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Incentives, Performance and Choking in Darts

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Abstract

This paper examines how within-match variation in incentives affects the performance of darts players. The game of darts offers an attractive naturally occurring research setting, because performance can be observed at the individual level and without obscuring effects of risk considerations and behavior of others. We analyze four data sets covering a total of 29,381 darts matches of professional, amateur, and youth players. We find that amateur and youth players display a sizable performance decrease at decisive moments. Professional players appear less susceptible of such choking under pressure. Our results speak to a growing literature on the limits of increasing incentives as a recipe for better performance.

Keywords: incentives; performance pressure; choking under pressure; darts
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1 Introduction

Incentives are at the core of economics. From labor supply to crime, and from consumption to education, incentives play a central role in economic theory. An important prediction is that people exert more effort when they face stronger incentives, and that this increased effort in turn leads to better performance. Various experimental studies have shown that higher monetary incentives indeed improve performance (Smith and Walker, 1993; Camerer and Hogarth, 1999; Gneezy and Rustichini, 2000). Outside the behavioral laboratory, research has similarly shown that workers produce more output when they are paid a piece rate rather than an hourly rate (Paarsch and Shearer, 1999; Prendergast, 1999; Lazear, 2000; Shearer, 2004) and that students perform better at tests when they are paid according to their performance (Levitt et al., 2016).

An alternative line of research, predominantly in psychology, suggests that higher incentives do not always improve performance and can even backfire (Kamenica, 2012). High incentives can cause people to consciously think about their actions in otherwise automatically performed tasks, and consequently impede performance (Baumeister, 1984; Beilock and Carr, 2001; Masters and Maxwell, 2008). Also, higher incentives can lead to more arousal. The Yerkes-Dodson law postulates that arousal has a non-monotonic effect on performance: moderate increases enhance performance, whereas the effect turns negative if arousal surpasses a critical threshold that depends on task difficulty (Yerkes and Dodson, 1908). Ariely et al. (2009) show that high stakes harm performance in a diverse set of experimental tasks that draw on subject's memory, creativity, or motor skills, but not in a task that solely requires physical effort. Inferior performance in the presence of incentives for superior performance is known as choking under pressure (Baumeister and Showers, 1986; Beilock, 2010).

The present paper contributes to the understanding of the link between incentives and performance by analyzing four large data sets of competitive darts matches of professional, amateur and youth players. Darts offers a unique combination of attractive features for this type of research. The game is played in a real-world natural environment. Like many other real-life activities—such as the work of pilots, bus drivers, soldiers, surgeons and dentists—the task is neither entirely physical nor entirely mental, but combines elements of both. The sustained concentration demanded by the game can be regarded as a form of effort. Just as with controlled experiments, the game has a clearly defined set of rules and objectives. Performance can be observed at the individual level, and unlike many other field tasks it is not confounded by behavior of others, such as colleagues and competitors. As opposed to many other field settings—where it can be rational for risk-averse individuals to shift to low-risk low-reward strategies when the stakes increase—the optimal approach to darts is independent of risk preferences, because a rational player, no matter how risk averse, will always try to maximize her probability of winning.

By using darts data, we connect to a broader literature that uses sports data to investigate economic hypotheses. Examples are the study of discrimination in basketball (Price and Wolfers, 2010), principal-agent theory in cricket (Gauriot and Page, 2015), and mixed-strategy Nash equilibria in soccer penalty shootouts (Chiappori et al., 2002). The prediction that athletes perform better under higher monetary incentives has been confirmed for various sports, including golf (Ehrenberg and Bognanno, 1990*a*,*b*), auto racing (Becker and Huselid, 1992), horse racing (Lynch, 2005), and tennis (Gilsdorf and Sukhatme, 2008*a*,*b*). Choking under pressure has previously been observed in, for example, penalty shootouts in soccer (Dohmen, 2008), free throws in basketball (Cao et al., 2011; Goldman and Rao, 2012; Toma, 2017; Böheim et al., 2018), putting in golf (Hickman and Metz, 2015), shooting in biathlon (Lindner, 2017; Harb-Wu and Krumer, 2019), and tennis (Paserman, 2010; Cohen-Zada et al., 2017).

To investigate the effect of incentives on performance in darts, we exploit naturally occurring within-match variation in the benefit (cost) of throwing well (poorly). We find that amateur and youth players display a sizable performance decrease at decisive moments. Professional players appear less susceptible of such choking under pressure.

In the remainder of the paper we explain the game of darts and our data (Section 2), present the analyses and results (Section 3), and conclude (Section 4).

Figure 1: Dartboard

2 Description Darts and Data

2.1 Darts

In darts, two players compete with each other by sequentially throwing darts at a dartboard. A dartboard is divided into areas that represent points in the range of 1 to 20 (see Figure 1). The number of points is doubled when a dart is thrown in the outer band, and tripled when it is thrown in the inner band. The outer ring in the center of the dartboard (or 'outer bull') gives 25 points, the inner circle (or 'inner bull') gives 50 points. The maximum score with one dart is 60 points (triple 20).

Darts matches are played in either 'leg' or 'set' format. A match in leg format is a best-of-n contest, where each of the n sub-contests is called a leg. A match in set format also is a best-of-n contest, but each sub-contest is then called a set, which in turn is a best-of-n contest with legs. A set thus resembles a match in leg format.

Players normally start a leg with 501 points each, and take turns to throw three darts. One turn of three darts is commonly referred to as one 'throw'. The sum of the points in a throw is subtracted from the remaining number of points. To finish and win a leg, a player is required to reach zero (exactly) by hitting either a ‘double’ or the inner bull. For example, a player with 18 points remaining can finish by hitting double 9. If the score of a dart exceeds the number of points the player has left, her entire throw of three darts is rendered invalid. Players take turns to start legs. The starter of the first leg is generally determined by shots at the center of the dartboard, with the player closest starting.

2.2 Data

Our data are from Darts for Windows (www.dartsforwindows.com). Darts for Windows collects data from various sources, most notably from darts associations and darts competitions that use the Darts for Windows computer software. There are four categories of data: Youth, Super League, British Inter-County Championship (BICC), and International. We downloaded all available International data on July 11, 2017, all available BICC data on November 26, 2017, and all available data for the other two categories on July 4, 2019.

The four data sets cover the matches of different types of players, ranging from amateur youth players to professional adults. The international tournaments sample covers 15,205 matches between professional players from 1974-2017, and includes matches played at famous tournaments such as the UK Open and the PDC World Darts Championship. The BICC is a competition between amateur players from various counties in the United Kingdom. The BICC sample comprises 10,369 matches played in the period 2005-2017. The Super League is a regional amateur league that is played mostly in the United Kingdom. The Super League sample contains 1,643 matches from 2007-2019. The Youth sample consists of 2,164 matches from tournaments for boys under 18, boys under 21, and girls under 21, that took place in the period 2001-2019.

For each match, we have granular data down to each player’s score in one throw of three darts. Along with the score per throw, we know the date of the match, players’ names, and the starter of the first leg.

In our analyses we treat sets as separate matches. Most matches in the Youth (51%), Super League (93%), and BICC (100%) sample are played in set format. These matches are virtually always between two teams, where each set is played by a different team member. Such sets can therefore rightfully be regarded as matches on their own. In the International sample, only a small proportion (5.6%) of the

Table 1: Summary statistics

	International	BICC	Super League	Youth
Matches	17,855	89,019	12,195	6,610
Legs	85,446	382,195	51,071	20,054
Throws	1,200,383	5,922,129	816,745	378,481
Players	2,644	10,788	5,414	2,978
Legs per match	4.79	4.29	4.19	3.03
Throws per leg	14.0	15.5	16.0	18.9
Points per throw (all)	65.8	60.1	57.7	49.0
Points per throw (first three)	79.6	70.6	67.5	59.3
Starter wins leg (proportion)	0.587	0.570	0.560	0.548
One-dart finish opportunities	111,241	587,876	81,385	45,893
One-dart finish opportunities (first only)	68,547	345,416	46,518	20,563
Successful one-dart finish (proportion)	0.465	0.425	0.419	0.314
Successful one-dart finish (proportion, first only)	0.528	0.473	0.465	0.363

Notes: Matches, *Legs*, *Throws* and *Players* are the number of matches, legs, throws, and players, respectively. *Legs per match* is the average number of legs per match. *Throws per leg* is the average number of throws by both players combined per leg. *Points per throw (all)* is the average number of points per throw across all throws. *Points per throw (first three)* is the average number of points per throw across players' first three throws in every leg. *Starter wins leg* is the proportion of legs won by the player who started the leg. *One-dart finish opportunities (first only)* is the number of throws where a player can finish the leg with one dart (for the first time in that leg). *Successful one-dart finish (first only)* is the proportion of throws where a player could finish the leg with one dart (for the first time in that leg) and finished the leg in the given throw.

matches are in set format, and sets are generally played by the same player. For consistency, we nevertheless similarly treat these sets as separate matches. To make sure that our results are not sensitive to this approach, we also conduct robustness analyses that exclude the data from matches in the International sample that were played in set format. Treating sets as matches increases the total number of matches in the four data sets combined from 29,381 to 126,440.

We exclude matches where legs do not start at 501 points, matches where one or more scores are missing, matches with more than two players, and matches where both players have the same name. After these cleaning operations, 125,679 matches remain.

Table 1 presents summary statistics. In total, our data comprise more than half a million legs and more than eight million throws. There are clear skill differences between the four categories, with average points per throw ranging from 49.0 (Youth) to 65.8 (International), and the percentage of successful one-dart finishes ranging from 31.4 (Youth) to 46.5 (International).[1] The skill differences are also reflected in the average leg length and in the proportion of starting players winning the leg, with

[1] A one-dart finish opportunity is a throw where a player can finish the leg with just one dart. The remaining number of points in such a situation is 2, 4, 6, ..., 36, 38, 40 or 50.

better players taking fewer throws and being more likely to benefit from throwing first. The proportion of successful one-dart finishes is higher if we consider only the first opportunity of every leg instead of all. This difference can be attributed to a selection effect, because better players are more likely to be successful on their first attempt.

3 Analyses and Results

The incentive to do well in darts varies both across and within matches. Across matches, players will be motivated by the amount of prestige, prize money, and media attention. Compare, for example, the final of the internationally televised PDC World Darts Championship where the 2019 winner (Dutchman Michael van Gerwen) took home £500,000, with a match in the first round of the men's singles tournament of the Lincolnshire Family Darts Festival where the 2019 winner cashed £2,000. Our data, however, does not contain sufficient information to systematically proxy for such variation.

Within matches, there is considerable variation in the impact of the quality of a dart throw on the likelihood of winning the match, and players can be expected to adjust their effort provision accordingly (Konrad, 2009). The incentive to throw well is relatively high when both players are close to winning a leg, and when both players are close to winning the match. Our analyses exploit this naturally-occurring within-match variation, and consider its effect on players' finishing performance (Section 3.1) and on the points they throw in the first three throws of a leg (Section 3.2).

3.1 Finishing

We first examine how players' finishing performance is affected when both players can win the match by winning the current leg. Such legs are highly consequential because poor performance can irreversibly result in losing the match, whereas strong performance can secure the win.[2] Second, we examine how players' finishing

[2] We intentionally only consider situations where *both* can win the match, and not those where only one can win. First, if only one can win, the incentive to do well can be both high and low, depending on the closeness of the match. Second, using situations where only one can win would lead to biased coefficient estimates due to regression to the mean: players who are ahead

performance is affected when their opponent can finish the leg in the subsequent throw. The pressure on a player to finish is relatively high when her opponent can also finish, and relatively low otherwise. Last, we consider the interaction of these conditions. In such critical cases, where both can win the match by winning the current leg and where the opponent can finish in the subsequent throw, the pressure to do well is especially high.

We exclusively consider situations where the player can finish the leg with one dart. This is the case when she has 2, 4, 6, ..., 36, 38, 40 or 50 points left. Strategy plays no role in these situations, because any approach other than trying to finish the leg in the current throw is sub-optimal. In contrast, if a player needs multiple darts to finish she might instead try to maneuver herself into a better finishing position for the next throw. Such a strategy can be attractive in situations where the opponent is unlikely or unable to finish, and would thus generate the false impression of lower performance in lower-incentive situations.

We use a fixed-effects logit model to regress finishing performance on incentives. We control for skill differences between players and across matches through player-match fixed effects, and for possible warming-up and fatigue effects within a match by including a polynomial of order n for the player's number of throws in the match prior to the current throw, where the value of n is chosen to minimize the AIC.[3] When a player displays no variation in one-dart finishing success within a match, her observations effectively do not contribute to the estimations of the coefficients; the average marginal effects that we present, however, are based on all observations.[4]

Table 2 presents the regression results.[5] Model 1 shows that the effect of *Decisive leg* is negative and significant at the one-percent level in all samples. A player's finishing probability on average deteriorates by 2.5-7.7 percentage points if both players can win the match by winning the leg, compared to situations where none or only one of them is close to winning the match. Scaled by the sample-specific

(behind) have on average been (un)lucky with their previous throws, and as a consequence their performance will in expectation decrease (increase).

[3] If the match has a set format, the number of throws includes the throws in previous sets played by the same player.

[4] In doing so we follow the conventional approach. Calculating average marginal effects on the basis of only the effective observations would amplify the effect sizes.

[5] Table A1 in the Appendix displays the underlying coefficient estimates. The p-values of the coefficients are higher than those of the average marginal effects, but support the same general conclusions.

Table 2: Regression results for the likelihood of finishing

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Panel A: International						
Decisive leg	-0.025^{***}			-0.006	0.026	0.026
	(0.008)			(0.008)	(0.026)	(0.026)
Opp. can finish		0.002			0.003	
		(0.005)			(0.005)	
Opp. can finish with 1 dart			-0.005			-0.003
			(0.005)			(0.006)
Opp. can finish with 2 darts			0.010^{*}			0.011^{*}
			(0.005)			(0.006)
Opp. can finish with 3 darts			-0.001			-0.0004
			(0.006)			(0.006)
Decisive leg x Opp. can finish					-0.036	
					(0.028)	
Decisive leg x Opp. can finish with 1 dart						-0.048
						(0.029)
Decisive leg x Opp. can finish with 2 darts						-0.033
						(0.030)
Decisive leg x Opp. can finish with 3 darts						-0.008
						(0.034)
Data	All	First only	First only	First only	First only	First only
Player-match fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Polynomial throw number (order)	3	3	3	3	3	3
McFadden pseudo R-squared	0.139	0.085	0.085	0.085	0.085	0.085
Observations	111,241	68,547	68,547	68,547	68,547	68,547
Effective observations	84,994	37,837	37,837	37,837	37,837	37,837

Notes: The table reports the average marginal effects resulting from logit regression analyses of finishing performance across throws where the player can finish the leg with one dart. Model 1 uses all one-dart finish opportunities, whereas Models 2-6 use players' first one-dart finish opportunity in a leg only. The dependent variable takes the value of 1 if the player finishes in the given throw, and 0 otherwise. *Decisive leg* is a dummy variable that takes the value of 1 if both players can win the match by winning the current leg. *Opp. can finish* (*with 1, 2, or 3 darts*) is a dummy variable that takes the value of 1 if the player's opponent can finish the leg in the subsequent throw (and needs one, two, or three darts). The regression specifications include player-match fixed effects, and a polynomial of order n for the player's prior number of throws in the match, where n is chosen to minimize the AIC. Average marginal effects are corrected for incidental parameter bias (Fernández-Val, 2009). *Effective observations* is the number of observations that contribute to the estimation of the underlying regression coefficients, which can be found in Table A1 in the Appendix. Standard errors are in parentheses. Asterisks denote significance at the 0.01 (***), 0.05 (**) and 0.1 (*) level.

proportion of successful one-dart finishes (see Table 1), the negative impact on performance ranges between 5.3 percent for International players and 18.1 percent for BICC players. For Super League and Youth the performance decreases are 8.4 and 15.3 percent, respectively.

To analyze how finishing performance is affected by the opponent's opportunity to finish the leg in the subsequent throw, we need to restrict the data to players' first finishing attempt in every leg. The inclusion of subsequent attempts would lead to biased estimates, because the random component in a player's performance in a match affects both the estimated "normal" skill of the player (as captured through

Table 2: Continued

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Panel B: BICC						
Decisive leg	-0.077^{***}			-0.059^{***}	-0.007	-0.008
	(0.003)			(0.003)	(0.008)	(0.008)
Opp. can finish		0.003			0.007^{***}	
		(0.002)			(0.003)	
Opp. can finish with 1 dart			0.001			0.007^{***}
			(0.003)			(0.003)
Opp. can finish with 2 darts			0.003			0.006^{**}
			(0.003)			(0.003)
Opp. can finish with 3 darts			0.006^{**}			0.008^{***}
			(0.003)			(0.003)
Decisive leg x Opp. can finish					-0.058^{***}	
					(0.008)	
Decisive leg x Opp. can finish with 1 dart						-0.079^{***}
						(0.009)
Decisive leg x Opp. can finish with 2 darts						-0.042^{***}
						(0.009)
Decisive leg x Opp. can finish with 3 darts						-0.032^{***}
						(0.010)
Data	All	First only	First only	First only	First only	First only
Player-match fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Polynomial throw number (order)	4	3	3	4	4	4
McFadden pseudo R-squared	0.124	0.072	0.072	0.073	0.073	0.073
Observations	587,876	345,416	345,416	345,416	345,416	345,416
Effective observations	463,690	193,135	193,135	193,135	193,135	193,135
Panel C: Super League						
Decisive leg	-0.035^{***}			-0.035^{***}	-0.001	-0.001
	(0.009)			(0.009)	(0.023)	(0.023)
Opp. can finish		0.003			0.005	
		(0.006)			(0.006)	
Opp. can finish with 1 dart			0.004			0.007
			(0.007)			(0.007)
Opp. can finish with 2 darts			-0.003			-0.002
			(0.007)			(0.007)
Opp. can finish with 3 darts			0.009			0.013^{*}
			(0.007)			(0.008)
Decisive leg x Opp. can finish					-0.039	
					(0.024)	
Decisive leg x Opp. can finish with 1 dart						-0.052^{**}
						(0.026)
Decisive leg x Opp. can finish with 2 darts						-0.013
						(0.027)
Decisive leg x Opp. can finish with 3 darts						-0.055^{*}
						(0.030)
Data	All	First only	First only	First only	First only	First only
Player-match fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Polynomial throw number (order)	4	3	3	3	3	3
McFadden pseudo R-squared	0.126	0.074	0.074	0.074	0.074	0.075
Observations	81,385	46,518	46,518	46,518	46,518	46,518
Effective observations	65,063	26,536	26,536	26,536	26,536	26,536

Table 2: Continued

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Panel D: Youth						
Decisive leg	-0.048^{***}			-0.028^{***}	0.007	0.007
	(0.010)			(0.010)	(0.026)	(0.026)
Opp. can finish		-0.032^{***}			-0.028^{***}	
		(0.008)			(0.009)	
Opp. can finish with 1 dart			-0.045^{***}			-0.039^{***}
			(0.009)			(0.010)
Opp. can finish with 2 darts			-0.030^{***}			-0.030^{***}
			(0.009)			(0.010)
Opp. can finish with 3 darts			-0.020^{**}			-0.020^{*}
			(0.010)			(0.010)
Decisive leg x Opp. can finish					-0.039	
					(0.026)	
Decisive leg x Opp. can finish with 1 dart						-0.065^{**}
						(0.028)
Decisive leg x Opp. can finish with 2 darts						-0.016
						(0.029)
Decisive leg x Opp. can finish with 3 darts						-0.010
						(0.033)
Data	All	First only	First only	First only	First only	First only
Player-match fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Polynomial throw number (order)	3	4	4	4	4	3
McFadden pseudo R-squared	0.133	0.061	0.061	0.061	0.061	0.062
Observations	45,893	20,563	20,563	20,563	20,563	20,563
Effective observations	36,385	9,322	9,322	9,322	9,322	9,322

the player-match fixed effects) and the likelihood that a situation arises where the opponent can finish. For example, if a player misses a finish opportunity, her finishing statistic for the match worsens, and if she then gets a new opportunity to finish, her opponent will be closer to finishing because of the extra turn. Hence, including subsequent attempts would positively bias the estimated effect of the opponent's opportunity to finish on performance.

Model 2 shows how a player's finishing probability changes if her opponent can finish the leg in the next throw, compared to situations where her opponent cannot finish. The pressure from an opponent who can finish deteriorates performance among Youth players only. Youth players are 3.2 percentage points less likely to finish as compared to situations where their opponent cannot finish. In the other three samples, the average marginal effects are close to zero and statistically insignificant.

Situations where the opponent can finish consist of three rather different types of cases, where finishing requires either one, two or three darts. Finishing difficulty increases with this minimum number of darts that are required. Three-dart finishes are particularly difficult, and an opponent in such a position consequently poses relatively little threat. Model 3 therefore distinguishes between situations where the opponent needs one, two or three darts. With this more fine-grained approach, the effect of an opponent who can finish generally remains statistically insignificant for professional and amateur players, even if the opponent's finishing difficulty is relatively low because she can finish with a single dart.[6] Among Youth players the performance deterioration increases with the pressure. Compared to situations where the opponent cannot finish, Youth players are 2.0, 3.0, and 4.5 percentage points less likely to finish when their opponent needs three darts, two darts, or one dart, respectively.

For completeness, Model 4 re-estimates the effect of *Decisive leg* for the restricted samples. The average marginal effects now range between -0.6 and -5.9 percentage points, and are consistently smaller than those of Model 1. This difference can be attributed to selection effects: the omitted data most likely contained a disproportionate amount of observations from players who choked under the pressure of a decisive leg, and from situations with additional pressure because the opponent was closer to finishing.

Model 5 combines the pressure effects of decisive legs and opponents who can finish, and also includes the interaction of the two. The pressure on a player is presumably highest when the two conditions apply simultaneously. Table 3 presents their joint effect on performance, which is equal to the sum of the marginal effects of *Decisive leg*, *Opp. can finish* and their interaction. Amateur and youth players display sizeable choking effects: BICC, Super League and Youth players perform 5.8, 3.5 and 6.0 percentage points worse, respectively, in situations where both conditions apply than in situations where neither apply. The three differences are statistically significant (all $p < 0.001$). Scaled by the sample-specific proportion of one-dart finishes (see Table 1), the effect sizes translate into performance deteriorations of 12.3, 7.5 and 16.5 percent, respectively.

Model 6 similarly combines the two types of pressure effects, but distinguishes between situations where the opponent needs one, two, or three darts. Table 3 presents the joint effect sizes, which correspond to the difference in performance between situations where the leg is decisive and the opponent needs one, two or

[6] Deutscher et al. (2018) analyze a data set that exclusively consists of about one year of professional darts matches organized by the Professional Darts Cooperation. For situations where a player can finish with one dart, they similarly find no evidence that performance is affected by her opponent's finish opportunity.

Table 3: Joint effects of decisive leg and opponent close to finishing

	Marginal effect	z-value	p-value
Panel A: International			
1/2/3 darts	-0.007	-0.657	0.511
1 dart	-0.025	-1.813	0.070
2 darts	0.004	0.280	0.779
3 darts	0.018	0.864	0.387
Panel B: BICC			
1/2/3 darts	-0.058	-14.372	0.000
1 dart	-0.080	-16.279	0.000
2 darts	-0.044	-8.293	0.000
3 darts	-0.032	-4.599	0.000
Panel C: Super League			
1/2/3 darts	-0.035	-3.188	0.001
1 dart	-0.046	-3.236	0.001
2 darts	-0.017	-1.130	0.259
3 darts	-0.044	-2.215	0.027
Panel D: Youth			
1/2/3 darts	-0.060	-4.750	0.000
1 dart	-0.094	-6.130	0.000
2 darts	-0.039	-2.271	0.023
3 darts	-0.023	-1.034	0.301

Notes: The table reports the sum of the average marginal effects of *Decisive leg*, *Opp. can finish* (*with 1, 2, or 3 darts*) and the interaction of these two variables, according to Models 5 and 6 in Table 2. Underlying coefficients can be found in Table A2 in the Appendix.

three darts, and situations where the leg is not decisive and the opponent cannot finish in the next throw. In line with the previous results, BICC, Super League, and Youth players display significant choking under pressure at the end of a close match. As expected, these choking effects are largest when the opponent can secure the win with only one dart. In this extreme situation, BICC, Super League and Youth players perform 8.0, 4.6 and 9.4 percentage points worse, respectively. The corresponding scaled deteriorations are 16.9, 9.9 and 25.8 percent.

In the category of International matches, with relatively skilled and experienced players, there is no compelling evidence of choking in decisive legs where opponents are close to finishing. Based on Model 5, the overall decrease in performance equals an insignificant 0.7 percentage points. According to Model 6, International players are 2.5 points less likely to finish at the end of a close match when the opponent can secure the win with a single dart. Statistically, this difference is only marginally significant.

Note that when both types of incentive variables and their interaction are included, the marginal effects of *Decisive leg* are relatively close to zero as compared to those in Model 4. This is not surprising, because in Model 5 and Model 6 the marginal effects for this variable exclusively refer to situations where the player is significantly ahead in the leg: the player can finish with one dart, while the opponent cannot finish in the next throw. In such situations, players do not have a particularly strong incentive to perform well. Furthermore, the marginal effects of the opponent's finish opportunity in Model 5 and Model 6 are similar to those in Model 2 and Model 3, which makes sense because decisive legs are only a fraction of the total number of legs. Last, the interaction effects are always negative and sometimes statistically significant, which suggests that the adverse impact of a decisive leg and that of an opponent being close to finishing amplify each other.

One possible concern about the previous results is that variation in one-dart finishing difficulty is not accounted for. Compare, for example, a player with 2 and a player with 40 points remaining. Both can finish with one dart (by hitting double 1 and double 20, respectively). If the player with 2 points misses and instead throws 1 point, her throw is over. If the player with 40 points misses and instead throws 20 points, she still has the opportunity to finish with her second or third dart (e.g., by hitting double 10). We can control for finishing difficulty by expanding the regression models with fixed effects for the number of points that the player has left at the start of her throw. Table A3 in the Appendix shows that including points-left fixed effects does not materially affect the results.

Another possible concern relates to our treatment of set-format matches and the relatively weak evidence of choking for International matches. Throughout our analyses, we have treated sets as separate matches, which especially makes sense if each set is played by a different player of a team. In international tournaments, however, set-format matches are generally entirely played between the same two players, and winning a set is therefore substantially less important than winning the match. Treating sets as matches may consequently have diluted possible evidence of choking effects at truly decisive moments in this category of data. Table A4 in the Appendix shows the results for the International sample after excluding all set-format matches. Notwithstanding the sensitivity of some average marginal effects, all previous conclusions remain the same.

Table 4: Regression results for the number of points thrown

	Model 1: Throw 1	Model 2: Throw 2	Model 3: Throw 3	Model 4: Throws 1-3
Panel A: International				
Decisive leg	-0.246	-0.992^{**}	-0.432	-0.533^{*}
	(0.485)	(0.486)	(0.484)	(0.279)
Player-match fixed effects	Yes	Yes	Yes	Yes
Throw fixed effects	-	-	-	Yes
Polynomial throw number (order)	9	5	9	7
Observations	170,892	170,892	170,884	512,668
Adjusted R^2	0.234	0.238	0.232	0.241
Panel B: BICC				
Decisive leg	-1.732^{***}	-1.943^{***}	-1.922^{***}	-1.735^{***}
	(0.205)	(0.206)	(0.206)	(0.118)
Player-match fixed effects	Yes	Yes	Yes	Yes
Throw fixed effects	-	-	-	Yes
Polynomial throw number (order)	9	9	9	9
Observations	764,390	764,390	764,384	2,293,164
Adjusted R^2	0.129	0.130	0.131	0.134
Panel C: Super League				
Decisive leg	-1.722^{***}	-0.661	-0.347	-0.948^{***}
	(0.544)	(0.542)	(0.556)	(0.315)
Player-match fixed effects	Yes	Yes	Yes	Yes
Throw fixed effects	-	-	-	Yes
Polynomial throw number (order)	5	4	9	5
Observations	102,142	102,142	102,132	306,416
Adjusted R^2	0.123	0.122	0.113	0.123
Panel D: Youth				
Decisive leg	-0.306	-1.035	-0.793	-0.791^{**}
	(0.685)	(0.687)	(0.691)	(0.379)
Player-match fixed effects	Yes	Yes	Yes	Yes
Throw fixed effects	-	-	-	Yes
Polynomial throw number (order)	6	4	9	2
Observations	40,106	40,106	40,092	120,304
Adjusted R^2	0.139	0.147	0.144	0.151

Notes: The table reports the coefficients resulting from OLS regression analyses of the number of points thrown in the first, second, and/or third throw of a leg. The regression specifications include a polynomial of order n for the player's prior number of throws in the match, where n is chosen to maximize the adjusted R-squared. Model 4 includes throw fixed effects to control for differences in the average across throws. Other definitions are as in Table 2.

3.2 Points Thrown

We now turn to the early stage of legs, to examine how point-throwing performance is affected if both players can win the match by winning the current leg. As explained in the previous section, such legs are highly consequential because poor performance can irreversibly result in losing the match, whereas strong performance can secure the win. We consider each player's first three throws in every leg only.[7] Strategy plays no role in these first few throws, because any approach other than trying to

[7] In the exceptional case where the opponent started the leg and won it in three throws, we can only consider a player's first two throws.

throw as many points as possible is sub-optimal.[8] In contrast, in subsequent throws a player may try to maneuver herself into a favorable finishing position, for example by trying to reach a remaining score of 40.[9] As in the previous analysis, we control for skill differences between players and through time by including player-match fixed effects, and for possible warming-up and fatigue effects within a match by including a polynomial of order n for the player's number of throws in the match prior to the current throw, where the value of n is chosen to maximize the adjusted R-squared.

Table 4 presents the OLS regression results. The first three models show how the number of points thrown is affected if both players can win the match by winning the leg, for each of the first three throws separately. The coefficients are consistently negative, but not always statistically significant. Model 4 shows the results for the first three throws combined. For completeness, this model includes throw fixed effects to control for small differences in the average performance across throws. Again, there is clear evidence of choking under pressure. In each of the four samples, throwing performance worsens significantly when the leg is decisive. The effect size is largest for BICC, and smallest (and only marginally significant) for International players. Scaled by the average number of points per throw in the first three throws (see Table 1), the coefficients mean that players' performance deteriorates by 2.5 and 0.7 percent in these two samples. For Super League and Youth, the relative performance decreases are 1.4 and 1.3 percent, respectively.

Following our approach in the previous section, we have also conducted the anal-

[8] In theory, some slight strategic adjustments are conceivable. To maximize the expected number of points, a high-skilled player should aim at triple 20 and a lower-skilled player should aim at triple 19 (Tibshirani et al., 2011). However, when playing against a substantially lower-skilled player, a high-skilled player may want to aim at triple 19 to reduce variance and thereby reduce the small probability of losing due to a streak of bad luck. Similarly, when playing against a substantially higher-skilled player, a low-skilled player may want to aim at triple 20 to increase variance in the hope of being lucky. In practice, however, players tend to aim at triple 20 regardless of their skill. Note that such strategic considerations should be independent of risk preferences for any player who wants to maximize her winning probability, and, more importantly, that there is no reason to suspect that such strategic adjustments would vary systematically between decisive and non-decisive legs.

[9] Technically, players may want to aim for less than the maximum number of points in throw three already if they did exceptionally well in the first two throws. Such situations are, however, extremely rare. Furthermore, our strategy of using the first three throws and excluding all subsequent throws is empirically supported by the average number of points: this statistic is stable across throw one, two and three, and decreases from throw four onwards.

yses using International leg-format matches only, to alleviate the concern that set-format matches diluted the possible evidence of choking among professional players. Table A5 in the Appendix gives the results. For the first three throws combined, the choking effect is slightly more pronounced as compared to the original results, but the effect size remains relatively small.

4 Conclusions and Discussion

The present paper examines how naturally-occurring within-match variation in the incentive to perform well impacts performance in darts. The game of darts offers an attractive naturally-occurring research setting, because performance can be observed at the individual level and without obscuring effects of risk considerations and behavior of others. Like many other real-life activities, playing darts is neither entirely physical nor entirely mental, but combines elements of both. We use four large data sets that cover the matches of different categories of players, ranging from amateur youth players to professional adults. We analyze how players perform in the early stage of a leg, when they have to throw as many points as possible, and in the final stage of a leg, when they have to finish by throwing a so-called 'double'.

Among youth and amateur players, performance deteriorates substantially if a player and her opponent are close to winning the match. More specifically, if both can win the match with just one dart, a player is 5-9 percentage points less likely to finish as compared to situations that do not bring this additional pressure. Relative to players' normal performance, these effect sizes mean that performance worsens by 10-26 percent. Such choking under pressure also occurs at the start of decisive legs, albeit to a weaker extent. When both players can win the match by winning the leg, youth and amateur players throw 1.3-2.5 percent fewer points in their first three throws than they normally do.

Professional players appear less susceptible of choking under the high pressure of decisive legs than youth and amateur players: there is limited evidence of deteriorating finishing performance, and for the number of points thrown the adverse impact is relatively small. The different findings for this category suggest that choking under pressure can be mitigated by training and decreases with experience. At the same time, however, because the ability to deal with pressure is a competitive advantage, the low sensitivity of professional players can also be the result of a selection effect. Most of the earlier studies that have found evidence for choking under pressure in sports focused on professionals. Our analysis uses a broader set of players, and suggests that choking under pressure is (even) more of a concern for lower-skilled individuals.

Our results speak to a growing literature on the limits of increasing incentives as a recipe for better performance. Conflicting with the classical prediction in economics that higher incentives improve performance, darts players display clear symptoms of choking under pressure. Our conjecture is that the additional pressure leads players to consciously think about their actions, which disrupts the normal automatic processing of the well-trained task of throwing darts.

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Appendix

Table A1: Coefficient estimates underlying the average marginal effects in Table 2

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Panel A: International						
Decisive leg	-0.128^{**}			-0.030	0.138	0.137
	(0.053)			(0.070)	(0.219)	(0.219)
Opp. can finish		0.009			0.015	
		(0.041)			(0.041)	
Opp. can finish with 1 dart			-0.025			-0.015
			(0.045)			(0.045)
Opp. can finish with 2 darts			0.051			0.056
			(0.045)			(0.046)
Opp. can finish with 3 darts			-0.003			-0.002
			(0.049)			(0.050)
Decisive leg x Opp. can finish					-0.187	
					(0.231)	
Decisive leg x Opp. can finish with 1 dart						-0.251
						(0.244)
Decisive leg x Opp. can finish with 2 darts						-0.171
						(0.251)
Decisive leg x Opp. can finish with 3 darts						-0.041
						(0.278)
Panel B: BICC						
Decisive leg	-0.395^{***}			-0.291^{***}	-0.036	-0.039
	(0.020)			(0.027)	(0.068)	(0.068)
Opp. can finish		0.015			0.035^{*}	
		(0.019)			(0.020)	
Opp. can finish with 1 dart			0.007			0.036^{*}
			(0.021)			(0.021)
Opp. can finish with 2 darts			0.017			0.030
			(0.021)			(0.022)
Opp. can finish with 3 darts			0.029			0.039
			(0.023)			(0.024)
Decisive leg x Opp. can finish					-0.286^{***}	
					(0.070)	
Decisive leg x Opp. can finish with 1 dart						-0.393^{***}
						(0.074)
Decisive leg x Opp. can finish with 2 darts						-0.206^{***}
						(0.076)
Decisive leg x Opp. can finish with 3 darts						-0.158^{*}
						(0.085)

Notes: The table reports the coefficient estimates resulting from logit regression analyses of finishing performance across throws where the player can finish the leg with one dart. Model 1 uses all one-dart finish opportunities, whereas Models 2-6 use players' first one-dart finish opportunity in a leg only. Definitions are as in Table 2.

Table A1: Continued

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Panel C: Super League						
Decisive leg	-0.176^{***}			-0.172^{**}	-0.004	-0.007
	(0.052)			(0.071)	(0.185)	(0.185)
Opp. can finish		0.013			0.025	
		(0.048)			(0.049)	
Opp. can finish with 1 dart			0.020			0.035
			(0.053)			(0.054)
Opp. can finish with 2 darts			-0.014			-0.011
			(0.053)			(0.054)
Opp. can finish with 3 darts			0.045			0.062
			(0.058)			(0.059)
Decisive leg x Opp. can finish					-0.190	
					(0.194)	
Decisive leg x Opp. can finish with 1 dart						-0.254
						(0.207)
Decisive leg x Opp. can finish with 2 darts						-0.064
						(0.212)
Decisive leg x Opp. can finish with 3 darts						-0.272
						(0.239)
Panel D: Youth						
Decisive leg	-0.278^{***}			-0.149	0.034	0.038
	(0.064)			(0.099)	(0.251)	(0.251)
Opp. can finish		-0.169^{**}			-0.148^{*}	
		(0.079)			(0.084)	
Opp. can finish with 1 dart			-0.238^{***}			-0.205^{**}
			(0.091)			(0.096)
Opp. can finish with 2 darts			-0.159^{*}			-0.159^{*}
			(0.089)			(0.094)
Opp. can finish with 3 darts			-0.106			-0.104
			(0.095)			(0.100)
Decisive leg x Opp. can finish					-0.209	
					(0.263)	
Decisive leg x Opp. can finish with 1 dart						-0.352
						(0.281)
Decisive leg x Opp. can finish with 2 darts						-0.085
						(0.290)
Decisive leg x Opp. can finish with 3 darts						-0.055
						(0.327)

Table A2: Coefficient estimates underlying the average marginal effects in Table 3

	Coefficient	z-value	p-value
Panel A: International			
1/2/3 darts	-0.034	-0.413	0.680
1 dart	-0.129	-1.136	0.256
2 darts	0.022	0.175	0.861
3 darts	0.094	0.544	0.587
Panel B: BICC			
1/2/3 darts	-0.287	-8.659	0.000
1 dart	-0.396	-9.745	0.000
2 darts	-0.215	-4.988	0.000
3 darts	-0.158	-2.761	0.006
Panel C: Super League			
1/2/3 darts	-0.170	-1.964	0.050
1 dart	-0.227	-2.000	0.046
2 darts	-0.083	-0.693	0.488
3 darts	-0.217	-1.355	0.175
Panel D: Youth			
1/2/3 darts	-0.323	-2.529	0.011
1 dart	-0.519	-3.237	0.001
2 darts	-0.206	-1.204	0.228
3 darts	-0.121	-0.541	0.588

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Table A3: Regression results for the likelihood of finishing, controlling for points-left fixed effects

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Panel A: International						
Decisive leg	-0.021^{**}			-0.008	0.022	0.022
	(0.008)			(0.008)	(0.026)	(0.026)
Opp. can finish		0.002			0.003	
		(0.005)			(0.005)	
Opp. can finish with 1 dart			-0.003			-0.001
			(0.005)			(0.006)
Opp. can finish with 2 darts			0.010^{*}			0.012^{**}
			(0.005)			(0.006)
Opp. can finish with 3 darts			-0.002			-0.002
			(0.006)			(0.006)
Decisive leg x Opp. can finish					-0.033	
					(0.028)	
Decisive leg x Opp. can finish with 1 dart						-0.044
						(0.029)
Decisive leg x Opp. can finish with 2 darts						-0.033
						(0.030)
Decisive leg x Opp. can finish with 3 darts						-0.005
						(0.033)
Data	All	First only	First only	First only	First only	First only
Player-match fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Points-left fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Polynomial throw number (order)	3	3	3	3	3	3
McFadden pseudo R-squared	0.151	0.094	0.094	0.094	0.094	0.094
Observations	111,241	68,547	68,547	68,547	68,547	68,547
Effective observations	84,994	37,837	37,837	37,837	37,837	37,837
Panel B: BICC						
Decisive leg	-0.072^{***}			-0.057^{***}	-0.007	-0.008
	(0.003)			(0.003)	(0.008)	(0.008)
Opp. can finish		0.005^{**}			0.010^{***}	
		(0.002)			(0.003)	
Opp. can finish with 1 dart			0.005^{**}			0.011^{***}
			(0.003)			(0.003)
Opp. can finish with 2 darts			0.005^{**}			0.008^{***}
			(0.003)			(0.003)
Opp. can finish with 3 darts			0.006^{**}			0.008^{***}
			(0.003)			(0.003)
Decisive leg x Opp. can finish					-0.056^{***}	
					(0.008)	
Decisive leg x Opp. can finish with 1 dart						-0.076^{***}
						(0.009)
Decisive leg x Opp. can finish with 2 darts						-0.041^{***}
						(0.009)
Decisive leg x Opp. can finish with 3 darts						-0.030^{***}
						(0.010)
Data	All	First only	First only	First only	First only	First only
Player-match fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Points-left fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Polynomial throw number (order)	4	3	3	3	3	3
McFadden pseudo R-squared	0.135	0.079	0.079	0.080	0.080	0.080
Observations	587,876	345,416	345,416	345,416	345,416	345,416
Effective observations	463,690	193,135	193,135	193,135	193,135	193,135

Notes: The table reports the average marginal effects resulting from logit regression analyses of finishing performance across throws where the player can finish the leg with one dart. Model 1 uses all one-dart finish opportunities, whereas Models 2-6 use players' first one-dart finish opportunity in a leg only. Definitions are as in Table 2. The regression specifications now in addition include points-left fixed effects.

Table A3: Continued

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Panel C: Super League						
Decisive leg	-0.032^{***}			-0.036^{***}	-0.002	-0.003
	(0.009)			(0.009)	(0.023)	(0.023)
Opp. can finish		0.003			0.006	
		(0.006)			(0.006)	
Opp. can finish with 1 dart			0.006			0.009
			(0.007)			(0.007)
Opp. can finish with 2 darts			-0.003			-0.003
			(0.007)			(0.007)
Opp. can finish with 3 darts			0.009			0.012
			(0.007)			(0.008)
Decisive leg x Opp. can finish					-0.038	
					(0.024)	
Decisive leg x Opp. can finish with 1 dart						-0.053^{**}
						(0.026)
Decisive leg x Opp. can finish with 2 darts						-0.014
						(0.026)
Decisive leg x Opp. can finish with 3 darts						-0.048
						(0.030)
Data	All	First only	First only	First only	First only	First only
Player-match fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Points-left fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Polynomial throw number (order)	2	3	3	3	3	3
McFadden pseudo R-squared	0.139	0.085	0.085	0.085	0.085	0.085
Observations	81,385	46,518	46,518	46,518	46,518	46,518
Effective observations	65,063	26,536	26,536	26,536	26,536	26,536
Panel D: Youth						
Decisive leg	-0.040^{***}			-0.028^{***}	0.007	0.006
	(0.010)			(0.010)	(0.026)	(0.025)
Opp. can finish		-0.031^{***}			-0.027^{***}	
		(0.009)			(0.009)	
Opp. can finish with 1 dart			-0.042^{***}			-0.034^{***}
			(0.010)			(0.010)
Opp. can finish with 2 darts			-0.029^{***}			-0.028^{***}
			(0.009)			(0.010)
Opp. can finish with 3 darts			-0.021^{**}			-0.020^{**}
			(0.010)			(0.010)
Decisive leg x Opp. can finish					-0.040	
					(0.026)	
Decisive leg x Opp. can finish with 1 dart						-0.068^{**}
						(0.028)
Decisive leg x Opp. can finish with 2 darts						-0.016
						(0.029)
Decisive leg x Opp. can finish with 3 darts						-0.008
						(0.033)
Data	All	First only	First only	First only	First only	First only
Player-match fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Points-left fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Polynomial throw number (order)	3	3	3	3	3	3
McFadden pseudo R-squared	0.151	0.074	0.074	0.073	0.074	0.075
Observations	45,893	20,563	20,563	20,563	20,563	20,563
Effective observations	36,385	9,322	9,322	9,322	9,322	9,322

Table A4: Regression results for the likelihood of finishing, using leg-format International matches only

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Decisive leg	-0.021^{**}			0.004	0.060^{**}	0.060^{*}
	(0.010)			(0.010)	(0.030)	(0.030)
Opp. can finish		0.002			0.004	
		(0.005)			(0.005)	
Opp. can finish with 1 dart			-0.005			-0.002
			(0.006)			(0.006)
Opp. can finish with 2 darts			0.013^{**}			0.014^{**}
			(0.006)			(0.006)
Opp. can finish with 3 darts			-0.002			-0.001
			(0.007)			(0.007)
Decisive leg x Opp. can finish					-0.063^{*}	
					(0.033)	
Decisive leg x Opp. can finish with 1 dart						-0.077^{**}
						(0.034)
Decisive leg x Opp. can finish with 2 darts						-0.058
						(0.036)
Decisive leg x Opp. can finish with 3 darts						-0.031
						(0.040)
Data	All	First only	First only	First only	First only	First only
Player-match fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Polynomial throw number (order)	3	1	1	1	1	1
McFadden pseudo R-squared	0.142	0.088	0.088	0.088	0.088	0.089
Observations	100,292	59,466	59,466	59,466	59,466	59,466
Effective observations	79,565	34,688	34,688	34,688	34,688	34,688

Notes: The table reports the average marginal effects resulting from logit regression analyses of finishing performance across throws where the player can finish the leg with one dart, for International matches with a leg format only. Model 1 uses all one-dart finish opportunities, whereas Models 2-6 use players' first one-dart finish opportunity in a leg only. Definitions are as in Table 2.

Table A5: Regression results for the number of points thrown, using leg-format International matches only

	Model 1: Throw 1	Model 2: Throw 2	Model 3: Throw 3	Model 4: Throws 1-3
Decisive leg	-0.277	-0.803	-1.077^{*}	-0.711^{**}
	(0.611)	(0.612)	(0.609)	(0.350)
Player-match fixed effects	Yes	Yes	Yes	Yes
Throw fixed effects	-	-	-	Yes
Polynomial throw number (order)	7	4	3	7
Observations	142,838	142,838	142,831	428,507
Adjusted R-squared	0.240	0.242	0.236	0.250

Notes: The table reports the coefficients resulting from OLS regression analyses of the number of points thrown in the first, second, and/or third throw of a leg, for International matches with a leg format only. Definitions are as in Table 4.