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Philippe Meier, Raphael Flepp, Maximilian Rüdisser, Egon Franck

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Contact Details

Philippe Meier

philippe.meier@business.uzh.ch

Raphael Flepp

raphael.flepp@business.uzh.ch

Maximilian Rüdisser

maximilian.ruedisser@business.uzh.ch

Egon Franck

egon.franck@business.uzh.ch

University of Zurich

Department of Business Adminstration

Affolternstrasse 56, CH-8050 Zurich, Switzerland

Investigating the conditions for psychological momentum in the field: Evidence from men's professional tennis*

Abstract

We examine how interruptions and personal and contextual factors affect the manifestation of psychological momentum (PM). Using men's singles tennis point-by-point data from the two Grand Slam tournaments, Wimbledon and Roland Garros, between 2009 and 2014 (N=29,934), we employ realized break points as the potential triggers of PM and rest periods between two sequential games as the exogenous task interruptions. Controlling for player ability and the state of the match, we find that players are more likely to win the next game after realizing a break point only if there is no rest period between games. Thus, our results suggest that interruptions terminate the momentum effect. Furthermore, we find that the effect of PM increases for players with a lesser relative ability and at a later stage within a match, showing the importance of personal and contextual factors for PM.

JEL Classification: D83, D91, L83

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1. Introduction

Whether it is a salesperson closing five deals in a row, an ice hockey club experiencing a losing streak, or a tennis player increasing his or her performance after winning an important point, the belief in psychological momentum (PM) has emerged and settled in realm of the general public. PM is conceptualized as a perceptual phenomenon that changes behavior and performance in a series of tasks or within a multiple-step workflow (Iso-Ahola and Dotson, 2016). According to Adler (1981, p. 29), PM is "a state of dynamic intensity marked by an elevated or depressed rate of motion, grace, and success". Taylor and Demick (1994) specify that a precipitating event produces changes in cognition, physiology, and affect, which will result in a shift in behavior and performance. Thus, the underlying tenet of PM is that current performance is significantly affected by previous performance (Iso-Ahola and Mobily, 1980). Consequently, success can lead to further success, i.e., positive momentum, or failure can lead to further failure, i.e., negative momentum. The focus of this paper will be on positive momentum because individuals usually try to gain positive momentum rather than avoid negative momentum (Iso-Ahola and Dotson, 2016).

While a precipitating event is critical for PM, several conceptual models of PM illustrate that contextual factors such as the importance of the precipitating event and personal factors such as the ability level influence the strength of PM (e.g., Taylor and Demick, 1994; Vallerand et al., 1988). Moreover, PM theory predicts that PM is terminated if the task performance is interrupted because performance must be started again, which increases energy expenditure and elicits feelings of frustration (Iso-Ahola and Dotson, 2016).

Empirically, PM has been predominantly examined in sports settings, where players, coaches, and commentators often refer to this phenomenon (Den Hartigh and Gernigon, 2018). In sports, different expressions, such as "hot hand" and being "on fire", "in the zone" or "in the rhythm", are used to describe PM when players exhibit winning streaks (e.g., Dietl and Nesseler, 2017; Green and Zwiebel, 2017). Most empirical studies address the question of whether PM exists or whether it is a cognitive illusion. While some studies find a significant change in performance following a precipitating event and thus supporting evidence for the existence of PM (e.g., Cohen-Zada et al., 2017; Green and Zwiebel, 2017; Iso-Ahola and Mobily, 1980), others fail to find evidence of the existence of PM (e.g., Gauriot and Page, 2018; Gilovich et al., 1985; Silva et al., 1988).

One potential reason for the mixed results is that the empirical literature has mostly neglected the importance of the contextual and personal factors as well as duration effects underlying the formation and strength of PM. In particular, the effect of interruptions on PM has only been investigated in laboratory experiments, where participants are asked about their perceptions of PM in artificial scenarios or audiovisual simulations (e.g., Briki et al., 2014; Den Hartigh and Gernigon, 2018; Markman and Guenther, 2007). One notable exception is the work of Mace et al. (1992), who show that momentum in collegiate basketball diminishes after timeouts. However, timeouts are endogenous interruptions that depend on recent performance, which complicates the interpretation of the results.

If interruptions have the potential to terminate PM, it is not surprising that several studies employing a setting where the performance task is interrupted find no evidence of PM (e.g., Gauriot and Page, 2018; Malueg and Yates, 2010; Parsons and Rohde, 2015). Furthermore, apart from several studies that find evidence of PM for men but not for women (e.g., Cohen-Zada et al.), only Livingston (2012) addresses experience as a personal factor, and Dietl and Nesseler (2017) address "controlling the match" as a contextual factor. Overall, although highlighted in several conceptual PM models, empirical field evidence of how interruptions and contextual and personal factors affect PM is scarce.

In this paper, we address this research gap by employing point-by-point-level data from professional Grand Slam tennis matches, which offer several key advantages. First, a tennis match consists of a series of performance tasks over time, which is necessary for PM to arise (Iso-Ahola and Mobily, 1980). Second, tennis is a face-to-face competition. Thus, in contrast to most team sports, it is not possible to transfer more defensive resources to the player who has gained positive PM (Green and Zwiebel, 2017). Third, the tennis rules require a changeover rest period of a maximum of 90 seconds after uneven game numbers, except after the first game, which exogenously interrupts the task performance. Finally, contextual and personal data, such as detailed information about the stage of the match or the player's relative ability inferred from the betting odds, are readily available.

Our data contain approximately 30,000 point-by-point observations from 80 Wimbledon and 61 Roland Garros men's singles matches, played between 2009 and 2014. We use realized break points[1] as the potential triggers of PM because winning a break point is a key event in tennis and a necessary

[1] A break point in tennis is realized if the receiver wins a game within a set. Section 3.1 explains the rules of tennis and its jargon in more detail.

milestone in winning the match (Klaassen and Magnus, 1998). Furthermore, we employ the exogenous resting periods, where players usually sit down and refresh, to properly differentiate between the subsequent performance effects with and without interruptions.

One personal factor that is expected to influence the strength of PM triggered by a realized break point is the relative ability of the players. Therefore, the effect of PM should become stronger if the relative ability of the player realizing a break point is lesser because realizing a break point against a stronger player is associated with a certain “wow” factor that might boost the player’s perception of being superior (Iso-Ahola and Dotson, 2014). To measure relative ability, we derive the implied winning probabilities from the betting odds prior to the match, which should provide an accurate estimate of players’ abilities (Bizzozero et al., 2016). Furthermore, the overall situation or context is an important determinant for PM to arise (Vallerand et al., 1988). In tennis, the stage within the match is likely to represent one such contextual factor. Thus, we test whether PM becomes stronger if more games (sets) have been played within a set (match).

Using match and serving player fixed-effect regressions, we find that players who realize a break point are more likely to win their subsequent game as well as points within that game if play is uninterrupted. However, we find no change in performance if play is interrupted by a changeover rest period. In all regressions, we control for the difference in ability of the players and the current score of the match. Furthermore, we find that the effect of PM is stronger for players with a lesser relative ability. While this finding supports our hypothesis that relative ability determines the strength of PM, it is inconsistent with the potential concern that ability is the sole driver of increased performance. Finally, we find weak evidence that the effect of PM strengthens with the number of games played in a set and with the number of sets played in a match. In total, we find evidence that both personal and contextual factors influence PM and that exogenous task interruptions terminate PM.

Our paper makes at least three major contributions to the PM literature. First, we analyze the fine-grained objective performance data of professional tennis players in a high-stake environment. Second, we are the first to properly test whether interruptions terminate PM in the field because changeover rest periods in tennis are exogenous. Indeed, our results suggest that PM can only build up if the task is uninterrupted. Finally, we show that both the relative ability and the stage within the match are important contextual and personal factors that affect the strength of PM. These insights highlight that PM is a multifaceted phenomenon, which helps to explain the mixed findings of earlier studies that have not sufficiently addressed contingency explanations.

The remainder of this paper is organized as follows. In Section 2, we present a theoretical background of PM and review the prior empirical studies. In Section 3, we describe our tennis setting and develop our hypotheses. In Section 4, we provide an overview of our data and estimation methods. In Section 5, we present our empirical findings. In Section 6, we conclude.

2. Psychological Momentum Theory and Related Empirical Literature

2.1 Psychological Momentum Theory

Iso-Ahola and Dotson (2016) conceptualize PM as a perceptual phenomenon that leads to changes in behavior and performance. Several theoretical models have been proposed to explain how perceptions of PM arise and how such perceptions influence performance. According to the antecedents-consequences model of PM by Vallerand et al. (1988), situational and personal antecedents facilitate perceptions of PM. These perceptions are associated with enhanced perceived control, confidence, optimism, energy, and synchronism. As a consequence, perceived PM affects actual performance. However, this relationship is moderated by both contextual factors, such as crowd noise and the importance of the outcome, and personal factors, such as the individual's ability level (Vallerand et al., 1988).

Taylor and Demick (1994) conceptualize PM in a multidimensional model of momentum. In this model, a precipitating event triggers the momentum chain, which may then produce changes in a variety of cognitive, affective, and physiological areas. These intrapersonal changes will manifest themselves behaviorally, leading to changes in activity level, pace or posture. Importantly, these behavioral changes depend on several factors, such as the valence of the momentum or the current level of the physiological arousal of the individual. Ultimately, the changes that have occurred result in a shift in performance and an immediate competitive outcome (Taylor and Demick, 1994). Furthermore, Markman and Guenther (2007) develop a more general theory of PM and conceptualize it in an analogy to physical momentum, defined as the product of mass and velocity. Thereby, a precipitating event corresponds to velocity, and mass is determined by the contextual aspects that connote the value or importance of the event.

Iso-Ahola and Dotson (2014) emphasize that initial success is the precipitating event that is critical for momentum building. In their PM model, Iso-Ahola and Dotson (2014) distinguish between the intensity, frequency and duration effects of initial success that affect the likelihood and strength of PM. If the initial success is intense and has a "wow" factor associated with, or if there occur two or more consecutive successes, the more likely subsequent success and winning are. Regarding the duration effect, Iso-Ahola and Dotson (2014) state that PM is terminated in one of two ways. First, PM is lost when an unsuccessful performance occurs. Because it is impossible to avoid errors in human performance, it is difficult to create extended periods of PM. Thus, PM is short-lived in general and more likely to occur within rather than between tasks and performances (Iso-Ahola and Dotson, 2016). Second, PM is terminated if performance is stopped. Indeed, interruptions in performance or task completions imply that performance must be started again, which is energy-consuming and naturally slows or thwarts performance (Iso-Ahola and Dotson, 2016). Similarly, if PM is perceived as an impetus, it is difficult to regain it once it is lost (Markman and Guenther, 2007).

Taken together, the conceptual models illustrate that PM is an elusive and multifaceted phenomenon. Although the conceptualizations are distinctive, we can derive several key theoretical properties of how PM arises and when it influences performance. First, a precipitating event is necessary for PM to arise. Second, contextual and personal factors influence the strength of PM and thus the change in actual performance. Finally, interruptions in task performance terminate PM.

2.2 Related Empirical Literature

Iso-Ahola and Mobily (1980) and Gilovich et al. (1985) conducted two of the initial empirical studies on PM. Whereas Gilovich et al. (1985) find no evidence for a positive relation between the outcomes of successive shots in basketball, Iso-Ahola and Mobily (1980) find support for the existence of PM by analyzing data from a competitive racquetball tournament. These contradicting results have persisted throughout various subsequent empirical examinations.

Investigating the performance of Major League Baseball players, Green and Zwiebel (2017) find results that are in line with PM theory. The authors examine ten different performance measures, such as the batting average or home runs per at bat, and show that the recent performance is predictive of the current outcomes for both hitters and pitchers. Page and Coates (2017) and Cohen-Zada et al. (2017) confirm these results for men but not for women. The former work analyzes the effect of tie-breaks in tennis, and the latter work investigates bronze medal fights in judo. In addition, Weinberg and Jackson (1989) show that male tennis players come from behind more often than female tennis players. Thus, there is evidence that the gender of an athlete affects PM. In two further studies, scholars have addressed additional factors at the personal and contextual levels that potentially influence the strength of PM. Livingston (2012) examines golfers' hole-by-hole performance and only finds evidence of PM for the least experienced group of golfers. Dietl and Nesseler (2017) investigate the outcome of sets in singles tennis matches and find results in line with PM only for players who control the match.

In contrast, many studies find no significant change in performance following a precipitating event. Several scholars have failed to find evidence of PM in tennis when examining the outcome of sets (Silva et al., 1988; Malueg and Yates, 2010) and when examining the sequences of service points (O'Donoghue and Brown, 2009). Additionally, Parsons and Rohde (2015) and Gauriot and Page (2018) find no support for the existence of PM in football. The authors examine the effect of certain events in the first half and find no significant effect on teams' second-half performance. These results are in line with those of Mago et al. (2013), who conduct an experimental analysis of a best-of-three contest that involves both intermediate prizes and a varying role of luck.

However, in most field studies, scholars have neglected the effect of interruptions on PM. Interruptions potentially terminate PM (Iso-Ahola and Dotson, 2016) and thus possibly explain why several studies that employ a setting where the performance task is interrupted fail to find evidence of PM. The effect of task interruptions on PM is mostly examined in laboratory experiments. By asking study participants about their perceptions of PM in artificial scenarios or audiovisual simulations, Briki et al. (2014), Den Hartigh and Gernigon (2018), and Markman and Guenther (2007) find that interruptions lead to a loss of perceived PM. However, the authors do not examine people's actual task performances. Furthermore, Gilden and Wilson (1995) conduct an experiment in golf putting and dart throwing and find that golf putting is much streakier than dart throwing. The authors conjecture that while there is no break in the activity in the putting experiment, the interruption between sets in darts might partly offset the momentum effects.

One noteworthy exception is the work of Mace et al. (1992), who study the effect of interruptions in the field. The authors analyze 14 college basketball games during the 1989 National Collegiate Athletic Association tournament. Mace et al. (1992) compare teams' relative performance three minutes prior and three minutes subsequent to a timeout and conclude that an interruption reduces a team's momentum. However, the study suffers from an endogeneity problem. Because a timeout call is self-chosen, teams presumably call a timeout in a situation in which the opposing team has an advantage. In turn, it is likely that the performance of both teams regresses to their average performance level after the interruption.

In summary, in Table 1, we list the main findings of the large body of research that has empirically investigated PM. Most of these studies have only focused on the existence of PM per se, even though several theoretical models of PM emphasize that contextual and personal factors affect PM and that interruptions terminate PM. Not surprisingly, the results from the empirical literature are widely mixed.

Table 1: Overview of empirical studies on psychological momentum

Reference	Setting	Description	Finding
Iso-Ahola and Mobily (1980)	Racquetball	Winning or losing racquetball matches after winning prior games	Evidence of PM; strongest effect for inexperienced male competitors
Green and Zwiebel (2017)	Baseball	Examination of various baseball-related statistics	Evidence of PM
Page and Coates (2017)	Tennis	Effect of winning a tie-break on the outcome of the subsequent set	Evidence of PM for men but not for women
Cohen-Zada et al. (2017)	Judo	Outcome of judo fights within a tournament	Evidence of PM for men but not for women
Weinberg and Jackson (1989)	Tennis	Players' ability to come from behind (set level) and win a tennis match	Males come from behind more often than females
Livingston (2012)	Golf	Golfers' hole-by-hole performances while dividing the golfers into four groups based on their experience	Limited evidence of PM; only for the least experienced group
Dietl and Nesseler (2017)	Tennis	Outcome of sets within single tennis matches	Limited evidence of PM; only when players control the match
		—	
Gilovich et al. (1985)	Basketball	Successive shots scored or missed within basketball games	No evidence of PM
Silva et al. (1988)	Tennis	Winning or losing tennis matches after winning prior sets	⋮
Malueg and Yates (2010)	Tennis	Winning or losing tennis matches after winning prior sets	
O'Donoghue and Brown (2009)	Tennis	Sequences of service points	
Gauriot and Page (2018)	Football	Effect of scoring before half time on performance in the second half	
Parsons and Rohde (2015)	Football	Effect of first-half goals on goals scored in the second half	
Mago et al. (2013)	Experiment	Outcomes and efforts in a best-of-three contest that includes both intermediate prizes and a varying role of luck	No evidence of PM
		—	
Briki et al. (2014)	Experiment	Perception of PM for participants watching an audiovisual simulation of table tennis	Interrupting positive (negative) momentum lowers (increases) PM perceptions
Den Hartigh and Gernigon (2018)	Experiment	Perception of PM for participants watching an audiovisual simulation of table tennis	Timeouts lead to a loss of positive PM and to a recovery in the negative PM situation
Markman and Guenther (2007)	Experiment	Perception of PM in various situations	Study participants believe PM to diminish after an interruption
Gilden and Wilson (1995)	Experiment	Streakiness in golf putting and dart throwing	Golf putting is streakier than dart throwing presumably because of interruptions between sets in darts
Mace et al. (1992)	Basketball	Sequences of scored and missed shots, turnovers, and fouls	Timeouts terminate PM

Notes: The table presents an overview of the empirical studies on psychological momentum.

3 Psychological Momentum in Tennis

3.1 Tennis Setting

In tennis, points are linked to games, games to sets and sets to the winning of the match (Bizzozero et al., 2016). A player wins a point if the opponent fails to return the ball. Points are counted from 0 ("love"), 15, 30, 40 to "game", each equaling one point. A player wins a game (a set) with a two-point (two-game) lead over his opponent and a minimum of four points (six games) within a game (set). A tie-break decides about the outcome of a set if both players win six games within a set. The winner of the tie-break is the player with a two-point lead over his opponent and at least seven successful points. In Grand Slam tennis, a player who wins three sets wins the match and progresses to the next tournament round. A Grand Slam tournament consists of seven rounds—the first round to the final round.

Between games, players alternate serving the ball. The server serves the ball and tries to place the ball into the receiver's service box. The server is more likely to win a game because the service allows for a faster and more accurate shot. A player realizes a game point if he wins the game when serving the ball and realizes a break point if he wins the game when receiving the ball. Because of its infrequent occurrence, realizing a break point is often enough to determine the outcome of a set. Thus, a realized break point is a key event in a tennis match (Klaassen and Magnus, 1998; Magnus and Klaassen, 1998).

After every odd game of each set, there is a changeover, where players switch sides. After the first game, there is no rest period before switching sides. However, starting at the end of the third game of each set within a match, there is a rest period of a maximum of 90 seconds between the two sequential games. Additionally, at the end of each set, there is a rest period of a maximum of 120 seconds.[2] These changeover rest periods interrupt the play because players usually sit down on the sidelines of the tennis court.

3.2 Measuring Psychological Momentum in Tennis

Grand Slam singles tennis offers an ideal opportunity to examine PM in the field. First, momentum involves dependency and requires a series of tasks within a multistep workflow (Iso-Ahola and Mobily, 1980; Adler, 1981; Vallerand et al., 1988; Taylor and Demick, 1994). In tennis, many points, games, sets and matches follow one another. Second, in singles tennis matches, players meet in a face-to-face competition in which player substitutions are not allowed. Thus, a player's performance does not depend on a team member's performance, and it is not possible to allocate more defensive resources to a player that has gained positive momentum (Green and Zwiebel, 2017). Third, the performance, i.e., winning or losing a point, is objective. Thus, an examination of point-by-point or game-by-game data provides an opportunity to obtain detailed insight into a player's changes in performance in the course

[2] The duration of the changeover interruptions between games and sets are officially stated in the International Tennis Federation's (ITF's) rule book. However, changeover interruptions are, in practice, often longer than 90 or 120 seconds.

of a match. Finally, changeover interruptions are exogenously given, and contextual and personal data such as information on the stage of a match, i.e., number of games and sets, and players' relative ability based on betting odds are readily available.

To investigate PM, we focus on points and games directly following a realized break point. Realized break points are key events in a tennis match because they are a necessary milestone in winning a match, but they occur infrequently (Klaassen and Magnus, 1998; Magnus and Klaassen, 1998). Statistics from the Association of Tennis Professionals (ATP) emphasize the rare occurrence of realized break points in a tennis match. In the 2009 to 2014 seasons, the top 10 tennis players in each year—regarding the number of service games won—were on average only broken between 11% and 13% in all their service games.[3] Thus, winning a break point is a possible precipitating event that might trigger PM.

To investigate whether interruptions terminate PM, we employ the rest periods of players when switching sides, starting at the end of the third game of each set within a match. Rest periods in tennis are exogenously given by the rules of tennis, whereas timeouts in other sports are taken in response to a certain play dynamic. Thus, the tennis setting allows us to properly test whether interruptions affect PM.

3.3 Hypotheses

If PM is experienced, individuals do not want to be interrupted in their task performance because the restarting of performance after interruptions is energy-consuming and may result in deteriorated performance (Iso-Ahola and Dotson, 2016). In tennis, the changeover rest periods interrupt task performance, and players usually sit down, which likely terminates any PM effects. Thus, we hypothesize the following:

> *H1a: A realized break point increases performance in the following game if there is no changeover interruption.*
>
> *H1b: A realized break point does not alter performance in the following game if there is a changeover interruption.*

[3] See https://www.atpworldtour.com/en/stats/service-games-won/.

The previous research highlights that the strength of PM depends on various personal and contextual factors (e.g., Vallerand et al., 1988; Markman and Guenther, 2007). One potential channel through which such factors influence PM is the perceived value and context of the precipitating event (Iso-Ahola and Dotson, 2014). In tennis, the value of a realized break point depends on the relative ability of the players. More specifically, a realized break point does not substantially alter the perceived likelihood of winning for a player whose ability is much greater compared to his or her opponent. In contrast, if a player with a lesser relative ability realizes a break point, there is a certain “wow” factor associated with it. The player might then perceive a gain in confidence and thus an increased likelihood of winning that combines to form stronger PM (Iso-Ahola and Dotson, 2014). Thus, the value of a realized break point is greater for players with a lesser relative ability, leading to a stronger PM. Under the condition that momentum is uninterrupted, we hypothesize the following:

H2: The momentum effect in H1a is stronger for players with a lesser relative ability.

Furthermore, the value of a realized break point also depends on the stage within the match. In tennis, points are linked to games, games to sets, and sets to matches (Bizzozero et al., 2016). Therefore, winning games and sets are necessary milestones for winning a match. Within a set, realizing a break is more valuable toward the end of the set because the opponent has fewer opportunities to catch up. This strengthens the perception of being closer to the milestone of winning the set, which should result in a stronger PM. Similarly, we expect a stronger PM after realizing a break later in the match compared to realizing a break earlier in the match because of the greater perceived importance of the former. Accordingly, we propose the following two hypotheses under the condition that momentum is uninterrupted:

H3a: The momentum effect in H1a strengthens with the number of games played in a set.

H3b: The momentum effect in H1a strengthens with the number of sets played in a match.

4. Data and Estimation Method

4.1 Dataset

Our data provided by IBM contain detailed information at the point level on 80 Wimbledon and 61 Roland Garros Grand Slam men's singles matches between 2009 and 2014.[4] IBM is the official supplier of information technology to Grand Slam tournaments. Altogether, our dataset comprises 31,018 point-level observations, of which 1,084 observations are data from tie-break games. First, the dataset includes the date, the tournament, the round within the tournament and the two opponents of the match. Second, we have information on the exact score within the course of the match, i.e., point, game, and set scores. Third, there is information on how long the points and the rest periods within a match last. Additionally, we have pre- and in-play betting data for each match from Betfair, provided by Fracsoft. Betfair is the world's largest betting exchange, and Fracsoft is the official data vendor.

Table 2 provides the descriptive statistics. A match in our dataset lasts, on average, 153.9 minutes and consists of 220.0 points, 35.6 games and 3.6 sets. The average server wins 28.1 game points, whereas the average receiver breaks his opponent 6.7 times. The data include 61 different tennis players and matches from all stages of a Grand Slam tournament—the first round to the final round.[5]

Table 2. Descriptive statistics

Variable	Mean	Std. dev.	Min.	Max.
Match information				
Duration (minutes)	153.9	51.0	32.0	284.8
Number of points	220.0	67.3	55	437
Number of games	35.6	10.3	9	77
Number of sets	3.6	0.7	1	5
Server information				
Number of game points won	28.1	9.7	8	72
Receiver information				
Number of break points won	6.7	3.1	1	16

Notes: The table reports descriptive statistics for the 141 Wimbledon and Roland Garros men's singles matches between 2009 and 2014.

[4] IBM did not provide us with any more recent data.

[5] Ivo Karlovic had to give up in the 2014 Roland Garros match against Kevin Anderson due to an injury. This match, lasting only one set, is the reason for the low minimum values. However, excluding this match from our dataset leaves our findings in this study unchanged.

4.2 Variables

We examine the performance of the players at the point (N=29,934) and at the game (N=4,930) level after excluding all tie-break games. We exclude our tie-break data because break points are measured differently in tie-breaks than in regular sets. We employ two objective performance measures, *ServerWinsPoint* at the point level and *ServerWinsGame* at the game level, to determine whether the server or receiver wins a point or game. The performance variables take a value of 1 if the server wins a point or a game and 0 otherwise.

To measure PM, we include the dummy variable *RealizedBreakpointPrevious*. At the game level, this variable equals 1 for the immediate game subsequent to a realized break point and 0 otherwise. At the point level, *RealizedBreakpointPrevious* takes a value of 1 for every point within the game directly following a realized break point and 0 otherwise. In every opening game of a set, the variable *RealizedBreakpointPrevious* is set to 0. This approach allows us to examine whether the probability of the server winning his service game and the points within that game increases after breaking the service of his opponent.[6] Moreover, we test the effect of interruptions on momentum by classifying the games as either *ChangeoverInterruption* or *NoChangeoverInterruption,* depending on the game number in a set.

We control for several factors that potentially influence our results. First, a crucial factor to correctly examine momentum is an appropriate control for the playing strength of the two competitors. Because the player with the increased performance is usually the stronger player, a lack of control for ability might yield an upward-biased estimate (Cohen-Zada et al., 2017; Malueg and Yates, 2010). We control for the two opponents' ability difference by using the Betfair betting odds at the beginning of the match. Thereby, the inverse of each player's betting odds represents his probability of winning the match and thus his strength (e.g., Bizzozero et al., 2018).[7] We define the variable *MatchWinPercentageDifference* as the difference between the winning percentage of the focal player and the winning percentage of the opponent, such that a higher value of *MatchWinPercentageDifference* implies a greater relative strength of the focal player.

[6] Note that the player who is serving the ball was receiving the ball in the previous game. Thus, a player who breaks his opponent is always acting as the server in the subsequent game.

[7] We employ the mid odds, which are the average of the best back and lay odds. The mid odds can take a value between 1.01 and 1000. Thus, the inverse of these odds can range between 0.1% and 99%.

Second, we account for differences in the stage of the match, i.e., differences between sets (*set dummies),* and for differences in the stage of the tournament, i.e., differences between rounds (*round dummies*). Third, we include dummies for the current score of the server (*set score server dummies, game score server dummies, and point score server dummies*) and the receiver (*set score receiver dummies, game score receiver dummies, and point score receiver dummies*). We categorize these variables as *score controls*. These *score controls* account for different strategic considerations of the two opponents during the course of a match. Finally, we include dummies for the match and the serving player to account for differences in the tournament, the court and the weather (*match dummies*) and for additional differences in the playing style and strengths and weaknesses of the two opponents while serving and receiving (*serving player dummies*).[8]

4.3 Estimation Equation

We use a linear probability model (LPM) to test for the existence of PM. All our estimations use heteroscedasticity-robust and clustered standard errors. Our equation at the point level can be written as follows:

$$ServerWinsPoint_{mp} = \alpha + \beta_1 RealizedBreakpointPrevious_{mp} + X'_{mp}\beta + \varepsilon_{mp}, \quad (1)$$

where *m* indicates the match and *p* indicates the point within the match. The performance variable *ServerWinsPoint* indicates whether the server wins a point, and the independent variable of interest *RealizedBreakpointPrevious* indicates whether the server broke his opponent in the previous game. We thus aim to examine whether the server wins more points in the game directly following a realized break point. *X* contains the control variables described in Section 4.2.

Our equation at the game level can be written as follows:

$$ServerWinsGame_{mg} = \alpha + \beta_1 RealizedBreakpointPrevious_{mg} + X'_{mg}\beta + \varepsilon_{mg}, \quad (2)$$

where *m* indicates the match and *g* indicates the game within the match. The performance variable *ServerWinsGame* indicates whether the server wins a game, and the independent variable of interest *RealizedBreakpointPrevious* indicates whether the server won the prior game. We thus aim to examine

[8] Empirically, including match and serving player dummies is equal to including serving player, receiving player and date dummies.

whether the performance of the two opponents increases in the game directly following a realized break point. *X* contains the control variables described in Section 4.2.

To test the effect of interruptions on momentum, we run Equations (1) and (2) while distinguishing between the games classified as *ChangeoverInterruption* and No*ChangeoverInterruption.* Moreover, to examine the role of personal and contextual factors in PM, we interact the independent variable of interest with i) the *MatchWinPercentageDifference*, ii) the number of games played in a set, and iii) the number of sets played in a match.

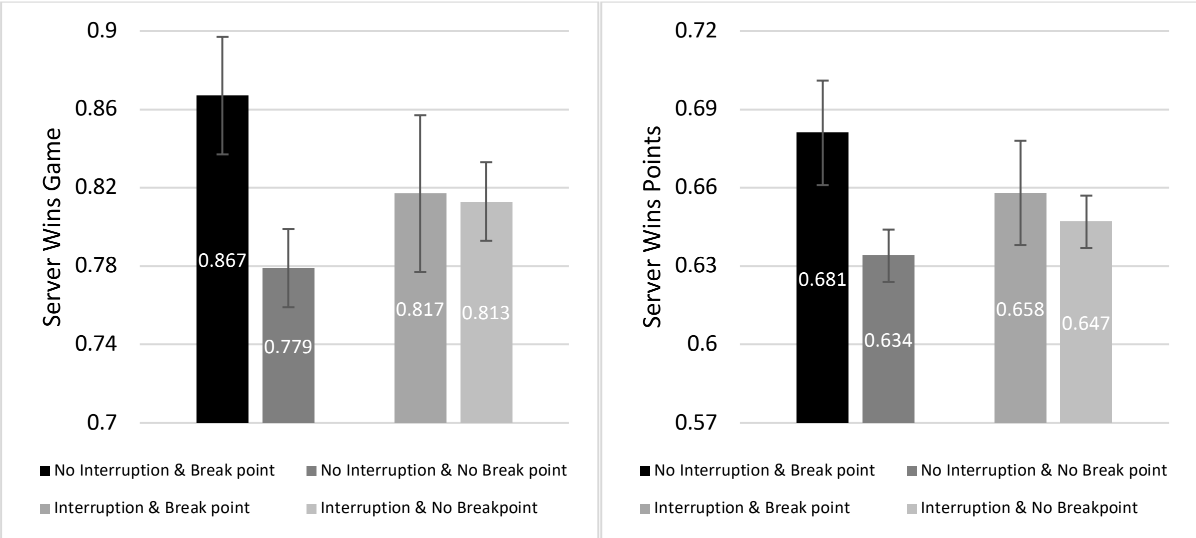
5. Results

5.1 PM and Interruptions

5.1.1 Descriptive Evidence

Figure 1 shows the average number of points and games that a server wins. The error bars show the 95% confidence interval of the averages. We distinguish between points and games that directly follow a realized break point and points and games not following a realized break point and, additionally, between games that take place subsequent to a changeover interruption and games that directly follow one another. We find consistent results at both point and game levels. If no rest period interrupts two successive games, the probability that the server wins the game and the points within that game is higher after a player breaks his opponent. Our results thus indicate that PM in tennis exists after realized break points. On the other hand, this effect disappears if a rest period interrupts the two sequential games. The observed descriptive findings are difficult to explain in relation to player ability because better players are expected to win more games, irrespective of interruptions. Figure 1 thus provides the first indication that realizing a break point triggers PM and that changeover interruptions terminate the momentum effects.

Figure 1. Points and games after realized break points with and without interruptions



Notes: The bars show the average number of points and games that a server wins in situations with and without prior realized break points and with and without prior changeover interruptions. The error bars show the 95% confidence interval of the averages.

5.1.2 Multivariate Evidence

In this section, we empirically examine the existence of PM in tennis using Equations (1) and (2) from Section 4.3.[9] We test the effect of interruptions on PM by examining the games classified as *ChangeoverInterruption* versus *NoChangeoverInterruption* separately. As depicted in Table 3, columns (1) and (2) contain the games classified as *NoChangeoverInterruption*, whereas columns (3) and (4) include the games classified as *ChangeoverInterruption*. Our examinations are at the point level in columns (1) and (3) and at the game level in columns (2) and (4).[10] In columns (1) and (2), the independent variable of interest, *RealizedBreakpointPrevious,* is significant and positive, whereas in columns (3) and (4), this variable is insignificant. Thus, a player is more likely to win the points in the game directly following a realized break point and the game itself only if uninterrupted. These findings support *Hypotheses 1a* and *1b* that PM exists after realized break points and that changeover interruptions terminate these momentum effects. [11]

[9] By testing these and all further equations using a Probit model, we find marginal effects that are almost identical to the effects using an LPM model.
[10] We employ the same structure in all subsequent tables.
[11] To test whether players' ability in the games with versus without prior changeover interruptions is not driving these results, we test for the difference in the variable *MatchWinPercentageDifference* in the games classified as *ChangeoverInterruption* and the games classified as *NoChangeoverInterruption.* Using Student's t-test, we find no significant difference in *MatchWinPercentageDifference* (p-value of 0.69). Thus, more skilled players are not more likely to realize a break in games subsequent to an interruption compared to games without a subsequent interruption.

Table 3. Effect of changeover interruptions on psychological momentum

	No Changeover Interruption		Changeover Interruption	
	ServerWinsPoint (1)	*ServerWinsGame* (2)	*ServerWinsPoint* (3)	*ServerWinsGame* (4)
RealizedBreak-pointPrevious	0.0437*** (3.30)	0.0934*** (3.73)	0.0070 (0.49)	0.0044 (0.15)
MatchWinPer-centageDifference	0.0880*** (6.17)	0.1518*** (5.53)	0.0836*** (5.13)	0.1153*** (3.64)
Round Dummies	X	X	X	X
Set Dummies	X	X	X	X
Score Controls	X	X	X	X
Match Dummies	X	X	X	X
Server Dummies	X	X	X	X
Observations	16,281	2,690	13,653	2,240
R^2	0.04	0.19	0.04	0.18

Notes: We use heteroscedasticity-robust and clustered standard errors. T-statistics are given in parentheses.

*** significant at 1%, ** significant at 5% and * significant at 10%.

5.1.3 Robustness Tests

In our previous analyses, we examined whether the performance of tennis players changes after a realized break point and whether a short rest period between games influences these performance changes. We find evidence that players experience PM after a realized break point and that the momentum effect disappears after a changeover interruption between games. However, the possibility remains that a player's performance changes in the course of a match, independent of the effect of PM. For example, a player might adapt to the serve or playing style of his opponent after a few games in a match. To address this potential concern, we employ two robustness tests. First, we focus solely on games directly before and directly after a realized break point and neglect all other games. These two games are closest to the precipitating event, i.e., the realized break point. Second, we use in-play odds to control for time-varying player strength during the course of a match.

In columns (1) to (4) in Table 4, we examine all games taking place immediately before and immediately after a realized break point. We thus analyze whether a player's performance in the game directly following a realized break point is different from his performance in the game immediately before the realized break point. The findings are in line with our previous results. The independent variable of interest is positive and significant in columns (1) and (2), i.e., in a noninterruption situation, and insignificant in columns (3) and (4), i.e., in the games subsequent to a short rest period. We thus confirm our previous findings that a realized break point triggers improved performance and that a short rest period interrupting two consecutive games terminates the observed effect.

Table 4. Robustness test comparing games directly before and after realized break points

	No Changeover Interruption		Changeover Interruption	
	ServerWinsPoint (1)	*ServerWinsGame* (2)	*ServerWinsPoint* (3)	*ServerWinsGame* (4)
RealizedBreak-pointPrevious	0.0757*** (3.60)	0.1666*** (3.75)	0.0104 (0.45)	0.0287 (0.68)
MatchWinPer-centageDifference	0.1104*** (2.81)	0.0596 (0.89)	0.1964** (2.57)	0.1981 (1.35)
Round Dummies	X	X	X	X
Set Dummies	X	X	X	X
Score Controls	X	X	X	X
Match Dummies	X	X	X	X
Server Dummies	X	X	X	X
Observations	4,909	825	4,072	681
R^2	0.07	0.34	0.08	0.38

Notes: We use heteroscedasticity-robust and clustered standard errors. T-statistics are given in parentheses.
*** significant at 1%, ** significant at 5% and * significant at 10%.

In our second robustness test, we exchange the variable *MatchWinPercentageDifference* with the current match-win percentage difference (*CurMatchWinPercentageDifference*) using in-play betting odds during the match instead of the preplay odds at the beginning of the match. The variable *CurMatch-WinPercentageDifference* consists of the one-point-lagged of the one-game-lagged match-win odds and thus reflects the server's probability difference of winning the match at the beginning of the point or game.[12] This variable allows us to control for a player's performance change in the course of the match that is not triggered by PM.

The results in Table 5 support our main findings. The variable *RealizedBreakpointPrevious* is positive in columns (1) and (2), i.e., in games not interrupted by a short rest period, and insignificant in columns (3) and (4), i.e., in games following an interruption. These results confirm that a player is more likely to win the points in the game directly following a realized break point and the game itself only if uninterrupted.

[12] Note that we use the match-win odds and not the odds of winning the next point or game.

Table 5. Robustness test using an alternative match-win percentage difference

	No Changeover Interruption		Changeover Interruption	
	ServerWinsPoint (1)	*ServerWinsGame* (2)	*ServerWinsPoint* (3)	*ServerWinsGame* (4)
RealizedBreak-pointPrevious	0.0419*** (3.16)	0.0914*** (3.65)	0.0066 (0.46)	0.0028 (0.10)
CurMatchWinPer-centageDifference	0.0882*** (6.11)	0.1205*** (4.27)	0.0874*** (5.14)	0.0457 (1.41)
Round Dummies	X	X	X	X
Set Dummies	X	X	X	X
Score Controls	X	X	X	X
Match Dummies	X	X	X	X
Server Dummies	X	X	X	X
Observations	16,281	2,690	13,653	2,240
R^2	0.04	0.18	0.04	0.17

Notes: We use heteroscedasticity-robust and clustered standard errors. T-statistics are given in parentheses.

*** significant at 1%, ** significant at 5% and * significant at 10%.

5.2 PM and Personal and Contextual Factors

To analyze the effect of personal and contextual factors on PM, we interact several variables with the independent variable of interest, *RealizedBreakpointPrevious*. To account for the relative ability difference between players and its effect on momentum, we interact the variable *MatchWinPercentageDifference* with the variable *RealizedBreakpointPrevious*. A higher value of *MatchWinPercentageDifference* implies a greater relative strength of the focal player. Additionally, this analysis allows us to address the possible concern that the results in Section 5.1 are driven by ability differences between players, i.e., in the case when a player wins the game subsequent to a realized break point because he is simply the better player.

Our results in Table 6 show insignificant values for the interaction term *RealizedBreakpointPrevious* × *MatchWinPercentageDifference* in the games classified as *ChangeoverInterruption*, i.e., in columns (3) and (4). In columns (1) and (2), the interaction term is negative and significant. PM is thus stronger for players with lesser relative ability. Altogether, we find support for *Hypothesis 2* and evidence against the potential concern that a player is more likely to win the game following a realized break point simply due to his ability advantage.

Table 6. Interaction of relative ability

	No Changeover Interruption		Changeover Interruption	
	ServerWinsPoint (1)	*ServerWinsGame* (2)	*ServerWinsPoint* (3)	*ServerWinsGame* (4)
RealizedBreak-pointPrevious × *MatchWinPer-centageDifference*	-0.0484*** (-2.73)	-0.0582* (-1.82)	0.0174 (0.89)	0.0443 (1.10)
RealizedBreak-pointPrevious	0.0506*** (3.73)	0.1020*** (3.85)	0.0043 (0.29)	-0.0043 (-0.14)
MatchWinPer-centageDifference	0.0940*** (6.53)	0.1589*** (5.76)	0.0821*** (5.02)	0.1115*** (3.51)
Round Dummies	X	X	X	X
Set Dummies	X	X	X	X
Score Controls	X	X	X	X
Match Dummies	X	X	X	X
Server Dummies	X	X	X	X
Observations	16,281	2,690	13,653	2,240
R^2	0.04	0.19	0.04	0.18

Notes: We use heteroscedasticity-robust and clustered standard errors. T-statistics are given in parentheses.

*** significant at 1%, ** significant at 5% and * significant at 10%.

To account for the stage of the match and thus for the perception of being closer to the milestone of winning the set or match, we interact the variable *RealizedBreakpointPrevious* with the number of games (*Game*) in a set and with the number sets (*Set*) in a match. Columns (1) to (4) in Table 7 depict the results of the former, whereas columns (1) to (4) in Table 8 depict the results of the latter.

Confirming our prior results, we find insignificant effects in columns (3) and (4) in both Tables 7 and 8. There is no evidence of PM after changeover interruptions. On the other hand, in both Tables 7 and 8, the interaction term is positive and significant in column (1) and positive but not significant in column (2). Our results thus confirm that PM is stronger toward the end of a set and toward the end of a match at the point level. However, this effect is not sufficient to actually produce a lasting gain at the game level. Altogether, we find weak support for *Hypotheses 3a* and *3b*.

Table 7. Interaction of number of games played

	No Changeover Interruption		Changeover Interruption	
	ServerWinsPoint (1)	*ServerWinsGame* (2)	*ServerWinsPoint* (3)	*ServerWinsGame* (4)
RealizedBreakpointPrevious × *Game*	0.0100** (2.09)	0.0127 (1.45)	-0.0060 (-0.86)	0.0045 (0.34)
RealizedBreakpointPrevious	-0.0157 (-0.50)	0.0172 (0.30)	0.0479 (0.97)	-0.0265 (-0.28)
Game	-0.0077 (-1.45)	-0.0083 (-0.76)	-0.0223 (-0.61)	-0.0068 (-0.21)
MatchWinPercentageDifference	0.0885*** (6.21)	0.1521*** (5.54)	0.0836*** (5.13)	0.1152*** (3.64)
Round Dummies	X	X	X	X
Set dummies	X	X	X	X
Score Controls	X	X	X	X
Match Dummies	X	X	X	X
Server Dummies	X	X	X	X
Observations	16,281	2,690	13,653	2,240
R^2	0.04	0.19	0.04	0.18

Notes: We use heteroscedasticity-robust and clustered standard errors. T-statistics are given in parentheses.

*** significant at 1%, ** significant at 5% and * significant at 10%.

Table 8. Interaction of number of sets played

	No Changeover Interruption		Changeover Interruption	
	ServerWinsPoint (1)	*ServerWinsGame* (2)	*ServerWinsPoint* (3)	*ServerWinsGame* (4)
RealizedBreakpointPrevious × *Set*	0.0185** (2.07)	0.0172 (1.15)	0.0154 (1.42)	0.0141 (0.68)
RealizedBreakpointPrevious	0.0005 (0.02)	0.0529 (1.21)	-0.0286 (-0.99)	-0.0288 (-0.51)
Set	-0.0085 (-1.16)	-0.0126 (-0.85)	-0.0071 (-0.87)	-0.0216 (-1.25)
MatchWinPercentageDifference	0.0899*** (6.28)	0.1534*** (5.57)	0.0833*** (5.11)	0.1150*** (3.63)
Round Dummies	X	X	X	X
Set dummies	X	X	X	X
Score Controls	X	X	X	X
Match Dummies	X	X	X	X
Server Dummies	X	X	X	X
Observations	16,281	2,690	13,653	2,240
R^2	0.04	0.19	0.04	0.18

Notes: We use heteroscedasticity-robust and clustered standard errors. T-statistics are given in parentheses.

*** significant at 1%, ** significant at 5% and * significant at 10%.

6. Conclusion

Various scholars have empirically examined PM. Whereas some studies have found evidence in line with the momentum effect, others have not. We propose that contextual and personal factors as well as duration effects play a role in the occurrence of PM and that the neglection of these factors in prior empirical studies has at least partly contributed to the mixed findings. Using tennis players' performance data in Grand Slam matches, we find support for the existence of PM and emphasize the role of an interruption as a possible terminating event of PM. Additionally, we show that players' relative ability and the stage within a match affect PM.

Our findings imply that an examination of the momentum effect per se is insufficient. It is a misconception that PM affects all individuals in the same way. Contextual and personal factors are important factors in the manifestation of PM. Additionally, we show that it is crucial not only to examine the precipitating events of PM but also to investigate the potential events that terminate PM.

The advantage of our setting, with the fine-grained tennis data and the exogenously given interruptions, is also the greatest limitation of this study. We find clear evidence that changeover interruptions terminate a tennis player's PM. However, a transfer of our findings to the labor market is difficult because the frequency and duration of the rest periods in tennis are exogenously given. In contrast, in the labor market, rest periods occur less frequently, and workers can, to a certain extent, choose the timing and duration of a rest period by themselves. Future research should thus address the question of how interruptions affect PM in more detail.

References

Adler, P., 1981. Momentum: A theory of social action. Beverly Hills, CA: Sage Publications.

Bizzozero, P., Flepp, R., Franck, E., 2016. The importance of suspense and surprise in entertainment demand: Evidence from Wimbledon. Journal of Economic Behavior and Organization 130, 47-63.

Bizzozero, P., Flepp, R., Franck, E., 2018. The effect of fast trading on price discovery and efficiency: Evidence from a betting exchange. Journal of Economic Behavior and Organization 156, 126-143.

Briki, W., Doron, J., Markman, K., Den Hartigh, R., Gernigon, C., 2014. Differential reactions of virtual actors and observers to the triggering and interruption of psychological momentum. Motivation and Emotion 38, 263-269.

Cohen-Zada, D., Krumer, A., Shtudiner, Z., 2017. Psychological momentum and gender. Journal of Economic Behavior and Organization 135, 66-81.

Den Hartigh, R. J., Gernigon, C., 2018. Time-out! How psychological momentum builds up and breaks down in table tennis. Journal of Sports Sciences 36(23), 2732-2737.

Dietl, H., Nesseler, C., 2017. Momentum in tennis: Controlling the match. International Journal of Sport Psychology 48(4), 459-471.

Gauriot, R., Page, L., 2018. Psychological momentum in contests: The case of scoring before half-time in football. Journal of Economic Behavior and Organization 149, 137-168.

Gilden, D. L., Wilson, S. G., 1995. Streaks in skilled performance. Psychonomic Bulletin and Review 2(2), 260-265.

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

Green, B., Zwiebel, J., 2017. The hot-hand fallacy: Cognitive mistakes or equilibrium adjustments? Evidence from Major League Baseball. Management Science 64(11), 5315-5348.

Iso-Ahola, S., Mobily, K., 1980. Psychological momentum: A phenomenon and an empirical (unobtrusive) validation of its influence in a competitive sport tournament. Psychological Reports 46, 391-401.

Iso-Ahola, S., Dotson, C., 2014. Psychological momentum: Why success breeds success. Review of General Psychology 18, 19-33.

Iso-Ahola, S., Dotson, C., 2016. Psychological momentum—A key continued success. Frontiers in Psychology 7, 1328.

Klaassen, F., Magnus, J., 1998. On the independence and identical distribution of points in tennis. Working paper. Tilburg University.

Klaassen, F., Magnus, J., 2014. Analyzing Wimbledon: The power of statistics. New York, NY: Oxford University Press.

Livingston, J., 2012. The hot hand and the cold hand in professional golf. Journal of Economic Behavior and Organization 81(1), 172-184.

Mace, C., Lalli, J., Shea, M., Nevin, J., 1992. Behavioral momentum in college basketball. Journal of Applied Behavior Analysis 25, 657-663.

Magnus, J., Klaassen, F., 1998. The importance of breaks in tennis: Four years at Wimbledon. Working paper. Tilburg University.

Mago, S., Sheremeta, R., Yates, A., 2013. Best-of-three contest experiments: Strategic versus psychological momentum. International Journal of Industrial Organization 31(3), 287-296.

Malueg, D., Yates, A., 2010. Testing contest theory: Evidence from best-of-three tennis matches. Review of Economics and Statistics 92(3), 689-692.

Markman, K., Guenther, C., 2007. Psychological momentum: Intuitive physics and naïve beliefs. Personality and Social Psychology Bulletin 33, 800-812.

O'Donoghue, P., 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.

Page, L., Coates, J., 2017. Winner and loser effects in human competitions: Evidence from equally matched tennis players. Evolution and Human Behavior 38, 530-535.

Parsons, S., Rohde, P., 2015. The hot hand fallacy re-examined: New evidence from the English Premier League. Applied Economics 47(4), 346-357.

Silva, J., Hardy, C., Crace, K., 1988. Analysis of psychological momentum in intercollegiate tennis. Journal of Sport and Exercise Psychology 10, 346-354.

Taylor, J., Demick, A., 1994. A multidimensional model of momentum in sports. Journal of Applied Sport Psychology 6, 51-70.

Vallerand, R., Colavecchio, P., Pelletier, L., 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.

Weinberg, R., Jackson, A., 1989. The effects of psychological momentum on male and female tennis players revisited. Journal of Sport Behavior 12, 167-179.