Momentum in US Open men's singles tennis

Ben Moss and Peter O'Donoghue

Cardiff School of Sport, Cardiff Metropolitan University, Cardiff, CF23 6XD, UK.

Abstract

Most of the research in racket sports has focussed on point outcomes rather than point sequences and other events that may trigger positive or negative momentum. Therefore, the purpose of the current investigation was to determine if point outcome in US Open men's singles tennis matches is associated with (a) the outcomes of the previous one, two or three points and (b) events within previous points such as aces, double faults, winners and errors. A further purpose was to investigate whether the outcomes of service games were significantly associated with the outcomes of the receiving and next serving games that followed. Ninety player performances from 45 US Open men's singles matches were analysed as a sample and individually. The outcomes of the previous 1 to 3 points within service games had no significant influence on the outcome of the current point ($p \geq 0.291$). Where breaks of serve had been achieved despite the server having game points, the player breaking serve was significantly more likely to hold serve in the next game (100% v 74%, $p < 0.001$). The investigation suggests that momentum effects different players in different ways which has implications for coaching and psychological support for tennis players.

Key words: momentum, tennis.

1. Introduction

Within sport, momentum is seen as a bi-directional construct, whereby successfully performed events increase the probability of subsequently performed events being successful and unsuccessful events decrease the probability of subsequent events being performed successfully (Cornelius *et al*., 1997). This creates the notion of positive and negative momentum (Burke and Houseworth, 1995; Taylor and Demick, 1984; Vallerand *et al*., 1988). Players, coaches and spectators all consider psychological momentum as a determinant of success (Stanimirovic and Hanrahan, 2004).

Sports science literature has used other terms besides 'momentum' for sequences of events with similar outcomes; these terms include 'streakiness' (Gould, 1989) and the 'hot hand' effect (Larkey *et al*., 1989). There is conflicting evidence as to whether momentum is observable in actual sports performance or if feelings of momentum come from misperceptions by performers and viewers (Burke *et al*., 1997; Bar Eli *et al*., 2006). Basketball players have been found to be just as likely to score their current shot no matter whether their previous shot had been successful or not (Gilovich *et al*., 1985; Tversky and Gilovich, 1989). At the level of whole performances, the winning streaks of NBA basketball teams have been found to be similar to those expected by chance (Vergin, 2000). Other studies using similar methods in a

number of different sports draw the same conclusions, that momentum is a misperception (Burke *et al.*, 1999; Miller and Weinberg, 1991; Richardson *et al.*, 1988; Wardrop, 1995; Rees and James, 2006).

Some previous research did not use inferential statistics to show the significance of associations between consecutive events within sports performances (Davies *et al.*, 2008; Hughes *et al.*, 2006; Murray and Hughes, 2001). These studies used graphical representations of sequences of events in squash. However without inferential statistics, it is possible that sequences of points of the same outcome were no longer than would be expected by chance. Some studies of game sports analysed shot-by-shot data without addressing performance context. For example, in basketball field goal success has been compared between shots when the previous 1, 2, or 3 field goal attempt had been successful or unsuccessful (Gilovich *et al.*, 1985). There are contextual factors about field goal attempts that were not included within the study. For example, the success of an individual's field goal shooting performance is influenced by defensive strategy and shot selection. Performers may choose to take more ambitious and risky shots as a result of rising confidence having scored previous shots. Furthermore, an individual who has missed a previous shot may elect to shoot from high-percentage positions in subsequent shots. Meanwhile the opposition may employ more aggressive defensive tactics against an individual who they believe is shooting well, restricting them to predominantly low-percentage shooting opportunities.

Tennis presents its own unique problems for the study of momentum. The dominance of the serve and players alternating service games make it unlikely that long sequences of points of the same outcome will be observed in professional tennis. Therefore, momentum research in tennis has considered serving and receiving performance separately (O'Donoghue and Brown, 2009). The disadvantage of such an approach is that sequences of points might include pairs of consecutive service points that are not even played within the same service game. Still, momentum is perceived to be important in tennis and it is almost impossible to watch a tennis match on television without hearing expert commentators referring to momentum. As with other sports, tennis research has also provided mixed evidence as to whether point outcomes are independent of previous point outcomes (Klaassen and Magnus, 2001; O'Donoghue and Brown, 2009). Klaassen and Magnus (2001) found that winning the previous point increased the probability of winning the current point by 0.3% in men's singles and 0.5% in women's singles at Wimbledon (1992-5). However, O'Donoghue and Brown (2009) found no significant association between point outcome and previous point outcome in 26 performances of 13 men's singles matches played in 2007 Grand Slam tournaments. This study can be criticised for only using 13 matches that television broadcasters chose to cover. There is evidence of momentum at the set level within 4 and 5 set men's singles tennis matches at Grand Slam tournaments. The winning players within such matches tended to lose the sets they lost earlier rather than later (Jackson and Mosurski, 1997; O'Donoghue, 2013).

The biggest criticism of previous momentum research in tennis is that they are limited to data about point or set outcomes. There are many different types of event during sports performance that may be triggers of momentum (Taylor and Demick, 1994; Jones and Harwood, 2008). In tennis such events could include dramatic shots, winning a game after several deuce points have been played, unforced errors at crucial points, and not converting break point opportunities. It is important for tennis coaches and players to understand events that may initiate positive or negative momentum given their hypothesised importance in determining match outcome (Cornelius *et al.*, 1997). Therefore, the purpose of the current investigation was

to analyse momentum at both point and games levels including process variables as well as outcome variables.

This is an original attempt to investigate the role of such process variables within tennis to test more general aspects of momentum theory. The research is made up of three studies. Firstly, the percentage of points won by the server is compared between occasions where there are different outcomes of previous points. These outcomes include winning and losing previous points as well as whether specific events, such as aces, double faults, winners and errors occurred within previous points. This first study attempts to identify general momentum effects within tennis matches without considering matches at an individual level. The second study uses similar events and outcomes of previous points as the first study. The differences is that matches are considered individually recognising that momentum may be observed in some matches but not in others. The third study analyses associations between game outcomes and subsequent game outcomes in an attempt to identify observable momentum at a game level.

2. Methods

2.1. Matches

Forty-five matches were analysed from the 2013 US Open Men's Singles Championships, including a total of 12,239 points. Data were collected from the official tournament website (www.usopen.org, accessed from 26/8/2013 to 11/9/2013). Data was collected from all matches where full point-by-point data sets were made available through the 'Slam Tracker' facility; at this tournament this was limited to the championships' five 'show courts'. A second criterion that the matches must consist of at least four sets in order to create a greater likelihood that the data meet the assumptions of the statistical tests used. The score at the start of the point, serving player, winning player and the manner in which the point ended were recorded for each point. The manner in which the point ended was classified into one of the following event types:

- Ace
- Double fault
- Serve winner – a serve which the returner fails to return in court, but does however make contact with the ball using their racquet.
- Forehand winner
- Forehand forced error
- Forehand unforced error
- Backhand winner
- Backhand forced error
- Backhand unforced error

2.2. Reliability

A quasi-estimation of reliability was made by the first author watching 10 matches of 202 to 331 points and comparing the values recorded for the score at the start of the point, serving player, winning player and the manner in which the point ended with the data provided by the 'Slam Tracker' facility. The score at the beginning of the point, the server and the point winner were agreed between the two methods for all 2619 points included in the reliability study. Cohen's (1960) kappa was calculated for the manner in which the point ended. When forced and unforced errors were distinguished, the level of reliability was lower ($\kappa = 0.64$) than when all errors were considered together ($\kappa = 0.89$). It was, therefore, decided not to distinguish

between forced and unforced errors within the current investigation. The level of reliability was no improved by merging forehand and backhand data ($\kappa = 0.89$) and, therefore, the use of forehand and backhand shots were distinguished in the data that were analysed.

2.3. Data processing

The Slam Tracker lists provides two rows of data for each point; the first contains details of who won the point and how and the second is the score after the point. The points are listed in reverse order. The text showing the point details is in the form shown below:

N. Djokovic loses the point with a forehand forced error

A spreadsheet was programmed to process this text identifying whether the point was won or lost by the named player (based on "wins" or "loses" being present) and the manner in which the point ended which is listed towards the right of the text string. The use of sorting, text processing and conditional functions in Microsoft Excel that is used to process Slam Tracker data are described by O'Donoghue and Holmes (2015, p.50-54). Any '0-0' scores in between points were used to change the serving player and match identification details were added to distinguish between the 45 different matches included in the study. This initial processing yielded a set of 12,239 points. The set of points was duplicated within the data set so that each row contained details of a point and the previous point. A separate copy of the spreadsheet was used to store point outcomes together with the outcomes of the previous 3 points. Pivot tables were used to cross-tabulate frequencies of outcomes and events within previous points to allow momentum to be investigated within each individual player performance.

Pivot tables were also used to produce overall frequency data for each player performance allowing percentage of points won to be calculated during different situations depending on the outcomes and events of previous points. This version of the data was imported into SPSS Version 20.0 (SPSS Inc., An IBM Company, Amarouk, NY) permitting non-parametric statistical testing.

A third spreadsheet was programmed to identify overall game details including whether serve was held, whether there were any Deuce points within the game, whether it was a love game, whether either serving or receiving player had held 2 or 3 point leads within the game, whether the serving player had any game points and whether the serving player faced any break points. These game level detail were pooled from the 45 matches to produce a single spreadsheet of game data including whether the following receiving game and the serving game 2 games later were won or lost. These data were cross-tabulated using pivot tables to facilitate analysis of the effect of game events on subsequent game outcomes.

2.4. Data analysis

2.4.1. Player performances

The 45 matches involved 90 player performances because two players contest each match. Each players' serving performances were analysed determining the percentage of points that were won for different conditions based on outcomes of previous points and the manners in which previous points ended. A series of Kolmogorov-Smirnov tests revealed that the percentage of points won was normally distributed for all combinations of outcomes of the previous 1, 2 and 3 points ($p > 0.05$). Furthermore, the percentage of points won was normally distributed for 6 of the 11 event types within previous points and 10 of the 11 conditions when these events did o not occur. Therefore, parametric statistical tests were used to compare the

percentage of points won under different conditions. A series of paired samples t-tests was performed to compare the percentage of points won between different pairs of conditions. These pairs conditions included when the previous point was won and when the previous point was not won as well as when a given manner of ending a point occurred in the previous point and when it didn't. There were four combinations of outcomes for the previous two points (both one, both lost, the first one and second lost, and the first lost and second won). The percentage of current points won was compared between these four combinations of the previous two points using a repeated measures ANOVA test. There are 8 combinations of the previous 3 points. However, some combinations did not occur in sufficient numbers within all matches to allow a meaningful comparison using a repeated measures ANOVA test. Therefore, the previous three points were broadly classified into when 2 or 3 of the previous points were won and when 1 or 0 of the previous 3 points were won. The percentage of current points that were won was compared between these two broad conditions using a paired samples t-test.

2.4.2. Individual player performances

The parametric tests used to analyse player performances assumed an average player performance where average values for the percentage of current points won could be compared between previous point conditions within the performances. The concept of momentum might apply within some performances but not within others. Therefore, individual performances were analysed to determine if there were associations between current point outcome and previous point outcomes or manner by which the previous point ended. Within each of the 90 serving performances, a series of chi square tests of independence were used to test these associations. Wald Wolfowitz run tests were also applied to each serving performance to determine if sequences of points of the same outcome were significantly longer than expected.

2.4.3. Game pairs

A third analysis that was performed on the data was at a game level rather than at a point or performance level. The purpose of this analysis to determine if the outcome of current service games was associated with the outcomes of the next game (receiving) or the next service game (two games later). The outcomes of the current service game that were compared were:

- Where serve was held and when it was broken.
- Where serve was held to Love, where serve was held within Deuce games and other holds.
- Where serve was held having faced break points and when serve was held without facing break points.
- When serve was held having trailed by 2 points, 3 points or other holds.
- When service was broken having had game points and when serve was broken without the server having game points.
- When the serve was broken when the server had led by 2 points, 3 points or other breaks.

These events do not occur frequently enough within tennis matches to support valid use of chi square tests of independence within individual performances or other non-parametric tests to compare the percentages of subsequent games won under different conditions for the average performance. Therefore, all service game pairs from the 45 matches were pooled together to allow chi square tests of independence to test association between current game outcome and the outcomes of the two games that followed.

2.4.4. Significance level

All statistical tests were considered to produce significant results if the p values were less than 0.05.

3. Results

3.1. Player performances (n=90)

The first analysis determined mean values for the 90 serving performances comparing the percentage of points won under different conditions within these 90 performances. Table 1 shows that the percentage of points won was not significantly influenced by the outcomes of the previous one, two or three points ($p > 0.05$).

Table 1. Influence of outcomes of the previous one to three points on the outcome of the current point.

Condition	%Won if condition holds	%Won if condition does not hold	p
Previous Point			
Point won	63.9±6.9	62.9±8.5	0.291 &
Previous 2 Points			
Won then Won	65.3±11.2	63.1±8.6	0.289 ^
Won then Lost	63.7±12.6	63.9±7.7	
Lost then Won	63.5±11.6	64.4±8.3	
Lost then Lost	61.8±15.7	64.5±7.9	
Previous 3 Points			
2 or more points won	64.9±9.8	63.2±13.4	0.296 &

& p value was calculated using a paired samples t-test.
^ p value was calculated using a repeated measures ANOVA test.

Table 2 shows that no event type within a point had a significant influence on the outcome of the next point ($p > 0.05$).

Table 2. Influence of events in the previous point on the outcome of the current point.

Event in previous point	Number of player performances where event occurred 5 or more times	%Won if event occurred	%Won if event did not occur	p
Ace	81	64.6±18.2	63.8±6.1	0.690
Serve winner	4	83.8±21.1	69.8±4.9	0.354
Double fault	49	68.0±23.9	62.5±5.8	0.121
Forehand winner	88	61.4±12.7	63.9±6.5	0.076
Opponent forehand winner	73	61.7±19.2	63.3±7.4	0.505
Backhand winner	47	60.8±17.7	63.2±5.5	0.335
Opponent backhand winner	37	65.6±18.2	62.4±6.0	0.340
Forehand error	90	61.4±11.7	63.5±7.3	0.110
Opponent forehand error	90	65.2±9.2	63.5±9.9	0.190
Backhand error	85	61.6±14.6	63.4±5.9	0.255
Opponent backhand error	90	63.4±11.5	64.6±8.0	0.335

3.2. Individual player performances (n = 90)

The previous section of the results considered tennis performances as a whole, assuming an average performance where the influence of previous points on current point outcome applied. There are some concepts in sports performance that may apply to some performers and not others. Therefore, the purpose of the current section of results is to consider this alternative paradigm and report where individual matches show characteristics of momentum. Table 3 shows that chi square tests of independence revealed that there were performances showing characteristics of momentum and others showing the opposite of a momentum effect. However, the majority of matches showed neither a momentum effect nor an effect that is opposite of a momentum effect. There were 7 of the 90 player performances that showed significantly longer sequences of points of the same outcome than expected ($p < 0.05$). Table 4 also shows that most matches did not show any momentum effects based on the manner of winning or losing the previous point.

Table 3. Number of serving performances with significant association between current point outcome and the outcome of previous points.

Player Serving	Opposite to momentum ($p < 0.05$)	Not significant ($p \geq 0.05$)	Consistent with momentum ($p < 0.05$)
Previous point	3	84	3
Previous 2 points	3	81	6
Previous 3 points	8	76	6

Table 4. Number of performances where there is an association between current point outcome and events within previous point.

Player Serving	Decreased chance of winning next point ($p < 0.05$)	Not significant ($p \geq 0.05$)	Increased chance of winning next point ($p < 0.05$)
Ace	1	89	0
Serve Winner	1	89	0
Double Fault	0	90	0
Forehand winner	2	87	1
Opponent forehand winner	0	90	0
Backhand winner	0	90	0
Opponent backhand winner	0	89	1
Forehand error	0	88	2
Opponent forehand error	2	85	3
Backhand error	3	86	1
Opponent backhand error	3	84	3

3.3. Game pairs (n=1898 for next receiving game and 1853 for next service game)

The game events identified in Table 5 do not occur enough within individual performances to allow chi square tests of independence to be validly applied. Therefore, pairs of games from the 90 performances have been pooled together to allow analyses of game outcomes and subsequent game outcomes. There were 1898 pairs of games including serving games and the receiving games that followed. There was one significant result which was that every occasion where a player lost their service game having had game points resulted in the player losing the next game where they were receiving serve. This was a significantly greater proportion than

the 245 out of 333 occasions where the next receiving game was lost when the player's serve was broken without the player having any game points ($p < 0.001$). There were 1853 pairs of service games, with a receiving game in between, that were analysed. No significant associations were found between the outcomes of service games and the service games played two games later.

Table 5. Association between service game outcome and the outcomes of the next two games.

Service Game Condition	Outcome of next receiving game					Outcome of next service game				
	Won	Lost	Total	%Won	p	Won	Lost	Total	%Won	p
All Games										
Service Hold	317	1180	1497	21.2	.738	1155	314	1469	78.6	.992
Service Break	88	313	401	21.9		302	82	384	78.6	
All Games	405	1493	1898	21.3		1457	396	1853	78.6	
Service Holds										
Love Hold	76	269	345	22.0	.838	270	65	335	80.6	.581
Deuce Hold	62	223	285	21.8		221	60	281	78.6	
Other Hold	179	688	867	20.6		664	189	853	77.8	
All Holds	317	1180	1497	21.2		1155	314	1469	78.6	
Break Points Saved	40	166	206	19.4	.506	153	51	204	75.0	.174
Other Hold	277	1014	1291	21.5		1002	263	1265	79.2	
All Holds	317	1180	1497	21.2		1155	314	1469	78.6	
-2 Disadvantage	20	113	133	15.0	.103	104	27	131	79.4	.861
-3 Disadvantage	2	16	18	11.1		15	3	18	83.3	
Other Hold	295	1051	1346	21.9		1036	284	1320	78.5	
All Holds	317	1180	1497	21.2		1155	314	1469	78.6	
Service Breaks										
Game points saved	0	68	68	0.0	.000	71	15	86	82.6	.315
Other breaks	88	245	333	26.4		231	67	298	77.5	
All breaks	88	313	401	21.9		302	82	384	78.6	
+2 Advantage	9	36	45	20.0	.928	31	13	44	70.5	.180
+3 Advantage	2	6	8	25.0		5	3	8	62.5	
Other Break	77	271	348	22.1		266	66	332	80.1	
All Breaks	88	313	401	21.9		302	82	384	78.6	

4. Discussion

Table 1 shows that there were no general effects of previous point outcomes on current point outcome. Furthermore, Table 2 shows that none of the event types within points (aces, double faults, backhand winners, forehand errors and backhand errors) had a significant effect on the chance of winning the next point. This suggests that perception of momentum in sport could be a result of memory bias (Gilovich *et al*., 1985). Long sequences of successfully performed events in sport are more memorable than sequences that appear to be random. Subsequently observers are likely to demonstrate an overestimation of momentum effects in sport. It is suggested that humans find it difficult to accept randomness in events (Vergin, 2000) with one study demonstrating how humans themselves are poor randomizers (Wagenaar, 1972). Participants in Waganaar's (1972) study were asked to produce a random series, with the subsequent results finding that the sequences contained too many short runs; if human perception is a belief that random sequences are so short, when they compare this to even the most mundane streak in sports they believe that this must be evidence of momentum (Vergin, 2000). An alternative explanation for point outcomes not resulting in an increased chance of winning the next point is that tennis is a sport where momentum may be possible without the type of immediately precipitating event we might see in a basketball match (Taylor and Demick, 1994).

When considering games played within the pooled set of matches, Table 5 shows that there was one significant effect. If a player breaks serve having faced game points against him, then he is more likely to hold serve in the next game than if the break was achieved without facing game points. In all 68 performances where the break was achieved having faced game points, the player held serve in the next game. This suggests that momentum may result from a series of events that combine to increase the chance of success (Taylor and Demick, 1994). There are theoretical explanations for players holding serve immediately after they have broken serve despite facing game points against them. Saving game points when receiving and then breaking the opponent's serve later in the game may be perceived by players as progress towards the end goal of winning the match. Progressing towards such end goals in sports performance has been proposed as contributing to psychological momentum (Vallerand *et al*., 1988). Vallerand *et al*. (1988) also suggested that important events had an impact on perceptions of momentum in sport. Breaking the opponent's serve is particularly important in men's singles tennis and often determines the winner of a set. The success with which tasks are performed in sport may influence confidence, arousal and persistence of players (Mack and Stephens, 2000). This may encourage players who have broken serve to strive to hold serve in the next game while having a more negative impact on their opponents. A tennis player who prevents a serving opponent from converting a game point to bring the score to Deuce has come from being behind within the game. Similarly, there is evidence from volleyball that teams that come from behind to level the score are more likely to win games than the teams that were ahead and lost the lead (Eisler and Spink, 1998; Miller and Weinberg, 1991). The current results in tennis show this effect going further in that the receiving player not only breaks serve in this situation but maintains momentum to hold their own serve in the next game.

Table 3 shows that there were 12 of the 90 performances where players won a significantly greater proportion of points where they had won the previous two or three points compared to where one or more had been lost. This might be explained by some of the game scores that are experienced when the server has won the previous two points. It has been suggested that receiving players might not chase shots down as vigorously when trailing by 2 or 3 points than when the score is different (Knight and O'Donoghue, 2011). By contrast, there were 8 of the

90 performances where serving players were more likely to lose a point if they had won the previous three points than if they had not won all of the previous 3 points. This might be explained by players risking the cannonball on second serve if they are leading 40-0 on their own serve (Ashe, 1981).

Table 4 provides some evidence that momentum is a bipolar concept with some performances showing unsuccessfully performed shots reducing the chance of winning the next point. There were 3 performances where backhand errors by serving players decreased their chance of winning the next point. There were also 6 matches where the receiving player was less likely to win a point if they had made forehand or backhand errors in the previous point. This agrees with existing momentum theory suggesting that momentum in sport is a bipolar concept (Burke *et al*., 1997).

Tables 4 and 5 show that there was observable momentum in some matches but not in others. This may be explained by elements of existing theory. For example, Taylor and Demick's (1994) Multi-Dimensional Model includes the role of players' experiences of positive and negative momentum. These experiences may vary between different players leading to events having impacts on performance that depend on individual player perception.

Besides the significant result for the effect of service breaks where game points had been lost by the server, Table 5 shows that there were no other significant results revealed by the analysis of game events. A possible explanation is that professional players have coping strategies to prevent opponents building positive momentum. Behaviours such as slowing the game down are used by tennis players to control what they believe as positive or negative momentum (Adler, 1981; Higham, 2000). The inter-game breaks in tennis can act as a momentum 'neutraliser' (Adler, 1981). While the analysis of games within sets has overcome the disadvantage of previous momentum research separating serving and receiving performances, the separation of serving and receiving performance is a limitation of the point level analysis within the current investigation.

In conclusion, the current investigation has provided evidence of momentum in tennis with breaks of serve in games where the server had lost game points having a significant influence on the outcome of the next game. There is also evidence that momentum can be observed in the performances of some players but not others. It is, therefore, recommended that momentum is considered for players individually when preparing for competition. This may involve psychological interventions for players who exhibit negative momentum or for players who may be facing opponents who exhibit positive momentum.

5. References

Adler, P. (1981). **Momentum: A Theory of Social Action**. Beverly Hills: Sage

Ashe, A. (1981). **Arthur Ashe's Tennis Clinic**. London: Heinemann.

Bar-Eli, M., Avugos, S. and Raab, M., 2006, Twenty years of "hot hand" research: Review and critique. **Psychology of Sport and Exercise**, 7(6), pp. 525-553.

Burke, K. L. and Houseworth, S. (1995). Structural charting and perceptions of momentum in intercollegiate volleyball. **Journal of Sport Behaviour**, 18, 167-182.

Burke, K. L. Edwards, T. C., Weigand, D. A. and Weinberg, R. S. (1997). Momentum in sport: a real or illusory phenomenon for spectators. **International Journal of Sport Psychology**, 28, 79-96.

Burke, K. L., Burke, M. M. & Joyner, A. B. (1999). Perceptions of momentum in college and high school basketball: An exploratory, case study investigation. **Journal of Sport Behavior**, 22, 303-309.

Cohen, J. (1960). A coefficient of agreement for nominal scales. **Educational and Psychological Measurement**, 20, 37-46.

Cornelius, A. E., Silva, J. M., Conroy, D. E. and Petersen, G. (1997). The projected performance model: relating cognitive and performance antecedents of psychological momentum. **Perceptual and Motor Skills**, 84, 475-485.

Davies, G., Fuller, A., Hughes, M. T., Murray, S., Hughes, M. D. and James, N. (2008). Momentum of perturbations in elite squash, in **Performance Analysis of Sport 8**. A. Hokelman and M. Brummund. Magdeburg, Germany: Otto-von-Guericke-Universitat Magdeburg Press, 77-99.

Eisler, L. and Spink, K.S. (1998), Effects of scoring configuration and task cohesion on the perception of psychological momentum, **Journal of Sport and Exercise Psychology**, 20, 311-320.

Gilovich, T., Vallone R. and Tversky, A. (1985). The hot hand in basketball: on the misperception of random sequences. **Cognitive Psychology**, 17, 295-314.

Higham, A. (2000). **Momentum: The hidden force in tennis**. Leeds: 1st4sport Publications and Meyer and Meyer Sport (UK) Ltd.

Hughes, M., Fenwick, B. and Murray, S. (2006). Expanding normative profiles of elite squash players using momentum of winners and errors. **International Journal of Performance Analysis in Sport**, 6(1), 161-171.

Jackson, D. and Mosurski, K. (1997). Heavy defeats in tennis: Psychological momentum or random effect. **Chance**, 10, 27-34.

Jones, M. I. and Harwood, C. (2008). Psychological momentum in competitive soccer: players' perspectives. **Journal of Applied Sport Psychology**, 20, 57-72.

Klaassen, F. J. H. M. and Magnus, J. R. (2001). Are points in tennis independent and identically distributed? Evidence from a dynamic binary panel data model. **Journal of the American Statistical Association**, 96, 500-509.

Knight, G. and O'Donoghue, P. (2011). The probability of winning break points in Grand Slam men's singles tennis. **European Journal of Sports Science**, 12(6), 462-268.

Larkey, P.D., Smith, R.A. and Kadane, J.B. (1989), It's ok to believe in the "hot hand", **Chance**, 2(4): 22-30.

Mack, M.G. and Stephens, D.E. (2000), An empirical test of Taylor and Demick's multidimensional model of momentum in sport, **Journal of Sport Behaviour**, 23(4), 349-363.

Miller, S. and Weinberg, R. (1991), Perceptions of psychological momentum and their relationship to performance, **The Sport Psychologist**, 5, 211-222.

Murray, S. and Hughes, M. (2001). Tactical performance profiling in elite level senior squash. In **PASS.COM** (edited by M. Hughes and I. M. Franks), Cardiff: CPA, UWIC, pp. 185-194.

O'Donoghue, P.G. (2013), Momentum in tennis matches at Grand Slam tournaments, In Peters, D. and O'Donoghue, P.G. (eds.) **Performance Analysis of Sport IX**, London: Routledge, pp. 174-179

O'Donoghue, P. and Brown, E. (2009). Sequences of service points and the misperception of momentum in elite tennis. **International Journal of Performance Analysis in Sport**, 9(1), 113-127.

O'Donoghue, P.G. and Holmes, L.A. (2015), **Data Analysis in Sport**, London: Routledge.

Rees, C. and James, N. (2006). A new approach to evaluating 'streakiness' in golf, a research paper presented at the 7th world congress of performance analysis in sport,

Szombathely, Hungary, August. In H. Dancs, M. Hughes and P. O'Donoghue (eds.) **Book of Proceedings of the World Congress of Performance Analysis of Sport VII**, Szombathely: Hungary. pp. 329-337.

Richardson, P. A., Adler, W. and Hankes, D. (1988). Game, set, match: psychological momentum in tennis. **The Sport Psychologist**, 2, 69-76.

Stanimirovic, R. and Hanrahan, S. J. (2004). Efficacy, affect and teams: is momentum a misnomer? **International Journal of Sport and Exercise Psychology**, 2, 43-62.

Taylor, J. and Demick, A. (1994). A multi-dimensional model of momentum in sports. **Journal of Applied Sport Psychology**, 6, 51-70.

Tversky, A. and Gilovich, T. (1989). The cold facts about the 'hot hand' in basketball. **Chance**, 2, 16-21.

Vallerand, R. J., Colacecchio, P. G. and Pelletier, L. G. (1988). Psychological momentum and performance inferences: a preliminary test of the antecedents-consequences psychological momentum model. **Journal of Sport and Exercise Psychology**, 10, 92-108.

Vergin, R. C. (2000). Winning streaks in sports and the misperception of momentum. **Journal of Sport Behaviour**, 23(2), 181-197.

Wagenaar, W. (1972). Generation of random sequences by human subjects: a critical survey of literature. **Psychological Bulletin**, 77, 65-72.

Wardrop, R. (1995). Simpson's paradox and the hot hand in basketball. **The American Statistician**, 49, 24-28.