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"Success breeds success" or "Pride goes before a fall"? [☆] Teams and individuals in multi-contest tournaments

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ABSTRACT

We study the impact of progress feedback on players' performance in multi-contest team tournaments, in which team members' efforts are not directly substitutable. In particular, we employ a real-effort laboratory experiment to understand, in a best-of-three tournament, how players' strategic mindsets change when they compete on a team compared to when they compete individually. Our data corroborate the theoretical predictions for teams: Neither a lead nor a lag in the first component contest affects a team's performance in the subsequent contests. In individual tournaments, however, contrary to the theoretical prediction, we observe that leaders perform worse—but laggards perform better—after learning the outcome of the first contest. Our findings offer the first empirical evidence from a controlled laboratory of the impact of progress feedback between team and individual tournaments, and contribute new insights on team incentives.

1. Introduction

Tournament-like competitive events are widespread in the economic landscape. Economic agents expend scarce resources to vie for a limited number of prizes, and they forfeit their resources regardless of win or loss. Such competitive activities appear in a diverse array of environments, including political campaigns, sports, R&D races, warfare, and even internal labor markets within firms.

A tournament often consists of more than a single static encounter and requires that parties meet on multiple fronts (see Konrad, 2009). One's success cannot be accomplished in a single stroke of effort, but rather depends on overall performance in a series of shots. Harris and Vickers (1987) propose a seminal race model in which two firms compete in a series of

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component contests to win a grand prize. Winning each component contest allows a firm to secure a discrete advance toward a given finish line; it wins the race if and only if it accumulates a sufficient number of advances ahead of its rival. Harris and Vickers use an analogy of an innovation race in which firms compete for multiple component technologies to describe their model. We label such competitions multi-contest tournaments.[1]

The economic literature on multi-contest tournaments conventionally assumes a rivalry between individual contenders, with each participating in all component contests. Many tournaments, however, involve competitions between teams (see Fu et al., 2015). Each team consists of a set of affiliated but independent players. A distinctive pair of players from rival teams are matched in each component contest, and a player's win allows his team to advance. Consider, for instance, political parties' electoral competitions for majority status—e.g., general elections in most democracies, and congressional elections in the U.S.: Candidates representing rival parties compete head-to-head for legislative seats in each constituency, and a party is allowed to form a government or set the legislative agenda if it achieves majority status. Team tournaments can also be intuitively exemplified by many sports events between teams, such as the Davis Cup for men's tennis, the Thomas Cup for men's badminton, and the Ryder Cup in golf. Alternatively, a large-scale military operation—e.g., World War II—usually includes a series of separate battles between matched individual units. The outcome of an individual battle depends on the maneuvers and commitments of the participating units.

Two common elements feature in these strategic interactions. First, unlike competitions between individuals, the tournament involves collective action. This leads to the usual free-riding problem, as individual players' efforts generate positive externality to their teammates. Second, it involves a unique team production process that differs from those previously considered in the literature. In the conventional group tournament or contest, group members join forces to perform a single task, and their efforts are aggregated into a single variable to be factored into contest success functions (see the literature reviews of Dechenaux et al., forthcoming; and Charness and Kuhn, 2011).[2] In our setting, each individual player is assigned to a distinctive component contest; team members' efforts do not simply sum up, as individual wins only discretely add to a team's margin.[3] These two common features compel us to investigate the strategic behavior in such multi-contest tournaments that take place between teams.

We present an experimental study to explore how players' behavior and the outcome of the tournament can be affected by the tournament's prevailing structure. In particular, we focus on how information on the state of the contest influences players' strategic behavior when they compete on a team. Consider, for instance, a sports event with two competing teams. How would a team's early lead affect the incentive of players who would appear in later matches and, therefore, the balance of the subsequent confrontations? Consider, alternatively, the dynamics in U.S. Senate elections, in which roughly one third of the 100 seats are up for election. How does a party's lead, due to past success or current turnover, affect rival candidates' strategies and the overall outcome of the competition?

The theoretical literature has predicted that players in multi-contest tournaments will react drastically differently to the outcomes of past component contests when standing alone vs. performing on teams. Harris and Vickers (1987) were among the first to identify a strategic-momentum or discouragement effect in multi-contest tournaments between individuals: Early victories generate additional momentum for leaders, yet discourage the laggards; as a result, early outcomes distort subsequent competitions and predict the ultimate winner (see also Klumpp and Polborn, 2006; Malueg and Yates, 2010; and Konrad and Kovenock, 2009). In contrast, Fu et al. (2015) demonstrate that the distorting effect caused by early outcomes does not loom large in team tournaments, and the outcome of each component contest—between each given pair of matched players—is independent of the prevailing feedback policy. Rather, it is determined purely by players' effort cost characteristics. To our knowledge, no studies have offered empirical or experimental evidence on how distinctive tournament structures (i.e., team vs. individual tournaments) affect players' strategic mindsets in reaction to progress feedback. We use a controlled laboratory setting to investigate this issue and bridge the gap.[4]

In reality, contests often involve nonpecuniary effort outlays, such as time, energy, and intellectual input that are typically unobservable or unverifiable. For this reason, measuring real effort directly from the field is notoriously difficult. To date, the majority of field data have been collected through piece-rate jobs in the workplace (see, e.g., Mas and Moretti, 2009; Bandiera et al., 2010; Hossain and List, 2012) or in sports contests (see, e.g., basketball: Berger and Pope, 2011; tennis: Magnus and Klaassen, 2001, and Malueg and Yates, 2010; golf: Guryan et al., 2009; and soccer: Kocher et al., 2012). While field data are of larger external validity, their problems have also been well recognized in the literature (e.g., Manski, 1993, 2000): It is difficult to isolate effort from ability, as well as other exogenous impacts exercised by institutional environments. Members of a given group may behave similarly because they share correlated, unobserved characteristics or work in similar institutional environments. It remains difficult to identify these factors and separate them from the exogenous

[1] Such a game is equivalently called "multi-battle contests" in other studies, e.g., Fu et al. (2015).

[2] In the literature on group contests, players' efforts are usually perfectly substitute for each other within a group. See, e.g., Kandel and Lazear (1992), Schotter and Weigelt (1992), Nalbantian and Schotter (1997), Ichino and Giovanni (2000), Croson (2001), van Dijk et al. (2001), Cadigan (2007), Abbink et al. (2010, 2012), and Ahn et al. (2011). Notable example can be seen in Cason et al. (2012) and Cason et al. (2015), in which the authors assume a perfectly complementary technology for team production.

[3] Consider an electoral competition between two parties for majority status, in which a candidate's lopsided win in one constituency cannot make up for the party's marginal losses in other constituencies.

[4] For a comprehensive review of contest theories, see Konrad (2009). Dechenaux et al. (forthcoming) provide a thorough review of both experimental and empirical papers on contests and tournaments.

impact exercised by institutional environments. As pointed out by Dechenaux et al. (forthcoming), an increasing number of experimental studies have adopted real-effort treatment to test contest and tournament theories, which allows for a more accurate measure of effort and, at the same time, improves external validity.[5] We follow in the same vein of this growing literature by pursuing our research question via a real-effort experiment. In this controlled real-effort environment, we are able to directly observe responses to feedback by manipulating the information displayed to the players.

Our experiment conducts a simple best-of-three tournament to simulate the competitions between two rival teams, with each team consisting of three players. Teams compete by counting the number of zeros in a series of 10-digit number strings composed of 0s and 1s. Players from rival teams are pairwise matched. Our theoretical model assumes that players are symmetric in terms of their abilities in each match and demonstrates, under this assumption, that the independence of feedback policy generally holds in a wide variety of environments. Following the assumption, we adopt a matching protocol that ensures that matched players are the closest in previous performance rankings.[6] The tournament proceeds potentially in three 5-minute component contests. In each contest, one pair of players competes head-to-head by performing the task on behalf of their respective teams. A team wins the tournament if and only if its players prevail in at least two component contests. A prize is awarded to the winning team and shared equally among its members. To better understand the reactions to feedback, subjects have to work in three stages: a piece-rate round, best-of-three tournament without feedback, and best-of-three tournament with feedback. This within-subject design allows for the maximum level of control of the confounding factors (such as players' abilities and the reflection effect) that can afflict field data. In addition, to further study the incentives in team tournaments and how they might differ from individual tournaments, we also add an *Individual* treatment in which the same players compete on their own behalf in pairwise best-of-three tournaments. Similarly, subjects in the *Individual* treatment must also work in a piece-rate round, best-of-three tournament without feedback, and best-of-three tournament with feedback. The within-subject comparison between tournaments with and without feedback will shed light on the impact of feedback under each tournament structure, while the between-subject comparison across treatment allows us to determine whether the impact of feedback, if any, varies in different tournament structures.

Our experimental results support the theoretical predictions for multi-contest team tournaments. Regardless of the nature of the feedback, players from both teams remain equally motivated after observing the outcome of the first component contest, and therefore a team tournament is equally likely to end after two or three component contests. By the theoretical prediction obtained in tournaments between individuals, we should expect these tournaments to be more likely to end with a clean sweep when there is feedback. Interestingly, however, we find that nearly half of all tournaments continue to the third component contest. Instead of being discouraged, laggards step up their performance relative to the previous contest after receiving feedback. On the other hand, the lead induces frontrunners to slack off and thereby perform worse than in the first component contest. This interaction decreases the likelihood that early leaders will eventually win, and consequently weakens the predictive power of early outcomes for ultimate winners. Among potential explanations, the utility-of-winning theory is consistent with behavior in both team and individual contests. The elicited-belief data also suggest that our results may be explained by the different impact progress feedback has on players' subjective beliefs of their winning probabilities.

An in-depth understanding of how people react to interim feedback is critical for the efficient design of competition schemes and incentive provisions within organizations, since progress feedback may exert both positive and negative influences (see, e.g., Fershtman and Gneezy, 2011; Charness et al., 2014). Previous studies on the impact of feedback schemes in contests and tournaments have paid little attention to competitions between teams and how they might differ from individual tournaments. Even for individual tournaments, findings on the impact of progress feedback have largely been inconclusive. Some studies detect the discouragement effect via field data in sports (Magnus and Klaassen, 2001; Malueg and Yates, 2010; Apesteguia and Palacios-Huerta, 2010; for a review, see Szymanski, 2003) and in controlled laboratory experiments (Gill and Prowse, 2012, 2014; Irfanoglu et al., 2014; Mago and Sheremeta, 2012; Mago et al., 2013). On the other hand, the opposite pattern—i.e., falling behind incentivizes laggards—is also observed both experimentally (Eriksson et al., 2009; Ludwig and Lünser, 2009; Kuhnen and Tymula, 2012; Gelder and Kovenock, 2014) and empirically (Berger and Pope, 2011). One possible reason is that the environments and designs in these studies vary substantially. Our research, therefore, offers direct comparisons of potential behavioral differences in team and individual tournaments, after carefully controlling for ability difference and other noises/confounding factors.

Our study also belongs to the broad literature on the role of communication in contests and tournaments. A handful of studies examine the impact of inter-player communication on performance in competitions. Harbring (2006) conducts an experimental study of a two-player rank-order tournament, in which the two players are allowed to communicate with each other, and finds that communication facilitates cooperative plays, i.e., by lowering competitive efforts. The seminal studies of Sutter and Strassmair (2009) and Cason et al. (2012) were among the first to explicitly bring team-based competitions onto the stage. They consider various communication treatments, allowing for both intra-team and inter-team communications, and focus on the coordinating role played by communication. The studies demonstrate that intra-team communications tend to overcome the usual free-riding problems and increase effort supply, while inter-team communications help teams collude. Sutter and Strassmair assume that team members' efforts are perfect substitutes, such that they sum up in producing the

[5] See van Dijk et al. (2001), Carpenter et al. (2010), and Cason et al. (2010).

[6] The theoretical foundation and robustness of our study will be described in more detail in Section 2.

joint output. In contrast, Cason et al. consider a perfectly complementary production function, such that the joint output of a team is determined by the minimum effort supplied by the players on the team. As the competitive effort can be wasteful from a social perspective, the coordinating role played by communication can be either socially constructive or destructive, depending on the nature of the communication. In contrast to these studies, which focus on communication among players about their intended actions or emotions, we examine communication between contest organizers and players in the form of progress feedback.

An interesting implication generated by our study helps us better understand a central question in organizations: Why are team productions essential? While working in teams facilitates skill specialization among members, it can also spawn free-riding and opportunism, which entail monitoring costs (Alchian and Demsetz, 1972; Williamson, 1975). Previous research has found that team-specific motivations, such as peer pressure (i.e., players are pressured to perform, since they are benchmarked against their teammates' performance) and team spirit (i.e., players cheer for each other), could mitigate the free-riding problem. Chen and Lim (2013), for instance, show that team-based tournaments can yield higher effort than individual tournaments, because team members are concerned about underperforming and letting their teammates down. In a field experiment, Hossain and List (2012) find that the effects of "framing manipulations" are in general stronger and more robust for teams than for individuals. As mentioned above, other papers, such as those by Sutter and Strassmair (2009) and Cason et al. (2012), expound the role played by intra-team communication in catalyzing team spirit and facilitating coordination. We complement these studies by making a claim about teams' responses to progress feedback. Our results indicate that relative to their individual counterparts, progress feedback causes less perturbation in performance in team tournaments, because it equally motivates both leading and lagging teams. It also implies that the evaluation of a performance-feedback mechanism must take into account the context, e.g., whether players stand alone or perform on teams.

The rest of the paper proceeds as follows. Section 2 constructs the theoretical framework upon which the experiment is built. Section 3 describes the experiment and the testing hypotheses. Section 4 reports the results. Section 5 discusses potential explanations, and Section 6 concludes.

2. Theoretical framework

Our simple theoretical framework is adapted from Klumpp and Polborn (2006) and Fu et al. (2015). Two parties, which can be either teams or individuals, are indexed by $i = 1, 2$. They compete in a tournament for a prize of value 1. The tournament proceeds in three periods, with one component contest being carried out in each period.

If the contest takes place between two individuals, each player performs in all component contests. A player wins the tournament if he secures two wins. In a team contest, two teams, each consisting of three players, compete against each other. In each period, one (distinctive) player performs on behalf of the team in only one component contest, in which he competes head-to-head with his matched opponent from the rival team. A team wins the tournament if and only if its players secure two victories. The prize awarded to the winning team is a public good, so each player receives a value of 1.

In both settings, we assume that players simultaneously commit to their effort entries in each component contest. Players are assumed to be identical in terms of ability, in that they have the same effort cost function $C(x)$ for effort $x \geq 0$, with $C'(\cdot) > 0$ and $C''(\cdot) \geq 0$ for $x \geq 0$, and $C(0) = 0$. The function $C(\cdot)$ is common knowledge.

We do not assume a specific form for the winner-selection mechanism for each component contest. Instead, we only impose the following standard regularity conditions on the contest game.[7] First, let $p_i(x_i, x_j)$ $i, j = 1, 2, i \neq j$ denote the probability of player i's winning an arbitrary two-player contest, with $p_1(x_1, x_2) + p_2(x_1, x_2) = 1$, and x_i be his effort. We require that the probability *increase* in his effort and *decrease* in his opponent's. Second, we require that the contest be *symmetric*: If two players equally value winning the component contest, a symmetric bidding equilibrium will be induced, in which they exert the same amount of expected effort and win with equal probability. Third, the contest is required to be *monotone*: A player with a higher valuation of winning is better incentivized and exerts more effort. Therefore, he is more likely to win in equilibrium. Fourth, the contest is *fair*: A tie is randomly broken if both players exert zero effort, and one wins a component contest with any positive effort if his opponent stays inactive.

We now analyze the two cases, individual tournament and team tournament. Our results demonstrate that history distorts future outcomes only in individual tournaments and not in team tournaments.

2.1. Individual tournaments

Suppose that players are informed of the outcomes of previous component contests. The game can be analyzed by backward induction. Suppose that each of the two players has won in one of the two previous component contests. The outcome of the third contest determines the ultimate winner. In a symmetric equilibrium, each wins with a probability of $\frac{1}{2}$. Let $C^e(x_3)$ be players' (symmetric) expected effort cost in the equilibrium. Each player thus expects a payoff of $v_3 = \frac{1}{2} - C^e(x_3)$ for participating in this component contest.

[7] Both Tullock rent-seeking contests and all-pay auctions satisfy these requirements.

We then consider players' expected payoffs and incentives in the second contest. Without loss of generality, we assume that player 1 has won the first contest. Players 1 and 2 choose their efforts $x_{1,2}$ and $x_{2,2}$, respectively, to maximize their expected payoffs. Let $p_{i,2}(x_{1,2}, x_{2,2})$ be a player i's probability of winning the second component contest for an effort profile $(x_{1,2}, x_{2,2})$.

For player 1, another win ends the tournament and allows him to collect a prize of value 1. Losing would erase his lead and force him to perform in another costly contest, from which he expects a gain of v_3. Player 1's expected payoff function is written as

$$u_{1,2} = p_{1,2}(x_{1,2}, x_{2,2}) \cdot 1 + (1 - p_{1,2}(x_{1,2}, x_{2,2}))v_3 - C(x_{1,2})$$
$$= p_{1,2}(x_{1,2}, x_{2,2})(1 - v_3) + v_3 - C(x_{1,2}). \tag{1}$$

For player 2, in contrast, the tournament proceeds to period 3 only if he outperforms player 1, in which case he receives a payoff v_3; otherwise he receives nothing. He maximizes his expected payoff

$$u_{2,2} = p_{2,2}(x_{1,2}, x_{2,2})v_3 + (1 - p_{2,2}(x_{1,2}, x_{2,2})) \cdot 0 - C(x_{2,2}),$$
$$= p_{2,2}(x_{1,2}, x_{2,2})v_3 - C(x_{2,2}). \tag{2}$$

By (1) and (2), the component contest is strategically equivalent to a standard static contest in which two players have valuations $1 - v_3$ and v_3, respectively. Player 1 responds to an "effective prize spread" of $1 - v_3 = \frac{1}{2} + C^e(x_3)$ when choosing $x_{1,2}$: He secures a "base reward" of v_3 regardless, while the differential between winning and losing, i.e., $1 - v_3$, motivates his effort. In any equilibrium, he would rationally choose his effort $x_{1,2} \in [0, C^{-1}(1 - v_3)]$ to maximize $u_{1,2}$. In contrast, player 2 has an effective prize spread of $v_3 - 0 = v_3$, which is $\frac{1}{2} - C^e(x_3)$ and strictly falls below that of player 1. In any equilibrium, he would rationally choose his effort $x_{2,2} \in [0, C^{-1}(v_3)]$ to maximize $u_{2,2}$. Because $1 - v_3 > v_3$, player 1 has more to win than player 2.

It should be noted that a player is allowed to stay inactive by exerting zero effort. There exists no equilibrium, though, in which a party bids zero with probability one, because of the fairness condition we have imposed. Player 1, the frontrunner in the tournament, is expected to have a stronger incentive and be more likely to win the second component contest.

This reasoning captures the usual strategic momentum effect or discouragement effect: Player 1 is better motivated in the second period simply because of his earlier victory. In fact, the ex-ante symmetric contest will be diverted into an asymmetric path after one obtains a lead. In short, progress feedback incentivizes the frontrunner, and discourages the laggard.

Consider, alternatively, the situation in which previous outcomes are not disclosed to players as the tournament proceeds. The case is straightforward: Because players are ex ante symmetric, they should have an equal chance of winning in all component contests.

Therefore, disclosing information about past outcomes causes distortion of the dynamic path of the tournament. It triggers the discouragement effect, which makes the tournament more likely to end with a clean sweep instead of going to a third (deciding) contest.

2.2. Team tournaments

Again, we first consider the situation in which past outcomes are disclosed. In contrast to the individual tournament, the strategic discouragement effort is nullified in a team setting.

A player is indexed by $i(t)$ if he is affiliated with a team i and assigned to the t-th component contest. Suppose that at the end of period 2, each team has each secured one win. Since we assume that players in the third component contest are identical, each team will win the contest with a probability of $\frac{1}{2}$.

Now consider the immediately preceding component contest, i.e., contest 2. Assume without loss of generality that player 1(1) has won the first component contest on behalf of team 1. If player 1(2) wins, his team wins, and he will receive an immediate prize of 1. If he loses, the contest proceeds to the finale. The deciding contest generates a value of $\frac{1}{2}$ to him: His teammate, player 1(3), is going to compete in that event, and player 1(3) is expected to have a probability of $\frac{1}{2}$ to outperform his opponent and win the tournament for the team. Let $p_{i(t)}(x_{1(t)}, x_{2(t)})$ denote the probability of player $i(t)$'s winning his component, with $p_{1(t)}(x_{1(t)}, x_{2(t)}) + p_{2(t)}(x_{1(t)}, x_{2(t)}) = 1$. Player 1(2) chooses his effort $x_{1(2)}$ to maximize his expected payoff

$$u_{1(2)} = p_{1(2)}(x_{1(2)}, x_{2(2)}) \cdot 1 + (1 - p_{1(2)}(x_{1(2)}, x_{2(2)})) \cdot \frac{1}{2} - C(x_{1(2)})$$
$$= p_{1(2)}(x_{1(2)}, x_{2(2)}) \cdot \frac{1}{2} + \frac{1}{2} - C(x_{1(2)}). \tag{3}$$

We now turn to player 2(2) from the lagging team. If he wins, the tournament proceeds to the final stage, which is between players 1(3) and 2(3). The component contest would generate a value of $\frac{1}{2}$ to player 2(2), since player 2(3) is expected to win component contest 3 with a probability of $\frac{1}{2}$. If he loses, the tournament ends, and he receives nothing. Player 2(2) chooses his effort $x_{1(2)}$ to maximize his expected payoff

$$\begin{aligned} u_{2(2)} &= p_{2(2)}(x_{1(2)}, x_{2(2)}) \cdot \frac{1}{2} + (1 - p_{1(2)}(x_{1(2)}, x_{2(2)})) \cdot 0 - C(x_{2(2)}) \\ &= p_{2(2)}(x_{1(2)}, x_{2(2)}) \cdot \frac{1}{2} - C(x_{2(2)}). \end{aligned} \tag{4}$$

By (3) and (4), the component contest is strategically equivalent to a static contest in which two players have the same valuation of $\frac{1}{2}$. Player 1(2)'s effective prize spread, which is the differential between winning and losing, is $1 - \frac{1}{2} = \frac{1}{2}$. He receives a base reward of $\frac{1}{2}$ automatically, and the differential between winning and losing, i.e., $1 - \frac{1}{2}$, motivates his effort. In any equilibrium, he would rationally choose effort $x_{1(2)} \in [0, C^{-1}(\frac{1}{2})]$ to maximize $u_{2(2)}$. Player 2(2)'s effective prize spread is $\frac{1}{2} - 0 = \frac{1}{2}$, which is the same as that of player 1(2). In any equilibrium, his effort would fall in the interval $[0, C^{-1}(\frac{1}{2})]$.

Again, there exists no equilibrium in which a party bids zero with probability one, thanks to the fairness condition. We expect that they will win the second component contest with equal probability, since winning the component contest brings them the same amount of premium relative to losing.

This observation highlights the key difference between team and individual tournaments. Recall that in the individual tournament, the third component contest generates a value of $v_3 < \frac{1}{2}$: Players exert costly effort in component contest 3, which dissipates future rent assessed from the viewpoint of players in period 2. Therefore, player 1, who is in the lead, has much to lose, while player 2 does not have much to win, which generates strategic momentum to the frontrunner and discourages the laggard.

In contrast to the individual tournament, the expected effort in period 3 does not enter player 1(2)'s payoff function when deciding how much effort to put into period 2, because the cost is to be borne by his teammate—i.e., player 1(3)—and not himself. The same applies to player 2(2). Component contest 3 boils down to a costless lottery, since it does not require continued input. He thus has a stronger incentive to even the score than his counterpart in the individual tournament. The strategic-momentum or discouragement effect, which emerges in the individual tournament, no longer exists. A team's initial lead does not distort the stochastic outcome of subsequent competitions.

Suppose, alternatively, that past outcomes are not revealed to players. Each component contest is symmetric, and players win with equal probability. Therefore, information disclosure does not distort the dynamic path of the tournament. The tournament is equally likely to end in two periods of competition or three, regardless of the prevailing feedback scheme.

3. The experiment

We employ a real-effort task—counting numbers—as a test bed. To mimic our theoretical framework, we select the task based on the following criteria. First, the task should be simple and require no previous task knowledge, so that the ability to finish one task correctly does not differ too much across subjects or change too much for the same subject over time. Second, the time required to finish one task should be as little as possible, so that performance better captures continuous, pure mechanical/physical effort. If a task takes too long, it is more difficult to accurately capture effort provision, especially toward the end of a period.[8] Third, the task should be sufficiently tedious. Conducting a fun task may generate intrinsic utility, thereby making it difficult to measure players' effort supplies in response to monetary prizes. In this spirit, we ran a pre-test on three popular tasks in the existing literature: an encryption task (see, e.g. Nisvan et al., 2011), a slider task (see, e.g., Gill and Prowse, 2012, 2014) and a counting task (see, e.g., Abeler et al., 2011). Based on the above criteria, we selected the counting task for our experiment.[9]

The experiment consists of two treatments: *Individual* and *Team*. Each treatment has three parts: piece rate, best-of-three tournament without feedback, and the same tournament with feedback. We describe each part in turn.

3.1. Part 1 (Piece-rate)

This part is identical in both treatments. Subjects were asked to count the number of zeros in a series of randomly generated 10-digit number strings that consists of zeros and ones. Fig. 1 shows a screen shot of a task presented to the subjects during the experiment. To facilitate comparison, subjects worked on the same strings and were paid a piece rate of €0.05 for each correct answer.

This part familiarized subjects with the counting task, and allowed them to accumulate earnings. More importantly, we could measure and control for ability heterogeneity—which is unavoidable in real-effort tasks—and rank and pair subjects

8 Imagine that two players both finish 4 tasks in 1 minute. Player 1 takes exactly 1 minute, and player 2 takes 15 seconds less (i.e., 45 seconds) to finish 4 tasks; he could have finished 5 tasks if he had one more second (i.e., 61 seconds). Compared to player 1, his extra effort in getting the 5th task done is effectively ignored, judging from the performance data, as both have exactly the same performance record.

9 Compared to the counting task, subjects spent much more time for both one encryption task and one slider task. Moreover, the slider task, which involves graphical images, occasionally failed to measure time per task correctly when all subjects in a session worked simultaneously.

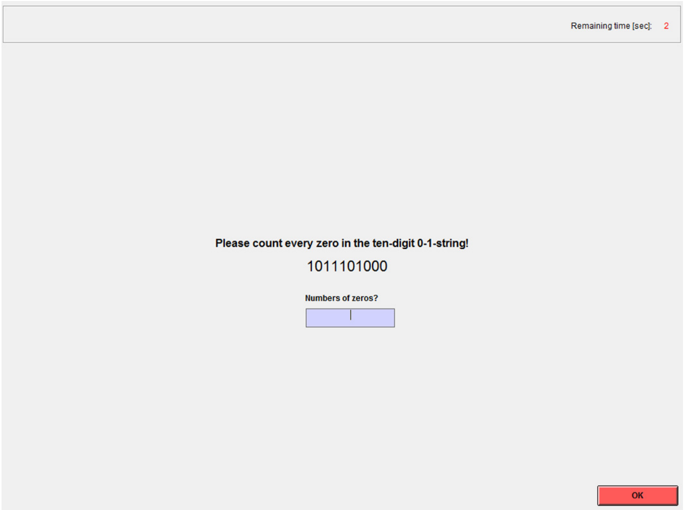

Fig. 1. A screen-shot of the counting task.

such that they compete against their most closely matched opponents.[10] At this stage of the experiment, subjects knew that the experiment would have three parts, but did not know any details of the upcoming experiments. We chose to withhold the information, because revealing more information could potentially distort subjects' incentive in the piece-rate round—namely, by manipulating their efforts and hiding their true ability in order to gain a favorable position in subsequent contests. Subjects could have formed their own conjectures regarding what would happen in subsequent parts. Without any specific information, however, they could not form beliefs that were systematically biased one way or the other; consequently, they should not substantially adjust their normal behavior in a certain direction.[11]

3.2. Part 2 (Tournaments without feedback)

In Part 2, subjects played a best-of-three tournament without any feedback within a period or across periods. We could observe subjects' performance and performance changes across periods when the outcome for each period was not revealed. Furthermore, performance in Part 2 could serve as a benchmark when we examined subjects' responses to feedback in Part 3.

At the beginning of Part 2, subjects were given a new set of instructions for the best-of-three tournament. To address our theoretical assumption of symmetry, we assigned the closest performers to pairwise matches. Specifically, at the beginning of Part 2, subjects were told that the computer program had ranked and matched them with their closest performer in Part 1. The matching process was carefully described to them as follows: "*The program first ranked all subjects according to the number of correct answers provided in Part 1. Then it matched the two subjects with the closest ranks into a pair. That is, the best performer was matched with the second-best performer, the third best was matched with the fourth best, etc.*" However, they were not informed of their exact ranks or with which participant in the room they were paired throughout the experiment.

In the *Individual* treatment, paired subjects competed in the best-of-three tournaments without any feedback. In each period, they competed in the same 5-minute counting task as in Part 1, and the one who had a higher score won the component contest in that period. A tie would be broken randomly. Given that there was no feedback, subjects were forced to compete in all three periods. At the end, whoever won in at least two out of the three periods won the tournament. Subjects neither received any feedback within a period or across distinctive periods, nor at the end of Part 2. Only at the end of the entire experiment did they learn their and their opponents' scores and the final outcomes of Part 2.

In the *Team* treatment, the computer ranked and paired subjects in the same way as in the *Individual* treatment. However, there was an additional group assignment stage after the ranking and pairing stage. The computer randomly selected three pairs of subjects and assigned the subjects in each pair to two *different* teams. For instance, imagine that subjects ranked

[10] Without this control we might still be able to analyze the data using piece-rate performance and belief elicitation to control for ability difference and belief updates. However, the data analysis would not be as straightforward as what we could do using the current design. It would be more difficult for us to disentangle the impact of feedback from the direct influence of both ability heterogeneity and subjects' perceived-ability difference on players' incentives to exert effort and the winning outcomes on individual-level data. Hence, to be cautious we opted for a design that allows for as much control as possible.

[11] This design could have drawbacks. For example, a participant from an earlier session could have told a friend in a later session that he/she would be matched in a tournament according to his/her performance in the earlier part. This information and experience exchange could undermine the validity of our results. However, the Munich subject pool is quite large—around 4100 students in total. Each time, only a small random sample is chosen to receive invitations. The chance that participants in the same experiment would know each other is very low. Information exchange among participants could be a serious problem if the subject pool were small and/or came from the same cohort. We believe that our subject pool is relatively immune to this problem, given its large size and how we recruited participants.

at 1 and 2, 5 and 6, and 17 and 18 are selected to form three pairs. In our group-assignment protocol, subjects 1, 5, and 17 could be on one team, while subjects 2, 6, and 18 could be on the other team; Alternatively, subjects 1, 6, and 18 could be on one team, while subjects 2, 5, and 17 could be on the other. This matching mechanism ensured that subjects with the closest performance records always competed with each other and the two teams were *ex-ante* equally competitive on average. In each period, a pair of contestants, each representing his or her own team, was randomly selected to compete in the 5-minute counting task, and the one who achieved a higher score won the component contest. Each pair competed only once. When the selected pair of players competed against each other, the other two pairs were asked to rest and wait quietly. Identical to the *Individual* treatment, no one received any feedback, either during or across periods. Whichever team led in at least two out of three periods received the prize for this part. Team assignment was again completely anonymous, i.e., no one knew which participants in the room were their teammates or their opponents on the rival teams.

3.3. Part 3 (Tournaments with feedback)

Part 3, the core of the experiment, was almost identical to Part 2, except that subjects received feedback after each period and were re-ranked and re-paired at the beginning of Part 3. Previous studies have documented that changes in incentive schemes can distort performances, especially for different genders (see, e.g., Gneezy et al., 2003; Healy and Pate, 2011).[12] For example, female players may shy away from competition or perform worse when they have to compete for a prize than under a piece-rate incentive scheme. Therefore, players' willingness to exert effort may vary from Part 1 to Part 2. Furthermore, players' ability to perform a task may also change over time. For instance, some subjects are more likely to perform better through learning, and others may do worse due to fatigue or losing focus. To address these issues, at the beginning of Part 3 we re-ranked subjects based on their overall performance in Part 2. We then re-paired and reassigned them to groups (in the *Team* treatment only) with the same matching mechanism used in Part 2.

While a rematching procedure allowed us to further control the possible factors that could vary across subjects over time, revealing the outcome at the end of each period allowed us to test the impact of feedback on performance in the subsequent component contests. Therefore, at the end of each period in Part 3, the outcome was announced to both players in a pair in the *Individual* treatment. In the *Team* treatment, the outcome was announced not only to the competing pair from the two teams but also to the other four players who were waiting.[13] With feedback across periods, the best-of-three tournaments ended as soon as one subject had won in two periods in the *Individual* treatment, or one team had won in two periods in the *Team* treatment. To minimize changes between Part 1 and Part 2, we did not give subjects any other information concerning their individual performance or rankings, either within or between period(s). The only information we revealed to subjects is whether they (or their team) had won or lost in a previous period.

Apart from collecting data on performance, we also elicited subjects' subjective beliefs about their rankings and odds of winning at the beginning of each period in Part 2 and Part 3 for both treatments. More specifically, in the *Individual* treatment, subjects were asked to predict how likely they were to win in the next period (on a scale of 0 to 100). In the *Team* treatment the question became, "How likely is it that your team will win in the next period?"[14] The question was given to all subjects, including those who would not be competing in the next period.

3.4. Testing hypotheses

Based on the theoretical analysis in Section 2, we construct two main testing hypotheses.

Hypothesis 1. *In the Individual treatment, with feedback across periods, a tournament is significantly more likely to end in two periods than in three periods. After receiving feedback, first-period laggards are discouraged in period 2 and reduce effort more than first-period leaders.*

Hypothesis 2. *In the Team treatment, after receiving feedback across periods, a tournament is equally likely to end in two or three periods. Effort provision in period 2 does not depend on whether a team led or lagged in period 1.*

3.5. Procedure

The experiment took place in the MELESSA lab at the University of Munich from April to June 2012. A total number of 186 subjects from various academic backgrounds were recruited via ORSEE (Greiner, 2004). The experiment was pro-

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12 See further discussion in an excellent review by Niederle and Vesterlund (2011).

13 Again, given that participants were anonymous throughout the entire experiment, the waiting players only knew that one of their team members was representing the team and competing against their counterpart on the opponent team.

14 We did not incentivize their answers, to prevent them from hedging their beliefs and effort. Other studies, such as Kuhnen and Tymula (2012), use the same approach.

Table 1
Treatment summary.

Treatment	No. of sessions	No. of participants	No. of independent observations	Average earnings
Individual	2	48	24	26.89
Team	6	138	23	18.74

Note: The difference in average earnings between the two treatments is largely due to the difference in prize values (€18 in Individual and €10 in Team).

grammed and conducted with z-Tree software (Fischbacher, 2007). We conducted two sessions for the *Individual* treatment and six sessions for the *Team* treatment, resulting in 24 pairs of competing individuals and 23 pairs of rival teams.[15] Table 1 summarizes the basic information for each treatment.

At the beginning of each session we informed subjects that the experiment consisted of several parts, but did not provide instructions for each new part until they had finished the previous one. Instructions in all parts were read aloud to ensure common knowledge of the rules (see Appendix A for sample instructions for the *Team* treatment). To ensure complete understanding, we provided subjects with 10 practice tasks (with no payment) to familiarize them with the task and the computer interface. Moreover, we ran control questions at the beginning of each part and waited until all subjects had correctly completed all control questions before running the main experiment.

At the end of the entire session, subjects were asked to fill in their social demographics and ex-post rationales for the strategies they used during the experiment. The prize for the tournament winner in each part was €18 in the *Individual* treatment and €10 for each winning player in the *Team* treatment. Although the experiments lasted a similar amount of time for both treatments, those who were in the *Individual* treatment needed to work in at least 5 periods (3 periods in Part 2 and 2 period in Part 3), while a team member only needed to compete in at most 2 periods (one period in Part 2 and at most one period in Part 3). Hence, the difference could be up to 3 to 5 periods of 5-minute tasks, which is 15 to 25 minutes of active, boring, real-effort work. Prize values were chosen to reflect not only the opportunity cost of time for the subjects, but also the physical effort required during the tournaments.[16] Each experimental session lasted about 1.5 hours, including the instruction and payment stages. Subjects earned an average of €20.84 (including the €4 show-up fee), and were paid separately and privately.

4. Results

The results of our experiment support the theoretical prediction for the *Team* treatment, but not for the *Individual* treatment. In this section, we first provide an overview of the performance for each treatment and each part. We then focus on testing the impact of feedback under distinct tournament structures.

4.1. Descriptive statistics

Across all periods in the experiment, subjects took 2.7 seconds (on average) to count one 10-digit 0–1 string. Overall accuracy was 97.07%, which indicates that subjects took the task seriously and attempted to provide accurate answers. Moreover, we do not find any evidence that subjects tried other strategies—for example, attempting to go through as many tasks as possible by randomly typing numbers near the end of each period.

Table 2 provides an overview of subjects' average performance in each part. First, in the piece-rate stage (Part 1), subjects correctly accomplished 97.88 tasks on average in the *Individual* treatment and 94.75 in the *Team* treatment. The difference is not statistically significant ($p = 0.46$, a two-sided Mann–Whitney ranksum test). This rules out the possibility that any observed treatment effects are caused by sample selection bias. Second, team players did not perform better than individual players in Part 2. To test this hypothesis, we compare the average performance of individual players in the *first* period of Part 2 to that of team players in *all three periods* (to control for potentially asymmetric learning experiences between team and individual players), given that individual players competed in three periods, but team players competed in only one out of three periods. A two-sided Mann–Whitney ranksum test reveals that they are not significantly different (107.85 versus 112.41, $p = 0.19$). This result implies that, in the absence of feedback, playing on a team per se does not lead to higher performance. Third, average performance slightly increased from Part 1 to Part 2. Wilcoxon sign-rank tests suggest that in both treatments, a player's average number of correct tasks in each part was higher than that in the previous part, with at least 5% significance. However, standard errors remain small and mostly constant in both treatments, regardless of the presence or absence of progress feedback. The result indicates that the distribution of subjects' strategies did not change significantly across periods, such as investing a lot of effort in one period and (strategically) shirking in others.

[15] Each session involved 24 subjects, except for one session of 18 subjects in the *Team* treatment due to no-shows.

[16] Moreover, the difference in prize values should not affect the incentive comparisons between Part 2 and Part 3 within *Team* or *Individual* treatments. In the experimental results section, we will also show that the difference in the prize values in *Team* and *Individual* treatments did not affect participants' willingness to exert effort.

Table 2
Average performance by treatment and period.

	Individual		Team	
	Mean	SE	Mean	SE
Part 1:	97.88	3.02	94.75	1.59
Part 2-period 1	107.85	3.14	116.30	1.71
Part 2-period 2	113.83	3.21	104.67	1.47
Part 2-period 3	116.04	3.05	116.26	1.72
Part 2-all three periods	112.58	3.07	112.41	1.70
Part 3-period 1	122.15	3.20	113.13	2.12
Part 3-period 2	122.17	3.25	124.54	1.77
Part 3-period 3	128.15	3.70	121.72	2.80
Part 3-all three periods	123.59	3.21	119.31	2.21
All three parts:	114.44	3.07	107.57	1.69

Notes: The "SE" columns report standard errors of the mean. The mean is calculated using the average performance of each subject in a given time frame (either one period, or one part, or all-three parts). If we pool all the data from both Individual and Team treatments in all three parts, the mean performance is 109.34, with a standard error of 1.50. The average performance of team players is lower in Part 2-period 2 (104.67) and Part 3-period 1 (113.13), because overall, those players had lower average rankings and performance records in Part 1.

In summary, without information, subjects' performance does not depend on whether they compete individually or on a team. In both treatments, average performance increased slightly with repetition due to learning.

4.2. Hypothesis testing: the impact of feedback

We now investigate the overall outcome of each tournament. We find that when there was feedback (in Part 3), 60.87% (14 out of 23) of team tournaments ended in two periods. This number is slightly higher than the theoretical prediction of 50%, but not significantly different from it ($p = 0.30$, two-sided proportional test). Our finding suggests that Hypothesis 2—i.e., that team tournaments should end in either two or three periods with equal probability—cannot be rejected.

In the *Individual* treatment, however, our result clearly contradicts the theoretical prediction. While the theory predicts that when there is feedback, significantly more than 50% of the tournaments should end in 2 periods, we find that only 58.33% (14 out of 24) of the tournaments ended in 2 periods. This number is not significantly different from 50% either ($p = 0.41$, two-sided proportional test).

To reconcile the dichotomy between the *Individual treatment* and *Team treatment* and further understand the role played by feedback, we first compare these observations to the benchmark setting in Part 2 (without feedback), then discuss subjects' own description of their behavior and strategies at the end of the experiment.

4.2.1. Comparison to benchmark (without feedback)

Progress feedback was unavailable in Part 2. Therefore, there was no strategic linkage among the competitions in the three periods. The tournament became a series of independent draws. Assuming symmetry, a tournament in Part 2 is predicted to end with a clean sweep—i.e., one party wins in all three periods—with a probability of 0.25.[17] We observe, however, that in the *Individual* treatment, 58.3% (14 out of 24) of the tournaments ended with 3:0, which *is* significantly different from the theoretical prediction of 25% ($p < 0.01$, two-sided proportional test). In the *Team* treatment, 17.4% (4 out of 23) of the tournaments ended with 3:0, which *is not* significantly different from the theoretical prediction of 25% ($p = 0.4$, two-sided proportional test).

Two remarks are in order. First, analogous to Part 3, the observations in Part 2 lend support to the corresponding theoretical predictions for the *Team* treatment, but contradict those in *Individual* treatment. Imperfectly controlled within-pair heterogeneity in subjects' abilities and our matching protocol could have contributed to this contrast. Second, a comparison between Part 2 and Part 3, together with the contrast between the *Individual* treatment and the *Team* treatment, further highlights the important role played by feedbacks. We now elaborate on this issue.

We first discuss how closely pairs were matched in terms of ability. Using performance as a proxy for underlying ability, we take the average of absolute performance differences between matched players in all three rounds in Part 2 and compare the distributions using box plots (see Fig. 2).[18] More than 80% of the paired players (19 out of 24 in the Individual treatment and 57 out of 69 in the *Team* treatment) have a task difference of no more than five in both treatments. That is

[17] In Part 2, the rules of the game was different from those in Part 3. Without feedback, a tournament was forced to last three periods regardless, which removed the dynamic linkage among the three component contests in a tournament. Our focus, therefore, must be on tournaments' overall outcomes over all three periods.

[18] A box (and whisker) plot is a convenient way of depicting a distribution graphically using quartiles. The bottom and top of the box represent the first and third quartiles (i.e., 25th percentile and 75th percentile), and the band inside the box is the second quartile (the median). The ends of the whiskers

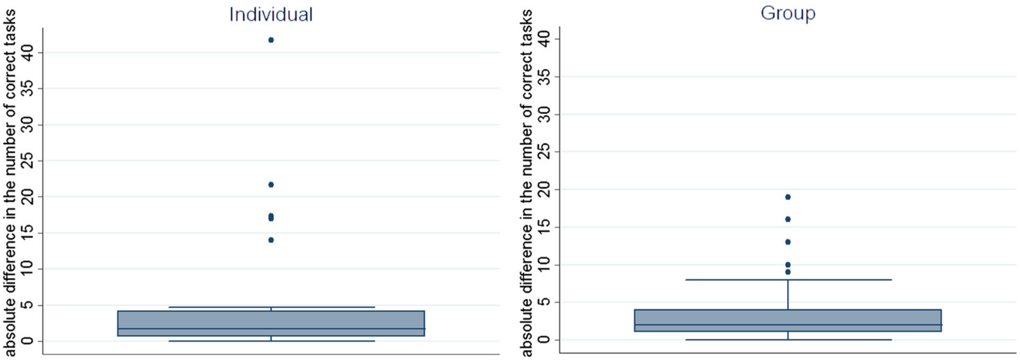


Fig. 2. Absolute performance difference within matched pairs in Part 2.

within 13.5 seconds' difference (considering that it takes about 2.7 seconds to finish a task), or less than 4.5% of the total performance in Part 2. Overall, the matching protocol worked reasonably well in matching players with very close abilities into pairs.

However, it is essentially impossible to guarantee fully symmetric players as required by the theoretical framework. Without the distortion of feedback on subjects' incentives, a small ex ante ability differential would largely predict the winner in a competition because a player only needs to outperform his/her opponent by one score to secure a victory. This could explain why, in the *Individual* treatment, a significantly higher proportion (58.3%) of the tournaments ended with 3:0. Moreover, we find that 87.5% (21 out of 24) of the first-period winners also won in the second period. This number is significantly different from the theoretically predicted 50% ($p < 0.01$, two-sided proportional test) under the assumption of symmetry (since all component contests are independent fair draws). However, when feedback was provided, only 14 out of 24 winners in period 1 continued to win in period 2. Compared to the case in which feedback was not provided, the winner in period 1 was much less likely to win in period 2 when feedback on the winning outcome in period 1 was provided (but everything else was the same). These results suggest that ex ante asymmetry became less powerful in predicting the winning outcomes in Part 3, which highlights the nontrivial role played by feedback in the *Individual treatment*.

Results for the *Team* treatment paint a different picture, which is due to both the matching protocol and the different impacts of feedback in a team tournament setting. In the *Team* treatment, we randomly assigned three pairs of players with the closest rankings to two teams. A slightly more competent player can be sent to either team. The overall ability heterogeneity between the two competing teams is minimized by randomization, so it is difficult for a team to be assigned advantageous players in all three pairwise matches. Not surprisingly, as shown above, only 17.4% (4 out of 23) of the tournaments ended with 3:0. Further, 43.5% (10 out of 23) of first-period winning teams also prevailed in the second period, which is not significantly different from the theoretical prediction of 50% under the assumption of symmetry ($p = 0.53$, two-sided proportional test). In addition, when there was feedback in Part 3, 14 out of 23 first-period winners won in period 2. Again, this is not significantly different from the theoretical prediction of 50%, if, as is suggested by the theory, feedback should not change team players' relative incentive to exert effort. Therefore, our results in the *Team* treatment are largely in line with theoretical predictions for both Part 2 and Part 3.

Game theory suggests that in a team tournament, first-period results should not cause asymmetric impacts on second-period players' incentives or their performance, whereas in individual tournaments, earlier results do affect the leader's and the laggard's incentives asymmetrically in the subsequent period. To unravel how feedback changed subjects incentive to work, and why theoretical predictions for the *Team* treatment are supported but not those for the *Individual* treatment, we further examine the within-subject performance changes across periods in Part 3, conditional on whether the feedback is positive or negative. In the *Individual* treatment, we simply compare each player's performance in period 2 to his/her own performance in period 1. In the *Team* treatment, however—since team players only play at most once in each part—we take each team player's own performance in Part 2 as a benchmark while computing their performance changes in Part 3.

Fig. 3 describes the distributions of percentage changes in performance for Part 3-period 2 using box plots. As shown in the right panel of Fig. 3, independent of winning outcomes in period 1 (Part 3), more than 70% of players from both the leading and lagging teams (on average) increased their performance in period 2 by 5.34% and 5.77% respectively, compared to their own performance in Part 2.[19] These changes (for leaders vs laggards) are not statistically different ($p = 0.76$,

in our plots always represent the upper or lower adjacent values (i.e., 1.5 interquartile range [IQR] of the upper or lower quartile). Outliers are plotted in separate dots.

[19] Note that we are not comparing team players' performance in period 2 to those who played in period 1, because it is not meaningful to compare different players with different abilities. Our aim is to investigate within-subject performance changes across periods to study how a player's incentive changed due to the nature of the feedback he/she received.

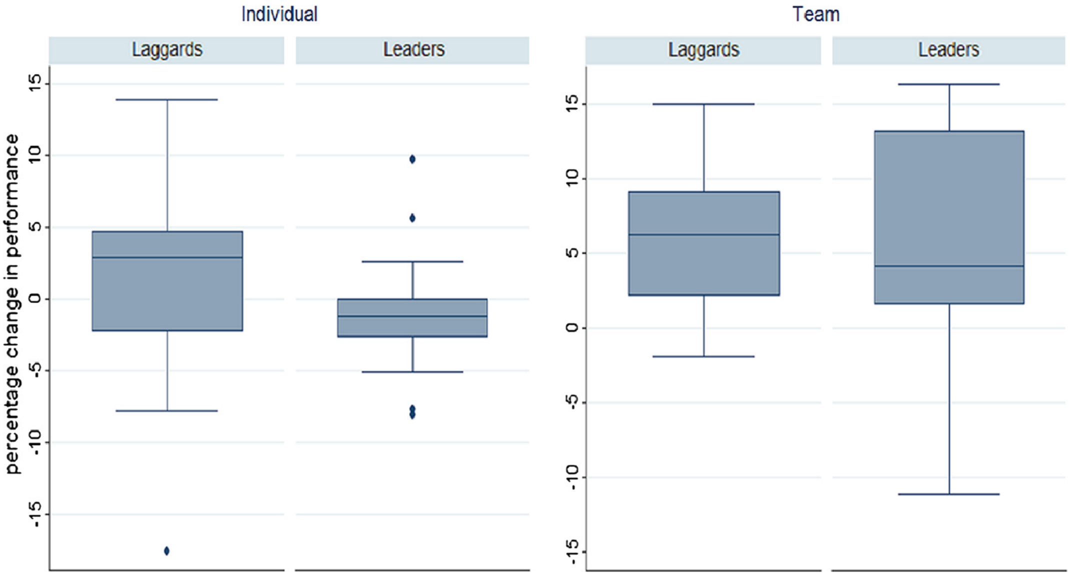


Fig. 3. Within-subject performance changes (in percentages) with feedback (Part 3).

a two-sided Mann–Whitney ranksum test). This implies that players remain equally incentivized, whether they are from the lagging or leading team.[20]

However, in the *Individual* treatment, we find a pattern that contradicts the "discouragement effect" identified in theory. The left panel of Fig. 3 shows that 79.2% of first-period leaders did not increase their performance in the second period. In fact, 58.33% of them strictly decreased their performance, whereas the corresponding number is only 29.17% for first-period laggards. On the other hand, 70.83% of the laggards performed *better* in period 2, compared to only 20.83% (5 out of 24) for leaders. A two-sided Mann–Whitney ranksum test shows that the performance changes of leaders and laggards clearly come from two different distributions ($p < 0.05$).

Could our results simply show regression to the mean—namely, the leaders who had good performances in the first period were more likely to perform worse than before, whereas the laggards who had worse performances were more likely to improve their performance in period 2? To rule out this explanation and further confirm whether feedback is responsible for the differences between team and individual tournaments, we further analyze the performance changes in Part 2 using the same approach (see Fig. 4). For the *Individual* treatment, we compare performance changes between period 1 and period 2 when there was no feedback. For the *Team* treatment, we compare performance changes for those who were from period 2 of Part 2 to their corresponding performance in Part 1. Not surprisingly, without explicitly knowing whether they were leading or lagging, their performance changes no longer depend on the results in period 1. We cannot reject that the performance changes of leaders and laggards are from the same distribution in both treatments ($p = 0.46$ for individuals and $p = 0.36$ for teams, two-sided Mann–Whitney ranksum tests). If regression to the mean were the true explanation, we should have observed similar patterns in Part 2 and Part 3 in the *Individual treatment*. However, our results clearly reject regression to the mean and favor the impact of the feedback on players' incentive to exert effort.

Our main results can be summarized as follows.

Result 1. *Hypothesis 1 is rejected. In individual tournaments with feedback, tournaments are not more likely to end in two periods. In contrast to the theoretical prediction, first-period leaders slack off, while the first-period laggards work harder to catch up.*

Result 2. *Hypothesis 2 cannot be rejected. In team tournaments with feedback, tournaments are equally likely to end in two or three periods. Progress feedback equally incentivizes players, regardless of whether they are leading or lagging.*

4.2.2. Subjects' strategy descriptions

To better understand how feedback affects players' effort incentive, we asked subjects to describe their behavior/strategies in the tournaments at the end of the experiment. Specifically, subjects answered the following multiple-choice question:

[20] As we explained in the summary of the average performance, subjects' performance increased slightly due to learning. The positive within-subject performance changes in the *Team* treatment shown in Fig. 3 is simply a reflection of learning.

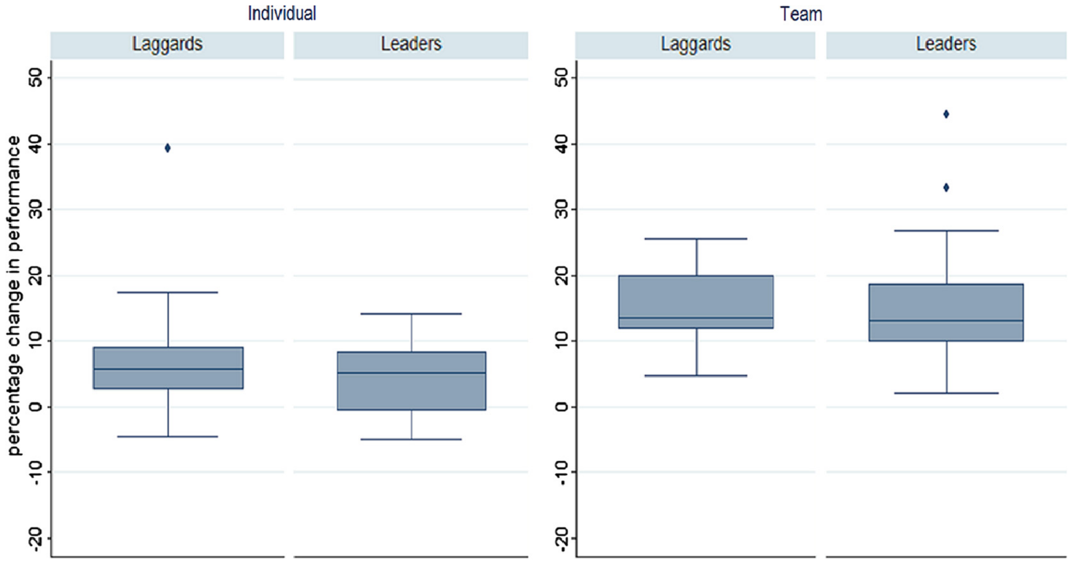


Fig. 4. Within-subject performance changes (in percentages) without feedback (Part 2).

Table 3
Correlation between subjective and actual output changes.

Output changes	Individual				Team			
	Leaders		Laggards		Leaders		Laggards	
	View	Action	View	Action	View	Action	View	Action
>0	33.33% (8)	20.83% (5)	62.5% (15)	70.83% (17)	86.96% (20)	78.26% (18)	78.26% (18)	82.61% (19)
=0	20.83% (5)	20.83% (5)	20.83% (5)	0 (0)	13.04% (3)	4.35% (1)	21.74% (5)	13.04% (3)
<0	45.83% (11)	58.33% (14)	16.67% (4)	29.17% (7)	0 (0)	16.67% (4)	0 (0)	4.35% (1)
Spearman correlation	0.41 $p = 0.05$		0.47 $p = 0.02$		0.34 $p = 0.09$		0.87 $p < 0.01$	

"In Part 3, how did the outcome in period 1 affect your performance in period 2?" The answer set offered was conditioned on whether they were leaders or laggards in period 1 (see more details in Appendix B). Table 3 displays the results.

Answers in the *Team* treatment indicate that players from both teams remain highly motivated regardless of what had happened in the previous period. For players on the lagging team, for instance, 78.26% (18 out of 23) answered, "I played harder in period 2 because I wanted to recover my team's loss from period 1." The remaining 21.74% (5 out of 23) answered, "The outcome in period 1 did not affect my performance in period 2." Players on the leading team also stated that they played harder in period 2 because "I wanted my team to win as early as possible" (86.96%, 20 out of 23). The remaining players who claimed that they played very hard ascribed this to the fact that "I became more confident after I learned that my team member had won in period 1" (13.04%, or 3 out of 23).

For the *Individual* treatment, we detect a distinctive pattern in the answers. The majority of laggards (62.5%, 15 out of 24) stated that they played harder in period 2 because "I wanted to recover my loss in period 1"; 20.83% (5 out of 24) reported that "The outcome in period 1 did not affect my performance in period 2." Only 16.67% (4 out of 24) stated that they played less hard, either because "I lost my confidence after losing in period 1" (1 out of 24) or "I was already behind and it was very difficult for me to win" (3 out of 24). On the other hand, nearly half of the leaders stated that "I played less hard in period 2 because I was ahead of my opponent already" (45.83%, 11 out of 24). About one third of the leaders claimed that they played harder either because "I did not want to play the third period" (20.83%, 5 out of 24) or "I became more confident after winning in period 1" (12.5%, 3 out of 24). The remaining 20.83% (5 out of 24) claimed that the outcome in period 1 did not affect their performance in period 2.

Note that we did not provide subjects with any extra feedback before they finished answering these questions, and therefore they did not know exactly how their performance had changed across periods and parts. Nevertheless, we find that subjects' performance changes and rationale are positively correlated, as the Spearman rank correlation is significantly larger than zero for both teams and individuals. This suggests that subjects mostly have a consistent rationale for their performance.[21] Consistently, our analysis shows that progress feedback indeed provides opposite incentives to individual leaders versus laggards, while it affects players on rival teams rather symmetrically.

5. Discussion

The main results of our experiment suggest that progress feedback affects players differently when they compete on a team and when they compete as individuals. Team players were not affected differently by positive or negative feedback, but individual players were. However, the direction of such impacts on individual players differs from what is suggested by economic theory. More specifically, it seems that individual laggards worked harder than their leading opponents to recover their losses. In this section, we discuss several potential explanations for our major findings.

5.1. Utility of winning: a potential explanation

Utility of winning is widely documented in the literature as an explanation for behavioral deviations from contest or auction theory, such as overbidding behavior in auctions (Cox et al., 1992; Cooper and Fang, 2008; Ertaç et al., 2011) or overdissipation in contests and tournaments (Chen et al., 2011; Sheremeta, 2010a, 2010b). Recent research in neuroscience suggests that utility of winning has a biological foundation as well: The mere fact of outperforming others affects brain activity at the ventral striatum, which is associated with processing rewards (Fliessbach et al., 2007; Dohmen et al., 2011).

Why does incorporating utility of winning generate consistent behavioral patterns? In individual tournaments, a laggard needs to win both of the remaining component contests to get the prize. When the psychological reward for winning a component contest is sufficiently large, it may motivate the laggard to outperform his leading opponent. A leader can gain the utility of winning once more at most, since the tournament ends immediately if he wins the second component contest. In contrast, a laggard could gain the utility of winning twice if he outperforms the leader in both the second and third contests. This effect, however, does not exist in team tournaments, in which players perform only once on behalf of their team. They can thus gain the utility of winning only once, regardless of the state of the tournament.[22]

To formally model the utility of winning based on our current theoretical framework, we allow a player to receive a utility $v_b \geq 0$ for winning the component contest in which he competes and a utility v_c from winning the entire tournament (independent of the monetary prize of value 1).[23] We first consider a tournament between individuals and analyze the game by backward induction. Suppose that the two players are even at the beginning of period 3. The expected payoff of each player is $u_3 = \frac{1}{2}(v_b + v_c + 1) - C^e(x_3)$, where $C^e(x_3)$ is one's expected effort cost in the competition. We then move back to period 2. Suppose that player 1 has a lead in the first period. Another win yields a total payoff of $v_b + v_c + 1$ for player 1, while a loss yields a payoff of u_3. Therefore, his effective prize spread is

$$\begin{aligned} u_{12} &= (v_b + v_c + 1) - u_3 \\ &= (v_b + v_c + 1) - [\frac{1}{2}(v_b + v_c + 1) - C^e(x_3)] \\ &= \frac{1}{2}(v_b + v_c + 1) + C^e(x_3). \end{aligned}$$

Player 2 would lose the entire contest if he could not catch up with player 1 in the second component contest. Therefore, his effective prize spread is $u_{22} = v_b + u_3 = v_b + \frac{1}{2}(v_b + v_c + 1) - C^e(x_3)$. Comparing u_{12} and u_{22}, we see that the laggard would have a larger incentive to outperform the leader in the second period if $v_b > 2C^e(x_3)$. In this case, we expect to observe a comeback effect instead of a discouragement effect. Consistent with this pattern, the strategy rationale presented in Table 3 suggests that more than 60% of laggards intentionally play harder, because "I wanted to recover my loss in period 1."

The same, however, would not be true for team contests. Let us consider the competition in period 2, and assume that team 1 has secured a lead. Player 1(2) receives a payoff $(v_b + v_c + 1)$ if he gains another lead in period 2 and $\frac{1}{2}(v_c + 1)$ if he loses his lead. His effective prize spread is therefore $(v_b + v_c + 1) - \frac{1}{2}(v_c + 1) = v_b + \frac{1}{2}(v_c + 1)$. Player 2(2) receives a payoff $v_b + \frac{1}{2}(v_c + 1)$ if he outperforms his rival and 0 if he fails. Therefore, his effective prize spread would be $v_b + \frac{1}{2}(v_c + 1)$. Comparing the expected payoff of both players, we can see that the relative incentives to compete are still the same for players on both teams. This pattern is also consistent with the strategy rationale (Table 3) of team players: They are equally motivated regardless of the first-period feedback.

[21] It is possible that subjects' intention was to justify their previous performance and outcomes when they answered the post-experiment questions. We nevertheless present these answers to further explore how progress feedback worked in different contest structures. However, due to the endogeneity problem, these answers can only be taken as supplementary evidence of why it differs.

[22] How to measure the magnitude of utility of winning is a much deeper question that warrants future studies. As long as people value winning per se, however, feedback could have different effects, depending on whether players compete as teams or individually.

[23] Here, we assume that players only gain extra utility from winning in the period in which they participated, or at least that they have stronger feelings about their own victories than their teammates' victories.

Table 4
Adjustment of subjective winning probability.

	Individual		Team			
	Leaders	Laggards	Competing players		Teammates	
			Leaders	Laggards	Leaders	Laggards
			Part 2			
Period 2 – Period 1:	−0.50	−2.71	1.82	−2.57	1.09	0.32
	(7.76)	(13.96)	(2.90)	(1.32)	(1.17)	(1.40)
	$p = 0.50$		$p = 0.12$		$p = 0.77$	
Outcome of Period 2	Winner	Loser	Winner	Loser	Winner	Loser
Period 3 – Period 2:	4.58	1.33	5.00	5.43	1.52	1.13
	(16.15)	(10.48)	(5.61)	(2.72)	(1.59)	(1.63)
	$p = 0.24$		$p = 0.42$		$p = 0.39$	
			Part 3			
Period 2 – Period 1:	9.50	−10.04	11.13	−2.61	8.26	−10.54
	(14.92)	(11.27)	(11.38)	(10.89)	(13.45)	(15.36)
	$p = 0.01^{***}$		$p = 0.01^{***}$		$p = 0.01^{***}$	
Period 3 – Period 2:	8.00	−16.5	10.78	−8.12	10.28	−9.06
	(13.37)	(30.37)	(11.69)	(12.34)	(15.00)	(10.83)
	$p = 0.03^{**}$		$p = 0.01^{***}$		$p = 0.01^{***}$	

Note: P-values are based on two-sided Mann–Whitney ranksum tests. “Leaders” and “Laggards” columns reflect teams’ relative performance at the beginning of period 2.

Note that if a tournament runs into period 3 due to a draw in the first two periods, competing teams or individuals are equally incentivized in period 3, since the tournament is symmetric again. Supported by our data, we find no difference in performance changes between leaders and laggards in either treatment ($p = 0.18$ for individuals and $p = 0.92$ for teams, two-sided Mann–Whitney ranksum tests). This observation means that after learning a tie, all period-three players are equally incentivized, whether they compete on a team or as an individual.

To sum up, for an individual tournament, the laggard can receive $2u_b$ from the utility of winning because he has the opportunity to compete in two periods of the tournament. The leader, however, can gain at most u_b from this source of psychological satisfaction, because another win would end the tournament. In contrast, a player in a *Team* treatment performs only once. This keeps the utility of winning the same across matched players throughout the competition, equalizing the relative incentives for players from both the leading and lagging teams. Utility of winning could consistently explain why progress feedback leads to a laggard’s comeback in individual, but not in team tournaments.

However, it must be noted that this rationale would lose its bite if strong team-specific motivations—e.g., team spirit—are present. A critical assumption is that utility of winning arises only when a player wins his/her own component contest and not when his/her teammates win. When players cheer for their teammates’ win, for instance, the externalities caused by team production are internalized. The strategic trade-off would resemble that of an individual tournament when evaluating the gain from utility of winning, and a comeback effect would loom large as a result. To visualize this, consider the second player on the leading team. Because another win would end the tournament, he/she can at most receive v_b once. In contrast, the second player on the lagging team could receive this utility gain twice (by his/her own win and the win of his/her teammate, who plays in the third period), which could cause his/her incentive to outweigh that of his/her opponent’s, as predicted for individual settings.

5.2. Belief updating

Although our matching protocol ensured that subjects who were competing with each other had the closest performance among all players, subjects did not know how close they were to each other. The assumption of homogeneous ability in the theoretical framework is not perfectly implemented in our experiment. Therefore, subjects may still form different beliefs about their opponents’ relative ability, and the belief-updating process may differ in the *Individual* and *Team* treatments when progress feedback is provided.

Table 4 presents changes in subjects’ beliefs about their winning probability from period 1 to 2 for leaders and laggards. We observe that belief adjustments in Part 2 between leaders and laggards do not differ significantly (from both period 1 to 2 and period 2 to 3), for either teams or individuals. However, when there was feedback in Part 3, the adjustments depended not only on the nature of the feedback, but on whether subjects play individually or on a team. When feedback was positive, both individual and team leaders adjusted their beliefs upward by a similar amount (11.13% in the *Team* treatment and 9.5% in the *Individual* treatment, $p = 0.423$, two-sided Mann–Whitney ranksum test). However, after a defeat, laggards adjusted their beliefs downward by 10.04% if they competed as individuals, but significantly less if they were on a team (−2.61% versus −10.04%, $p = 0.03$, a two-sided Mann–Whitney ranksum test). We further observe that for the waiting teammates—who were resting and waiting during period 2—they adjusted their beliefs similarly to those in the *Individual* treatment, irrespective of whether their team won (8.26% in *Team* vs. 9.50% in *Individual* treatment, $p = 0.7210$, two-sided Mann–Whitney ranksum test) or lost (−10.54% in *Team* vs. −10.04% in *Individual* treatment, $p = 0.9236$, two-sided Mann–

Whitney ranksum test) in period 1. The belief adjustments from period 2 to period 3 show pattern similar to those from period 1 to period 2. The laggards again adjusted their beliefs downward much more if they played individually, compared to those who played on the lagging team (−16.5% in *Individual* vs. −8.12% in *Team* treatment). This difference is not significantly different from each other, however, potentially due to the small number of observations we have for period 3. These results seem to support the conjecture that subjects could have adjusted their beliefs differently in the *Individual* versus in the *Team* treatment when feedback was provided.

In summary, the above results show that competing players adjusted subjective winning probabilities asymmetrically, depending on whether they competed individually or on a team. Although it is difficult to exactly identify the underlying reasons for belief updates in our current design, the data offer another potential explanation for why we observed asymmetric responses to feedback in individual tournaments but symmetric responses in team tournaments. We hypothesize that individual players could have updated their beliefs based on their own ability relative to that of their opponents. To put it more concretely, a leader slacked off in period 2 because he might have become excessively confident that he was more capable than his opponent after receiving positive feedback in period 1. Similarly, individual laggards increased their efforts because they might have perceived the previous loss as a disadvantage in ability, and the only way to compensate for that was to work even harder. In a team tournament, however, what we captured in the belief data might be subjects' psychological feelings instead of proxies for their self-evaluated abilities, since team tournaments involved an entirely different pair of players in each tournament, which prevented a player from inferring his/her opponent's ability from progress feedback. Therefore, despite being slightly discouraged by their teammates' loss, players from the lagging team worked as hard as usual, since they did not believe that their teammates' failure in the previous period necessarily implied their own failure in the current period. Players from the leading teams might have experienced a boost in self-confidence after a victory; even though it came from their teammates, they still played equally hard, because they understood that such psychological feelings did not reflect their own winning prospects.

5.3. Reference-dependent goals

Several studies of progress feedback also integrate reference-dependent utilities into theoretical frameworks (see, e.g., Berger and Pope, 2011). Based on prospect theory (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992), agents view their goals as reference points and adjust their subsequent effort decisions by comparing their current performance with their goals. In the *Individual* treatment, interactions between leaders and laggards in response to feedback are analogous to the tortoise and hare fable. Leaders, having achieved their intermediate goal—i.e., winning the first period—are more relaxed, and therefore decrease their subsequent performance, since they are in the gain domain. In contrast, laggards, even after being slightly behind, increase their effort to catch up with their goal.

Nevertheless, a story based solely on reference-dependent goals is unable to fully explain the results for team tournaments. If players had viewed winning the tournament as their goal, then second-period players on a leading team should have behaved similarly to their individual counterparts: Since their team was already ahead of their rivals', shirking became less costly. Even if they slack off and lose the lead, their team could still win the tournament in the final period. Our data show, however, that the percentage increase in their performance is comparable to that of their competitors from the lagging team (5.34% versus 5.77%, $p = 0.76$, a two-sided Mann–Whitney ranksum test). We thus conclude that a reference-dependent utility cannot bridge the gap between behavioral responses to feedback observed in the *Individual* and *Team* treatments.

5.4. Responsibility and accountability within teams

One might argue that competing on a team triggers distinctive psychological feelings and, therefore, different decisions. More specifically, being on a team might induce a player to feel responsible for his or her teammates' welfare. A player on a lagging team might be reluctant to give up, due to feeling accountable for losing the competition, even though an early lag has already limited the team's winning prospect. However, our results show that laggards' performance changes are similar to those of leaders in team tournaments.

Moreover, if responsibility plays a significant role, we should expect subjects in the *Team* treatment to perform better than those in the *Individual* treatment, because responsibility provides an additional incentive for players. The pattern should hold regardless of the presence of progress feedback. Nevertheless, we do not observe significant performance differences across the two treatments when feedback was absent. Two-sided Mann–Whitney ranksum tests show that whether we compare the average performance of team players with those of individuals—either in all three periods (112.58 versus 112.41, $p = 0.46$), or only the first period (107.85 versus 112.41, $p = 0.19$), to control for the number of repetitions—the results are not significant.

5.5. (Opportunity) cost of effort

One common concern in real-effort experiments is that subjects could be unresponsive to changes in incentive due to the absence of outside options. A trivial effort cost would mute the discouragement effect in our setting. Our solution is to

Table 5
Comparisons of possible explanations.

Explanations Part 3 period 2	Individual				Team			
	Leaders		Laggards		Leaders		Laggards	
	Behavior	Belief	Behavior	Belief	Behavior	Belief	Behavior	Belief
Utility of winning	X	–	X	–	X	–	X	–
Belief updating	X	X	X	X	X	X	X	X
Reference-dependent goals	X	X	X	X				
Responsibility to team	–	–	–	–	X	–		–
Opportunity cost of effort		–		–	X	–	X	–

Note: "X" means that players' behavior or beliefs are consistent with a given explanation. A "–" sign means that the theory does not generate implications about behavior or belief adjustment.

allow participants to bring in their own reading material during the experiment. Therefore, they were not forced to only work on their assigned task during the experiment. Actively participating in the competitive activities was indeed costly for our subjects.[24]

Even though subjects were allowed to read their own material as an alternative to working, one can still contend that the cost of exerting effort in a controlled laboratory remained low regardless, due to the short length of each match (five minutes) and the assumption that subjects' primary incentive is to earn money in these experiments. While this might explain why players were equally incentivized in the second period in the *Team* treatment, it fails to explain why leaders slacked off, while laggards worked harder in the *Individual* treatment. Moreover, if we already observe leaders slacking off when the outside option is not appealing, this pattern tends to be even stronger when the opportunity cost is higher.

Table 5 summarizes the explanations for players' behavior and beliefs in the experiment discussed in this section. Among the alternative theories, utility of winning theory offers predictions that are consistent with the behavior observed in both individual and team tournaments. Belief updating is also a potentially consistent explanation for our results. Further experiments will be required to distinguish between alternative theories.

6. Concluding remarks

Multi-contest team tournaments, in which players in alliances compete on distinctive component contests, are ubiquitous. We experimentally study how progress feedback affects performance in team tournaments (in which each player is responsible for only one component contest) and how these effects (if any) differ under team versus individual tournament structures. Game theory predicts that feedback should not affect the stochastic outcome in team tournaments but, in contrast, should disincentivize laggards in individual tournaments. The behavior observed in our experiment supports the prediction for team tournaments, but suggests an opposite pattern for individual tournaments. Among several possible candidates, both utility of winning and belief updating seem to be consistent with actions in both treatments. If nonmonetary utility is sufficiently large, we could even observe that individuals or teams remain willing to play in the third period, even though they have lost rounds 1 and 2 and the final outcome would not change. This finding, which corroborates Kuhnen and Tymula's (2012) main result, is supported by real-life examples; it could explain the "never give up" spirit in sports events. In marathons, for instance, runners still finish the match, even when they know that their chance of winning is zero. In soccer games, teams that are bound to lose at the penultimate stage increase their performance in the last game (Page and Page, 2009).[25] Apart from the utility of winning theory, our results may also be explained by adjustment of subjective winning probabilities, since players' expectations for winning in subsequent periods are affected by progress feedback.

Our findings, nevertheless, generate interesting implications for feedback design to motivate employees in organizations. Previous research has focused on the conditions in which feedback can influence productivity. For instance, for people who care about their relative status in the business, providing feedback is more likely to influence productivity if the compensation scheme is performance-based (Luttmer, 2005). This is not always effective, however, since people could also sabotage the system (Charness et al., 2014). Our results suggest that the impact of progress feedback also depends on the tournament structure. The same feedback mechanism could affect a player's performance and incentives differently, depending on whether the production is team-based or individual-based. When a task is individual-based, but bonuses are distributed based on relative performance evaluation, it is important to consider how intermediate feedback is revealed. Some previous research suggests that being slightly behind motivates more effort provision (e.g., Berger and Pope, 2011). While this result

[24] Corgnet et al. (2011) allow subjects to allocate their time between a real-effort task (value-creation for the organization) and browsing the Internet (value-creation for individuals). They find that subjects working as a team reduce their effort more than subjects working as individuals, unless combined with a peer-monitoring mechanism.

[25] Apart from field evidence, Sheremeta (2010b) documents this psychological effect via a controlled laboratory experiment. He elicits the subjects' nonmonetary utility of winning by letting them participate in a simple lottery contest with a prize value of zero. He finds that more than 40% of subjects pay a positive cost to bid for a prize value of zero. These efforts are not purely random, but are correlated with effort in contests for a strictly positive prize.

is supported by our data, we also find that the frontrunners in individual tournaments could be disincentivized and decrease their effort provision. Nevertheless, when a task is team-based, players are less responsive to feedback. Therefore, one has to take into account the structure of the production process when designing a feedback policy.

From such a perspective, our paper is naturally linked to the literature on group decision making. As pointed out by Kugler et al. (2012) and Charness and Sutter (2012), many experimental studies have consistently found that decisions made in groups conform more closely to the prediction based on standard game theory than those made by individual subjects (see literature review by Bornstein and Yaniv, 1998; Bornstein et al., 2004; Charness and Sutter, 2012; Kugler et al., 2012). Several rationales have been provided in the literature to explore the sources of the differences between group and individual behavior. These studies argue that interpersonal interaction in the decision process could help overcome various behavioral biases or cognitive limitations faced by individuals. Communication, as argued by Charness and Sutter, could facilitate coordination and compel players to maximize their groups' joint payoffs. Our experimental results also demonstrate the sharp contrast between group and individual behavior when benchmarked against theoretical predictions. Our study, however, is set in a sharply different environment, as it does not involve an explicit intra-team interactive process in which unitary teams make one joint decision together after discussion and, perhaps, a collective voting procedure. In our setting, as stated above, each player on a team is responsible for only one component battle, and his input is determined by himself, without explicit intervention or verbal influence from his/her teammates. In short, compared to the group decision-making literature, the team members in our group tournaments retain autonomy in the way they make decisions, and are only interdependent via the payoff. More thorough studies are in need to explore the source of such differences in team-tournament settings (see, e.g., Balafoutas et al., 2014).

Admittedly, our study has a number of limitations and leaves ample room for future research. For instance, since our experimental design does not disclose actual performance data, it does not allow us to examine how the magnitude of difference in previous performance affects future motivation in effort provision. Moreover, we focus on one-shot instead of repeated interactions, in that subjects cannot adjust their reactions as experience accumulates. The learning effect could loom large in a wide variety of contexts, such as sports competitions. Existing empirical evidence, however, yields mixed implications for the nature of learning. For instance, Irfanoglu et al. (2014) show that in Tullock contest laboratory experiments, in which subjects whose effort is substitutable have the opportunity to observe each other's effort at the end of each period, laggards decrease their effort in subsequent periods with repetition. However, via a 40-year panel dataset, Gould and Winter (2009) find that a pitcher's performance on a professional baseball team increases with the pitching performance of his substitutes (i.e., the other pitchers on the team). Future research is warranted to reconcile these findings.

Lastly, it should be noted that our paper focuses primarily on players' reactions to progress feedback under different tournament environments—i.e., standing alone vs. competing on teams. For this purpose, we isolate our laboratory environment from many other factors that could also significantly affect players' effort incentives in response to outcomes of past plays in dynamic tournaments. We make an attempt to highlight the effect of the unique payoff structure of team tournaments, but do not explicitly consider various team-specific motivations espoused by previous studies (see, for example, Chen and Lim, 2013), such as team spirit—e.g., players cheer for each other—and peer pressure—e.g., players are pressured to perform, as they are benchmarked against their teammates' performance. Such team-specific motivation could nontrivially affect the payoff structure of the competitions and players' incentives. For instance, it may help internalize the externality caused by the public-good nature of the incentive scheme. It may also increase players' pleasure when they win their own component contests. Future studies are warranted to explore whether and how team players' reactions to progress feedback would vary in an environment in which team-specific motivation is more likely to breed, e.g., when communication among teammates is allowed (see Sutter and Strassmair, 2009, and Cason et al., 2012).

Appendix A

Instructions for the Team treatment

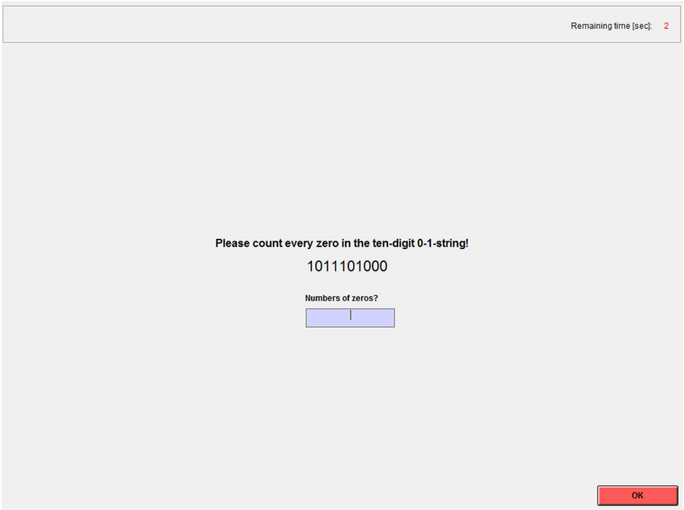
Welcome to this experiment! You will receive €4.00 for showing up on time. Please read these instructions carefully and completely. Properly understanding the instructions will help you to make better decisions and, hence, to earn more money. If you read these instructions carefully and perform well in the experiment, you can earn a considerable amount of money (which will be paid out to you in cash at the end of the experiment).

Please keep in mind that you are not allowed to communicate with other participants during the experiment. If you do not obey this rule you will be asked to leave the laboratory and will not be paid. Whenever you have a question, please raise your hand; an experimenter will assist you.

This experiment consists of three parts. You will receive separate instructions for each part in which you participate. Your final payment will be the sum of your earnings from all three parts, plus your show-up fee.

Part 1

In this task, you will be asked to count the number of *zeros* in a series of *ten-digit* numbers, randomly composed by *zeros* and *ones*. The following figure shows the work screen you will later use.



You will need to enter the number of *zeros* into the box below the numbers. After you have entered your answer, please click the OK button to proceed. Once you click the OK button, no matter whether your answer is right or wrong, the computer will present you with another set of ten-digit zeros and ones. However, only when you count the number of zeros correctly do you get paid.

Your goal is to finish as many tasks correctly as possible. You have a time limit of 300 seconds (5 minutes). Again, please remember that you will only be paid for the correct answers. For each correct answer you will earn €0.05, and, hence, the total income you earn in this part will be "the total number of correct answers you give in 5 minutes $\times$ €0.05. However, your performance and total income in this part will only be shown to you at the end of the entire experiment.

To make sure that you understand the task and know how to work, you will be given 10 ten-digit numbers as practice before we start the 5-minute task. Although these 10 tasks will not be paid, you are still kindly asked to count the number of zeros as quickly as you can. If you have any questions now or during your practice time, please raise your hand. After everyone has finished the 10 tasks and there are no further questions, we will start the 5-minute task.

Part 2

Matching

In Part 1, you were asked to work on a 5-minute counting task, and were paid by the total number of correct answers. At the beginning of this part, the computer will rank all the participants in this session according to the number of correct answers provided in Part 1. Then it will match the two participants with the closest ranks into a pair. For instance, a participant with rank 1 will be paired with a participant with rank 2, and a participant with rank 3 will be paired with the one in rank 4, etc.

After ranking and pairing, the computer will randomly select three pairs (six participants) and assigns the two participants in each pair to two different teams. For instance, the computer selects pairs A, C and F to form two teams. Suppose pair A consists of players 1 and 2 (whose ranks are closest to each other); pair C consists of players 5 and 6 (whose ranks are closest to each other); and pair F consists of players 13 and 14 (whose ranks are closest to each other). Then, it is possible that players 1, 5 and 13 are grouped together into one team, and players 2, 6 and 14 are grouped together into the other team. Likewise, it is also possible that players 1, 6 and 13 are grouped together into a team, and players 2, 5 and 14 are grouped together into the other team. However, it is never possible that both players in the same pair are assigned to the same team, because the two participants in each pair will compete against each other on behalf of their teams (see next section for more details). The purpose of this random assignment to teams is to equalize the average rankings of the two teams and to make sure the two teams are equally competitive. Once the teams are formed, the members in a team and the paired opponent in the other team will remain unchanged for the duration of this part of the experiment.

The ranking, pairing and team assignments remain anonymous throughout the entire experiment. You will not be told which participant in this room is paired with you or who your team members are or the members of your competing team. You will also not be able to learn your actual rank or the rank of anyone else. All you should keep in mind is that your potential opponent has the closest rank to you (based on performance records from Part 1). The same principles apply to the other two members in the team.

Competition

The two teams will compete against each other in the same 5-minute counting task as in Part 1. The competition consists of three independent periods. After the three periods, the team that wins (at least) two out of the three periods will win the competition for this part.

In period 1, the computer randomly selects one (out of three) pairs of participants from the two competing teams. These two participants in a pair will simultaneously work on the same 5-minute counting task. The one who offers more correct answers (i.e. correctly count the number of zeros) at the end of 5 minutes will be the leader in period 1. If the two participants make the same number of correct answers, the computer will randomly select a leader.

The two competing participants will NOT learn how many correct answers each has provided during the competition. Nonetheless, the more correct answers one makes within 5 minutes, the more likely he/she is to win the period.

While the selected pair is competing, the other two pairs of participants should wait quietly and patiently. The waiting pairs also cannot observe how well the competing pair of participants is performing during the task. Note that each pair of participants only competes once. That is, when period 1 is finished, the computer will randomly pick one of the two remaining pairs to compete in period 2. And at the end of period 2, the last remaining pair will compete in period 3. The competition rules for periods 2 and 3 are exactly the same as for period 1. There is no feedback on performance or outcome during or after each period.

Your earnings

Each of the three participants in the winning team will receive 10 Euros in this part. The three participants in the other team will not receive any payment. Information on performance, which period(s) your team has won or lost, and if your team has won the whole competition in this part will NOT be shown to you until the end of the entire experiment.

Part 3

Matching

In Part 2, you competed on the counting task in a team against another team whose members had the closest ranks to those in your team. In this part, participants will continue to compete in teams. Although your team members and/or the members from the competing team may be different, the principles of ranking, pairing and team assignment are still the same as in Part 2.

At the beginning of this part, the computer will rank all the participants according to the total number of correct answers provided in Part 2 (all three periods together). The computer then matches the two participants with the closest ranks into a pair. For instance, a participant with rank 1 will be paired with a participant with rank 2, and a participant with rank 3 will be paired with the one in rank 4, etc.

After ranking and pairing, the computer will randomly select three pairs (six participants) and assign the two participants in each pair to two teams. The procedure is exactly the same as in Part 2. The purpose of this random assignment to teams is to equalize the average rankings of the two teams and to make sure the two teams are equally competitive. Once the teams are formed, the members in a team and the paired opponents in the other team will remain unchanged for the duration of this part of the experiment.

Ranking, pairing and team assignments remain anonymous throughout the entire experiment. You will not be told which participant in this room is paired with you or who your team members are or the members of your competing team. You will also not be able to learn your actual rank or the rank of anyone else. All you should keep in mind is that your potential opponent has the closest rank to you (based on performance records from Part 2). The same principal applies to the other two members in the team.

Competition

Similar to Part 2, the two teams will compete against each other in the 5-minute counting task. The competition consists of a maximum of three periods. The team that wins two out of the three periods will win the competition for this part.

In period 1, the computer randomly selects one pair (out of three) of participants from the two competing teams. These two paired participants will simultaneously work on the same 5-minute counting task. The one who provides more correct answers (i.e. correctly count the number of zeros) at the end of 5 minutes will be the leader in period 1. If the two participants made the same number of correct answers, the computer will randomly select a leader.

Similar to Part 2, the two competing pairs of participants will NOT learn how many correct answers each has provided during the competition. Nonetheless, the more correct answers one makes within 5 minutes, the more likely he/she is to win the period.

While the selected pair is competing, the other two pairs of participants should wait quietly and patiently. The waiting pairs also cannot observe how well the competing pair of participants is performing during the task. Note that each pair of participants only competes once. That is, when period 1 is finished, the computer will randomly pick one of the two remaining pairs to compete in period 2. And at the end of period 2, the last remaining pair will compete in period 3. The competition rules for periods 2 and 3 are exactly the same as for period 1.

Unlike Part 2, you will receive some feedback after each period. In particular, after each period, all the members of the teams will be told whether their team has won that period or not. However, you will NOT learn how many correct answers you or your teammate has finished in that period.

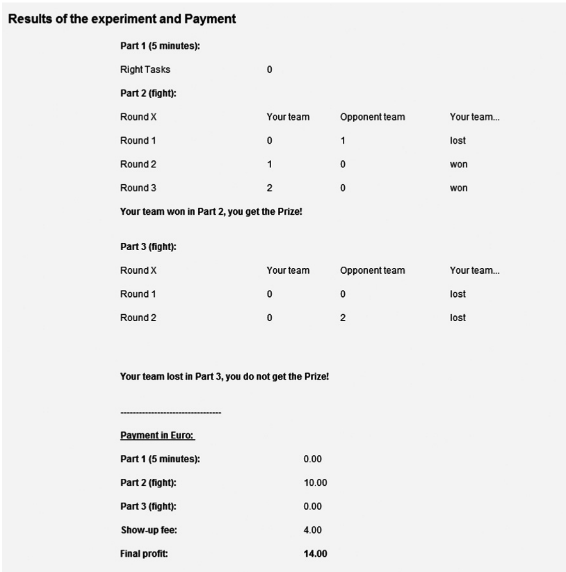
Another change in this part is the total number of periods of the competition. The competition ends as soon as the first two participants in the same team have won two periods. That means, if one team has won the first two periods, the competition ends before a third period. Hence, the competition can consist of either two or three periods.

Your earnings

Each of the three players in the winning team will receive 10 Euros in this part. The three participants in the other team will not receive any payment.

After your team has finished the competition in Part 3, you will need to finish a simple exit questionnaire. All the information you provide in this questionnaire, as well as your performance data in the experiment will only be used for statistical analysis and will be kept anonymous and strictly confidential.

Once you finish the questionnaire, a final screen, which shows both teams' performances in each part, which period(s) your team won or lost and whether your team won Parts 2 and 3, and your total earnings from all the three parts will be displayed (a sample screen is shown below).



Results of the experiment and Payment

Part 1 (5 minutes):

Right Tasks	0

Part 2 (fight):

Round X	Your team	Opponent team	Your team...
Round 1	0	1	lost
Round 2	1	0	won
Round 3	2	0	won

Your team won in Part 2, you get the Prize!

Part 3 (fight):

Round X	Your team	Opponent team	Your team...
Round 1	0	0	lost
Round 2	0	2	lost

Your team lost in Part 3, you do not get the Prize!

Payment in Euro:

Part 1 (5 minutes):	0.00
Part 2 (fight):	10.00
Part 3 (fight):	0.00
Show-up fee:	4.00
Final profit:	**14.00**

Before we start Part 3, please complete the control questions on your screen to make sure that you have understood these instructions completely.

Appendix B

Post-experiment Questionnaire

Question for first period winners in Part 3 in Individual treatment:

In Part 3, how did the outcome in round 1 affect your performance in round 2?

A. I played harder in round 2 because I did not want to play the third round.
B. I played harder in round 2 because I became more confident after winning in round 1.
C. I played less hard in round 2 because I was ahead of my opponent already.
D. The outcome in round 1 did not affect my performance in round 2.

Question for first period losers in Part 3 in Individual treatment:

In Part 3, how did the outcome in round 1 affect your performance in round 2?

A. I played harder in round 2 because I wanted to recover my loss in round 1.
B. I played less hard in round 2 because I lost my confidence after losing in round 1.
C. I played less hard in round 2 since I was already behind and it is very difficult for me to win.
D. The outcome in round 1 did not affect my performance in round 2.

Question for the first period winning teams in Part 3 in Team treatment:

How did the outcome in round 1 of Part 3 affect your performance in round 2 of Part 3?

A. I played very hard in round 2 because I wanted my team to win as early as possible.
B. I played very hard in round 2 because I became more confident after I learned that my team member had won in round 1.
C. I did not play very hard in round 2 because my team was already ahead of the other team.
D. The outcome of round 1 did not affect my performance in round 2.

Question for the first period losing teams in Part 3 in Team treatment:

How did the outcome in round 1 affect your performance in round 2 of Part 3?

A. I played harder in round 2 because I wanted to recover my team's loss from round 1.

B. I did not play very hard in round 2 because I lost my confidence after learning that my team had lost in round 1.

C. I did not play very hard in round 2 since my team was already behind, making it very difficult for my team to win.

D. The outcome of round 1 did not affect my performance in round 2.

References

Abbink, K., Brandts, J., Herrmann, B., Orzen, H., 2010. Inter-group conflict and intra-group punishment in an experimental contest game. Amer. Econ. Rev. 100, 420–447.

Abbink, K., Brandts, J., Herrmann, B., Orzen, H., 2012. Parochial altruism in inter-group conflicts. Econ. Letters 117 (1), 45–48.

Abeler, J., Falk, A., Goette, L., Huffman, D., 2011. Reference points and effort provision. Amer. Econ. Rev. 101 (2), 470–492.

Ahn, T., Isaac, M., Salmon, T., 2011. Rent seeking in groups. Int. J. Ind. Organ. 29, 116–125.

Alchian, A., Demsetz, H., 1972. Production, information costs, and economic organization. Amer. Econ. Rev. 62, 777–795.

Apesteguia, J., Palacios-Huerta, I., 2010. Psychological pressure in competitive environments: evidence from a randomized natural experiment. Amer. Econ. Rev. 100, 2548–2564.

Balafoutas, L., Kerschbamer, R., Kocher, M., Sutter, M., 2014. Revealed distributional preferences: individuals vs. teams. J. Econ. Behav. Organ. 108, 319–330.

Bandiera, O., Barankay, I., Rasul, I., 2010. Social incentives in the workplace. Rev. Econ. Stud. 77 (2), 417–458.

Berger, J., Pope, D., 2011. Can losing lead to winning? Manage. Sci. 57 (5), 817–827.

Bornstein, G., Yaniv, I., 1998. Individual and group behavior in the ultimatum game: are groups more "rational" than players? Exper. Econ. 1, 101–108.

Bornstein, G., Kugler, T., Ziegelmeyer, A., 2004. Individual and group behavior in the Centipede game: are groups more "rational" players? J. Exp. Soc. Psychol. 40, 599–605.

Cadigan, J., 2007. Two-stage team rent-seeking: experimental analysis. Southern Econ. J. 74, 85–103.

Carpenter, J., Matthews, P., Schirm, J., 2010. Tournaments and office politics: evidence from a real effort experiment. Amer. Econ. Rev. 100, 504–517.

Cason, T.N., Masters, W.A., Sheremeta, R.M., 2010. Entry into winner-take-all and proportional-prize contests: an experimental study. J. Public Econ. 94, 604–611.

Cason, T.N., Sheremeta, R.M., Zhang, J., 2012. Communication and efficiency in competitive coordination games. Games Econ. Behav. 76 (1), 26–43.

Cason, T.N., Sheremeta, R.M., Zhang, J., 2015. Asymmetric and endogenous communication in competition between groups. Working paper.

Charness, G., Kuhn, P., 2011. Lab labor: what can labor economists learn from the Lab? In: Handbook of Labor Economics, vol. 4(A), pp. 229–330.

Charness, G., Masclet, D., Villeval, M.C., 2014. The dark side of competition for status. Manage. Sci. 60 (1), 38–55.

Charness, G., Sutter, M., 2012. Groups make better self-interested decisions. J. Econ. Perspect. 26 (3), 157–176.

Chen, H., Ham, S., Lim, N., 2011. Designing multiperson tournaments with asymmetric players: an experimental study. Manage. Sci. 57, 864–883.

Chen, H., Lim, N., 2013. Should managers use team-based contests? Manage. Sci. 59 (12), 2823–2836.

Cooper, D., Fang, H., 2008. Understanding overbidding in second price auctions: an experimental study. Econ. J. 118 (532), 1572–1595.

Corgnet, B., Hernán-González, R., Rassenti, S., 2011. Real effort, real leisure and real-time supervision: incentives and peer pressure in virtual organizations. Working paper. Chapman University, Economic Science Institute.

Cox, J., Smith, V., Walker, J., 1992. Theory and misbehavior of first-price auctions: comment. Amer. Econ. Rev. 82 (5), 1392–1412.

Croson, R., 2001. Feedback in voluntary contribution mechanisms: an experiment in team production. Res. Exp. Econ. 8, 85–97.

Dechenaux, E., Kovenock, D., Sheremeta, R., forthcoming. A survey of experimental research on contests, all-pay auctions and tournaments. Exper. Econ.

Dohmen, T., Falk, A., Fliessbach, K., Sunde, U., Weber, B., 2011. Relative versus absolute income, utility of winning, and gender: brain imaging evidence. J. Public Econ. 95 (3), 279–285.

Eriksson, T., Poulsen, A., Villevall, M.C., 2009. Feedback and incentives: experimental evidence. Lab. Econ. 16, 679–688.

Ertaç, S., Hortacsu, A., Roberts, J.W., 2011. Entry into auctions: an experimental analysis. Int. J. Ind. Organ. 29, 168–178.

Fershtman, C., Gneezy, U., 2011. The tradeoff between performance and quitting in high power tournaments. J. Europ. Econ. Assoc. 9 (2), 318–336.

Fischbacher, U., 2007. z-Tree: Zurich toolbox for ready-made economic experiments. Exper. Econ. 10, 171–178.

Fliessbach, K., Weber, B., Trautner, P., Dohmen, T., Sunde, U., Elger, C., Falk, A., 2007. Social comparison affects reward-related brain activity in the ventral striatum. Science 318, 1305–1308.

Fu, Q., Lu, J., Pan, Y., 2015. Team contests with multiple pairwise battles. Amer. Econ. Rev. 105 (7), 2120–2140.

Gelder, A., Kovenock, D., 2014. Fight or surrender: experimental analysis of last stand behavior. Working paper.

Gill, D., Prowse, V., 2012. A structural analysis of disappointment aversion in a real effort competition. Amer. Econ. Rev. 102 (1), 469–503.

Gill, D., Prowse, V., 2014. Gender differences and dynamics in competition: the role of luck. Quant. Econ. 5, 351–376.

Gneezy, U., Niederle, M., Rustichini, A., 2003. Performance in competitive environments: gender differences. Quart. J. Econ. 118 (3), 1049–1074.

Gould, E., Winter, E., 2009. Interactions between workers and the technology of production: evidence from professional baseball. Rev. Econ. Statist. 91 (1), 188–200.

Greiner, B., 2004. An online recruitment system for economic experiment. In: Kremer, K., Macho, V. (Eds.), Forschung und wissenschaftliches Rechnen 2003. Göttingen. In: GWDG Bericht, vol. 63, pp. 79–93.

Guryan, J., Kroft, K., Notowidigdo, M.J., 2009. Peer effects in the workplace: evidence from random groupings in professional golf tournaments. Amer. Econ. J. Appl. Econ. 1 (4), 34–68.

Harbring, C., 2006. The effect of communication in incentive systems—an experimental study. Managerial Dec. Econ. 27 (5), 333–353.

Harris, C., Vickers, J., 1987. Racing with uncertainty. Rev. Econ. Stud. 54, 1–21.

Healy, A., Pate, J., 2011. Can teams help to close the gender competition gap? Econ. J. 121 (555), 1192–1202.

Hossain, T., List, J.A., 2012. The behavioralist visits the factory: increasing productivity using simple framing manipulations. Manage. Sci. 58 (12), 2151–2167.

Ichino, A., Giovanni, M., 2000. Work environment and individual background: explaining regional shirking differentials in a large Italian firm. Quart. J. Econ. CXV (3), 1057–1090.

Irfanoglu, B., Mago, S., Sheremeta, R., 2014. The New Hampshire effect: behavior in sequential and simultaneous election contests. Working paper.

Kahneman, D., Tversky, A., 1979. Prospect theory: an analysis of decisions under risk. Econometrica 47, 313–327.

Kandel, E., Lazear, E.P., 1992. Peer pressure and partnerships. J. Polit. Economy 100 (4), 801–817.

Klumpp, T., Polborn, M., 2006. Primaries and the New Hamshire effect. J. Public Econ. 90, 1073–1114.

Kocher, M., Lenz, M., Sutter, M., 2012. Psychological pressure in competitive environments: new evidence from randomized natural experiments. Manage. Sci. 58 (8), 1585–1591.

Konrad, K., 2009. Strategy and Dynamics in Contests. Oxford University Press, Oxford, London.

Konrad, K., Kovenock, D., 2009. Multi-battle contests. Games Econ. Behav. 66 (1), 256–274.

Kugler, T., Kausel, E.E., Kocher, M.G., 2012. Are groups more rational than individuals? A review of interactive decision making in groups. WIREs Cogn. Sci., 471–482.

Kuhnen, C., Tymula, A., 2012. Feedback, self-esteem and performance in organizations. Manage. Sci. 58 (1), 94–113.

Ludwig, S., Lünser, G.K., 2009. Knowing the gap – intermediate information in tournaments. Working paper.

Luttmer, E., 2005. Neighbors as negative: relative earnings and well-being. Quart. J. Econ. 120 (3), 963–1002.

Magnus, J.R., Klaassen, F.J.G.M., 2001. On the advantage of serving first in a tennis set: four years at Wimbledon. J. R. Stat. Soc., Ser. D Stat. 48 (2), 247–256.

Mago, S., Sheremeta, R., 2012. Multi-battle contests: an experimental study. Working paper.

Mago, S., Sheremeta, R., Yates, A., 2013. Best-of-three contest experiments: strategic versus psychological momentum. Int. J. Ind. Organ. 31 (3), 287–296.

Malueg, D., Yates, A., 2010. Testing contest theory: evidence from best-of-three tennis matches. Rev. Econ. Statist. 92, 689–692.

Manski, C., 1993. Identification of endogenous social effects: the reflection problem. Rev. Econ. Stud. 60 (3), 531–542.

Manski, C., 2000. Economic analysis of social interactions. J. Econ. Perspect. 14 (3), 115–136.

Mas, A., Moretti, E., 2009. Peers at work. Amer. Econ. Rev. 99 (1), 112–145.

Nalbantian, H., Schotter, A., 1997. Productivity under group incentives: an experimental study. Amer. Econ. Rev. 87 (3), 314–341.

Niederle, M., Vesterlund, L., 2011. Gender and competition. Annu. Rev. Econ. 3, 601–630.

Nisvan, E., Gangadharan, L., Nikiforakis, N., 2011. Relative earnings and giving in a real effort experiment. Amer. Econ. Rev. 101 (7), 3330–3348.

Page, L., Page, K., 2009. Stakes and motivation in tournaments: playing when there is nothing to play for but pride. Econ. Anal. Pol. 39 (3), 455–464.

Schotter, A., Weigelt, K., 1992. Asymmetric tournaments, equal opportunity laws, and affirmative action: some experimental results. Quart. J. Econ. 107 (2), 511–539.

Sheremeta, R.M., 2010a. Expenditures and information disclosure in two-stage political contests. J. Conflict Resolution 54, 771–798.

Sheremeta, R.M., 2010b. Experimental comparison of multi-stage and one-stage contests. Games Econ. Behav. 68, 731–747.

Sutter, M., Strassmair, C., 2009. Communication, cooperation and collusion in team tournaments – an experimental study. Games Econ. Behav. 66 (1), 506–525.

Szymanski, S., 2003. The economic design of sporting contests. J. Econ. Lit. 41 (4), 1137–1187.

Tversky, A., Kahneman, D., 1992. Advances in prospect theory: cumulative representation of uncertainty. J. Risk Uncertainty 5 (4), 297–323.

van Dijk, F., Sonnemans, J., Van Winden, F., 2001. Incentive systems in a real effort experiment. Europ. Econ. Rev. 45 (2), 187–214.

Williamson, O., 1975. Markets and Hierarchies: Analysis and Antitrust Implications. Free Press, New York.