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Individual Contribution in Team Contests

Antoine Chapsal & Jean-Baptiste Vilain*

July 3, 2018

Abstract

This paper empirically analyzes team effects in multiple pairwise battles, where players from two rival teams compete sequentially. Using international squash tournaments as a randomized natural experiment, we show that winning the first battle significantly increases the probability of winning the subsequent one. This result contradicts recent theoretical literature on multi-battle team contests, according to which outcomes of past confrontations should not affect the present ones. Furthermore, we derive testable predictions from a theoretical model in order to identify the effect at play. We provide compelling evidence of an *individual contribution effect*: players not only benefit from their team's win, but also value the fact of being individually – even partly – responsible for their team's collective success. Such an effect is of prime importance to understanding why individuals can make a significant effort when offered collective-based incentives.

JEL Classification C72, D79, L83, M54.

Keywords Team Economics; Multiple Pairwise Battles; Individual Contribution.

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1 Introduction

Many economic achievements are produced by groups, such as teams or partnerships, in which each individual outcome mainly depends on other teammates' effort decisions. This is why there is an extensive body of economic literature devoted to understanding individuals' behavior in teams and exploring the design of team-based incentives. The conventional economic wisdom is that team-based incentives induce individuals to exert less effort than individual-based contracts, simply because rational and self-interested individuals free ride and do not internalize their teammates' utility when making effort decisions.¹ However, recent literature has found that individuals could make a significant effort for their team, not only when they react to peer pressure, but also in order to avoid feeling guilty, i.e., living up to the expectations of others (Kandel & Lazear (1992), Charness & Dufwenberg (2006), Chen & Lim (2013)). In this paper, we provide compelling evidence that individuals value being at least partly responsible for their team's success. Teammates make a significant effort in teams because they want to take part in the group's success. We refer to this important team effect as *individual contribution*: when involved within a team, individuals positively take into account the role they can play to achieve collective success.

Assessing individual contribution to team output is extremely challenging, especially when teammates' efforts interact in a subtle manner (Alchian & Demsetz (1972)). We focus on a special kind of team setting, "multiple pairwise battles," where individual production is fully observable, thereby allowing us to test whether individuals value contributing to their team's victory. Multiple pairwise battles² refer to extremely common situations where players from two rival teams compete sequentially. Such situations include for instance competition between firms to win local markets, large-scale military operations, and sports events. A famous example is the Davis Cup tennis tournament, where the players from two national teams compete sequentially in a best-of-five contest.

Fu, Lu & Pan (2015) present a benchmark theoretical analysis of multiple pairwise battles. They show, under standard assumptions, that the outcome of a battle is independent from

¹See Prendergast (1999) and Sheremeta (2017) for surveys on this topic.

²The expression "multiple pairwise battles" is used by Fu, Lu & Pan (2015). The alternative expression "multi-battle team contest" is also used by some authors. In this paper, we refer to each component of a contest as a battle, a match or a confrontation.

the outcome of previous and subsequent confrontations. Such a result, which they refer to as “neutrality,” implies that confrontations can be considered independent. There is not any “dynamic linkage” between subsequent battles and the order of play does not affect the final result. Neutrality is derived from the fact that players do not internalize the cost of effort of upcoming battles, for the simple reason that it is borne by their teammates.

This paper empirically analyzes individual behaviors in multiple pairwise battles using international squash team championships as a randomized natural experiment. International squash team confrontations offer a perfect empirical setting, as they consist in best-of-three team contests, where players from rival teams compete sequentially, with each player playing only once. More importantly, the sequence of battles in a team confrontation is randomly drawn and cannot be manipulated.

The main results of the paper are as follows:

1. We find evidence of a dynamic linkage between subsequent battles. More precisely, we show that, *ceteris paribus*, winning the first battle significantly increases the probability of winning the second battle. This team effect contradicts neutrality.
2. We derive testable predictions from a theoretical model to further explain outcome dependence in this team setting. We provide compelling evidence that outcome dependence in battles results from individual contribution: players value being (at least partly) responsible for collective success.

Our results are robust to several specifications and alternative tests. To the best of our knowledge, this is the first paper to provide field evidence that teammates individually value contributing to their team’s success. The implications of both results extend beyond contest designs. Individual contribution is of prime importance to understanding why team-based incentives induce individuals to make a significant effort. Theoretical models generally predict that individuals free ride on their teammates, but this result contradicts most empirical and behavioral studies showing that players’ efforts are not necessarily lower in teams than in individual settings. Individual contribution mitigates free-riding behaviors: individuals make significant efforts for their team as they value taking part in the group’s success.

The remainder of this paper is organized as follows. Section 2 presents the related literature. Section 3 provides empirical evidence against neutrality in multiple pairwise battles: winning the first battle significantly increases the probability of winning the second battle. Section 4

pinpoints the mechanism driving non-neutrality: outcome dependence is explained by the fact that players value not only the final reward yielded by their team’s win, but also playing an active part in collective success. Lastly, we present robustness tests that confirm the existence of individual contribution in multiple pairwise battles and rule out alternative explanations. Section 5 concludes the paper with a discussion of the main implications of the individual contribution effect.

2 Related literature

Neutrality specifies how individuals behave in multiple pairwise battles. From a theoretical viewpoint, one can draw a contrast with the “discouragement” effect, which arises in *individual* multi-battle contests in which the same players square off against one another sequentially.³ In individual contests (e.g., a two-set tennis match), winning the first confrontation (or the first set) positively affects the probability of winning the next one: the remaining effort required to win the contest is lower for the frontrunner than for the laggard. The former is therefore more likely to win than the latter.

The discouragement effect, which has been studied extensively,⁴ cannot occur in multiple pairwise battles, as the remaining effort required to obtain the final payoff after a non-definitive battle is not to be borne by the current player. The discouragement effect in individual contests is caused by the fact that prize spreads – i.e., the difference in expected payoff between winning and losing a battle – are not symmetric: the frontrunner has a higher prize spread than the laggard and, as a result, more incentive to win. Conversely, neutrality occurs when the prize

³See Dechenaux, Kovenock & Sheremeta (2015) for a survey.

⁴There is an abundant literature on individual contests, which finds evidence of the dependence of outcomes in subsequent individual confrontations and confirms the discouragement effect. For instance, Klumpp & Polborn (2006) model U.S. presidential primaries as a best-of-N contest between two candidates and show that winning the early districts strongly affects the probability of winning later districts. Malueg & Yates (2010) find empirical evidence of strategic effects in individual tennis matches. Taking a sample of equally skilled players, they show that the winner of the first set exerts more effort in the second set than the loser. Mago, Sheremeta & Yates (2013) provide experimental evidence of a discouragement effect in a best-of-three Tullock contest. They also show that this effect is strategic, not psychological. Harris & Vickers (1987) show that in a two-firm R&D race model, an early lead yields easy wins in subsequent battles because of the discouragement effect on the lagging opponent. Konrad & Kovenock (2009) show in a theoretical framework that the introduction of intermediate prizes for component battles (i.e., payoff from winning a single battle even if the match is lost) reduces discouragement.

spread is the same for both opposing players, meaning that the outcome of a battle does not depend on previous outcomes.

As Fu, Lu & Pan (2015) stress, the neutrality result contrasts sharply with conventional wisdom, which holds that battles are not independent in a team contest. From a theoretical perspective,⁵ two kinds of effects would explain why winning the first battle should affect the outcome of the subsequent one in multiple pairwise battles: (i) effects that endogenously alter players' ability; and (ii) effects that endogenously affect prize spread symmetry.

First, two effects, "choking under pressure" and "psychological momentum," may explain the absence of neutrality as they alter players' ability.

Choking under pressure may occur if a player in the lagging team faces more pressure than a player in the leading team because the former has to win in order to keep his team in the contest. This pressure might have a detrimental effect on performance and might thus explain why winning the first battle would affect the probability of winning the next one. Indeed, research in psychology has shown that an emphasis on the importance of the situation can limit the individual's capacity to exhibit his "true" ability. Such a reaction can be driven by increased arousal, narrowed attention, and preoccupation with the reward or absence of reward (see Beilock (2010)). Apesteguia & Palacios-Huerta (2010) use the random nature of the order of soccer penalty shoot-outs to provide evidence of such psychological pressure. Teams that take the first kick in the sequence win the penalty shoot-out 60.5 percent of the time. Taking into account the characteristics of the setting, they attribute this significant difference in performance to psychological effects resulting from the consequences of the kicking order. However, Kocher, Lenz & Sutter (2012) find different results using a larger sample of penalty shoot-outs. Ariely, Gneezy, Loewenstein & Mazar (2009) show, based on experimental data, that choking under pressure has a stronger deterrent effect on performance when the task is publicly observable.

Psychological momentum, which has been mainly documented in individual settings, denotes the idea that winning a battle boosts players' confidence and helps them win the next one. In other words, initial success in a contest produces momentum that leads to future success. Rosenqvist & Skans (2015) provide field evidence on the causal impact of past individual successes on future performance. They use data from European golf tournaments to show that players who (marginally) succeeded in making the cut substantially increased their performance

⁵See section 3.1.

in subsequent tournaments relative to players who (marginally) failed to make the cut. On the contrary, Berger & Pope (2011) perform a regression discontinuity analysis of professional basketball games and find that teams that are very slightly behind at halftime (by 1 or 2 points) actually win more often than teams that are very slightly ahead. Gauriot & Page (2014) also use this powerful identification strategy to test for the existence of a momentum effect. They base their analysis on point by point ball tracking data in tennis matches, which allow them to isolate situations where balls bounce very close to the limits of the court, landing either in or out. These random variations in the probability of winning the point are used to investigate how professional tennis players' performance changes after winning or losing a point. The authors rule out the existence of a psychological momentum and provide evidence of a strategic momentum, which is a consequence of variations in incentives that occur in a dynamic contest.

Second, outcome dependence in multiple pairwise battles may be explained by asymmetric incentives among players, which may be caused by three potential phenomena.

A first effect that may distort players' incentives and generate outcome dependence is "guilt aversion:" a player may dread being (partly) responsible for his team's defeat. Baumeister, Stillwell & Heatherton (1994) define guilt as "an individual's unpleasant emotional state associated with possible objections to his or her actions, inaction, circumstances, or intentions. Guilt is an aroused form of emotional distress that is distinct from fear and anger and based on the possibility that one may be in the wrong or that others may have such a perception". Charness & Dufwenberg (2006) examine experimentally the impact of communication on trust and cooperation. Their design admits observation of promises, lies, and beliefs. They find evidence of guilt aversion showing that people strive to live up to others' expectations. Furthermore, Chen & Lim (2013) analyze whether managers should organize employees to compete in teams or as individuals. Their main conclusion according to which team-based contests yield greater effort than individual-based contests, is rooted in guilt aversion.

Second, a player may dread losing his battle in a team that performs very well, and *vice versa*. We refer to this phenomenon as "inequity aversion."⁶ This idea is connected to some results from the growing literature on individuals' relative performance. Information on relative performance allows for social comparison: individuals can evaluate their own performance by comparing them-

⁶We thank the referees for this important suggestion.

selves to others, thereby adapting their effort.⁷ If players value achieving a level of performance close to their teammates', this would generate outcome dependence with subsequent battles. Third, altruism, i.e., the fact that players internalize their teammates' costs of effort, would generate a linkage between subsequent battles. If individuals were altruistic, bearing part of their teammates' costs, the discouragement effect would be at play in multiple pairwise battles. Finally, one may also consider another kind of effect, which we refer to as "individual contribution:" players may value being partly responsible for collective success. In such a case, a player on the leading team has a higher probability of being (partly) responsible for collective success than his opponent. This higher probability increases his incentive to make a more costly effort, thereby increasing his probability of winning. If players value contributing to their team's success, then the prize spread is no longer the same for the frontrunner and the laggard. It would follow, then, that winning the first battle endogenously creates asymmetry in prize spreads and may therefore lead to outcome dependence with subsequent battles.

These potentially strong effects are grounds to empirically test for neutrality, which consists in analyzing whether winning the first battle affects the probability of winning the second one. This type of analysis poses two main empirical challenges.

First, failure to account for peer effects would generate a spurious correlation between the outcomes of subsequent battles. Being in a more stimulating environment might increase each teammate's probability of winning, thereby generating some spurious correlation between the probabilities of victory in the first two battles. The existence of peer effects continues to be debated in the literature. For instance, Mas & Moretti (2009) show, using high-frequency data from a field experiment, that the introduction of highly productive personnel into a team has a positive effect on worker productivity. On the contrary, Guryan, Kroft & Notowidigdo (2009) find no evidence of peer effects in a highly skilled professional labor market: neither the ability nor the current performance of playing partners affects the performance of professional golfers.

Second, belonging to the lagging team should not induce the player involved in the second battle to adopt a particular strategy that would affect the outcome of his match. The literature has focused on the fact that players could adopt riskier strategies when facing critical situations. Knoeber & Thurman (1994) compare tournament and linear payment schemes using data from a sample of U.S. broiler producers. They examine the impact of prizes on performance level

⁷See Festinger (1954) for a seminal analysis.

and variability, concluding that less able producers adopt riskier strategies. On the contrary, Brown (2011), who shows that professional golfers underperform when they are paired with a superstar, concludes that this reduced performance is not attributable to the adoption of risky strategies.

A few papers directly test for neutrality. Fu, Ke & Tan (2015) conduct a simple best-of-three team contest experiment, in which players from two rival teams are pairwise matched and compete by counting the number of zeros in a series of 10-digit number strings composed of 0s and 1s. They find evidence that 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. Dong & Huang (2018) use team squash data and do not find evidence against neutrality. Their findings are based on a limited number of matches. Huang & Murad (2017) develop an experiment to test for neutrality in a sequential best-of-three team contest. In their experiment, subjects have a fixed amount of time to catch balls that fall from the top of a computer screen by using mouse clicks. In a benchmark environment where there is no communication amongst teammates, who only share the same fate in terms of financial incentives, they find that second movers in lagging positions drop out of competition more often than second movers in leading positions. This result contradicts neutrality and can be supported by a psychological momentum. However, when teammates chat at the beginning of contests, the outcomes of the first two battles are independent. Huang & Murad (2017)'s interpretation is that guilt aversion compensates the psychological effect observed in the benchmark situation.

3 Testing for neutrality in multiple pairwise battles

3.1 Theoretical framework

This section theoretically analyzes individual behaviors in multiple pairwise battles and presents the equilibrium probability of winning a component battle in a tractable form, which allows us to (i) show that the neutrality result from Fu, Lu & Pan (2015) depends on two important assumptions, and (ii) derive predictions for the empirical analysis.

3.1.1 Setting

We consider a best-of-three team contest with complete information. A team X is opposed to a team Y . The contest presents the following features: (i) there are 3 risk-neutral players in each team. Each player only plays one battle. X_i (respectively Y_i) is the player from team X (respectively Y) that plays the i^{th} battle, $i \in \{1, 2, 3\}$; (ii) team X wins as soon as it wins two battles and loses as soon as it loses two battles; and (iii) the third battle is non-trivial only if team X and team Y have both won one of the two previous battles.

Let p_i be the probability that X_i wins his battle against Y_i ,

$$p_i = \frac{x_i}{x_i + y_i},$$

where x_i is the level of effort of X_i and y_i is the level of effort of Y_i . This function is the simplest version of the Tullock contest success function,⁸ also referred to as a lottery contest. Players do not have the same ability. This is reflected in a linear cost function, given by

$$C_{X_i}(x_i) = \frac{x_i}{\theta_{X_i}},$$

where θ_{X_i} is the innate ability of X_i . The cost of effort is thus a decreasing function of the innate ability of a player. The payoff associated with the collective win (denoted V) is the same for every player. Players also get a battle reward v when they win their own battle (independently of their team's outcome). V and v are strictly positive.

3.1.2 Theoretical result

Let $U_{J_i|Win_{K_i}}$ (respectively $U_{J_i|Loss_{K_i}}$) be the utility of player J_i , $J_i \in \{X_i, Y_i\}$, when K_i wins (respectively loses) battle i , $K_i \in \{X_i, Y_i\}$.

Result 1. *Equilibrium probability of winning.* *In a multiple pairwise battle, players choose their optimal level of effort such that the probability that player X_i wins a confrontation is given by*

$$p_i^* = \frac{\theta_{X_i} \Delta_{U_{X_i}}}{\theta_{X_i} \Delta_{U_{X_i}} + \theta_{Y_i} \Delta_{U_{Y_i}}},$$

where $\Delta_{U_{X_i}} = (U_{X_i|Win_{X_i}}) - (U_{X_i|Loss_{X_i}})$, respectively $\Delta_{U_{Y_i}} = (U_{Y_i|Loss_{X_i}}) - (U_{Y_i|Win_{X_i}})$, is the prize spread of player X_i , respectively Y_i .

⁸See Buchanan, Tollison & Tullock (1980).

Proof. See Appendix. □

This result shows that the outcome of a battle depends on two parameters only, which are (i) players' relative prize spreads, and (ii) players' relative ability (or cost of effort).

Therefore, if players have the same prize spreads (i.e., $\Delta_{U_{X_i}} = \Delta_{U_{Y_i}}$) and the circumstances of the battle do not asymmetrically affect players' cost of effort (i.e., θ_{X_i} and θ_{Y_i} are not asymmetrically affected by the state of the contest), the equilibrium probability of winning only depends on players' relative ability:

$$P_{iNeutrality}^* = \frac{\theta_{X_i}}{\theta_{X_i} + \theta_{Y_i}}.$$

In this case, the team contest boils down to a series of independent lotteries, yielding Fu, Lu & Pan (2015)'s neutrality result according to which the outcome of a battle does not affect the outcome of the subsequent ones (i.e., leading or lagging behind has no effect).

Therefore, one would observe neutrality if the two following conditions were satisfied: (i) common prize spreads, and (ii) the absence of phenomena asymmetrically altering players' effort cost or ability.⁹

(i) Common prize spreads This condition is satisfied in the case where players only value the collective win (payoff V) and the battle reward (payoff v). In a decisive battle 3,¹⁰ both players have a prize spread of $V + v$, as they get both the collective and the battle rewards if they win and a payoff of 0 if they lose. In battle 2, both players also have the same prize spread: the player in the leading team gets $V + v$ if he wins, and p_3^*V if he loses (as he can still get the collective reward V if his teammate wins battle 3, which occurs with a probability p_3^*), so his prize spread is $V + v - p_3^*V = v + (1 - p_3^*)V$. The player in the lagging team gets $v + (1 - p_3^*)V$ if he wins, as he is certain to receive the battle reward and he also gets the collective reward if his teammate wins battle 3, which occurs with a probability $(1 - p_3^*)$. If he loses, the contest ends and he gets a payoff 0, so his prize spread is also $v + (1 - p_3^*)V$. A similar logic applies to battle 1.

⁹These two conditions are sufficient, not necessary. For instance, neutrality may occur if the asymmetry in prize spreads is compensated by a change in players' ability.

¹⁰A decisive – or non-trivial – battle is a battle for which the winning team has not been determined yet. In a best-of-three team contest, battle 3 is decisive if and only if each team has won one battle in the two previous rounds.

A necessary condition for players to have common prize spreads is that they do not take into account their teammates' costs of effort. A situation where players would, for any reason, act in an altruistic way and internalize part of their teammates' effort cost would generate asymmetric prize spreads in battle 2. This would explain why there could exist a dynamic linkage between subsequent battles.

Furthermore, players might not only value the team win and the battle reward but also being individually (partly) responsible for collective success. If such motivation exists, the prize spreads become asymmetric in battle 2: the player in the leading team has more incentive to win than his opponent because he is sure to contribute to the success of his team if he wins his battle, while his opponent will be "success-responsible" if and only if his teammate also wins in period 3. Thus, an *individual contribution* effect would invalidate the assumption of common prize spreads and explain the absence of neutrality.

(ii) Absence of effects asymmetrically altering players' effort cost If we observe common prize spreads, neutrality would occur if players' cost of effort is not asymmetrically affected by the circumstances of the contest. In that case, the outcome of a battle would only depend on players' relative abilities (θ_{X_i} and θ_{Y_i}), which remain fixed.

However, players' effort cost may be affected in an asymmetric way by psychological factors related to the situation at hand. A player might have *psychological momentum* following the victory of his teammate, which would be equivalent to a decrease in his effort cost. Conversely, players' cost of effort could increase when they are under pressure. This *choking under pressure* phenomenon could occur when the stakes of the battle are particularly high for one of the players, such as the player from the lagging team involved in battle 2, whose defeat would lead to collective failure. Incorporating such effects in the cost function of players would also lead to non-neutrality.

These are the phenomena that might explain why these two crucial assumptions do not necessarily hold. The next section presents an empirical strategy to test for neutrality.

3.2 Empirical setting and data

3.2.1 International squash championships as a randomized natural experiment

Professional squash team data are particularly well suited to analysis of multiple pairwise battles. The structure of international squash competitions mirrors a theoretical best-of-three team contest with complete information: both the identity of the six players (three in each rival team) taking part and the order in which they play are determined before the beginning of the contest. Battles are played sequentially; each player only plays one battle. A team wins as soon as two of its players win. International squash tournaments can be utilized as a randomized natural experiment to analyze potential team effects in multiple pairwise battles because the order of play is randomly drawn ex ante. Each National Squash Association has to rank its players by descending order of strength and has to declare this order truthfully: opponents or organizers may object to a within-team ranking that does not reflect the actual hierarchy amongst teammates. More importantly, the order of the three battles is randomly drawn from four possibilities for every confrontation: 1-2-3, meaning that players ranked first play the first game, players ranked second play the second game and players ranked third play the third game, 1-3-2, 2-1-3, and 3-1-2. This ex-ante randomly-drawn order of play ensures that teams cannot manipulate the sequence of games to be played in any way.¹¹

3.2.2 Data

We construct a comprehensive dataset of international squash team confrontations from 1998 to 2016¹² that includes 2,039 national team matches. We consider 55 international team tournaments, including Men’s and Women’s World Team Championships, Men’s and Women’s Asian Team Championships and Women’s European Team Championships.¹³ The World Team Championships are organized by the World Squash Federation (WSF). The competition is held once every two years, each time in a different venue. The men’s and women’s events are held sepa-

¹¹See Section S1 of the WSF Regulations, Section L1 of the ESF Regulations and Section T1 of the ASF Regulations for more details.

¹²The data were gathered from the website <http://www.squashinfo.com>.

¹³We do not include Men’s European Team Championships in our sample because the tournament uses a best-of-four structure with ties broken by points count back.

rately in different years.¹⁴ The Asian Team Championships are organized by the Asian Squash Federation (ASF) and take place every two years. Finally, the European Squash Federation (ESF) holds the European Team Championships annually.

We have also recorded additional information: match durations (for most entries), locations and exact scores. The official scoring system for all levels of professional and amateur squash is called “point-a-rally scoring” (PARS). In PARS, the winner of a rally always receives a point, regardless of whether he served or returned. Sets are now played to 11, but were played to 9 until 2007 at Men’s World Team Championships, 2008 at Women’s World Team Championships, 2009 at Women’s European Team Championships, and 2010 at Men’s and Women’s Asian Team Championships. Players win a set by two clear points, i.e., if the score reaches 10–10, play continues until one player wins two consecutive points. Battles are the best-of-five sets, and the contest is a best-of-three battle.

Finally, we collected professional players’ monthly world rankings, which are published by the Professional Squash Association (PSA).¹⁵ These rankings are based solely on players’ performance in individual tournaments and, as such, are not correlated with their performance in past team tournaments. We use the PSA rankings as a proxy for players’ ability.

3.2.3 Descriptive statistics

This section provides a series of descriptive statistics on international squash team confrontations from 1998 to 2016.

We first compare the rankings of the players involved in battle 1, battle 2 and battle 3. This allows us to ensure that (i) PSA rankings reflect correctly players’ ability and (ii) the professional squash events comply with World Squash Championship Regulations. According to these regulations, each National Squash Association has to rank its players by descending order of strength. We do not identify each player’s position (i.e., first, second or third) within his team, but this should be correlated with PSA rankings. Moreover, these regulations impose that the order of the three battles is randomly drawn from the following four possibilities: 1-2-3 (i.e., players ranked first play the first game, players ranked second play the second game and players ranked third play the third game), 1-3-2, 2-1-3, and 3-1-2. Therefore, the corresponding

¹⁴The 2015 Men’s World Team Championship, which was to be held in Cairo, Egypt, has been canceled.

¹⁵Note that amateur squash players that might be involved in team championships have no PSA ranking.

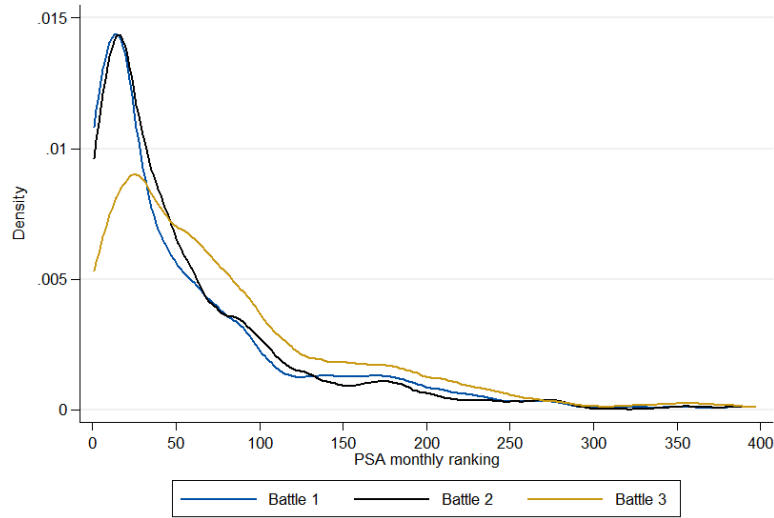
theoretical probabilities that battle i involves a player ranked first, second or third are as follows (see table 1).

Table 1: Within-team rankings of players involved in each battle according to WSF regulation

	Battle 1	Battle 2	Battle 3
Probability that battle i involves players ranked			
First	50%	50%	0%
Second	25%	25%	50%
Third	25%	25%	50%
Total	100%	100%	100%

Accordingly, the distribution of the PSA rankings of the players involved in battle 1 and battle 2 should be similar: the first two confrontations involve players who are ranked first with a 50% probability and ranked second or third with a 25% probability. On average, the PSA rankings of the players involved in battle 3 should be higher than that of those competing in battle 1 and battle 2. In battle 3, there are no top-ranked players, and players ranked second and third are equally distributed. Figure 1 provides the distribution of the rankings of the players involved in battle 1, battle 2 and battle 3. As expected, ranking distributions are similar for the first two rounds. Moreover, players involved in battle 3 have, on average, a higher PSA ranking than teammates involved in previous confrontations. This is perfectly consistent with the fact that (i) each National Squash Association ranks its players by descending order of ability; and that (ii) the order of the three confrontations is randomly drawn from the four scenarios described above (1-2-3, 1-3-2, 2-1-3 and 3-1-2). This also shows that PSA rankings correctly reflect players' ability.

Figure 1: Distribution of players' monthly PSA rankings, per round – 1998-2016



Furthermore, we compare the characteristics of the matches that take place in battle 1, battle 2, and battle 3. We do so to check if there are any significant differences between these confrontations to ensure that, in battle 2, the player in the lagging team does not adopt a risky strategy, as he must win to keep his team in the contest. If this were the case, one would expect to observe significant differences amongst the main characteristics of battle 1 and battle 2 matches. In particular, risky strategies should reduce the duration of a match: a player who gambles effectively tries to shorten each rally by attempting winning shots.

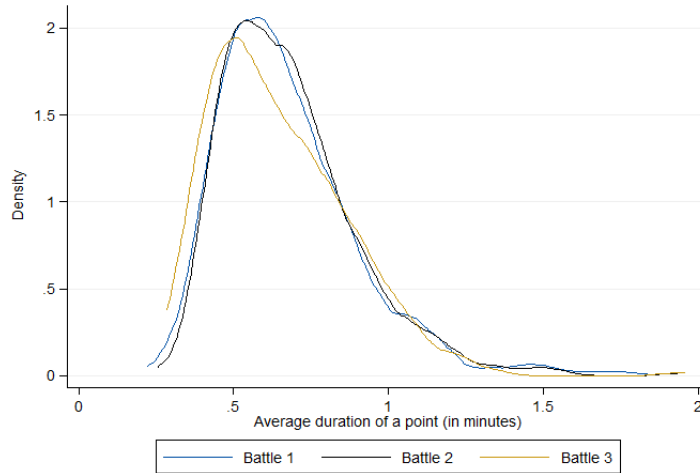
Table 2 displays, for each round (i.e., battle 1, battle 2 and battle 3), the average number of sets per match; the proportion of three-set matches (whose final score is necessarily 3-0), four-set matches (3-1) and five-set matches (3-2); the average number of points per match and per set; the average proportion of points won by the winner; and the average match duration.

Table 2: Characteristics of international squash team matches, per round – 1998-2016

	Battle 1	Battle 2	Battle 3	Total
Average number of sets per match	3.5	3.5	3.5	3.5
% of matches with a final score of				
3-0	60.7%	61.2%	64.9%	61.8%
3-1	26.2%	23.4%	23.7%	24.6%
3-2	13.1%	15.3%	11.4%	13.6%
Average number of points per match	52.2	53.6	52.8	52.9
Average number of points per set	14.9	15.3	15.1	15.1
Average duration (minutes)	38.2	38.8	33.7	37.3

These descriptive statistics show that battle 1 and battle 2 matches have similar characteristics. In addition, figure 2 shows the distribution of the average duration of a point in matches that take place in battle 1, battle 2 and battle 3. For each confrontation, we compute the ratio of the total duration of the match and the number of points played. If the players who belong to the lagging team gambled in battle 2, the average duration of a rally in battle 2 would be shorter than in battle 1, where none of the players has reason to adopt a particularly risky strategy. This is not what is observed in our data: Figure 2 shows that the distribution of the average duration of points played in battle 2 matches is the same as in battle 1 games.

Figure 2: Distribution of the average duration of points played in squash matches, per round – 1998-2016



The descriptive statistics confirm that players do not adopt a risky strategy based on the result of the first confrontation. Battle 1 and battle 2 matches display similar observable characteristics.

3.2.4 Measures of players' relative ability

In this paper, we want to estimate how past battles may affect the current battle outcome, in order to further analyze individual behaviors in teams. The outcome of a given battle mainly depends on the relative ability of both competing players. As mentioned in section 3.2.3, PSA rankings correctly reflect players' ability. In our empirical analysis, we use three different measures of players' ability based on PSA rankings as control variables.

First, we use rankings as a categorical variable with seven modalities: Top 5; 6-15; 16-30; 31-50; 51-75; 76-105; and 106-450. These specific modalities are constructed by increasing the size of the ranking range by 5 from one category to the next (except for the last one). This accounts for the fact that a small gap between two top players reflects a significant difference in their respective ability compared to a similar ranking gap between two second-tier professional players. These categories allow us to strike a good balance between an accurate measure of players' ability and a sufficient number of observations in each modality.

Second, we introduce each possible interaction between the aforementioned categories into our empirical models (e.g. Top 5 vs 16-30). We therefore generate 49 variables, which correspond

to the couple of ranking categories for each pair of competing players.

Finally, we consider the ratio of players' rankings. When this ratio is used as a control variable in our empirical model, we define it in such a way that it always lies between 0 and 1, i.e., we always consider the ratio of the ranking of the best player, with the lowest ranking, against the ranking of the worst. This allows us to avoid extreme values. However, the ratio of the worst player's ranking on the best player's ranking, which is larger than 1, is more relevant when we want to use this measure to restrict the sample to players of similar rankings.

All the results presented in the remainder of this paper are robust to these three different measures of players' relative ability.

3.3 Testing for neutrality in multiple pairwise battles

According to Fu, Lu & Pan (2015)'s model, the probability of winning a battle is not affected by the outcome of previous battles – all that matters is the relative ability of the players involved in a given battle. Neutrality is derived from the fact that both players have the same incentive to win because they have the same prize spread (i.e., the same utility gap between winning and losing).

Test 1. *There is evidence in support of neutrality if winning battle 1 does not affect the probability of winning battle 2.*

3.3.1 The absence of neutrality: statistical evidence

The most direct way to assess whether winning the first battle affects the probability of winning the second is to construct a sample in which players from both teams involved in the second battle have similar rankings. Based on this sample of equally skilled players, one would expect, if there were neutrality, half of the contests to be won by the player who belongs to the leading team.¹⁶

We use two different methods to restrict our sample of equally skilled players. The first method is based on the ratio of the rankings of both players involved in the second battle, and we restrict our sample to observations where this ratio is close to 1. In this case, the difference in rankings is easier to assess if the ratio is larger than 1: we thus consider the ratio of the worst

¹⁶This type of identification strategy is implemented by Malueg & Yates (2010), who construct a sample of tennis matches with equally skilled players.

player’s ranking on the best player’s, and we consider the following thresholds: (i) $ratio < 1.5$ – variant 1, (ii) $ratio < 1.4$ – variant 2, (iii) $ratio < 1.3$ – variant 3 and finally (iv) $ratio < 1.2$ – variant 4. According to this definition, a match between a player ranked 15 and a player ranked 25 will not be included in any variant (the ratio of these rankings being 1.66), while a match between a player ranked 15 and a player ranked 17 will be included in the four variants (the ratio of these rankings being 1.13). The second approach consists in considering only battle 2 matches in which both players’ rankings belong to the same category (Top 5; 6-15; 16-30; 31-5; 51-75; 76-105; and 106-450). Therefore, we only take into account a confrontation that involves a player ranked e.g. 6-15 if his opponent’s ranking lies within the same category.

We note X_1 the player who won the first battle against Y_1 , and X_2 the player who belongs to the leading team involved in battle 2 against Y_2 . Table 3 reports the empirical probability that X_2 wins the second battle for each of the variants considered.

Table 3: Statistical evidence against neutrality

	Ratio of rankings lower than				Same category
	1.5	1.4	1.3	1.2	
X_2 wins battle 2	59.7%***	59.1%**	60.4%**	60.4%**	56.7%*
Number of observations	211	181	139	91	203

Statistically different from 50% at * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The results presented in table 3 show that the probability that the player on the leading team wins is greater than 50%. In other terms, the figures suggest the absence of neutrality: winning the first battle increases the probability of winning the second one.

3.3.2 Evidence against neutrality: main specification

Restricting the sample to players who have similar rankings is a simple way to control for players’ relative ability but it considerably reduces the number of observations. We therefore integrate our measures of players’ relative ability as a control variable in order to use our entire sample.

To do so, we label the two opposing teams as “Team A” and “Team B”¹⁷ and their players

¹⁷In the remainder of this paper, we label “Team A” and “Team B” each of the opposing teams in a given confrontation, with no further conditions on the outcome of the first battle. When we deliberately choose the team that won the first battle, we refer to it as “Team X”, or “X”.

as A_1 , A_2 , A_3 , B_1 , B_2 and B_3 , where the subscript indicates the battle in which the player is engaged. We can test for neutrality by assessing whether the probability that A_2 defeats B_2 is higher when A_1 won against B_1 in the previous battle, controlling for A_2 's and B_2 's ability. Thus we regress the dummy variable indicating whether A_2 wins or loses battle 2 on a dummy variable indicating whether A_1 won or lost battle 1 and on a measure of A_2 and B_2 's relative ability based on their rankings. The tested econometric specification is as follows.

$$A_2 \text{ wins battle } 2 = \beta_0 + \beta_{\text{Non-neutrality}} \times A_1 \text{ won battle } 1 + f(\text{Ranking}_{A_2}, \text{Ranking}_{B_2}) + \epsilon_{AB2},$$

where $f(\text{Ranking}_{A_2}, \text{Ranking}_{B_2})$ refers to one of the three measures of players' relative ability described in the previous section: i) ranking modalities, (ii) interacted ranking modalities, (iii) the ratio of rankings. We integrate these measures of players' ability taking into account the symmetric structure of the dataset: the outcome of a battle depends on the characteristics of the two players. Hence, when we use ranking modalities and interacted modalities, we break down every battle into two observations and weight each observation by $\frac{1}{2}$ so as to adjust standard errors correctly. When we use the ratio of rankings as a proxy for relative ability, we define player A_i as the player who has the better ranking, so that the ratio of rankings always lies between 0 and 1.

We use a linear probability model as it makes the interpretation of the coefficients of interest easy.¹⁸ The results are displayed in columns (1), (3), (5) of table 4. The coefficient associated with A_1 won battle 1 is significant at the 0.1% level using any of the measures of players' ability. The magnitude of the effect is very strong (from 9.8 to 14.2 percentage points depending on the ability measure used). This means that in a battle involving two players with similar rankings, the player on the leading team wins with a probability that lies between 54.9% and 57.1%.

This series of results suggests the absence of neutrality. However, as explained above, we need to account for potential peer effects. Being on a team with high-performing teammates may increase a player's productivity, as a more stimulating environment may boost performance. Since high-performing players tend to win their battle, the player on the leading team is likely to be surrounded by more talented teammates than the player on the lagging team. Therefore, peer effects might be a confounding factor for sequence dependence. We take into account environment effects and other unobservables, such as the relative quality of the teams'

¹⁸We obtain very similar results with probit and logit estimations. The result of logit and probit estimations are displayed in Appendix.

managers and the cohesiveness between players, by including the teams' rankings (each team is seeded) as additional continuous control variables in specifications (2), (4) and (6). The teams' rankings reflect the extent to which they are favorites and are determined before the beginning of the competition by specialists, who base their judgment on all available information. As such, the rankings encompass most of the environment effects that may be at play, including the current physical condition of each player. We also add controls regarding the location of the confrontation, as playing at home can affect the outcome. Accordingly, we add dummies indicating whether team A is playing at home or away (the reference being the neutral field).

Winning the first battle remains significant at the 0.1% level once teams' rankings are introduced. The magnitude of the effect decreases slightly but remains substantial (from 8.7 to 11.4 percentage points depending on the specification). This is clear evidence that sequence dependence is not caused by confounding peer effects.

Table 4: Evidence against neutrality

<i>Dep. var.</i> : A_2 wins battle 2	(1)	(2)	(3)	(4)	(5)	(6)
A_1 won battle 1	0.142*** (0.029)	0.114*** (0.031)	0.128*** (0.029)	0.097** (0.031)	0.098*** (0.028)	0.087** (0.030)
A_2 's ranking: Top 5	0.721*** (0.057)	0.646*** (0.070)				
A_2 's ranking: 6-15	0.576*** (0.046)	0.518*** (0.056)				
A_2 's ranking: 16-30	0.466*** (0.043)	0.417*** (0.050)				
A_2 's ranking: 31-50	0.293*** (0.043)	0.260*** (0.047)				
A_2 's ranking: 51-75	0.184*** (0.046)	0.154** (0.049)				
A_2 's ranking: 76-105	0.093* (0.047)	0.073 (0.049)				
B_2 's ranking: Top 5	-0.721*** (0.057)	-0.646*** (0.070)				
B_2 's ranking: 6-15	-0.576*** (0.046)	-0.518*** (0.056)				
B_2 's ranking: 16-30	-0.466*** (0.043)	-0.417*** (0.050)				
B_2 's ranking: 31-50	-0.293*** (0.043)	-0.260*** (0.047)				
B_2 's ranking: 51-75	-0.184*** (0.046)	-0.154** (0.049)				
B_2 's ranking: 76-105	-0.093* (0.047)	-0.073 (0.049)				
A_2 's ranking vs B_2 's ranking			X	X		
$\frac{Ranking_{A_2}}{Ranking_{B_2}} (< 1)$					-0.535*** (0.046)	-0.522*** (0.054)
A_2 at home		0.009 (0.052)		0.010 (0.052)		0.085 (0.049)
B_2 at home		-0.009 (0.052)		-0.010 (0.052)		0.048 (0.050)
A_2 's team ranking		-0.007* (0.004)		-0.008* (0.004)		-0.008* (0.004)
B_2 's team ranking		0.007* (0.004)		0.008* (0.004)		0.004 (0.003)
Constant	0.429*** (0.037)	0.443*** (0.058)	0.436*** (0.048)	0.451*** (0.069)	0.436*** (0.048)	0.451*** (0.069)
Controls for players' ability						
Ranking category	YES	YES	NO	NO	NO	NO
Interaction of rkg categories	NO	NO	YES	YES	NO	NO
Ratio of rankings	NO	NO	NO	NO	YES	YES
Observations	934	896	934	896	934	896
R^2	0.42	0.42	0.45	0.46	0.17	0.17

Standard errors in parentheses: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Reading note (column 1): the probability that A_2 wins increases by 0.142 when his teammate A_1 won battle 1.

Reading note (column 1): the probability of winning of a player ranked in the Top 5 is 0.721 higher than the probability of winning of a player ranked 106-450 (reference category).

Note: the number of observations decreases from 934 in specifications (1), (3), (5) to 896 in specifications (2), (4),(6) because there are 38 contests for which teams' rankings are missing.

We find strong evidence that winning the first battle increases the probability of winning the second one. This contradicts neutrality.

4 The role of individual contribution to team success

In this section, we explain the absence of neutrality by providing compelling evidence, based on the predictions of the model developed in section 3.1, that individuals are willing to contribute to the success of their team. The outcomes of subsequent battles are dependent because players value being responsible for their team’s success. Outcome dependence is driven by what we refer to as “individual contribution.” Furthermore, we perform robustness checks, which confirm the existence of individual contribution in multiple pairwise battles and rule out alternative explanations developed in the existing literature on other team settings. In particular, we rule out guilt aversion, which refers to the symmetric effect of individual contribution: in such a case, players might suffer from being (partly) responsible for the failure of their team.

4.1 Evidence for individual contribution

Players might value being partly responsible for the success of their team. If players individually value their contribution to the team, they get an additional reward c ($c > 0$) when their victory leads their team to success. Table 5 displays players’ payoffs when there is individual contribution.

Table 5: Payoffs in the individual contribution scenario

	Player’s team wins	Player’s team loses
Player wins	$v + V + c$	v
Player loses	V	0

In such a case, the main intuition is that the player on the leading team would have more incentive to win the second battle than the player on the lagging team because the former is sure to contribute to his team’s success if he wins while the player on the lagging team will be “success-responsible” if and only if his teammate also wins the third battle. This asymmetry of incentives between the two players depends on the expected outcome of battle 3. For example, if X_1 wins battle 1 and X_3 has a extremely low probability of winning the third match (i.e., p_3^* falls to 0), both players can contribute to their team’s victory by winning battle 2, and both

players would make a symmetrical positive effort to get the additional reward. In this extreme case, winning the first battle should have no effect on the probability of winning the second one. Conversely, in the extreme case where X_1 wins battle 1 and X_3 has an extremely high probability of winning the third match (i.e., p_3^* increases to 1), the asymmetry between the two players reaches its maximum: X_2 is certain to receive the contribution reward if he wins while Y_2 has no chance of getting it.

Main test Formally, we obtain the following predictions, which confirm the role played by p_3^* in the individual contribution scenario:¹⁹

$$p_{2IC}^* = \frac{\theta_{X_2}(v + (1 - p_3^*)V + c)}{\theta_{X_2}(v + (1 - p_3^*)V + c) + \theta_{Y_2}(v + (1 - p_3^*)(V + c))},$$

where team X won battle 1.

This gives the two following results: first, $p_{2IC}^* > \frac{\theta_{X_2}}{\theta_{X_2} + \theta_{Y_2}}$, so winning battle 1 increases the probability of winning battle 2. Second, $\frac{\partial p_{2IC}^*}{\partial p_3^*} > 0$ and $\frac{\partial(1 - p_{2IC}^*)}{\partial(1 - p_3^*)} > 0$, so the probability of winning battle 2 increases with the teammate's probability of winning battle 3. This allows us to derive the following empirical test for individual contribution.

Test 2. *There is evidence in support of an “individual contribution” effect if*

- *Winning battle 1 increases the probability of winning battle 2.*
- *The probability of winning battle 2 increases with the probability of winning battle 3.*

The first condition given by test 2 is satisfied, as the results of test 1 show. We can test for the second condition of test 2 by assessing whether the probability that A_2 wins against B_2 increases with the extent to which A_3 is the favorite in battle 3. We use the gap between A_3 's and B_3 's ranking modalities, labelled $RM_{A_3} - RM_{B_3}$, as a proxy for the probability of winning of A_3 . For example, when A_3 ranks in the Top 5 and B_3 ranks between 16 and 30, $RM_{A_3} - RM_{B_3} = 2$.²⁰

We regress the dummy variable indicating whether A_2 wins battle 2 on $RM_{A_3} - RM_{B_3}$, on a measure of A_2 's and B_2 's relative ability and on the control variables used previously (playing

¹⁹See Appendix for detailed computations.

²⁰In order to perform the estimation on the same sample as the one used to test for neutrality (table 4), we create an additional ranking modality for amateur squash players involved in battle 3, whose level is too low to have a PSA ranking. Hence, if a player A_3 ranked 51-75 is opposed to an amateur player B_3 , $RM_{A_3} - RM_{B_3} = 2$.

home/away and teams' rankings). The tested econometric specification is therefore as follows.

$$A_2 \text{ wins battle } 2 = \beta_0 + \beta_{IC} \times (RM_{A_3} - RM_{B_3}) + f(\text{Ranking}_{A_2}, \text{Ranking}_{B_2}) \\ + \beta_{home} \times Home_A + \beta_{away} \times Away_A + \beta_{tA} \times Team's \text{ ranking}_A - \beta_{tB} \times Team's \text{ ranking}_B + \epsilon_{AB2}.$$

The results obtained with the three measures of players' relative ability are reported in columns (1), (3) and (5) of table 6. As predicted in the individual contribution scenario, the variable $RM_{A_3} - RM_{B_3}$ is positive and significant at the 1% level in the three specifications, showing that the probability of winning battle 2 increases with the probability of winning battle 3. When the difference in ranking modalities between the two players involved in battle 3 increases by 1, the probability of winning battle 2 increases by about 2 percentage points. Hence, a gap of 5 ranking modalities – which comes very close to the extreme case where p_3^* goes to 1 – increases the probability of winning battle 2 by 0.1. This effect is about as strong as the estimated effect of winning battle 1 (see table 4). This finding is perfectly consistent with the individual contribution effect, according to which winning battle 1 has no effect on battle 2 when the opposing team is expected to win battle 3.

One potential concern with specifications (1), (3) and (5) is confounding peer effects: being the favorite in battle 3 might be significant because it might imply that the player is in a more stimulating environment with more able teammates. If such an effect were at play, being the favorite in battle 1 should have the same effect, as there is no reason to believe that the influence of the teammate involved in battle 1 would be different from the influence of the teammate playing battle 3. In specifications (2), (4) and (6), we include the gap between A_1 's and B_1 's ranking modalities (labelled $RM_{A_1} - RM_{B_1}$) as a control to test for peer effects. The variable $RM_{A_1} - RM_{B_1}$ is not significant in any of the specifications and its inclusion does not affect the coefficient associated with our variable of interest, $RM_{A_3} - RM_{B_3}$. This confirms that peer effects are not at play and provides compelling evidence that individual contribution drives the observed linkage between subsequent battles.

Table 6: Individual contribution – Main test

<i>Dep. var.</i> : A_2 wins battle 2	(1)	(2)	(3)	(4)	(5)	(6)
$RM_{A_3} - RM_{B_3}$	0.024*** (0.007)	0.024*** (0.007)	0.023** (0.007)	0.024** (0.007)	0.021** (0.007)	0.021** (0.007)
$RM_{A_1} - RM_{B_1}$		-0.002 (0.007)		-0.004 (0.007)		-0.004 (0.007)
A_2 's ranking: Top 5	0.625*** (0.072)	0.630*** (0.073)				
A_2 's ranking: 6-15	0.513*** (0.058)	0.516*** (0.059)				
A_2 's ranking: 16-30	0.424*** (0.051)	0.426*** (0.052)				
A_2 's ranking: 31-50	0.273*** (0.047)	0.275*** (0.047)				
A_2 's ranking: 51-75	0.174*** (0.050)	0.175*** (0.050)				
A_2 's ranking: 76-105	0.082 (0.050)	0.083 (0.050)				
B_2 's ranking: Top 5	-0.625*** (0.072)	-0.630*** (0.073)				
B_2 's ranking: 6-15	-0.513*** (0.058)	-0.516*** (0.059)				
B_2 's ranking: 16-30	-0.424*** (0.051)	-0.426*** (0.052)				
B_2 's ranking: 31-50	-0.273*** (0.047)	-0.275*** (0.047)				
B_2 's ranking: 51-75	-0.174*** (0.050)	-0.175*** (0.050)				
B_2 's ranking: 76-105	-0.082 (0.050)	-0.083 (0.050)				
A_2 's ranking vs B_2 's ranking			X	X		
$\frac{Ranking_{A_2}}{Ranking_{B_2}} (< 1)$					-0.503*** (0.055)	-0.508*** (0.056)
A_2 at home	0.009 (0.052)	0.009 (0.053)	0.010 (0.052)	0.010 (0.052)	0.076 (0.048)	0.075 (0.048)
B_2 at home	-0.009 (0.052)	-0.009 (0.053)	-0.010 (0.052)	-0.010 (0.052)	0.045 (0.050)	0.043 (0.050)
A_2 's team ranking	-0.006 (0.004)	-0.006 (0.004)	-0.006 (0.004)	-0.007 (0.004)	0.002 (0.004)	0.001 (0.004)
B_2 's team ranking	0.006 (0.004)	0.006 (0.004)	0.006 (0.004)	0.007 (0.004)	0.002 (0.003)	0.003 (0.003)
Constant	0.500*** (0.057)	0.500*** (0.057)	0.500*** (0.069)	0.500*** (0.069)	0.946*** (0.038)	0.952*** (0.040)
Controls for players' ability						
Ranking category	YES	YES	NO	NO	NO	NO
Interaction of rkg categories	NO	NO	YES	YES	NO	NO
Ratio of rankings	NO	NO	NO	NO	YES	YES
Observations	874	874	874	874	874	874
R^2	0.43	0.43	0.47	0.47	0.17	0.17

Standard errors in parentheses.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Note: the number of observations drops from 896 in table 4 to 874 in this table as 22 trivial battles 3 are not played.

Additional test One may argue that the individual contribution effect should also be at play in a trivial battle 3 – where, by definition, the winning team has already been determined. In a best-of-three team contest, battle 3 is trivial if one team has already won the two previous confrontations. A player involved in a trivial battle 3 whose team has already won the contest should also value winning his match, so as to take part, albeit less directly than his teammates, in the success of his team. Winning allows him to be part of his team’s victory even if he was randomly assigned to the third battle, which happens to be trivial. Therefore, if individual contribution is at play, we should observe that his probability of winning the last trivial battle is *ceteris paribus* higher than his opponent’s. Formally, we obtain the following prediction:²¹

$$p_{3ICtrivial}^* = \frac{\theta_{X_3}(v+c)}{\theta_{X_3}(v+c) + \theta_{Y_3}v},$$

where team X won battle 1 and battle 2. As $p_{3ICtrivial}^* > \frac{\theta_{X_3}}{\theta_{X_3} + \theta_{Y_3}}$, we can derive the following empirical test for individual contribution.

Test 3. *There is evidence in support of an “individual contribution” effect if winning battle 1 and battle 2 increases the probability of winning trivial battle 3.*

We implement this additional test by restricting our sample to trivial battles 3²² and assessing whether being in the team that won the first two battles increases the probability of winning the last. The tested econometric specification is as follows.

$$A_3 \text{ wins battle 3} = \beta_0 + \beta_{IC} \times A_1 \text{ won battle 1 and } A_2 \text{ won battle 2} + f(\text{Ranking}_{A_3}, \text{Ranking}_{B_3}) + \beta_{home} \times Home_A + \beta_{away} \times Away_A + \beta_{tA} \times Team's \text{ ranking}_A - \beta_{tB} \times Team's \text{ ranking}_B + \epsilon_{AB3}.$$

The results are reported in table 7 for the three measures of the relative ability of players involved in trivial battles 3. The coefficient of interest is statistically significant and positive in the three specifications. This confirms that a player – whatever the stake of the battle he has been randomly assigned to – is motivated to participate in his team’s success.

²¹See Appendix for detailed computations.

²²This is why the number of observations drops to 378 in table 7.

Table 7: Individual contribution – Additional test

<i>Dep. var:</i> A_3 wins battle 3	(1)	(2)	(3)
A_1 won battle 1 and A_2 won battle 2	0.273*** (0.055)	0.176** (0.060)	0.133* (0.055)
A_3 's ranking: Top 5	0.417*** (0.111)		
A_3 's ranking: 6-15	0.326*** (0.077)		
A_3 's ranking: 16-30	0.318*** (0.068)		
A_3 's ranking: 31-50	0.191** (0.062)		
A_3 's ranking: 51-75	0.059 (0.061)		
A_3 's ranking: 76-105	0.122* (0.058)		
B_3 's ranking: Top 5	-0.417*** (0.111)		
B_3 's ranking: 6-15	-0.326*** (0.077)		
B_3 's ranking: 16-30	-0.318*** (0.068)		
B_3 's ranking: 31-50	-0.191** (0.062)		
B_3 's ranking: 51-75	-0.059 (0.061)		
B_3 's ranking: 76-105	-0.122* (0.058)		
A_3 's ranking vs B_3 's ranking		X	
$\frac{Ranking_{A_3}}{Ranking_{B_3}} (< 1)$			-0.241** (0.076)
A_3 at home	0.064 (0.071)	0.042 (0.072)	0.124* (0.058)
B_3 at home	-0.064 (0.071)	-0.042 (0.072)	0.075 (0.079)
A_3 's team ranking	-0.012** (0.004)	-0.014** (0.005)	-0.012* (0.005)
B_3 's team ranking	0.012** (0.004)	0.014** (0.005)	0.008* (0.004)
Constant	0.364*** (0.075)	0.412*** (0.088)	0.823*** (0.068)
Controls for players' ability			
Ranking category	YES	NO	NO
Interaction of rkg categories	NO	YES	NO
Ratio of rankings	NO	NO	YES
Observations	378	378	378
R^2	0.59	0.64	0.17

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Thus, our results show that the absence of neutrality is driven by the fact that players individually value being responsible for their team's success.

4.2 Robustness checks and alternative explanations

The empirical strategy based on our theoretical predictions shows that the dynamic linkage between subsequent battles observed in our data is in line with an individual contribution effect. Players value being responsible for collective success.

We confirm the existence of individual contribution by testing for alternative effects, which

could also explain the observed dependence of the outcomes of the first two battles.

These effects are summarized in table 8.

Table 8: Individual contribution and alternative explanations

Type	Effect	Description
Asymmetry in prize spreads	Individual contribution	Individuals value being responsible for collective success
	Guilt aversion	Individuals dread being responsible for collective failure
	Inequity aversion	Individuals dread performing differently compared to teammates
	Altruism	Individuals internalize their teammates' costs of effort
Alteration of players' ability	Choking under pressure	Pressure has a detrimental effect on performance
	Momentum	Recent success increases confidence

Other effects that generate a gap in prize spreads: Guilt aversion, inequity aversion and altruism

Guilt aversion Players might suffer from being (partly) responsible for the failure of their team. In this case, a player who loses his battle and consequently contributes to his team's overall defeat bears an additional loss ($-s$, $s > 0$). This additional loss asymmetrically affects players' prize spreads and therefore may explain the absence of neutrality (see table 9).

Table 9: Payoffs in the guilt aversion scenario

	Player's team wins	Player's team loses
Player wins	$v + V$	v
Player loses	V	$-s$

Under this scenario, we derive from Result 1 the following predictions:²³

$$p_{2GA}^* = \frac{\theta_{X_2}(v + (1 - p_3^*)(V + s))}{\theta_{X_2}(v + (1 - p_3^*)(V + s)) + \theta_{Y_2}(v + (1 - p_3^*)V + s)},$$

where team X is defined as the team that won battle 1. $p_{2GA}^* < \frac{\theta_{X_2}}{\theta_{X_2} + \theta_{Y_2}}$, which yields the following empirical test.

Test 4. *There is evidence in support of guilt aversion if winning battle 1 decreases the probability of winning battle 2.*

²³See Appendix for detailed computations.

Guilt aversion implies that winning battle 1 decreases the probability of winning battle 2. The main intuition that explains this result is as follows: The player on the leading team would have a lower incentive to exert significant effort in the second battle than the player on the trailing team because the former feels guilty when losing only when his team also loses the third battle. This is not the case for the player from the trailing team, who feels guilty for sure when losing.

In our setting, winning battle 1 increases the probability of winning battle 2 (see table 4). Non-neutrality is not driven by guilt aversion.

Inequity aversion A player may dread losing in a team that performs very well, and winning in a team that underperforms. We refer to this phenomenon as "inequity aversion." This effect clearly depends on whether teammates won their own battles. It also depends on teammates' performance: losing when a teammate won while was expected to lose (i.e., overperformed) is even costlier for the current player. In that case, inequity aversion should therefore induce the current player to exert significant effort. Accordingly, the player who belongs to the leading team has more incentive to win battle 2 than his opponent. Indeed, if he wins, he will not have to pay the inequity aversion cost, whereas the player in the lagging team will not have to pay it only if his teammate involved in battle 3 also wins.

Table 10: Payoffs in the inequity aversion scenario

	Player's team wins	Player's team loses
Player wins	$v + V$	$v - \Upsilon_{-i}$
Player loses	$V - \Omega_{-i}$	0

Υ_{-i} corresponds to the aggregated underperformance of the two players who lose in case of collective defeat and Ω_{-i} corresponds to the aggregated overperformance of the two players who win their individual battles in case of collective victory. A player overperforms if he wins against an opponent whose ranking lies in a better ranking modality. For example, if a player ranked in the 6-15 modality wins against a player in the top 5, his overperformance is 1. If a player in the 16-30 ranking modality wins against a player in the top 5, his overperformance is 2 (gap of two ranking modalities) and so on. If the player wins against a player whose ranking lies in the same or in a worse category than his, we consider that he does not overperform (his

overperformance is therefore equal to 0). Symmetrically, if a player loses against a player in the same modality or in a better modality, he does not underperform (underperformance is equal to 0). If he loses against a player in a worse ranking modality, his underperformance corresponds to the gap in ranking modalities. Given this symmetry, the overperformance of one team is equal to the underperformance of the other team (if team X is the winning team, $\Omega_{X-i} = \Upsilon_{Y-i}$), which allows us to simplify the computation. We derive the following prediction from Result 1:²⁴

$$p_{2IA}^* = \frac{\theta_{X_2}(v + (1 - p_3^*)V + p_3^*\Omega_{X_1, X_3})}{\theta_{X_2}v + (1 - p_3^*)V + p_3^*\Omega_{X_1, X_3} + \theta_{Y_2}(v + (1 - p_3^*)V - p_3^*\Omega_{X_1, X_3})},$$

where team X won battle 1.

This gives the three following results: first, $p_{2IA}^* > \frac{\theta_{X_2}}{\theta_{X_2} + \theta_{Y_2}}$, so winning battle 1 increases the probability of winning battle 2. Second, $\frac{\partial p_{2IA}^*}{\partial p_3^*} > 0$ and $\frac{\partial(1-p_{2IA}^*)}{\partial(1-p_3^*)} > 0$, so the probability of winning battle 2 increases with the teammate's probability of winning battle 3. Third, $\frac{\partial p_{2IA}^*}{\partial \Omega_{X_1, X_3}} > 0$ so the probability of winning battle 2 increases when the teammate implied in battle 1 overperformed and decreases when the teammate implied in battle 1 underperformed.

Test 5. *There is evidence in support of an “inequity aversion” effect if*

- *Winning battle 1 increases the probability of winning battle 2;*
- *The probability of winning battle 2 increases with the probability of winning battle 3;*
- *The probability of winning battle 2 increases when the teammate implied in battle 1 overperformed and decreases when the teammate involved in battle 1 underperformed.*

The two first conditions are met in the data (see Table 4 and Table 6). We test the third condition. We add in the non-neutrality specification, the variables associated to overperformance and underperformance.

$$\begin{aligned} A_2 \text{ wins battle 2} &= \beta_0 + \beta_{Non-neutrality} \times A_1 \text{ won battle 1} \\ &\quad + \beta_{\Omega} \times A_1 \text{ won battle 1} \times \mathbb{1}_{(RM_{A_1} < RM_{B_1})} \times (RM_{B_1} - RM_{A_1}) \\ &\quad + \beta_{\Upsilon} \times (1 - A_1 \text{ won battle 1}) \times \mathbb{1}_{(RM_{A_1} > RM_{B_1})} \times (RM_{A_1} - RM_{B_1}) \\ &\quad + f(\text{Ranking}_{A_2}, \text{Ranking}_{B_2}) + \beta_{home} \times Home_A + \beta_{away} \times Away_A \\ &\quad + \beta_{tA} \times Team's \text{ ranking}_A - \beta_{tB} \times Team's \text{ ranking}_B + \epsilon_{AB2} \end{aligned}$$

²⁴See Appendix for detailed computation.

The inequity aversion scenario implies that the player involved in battle 2 will have stronger incentives to win if his teammate overperformed in battle 1 (i.e., won against an opponent with a better ranking) and he will have lower incentives to win if his teammate underperformed in battle 1 (i.e., lost against an opponent with a worse ranking). Therefore, inequity aversion implies that β_{Ω} should be significant and positive and β_{Υ} should be significant and negative.

Results with the three measures of players' relative ability are reported in table 11. β_{Ω} and β_{Υ} are not significant with any of the three measures. This result rules out inequity aversion and confirms the individual contribution effect. Indeed, according to the individual contribution effect, players only value bringing one point back for their team. Therefore, β_{Ω} and β_{Υ} should not be significant.

Table 11: Evidence against inequity aversion

<i>Dep. var:</i> A_2 wins battle 2	(1)	(2)	(3)
A_1 won battle 1	0.097** (0.034)	0.069* (0.034)	0.056 (0.033)
A_1 's Ω	-0.011 (0.021)	0.000 (0.021)	0.009 (0.021)
A_1 's Υ	0.011 (0.021)	-0.000 (0.021)	-0.002 (0.019)
A_2 's ranking: Top 5	0.658*** (0.071)		
A_2 's ranking: 6-15	0.530*** (0.057)		
A_2 's ranking:: 16-30	0.427*** (0.051)		
A_2 's ranking: 31-50	0.269*** (0.047)		
A_2 's ranking: 51-75	0.171*** (0.050)		
A_2 's ranking: 76-105	0.076 (0.050)		
B_2 's ranking: Top 5	-0.658*** (0.071)		
B_2 's ranking: 6-15	-0.530*** (0.057)		
B_2 's ranking: 16-30	-0.427*** (0.051)		
B_2 's ranking: 31-50	-0.269*** (0.047)		
B_2 's ranking: 51-75	-0.171*** (0.050)		
B_2 's ranking: 76-105	-0.076 (0.050)		
A_2 's ranking vs B_2 's ranking		X	
$\frac{Ranking_{A_2}}{Ranking_{B_2}} (< 1)$			-0.527*** (0.055)
A_2 at home	0.018 (0.052)	0.019 (0.052)	0.080 (0.048)
B_2 at home	-0.018 (0.052)	-0.019 (0.052)	0.033 (0.050)
A_2 's team ranking	-0.007* (0.004)	-0.008* (0.004)	-0.002 (0.004)
B_2 's team ranking	0.007* (0.004)	0.008* (0.004)	0.004 (0.003)
Constant	0.451*** (0.060)	0.466*** (0.071)	0.949*** (0.044)
Controls for players' ability			
Ranking category	YES	NO	NO
Interaction of rkg categories	NO	YES	NO
Ratio of rankings	NO	NO	YES
Observations	874	874	874
R^2	0.42	0.46	0.17

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Altruism Our results up to this point have been based on the assumption that players do not take into account their teammates' costs of effort. However, the observed link between the first two battles of the contest could be driven by the fact that individuals internalize their teammates' effort costs. This effect could be referred to as "altruism," signifying that each player on a team maximizes his utility function, taking into account not only his own effort cost but also his teammates'. For instance, the player on the leading team involved in battle 2

could make an additional effort in order to win, thereby preventing his teammate from playing a decisive battle 3 and incurring the corresponding effort cost.

The idea that individuals internalize their teammates' costs calls for the following two remarks. First, we refer to this phenomenon as "altruism," but one may argue that a player might internalize the effort cost of teammates involved in battle 3 in order to prevent them from playing a high-stake match because it is in his interest to preserve their stamina for the next rounds. This interpretation would not affect the empirical test presented below. Second, players could internalize not only their partners' effort costs, but also the various benefits they derive from playing a match. If the benefits from playing are greater than the afferent costs, an altruistic player would behave in a way that enables his teammate to play. This would imply that winning battle 1 has a negative impact on the probability of winning battle 2, which is not supported by our data (see table 4).

We develop a test to address the fact that individuals may internalize their teammates' costs. This test allows us to distinguish between individual contribution and altruism. Intuitively, our identification strategy is based on the fact that, in a best-of-three contest, altruistic players involved in the first battle cannot prevent their teammates from playing a high-stake second match, and can only internalize the cost of effort of the players involved in the third (potentially trivial) battle. Accordingly, we focus on battle 1 and limit our sample to contests where the favorites in battles 2 and 3²⁵ do not belong to the same team. Hence, there are only two possible scenarios regarding future battles: either i) *A₂ is the favorite and A₃ is the underdog* or ii) *A₂ is the underdog and A₃ is the favorite*. According to the individual contribution effect, these two scenarios are equivalent, as player *A₁* is equally likely to get the contribution reward in either setting. On the contrary, if players were altruistic, the scenario *A₂ favorite, A₃ underdog* would be much more motivating for player *A₁*. Indeed, when *A₂* is favorite, *A₁* knows that winning battle 1 implies that his teammate *A₃* will probably not have to play a decisive battle 3 and thereby make a significant effort. On the other hand, when *A₂* is underdog, *A₁* knows that winning battle 1 implies that his teammate *A₃* is very likely to play a decisive battle 3 and to exert a significant effort. Thus, altruism implies that *A₁* has more incentive to win when *A₂* is the favorite and *A₃* is the underdog than in the symmetric situation.²⁶

Test 6. *There is evidence in support of*

²⁵A player is defined as the favorite when he has a better ranking than his opponent.

²⁶See Appendix for more formal details on this test.

- *Altruism if the probability that A_1 wins battle 1 is larger ceteris paribus in the scenario “ A_2 favorite, A_3 underdog” than in the scenario “ A_2 underdog, A_3 favorite.”*
- *Individual contribution if the probability that A_1 wins battle 1 is the same in both scenarios.*

Accordingly, we regress A_1 's victory on a dummy variable indicating the situation regarding battles 2 and 3 (which equals 1 when A_2 is favorite and A_3 is underdog, and 0 when A_2 is the underdog and A_3 is the favorite), on a measure of A_1 's and B_1 's relative ability as well as the usual control variables (playing home/away and teams' rankings).

$$A_1 \text{ wins battle 1} = \beta_0 + \beta_{\text{altruism}} \times A_2 \text{ favorite, } A_3 \text{ underdog} + f(\text{Ranking}_{A_1}, \text{Ranking}_{B_1}) \\ + \beta_{\text{home}} \times \text{Home}_A + \beta_{\text{away}} \times \text{Away}_A + \beta_{tA} \times \text{Team's ranking}_A - \beta_{tB} \times \text{Team's ranking}_B + \epsilon_{AB1}.$$

Individual contribution predicts that the variable A_2 favorite, A_3 underdog has no significant effect on the probability that A_1 wins battle 1. On the contrary, if players were altruistic, our model would predict that the variable A_2 favorite, A_3 underdog should have a statistically significant positive effect on the probability that A_1 wins battle 1. Results are reported in table 12. The coefficient associated with the variable of interest is negative and not statistically significant using any of the three measures of players' ability. This confirms the individual contribution effect and rules out altruism: players do not internalize their teammates' effort costs in our setting.

Table 12: Evidence against altruism

<i>Dep. var:</i> A_1 wins battle 1	(1)	(2)	(3)
A_2 favorite, A_3 underdog	-0.086 (0.065)	-0.086 (0.071)	-0.106 (0.061)
A_1 's ranking: Top 5	0.837*** (0.188)		
A_1 's ranking: 6-15	0.695*** (0.153)		
A_1 's ranking: 16-30	0.462*** (0.134)		
A_1 's ranking: 31-50	0.361* (0.141)		
A_1 's ranking: 51-75	0.301* (0.124)		
A_1 's ranking: 76-105	0.167 (0.128)		
B_1 's ranking: Top 5	-0.837*** (0.188)		
B_1 's ranking: 6-15	-0.695*** (0.153)		
B_1 's ranking: 16-30	-0.462*** (0.134)		
B_1 's ranking: 31-50	-0.361* (0.141)		
B_1 's ranking: 51-75	-0.301* (0.124)		
B_1 's ranking: 76-105	-0.167 (0.128)		
A_1 's ranking vs B_1 's ranking		X	
$\frac{Ranking_{A_1}}{Ranking_{B_1}} (< 1)$			-0.522*** (0.129)
A_1 at home	0.080 (0.130)	0.082 (0.144)	0.137 (0.125)
B_1 at home	-0.080 (0.130)	-0.082 (0.144)	0.002 (0.121)
A_1 's team ranking	-0.007 (0.010)	-0.005 (0.011)	-0.001 (0.010)
B_1 's team ranking	0.007 (0.010)	0.005 (0.011)	0.002 (0.009)
Constant	0.543*** (0.159)	0.543** (0.189)	1.027*** (0.102)
Controls for players' ability			
Ranking category	YES	NO	NO
Interaction of rkg categories	NO	YES	NO
Ratio of rankings	NO	NO	YES
Observations	208	208	208
R^2	0.25	0.28	0.11

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Effects that alter players' ability: Choking under pressure and psychological momentum

Choking under pressure Dynamic competitive settings may exert psychological pressure on competitors, thereby affecting their performance. In period 2, the player who belongs to the lagging team might – all other things being equal – face more pressure than the player in the leading team, as the former needs to win to ensure that his team remains in the contest. Such a phenomenon might explain why we observe a positive effect of a win in the first game on the

probability of winning the next.

We incorporate choking under pressure into our theoretical setting by multiplying by η ($0 < \eta < 1$) the ability of players who must win their individual battle to ensure that their team remains in the contest. In $T=2$, the player in the leading team (X_2) does not face pressure because losing his battle does not imply that his team loses. On the contrary, the player in the lagging team (Y_2) might choke under pressure because losing his battle induces that his team loses. Hence, the choking-under-pressure effect yields the following prediction in battle 2:²⁷

$$p_{2CUP}^* = \frac{\theta_{X_2}}{\theta_{X_2} + \theta_{Y_2}\eta} > \frac{\theta_{X_2}}{\theta_{X_2} + \theta_{Y_2}}$$

where team X is defined as the team that won battle 1.

In a trivial battle 3 (*i.e.* one team has already won two battles), none of the players face pressure because the outcome of their individual battle does not affect the collective outcome. Therefore, we obtain the following prediction:²⁸

$$p_{3CUPtrivial}^* = p_3^* = \frac{\theta_{X_3}}{\theta_{X_3} + \theta_{Y_3}}$$

where team X is defined as the team that won battles 1 and 2.

As $p_{2CUP}^* > \frac{\theta_{X_2}}{\theta_{X_2} + \theta_{Y_2}}$ and $p_{3CUPtrivial}^* = \frac{\theta_{X_3}}{\theta_{X_3} + \theta_{Y_3}}$, the following empirical test can be derived from our theoretical setting.

Test 7. *There is evidence in support of a “choking-under-pressure” effect if:*

1. *Winning battle 1 increases the probability of winning battle 2.*
2. *Winning battle 1 and battle 2 does not affect the probability of winning a trivial battle 3.*

The first condition is met (see table 4) while the second condition is not. Indeed, our additional test on the individual contribution effect shows that winning battles 1 and 2 has a statistically significant effect on the probability of winning a trivial battle 3. Depending on the measure of relative ability that is used, the effect ranges from 13 to 27 percentage points (see table 7). This allows us to reject choking under pressure and to put forward the individual contribution effect.

²⁷See Appendix for detailed computations.

²⁸See Appendix for detailed computations.

Psychological momentum Psychological momentum implies that winning a battle increases a player’s confidence and makes him more likely to win the next one (“success breeds success”).

We incorporate psychological momentum into our theoretical setting by multiplying by ψ ($\psi > 1$) the ability of the player whose team won the last battle. This changes the probability that player X_2 and player X_3 win. In this case,²⁹

$$p_{3PM}^* = \frac{\theta_{X_3}}{\theta_{X_3} + \theta_{Y_3}\psi},$$

where team X is defined as the team that won battle 1 and lost battle 2.

$$p_{2PM}^* = \frac{\theta_{X_2}\psi}{\theta_{X_2}\psi + \theta_{Y_2}},$$

where team X is defined as the team that won battle 1.

As $p_{2PM}^* > \frac{\theta_{X_2}}{\theta_{X_2} + \theta_{Y_2}}$ and $p_{3PM}^* < \frac{\theta_{X_3}}{\theta_{X_3} + \theta_{Y_3}}$, the following empirical test can be derived from our theoretical setting.

Test 8. *There is evidence in support of psychological momentum if:*

1. *Winning battle 1 increases the probability of winning battle 2.*
2. *In a non-trivial battle 3, the player in the team that won battle 2 is more likely to win than the player in the team that won battle 1.*³⁰

To test for the second condition, we focus on the subsample of non-trivial battle 3s (i.e., the matches in which the winning team had not been determined after the first two battles). For these matches, there are only two possible scenarios regarding the outcome of the two previous battles: either A_1 won battle 1 and A_2 lost battle 2, or A_1 lost battle 1 and A_2 won battle 2. We create a dummy variable that is equal to 0 in the first scenario and to 1 in the second scenario. Psychological momentum would imply that this variable has a positive and statistically significant effect on A_3 wins battle 3. On the contrary, individual contribution predicts that this variable should not have any effect, as both players face symmetric incentives in a decisive battle

²⁹See Appendix for detailed computations.

³⁰This identification strategy is also used by Malueg & Yates (2010) and Mago et al. (2013).

3. The model is therefore given by:

$$A_3 \text{ wins battle } 3 = \beta_0 + \beta_{PM} \times A_1 \text{ lost battle } 1 \text{ and } A_2 \text{ won battle } 2 + f(\text{Ranking}_{A_3}, \text{Ranking}_{B_3}) \\ + \beta_{home} \times Home_A + \beta_{away} \times Away_A + \beta_{tA} \times Team's \text{ ranking}_A - \beta_{tB} \times Team's \text{ ranking}_B + \epsilon_{AB3}$$

Table 13 reports the results obtained with the three measures of players' ability. The effect of the sequence variable A_1 lost battle 1 and A_2 won battle 2 is not statistically significant in any of the three specifications. This is evidence in favor of individual contribution and against psychological momentum.

Table 13: Evidence against psychological momentum

<i>Dep. var:</i> A_3 wins battle 3	(1)	(2)	(3)
A_1 lost battle 1 and A_2 won battle 2	-0.026 (0.067)	-0.027 (0.072)	-0.002 (0.063)
A_3 's ranking: Top 5	0.765** (0.261)		
A_3 's ranking: 6-15	0.548*** (0.153)		
A_3 's ranking: 16-30	0.376** (0.141)		
A_3 's ranking: 31-50	0.261* (0.127)		
A_3 's ranking: 51-75	0.185 (0.114)		
A_3 's ranking: 76-105	0.006 (0.116)		
B_3 's ranking: Top 5	-0.765** (0.261)		
B_3 's ranking: 6-15	-0.548*** (0.153)		
B_3 's ranking: 16-30	-0.376** (0.141)		
B_3 's ranking: 31-50	-0.261* (0.127)		
B_3 's ranking: 51-75	-0.185 (0.114)		
B_3 's ranking: 76-105	-0.006 (0.116)		
A_3 's ranking vs B_3 's ranking		X	
$\frac{Ranking_{A_3}}{Ranking_{B_3}} (< 1)$			-0.364** (0.134)
A_3 at home	-0.018 (0.127)	-0.039 (0.143)	-0.126 (0.114)
B_3 at home	0.018 (0.127)	0.039 (0.143)	-0.071 (0.123)
A_3 's team ranking	-0.020 (0.011)	-0.019 (0.012)	-0.021* (0.011)
B_3 's team ranking	0.020 (0.011)	0.019 (0.012)	0.015 (0.010)
Constant	0.513*** (0.142)	0.514** (0.161)	0.971*** (0.106)
Controls for players' ability			
Ranking category	YES	NO	NO
Interaction of rkg categories	NO	YES	NO
Ratio of rankings	NO	NO	YES
Observations	191	191	191
R^2	0.26	0.29	0.10

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

5 Conclusion

Using team squash championships as a randomized natural experiment, we provide compelling empirical evidence against neutrality in multiple pairwise battles: in a best-of-three team contest, winning the first battle increases, *ceteris paribus*, the probability of winning the second battle. We show that this team dynamic is not driven by effects that would alter players' ability such as choking under pressure or psychological momentum. We further show that guilt aversion, inequity aversion and altruism, three effects that affect players' prize spread, also fail to explain

the absence of neutrality.

The observed dynamic linkage is driven by another incentive effect, which we refer to as *individual contribution*: people derive utility from contributing to their team's success. To the best of our knowledge, this is the first paper providing empirical field evidence that individuals value contributing to their team's success. These findings cast new light on the way individuals behave in teams and open several potential avenues for future research.

While this effect should exist in other settings and in other kinds of contests outside the ones studied here, the subject merits further scrutiny. One important pending question is whether individual contribution depends on the observability of each teammate's performance. This has crucial implications with regard to management practices and contest design. If individual contribution only comes into play when performance is observable – as it is in the setting under scrutiny – organizations should design contests and team-based contracts in such a way that each teammate's performance is made public and the link between individual outcomes and team success is easily appreciable. For instance, the temporal structure of contests could play a major role in enabling organizations to reap the benefits of individual contribution, and sequential rounds could be much more efficient than simultaneous contests in inducing individuals to make a significant effort.

In any case, this effect is of prime importance to understanding team-based contests and contracts. Economic models of teams predict that individuals have an incentive to free ride, as they do not internalize the benefits accrued by other members of the team when making effort decisions.³¹ Hence, the optimal level of effort exerted in individual contests should be higher than the effort observed in team-based incentive contests when the individual reward is based on team production. However, this theoretical result seems to contradict both experimental and behavioral literature on teams.³² Individual contribution is a mechanism that mitigates free-riding behaviors. Each teammate values being responsible for collective success and therefore makes a significant effort, which could be higher than the effort that he would make in an individual contest. Individual contribution appears to be one of the reasons why so many firms use collective incentive and profit-sharing plans.

³¹See Lazear & Rosen (1981) for a seminal analysis of the relation between compensation and incentives in the presence of costly monitoring of worker's effort and output; and Prendergast (1999) for a survey of team production.

³²See, for instance, Kandel & Lazear (1992). Chen & Lim (2013) show, using an experiment, that guilt is at play in teams and can explain why team-based incentives are more efficient than individual-based contracts.

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Appendix A – Proofs

Result 1

Let $U_{J_i}|Win_{K_i}$ (respectively $U_{J_i}|Loss_{K_i}$) be the utility of player J_i , $J_i \in \{X_i, Y_i\}$, when K_i wins (respectively loses) battle i , $K_i \in \{X_i, Y_i\}$.

Both players choose their level of effort to maximize their expected utility:

$$\max_{x_i} \left(\frac{x_i}{x_i + y_i} (U_{X_i}|Win_{X_i}) + \frac{y_i}{x_i + y_i} (U_{X_i}|Loss_{X_i}) - \frac{x_i}{\theta_{X_i}} \right),$$

$$\max_{y_i} \left(\frac{y_i}{x_i + y_i} (U_{Y_i}|Loss_{X_i}) + \frac{x_i}{x_i + y_i} (U_{Y_i}|Win_{X_i}) - \frac{y_i}{\theta_{Y_i}} \right).$$

Assuming that U s are independent of x_i and y_i , the first order conditions yield the following optimal levels of effort and equilibrium probability of winning p_i^* :

$$x_i^* = \frac{(\theta_{X_i} \Delta_{U_{X_i}})^2 \theta_{Y_i} \Delta_{U_{Y_i}}}{(\theta_{X_i} \Delta_{U_{X_i}} + \theta_{Y_i} \Delta_{U_{Y_i}})^2},$$

$$y_i^* = \frac{\theta_{X_i} \Delta_{U_{X_i}} (\theta_{Y_i} \Delta_{U_{Y_i}})^2}{(\theta_{X_i} \Delta_{U_{X_i}} + \theta_{Y_i} \Delta_{U_{Y_i}})^2}.$$

Finally,

$$p_i^* = \frac{\theta_{X_i} \Delta_{U_{X_i}}}{\theta_{X_i} \Delta_{U_{X_i}} + \theta_{Y_i} \Delta_{U_{Y_i}}}.$$

where $\Delta_{U_{X_i}} = (U_{X_i}|Win_{X_i}) - (U_{X_i}|Loss_{X_i})$ – respectively, $\Delta_{U_{Y_i}} = (U_{Y_i}|Loss_{X_i}) - (U_{Y_i}|Win_{X_i})$, denotes player X_i 's – respectively, player Y_i 's prize spread.

Neutrality

T=3 (decisive battle) Both teams won one individual battle. Players X_3 and Y_3 are now facing off in a decisive game. If X_3 wins, which occurs with a probability $\frac{x_3}{x_3 + y_3}$, he gets both the individual battle reward v and the collective reward V . If he loses, he gets a payoff 0. Whatever the result, he has to pay the cost of effort $\frac{x_3}{\theta_{X_3}}$. X_3 's maximization problem is therefore given by

$$\max_{x_3} \left(\frac{x_3}{x_3 + y_3} (v + V) - \frac{x_3}{\theta_{X_3}} \right).$$

Symmetrically, for player Y_3 :

$$\max_{y_3} \left(\frac{y_3}{x_3 + y_3} (v + V) - \frac{y_3}{\theta_{Y_3}} \right).$$

First-order conditions give the optimal levels of effort and p_3^* :

$$x_3^* = (v + V) \frac{\theta_{X_3}^2 \theta_{Y_3}}{(\theta_{X_3} + \theta_{Y_3})^2},$$

$$y_3^* = (v + V) \frac{\theta_{X_3} \theta_{Y_3}^2}{(\theta_{X_3} + \theta_{Y_3})^2},$$

$$p_3^* = \frac{\theta_{X_3}}{\theta_{X_3} + \theta_{Y_3}}.$$

This yields the following prediction:

Prediction The outcome of a decisive battle 3 depends solely on the relative ability of the players involved in battle 3.

T=2 Team X won the first battle (X_1 won against Y_1).

X_2 chooses his level of effort x_2 to maximize his utility. If he wins, which occurs with a probability $\frac{x_2}{x_2 + y_2}$, he gets both the battle reward and the collective reward ($v + V$). If he loses, which occurs with a probability $\frac{y_2}{x_2 + y_2}$, he can still get the collective reward V if his teammate X_3 wins the third battle (which occurs with a probability p_3^*). Finally, whatever the outcome of the battle, he has to pay the cost of his effort $\frac{x_2}{\theta_{X_2}}$. X_2 's maximization problem is therefore given by:

$$\max_{x_2} \left(\frac{x_2}{x_2 + y_2} (v + V) + \frac{y_2}{x_2 + y_2} p_3^* V - \frac{x_2}{\theta_{X_2}} \right).$$

Y_2 chooses his level of effort y_2 to maximize his utility. If he wins, which occurs with a probability $\frac{y_2}{x_2 + y_2}$, he will get a payoff $v + (1 - p_3^*)V$. If he loses, the match ends and he gets a payoff 0. He has to pay the cost of effort $\frac{y_2}{\theta_{Y_2}}$, whatever the outcome of the battle. Note that in the neutrality model, the two players have the same prize spread (difference of utility between winning and losing): $v + (1 - p_3^*)V$. Y_2 's maximization problem is

$$\max_{y_2} \left(\frac{y_2}{x_2 + y_2} (v + (1 - p_3^*)V) - \frac{y_2}{\theta_{Y_2}} \right).$$

First-order conditions yield the optimal levels of effort and p_2^* :

$$x_2^* = (v + (1 - p_3^*)V) \frac{\theta_{X_2}^2 \theta_{Y_2}}{(\theta_{X_2} + \theta_{Y_2})^2};$$

$$y_2^* = (v + (1 - p_3^*)V) \frac{\theta_{X_2} \theta_{Y_2}^2}{(\theta_{X_2} + \theta_{Y_2})^2};$$

$$p_2^* = \frac{\theta_{X_2}}{\theta_{X_2} + \theta_{Y_2}}.$$

This yields the two following predictions.

Prediction 1 Winning battle 1 does not affect the probability of winning battle 2.

Prediction 2 The outcome of battle 2 only depends on the two players involved in battle 2.

Individual contribution

When a player wins and his team wins, he gets an additional payoff of individual contribution c .

	Player's team wins	Player's team loses
Player wins	$v + V + c$	v
Player loses	V	0

T=3 (trivial battle) Team X won battle 1 and battle 2, so battle 3 is trivial. If X_3 wins, which occurs with a probability $\frac{x_3}{x_3 + y_3}$, he gets a payoff $v + V + c$ corresponding to the battle reward, the collective reward and the individual contribution effect. If he loses, he gets a payoff V (his team wins but he does not get the battle reward nor the individual contribution reward). Whatever the result, he has to pay the cost of effort $\frac{x_3}{\theta_{X_3}}$.

$$\max_{x_3} \left(\frac{x_3}{x_3 + y_3} (v + V + c) + \frac{y_3}{x_3 + y_3} V - \frac{x_3}{\theta_{X_3}} \right).$$

For player Y_3 , the only stake is the battle reward v . As his team already lost, he is sure he will not get the collective reward, nor the individual contribution reward:

$$\max_{y_3} \left(\frac{y_3}{x_3 + y_3} v - \frac{y_3}{\theta_{Y_3}} \right).$$

The first-order conditions give the optimal levels of effort and $p_{3ICtrivial}^*$:

$$x_{3ICtrivial}^* = \frac{(\theta_{X_3}(v+c))^2 \theta_{Y_3} v}{(\theta_{X_3}(v+c) + \theta_{Y_3} v)^2},$$

$$y_{3ICtrivial}^* = \frac{\theta_{X_3}(v+c)(\theta_{Y_3} v)^2}{(\theta_{X_3}(v+c) + \theta_{Y_3} v)^2},$$

$$p_{3ICtrivial}^* = \frac{\theta_{X_3}(v+c)}{\theta_{X_3}(v+c) + \theta_{Y_3} v}.$$

This yields the following prediction.

Prediction Winning battle 1 and battle 2 increases the probability of winning a trivial battle 3.

T=3 (decisive battle) Both teams won one individual battle. Players X_3 and Y_3 are now facing off in a decisive game. If X_3 wins, which occurs with a probability $\frac{x_3}{x_3+y_3}$, his team wins and he gets a payoff $v + V + c$. If he loses, he gets a payoff 0. Whatever the result, he has to pay the cost of effort $\frac{x_3}{\theta_{X_3}}$.

$$\max_{x_3} \left(\frac{x_3}{x_3 + y_3} (v + V + c) - \frac{x_3}{\theta_{X_3}} \right).$$

Symmetrically for player Y_3 :

$$\max_{y_3} \left(\frac{y_3}{x_3 + y_3} (v + V + c) - \frac{y_3}{\theta_{Y_3}} \right).$$

The first-order conditions give the optimal levels of effort and $p_{3ICdecisive}^*$:

$$x_{3ICdecisive}^* = (v + V + c) \frac{\theta_{Y_3} \theta_{X_3}^2}{(\theta_{X_3} + \theta_{Y_3})^2};$$

$$y_{3ICdecisive}^* = (v + V + c) \frac{\theta_{X_3} \theta_{Y_3}^2}{(\theta_{X_3} + \theta_{Y_3})^2};$$

$$p_{3ICdecisive}^* = p_3^* = \frac{\theta_{X_3}}{\theta_{X_3} + \theta_{Y_3}}.$$

This yields the following prediction.

Prediction The outcome of a decisive battle 3 depends solely on the relative ability of the players involved in this battle.

T=2 Team X won the first battle (X_1 won against Y_1). Contrary to T=3 (decisive battle), the two players do not face the same optimization problem. X_2 chooses his level of effort x_2 to maximize his utility. If he wins, he gets a payoff of $v + V + c$. If he loses, he gets a payoff of p_3^*V (he will get neither the private reward nor the “contribution reward” but he will get the collective reward if his teammate wins in T=3, which will occur with a probability p_3^*). Therefore, X_2 's maximization problem is given by

$$\max_{x_2} \left(\frac{x_2}{x_2 + y_2} (v + V + c) + \frac{y_2}{x_2 + y_2} p_3^* V - \frac{x_2}{\theta_{X_2}} \right).$$

Y_2 chooses his level of effort y_2 to maximize his utility. If he wins he gets a payoff of $v + (1 - p_3^*)(V + c)$ because he will get the battle reward for sure and the collective reward and the individual contribution reward if his teammate wins, which will occur with a probability $(1 - p_3^*)$. If he loses he does not get any reward and ends up with a payoff 0:

$$\max_{y_2} \left(\frac{y_2}{x_2 + y_2} (v + (1 - p_3^*)(V + c)) - \frac{y_2}{\theta_{Y_2}} \right).$$

Thus, X_2 has more incentive to win than Y_2 because X_2 is sure to get the “contribution reward” if he wins his battle while Y_2 will get the “responsibility reward” if and only if his teammate also wins in T=3.

The first-order conditions yield the optimal levels of effort and p_{2IC}^* :

$$x_{2IC}^* = \frac{\theta_{X_2}^2 (v + (1 - p_3^*)V + c) \theta_{Y_2} (v + (1 - p_3^*)(V + c))}{[\theta_{X_2} (v + (1 - p_3^*)V + c) + \theta_{Y_2} (v + (1 - p_3^*)(V + c))]^2},$$

$$y_{2IC}^* = \frac{\theta_{X_2} (v + (1 - p_3^*)V + c) \theta_{Y_2}^2 (v + (1 - p_3^*)(V + c))^2}{[\theta_{X_2} (v + (1 - p_3^*)V + c) + \theta_{Y_2} (v + (1 - p_3^*)(V + c))]^2},$$

$$p_{2IC}^* = \frac{\theta_{X_2} (v + (1 - p_3^*)V + c)}{\theta_{X_2} (v + (1 - p_3^*)V + c) + \theta_{Y_2} (v + (1 - p_3^*)(V + c))}.$$

As $p_{2IC}^* > \frac{\theta_{X_2}}{\theta_{X_2} + \theta_{Y_2}}$ and $\frac{\partial p_{2IC}^*}{\partial p_3^*} > 0$, this yields the two following predictions.

Prediction 1 Winning battle 1 increases the probability of winning battle 2.

Prediction 2 The probability of winning battle 2 increases with the probability of winning battle 3.

Guilt aversion

When a player loses and his team loses, he gets a negative payoff payoff $-s$.

	Player's team wins	Player's team loses
Player wins	$v + V$	v
Player loses	V	$-s$

T=3 (decisive battle) Both teams won one individual battle. Players X_3 and Y_3 are now facing off in a decisive game. If X_3 wins, which occurs with a probability $\frac{x_3}{x_3+y_3}$, his team wins and he gets a payoff $v + V$. If he loses, he gets a payoff $-s$ because he is “guilt-averse:” being partly responsible for the failure of his team is costly for him. Whatever the result, he has to pay the cost of effort $\frac{x_3}{\theta_{X_3}}$ and faces the following maximization problem:

$$\max_{x_3} \left(\frac{x_3}{x_3 + y_3} (v + V) + \frac{y_3}{x_3 + y_3} (-s) - \frac{x_3}{\theta_{X_3}} \right).$$

Symmetrically for player Y_3 :

$$\max_{y_3} \left(\frac{y_3}{x_3 + y_3} (v + V) + \frac{x_3}{x_3 + y_3} (-s) - \frac{y_3}{\theta_{Y_3}} \right).$$

The optimal levels of effort and p_{3GA}^* are given by:

$$x_{3GA}^* = (v + V + s) \frac{\theta_{X_3}^2 \theta_{Y_3}}{(\theta_{X_3} + \theta_{Y_3})^2},$$

$$y_{3GA}^* = (v + V + s) \frac{\theta_{X_3} \theta_{Y_3}^2}{(\theta_{X_3} + \theta_{Y_3})^2},$$

$$p_{3GA}^* = p_3^* = \frac{\theta_{X_3}}{\theta_{X_3} + \theta_{Y_3}}.$$

This yields the following prediction.

Prediction The outcome of a decisive battle 3 depends solely on the relative ability of the players involved in this battle.

T=2 Team X won the first battle (X_1 won against Y_1). X_2 chooses his level of effort x_2 to maximize his utility. If he wins, which occurs with a probability $\frac{x_2}{x_2+y_2}$, he gets a payoff $v + V$. If he loses, which occurs with a probability $\frac{y_2}{x_2+y_2}$, he gets a payoff V with a probability p_3^* and $-s$ with a probability $1 - p_3^*$. Finally, whatever the outcome of the battle, he has to pay the cost of his effort $\frac{x_2}{\theta_{X_2}}$. His maximization problem is:

$$\max_{x_2} \left(\frac{x_2}{x_2 + y_2} (v + V) + \frac{y_2}{x_2 + y_2} (p_3^* V + (1 - p_3^*) (-s)) - \frac{x_2}{\theta_{X_2}} \right).$$

Y_2 chooses his level of effort y_2 to maximize his utility. If he wins, which occurs with a probability $\frac{y_2}{x_2+y_2}$, he will get a payoff $v + (1 - p_3^*)V$. If Y_2 loses, the match ends and he gets a payoff $-s$. He has to pay the cost of effort $\frac{y_2}{\theta_{Y_2}}$, whatever the outcome of the battle.

$$\max_{y_2} \left(\frac{y_2}{x_2 + y_2} (v + (1 - p_3^*)V) + \frac{x_2}{x_2 + y_2} (-s) - \frac{y_2}{\theta_{Y_2}} \right).$$

Thus, Y_2 has more incentive to win than X_2 because Y_2 is sure to be partly “defeat-responsible” if he loses his battle while X_2 will be “defeat-responsible” if and only if his teammate also loses in T=3.

Deriving the first-order conditions yield the optimal levels of effort and p_{2GA}^* :

$$x_{2GA}^* = \frac{\theta_{X_2}^2 (v + (1 - p_3^*)(V + s))^2 \theta_{Y_2} (v + (1 - p_3^*)V + s)}{[\theta_{X_2} (v + (1 - p_3^*)(V + s)) + \theta_{Y_2} (v + (1 - p_3^*)V + s)]^2},$$

$$y_{2GA}^* = \frac{\theta_{X_2} (v + (1 - p_3^*)(V + s)) \theta_{Y_2}^2 (v + (1 - p_3^*)V + s)^2}{[\theta_{X_2} (v + (1 - p_3^*)(V + s)) + \theta_{Y_2} (v + (1 - p_3^*)V + s)]^2},$$

$$p_{2GA}^* = \frac{\theta_{X_2} (v + (1 - p_3^*)(V + s))}{\theta_{X_2} (v + (1 - p_3^*)(V + s)) + \theta_{Y_2} (v + (1 - p_3^*)V + s)}.$$

As $p_{2GA}^* < \frac{\theta_{X_2}}{\theta_{X_2} + \theta_{Y_2}}$ and $\frac{\partial p_{2GA}^*}{\partial p_3^*} < 0$, this yields the two following predictions, this yields the two following predictions.

Prediction 1 Winning battle 1 decreases the probability of winning battle 2.

Prediction 2 The probability of winning battle 2 decreases with the probability of winning battle 3.

Inequity aversion

According to the inequity aversion scenario, a player dreads losing when his teammates overperform and vice versa. Hence, a negative component enters in the player's utility if he wins and his two teammates lose; or if he loses and his two teammates win. The magnitude of this effect increases with the extent of the underperformance or overperformance of his teammates (denoted Υ_{-i} and Ω_{-i} below).

Table 14: Payoffs in the inequity aversion scenario

	Player's team wins	Player's team loses
Player wins	$v + V$	$v - \Upsilon_{-i}$
Player loses	$V - \Omega_{-i}$	0

T=3 (decisive battle) Both teams won one individual battle. Players X_3 and Y_3 are now facing off in a decisive game. If X_3 wins, which occurs with a probability $\frac{x_3}{x_3+y_3}$, his team wins and he gets a payoff $v + V$. If he loses, he gets a payoff 0. Whatever the result, he has to pay the cost of effort $\frac{x_3}{\theta_{X_3}}$ and faces the following maximization problem:

$$\max_{x_3} \left(\frac{x_3}{x_3 + y_3} (v + V) - \frac{x_3}{\theta_{X_3}} \right).$$

Symmetrically for player Y_3 :

$$\max_{y_3} \left(\frac{y_3}{x_3 + y_3} (v + V) - \frac{y_3}{\theta_{Y_3}} \right).$$

The optimal levels of effort and p_{3IA}^* are given by:

$$x_{3IA}^* = (v + V) \frac{\theta_{X_3}^2 \theta_{Y_3}}{(\theta_{X_3} + \theta_{Y_3})^2},$$

$$y_{3IA}^* = (v + V) \frac{\theta_{X_3} \theta_{Y_3}^2}{(\theta_{X_3} + \theta_{Y_3})^2},$$

$$p_{3IA}^* = p_3^* = \frac{\theta_{X_3}}{\theta_{X_3} + \theta_{Y_3}}.$$

This yields the following prediction.

Prediction The outcome of a decisive battle 3 depends solely on the relative ability of the players involved in this battle.

T=2 Team X won the first battle (X_1 won against Y_1). X_2 chooses his level of effort x_2 to maximize his utility. If he wins, which occurs with a probability $\frac{x_2}{x_2+y_2}$, he gets $v + V$. If he loses, which occurs with a probability $\frac{y_2}{x_2+y_2}$, he gets $(V - \Omega_{X_1, X_3})$ if his teammate wins in T=3 (probability p_3^*) and 0 if his teammate loses in T=3 (probability $1 - p_3^*$). Whatever the outcome of the battle, he has to pay the cost of his effort $\frac{x_2}{\theta_{X_2}}$. His maximization problem is given by:

$$\max_{x_2} \left(\frac{x_2}{x_2 + y_2} (v + V) + \frac{y_2}{x_2 + y_2} (p_3^* (V - \Omega_{X_1, X_3})) - \frac{x_2}{\theta_{X_2}} \right).$$

Y_2 chooses his level of effort y_2 to maximize his utility. If he wins, which occurs with a probability $\frac{y_2}{x_2+y_2}$, he gets $(v + V)$ if his teammate wins battle 3 (probability $(1 - p_3^*)$), and $(v - \Upsilon_{Y_1, Y_3})$ if his teammate loses battle 3 (probability p_3^*). If Y_2 loses, the contest ends and he gets a payoff 0. He has to pay the cost of effort $\frac{y_2}{\theta_{Y_2}}$, whatever the outcome of the battle. As $\Upsilon_{Y_1, Y_3} = \Omega_{X_1, X_3}$, player Y_2 faces the following maximization problem:

$$\max_{y_2} \left(\frac{y_2}{x_2 + y_2} ((1 - p_3^*)(v + V) + p_3^*(v - \Omega_{X_1, X_3})) - \frac{y_2}{\theta_{Y_2}} \right).$$

Thus, X_2 has more incentive to win than Y_2 because X_2 is sure to avoid the inequity cost if he wins whereas Y_2 will avoid the inequity cost if he wins, only if his teammate also wins in T=3.

Deriving the first-order conditions yield the optimal levels of effort and p_{2IA}^* :

$$x_{2IA}^* = \frac{\theta_{X_2}^2 (v + (1 - p_3^*)V + p_3^* \Omega_{X_1, X_3})^2 \theta_{Y_2} (v + (1 - p_3^*)V - p_3^* \Omega_{X_1, X_3})}{[\theta_{X_2} (v + (1 - p_3^*)V + p_3^* \Omega_{X_1, X_3}) + \theta_{Y_2} (v + (1 - p_3^*)V - p_3^* \Omega_{X_1, X_3})]^2},$$

$$y_{2IA}^* = \frac{\theta_{X_2} (v + (1 - p_3^*)V + p_3^* \Omega_{X_1, X_3}) \theta_{Y_2}^2 (v + (1 - p_3^*)V - p_3^* \Omega_{X_1, X_3})^2}{[\theta_{X_2} (v + (1 - p_3^*)V + p_3^* \Omega_{X_1, X_3}) + \theta_{Y_2} (v + (1 - p_3^*)V - p_3^* \Omega_{X_1, X_3})]^2},$$

$$p_{2IA}^* = \frac{\theta_{X_2} (v + (1 - p_3^*)V + p_3^* \Omega_{X_1, X_3})}{\theta_{X_2} (v + (1 - p_3^*)V + p_3^* \Omega_{X_1, X_3}) + \theta_{Y_2} (v + (1 - p_3^*)V - p_3^* \Omega_{X_1, X_3})}.$$

As $p_{2IA}^* > \frac{\theta_{X_2}}{\theta_{X_2} + \theta_{Y_2}}$; $\frac{\partial p_{2IA}^*}{\partial p_3^*} > 0$ and $\frac{\partial p_{2IA}^*}{\partial \Omega_{X_1, X_3}} > 0$, we obtain the three following predictions.

Prediction 1 Winning battle 1 decreases the probability of winning battle 2.

Prediction 2 The probability of winning battle 2 increases with the probability of winning battle 3.

Prediction 3 The probability of winning battle 2 increases when the teammate involved in battle 1 overperformed.

Disentangling individual contribution and altruism

We compare the predictions of individual contribution and altruism in battle 1 in the case where the favorites for battles 2 and 3 do not belong to the same team. Let X denote the team whose players are favorites in battle 2 and underdogs in battle 3. For simplicity, we furthermore assume that X_2 will win with certainty and X_3 will lose with certainty.³³

Individual contribution Player X_1 gets the battle reward v , the collective reward V , and the individual contribution reward c if he wins (as his teammate X_2 will win battle 2 and end the contest) and he gets a payoff 0 if he loses. Player Y_1 faces the same prize spread as he also gets $V + v + c$ if he wins and 0 if he loses:

$$\Delta_{U_{X_1}} = \Delta_{U_{Y_1}} = v + V + c.$$

Altruism If players X_1 and Y_1 were altruistic, their incentives would no longer be symmetric. If X_1 wins, he will get both the battle reward v and the collective reward V and he will prevent his teammate X_3 from making a high effort in a decisive battle 3 (as the contest will be won after battle 2 thanks to the victory of X_2). On the contrary, if X_1 loses, he will get neither the battle reward nor the collective reward and he will force his teammate X_3 to play, which induces a negative payoff $-\alpha C(X_3)$ where $C(X_3)$ is the cost of effort of X_3 in a decisive battle 3 and α reflects the degree to which X_1 internalizes this cost ($0 < \alpha < 1$). Hence the prize spread of X_1 will be $v + V + \alpha C(X_3)$. His opponent Y_1 faces a different problem. If he wins, he gets both v and V as his team will win the contest but he forces his teammate Y_3 to play a decisive battle 3, which is partly internalized by him ($-\alpha C(Y_3)$). If Y_1 loses, he gets neither v nor V but he prevents Y_3 from playing. Hence his prize spread is $v + V - \alpha C(Y_3)$.

³³Note that the logic would be the same with a more general framework where X_2 is “as much of a favorite as X_3 is an underdog”.

$$\Delta_{U_{X_1}} = v + V + \alpha C(X_3) > \Delta_{U_{Y_1}} = v + V - \alpha C(Y_3)$$

Different predictions Thus, individual contribution predicts that X_1 and Y_1 have the same prize spread while altruism predicts that X_1 has a higher prize spread than Y_1 . Since $p_1^* = \frac{\theta_{X_1} \Delta_{U_{X_1}}}{\theta_{X_1} \Delta_{U_{X_1}} + \theta_{Y_1} \Delta_{U_{Y_1}}}$, individual contribution predicts that being the favorite in battle 2 is equivalent to being the favorite in battle 3 whereas altruism predicts that being the favorite in battle 2 is preferable to being the favorite in battle 3. This finding is the basis for our empirical test in section 4.2.

Choking under pressure

T=3 (trivial battle) Team X already won battles 1 and 2, so battle 3 becomes stakeless (except for the battle reward) and neither of the two players faces pressure. Hence their cost of effort are not affected.

Player X_3 is sure to get the collective reward V whatever the outcome of battle 3 but he will get the battle reward v only if he wins battle 3.

$$\max_{x_3} \left(V + \frac{x_3}{x_3 + y_3} v - \frac{x_3}{\theta_{X_3}} \right)$$

Player Y_3 will not get the collective reward but he can get the battle reward v if he wins.

$$\max_{y_3} \left(\frac{y_3}{x_3 + y_3} v - \frac{y_3}{\theta_{Y_3}} \right)$$

First-order conditions give the optimal levels of effort and $p_{3CUPtrivial}^*$:

$$x_{3CUPtrivial}^* = v \frac{\theta_{X_3}^2 \theta_{Y_3}}{(\theta_{X_3} + \theta_{Y_3})^2},$$

$$y_{3CUPtrivial}^* = v \frac{\theta_{X_3} \theta_{Y_3}^2}{(\theta_{X_3} + \theta_{Y_3})^2},$$

$$p_{3CUPtrivial}^* = p_3^* = \frac{\theta_{X_3}}{\theta_{X_3} + \theta_{Y_3}}.$$

This yields the following prediction.

Prediction Winning battle 1 and battle 2 does not affect the probability of winning a trivial battle 3.

T=3 (decisive battle) Both team won one individual battle. Players X_3 and Y_3 are now opposed in a decisive game. Since battle 3 is pivotal, players X_3 and Y_3 might both choke under pressure as losing the battle implies the defeat of their team. This is conceptually equivalent to multiplying their ability by η with $0 < \eta < 1$.

$$\max_{x_3} \left(\frac{x_3}{x_3 + y_3} (v + V) - \frac{x_3}{\theta_{X_3} \eta} \right)$$

Symmetrically for player Y_3 :

$$\max_{y_3} \left(\frac{y_3}{x_3 + y_3} (v + V) - \frac{y_3}{\theta_{Y_3} \eta} \right)$$

Deriving the FOCs yield the optimal levels of effort and p_3^* :

$$x_{3CUPdecisive}^* = (v + V) \eta \frac{\theta_{X_3}^2 \theta_{Y_3}}{(\theta_{X_3} + \theta_{Y_3})^2}$$

$$y_{3CUPdecisive}^* = (v + V) \eta \frac{\theta_{X_3} \theta_{Y_3}^2}{(\theta_{X_3} + \theta_{Y_3})^2}$$

$$p_{3CUPdecisive}^* = p_3^* = \frac{\theta_{X_3}}{\theta_{X_3} + \theta_{Y_3}}$$

This yields the following prediction.

Prediction The outcome of a decisive battle 3 depends solely on the relative ability of the players involved in this battle.

T=2 Team X won the first battle (X_1 won against Y_1). There is an asymmetry between the two players. Player X_2 has no reason to choke under pressure because his team will remain in the contest if he loses battle 2. On the contrary, player Y_2 knows that losing battle 2 implies that his team loses the contest. Thus, he may choke under pressure, which can be modelled by multiplying his ability by a factor η ($0 < \eta < 1$).

$$\max_{x_2} \left(\frac{x_2}{x_2 + y_2} (v + V) + \frac{y_2}{x_2 + y_2} p_3^* V - \frac{x_2}{\theta_{X_2}} \right).$$

$$\max_{y_2} \left(\frac{y_2}{x_2 + y_2} (v + (1 - p_3^*) V) - \frac{y_2}{\theta_{Y_2} \eta} \right).$$

First-order conditions yield the optimal levels of effort and p_2^* :

$$x_{2CUP}^* = (v + (1 - p_3^*)V) \frac{\theta_{X_2}^2 \theta_{Y_2} \eta}{(\theta_{X_2} + \theta_{Y_2} \eta)^2};$$

$$y_{2CUP}^* = (v + (1 - p_3^*)V) \frac{\theta_{X_2} (\theta_{Y_2} \eta)^2}{(\theta_{X_2} + \theta_{Y_2} \eta)^2};$$

$$p_{2CUP}^* = \frac{\theta_{X_2}}{\theta_{X_2} + \theta_{Y_2} \eta}$$

As $p_{2CUP}^* > \frac{\theta_{X_2}}{\theta_{X_2} + \theta_{Y_2}}$, this yields the following prediction.

Prediction Winning battle 1 increases the probability of winning battle 2.

Psychological momentum

T=3 (decisive battle) Team X won the first battle and lost the second battle (X_1 won against Y_1 and X_2 lost against Y_2). Y_3 has psychological momentum because his teammate won the previous battle. This is conceptually equivalent to multiplying his ability by a factor ψ (with $\psi > 1$). The maximization problem is:

$$\max_{x_3} \left(\frac{x_3}{x_3 + y_3} (v + V) - \frac{x_3}{\theta_{X_3}} \right),$$

$$\max_{y_3} \left(\frac{y_3}{x_3 + y_3} (v + V) - \frac{y_3}{\theta_{Y_3} \psi} \right).$$

Optimal levels of effort and p_{3PM}^* are therefore given by:

$$x_{3PM}^* = (v + V) \frac{\theta_{X_3}^2 (\theta_{Y_3} \psi)}{(\theta_{X_3} + \theta_{Y_3} \psi)^2},$$

$$y_{3PM}^* = (v + V) \frac{\theta_{X_3} (\theta_{Y_3} \psi)^2}{(\theta_{X_3} + \theta_{Y_3} \psi)^2},$$

$$p_{3PM}^* = \frac{\theta_{X_3}}{\theta_{X_3} + \theta_{Y_3} \psi}.$$

As $p_{3PM}^* < \frac{\theta_{X_3}}{\theta_{X_3} + \theta_{Y_3}}$, this yields the following prediction.

Prediction In a decisive battle 3, the player in the team that won battle 2 is more likely to win than the player in the team that won battle 1.

T=2 Team X won the first battle (X_1 won against Y_1). X_2 has psychological momentum because his teammate won the previous battle. This is conceptually equivalent to multiplying his ability by a factor ψ (with $\psi > 1$). We therefore have the following maximization problems:

$$\max_{x_2} \left(\frac{x_2}{x_2 + y_2} (v + V) + \frac{y_2}{x_2 + y_2} p_{3PM}^* V - \frac{x_2}{\theta_{X_2} \psi} \right),$$

$$\max_{y_2} \left(\frac{y_2}{x_2 + y_2} (v + (1 - p_{3PM}^*) V) - \frac{y_2}{\theta_{Y_2}} \right).$$

Deriving the first order conditions yield the optimal levels of effort and p_{2PM}^* :

$$x_{2PM}^* = (v + (1 - p_{3PM}^*) V) \frac{(\theta_{X_2} \psi)^2 \theta_{Y_2}}{(\theta_{X_2} \psi + \theta_{Y_2})^2};$$

$$y_{2PM}^* = (v + (1 - p_{3PM}^*) V) \frac{(\theta_{X_2} \psi) \theta_{Y_2}^2}{(\theta_{X_2} \psi + \theta_{Y_2})^2};$$

$$p_{2PM}^* = \frac{\theta_{X_2} \psi}{\theta_{X_2} \psi + \theta_{Y_2}}.$$

As $p_{2PM}^* > \frac{\theta_{X_2}}{\theta_{X_2} + \theta_{Y_2}}$, this yields the following prediction.

Prediction Winning battle 1 increases the probability of winning battle 2.

Appendix B – Probit and Logit estimations

Probit estimations

Table 15: Evidence against neutrality (PROBIT estimation - average marginal effects)

	(1)	(2)	(3)	(4)	(5)	(6)
A_1 won battle 1	0.105*** (0.025)	0.073** (0.027)	0.117*** (0.027)	0.081** (0.029)	0.083*** (0.024)	0.063* (0.026)
Controls for players' ability						
Ranking category	YES	YES	NO	NO	NO	NO
Interaction of rkg categories	NO	NO	YES	YES	NO	NO
Ratio of rankings	NO	NO	NO	NO	YES	YES
Other controls						
Playing home + teams' rankings	NO	YES	NO	YES	NO	YES
Observations	934	896	934	896	934	896

Standard errors in parentheses: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Reading note (column 1): the average marginal effect of winning battle 1 on the probability of winning battle 2 is 10.5 pp.

Note: the number of observations decreases from 934 in specifications (1), (3), (5) to 896 in specifications (2), (4),(6) because there are 38 contests for which teams' rankings are missing.

Table 16: Evidence against neutrality (PROBIT estimation - full table)

	(1)	(2)	(3)	(4)	(5)	(6)
A₁ won battle 1	0.440*** (0.106)	0.308** (0.115)	0.457*** (0.108)	0.317** (0.118)	0.363*** (0.108)	0.278* (0.116)
A ₂ 's ranking: Top 5	3.071*** (0.278)	2.672*** (0.315)				
A ₂ 's ranking: 6-15	2.483*** (0.222)	2.159*** (0.251)				
A ₂ 's ranking: 16-30	1.911*** (0.194)	1.647*** (0.217)				
A ₂ 's ranking: 31-50	1.172*** (0.176)	0.998*** (0.191)				
A ₂ 's ranking: 51-75	0.735*** (0.188)	0.587** (0.199)				
A ₂ 's ranking: 76-105	0.378* (0.188)	0.292 (0.198)				
B ₂ 's ranking: Top 5	-3.071*** (0.278)	-2.672*** (0.315)				
B ₂ 's ranking: 6-15	-2.483*** (0.222)	-2.159*** (0.251)				
B ₂ 's ranking: 16-30	-1.911*** (0.194)	-1.647*** (0.217)				
B ₂ 's ranking: 31-50	-1.172*** (0.176)	-0.998*** (0.191)				
B ₂ 's ranking: 51-75	-0.735*** (0.188)	-0.587** (0.199)				
B ₂ 's ranking: 76-105	-0.378* (0.188)	-0.292 (0.198)				
A ₂ 's ranking vs B ₂ 's ranking			X	X		
$\frac{Ranking_{A_2}}{Ranking_{B_2}} (< 1)$					-2.120*** (0.202)	-1.998*** (0.229)
A ₂ at home		0.034 (0.210)		0.040 (0.215)		0.410 (0.238)
B ₂ at home		-0.034 (0.210)		-0.040 (0.215)		0.182 (0.212)
A ₂ 's team ranking		-0.043** (0.016)		-0.044** (0.016)		-0.020 (0.017)
B ₂ 's team ranking		0.043** (0.016)		0.044** (0.016)		0.033* (0.015)
Constant	-0.220 (0.140)	-0.154 (0.228)	-0.228 (0.163)	-0.158 (0.259)	1.647*** (0.147)	1.428*** (0.176)
Controls for players' ability						
Ranking category	YES	YES	NO	NO	NO	NO
Interaction of rkg categories	NO	NO	YES	YES	NO	NO
Ratio of rankings	NO	NO	NO	NO	YES	YES
Observations	934	896	934	896	934	896

Standard errors in parentheses: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Note: the number of observations decreases from 934 in specifications (1), (3), (5) to 896 in specifications (2), (4),(6) because there are 38 contests for which teams' rankings are missing.

Logit estimation

Table 17: Evidence against neutrality (LOGIT estimation - average marginal effects)

	(1)	(2)	(3)	(4)	(5)	(6)
A_1 won battle 1	0.101*** (0.024)	0.071** (0.026)	0.113*** (0.026)	0.078** (0.029)	0.084*** (0.024)	0.064* (0.026)
Controls for players' ability						
Ranking category	YES	YES	NO	NO	NO	NO
Interaction of rkg categories	NO	NO	YES	YES	NO	NO
Ratio of rankings	NO	NO	NO	NO	YES	YES
Other controls						
Playing home + teams' rankings	NO	YES	NO	YES	NO	YES
Observations	934	896	934	896	934	896

Standard errors in parentheses: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Reading note (column 1): the average marginal effect of winning battle 1 on the probability of winning battle 2 is 10.1 pp.

Note: the number of observations decreases from 934 in specifications (1), (3), (5) to 896 in specifications (2), (4), (6)

because there are 38 contests for which teams' rankings are missing.

Table 18: Evidence against neutrality (LOGIT estimation - full table)

	(1)	(2)	(3)	(4)	(5)	(6)
A₁ won battle 1	0.734*** (0.180)	0.518** (0.194)	0.748*** (0.182)	0.521** (0.197)	0.639*** (0.186)	0.494* (0.200)
A ₂ 's ranking: Top 5	5.477*** (0.522)	4.792*** (0.579)				
A ₂ 's ranking: 6-15	4.403*** (0.413)	3.831*** (0.459)				
A ₂ 's ranking: 16-30	3.337*** (0.355)	2.871*** (0.391)				
A ₂ 's ranking: 31-50	2.011*** (0.313)	1.704*** (0.337)				
A ₂ 's ranking: 51-75	1.280*** (0.326)	1.018** (0.345)				
A ₂ 's ranking: 76-105	0.663* (0.317)	0.520 (0.335)				
B ₂ 's ranking: Top 5	-5.477*** (0.522)	-4.792*** (0.579)				
B ₂ 's ranking: 6-15	-4.403*** (0.413)	-3.831*** (0.459)				
B ₂ 's ranking: 16-30	-3.337*** (0.355)	-2.871*** (0.391)				
B ₂ 's ranking: 31-50	-2.011*** (0.313)	-1.704*** (0.337)				
B ₂ 's ranking: 51-75	-1.280*** (0.326)	-1.018** (0.345)				
B ₂ 's ranking: 76-105	-0.663* (0.317)	-0.520 (0.335)				
A ₂ 's ranking vs B ₂ 's ranking			X	X		
$\frac{Ranking_{A_2}}{Ranking_{B_2}} (< 1)$					-3.670*** (0.362)	-3.445*** (0.405)
A ₂ at home		0.058 (0.358)		0.067 (0.358)		0.672 (0.423)
B ₂ at home		-0.058 (0.358)		-0.067 (0.358)		0.287 (0.370)
A ₂ 's team ranking		-0.073** (0.027)		-0.075** (0.028)		-0.036 (0.029)
B ₂ 's team ranking		0.073** (0.027)		0.075** (0.028)		0.058* (0.026)
Constant	-0.367 (0.233)	-0.259 (0.386)	-0.374 (0.263)	-0.260 (0.427)	2.826*** (0.265)	2.442*** (0.314)
Controls for players' ability						
Ranking category	YES	YES	NO	NO	NO	NO
Interaction of rkg categories	NO	NO	YES	YES	NO	NO
Ratio of rankings	NO	NO	NO	NO	YES	YES
Observations	934	896	934	896	934	896

Standard errors in parentheses: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Note: the number of observations decreases from 934 in specifications (1), (3), (5) to 896 in specifications (2), (4),(6) because there are 38 contests for which teams' rankings are missing.