STOR 538: Sports Analytics

501 DARTS

ANALYZING SUCCESS THROUGH PLAYER DYNAMICS

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INTRODUCTION

In the thrilling realm of professional darts, 501 Darts stands out as one of the most prevalent and captivating games. As players step up to the oche in the prestigious PDC 2024 World Championship, they engage in a test of skill, strategy, and nerves within the framework of this iconic game. In 501 Darts, each player commences with a score of 501 points and wields three darts per turn to make their mark on the board. The dartboard, adorned with 20 distinct score zones, offers opportunities for players to accrue points. The outer ring doubles the score zone value, while the inner ring triples it. Additionally, the central green zone awards 25 points, while the bullseye at the heart of the board boasts a hefty 50 points.

Alternating turns, players meticulously aim and release their darts, deducting the points scored from their initial 501 total. The objective? To be the first to reduce their score to zero, thereby claiming victory in the leg. While the exact number of turns per leg may vary, players typically engage in 4-7 turns per leg, intensifying the suspense with each dart thrown. Within the broader context of a match, legs serve as the building blocks of competition. A match is segmented into a predetermined number of legs, usually between 8-11, with the player required to clinch the majority of legs to emerge victorious overall.

However, achieving victory in a leg isn't merely about reaching zero points. Players must adhere to the principle of "doubling out" or finishing with a bullseye to seal the deal. Doubling out necessitates landing a dart in the double zone that reduces the player's score to zero, exemplified by targeting the double 12 when sitting on 24 points. Notably, a player must exercise caution, as surpassing zero points halts their turn, leaving them stranded at their previous score.

Purpose

Our group has opted to examine 501 Darts in order to ascertain the significant factors that contribute to success. We speculated that players with more consistent throwing form would be more successful in winning legs, winning sets, and consequently going farther in the tournament. This consistency in throwing form is measured by the variability of Time_Between_Throws_AVG for each player across different sets and legs. Furthermore, with the PDC Championship tournament being the professional debut of stand-out Luke Litter, we

looked into his impact on overall predictive statistics. Our overarching objective is to discern which facets of the game have the greatest impact on players' success and to investigate the interplay between various variables.

Methodology

Our team collected data by viewing the Professional Darts Competition 2024 matches on YouTube and collecting data through the live scores PDC website. To ensure consistency in data collection, we discussed how to collect each variable before starting our data collection. The data was recorded leg by leg in a communal Google Sheets. This tournament was selected due to its prominence on the annual darts calendar, featuring the top 24 darts players competing over the weekend of December 15 to January 3 in the Alexandra Palace in North London. The dataset encompasses 12 matches with a total of 554 observations, with each match involving two players facing off against each other. Each of the members in our group was responsible for watching specific games throughout the PDC Tournament and collecting the respective data necessary for those rounds.

Data Preview

Tournament_Stage	Set	Leg	Player	World_Rank	Age	Time_Between_Throws_AVG	Three_Drt_AVG	End_Double_Ptg	Leg_Winner	Set_Winner	Game_Winner
Finale	1	1	Luke Littler	164	16	2.1508	83.50	100	Luke Littler	Luke Littler	Luke Humphries
Finale	1	1	Luke Humphries	3	28	2.0770	96.20	0	Luke Littler	Luke Littler	Luke Humphries
Finale	1	2	Luke Littler	164	16	1.8863	78.25	0	Luke Humphries	Luke Humphries	Luke Humphries
Finale	1	2	Luke Humphries	3	28	2.3630	100.20	50	Luke Humphries	Luke Humphries	Luke Humphries
Finale	1	3	Luke Littler	164	16	1.9042	79.50	0	Luke Humphries	Luke Humphries	Luke Humphries
Finale	1	3	Luke Humphries	3	28	2.2150	83.50	100	Luke Humphries	Luke Humphries	Luke Humphries

This preview of our dataset depicts data for the first three legs of the Finale. Data is per leg per player, yielding two rows for each leg. While this may seem unconventional, the level of data collection for this project allows for granular analysis. The following variables were

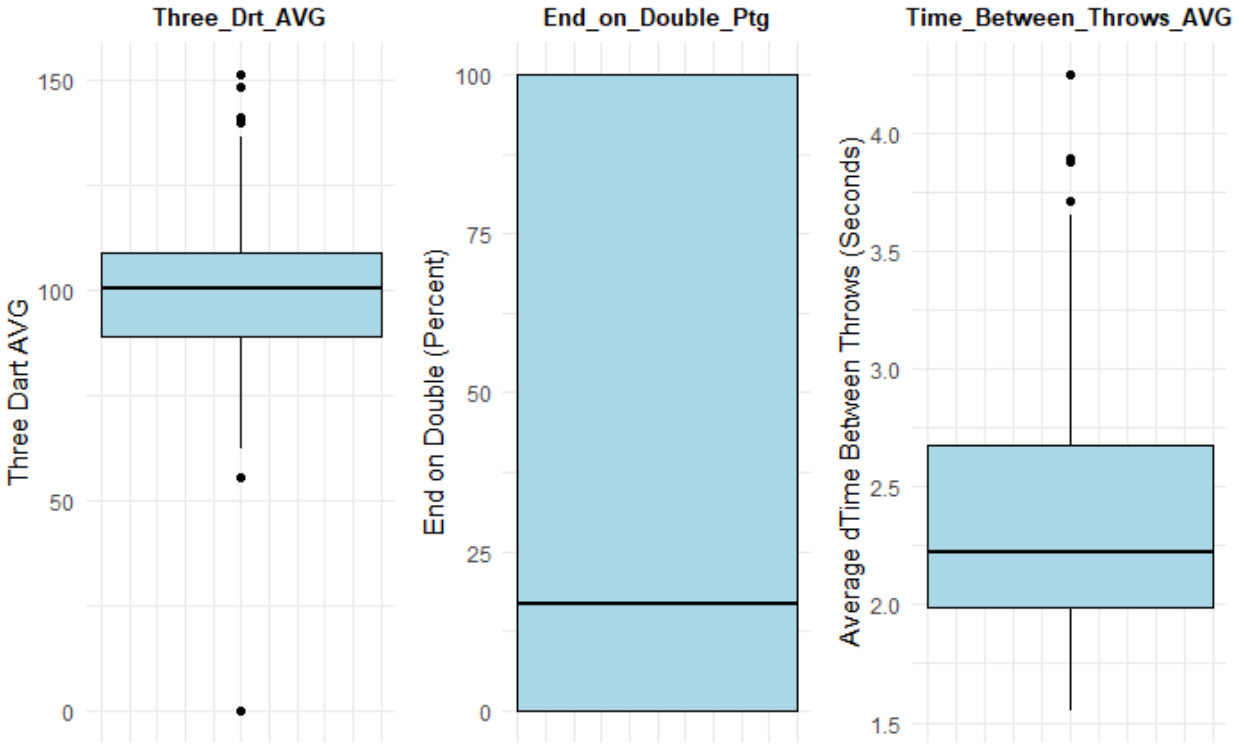
collected by hand: Set, Leg, Time_Between_Throws_AVG, Three_Drt_AVG, End_Double_Ptg, Set_Winner, and Leg_Winner. Below is a description of each variable in the data.

Description of Variables

Variable	Description
Tournament_Stage	The stage of the tournament that was played (Finals, Semi-finals, or Lower Stages.)
Set	The set number being observed.
Leg	The leg number being observed.
Player	The player observed during the selected leg.
World_Rank	The observed player's world ranking before this tournament. For example, the player with World_Rank=1 won the PDC Tournament last year. These rankings were found on the official PDC darts rankings website.
Age	The observed player's age in years. The age of the player was stated at the beginning of each match.
Time_Between_Throws_AVG (in seconds)	The average number of seconds it took to throw the first dart to reach the board until the last one per leg. This was calculated by adding up all the times each player spent per turn and divided by total number of turns for each leg. Times were recorded with the timer lap feature on an iPhone.
Three_Drt_AVG (3 Dart Point Average)	This was calculated by dividing a player's remaining leg score (from 501 to 0) by their number of throws, then multiplying by 3 to obtain a scaled Three Dart average.
End_Double_Ptg (Final Doubles Hit Percentage)	The number of times the player hit a double to end the leg divided by the number of times they had an opportunity to hit a double to win the leg. A value of 0 meant the player did not have an opportunity to win the leg with a double.
Leg Winner	The winner of the leg being played.
Set Winner	The winner of the set being played.
Game Winner	The winner of the game being played.

SUMMARY

Preliminary Summary of Quantitative Variables



Three_Drt_AVG		End_Double_Ptg		Time_Between_Throws_AVG	
Mean	99.69	Mean	39.47	Mean	2.34
Std.Dev	16.27	Std.Dev	43.73	Std.Dev	0.47
Min	0.00	Min	0.00	Min	1.55
Q1	88.75	Q1	0.00	Q1	1.98
Median	100.20	Median	16.67	Median	2.22
Q3	109.00	Q3	100.00	Q3	2.67
Max	151.33	Max	100.00	Max	4.25

Above is a numeric summary of our quantitative variables of interest. The variability in Three_Drt_AVG can be accounted for when considering variability in strategy for different game situations, and accuracy in hitting the intended spot on the board. End_Double_Ptg is considerably skewed with many players being able to end on a double with their first attempt. Time_Between_Throws_AVG varies mainly in the 2-3.5 second range, but the right tailed skew accounts for certain throws where a player takes more time to focus on accuracy.

Preliminary Summary of Categorical Variables

Set_Winner	Number_of_Observations	Relative_Frequency
Brendan Dolan	30	0.0541516
Chris Dobey	62	0.1119134
Dave Chisnall	10	0.0180505
Gary Anderson	26	0.0469314
Luke Humphries	142	0.2563177
Luke Littler	132	0.2382671
Michael van Gerwen	36	0.0649819
Raymond van Barneveld	10	0.0180505
Rob Cross	106	0.1913357

Leg_Winner	Number_of_Observations	Relative_Frequency
Brendan Dolan	32	0.0577617
Chris Dobey	64	0.1155235
Dave Chisnall	18	0.0324910
Gary Anderson	24	0.0433213
Jonny Clayton	8	0.0144404
Luke Humphries	122	0.2202166
Luke Littler	118	0.2129964
Michael Smith	8	0.0144404
Michael van Gerwen	24	0.0433213
Raymond van Barneveld	18	0.0324910
Rob Cross	94	0.1696751
Scott Williams	12	0.0216606
Stephen Bunting	12	0.0216606

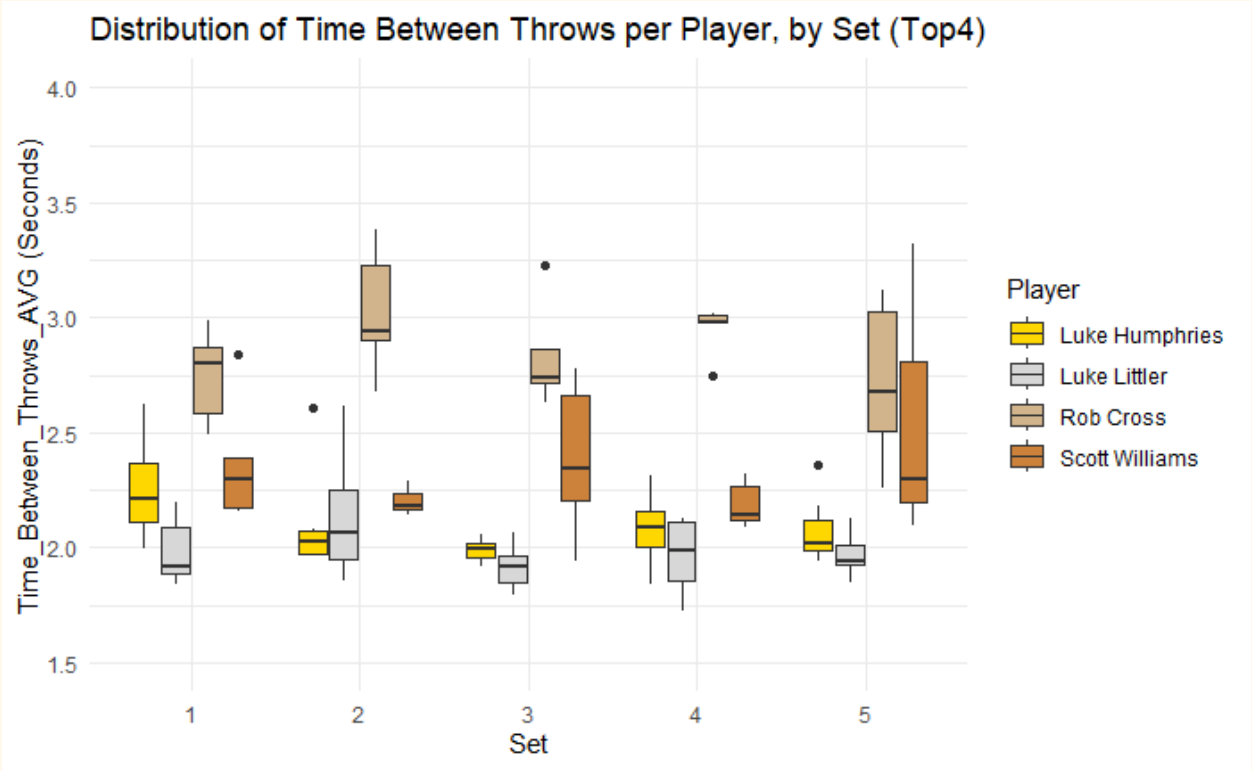
Above is a summary of some of our categorical variables of interest. The number of observations for Set_Winner depends on player performance per match and success in the PDC Tournament, while Leg_Winner depends on player performance per set and tournament success. For the predictive section of this analysis, understanding the distribution of these variables is imperative to insightful modeling.

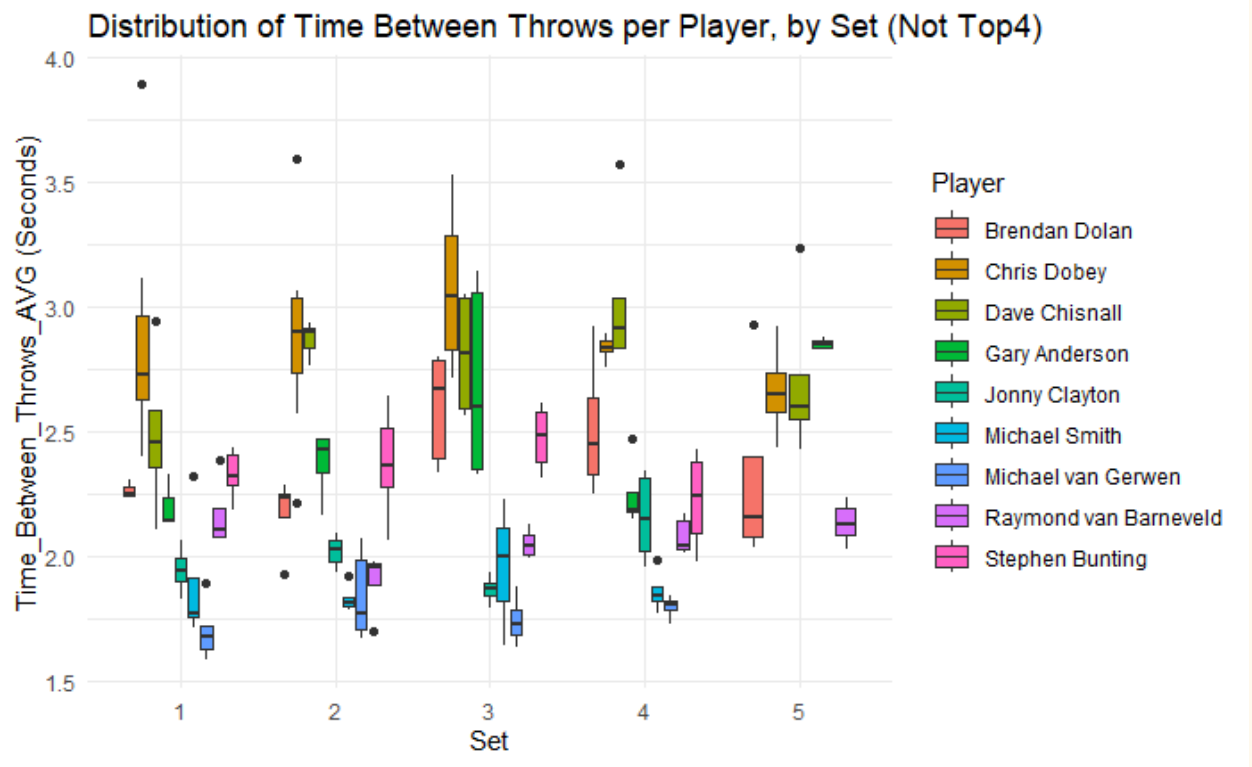
Variability Analysis in Time_Between_Throws_AVG

The following figures (figure 1, 2, 3, and 4) show the per-player distribution of Time_Between_Throws_AVG (in seconds) across sets (figure 1 and 2) and across legs (figure 3 and 4) with boxplots. Figures 1 and 3 display the Top 4 players (Semi-Finalists and Finalists) with the players color-coded by success (Gold is 1st Place, Silver 2nd, Bronze 3rd and 4th). Figures 2 and 4 display the rest of the field with arbitrary colors per player. The following two pages contain figures 1 through 4.

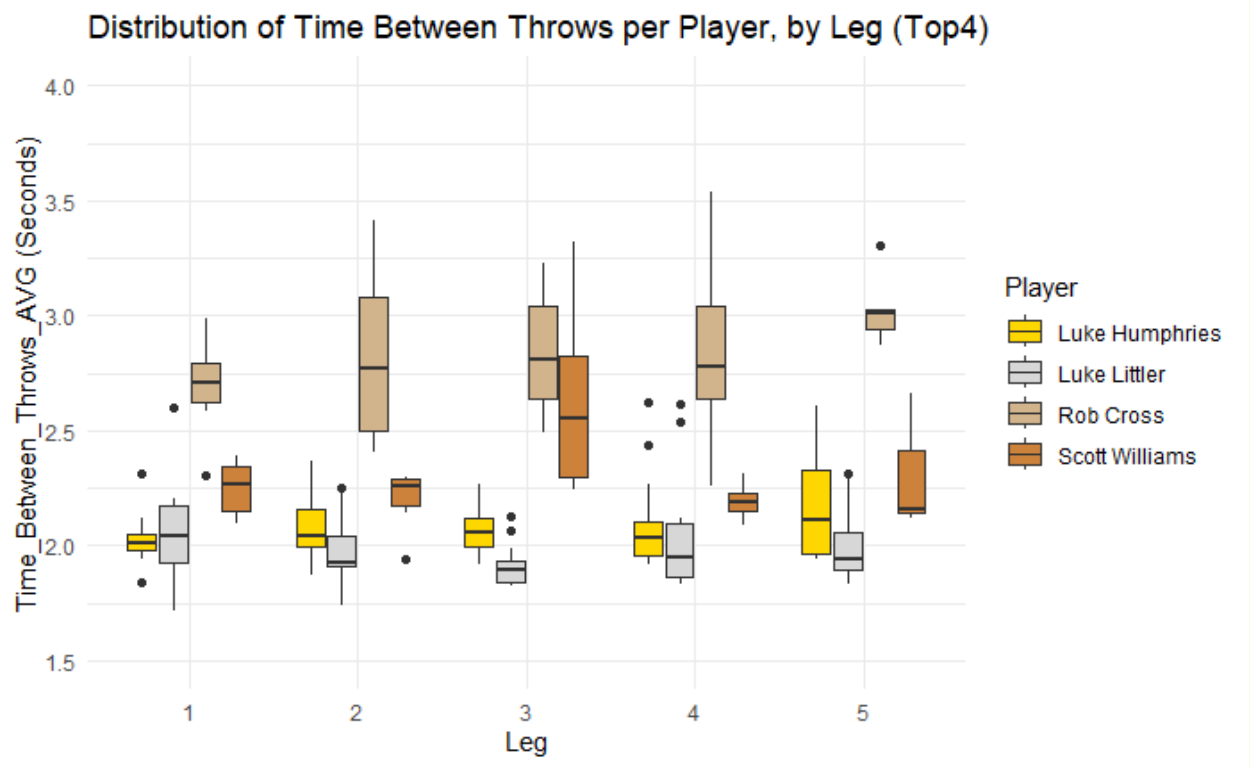
The following tables on page 9 (table 1 and 2) show the linear model feature selection results, AIC, and Adjusted R-squared for each linear model developed.

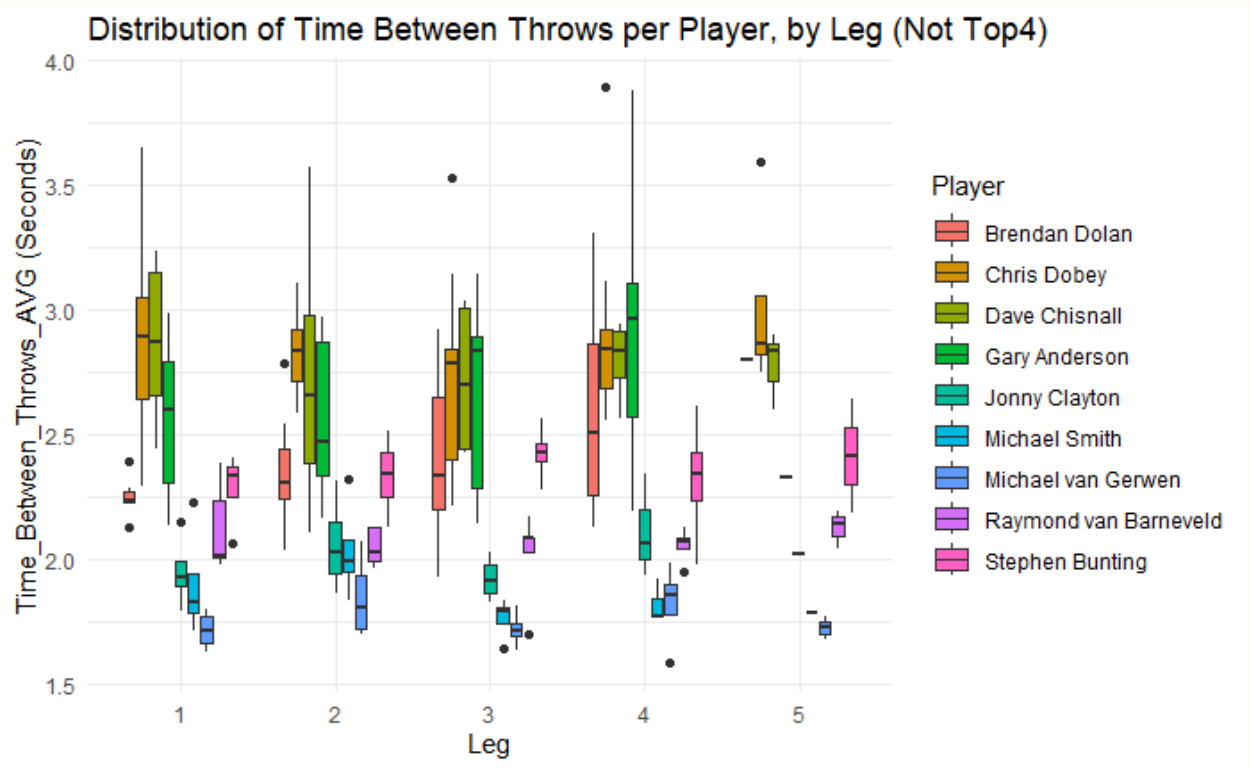
Set Variability of Time Between Throws by Player (Figures 1 and 2)





Leg Variability of Time Between Throws by Player (Figures 3 and 4)





Linear Model Feature Selection Results (Table 1)

Formula	AIC	Adjusted R-Squared
Leg Winner = -1.478 + 0.6384*Time_Between_Throws_AVG + 0.005988*World_Rank + 0.01247*Age + 0.008579*Three_Drt_AVG + 0.01437*End_Double_Ptg - 0.002802*Time_Between_Throws_AVG*World_Rank - 0.005347*Time_Between_Throws_AVG*Age - 0.003331*Time_Between_Throws_AVG*Three_Drt_AVG - 0.00003889*Three_Drt_AVG*End_Double_Ptg	9.19	0.8272
Set Winner = 0.3854283 - 0.000819*World_Rank - 0.0043978*Age + 0.9660998*Leg_Winner - 0.0120891*Age*Leg_Winner	-4.04	0.3967

Linear Model Feature Selection Results (Table 2)

Formula	AIC	Adjusted R-Squared
Leg Winner = -1.464 + 0.5927*Time_Between_Throws_AVG + 0.0008898*World_Rank + 0.01842*Age + 0.006317*Three_Drt_AVG + 0.0145*End_Double_Ptg + 0.2454*Set_Winner - 0.00743*Time_Between_Throws_AVG*Age - 0.0247*Time_Between_Throws_AVG*Three_Drt_AVG - 0.00003279*Three_Drt_AVG*End_Double_Ptg - 0.003271*World_Rank*Set_Winner - 0.002462*End_Double_Ptg*Set_Winner	9.37	0.8454
Set Winner = 0.9986776 + 0.1225034*Time_Between_Throws_AVG - 0.056219*World_Rank - 0.0294701*Age + 0.5926293*Leg_Winner + 0.0014017*World_Rank*Age + 0.0001089*World_Rank*End_Double*Ptg -0.0169069*World_Rank*Leg_Winner	5.05	0.3766

INSIGHTS

Time Between Throws Variability Analysis

The different sets of graphics represent player consistency in Time_Between_Throw_AVG across different granularities. Figures 1 and 2 provide insights into long-term fatigue and pressure over multiple sets, whereas figures 3 and 4 depict short-term fatigue and pressure within individual legs. Regardless of the definition of stress, it is reasonable to assume that legs with higher numbers and/or sets could impose greater pressure on players, given their greater influence on the match outcome. Consistency in Time_Between_Throws is our metric for measuring consistent form in a player's throws across these varying levels of stress and fatigue.

Figures 1 and 2 differentiate the Top 4 players (Semi-Finalists and Finalists) from the rest of the field, displaying a visual analysis of Time_Between_Throws_AVG variability per set. In comparison to their counterparts, the top two players (Littler and Humphries) demonstrate exceptional consistency in median values and low interquartile ranges for Time_Between_Throws_AVG across sets. This suggests that these players possess remarkable levels of long-term stamina and focus, enabling them to perform consistently even in high-pressure situations, potentially deciding the outcome of crucial sets.

Figures 3 and 4 distinguish the Top 4 players from the remaining contestants in the variability of Time_Between_Throws_AVG per leg. Three of the Top 4 players (Littler, Humphries, and Williams) exhibit noticeably narrower interquartile ranges (IQR) per leg compared to many players in figure 2. Outside the Top 4, three players demonstrate consistently low IQR values across all legs: Clayton (World_Rank = 9), Smith (World_Rank = 1), and van Gerwen (World_Rank = 2). The World_Rank of these players is indicative of their success in the previous PDC Tournament. The sustained low IQR values in Time_Between_Throws_AVG across all legs suggests the above players have exceptional short-term focus and consistency in form across legs. The success of these players in the previous two tournaments combined with their consistency in form suggests that Time_Between_Throw_AVG across legs plays a role in PDC Tournament success.

In summary, figures 1 through 4 indicate that maintaining a certain level of consistency in Time_Between_Throws_AVG across legs and sets sets apart players who advance far in the tournament from their counterparts. These observations align with the hypothesis that players with greater consistency in their form are likely to excel in winning sets, legs, matches, and ultimately tournaments.

Predictive Analysis Insights

Many formulas fitted on the complete dataset yielded subpar results, as depicted in Table 1. Despite being selected as the most suitable through methods such as backwards elimination and ANOVA comparisons, they frequently exhibited less than optimal AICs and adjusted R-squared values. These formulas underwent testing to assess their efficacy in accurately predicting wins, leading to the creation of the following confusion matrices.

Leg Winner

	Actually Lost	Actually Won
Predicted Loss	276	19
Predicted Win	0	258

Set Winner

	Actually Lost	Actually Won
Predicted Loss	229	69
Predicted Win	48	208

The Leg Winner formula demonstrated a high level of accuracy, correctly predicting outcomes between 94.69% and 97.92% of the time with a 95% confidence interval. Conversely, the Set Winner formula exhibited lower accuracy, with correct predictions falling within the range of 75.24% and 82.21% of the time, also with a 95% confidence interval.

After considering the impact of Luke Littler on the formulas, a subset of the data was created excluding his entries. Despite this adjustment, minimal improvement, if any, was observed in the formulas, as shown in Table 2. Subsequently, the revised formulas were subjected to the same prediction algorithm, resulting in the following confusion matrices.

Leg Winner

	Actually Lost	Actually Won
Predicted Loss	227	20
Predicted Win	0	198

Set Winner

	Actually Lost	Actually Won
Predicted Loss	196	51
Predicted Win	39	159

The Leg formula maintained a high level of accuracy, predicting outcomes correctly between 93.14% and 97.23% of the time with a 95% confidence interval, albeit experiencing a slight decrease compared to the previous model. On the other hand, the Set formula exhibited a slight improvement, correctly predicting outcomes within the range of 75.74% to 83.41% of the time with a 95% confidence interval. The analysis of confusion matrices, along with the adjusted R-squared values, indicates that Luke Littler's data does not significantly influence the predictive capabilities of the models.

The observation of a positive correlation between Time_Between_Throws_AVG and winning, whether in a Set or a Leg, holds true across the analyzed data. Notably, the only formula lacking this variable is the Set Winner formula within the dataset including Luke Littler. This omission is likely attributable to his below-average time, which may have perturbed the dataset sufficiently to influence the variables included in the formula, albeit not to the extent of compromising overall accuracy.

Critique

There is a potential flaw in the variability analysis of Time_Between_Throws_AVG related to the tournament-styled nature of the PDC competition. Because the tournament was single elimination, there are some players that played many more matches than others, meaning more set and leg data for some players rather than others. When doing an analysis on variability, it is important to consider that differing sample sizes per player may affect results. However, players outside the Top 4 that were highly ranked at the start of the tournament had low variability in Time_Between_Throws_AVG, giving some encouragement that variability in Time_Between_Throws_AVG is not just a product of having more data for the Top 4 players. Regardless, this flaw in our data collection could easily be solved with additional data collection in future PDC Tournaments.

In critiquing the study on success factors in 501 Darts, there were areas in which we could have improved our study for future reference. One such critique involves accounting for potential confounding variables, such as the amount of practice time players dedicate outside of competitive events to improve their skills. This variable could impact both the independent and dependent variables outlined in our introduction. Our interest in this aspect was piqued as we analyzed the final championship results and reviewed relevant articles afterward. Notably, we encountered an article discussing Luke Littler, a rising 16-year-old player who, despite previously holding a ranking of 164, participated in the 2024 PDC finals. The article revealed that Littler reportedly only practiced for approximately 20 minutes to an hour per day and frequently found himself distracted by his XBOX, highlighting the potential significance of practice habits in performance outcomes. Furthermore, we noticed during the final championship match between Luke Littler and Luke Humphries, the stark contrast in emotion as Littler kept a monotone expression while Humphries clearly showcased his reactions. Accordingly, our study could benefit from incorporating data on additional factors that could impact players' performance, such as player fatigue or psychological factors by measuring heart rate, facial expressions, reactions, etc. By broadening the scope of variables considered, the study would offer a more comprehensive analysis of the determinants of success in 501 Darts, aligning with the overarching objective outlined in the introduction. Lastly, while the data

collection process is described, there is a lack of information on the reliability and validity of the methods employed, as noted in the introduction's discussion of methodology. As almost all data is standard to human error, our data collection technique for recording average time between throws on an iPhone stopwatch is yet the same and could have been better recorded by implementing a more precise timer. Incorporating details on pilot testing or reliability checks would enhance the study's methodological rigor and bolster confidence in its findings.