Finally, the average subject in the 50%-treatment always decreases her effort after a win and always increases it after a loss.

To test Hypothesis 5, we estimate panel models of the change in subjects' efforts between the second and the first match, $\text{effort}_2 - \text{effort}_1$. All models include as explanatory variables a dummy for the outcome of the first match fully interacted with treatment dummies and they allow for subject-specific random effects. Further specifications also include dummies for the different players and their interaction as well as control variables.

Table 9: Panel Model Estimations for Effort Dynamics

Dep. Variable	effort_2 - effort_1			
Model	(1)	(2)	(3)	(4)
Constant	-46.57***	-77.88*	-46.61***	-92.63**
	(9.821)	(39.660)	(9.528)	(36.934)
0%-Treatment	132.48***	133.57***	144.12***	140.58***
	(16.583)	(16.030)	(36.992)	(33.930)
50%-Treatment	29.01**	35.64**	31.50**	34.54**
	(10.122)	(11.833)	(9.832)	(11.060)
Loser_1				
× 0%-Treatm.	-102.74***	-102.53***	-88.24***	-88.69***
	(12.873)	(13.640)	(25.203)	(25.382)
× 50%-Treatm.	36.11***	35.73***	20.41***	20.32***
	(2.519)	(3.269)	(3.965)	(4.179)
× 100%-Treatm.	86.55***	86.17***	67.45***	68.20***
	(14.039)	(13.580)	(14.534)	(13.988)
Player 2			16.18	11.15
			(18.707)	(17.245)
× 0%-Treatm.			12.45	20.74
			(45.026)	(45.545)
× 50%-Treatm.			-22.83	-15.73
			(19.556)	(18.366)
× Loser_1 × 0%-Tr.			-43.84	-43.45
			(32.127)	(31.908)
× Loser_1 × 50%-Tr.			28.97*	27.24*
			(15.361)	(14.390)
× Loser_1 × 100%-Tr.			13.99	12.66
			(21.920)	(22.081)
Player 3			-11.21	-13.48
			(11.918)	(10.635)
× 0%-Treatment			-50.61	-46.53
			(43.959)	(41.027)
× 50%-Treatment			7.62	10.64
			(12.325)	(13.600)
× Loser_1 × 0%-Tr.			0.41	0.80
			(14.379)	(14.590)
× Loser_1 × 50%-Tr.			22.59*	21.57**
			(10.136)	(9.314)
× Loser_1 × 100%-Tr.			41.46	39.13
			(28.370)	(28.159)
Control Variables	No	Yes	No	Yes
Observations	2,148	2,148	2,148	2,148
Subjects	168	168	168	168
R^2	0.104	0.129	0.138	0.159

Note: Loser_1 $\triangleq$ Indicator whether the first match was lost. Robust standard errors in parentheses, clustered at the session level and corrected for the finite number of clusters. All models include a subject-specific random effects error structure.
Significance level: *** (1%), ** (5%), * (10%)

We calculate robust standard errors which account for clustering of observations at the session level and are corrected for the finite number of clusters. The results are presented in table 9.

The estimation results lend clear support to Hypothesis 5: After winning the first match, subjects significantly decrease their efforts in the 100%-treatment (part a), and they significantly increase their effort in the 0%-treatment. In the 100%-treatment, this holds for all players and is robust to the inclusion of control variables. In the 0%-treatment, this mainly holds for player 2, whereas the effect is smaller for player 1 and becomes insignificant once controls are added, and it even becomes (insignificantly) negative for player 3 with controls.

Result 5. *After winning the first match, subjects exhibit a lean-back effect in the 100%-treatment regardless of the player number, and they exhibit a strategic momentum in the 0%-treatment, especially when acting as player 2.*

Our results also suggest that the effects of winning are by and large not mirrored by the effects of losing. In the 0%-treatment, only player 3 significantly decreases her effort after a loss. In the 100%-treatment, the estimated changes in efforts are small for players 2 and 3, and negative for player 1.

Finally, we obtain mixed results with regard to the 50%-treatment. While the estimation results without controls suggest a reverse momentum, i.e. a decrease of efforts after winning and an increase after losing, these effects disappear once we account for controls. In addition, the estimated changes in efforts after losing become negative with controls. Given that estimated changes are small and taking into account that equilibrium mixed strategy play would imply a mean reversion,[19] our results for the 50%-treatment might actually conceal a psychological momentum rather than a reverse momentum.

5.5 Complementary Analyses

To shed more light on the driving forces of our findings in the 50%-treatment, we complement our analysis in three ways: First, we investigate whether players indeed play mixed strategies. Second, we report on the results from an additional treatment which is similar to the 50%-treatment with the sole exception that individual matches are conducted as a Tullock contest. Hence, the theoretical benchmark does not involve mixed strategies. Finally, we investigate whether dynamic effects occur not only within but also between round-robin tournaments in the 50%-treatment.

By and large, the complementary results suggest that a reverse psychological momentum exists in this setting. Yet, more evidence is needed to quantify its effects.

5.5.1 Evidence on Mixed Strategy Play

Figure 4 plots the empirical cumulative distribution functions of efforts in the 50%-treatment, separately for each node and player. The upper two panels show the empirical distribution for the first and second match, respectively, whereas the lower two panels show the empirical distributions for the third match, separated into nodes A/B and nodes C/C' for readability. Each figure also contains the theoretical benchmark which is a uniform distribution between zero and 200 points for each match, node, and player.

[19]The estimated effort conditional on winning (losing) is 150 (50) points at each node.

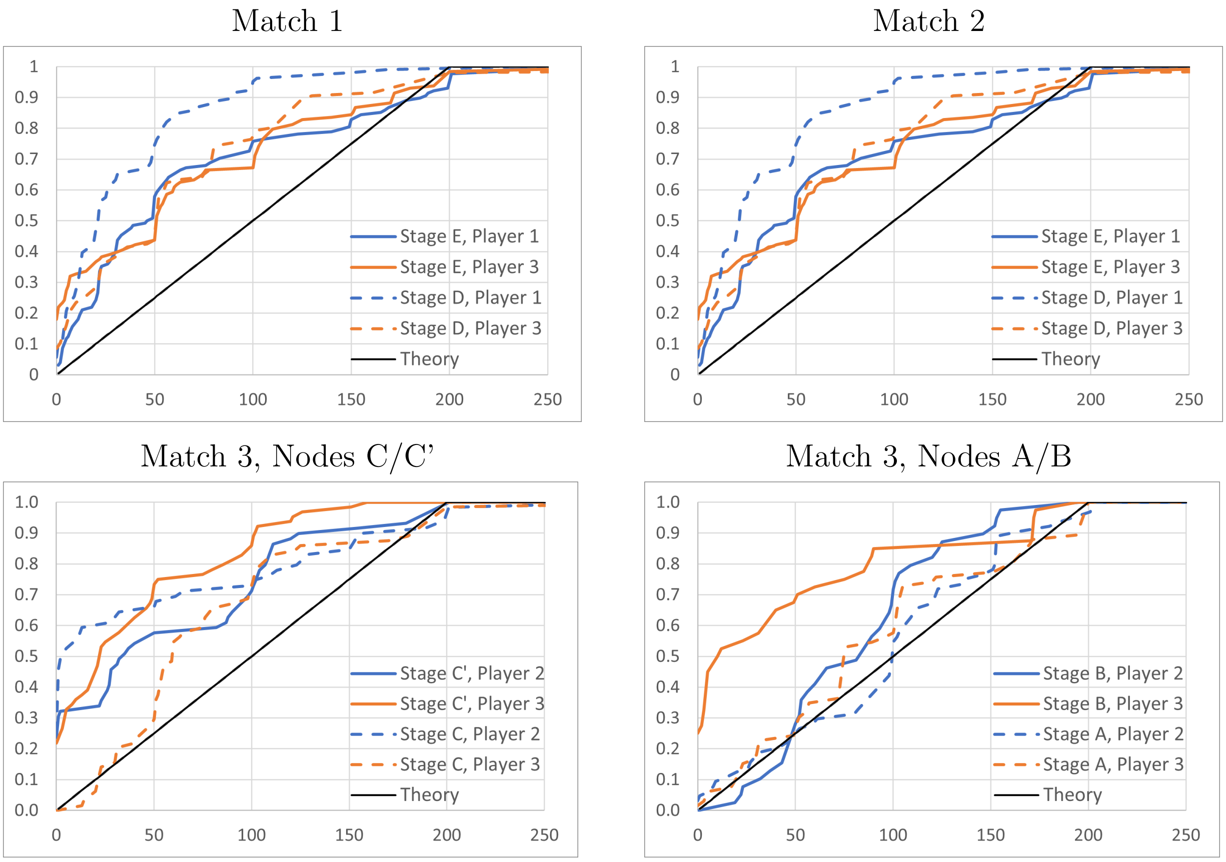


Figure 4: Empirical Cumulative Distribution of Efforts in the 50%-Treatment

Except for an effort of zero (and, less frequently, one), we find little evidence for a systematic clustering of effort choices for either of the nodes and players. Compared to the theoretical benchmark, the figures reveal a systematic shift of the distribution of effort choices towards lower efforts in each case. But this does not seem to involve a shift towards a few selected effort levels.

Still, the empirical distributions across subjects only provide partial evidence for mixed strategy play. Indeed, they might result from a mixture of subject-specific pure strategies. To rule out this alternative explanation, table 10 provides summary statistics of individual subject's choices at each node. Concretely, the table collects for each node and player (i) the average number of choices a single subject assigned the given player number made at the given node (across the last 13 periods), (ii) the average number of *distinct* effort levels chosen by a single subject, and (iii) the average relative standard deviation of the efforts chosen by a single subject.

We find that most subjects frequently experiment in all choice situations even in late periods. The average subject chooses each effort level two to three times at node F and less than twice at all other nodes.[20] Moreover, the average relative standard deviation is substantial at all nodes. In addition, we find that subjects experiment more in later matches. These facts provide evidence that many subjects do not play pure strategies. On the other hand, for each node and player there are between one and four subjects who make at least two choices and pick the same effort level in each case. Hence, not all subjects play mixed strategies.

[20]The number of distinct choices divided by the total number of choices is 0.51 (0.43) for player 1 (2) at node F, and larger than 0.5 at all other nodes for all players.

Table 10: Summary statistics on subjects' strategies in the 50%-treatment

	Player 1			Player 2			Player 3		
Node	$\bar{n}$	n_{dist}	RSD	$\bar{n}$	n_{dist}	RSD	$\bar{n}$	n_{dist}	RSD
A				4.6	3.5	0.34	4.1	2.8	0.32
B				3.3	2.4	0.24	3.1	1.8	0.34
C				3.9	2.3	0.54	4.6	2.9	0.24
C'				3.9	2.6	0.26	4.0	2.7	0.61
D	5.9	3.7	0.49				5.9	2.7	0.35
E	7.1	4.6	0.61				7.1	4.0	0.72
F	13	6.6	0.51	13	5.5	0.65			

Note: $\bar{n} \triangleq$ average number of choices, $n_{dist} \triangleq$ average number of distinct effort levels, RSD$\triangleq$ relative standard deviation

Overall, our results suggest that the strategies selected by subjects should lead to some reverse momentum, but less than predicted in the SPE.

5.5.2 Lottery Contest Treatment

To test whether subjects change their efforts in response to the outcome of the first match for non-strategic (e.g., psychological) reasons, we implement a treatment with a prize structure identical to the 50%-treatment but without a theoretical prediction in mixed-strategies. Concretely, in each session subjects play 20 round-robin tournaments where individual matches are organized as a Tullock lottery contest. Hence, given efforts x_i^k and x_j^k of players i and j in match k, the winning probability of player i is given by $p_i^k = x_i^k / \left(x_i^k + x_j^k\right)$. We term this treatment the *50%-LC-treatment*, where LC stands for *lottery contest*. Design and procedure of the experiment are almost identical to those in the 50%-treatment, with slight adjustments to the control questions. Two sessions with 15 subjects each were conducted in November 2019.[21]

All Subjects   Reduced Sample

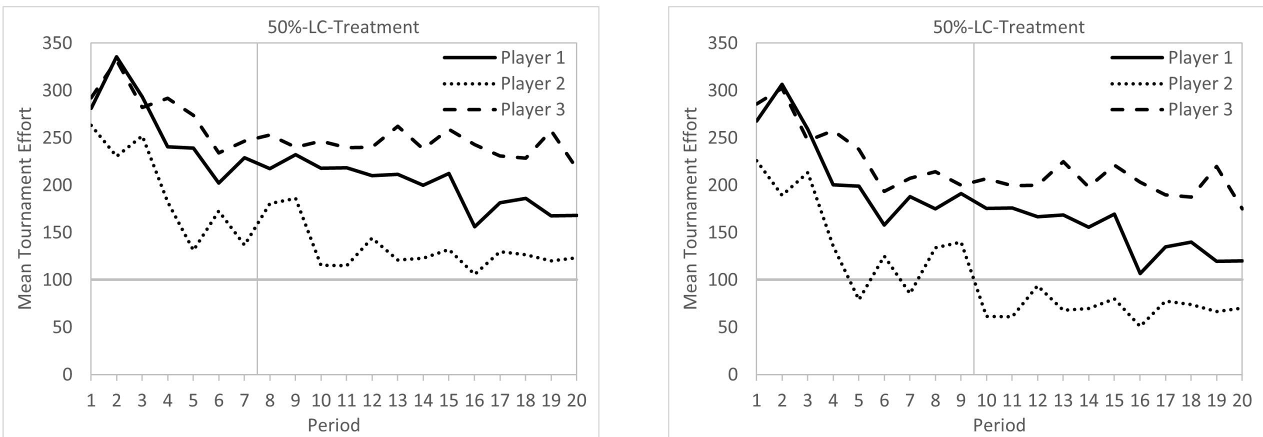


Figure 5: Mean effort in the 50%-LC-treatment

Figure 5 illustrates the evolution of the average total tournament effort in the 50%-LC-

[21]Further sessions were suspended due to regulations related to the CoVid-19 pandemic.

treatment. As for our three main treatments, some players seem to not have understood the task as they (almost) always invest their entire endowment across the two matches.[22] The right panel of the figure presents the effort levels when those subjects are excluded, whereas the left panel includes all subjects. As can be seen, average efforts of all players are shifted substantially downwards in the reduced sample. Moreover, we observe a clear downward trend of total efforts for all players irrespective of the sample. In the full (reduced) sample, the average total effort decreases from 252.2 (216.0) in the first nine periods (F9) to 193.6 (148.4) in the last eleven periods (L11) for player 1, from 192.7 to 123.2 (147.5 to 70.2) for player 2, and from 271.7 to 242.0 (238.3 to 202.2) for player 3. For comparison ,the SPE would predict a total effort of 100 for each player (and an effort of 50 at each node). A panel regression of the total effort on the inverse of the period fully interacted with player dummies and allowing for subject-specific random effects confirms a significant downward trend of efforts.[23] Accordingly, we focus henceforth on the reduced sample and the last eleven periods. Results for the full sample and all periods can be found in the supplementary material.

Table 11: Change of Efforts between First and Second Match in the 50%-LC-Treatment

Player	1	1	2	2	2	2	3	3	3	3
1st Node	F	F	F	F	F	F	E	D	E	D
2nd Node	E	D	B	A	C’	C	C	A	C’	B
Match 1	Win	Loss	Win	Win	Loss	Loss	Win	Win	Loss	Loss
$\bar{x}_i^1$	125.1	35.3	44.9	44.9	19.2	19.2	122.5	153.5	76.8	53.7
$\bar{x}_i^2$	118.4	46.0	34.5	50.2	29.1	31.9	74.3	98.1	73.9	81.4

Note: $\bar{x}_i^m \triangleq$ Average effort of player i subjects in her mth match.

Table 11 provides the average effort choices of players in their first and their second match, separated by nodes. Again, the stated average effort in the first match is conditioned on the outcome of the match. The results are mixed: After a win in the first match, players 1 and 3 both increase their effort, whereas player 2 either increases or decreases her effort depending on the course of the tournament. After a loss in the first match, each player type increases her effort except for player 3 in node C’. The average effort choices therefore provide some evidence for a reverse momentum. To statistically test these findings, we estimate a panel model of the change in efforts similar to the one in Table 9. While we find that the average subject decreases (increases) her effort after a win (loss) in the first match, the estimated effects are insignificant.[24]

5.5.3 Inter-tournament

In our experiment, we explicitly mention that subjects interact in twenty consecutive and independent round-robin tournaments. In other words, subjects compete in every round-robin tournaments against new opponents and with their full endowment regardless of the outcome of previous matches and tournaments. A subject’s final rank in a tournament should therefore have no strategic effect on the subsequent tournament.

[22]Concretely, this comprises three subjects (with IDs 248, 265, and 269).

[23]See the online supplementary material. Due to the low number of session, we do not calculate cluster-robust standard errors in this case.

[24]The results are available from the authors upon request.

To statistically test this prediction, we estimate a panel regression model of the change in subjects' total tournament efforts which includes as the main explanatory variable the rank in the previous tournament. In further specifications, we also interact this lagged rank with the treatment, and we include control variables. In all models, we allow for subject-specific random effects and we estimate robust standard errors which account for clustering of observation sat the session level and are corrected for the small number of clusters. The estimation results are presented in Table 12.

Table 12: Effort Dynamics between Tournaments

Dep. Variable	$x_i(t)$ - $x_i(t-1)$			
Model	(1)	(2)	(3)	(4)
Constant	-47.28**	-75.89**	-18.24***	-40.73**
	(16.844)	(26.589)	(0.495)	(15.163)
Rank 2	48.41**	51.74**	15.73***	19.09***
	(20.209)	(21.591)	(1.852)	(3.657)
Rank 3	87.07**	97.34**	36.37***	49.06***
	(30.132)	(34.527)	(5.564)	(6.345)
0%-Treatment			-84.73***	-87.93***
			(21.666)	(21.090)
× Rank 2			89.37**	90.05**
			(33.819)	(34.644)
× Rank 3			152.43***	153.15***
			(38.376)	(37.365)
100%-Treatment			9.96	12.02*
			(7.322)	(6.079)
× Rank 2			-3.85	-5.81
			(8.202)	(7.790)
× Rank 3			-23.36	-29.09*
			(15.219)	(14.734)
Control Variables	No	Yes	No	Yes
Observations	2,148	2,148	2,148	2,148
Subjects	168	168	168	168
R^2	0.073	0.081	0.135	0.145

Note: Robust standard errors in parentheses, clustered at the session level and corrected for the finite number of clusters. All models include a subject-specific random effects error structure.
Significance level: *** (1%), ** (5%), * (10%)

We find clear evidence that subjects change their total tournament effort in a round-robin tournament dependent on their rank in the previous tournament. After a first (third) rank, subjects decrease (increase) total tournament effort by about 47 (40) points. After a second rank, subjects total tournament effort almost remains unchanged. The negative impact of a first rank remains significant once controls are added.

Moreover, we find that the impact of the extreme ranks is the larger, the smaller is the second prize. Accordingly, the average subject decreases (increases) her total tournament effort after a first (third) rank the most in the 0%-treatment, to a moderate but significant degree in the 50%-treatment, and the least and insignificantly in the 100%-treatment.

As strategic effects are absent between tournaments, those dynamics clearly reveal a psychological reverse momentum.

6 Conclusion

In this article we have introduced a laboratory experiment that investigates how the prize structure influences the intensity, fairness, and dynamic behavior in round-robin tournaments with three players as a frequently used form of dynamic contests. Each single match is organized as an all-pay auction and the third prize is normalized to zero. We compare three treatments: tournaments with a second prize equal to either 0%, 50%, or 100% of the first prize.

While theory predicts the 50%-treatment to be most intense, we find that aggregate effort is highest in the 0%-treatment. In contrast, our evidence supports the predicted late mover disadvantage (advantage) in the 0%-treatment (100%-treatment) and that the 50%-treatment induces the fairest ranking (though not perfectly fair). Together, these experimental findings suggest that a prize-allocating contest designer of three-player round-robin tournaments faces a trade-off between maximizing intensity and fairness (although theory does not predict such a trade-off if matches are organized as all-pay auctions, see Laica et al., 2021).

Moreover, in line with the theory, we identify a *strategic* (reverse) momentum in the players' dynamic behavior: after winning the first match, a player increases (decreases) effort in the second match of the 0%-treatment (100%-treatment). Several findings suggest, however, that dynamic behavior is also subject to a reverse *psychological* momentum. Additional experiments that include a more comprehensive analysis of strategically neutral 50%-treatments with pure strategy equilibria (like in the case of matches organized as lottery contests) could help to determine whether this "hare-tortoise" heuristic proposed by Tong and Leung (2002) generally applies in round-robin tournaments.

In view of the announced transition from a four-player group stage to a three-player group stage in the first round of the FIFA World Cup 2026, the experimental study of round-robin tournaments with four players and multiple prizes could provide further insights. Besides the investigation of momentum effects, an open question is whether the theoretical prediction that sequential round-tournaments with more than three players are never ex-ante fair (Laica et al., 2021) also holds empirically.

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