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N.S. Avkhimovich
HSE University, Moscow, Russia

Should the strongest be the last? Strategic choice of ordering in sports relays[1]

Abstract. In this paper, we analyse the strategic order of athletes in sports relays. It is generally believed that the strongest athlete should perform the last. In sports, 'choking under pressure' is a major phenomenon that manifests in athletes' performance decrement when faced the stressful conditions. We focus on the pressure the athletes experience when their team is lagging behind the competitor in accuracy-based relays. In theoretical models, we found that choking under pressure has an impact on strategic decisions on team formation when teams consist of players with differentiated skills. Without 'choking under pressure', teams are indifferent to athletes' order. If all athletes experience the same magnitude of performance decrements, the strictly dominant strategy is: a stronger athlete starts and a weaker athlete finishes the race. For the case of differentiated performance decrements, we find the optimal strategy as a function of those decrements. The conventional wisdom strategy "Weaker to start, stronger to finish" is strictly dominant only when the resilience of a strong player is high enough and the performance decrement is much lower than a weak player's.

Keywords: *choking under pressure, relay races, strategic athletes' ordering, team formation.*

JEL Classification: C61, C70, L83.

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1. Introduction

In 2017, the Laver Cup was founded to "[push] the boundaries of tennis as we know" (Christie, 2017). Tennis tournament between Team Europe and Team World with a unique format of competition, where "strategy and tactics from the team captains could also be a key to victory" in Laver Cup (Abulleil, 2017). One of the key novelties was the introduction of a lineup card blind exchange between coaches, with matchups revealed just before the start of the matches[2]. Matches are happening consecutively, and since each athlete knows the results of previous matches, and hence — the team's total score. This might influence their performance. For example, if the team is losing, the playing athlete would feel additional pressure and might 'choke under pressure'.

'Choking under pressure' is defined as performance decrements under circumstances that increase the importance of good or improved performance (Baumeister, 1984). In this paper, we focus on accuracy- (or precision-) based tasks (e.g., math relay contests), penalty shoot-outs in football, and tennis matches), as the impact of the choking effect is different for endurance-based tasks (e.g., swimming relays). According to a meta-analysis performed by (Bond, Titus, 1983), performance based on strength

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Correspondence concerning this article should be addressed to Nikolai Avkhimovich, Laboratory of Sports Studies, Faculty of Economic Sciences, HSE University, Moscow, Russia. E-mail: navkhimovich@nes.ru

[2] Each team is formed of six players. The tournament is played over three days (Friday — Sunday), e.g., three singles matches are played on Day 1 (Friday). One day before captains should submit their lineup cards with the order of three players from their team for Day 1 to the referee in a blind exchange.

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and stamina was not worse but even better under pressure, whereas performance based on accuracy deteriorated under pressure. There is further broad research on different theories of choking (e.g., distraction theory and explicit monitoring theory) and sources of competitive anxiety for accuracy-based tasks: for example, (Martens et al., 1990; Lewis, Linder, 1997; Beilock, Carr, 2001; Beilock et al., 2004).

For accuracy-based activities, where pressure negatively affects attention and, hence, performance, the choking under pressure effect was analysed in different sports. Most studies focus on the pressure of intense competition or during decisive moments: when the competitor's result is close to your own or you are lagging behind. (Cao et al., 2011) concluded that being at the final stage of a very close basketball game decreases the shooting accuracy by 5–10%. The evidence is in line with the results of (Toma, 2017), who observes that athletes' free throw percentage drops in the last seconds of tight games, especially when their team is lagging. A recent paper by (Bucciol, Castagnetti, 2020) addressed questions about performance decrements in archery. One of their main findings is that being under pressure during tiebreaks (a decisive moment of the game) has a significant negative impact on the sportsmen's performance. (Teeselink et al., 2020) also found evidence of worse performance in decisive moments when analyzing dart competitions. Similar results of performance decrements under pressure are observed in other accuracy-based competitions: tennis (Cohen-Zada et al., 2017), golf (Wells, Skowronski, 2012; Hickman et al., 2019) and hockey-dribbling tasks (Ashford, Jackson, 2010).

How should Björn Borg and John McEnroe, the captains of Team Europe and Team World at the 2017 Laver Cup, decide on the order of their players? In some sports with competitions in the form of relay races (e.g., running, swimming), there is a conventional wisdom that "the runner finishing the race will generally be the fastest sprinter in a team" (Olympics.com, 2023). A similar view is widespread among the coaches of athletes of different ages: "[for] kids' relay teams we often see that the fastest runner gets to run last" (Wensor, 2017) and "most schools run their fastest runners last" (Niekerk, 2012). Should the same logic be applied to the coaches' decisions at the Laver Cup and other competitions (e.g., math relays)? Does there exist a strategy to select the order of the athletes optimally and minimise the negative impact of choking under pressure?

To the best of our knowledge, the theoretical framing of coaches' strategic choice of athletes' ordering in relation to the choking under pressure effect was not addressed in academic literature. This paper aims to narrow this gap. It is organized as follows. Section 2 introduces a specific analytical framework of competition, as well as discusses the results of several models: without choking effect, with non-differentiated choking, and with differentiated choking effect. In Section 3, the main insights are summarized and key conclusions with possible future implications of the research are discussed. Formal proof of statements are provided in the Appendix.

2. Theoretical models

Consider a two-round competition where two teams, A and B, each consisting of two players, simultaneously choose which player participates in which round. In each of two consecutive rounds, the assigned athlete plays a match against the chosen athlete from the opposite team. Each match results in a victory for one of the players

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(no draws in individual matches are possible). The winner of the round brings one point to their team. If, after two rounds, the score is 2:0, the leading team is declared the winner of the competition. If, after two rounds, the score is 1:1, the winner of the competition is determined in a fair lottery, and each team wins with a probability of 0.5. The objective of the team is to maximize the probability of winning the competition by choosing the optimal order of its athletes.

The players are differentiated by their skills: a "strong" athlete ("*s*") has a higher probability of winning the round against a "weak" athlete ("*w*"). Then, for a team, there are three possible cases of skills combinations: 1) both players are weak; 2) both players are strong; 3) one player is strong and the other player is weak.

Therefore, for teams *A* and *B* there are 9 possible cases of all players skills combinations. All 9 cases will be considered in our analysis. However, some of them will be non-strategic and, hence, trivial.

The probability of winning the match in the first round is a function of two variables — the skills of the athletes of both teams. Table 1 represents probabilities of winning the first round of a match for two competitors of given types.

The probability of winning the match in the second round is a function of three variables — the skills of the athletes of both teams and the result of the first round. The team that lost the first round might choke under pressure in the second round, resulting in performance decrement (Table 2).

Note that matrices in Tables 1 and 2 do not represent games, that is, athletes do not choose strategies. The types of the athletes are pre-determined (recall that there

Table 1

The matrix represents probabilities of winning the first round of a match for two competitors of given types (strong and weak). The first number in each cell corresponds to the first player's probability of winning. Here, $p > 0.5$ is the probability of winning the match by a strong player over a weak player

	s	w
s	0.5; 0.5	p; $1 - p$
w	$1 - p$; p	0.5; 0.5

Table 2

The matrices represent probabilities of winning the second round of competition for teams *A* and *B* for given types of athletes (strong and weak) and for a given result of the first round. The left (right) matrix provides probabilities of winning in the second round if team *A* won (lost) the first round. The first number in each cell corresponds to team *A*'s probability of winning. Here, $\Theta_S > 0$ and $\Theta_W > 0$ are the performance decrements for the strong and weak players, respectively

Team *A* 1:0 Team *B*

	s_B	w_B
s_A	$0.5+\Theta_S; 0.5-\Theta_S$	$p+\Theta_W; 1-p-\Theta_W$
w_A	$1-p+\Theta_S; p-\Theta_S$	$0.5+\Theta_W; 0.5-\Theta_W$

Team *A* 0:1 Team *B*

	s_B	w_B
s_A	$0.5-\Theta_S; 0.5+\Theta_S$	$p-\Theta_S; 1-p+\Theta_S$
w_A	$1-p-\Theta_W; p+\Theta_W$	$0.5-\Theta_W; 0.5+\Theta_W$

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are 9 possible cases of skills combinations). Instead, the matrices contain probabilities of winning the round for given types of athletes.

We consider three different types of choking under pressure decrement. Subsection 2.1 covers the case without performance decrement: $\Theta_S = \Theta_W = 0$. In Subsection 2.2, we solve the model with non-differentiated performance decrements for strong and weak players: $\Theta_S = \Theta_W = \Theta > 0$. Finally, in Subsection 2.3, we investigate the model with differentiated performance decrements: $\Theta_S \neq \Theta_W$.

Denote player's x affiliation with team i as x_i. Let the notation $x \succ y$ mean a victory of player x over player y in their match. Denote a strategy of assigning player x for the first round and player y for the second round as $x \to y$.

Note that if a team has two equally skilled players, there are no strategic decisions to make. In contrast, if a team consists of strong and weak players, its order in the competition has an impact on the probability of winning in the first round and, therefore, on the probability of choking under pressure in the second round. As a result, the order of the players affects the probability of winning the whole competition, which is an objective function for each team. In further analysis, for any possible combination of players' skills of team *B*, we derive team *A*'s optimal strategy. All cases where team *A* has two strong or two weak players, are non-strategic. We omit those cases as trivial. The remaining cases are:

- Case 1:
  - team *A*: one player is strong and the other player is weak;
  - team *B*: both players are weak;
- Case 2:
  - team *A*: one player is strong and the other player is weak;
  - team *B*: both players are strong;
- Case 3:
  - team *A*: one player is strong and the other player is weak;
  - team *B*: one player is strong and the other player is weak.

2.1. Model with no choking

First, suppose there is no performance decrement: $\Theta_S = \Theta_W = 0$. In this case, the probability of winning the second round depends only on the skills of the athletes from both teams (Table 3). Note that these probabilities are equal to the probabilities of winning the first round.

Table 3

The matrix represents probabilities of winning the second round of competition for teams *A* and *B* for given types of athletes (strong and weak) without performance decrement

	s_B	w_B
s_A	0.5; 0.5	p; $1-p$
w_A	$1-p$; p	0.5; 0.5

It appears that, in the absence of choking under pressure, both strategies of team *A* are always equally good.

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Proposition 1. *For any skills combination of team B's players and for any strategy of team B, team A is indifferent to athletes' order*[3].

In the absence of choking under pressure, both strategies – $w_A \to s_A$ ("Weaker to start, stronger to finish") and $s_A \to w_A$ ("Stronger to start, weaker to finish") – provide team *A* with the same winning probability for any team *B*'s skills combination and strategy used.

2.2. Model with non-differentiated choking

In this subsection, we solve the model with non-differentiated performance decrement for strong and weak players: $\Theta_S = \Theta_W = \Theta \in (0,\ 0.5)$[4]. The player from the team that lost the first round chokes and faces performance decrement in the second round (Table 4).

Table 4

The matrices represent probabilities of winning the second round of competition for teams *A* and *B* for given types of athletes (strong and weak) and for a given result of the first round. The left (right) matrix provides probabilities of winning in the second round if team *A* won (lost) the first round

Team *A* 1:0 Team B

	s_B	w_B
s_A	$0.5+\Theta;\ 0.5-\Theta$	$p+\Theta; 1-p-\Theta$
w_A	$1-p+\Theta; p-\Theta$	$0.5+\Theta;\ 0.5-\Theta$

Team *A* 0:1 Team B

	s_B	w_B
s_A	$0.5-\Theta;\ 0.5+\Theta$	$p-\Theta; 1-p+\Theta$
w_A	$1-p-\Theta; p+\Theta$	$0.5-\Theta;\ 0.5+\Theta$

It appears that in the case of non-differentiated performance decrements for strong and weak players, team *A* always prefers to start with a stronger player and finish with a weaker player.

Proposition 2. *For any skills combination of team B's players and for any strategy of team B, team A's strategy* $s_A \to w_A$ *is strictly dominant.*

Despite conventional wisdom that the strongest athlete should perform after all other athletes in the team, Proposition 2 shows that it is optimal for a team to start with a stronger player. Since the performance decrement appears only when the team loses the first round, the team prefers to avoid situations when the players are under pressure. Instead, the team strives to put pressure on the competitor in the second round.

2.3. Model with differentiated choking

In this subsection, we investigate the model with differentiated performance decrements: $\Theta_S \neq \Theta_W$, as, in reality, athletes could feel pressure differently, and the impact of choking could vary significantly. In academic literature, there is no clear answer to who chokes more and whether the magnitude of choking is correlated with athletes' skills. (Teeselink et al., 2020) found that "amateur players display a sizable performance decrease, ... [while] professional players appear less susceptible of such choking" in darts. (Cao et al., 2011) observed that the negative impact decreases with player experience. However, according to (Dilmaghani, 2020), "female underperformance is greater among the elite players" in chess. We consider both cases: when a strong player chokes more than a weak one and the other way around.

3 All proofs are relegated to the Appendix.

4 $\Theta_s < 0.5$ and $\Theta_w < 0.5$ to fulfill the constraint on non-negative probability values.

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First, suppose that $\Theta_S > \Theta_W$. It means a strong player is less resilient to choking than a weak player.

Proposition 3. *If $\Theta_S > \Theta_W$, then for any skills combination of team B's players and for any strategy of team B, team A's strategy $s_A \to w_A$ is strictly dominant.*

When a strong player feels pressure more than a weak player, the optimal result is the same as in the model with non-differentiated choking. Since the team tries to avoid situations when the players are under pressure, team *A* prefers to start with s_A to increase the probability of winning the first round. In addition, the opposite strategy $w_A \to s_A$ ("Weaker to start, stronger to finish") is even worse than in the case of non-differentiated choking: if w_A loses the first round (which is more likely), s_A faces a higher performance decrement. As a result, it is optimal for the coach to start with a stronger player.

Now suppose that $\Theta_S < \Theta_W$ – the resilience to choking of a strong player is higher than that of a weak player.

Proposition 4. *Let* $\Theta_S < \Theta_W$.

1. *If $\Theta_W / (4p-1) < \Theta_S < \Theta_W$, then for any skills combination of team B's players and for any strategy of team B, team A's strategy $s_A \to w_A$ is strictly dominant.*

2. *If $\Theta_S = \Theta_W / (4p-1)$, then:*

 i) *if team B has at least one weak player, then team A's strategy $s_A \to w_A$ is strictly dominant,*

 ii) *otherwise, team A is indifferent to athletes' order.*

3. *If $(1-p)\Theta_W / p < \Theta_S < \Theta_W / (4p-1)$, then:*

 i) *if team B has at least one weak player, then team A's strategy $s_A \to w_A$ is strictly dominant,*

 ii) *otherwise, team A's strategy $w_A \to s_A$ is strictly dominant.*

4. *If $\Theta_S = (1-p)\Theta_W / p$, then:*

 i) *if team B has two weak players, then team A's strategy $s_A \to w_A$ is strictly dominant,*

 ii) *if team B has one weak player, then team A is indifferent to athletes' order,*

 iii) *otherwise, team A's strategy $w_A \to s_A$ is strictly dominant;*

5. *If $(3-4p)\Theta_W < \Theta_S < (1-p)\Theta_W / p$, then:*

 i) *if team B has two weak players, then team A's strategy $s_A \to w_A$ is strictly dominant,*

 ii) *otherwise, team A's strategy $w_A \to s_A$ is strictly dominant;*

6. *If $\Theta_S = (3-4p)\Theta_W$, then:*

 i) *if team B has two weak players, then team A is indifferent to athletes' order,*

 ii) *otherwise, team A's strategy $w_A \to s_A$ is strictly dominant.*

7. *If $0 < \Theta_S < (3-4p)\Theta_W$, then for any skills combination of team B's players and for any strategy of team B, team A's strategy $w_A \to s_A$ is strictly dominant.*

A summary of Proposition 4 statements is presented in Table 5.

There are two main effects that team *A* considers when choosing the athletes' order. On the one hand, s_A chokes less than w_A, hence the team might prefer to select a strong player for the second round (*resilience effect*). On the other hand, s_A has a higher probability of winning the first round to avoid a performance decrement for the team in the second round (*performance effect*).

Consider how team *A*'s optimal strategy depends on the magnitude of performance decrements for strong and weak players. Note that for any given combination of team *B*'s players' skills, there is a knife-edge set of parameter values where team *A*'s optimal strategy switches. If the difference in performance decrements between them,

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Table 5

The matrix represents team A's strictly dominant strategy for given types of team B's athletes (strong and weak) and for a given performance decrements (Θ_S and Θ_W)

Condition	Skills combination of team B's players		
	Both players are weak	One player is weak, the other player is strong	Both players are strong
$\Theta_S \in (\Theta_W / (4p-1),\ \Theta_W)$	$s_A \to w_A$	$s_A \to w_A$	$s_A \to w_A$
$\Theta_S = \Theta_W / (4p-1)$	$s_A \to w_A$	$s_A \to w_A$	Indifferent
$\Theta_S \in ((1-p)\Theta_W / p,\ \Theta_W / (4p-1))$	$s_A \to w_A$	$s_A \to w_A$	$w_A \to s_A$
$\Theta_S = (1-p)\Theta_W / p$	$s_A \to w_A$	Indifferent	$w_A \to s_A$
$\Theta_S \in ((3-4p)\Theta_W,\ (1-p)\Theta_W / p)$	$s_A \to w_A$	$w_A \to s_A$	$w_A \to s_A$
$\Theta_S = (3-4p)\Theta_W$	Indifferent	$w_A \to s_A$	$w_A \to s_A$
$\Theta_S \in (0,\ (3-4p)\Theta_W)$	$w_A \to s_A$	$w_A \to s_A$	$w_A \to s_A$

$(\Theta_W - \Theta_S)$, is small (upper row in Table 5), then the performance effect prevails, and it is optimal to select a stronger player for the first round (strategy $s_A \to w_A$). With the larger difference in performance decrements (in extreme cases, s_A almost does not feel any pressure), the resilience effect starts dominating. Therefore, team A prefers to select a strong player for the second round because decreasing the effect of choking under pressure in the second round is more important than increasing the probability of winning the first round.

Now consider how team A's optimal strategy changes depending on a certain combination of players' skills of team B, given that p, Θ_S, and Θ_W are fixed. When team B has two weak players, it is more likely for team A to win the first round than to lose it[5]. For intermediate values of Θ_S, the team prefers to select a strong player for the first round to avoid performance decrement in the second round. When team B has two strong players, the probability of being under pressure in the second round for team A increases. Therefore, team A prefers to select a more pressure-resilient player (a strong one) to participate in the second round. However, for the extreme cases of Θ_S, team A's-optimal strategy does not depend on team B's players' skills combination.

Finally, consider comparative statics of the model with respect to parameter p (see also Figure). With higher values of p, the certainty of winning the first round with a strong player increases, and the performance effect prevails. Therefore, the team prefers to select a strong player for the first round to avoid performance decrement in the second round. With $p \to 0.5$, having a player with higher resilience to pressure in the second round becomes more important; in those cases, the strategy $w_A \to s_A$ is a preferred one.

[5] Recall that the probability of winning the first round for team A is 0.5 for strategy $w_A \to s_A$ and $p > 0.5$ for strategy $s_A \to w_A$, as they compete with the weak player from team B.

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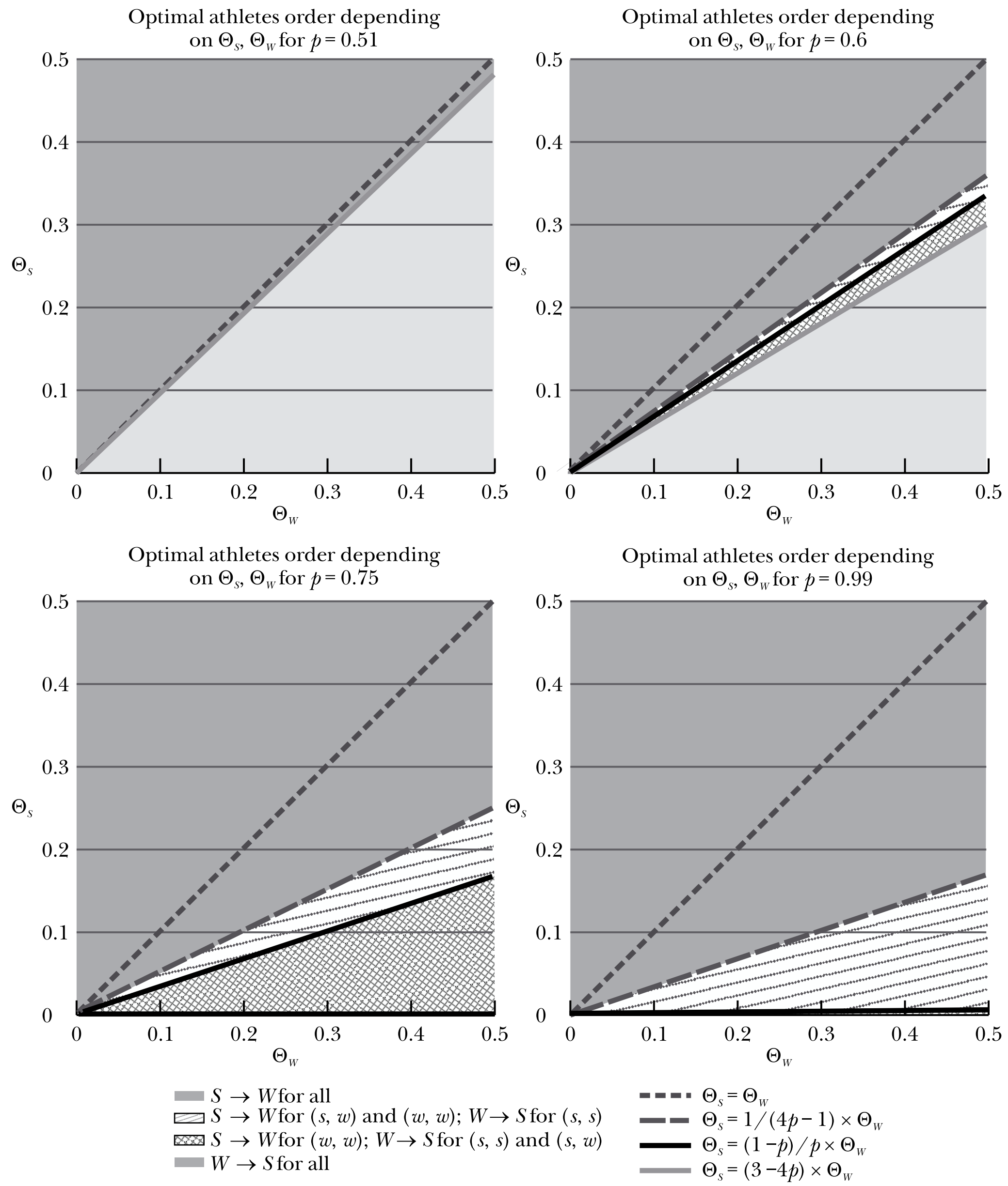

Figure

Team A's optimal athletes' ordering strategy (in different colours) for given values of Θ_S, Θ_W, and specific values of p. segments: $s_A \to w_A$ is team A's strictly dominant strategy for any skills combination of team B's players. segments: $s_A \to w_A$ is team A's strictly dominant strategy when team B has at least one weak player, and otherwise, $w_A \to s_A$. segments: $s_A \to w_A$ is team A's strictly dominant strategy when team B has two weak players, and otherwise, $w_A \to s_A$. segments: $w_A \to s_A$ is team A's strictly dominant strategy for any skills combination of team B

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3. Conclusion

We found that the strategic decision of athletes' ordering in accuracy-based relays is affected by choking under pressure, which worsens the players' performance. We proved that, in the absence of choking, teams are indifferent to athletes' ordering. With the choking under pressure effect, the results change significantly: if all the athletes experience the same magnitude of performance decrements; strategy $s \to w$ ("Stronger to start, weaker to finish") is strictly dominant for any combination of competitor players' skills and for any strategy the competitor's team is following. Those effects are driven by avoiding the loss in the first round and not to face choking under pressure in the second round.

Moreover, we demonstrated that the optimal athletes' order varies depending on the relative magnitude of performance decrements for strong and weak players. If a strong player is less resilient to choking than a weak player, then strategy $s \to w$ is strictly dominant. If the opposite holds – the negative impact from choking is higher for a weak player – then the optimal strategy depends on the relative magnitude of performance decrements for strong and weak players and on a combination of competitor players' skills. When the resilience of a strong player is high enough, the strategy $w \to s$ ("Weaker to start, stronger to finish") is strictly dominant, as a lower performance decrement in the second round by a strong player justifies a lower probability of winning the first round by a weak player.

The main practical advice based on this paper is not just to follow the conventional wisdom that the strongest athlete should always perform the last. As 'choking under pressure' has a significant impact on the performance of the athletes, a team should take into account not only players' skills but also each player's resilience to stress. Further research in that area could focus on a comprehensive assessment of the connection between player's skills and resilience. That would help to determine which players usually tend to choke more and enrich the discussion around the relative magnitude of performance decrements for strong and weak players when 'choking under pressure'.

APPENDIX

Proof of Proposition 1. To prove the Proposition, we calculate the probability of winning the competition for team A for any possible combination of team B players' skills (and any team B's strategy, if there are several possible strategies of team B). We consider all three possible cases of skills combinations for team B: both players are weak (Case I), both players are strong (Case II), one player is strong and the other player is weak (Case III). In the Case III team B can use any of two strategies: $w_B \to s_B$ or $s_B \to w_B$.

Denote by $Pr(m:n)$ the probability of the final score between team A and team B, where m is the number of points earned by athletes from team A and n – by athletes from team B; where $m,n \in \{0,1,2\}$, and $m+n=2$. Let $Pr(i)$, where $i \in \{A,B\}$, be the probability of team i winning the competition.

Case I. Both team B players are weak.

Since there is no differentiation in team B's players' skills, there is only one team B's strategy possible: $w_B \to w_B$. As there is no choking, the probability of winning an individual match in each of the rounds is the same for team A's strategies $w_A \to s_A$

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and $s_A \to w_A$. It is easy to see that each of three probabilities – $Pr(2:0)$, $Pr(0:2)$ and $Pr(1:1)$ – are the same for both team A's strategies:

$$\begin{cases} Pr(2:0) = Pr(w_A \succ w_B)Pr(s_A \succ w_B) = Pr(s_A \succ w_B)Pr(w_A \succ w_B) = 0.5p; \\ Pr(0:2) = Pr(w_B \succ w_A)Pr(w_B \succ s_A) = Pr(w_B \succ s_A)Pr(w_B \succ w_A) = 0.5(1-p); \\ Pr(1:1) = 1 - 0.5p - 0.5(1-p) = 0.5. \end{cases}$$

Note that the probability of winning the competition for team A is $Pr(A) = Pr(2:0) + 0.5Pr(1:1) = 0.25 + 0.5p$ for both strategies $w_A \to s_A$ and $s_A \to w_A$. Therefore, team A is indifferent to both those strategies.

Case II. Both team B's players are strong.

Similarly to case I, the only possible team B's strategy is $s_B \to s_B$. Each of three probabilities $Pr(2:0)$, $Pr(0:2)$ and $Pr(1:1)$ is the same for both team A's strategies: $w_A \to s_A$ and $s_A \to w_A$.

$$\begin{cases} Pr(2:0) = Pr(w_A \succ s_B)Pr(s_A \succ s_B) = Pr(s_A \succ s_B)Pr(w_A \succ s_B) = 0.5(1-p); \\ Pr(0:2) = Pr(s_B \succ w_A)Pr(s_B \succ s_A) = Pr(s_B \succ s_A)Pr(s_B \succ w_A) = 0.5p; \\ Pr(1:1) = 1 - 0.5(1-p) - 0.5p = 0.5. \end{cases}$$

$Pr(A)$ is the same for both strategies $w_A \to s_A$ and $s_A \to w_A$, and equal to $0.75 - 0.5p$. Therefore, team A is indifferent to both those strategies.

Case III. One team B's player is strong, the other player is weak.

In this case, we consider both team B's strategies: $w_B \to s_B$ and $s_B \to w_B$.

1. Team *B*'s strategy: $w_B \to s_B$.

Consider both strategies of team A and calculate $Pr(A)$.

Team *A*'s strategy: $w_A \to s_A$.

$$Pr(2:0) = Pr(w_A \succ w_B)Pr(s_A \succ s_B) = 0.25;$$
$$Pr(0:2) = Pr(w_B \succ w_A)Pr(s_B \succ s_A) = 0.25;$$
$$Pr(1:1) = 1 - 0.25 - 0.25 = 0.5;$$
$$Pr(A) = 0.25 + 0.5 \times 0.5 = 0.5.$$

Team *A*'s strategy: $s_A \to w_A$.

$$Pr(2:0) = Pr(s_A \succ w_B)Pr(w_A \succ s_B) = p(1-p);$$
$$Pr(0:2) = Pr(w_B \succ s_A)Pr(s_B \succ w_A) = p(1-p);$$
$$Pr(1:1) = 1 - 2p(1-p);$$
$$Pr(A) = p(1-p) + 0.5(1 - 2p(1-p)) = p - p^2 + 0.5 - p + p^2 = 0.5.$$

$Pr(A)$ is the same for both team A's strategies $w_A \to s_A$ and $s_A \to w_A$, and equal to 0.5. Therefore, team A is indifferent to both those strategies.

2. Team *B*'s strategy: $s_B \to s_B$.

Similarly, consider both strategies of team A and calculate $Pr(A)$.

Team *A*'s strategy: $w_A \to s_A$.

$$Pr(2:0) = Pr(w_A \succ s_B)Pr(s_A \succ w_B) = p(1-p);$$
$$Pr(0:2) = Pr(s_B \succ w_A)Pr(w_B \succ s_A) = p(1-p);$$
$$Pr(1:1) = 1 - 2p(1-p);$$
$$Pr(A) = p(1-p) + 0.5(1 - 2p(1-p))p - p^2 + 0.5 - p + p^2 = 0.5.$$

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Team *A*'s strategy: $s_A \to w_A$.

$$Pr(2:0) = Pr(s_A \succ s_B)Pr(w_A \succ w_B) = 0.25;$$
$$Pr(0:2) = Pr(s_B \succ s_A)Pr(w_B \succ w_A) = 0.25;$$
$$Pr(1:1) = 1 - 0.25 - 0.25 = 0.5;$$
$$Pr(A) = 0.25 + 0.5 \cdot 0.5 = 0.5.$$

$Pr(A)$ is the same for both team *A*'s strategies $w_A \to s_A$ and $s_A \to w_A$, and equal to 0.5. Therefore, team *A* is indifferent to both those strategies.

We confirmed that for any skills combination of team *B*'s players and for any strategy of team *B*, team *A* is indifferent to athletes' order. ■

Proof of Proposition 2. For the model with non-differentiated performance decrements for strong and weak players, we follow a similar approach as for Proposition's 1 proof. For any skills combination of team *B*'s players and for any strategy of team *B*, we calculate team *A*'s probability of winning the competition for each of strategies — $w_A \to s_A$ and $s_A \to w_A$.

Denote by $\overline{x}$ the player *x* who chokes under pressure in the second round of the competition after the player's team lost the first round.

Case I. Both team *B*'s players are weak.

In this case, $w_B \to w_B$ is the only possible strategy because there is no differentiation in team *B* players' skills.

Team *A*'s strategy: $w_A \to s_A$.

$$Pr(2:0) = Pr(w_A \succ w_B)Pr(s_A \succ \overline{w}_B) = 0.5(p + \Theta);$$
$$Pr(0:2) = Pr(w_B \succ w_A)Pr(w_B \succ \overline{s}_A) = 0.5(1 - p + \Theta);$$
$$Pr(1:1) = 1 - 0.5(p + \Theta) - 0.5(1 - p + \Theta) = 0.5 - \Theta;$$
$$Pr(A) = 0.5(p + \Theta) + 0.5(0.5 - \Theta) = 0.25 + 0.5p.$$

Team *A*'s strategy: $s_A \to w_A$.

$$Pr(2:0) = Pr(s_A \succ w_B)Pr(w_A \succ \overline{w}_B) = p(0.5 + \Theta);$$
$$Pr(0:2) = Pr(w_B \succ s_A)Pr(w_B \succ \overline{w}_A) = (1 - p)(0.5 + \Theta);$$
$$Pr(1:1) = 1 - p(0.5 + \Theta) - (1 - p)(0.5 + \Theta) = 0.5 - \Theta;$$
$$Pr(A) = p(0.5 + \Theta) + 0.5(0.5 - \Theta) = 0.25 + 0.5p + p\Theta - 0.5\Theta.$$

Compare winning probabilities for strategies $w_A \to s_A$ and $s_A \to w_A$. $Pr(A)$ is higher for strategy $s_A \to w_A$ because $p > 0.5$ and $\Theta > 0$.

Case II. Both team *B*'s players are strong.

In this case, $s_B \to s_B$ is the only possible strategy because there is no differentiation in team *B* players' skills.

Team *A*'s strategy: $w_A \to s_A$.

$$Pr(2:0) = Pr(w_A \succ s_B)Pr(s_A \succ \overline{s}_B) = (1 - p)(0.5 + \Theta);$$
$$Pr(0:2) = Pr(s_B \succ w_A)Pr(s_B \succ \overline{s}_A) = p(0.5 + \Theta);$$
$$Pr(1:1) = 1 - (1 - p)(0.5 + \Theta) - p(0.5 + \Theta) = 0.5 - \Theta;$$
$$Pr(A) = (1 - p)(0.5 + \Theta) + 0.5(0.5 - \Theta) = 0.75 - 0.5p + 0.5\Theta - p\Theta.$$

Team *A*'s strategy: $s_A \to w_A$.

$$Pr(2:0) = Pr(s_A \succ s_B)Pr(w_A \succ \overline{s}_B) = 0.5(1 - p + \Theta);$$
$$Pr(0:2) = Pr(s_B \succ s_A)Pr(s_B \succ \overline{w}_A) = 0.5(p + \Theta);$$
$$Pr(1:1) = 1 - 0.5(1 - p + \Theta) - 0.5(p + \Theta) = 0.5 - \Theta;$$
$$Pr(A) = 0.5(1 - p + \Theta) + 0.5(0.5 - \Theta) = 0.75 - 0.5p.$$

Compare winning probabilities for strategies $w_A \to s_A$ and $s_A \to w_A$. $Pr(A)$ is higher for strategy $s_A \to w_A$ because $p > 0.5$ and $\Theta > 0$.

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Case III. One team B's player is strong, the other player is weak.

In this case, we consider both team B's strategies: $w_B \to s_B$ and $s_B \to w_B$.

1. Team B's strategy: $w_B \to s_B$

Consider both strategies of team A and calculate $Pr(A)$.

Team A's strategy: $w_A \to s_A$.

$$Pr(2:0) = Pr(w_A \succ w_B)Pr(s_A \succ \overline{s}_B) = 0.5(0.5+\Theta);$$
$$Pr(0:2) = Pr(w_B \succ w_A)Pr(s_B \succ \overline{s}_A) = 0.5(0.5+\Theta);$$
$$Pr(1:1) = 1-0.5(0.5+\Theta)-0.5(0.5+\Theta) = 0.5-\Theta;$$
$$Pr(A) = 0.5(0.5+\Theta)+0.5(0.5-\Theta) = 0.5.$$

Team A's strategy: $s_A \to w_A$.

$$Pr(2:0) = Pr(s_A \succ w_B)Pr(w_A \succ \overline{s}_B) = p(1-p+\Theta);$$
$$Pr(0:2) = Pr(w_B \succ s_A)Pr(s_B \succ \overline{w}_A) = (1-p)(p+\Theta);$$
$$Pr(1:1) = 1-p(1-p+\Theta)-(1-p)(p+\Theta) = 1-2p+2p^2-\Theta;$$
$$Pr(A) = p(1-p+\Theta)+0.5(1-2p+2p^2-\Theta) = 0.5-0.5\Theta+p\Theta.$$

Compare winning probabilities for strategies $w_A \to s_A$ and $s_A \to w_A$. $Pr(A)$ is higher for strategy $s_A \to w_A$ because $p > 0.5$ and $\Theta > 0$.

2. Team B's strategy: $s_B \to w_B$.

Similarly, consider both strategies of team A and calculate $Pr(A)$.

Team A's strategy: $w_A \to s_A$

$$Pr(2:0) = Pr(w_A \succ s_B)Pr(s_A \succ \overline{w}_B) = (1-p)(p+\Theta);$$
$$Pr(0:2) = Pr(s_B \succ w_A)Pr(w_B \succ \overline{s}_A) = p(1-p+\Theta);$$
$$Pr(1:1) = 1-(1-p)(p+\Theta)-p(1-p+\Theta) = 1-2p+2p^2-\Theta;$$
$$Pr(A) = (1-p)(p+\Theta)+0.5(1-2p+2p^2-\Theta) = 0.5+0.5\Theta-p\Theta.$$

Team A's strategy: $s_A \to w_A$.

$$Pr(2:0) = Pr(s_A \succ s_B)Pr(w_A \succ \overline{w}_B) = 0.5(0.5+\Theta);$$
$$Pr(0:2) = Pr(s_B \succ s_A)Pr(w_B \succ \overline{w}_A) = 0.5(0.5+\Theta);$$
$$Pr(1:1) = 1-0.5(0.5+\Theta)-0.5(0.5+\Theta) = 0.5-\Theta;$$
$$Pr(A) = 0.5(0.5+\Theta)+0.5(0.5-\Theta) = 0.5.$$

Compare winning probabilities for strategies $w_A \to s_A$ and $s_A \to w_A$. $Pr(A)$ is higher for strategy $s_A \to w_A$ because $p > 0.5$ and $\Theta > 0$.

We confirmed that for any skills combination of team B's players and for any strategy of team B, team A's strategy $s_A \to w_A$ is strictly dominant. ■

Proof of Proposition 3. For the model with differentiated performance decrements for strong and weak players we calculate team A's probability of winning the competition for each of two strategies $w_A \to s_A$ and $s_A \to w_A$. Similarly to the proof of the Proposition 1, we consider any skills combination of team B's players and any strategy of team B.

Case I. Both team B's players are weak.

In this case $w_B \to w_B$ is the only possible strategy because there is no differentiation in team B players' skills.

Team A's strategy: $w_A \to s_A$

$$Pr(2:0) = Pr(w_A \succ w_B)Pr(s_A \succ \overline{w}_B) = 0.5(p+\Theta_w);$$
$$Pr(2:0) = Pr(w_B \succ w_A)Pr(w_B \succ \overline{s}_A) = 0.5(1-p+\Theta_s);$$
$$Pr(1:1) = 1-0.5(p+\Theta_w)-0.5(1-p+\Theta_s) = 0.5-\Theta_w-0.5\Theta_s;$$
$$Pr(A) = 0.5(p+\Theta_w)+0.5(0.5-0.5\Theta_w-0.5\Theta_s) = 0.25+0.5p+0.25\Theta_w-0.25\Theta_s.$$

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Team *A*'s strategy: $s_A \to w_A$

$$Pr(2:0) = Pr(s_A \succ w_B)Pr(w_A \succ \overline{w}_B) = p(0.5+\Theta_w);$$
$$Pr(0:2) = Pr(w_B \succ s_A)Pr(w_B \succ \overline{w}_A) = (1-p)(0.5+\Theta_w);$$
$$Pr(1:1) = 1-p(0.5+\Theta_w)-(1-p)(0.5+\Theta_s) = 0.5-\Theta_w;$$
$$Pr(A) = p(0.5+\Theta)+0.5(0.5-\Theta) = 0.25+0.5p+p\Theta_w-0.5\Theta_w.$$

Compare winning probabilities for strategies $w_A \to s_A$ and $s_A \to w_A$. $Pr(A)$ is higher for strategy $s_A \to w_A$ because $p > 0.5$ and $\Theta_S > \Theta_W > 0$.

Case II. Both team *B*'s players are strong.

In this case, $s_B \to s_B$ is the only possible strategy because there is no differentiation in team *B* players' skills.

Team *A*'s strategy: $w_A \to s_A$.

$$Pr(2:0) = Pr(w_A \succ s_B)Pr(s_A \succ \overline{s}_B) = (1-p)(0.5+\Theta_s);$$
$$Pr(0:2) = Pr(s_B \succ w_A)Pr(s_B \succ \overline{s}_A) = p(0.5+\Theta_s);$$
$$Pr(1:1) = 1-(1-p)(0.5+\Theta_s)-p(0.5+\Theta_S) = 0.5-\Theta_s;$$
$$Pr(A) = (1-p)(0.5+\Theta_s)+0.5(0.5-\Theta_s) = 0.75-0.5p+0.5\Theta_s-p\Theta_s.$$

Team *A*'s strategy: $s_A \to w_A$.

$$Pr(2:0) = Pr(s_A \succ s_B)Pr(w_A \succ \overline{s}_B) = 0.5(1-p+\Theta_s);$$
$$Pr(0:2) = Pr(s_B \succ s_A)Pr(s_B \succ \overline{w}_A) = 0.5(p+\Theta_w);$$
$$Pr(1:1) = 1-0.5(1-p+\Theta_s)-0.5(p+\Theta_w) = 0.5-0.5\Theta_s+0.5\Theta_w;$$
$$Pr(A) = 0.5(1-p+\Theta_s)+0.5(0.5-0.5\Theta_s-0.5\Theta_w) = 0.75-0.5p+0.25\Theta_s-0.25\Theta_w.$$

Compare winning probabilities for strategies $w_A \to s_A$ and $s_A \to w_A$. $Pr(A)$ is higher for strategy $s_A \to w_A$ because $p > 0.5$ and $\Theta_S > \Theta_W > 0$.

Case III. One team *B*'s player is strong, the other player is weak.

In this case, we consider both team *B*'s strategies: $w_B \to s_B$ and $s_B \to w_B$.

1. Team *B*'s strategy: $w_B \to s_B$.

Consider both strategies of team *A* and calculate $Pr(A)$.

Team *A*'s strategy: $w_A \to s_A$.

$$Pr(2:0) = Pr(w_A \succ w_B)Pr(s_A \succ \overline{s}_B) = 0.5(0.5+\Theta_s);$$
$$Pr(0:2) = Pr(w_B \succ w_A)Pr(s_B \succ \overline{s}_A) = 0.5(0.5+\Theta_s);$$
$$Pr(1:1) = 1-0.5(0.5+\Theta_s)-0.5(0.5+\Theta_s) = 0.5-\Theta_s;$$
$$Pr(A) = 0.5(0.5+\Theta_s)+0.5(0.5-\Theta_s) = 0.5.$$

Team *A*'s strategy: $s_A \to w_A$.

$$Pr(2:0) = Pr(s_A \succ w_B)Pr(w_A \succ \overline{s}_B) = p(1-p+\Theta_s);$$
$$Pr(0:2) = Pr(w_B \succ s_A)Pr(s_B \succ \overline{w}_A) = (1-p)(p+\Theta_w);$$
$$Pr(1:1) = 1-p(1-p+\Theta)-(1-p)(p+\Theta) = 1-2p+2p^2-p\Theta_s-\Theta_w+p\Theta_w;$$
$$Pr(A) = p(1-p+\Theta_s)+0.5(1-2p+2p^2-p\Theta_s-\Theta_w+p\Theta_w) = 0.5-0.5p\Theta_s+0.5p\Theta_w-0.5\Theta_w.$$

Compare winning probabilities for strategies $w_A \to s_A$ and $s_A \to w_A$. $Pr(A)$ is higher for strategy $s_A \to w_A$ because $p > 0.5$ and $\Theta > 0$.

2. Team *B*'s strategy: $s_B \to w_B$.

Similarly, consider both strategies of team *A* and calculate $Pr(A)$.

Team *A*'s strategy: $w_A \to s_A$.

$$Pr(2:0) = Pr(w_A \succ s_B)Pr(s_A \succ \overline{w}_B) = (1-p)(p+\Theta_w);$$
$$Pr(0:2) = Pr(s_B \succ w_A)Pr(w_B \succ \overline{s}_A) = p(1-p+\Theta_s);$$
$$Pr(1:1) = 1-(1-p)(p+p\Theta_w)-p(1-p+\Theta_s) = 1-2p+2p^2-\Theta_w+p\Theta_w-p\Theta_s;$$
$$Pr(A) = (1-p)(p-\Theta_w)+0.5(1-2p+2p^2-\Theta_w+p\Theta_w-p\Theta_s) = 0.5+0.5\Theta_w-0.5p\Theta_w-0.5\Theta_s.$$

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Team *A*'s strategy: $s_A \to w_A$

$$Pr(2:0) = Pr(s_A \succ s_B) Pr(w_A \succ \overline{w}_B) = 0.5(0.5 + \Theta_w);$$
$$Pr(0:2) = Pr(s_B \succ s_A) Pr(w_B \succ \overline{w}_A) = 0.5(0.5 + \Theta_w);$$
$$Pr(1:1) = 1 - 0.5(0.5 + \Theta_w) - 0.5(0.5 + \Theta_w) = 0.5 - \Theta_w;$$
$$Pr(A) = 0.5(0.5 + \Theta_w) + 0.5(0.5 - \Theta_w) = 0.5.$$

Compare winning probabilities for strategies $w_A \to s_A$ and $s_A \to w_A$. $Pr(A)$ is higher for strategy $s_A \to w_A$ because $p > 0.5$ and $\Theta_S > \Theta_W > 0$.

We confirmed that for any skills combination of team *B*'s players and for any strategy of team *B*, team *A*'s strategy $s_A \to w_A$ is strictly dominant. ■

Before Proposition 4 proof, we derive several auxiliary lemmas. Note that by formulation of Proposition 4, $\Theta_S < \Theta_W$ – choking resilience of a strong player is higher than of a weak player.

One can easily repeat the arguments of Cases I–III of Proposition 3 proof and conclude the following Lemmas 1–4.

Lemma 1. *Assume that team B has two weak players. Then, strictly dominant strategy for team A is:*

- $s_A \to w_A$ *if and only if* $\Theta_S > \Theta_W(3 - 4p)$;
- $w_A \to s_A$ *if and only if* $\Theta_S < \Theta_W(3 - 4p)$;
- *otherwise, team A is indifferent to strategies* $s_A \to w_A$ *and* $w_A \to s_A$.

Lemma 2. *Assume that team B has two strong players. Then, strictly dominant strategy for team A is:*

- $s_A \to w_A$ *if and only if* $\Theta_S > \Theta_W / (4p - 1)$;
- $w_A \to s_A$ *if and only if* $\Theta_S < \Theta_W / (4p - 1)$;
- *otherwise, team A is indifferent to strategies* $s_A \to w_A$ *and* $w_A \to s_A$.

Lemma 3. *Assume that team B has one strong and one weak players, and team B's strategy is* $w_B \to s_B$. *Then, strictly dominant strategy for team A is:*

- $s_A \to w_A$ *if and only if* $\Theta_S > (1 - p)\Theta_W / p$;
- $w_A \to s_A$ *if and only if* $\Theta_S < (1 - p)\Theta_W / p$;
- *otherwise, team A is indifferent to strategies* $s_A \to w_A$ *and* $w_A \to s_A$.

Lemma 4. *Assume that team B has one strong and one weak players, and team B's strategy is* $s_B \to w_B$. *Then, strictly dominant strategy for team A is:*

- $s_A \to w_A$ *if and only if* $\Theta_S > (1 - p)\Theta_W / p$;
- $w_A \to s_A$ *if and only if* $\Theta_S < (1 - p)\Theta_W / p$;
- *otherwise, team A is indifferent to strategies* $s_A \to w_A$ *and* $w_A \to s_A$.

From Lemmas 3 and 4 it follows, that if team *B* has one strong and one weak players, then team *A*'s strictly dominant strategy is the same for team *B*'s strategies $w_B \to s_B$ and $s_B \to w_B$. Formally,

Lemma 5. *Assume that team B has one weak and one strong player. Then, for any of team B's strategies, strictly dominant strategy for team A is:*

- $s_A \to w_A$ *if and only if* $\Theta_S > (1 - p)\Theta_W / p$;
- $w_A \to s_A$ *if and only if* $\Theta_S < (1 - p)\Theta_W / p$;
- *otherwise, team A is indifferent to strategies* $s_A \to w_A$ *and* $w_A \to s_A$.

Lemmas 6 and 7 make the next steps in deriving team *A*'s optimal strategy.

Lemma 6. *Assume team B has two strong players, and* $s_A \to w_A$ *is strictly dominant strategy for team A. Then if team B has one weak and one strong players, then the same team A's strategy* $s_A \to w_A$ *is strictly dominant.*

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Proof. From Lemma 2 it follows that if team A's strategy $s_A \to w_A$ is strictly dominant, then $\Theta_S > \Theta_W / (4p-1)$. Note for any $p > 0.5$ and $\Theta_W > 0$ the following inequality holds:

$$\Theta_W / (4p-1) > (1-p)\Theta_W / p \tag{1}$$

In this case, $\Theta_S > \Theta_W / (4p-1) > (1-p)\Theta_W / p$. From Lemma 5 it follows that $s_A \to w_A$ is strictly dominant strategy for team A. ■

Lemma 7. *Assume, team B has one weak and one strong players, and $s_A \to w_A$ is strictly dominant strategy for team A. Then if team B has two weak players, then the same team A's strategy $s_A \to w_A$ is strictly dominant.*

Proof. From Lemma 5 it follows that if team A's strategy $s_A \to w_A$ is strictly dominant, then $\Theta_S > (1-p)\Theta_W / p$. Note for any $p > 0.5$ and $\Theta_W > 0$ the following inequality holds:

$$(1-p)\Theta_W / p > (3-4p)\Theta_W. \tag{2}$$

In this case, $\Theta_S > (1-p)\Theta_W / p > (3-4p)\Theta_W$. From Lemma 1 it follows that $s_A \to w_A$ is strictly dominant strategy for team A. ■

Now we are ready to prove Proposition 4.

Proof of Proposition 4. We prove each statement of Proposition 4 separately.

1. Let $\Theta_S > \Theta_W / (4p-1)$. Therefore, from Lemma 2 it follows that $s_A \to w_A$ is team A's strictly dominant strategy when team B has two strong players. Therefore, based on Lemma 6, $s_A \to w_A$ is team A's strictly dominant strategy, when team B has one weak and one strong players. Then, based on Lemma 5, $s_A \to w_A$ is team A's strictly dominant strategy for any of team B's strategies. Also, based on Lemma 7, $s_A \to w_A$ is team A's strictly dominant strategy when team B has two weak players. We confirmed that for any skills combination of team B's players and for any strategy of team B, team A's strategy $s_A \to w_A$ is strictly dominant.

2. Let $\Theta_S = \Theta_W / (4p-1)$:

i) From inequality (1) it follows that $\Theta_S = \Theta_W / (4p-1) > (1-p)\Theta_W / p$. Therefore, based on Lemma 5, team A's strictly dominant strategy is $s_A \to w_A$, when team B has one weak and one strong players. Then, based on Lemma 7, $s_A \to w_A$ is team A's strictly dominant strategy when team B has two weak players. We confirmed that if team B has at least one weak player, then team A's strategy $s_A \to w_A$ is strictly dominant;

ii) From Lemma 2 it follows that if team B has two strong players, and $\Theta_S = \Theta_W / (4p-1)$, then team A is indifferent to strategies $s_A \to w_A$ and $w_A \to s_A$.

3. Let $(1-p)\Theta_W / p < \Theta_S < \Theta_W / (4p-1)$:

i) Similarly to 2(I) proof, as $\Theta_S > (1-p)\Theta_W / p$;

ii) From Lemma 2 it follows, that if team B has two strong players and $\Theta_S < \Theta_W / (4p-1)$, then team A's strategy $w_A \to s_A$ is strictly dominant.

4. Let $\Theta_S = (1-p)/p\Theta_W$:

i) From inequality (2) it follows that $\Theta_S = (1-p)\Theta_W / p > (3-4p)\Theta_W$. Then, based on Lemma 1, team A's strategy $s_A \to w_A$ is strictly dominant, when team B has two weak players;

ii) From Lemma 5 it follows that if team B has one weak and one strong players and $\Theta_S = (1-p)\Theta_W / p$, then team A is indifferent between strategies $s_A \to w_A$ and $w_A \to s_A$;

iii) From inequality (1) it follows $\Theta_S = (1-p)\Theta_W / p < \Theta_W / (4p-1)$. Then, based on Lemma 2, team *A*'s strategy $w_A \to s_A$ is strictly dominant when team *B* has two strong players.

5. Let $(3-4p)\Theta_W < \Theta_S < (1-p)\Theta_W / p$:

i) Similarly to 4.i proof, as $\Theta_S > (3-4p)\Theta_W$;

ii) From Lemma 5 it follows that if team *B* has one weak and one strong players and $\Theta_S < (1-p)\Theta_W / p$, then team *A*'s strictly dominant strategy is $w_A \to s_A$. Also, based on inequality (1), $\Theta_S < (1-p)/ p\Theta_W < \Theta_W / (4p-1)$. Then, based on Lemma 2, team *A*'s strictly dominant strategy is $w_A \to s_A$, when team *B* has two strong players. We confirmed that if team *B* has at least one strong player, then team *A*'s strategy $w_A \to s_A$ is strictly dominant.

6. Let $\Theta_S = (3-4p)\Theta_W$:

i) From Lemma 1 it follows that if team *B* has two weak players and $\Theta_S = (3-4p)\Theta_W$, team *A* is indifferent to strategies $s_A \to w_A$ and $w_A \to s_A$;

ii) Similarly to 5.ii proof, as from inequality (2) it follows that $\Theta_S = (3-4p)\Theta_W < (1-p)\Theta_W / p$.

7. Let $\Theta_S < (3-4p)\Theta_W$. Then, based on Lemma 1, $w_A \to s_A$ is team *A*'s strictly dominant strategy when team *B* has two weak players. From inequality (2) it follows that $\Theta_S < (3-4p)\Theta_W < (1-p)\Theta_W / p$. Then, based on Lemma 5, team *A*'s strictly dominant strategy is $w_A \to s_A$, when team *B* has one weak and one strong players. Also, from inequality (1) it follows that $\Theta_S < (3-4p)\Theta_W < (1-p)\Theta_W / p < \Theta_W / (4p-1)$. Then, based on Lemma 2, team *A*'s strictly dominant strategy is $w_A \to s_A$, when team *B* has two strong players. We confirmed that for any skills combination of team *B*'s players and for any strategy of team *B*, team *A*'s strategy $w_A \to s_A$ is strictly dominant.

Now all statements of Proposition 4 hold. ■

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Н.С. Авхимович
НИУ ВШЭ, Москва

Будет ли самый быстрый последним? Стратегический выбор очередности спортсменов в эстафетах[6]

Аннотация. В данной работе рассматривается стратегический выбор очередности спортсменов в эстафетных гонках. Считается, что самый сильный участник должен выступать на заключительном этапе гонки. В спорте эффект «choking under pressure» (например, когда в эстафетных гонках соперник «дышит в спину») приводит к снижению продуктивности атлета в стрессовых условиях — например, когда спортсмен отстает от соперника. С помощью теоретических моделей мы обнаружили, что эффект «choking under pressure» влияет на стратегический выбор очередности спортсменов с различным уровнем навыков. Например, без эффекта «choking under pressure» команда безразлична к очередности спортсменов. Если у всех игроков наблюдается одинаковое снижение производительности под давлением, то строго доминирующей стратегией будет последовательность «сильный – слабый», когда более сильный спортсмен начинает гонку, а более слабый заканчивает. В случае дифференцированных параметров снижения производительности спортсменов под давлением мы определяем оптимальную стратегию команд как функцию этих параметров. Распространенная стратегия «слабый – сильный» является строго доминирующей только в тех случаях, когда стрессоустойчивость сильного игрока выше, чем стрессоустойчивость слабого игрока.

Ключевые слова: *стратегическое построение команды, тактический выбор тренеров, очередность спортсменов, эстафетные гонки, эффект «choking under pressure»*.

Классификация JEL: C61, C70, L83.

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