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Momentum in Tournaments: Evidence from Three-Cushion Billiards

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ABSTRACT

This paper examines the effect of momentum on a sport without set limits, specifically, three-cushion billiards tournaments. Using Poisson estimation of inning-by-inning scores for the 2019 Union Mondiale de Billard (UMB) three-cushion billiards season, we determine the effects of player momentum and the mandatory mid-game break on scoring. We find no evidence of positive momentum, but instead find that "losing" the previous inning makes a player approximately 8.8% less likely to score in the following inning. We also find that the mid-game break does little to restore momentum to the losing player, but significantly helps the leading player.

Keywords: momentum, precision sports, billiards.

INTRODUCTION

Though frequently mentioned by sports announcers, the concept of "momentum" remains a term with a somewhat vague definition. "Momentum" can carry several definitions in sports, business, politics, and behavioral science. Yet in many aspects it remains understudied. In this specific case, we investigate the multidimensional aspects of momentum. Using a sport that relies heavily on precision, we examine the nature of momentum, specifically whether "momentum" is driven by successful individual actions, or successful actions with regard to one's opponent's actions (or both).

This paper adds to the existing literature on the effects of psychological momentum on performance using a little-studied precision sport, specifically, three-cushion billiards. Though less popular in the United States, the sport is one of the most popular billiard games in Asia and Continental Europe. Despite this, very little empirical research exists pertaining to the sport.

Three-cushion billiards tournaments follow similar structures as other cue sports, such as snooker. Competitive tournaments consist of a head-to-head single elimination bracket. Players alternate turns (with an inning ending after both players complete a turn), scoring points until one player reaches a target aggregate score, which can vary between 30 and 40 points in our sample. Due to its nature as a head-to-head competitive sport, in addition to its reliance on precision, makes the sport an excellent environment to study the effects of momentum. The structure of the paper is as follows. First, we will provide a short description of three-cushion

billiards gameplay, followed by a review of the psychological momentum literature, then provide details on our data and estimation strategy, before finally discussing our regression results and offering a short conclusion.

The object of three-cushion billiards is to carom (strike) the cue ball off two object balls while contacting the rail cushion at least three times. Each successful carom scores one point. If a player scores a point, they can continue to attempt shots, with their turn ending when they fail to score a point.

A game begins with each player offering a precision shot, where a player's ball must bounce off the far cushion of the table and roll back. The player whose first shot lands closest to the initial side goes first. The game ends after one player reaches the target score. Although ties are possible in non-knockout games when starting players reach the final point first and the second player, guaranteed a turn, also scores the target point, we will mainly discuss games with an evident winner and loser[1]. Importantly, after a player scores one-half of the total necessary to win (and their turn ends), a five-minute break commences. Because the break is determined by score, it can occur at theoretically any inning. Because the game ends only when a target score is reached, three-cushion billiards is quite different from other innings- or set-based sports, and thus, psychological momentum may be somewhat more complicated than in what has been found in other sports by, for example, Malueg & Yates [2010] or Zhao & Zhang [2023].

Dating back to Iso-Ahola & Mobily [1980], psychological momentum describes a psychological power gained from success that influences future performance. This phenomenon has been further modeled by Taylor & Demick [1994]. Iso-Ahola & Mobily [1980] and Iso-Ahola & Blanchard [1986] both analyze best-of-three racquetball contests, finding that the winner of the first match was more likely to win the second match. However, results are mixed for the third match. Studies of momentum have now expanded into almost all sports [such as O'Donoghue & Brown 2009 with tennis, Mortimer & Burt 2014 with handball, and Morgulev et al. 2020 with basketball; as well as laboratory-based experiments such as Perreault et al. 1998 and Den Hartigh et al. 2014, among others], with somewhat mixed results. More recently has been the rise of "strategic momentum". Malueg & Yates [2010] offer a counter of "strategic momentum" where in best-of-three games, the winner of match 1 is more likely to win match 2; however, if the game goes to 3 matches, both players are equally likely to win match 3. In this case, the loser from match 1 exerts more effort to win match 2, foregoing any advantage for match 3. Follow-up studies of "best-of-N" set sports, including Depken et al. [2022] and Gauriot & Page [2019] generally find evidence in support of strategic momentum. Laboratory experiments like those performed by Mago et al. [2013] seem to confirm evidence of both psychological and strategic momentum. However, Meier et al. [2020] conclude that psychological momentum remains the dominant motivator.

Psychological momentum has also been studied in precision sports. Adams [1995] finds evidence of momentum in 9-ball billiards players, with the winner of the opening game much more likely to win the entire match. However, this study lacks some of the econometric rigor found in more recent studies. Nevertheless, subsequent studies have found similar results.

[1] There are only 3 ties in our sample of 140 games.

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Bucciol & Castagnetti [2020], for example, finds evidence of psychological momentum in archery tournaments.

Another element of study specific to this sport is the inclusion of a mandatory break. The effects of game breaks on momentum have been studied. Mace et al. [1992] finds evidence that timeouts can successfully deter momentum in basketball. Gómez et al. [2011] finds performance increases in basketball after calling a timeout. In a laboratory experiment of table tennis players, Den Hartigh & Gernigon [2018] finds evidence that a timeout can weaken psychological momentum of leading players and can stabilize losing players. In contrast, Wanzek et al. [2012] finds that volleyball points are not affected by a timeout called. These frameworks of study are somewhat different from a billiards game. The mid-game break, unlike a timeout, is enforced at a specific time in the game, but, like a timeout, it cannot be predicted ex-ante before the game begins. Figure 1 reflects this variation of the break time.

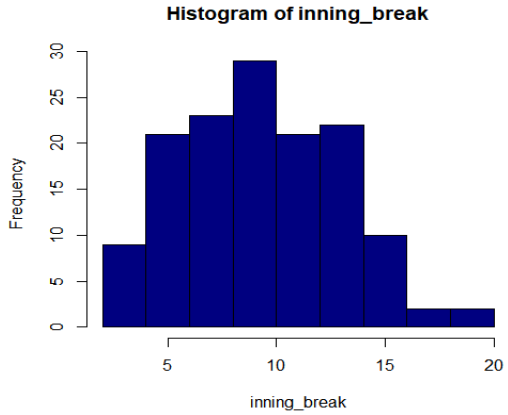

Figure 1: Distribution of break times

The research on psychological momentum is closely associated with research related to the "hot hand": the prevailing belief that successful events by a player are positively related, and can forecast future successful events. The hot hand has been extensively studied in a variety of environments [Gilovich et al. 1985, Offerman & Sonnemans 2004, Bar-Eli et al. 2006, and Ötting et al. 2020], with generally mixed results. Semantically, the hot hand generally refers to a player making successive actions without regard to one's opponent (such as making a free throw in basketball). The psychological momentum literature focuses instead on a player's action with regard to their opponent (such as a tennis player winning a set). Because billiards involves both hot hand effects (making a shot or not making a shot) and psychological momentum effects (winning an inning against your opponent or not), disentangling the two levers will be difficult. One unique advantage of using three-cushion billiards is the fact that games have no set limit. Games end after a player reaches a certain score, not a certain number of innings or after winning several sets. Games can extend for long periods[2]. This may allow for possible psychological momentum to extend for long portions of the game. In addition, the five-minute break, which begins after one player reaches half of the scoring target, also provides an opportunity for a player's momentum to dissipate (or for a losing player to regain composure). The goal of this paper is to examine the impact of momentum, measured by scoring in the previous inning, on performance. We also measure the effects of the mid-game break to see if

[2] The longest game in our sample is 33 innings.

it impairs the performance of the leading player. In addition, we also control for differences in rank between players and examine the effect of first-mover advantage [pesteguia & Palacios-Huerta 2010, Vandebroek et al. 2018, Santos 2022].

DATA

We use hand-collected shot-by-shot data for the 2019 Union Mondiale de Billard (UMB) three-cushion billiards season, consisting of 4 tournaments and 140 individual games (5,120 total player-innings). 50 total players competed in these tournaments. Data were collected using game recordings from the *Five and Six* YouTube channel, as shot data is not recorded by the UMB or, to our knowledge, any other organization. Since including multiple years could have provided a wider range to acknowledge the phenomenon, solely selecting 2019 could be a potential limitation in the following analyses. However, due to the substantial amount of legwork to hand-collect such data, expanding the sample to multiple years was not feasible. For each inning, we collect data on the number of points scored by each player, the "winner" of each inning (who scored the most points), the total score for each player, the inning number, and when the five-minute break occurred.

For control variables, we also collect each player's UMB ranking. The difference in rank between each competitor serves as our measure of competitiveness and closeness of matches. Rankings are determined by the net total of points scored in the year-to-date, making them a dynamic variable across the sample. A few additional statistics may provide a better description of games. First, by examining means, there does not appear to be a pronounced first-mover advantage; only 45.7% of games are won by the player that goes first. In addition, over three-quarters of games (77.1%) were won by the player who led at the half-time break, with an average score difference at the break of 9.88 points. This reveals a limitation in the data: there are only a small number of close games where psychological (dis-)advantages are meaningful. This is typical of the sport and not exclusive to our data. However, game outcomes remain fairly competitive, as only 60% of games were won by the higher-ranked player. Summary statistics can be found in Table 1. We can also calculate the timing of the five-minute game break. Figure 1 shows the distribution of which inning the mid-game break occurred.

Table 1: Summary Statistics

Variable	N	Mean	St. Dev.	Min	Max
Score per inning	5,612	1.685	2.281	0	23
Player "won" prev. inning	5,622	0.356	0.479	0	1
Player scored prev. inning	5,622	0.556	0.497	0	1
Prev. inning score	5,622	1.559	2.233	0	23
Player "lost" prev. inning	5,622	0.358	0.479	0	1
Inning	5,622	11.218	6.876	1	33
Post-break	5,622	0.025	0.156	0	1
Post-break * leader	5,622	0.025	0.156	0	1
First mover	5,622	0.500	0.500	0	1
Rank difference	5,126	0.000	112.649	-657	657

ESTIMATION

We use a standard Poisson regression to test for the presence of psychological momentum. Poisson is employed because a sizeable portion of the total innings results in zero points scored.

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40% (2,264) of all player-innings score zero points. Because of this, combined with the fact that points scored are a discreet variable, Poisson regression makes for the best choice to model the data. A graph of the distribution is shown in Figure 2.

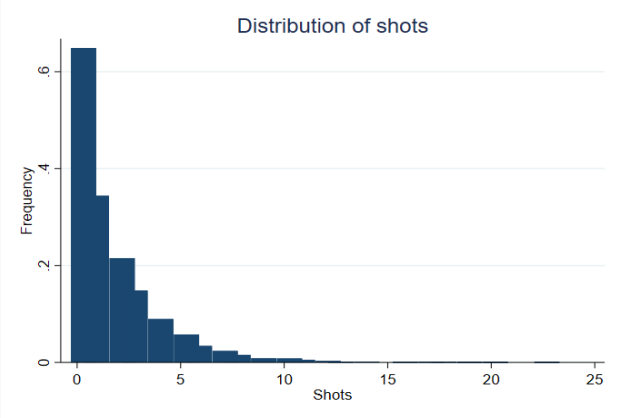

Figure 2: Distribution of inning scores

To try to separate hot hand effects from psychological momentum effects, we try to categorize different actions under each classification. To measure hot hand effects, we use a dummy variable if the player scored the previous inning, as well as the number of points they scored the previous inning. These values should be less likely to be influenced by the player's opponent[3]. To measure psychological momentum, we measure how the player scored in the previous inning compared to their opponent. We generate a dummy variable if a player outscored their opponent, or "won" the inning, as well as if the player was outscored ("lost" the inning). We also examine the effects of consecutively "winning" or "losing" innings.

A linear approximation of our regression model is as follows,

$$Score_{ijk} = \beta_0 + \beta_1 Momentum_{ijk} + \beta_2 Inning_{jk} + \beta_3 PostBreak_{ijk} + \beta_4 PostBreak_{ijk} * Leader_{ijk} + \beta_5 Firstmover_{ijk} + \beta_6 RankDifference_{ij} + \epsilon_{ijk} \quad (1)$$

where *Score* is the points scored by player i in game j during inning k, *Inning* is the inning number, and *RankDifference* is the difference in rank between players. We should expect larger differences in rank to lead to more unbalanced games and for players to score more when rank difference is higher. The coefficient on *Inning* is somewhat ambiguous; though fatigue likely plays a role, it could also be the case that players need a few innings to hone their accuracy. *Firstmover* is a dummy variable equal to one if the player goes first in the game. Since playing order is itself determined by a test of skill, this may be positively associated with a player's ability. We include a dummy variable for if the inning that occurs after the midgame break (*PostBreak*), which should be able to identify possible breaks in momentum. Because the leading and trailing players may behave differently after the break, we also have an interaction term for the leader's inning after the midgame break.

[3] However, we must concede that, because a player's shot can move the object balls, it still may be the case that players influence the number of points their opponent scores the following inning, by for example caroming the object balls into a difficult position.

We use several different measures of *Momentum*. First, we implement a dummy variable if the player scored more points than their opponent in the previous inning (the player "won" the previous inning), as well as a dummy if the player was outscored ("lost") the previous inning. This should measure the momentum of each player with respect to their opponent, and how well each player is playing with respect to how well their opponent is playing. To test for hot hand, we use a dummy variable equal to one if the player scored the previous inning, as well as the number of points each player scored in the previous inning, to track high-scoring "runs".

RESULTS

Results are found in Table 2. Column 1 uses a dummy variable for if the player "won" the previous inning, Column 3 uses a dummy variable for if the player "lost" the previous inning, Columns 2 and 4 use consecutive "wins" and "losses", respectively, Column 5 uses a dummy variable if the player scored any points the previous inning, and Column 6 uses the number of points scored the previous inning.

Table 2: Poisson Results

Variable	**Score per inning**					
	(1)	(2)	(3)	(4)	(5)	(6)
Player "won" previous inning	-0.09 (0.022)					
Consecutive winning innings		0.032 (0.031)				
Player "lost" previous inning			-0.088*** (0.023)			
Consecutive losing innings				-0.165*** (0.034)		
Player scored previous inning					-0.051** (0.022)	
Points scored previous inning						-0.016*** (0.005)
Inning	-0.012*** (0.002)	-0.012*** (0.002)	-0.011*** (0.002)	-0.011*** (0.002)	-0.012*** (0.002)	-0.012*** (0.002)
Post-break	0.071 (0.065)	0.075 (0.065)	0.099 (0.065)	0.102 (0.065)	0.070 (0.065)	0.071 (0.065)
Post-break x Leader	0.174*** (0.063)	0.162*** (0.063)	0.152*** (0.062)	0.155*** (0.062)	0.193*** (0.063)	0.233*** (0.065)
First mover	-0.033 (0.022)	-0.031 (0.022)	-0.030 (0.022)	-0.027 (0.022)	-0.033 (0.022)	-0.033 (0.022)
Rank difference	-0.0003*** (0.0001)	-0.0003*** (0.0001)	-0.0003*** (0.0001)	-0.0003*** (0.0001)	-0.0003*** (0.0001)	-0.0003*** (0.0001)
Constant	0.692*** (0.024)	0.685*** (0.023)	0.715*** (0.024)	0.701*** (0.023)	0.715*** (0.025)	0.714** (0.024)
Observations	5,120	5,120	5,120	5,120	5,120	5,120
Note: standard errors in parentheses. *, **, & *** correspond to 0.1, 0.05, and 0.01 significance levels, respectively						

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Examining the control variables, most coefficients match expectations. The negative coefficient on *Inning* seems reflective of fatigue, as players have more difficulty making shots at the end of the game. We find no evidence of a first-mover advantage, as the coefficient is insignificant. The difference in rank coefficient is negative and significant, which is unusual, but the coefficient is very close to zero in magnitude. This may reflect the (relative) parity of billiards games, where players of even large differences in rank have similar probabilities of winning the game.

With regard to the momentum measures, the most significant is the player "losing" the previous inning. Being outscored by one's opponent the previous inning makes a player approximately 8.8% less likely to score in the following inning. The consecutive inning loss term is also significant, but equal to roughly twice the size of the coefficient in Column 3, suggesting limited compounding effects. This appears to support the case for losing momentum: disappointments may cascade to decrease performance in later periods. However, we find no effect of winning momentum. Winning the previous inning does not affect the odds of scoring the following inning. This is a sharp contrast to much of the existing psychological momentum literature.

Also of interest are the hot hand results. We find that scoring in the previous inning is associated with a player *less* likely to score in the subsequent inning. Players who score any points in the previous inning are approximately 5% less likely to score the next inning. This is contrary to much of the hot hand literature. Column 6 also reflects these findings, with the likelihood of scoring decreasing by approximately 1.6% for each point scored the previous inning. This may suggest that players are strategically "taking innings off" and resting after big runs. The magnitude of these findings may also suggest that simply scoring (or being scored upon) has a relatively small effect on a player's behavior. However, the act of performing poorly *compared to one's opponent* can severely impact a player's game. Regarding the mid-game break, there appears to be no combined effect between both players. However, the results are different when examining the leader's performance. After the break, the leading player sees a performance boost and becomes as much as 23% more likely to score their next inning. It appears that the rest of the break rejuvenates the leading player, but does not stop any momentum.

Though there may be criticisms regarding the use of a niche sport for the study of momentum, three-cushion billiards allows for an environment to disentangle between individual momentum (how one performs in a vacuum) and comparative momentum (how one performs compared to their opponent). We conclude that comparative momentum is the dominating force for momentum in three-cushion billiards. This methodology could be extended to other environments where success could be described in individual or comparative terms, such as politics (an increased number of votes for a certain candidate, but not enough to win an election) or business (an increase in sales, but at a lower rate compared to a competing firm).

CONCLUSION

This paper provides an investigation into momentum in a precision sport without a set time limit, three-cushion billiards. The unique aspects of the game allow us to examine three unique components: a psychological momentum related to scoring more than one's opponent, a "hot-hand" effect related to scoring the previous inning, and how this possible momentum can be broken after a mid-game break (that cannot be ex-ante predicted at the start of the game). We find evidence of a strong negative momentum effect with regard to being outscored by one's

opponent. The hot hand effect, as measured by scoring the previous inning and the number of points scored, appears to be primarily negative, but considerably weaker than the psychological momentum effect. Finally, the mid-game break appears to have a positive effect on the performance of the leading player.

It is necessary to address some of the limitations of this paper. First and most importantly, billiards is a game made up of complicated positioning, where players actively try to put themselves into better positions and their opponent into worse positions. We do not have measures of shot positioning or quality beyond points scored. It could be the case that, in some scenarios, a "successful" shot may not necessarily mean scoring, but putting one's opponent in a difficult position. These shots would not show up with our data. Relatedly, we do not account for the difficulty of each shot, which could affect results. It could be that leading players have an advantage caused by forcing the trailing player into having to make more difficult shots. Finally, though hand-collecting scoring data for one season requires considerable effort, there may be fair criticisms of only using data from one season to reach these conclusions.

This paper contributes to the growing momentum literature by expanding the study to a sport that, to our knowledge, has never been studied before. In addition, this study not only contributes to the understanding of performance dynamics in three-cushion billiards but also provides insights applicable to strategic decision-making in other dynamic and momentum-driven contexts. There are several opportunities for future research by expanding momentum studies to other target sports and specifically to cue sports. There may also be a research avenue exploring the effects of fatigue in sports that may not seem at first to be physically demanding.

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