EFFECTS OF SCORE LINE ON MATCH PERFORMANCE IN PROFESSIONAL SOCCER PLAYERS

ATHALIE REDWOOD-BROWN

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Copyright Statement

Abstract

Investigating the impact of score line on performance in professional soccer players is of major interest to managers and coaches within professional soccer. However, the majority of studies investigating score line have omitted important components of performance such as team and opposition ability, goal difference and fatigue. Little is also known, regarding the impact of score line on the performance of different playing positions in different areas of the pitch. Thus, the aim of this thesis was to examine the effects of score line on the technical, physical and psychological components of performance across a number of variables (team ability, opposition ability, match location, pitch position, playing position) using new methods of automated tracking and data collection. The majority of participants were recruited from the English Premier League consisting of 1027 players and 501 games analysed across multiple seasons (2004-2005, 2007-2008, 2011-2012). The exception to this was Chapter 5 where the 75 participants were recruited from both EPL and Championship teams. Across all chapters playing position was characterised as striker (attacker), defender and midfielder and ability (both team and opposition) was defined as final league finish position. **Chapter 3** revealed in the 5 minutes that preceded a goal, the scoring team played a significantly greater percentage of passes accurately (72.4 ± 12.7) compared to the average for the half (70.2 ± 7.5) ($P<0.017$) while the conceding team played significantly fewer passes before (19.3 ± 8.4) compared to the average for the half (22.9 ± 4.3) ($P<0.017$). After the goal was scored, the scoring team played significantly fewer passes (21.5 ± 11.1) and a lower percentage of passes were played accurately (67.3 ± 14.7) than the average for the half of the match where the goal was scored (23.2 ± 5.2) (70.2 ± 7.5) ($P<0.017$). **Chapter 4** established a typical fatigue pattern using data from 79 player performances during five 0-0 drawn English FA Premier League matches. This typical fatigue pattern was used to adjust the work-rate of 90 player

performances in five English FA Premier League matches. There was a significant interaction between player position and score-line (p = .010) with forwards spending a greater percentage of time moving at 4 $m.s^{-1}$ or faster when their team was leading than when level while defenders spent a greater percentage of time moving at 4 $m.s^{-1}$ or faster when their team was trailing than when level. **Chapter 5** provided insight into the key experiences of psychological momentum (PM) and the strategies associated with positive and negative momentum using both questionnaires and interviews. Scoring or conceding a goal was an important factor that affected players' perceptions of positive and negative momentum, respectively. In addition, "feeling confident", "having a positive attitude" and "being cohesive as a team" were important aspects of positive PM. A "perceived lack of ability" and "feeling anxious" were the most frequently reported experiences of negative PM. The majority of key responses reported in the interviews were supported by the questionnaire data. The similarity of results from both methods support the measure as a useful tool for coaches to collect data pertaining to players' experiences and perceptions of PM. In order to investigate player movement in different score lines in **Chapter 6,** the validity of the Venatrack automated tracking system was tested. The system was compared to calibrated speed gates within a stadium environment. For all the runs combined the mean speed recorded by the automated system was 15.4 ± 5.5 $km \cdot h^{-1}$ compared with the recorded mean speed of 15.2 ± 5.4 $km \cdot h^{-1}$ and the mean difference and 95% limits of agreement were -0.25 ± 0.64 $km \cdot h^{-1}$. Pearson correlations (r) among timing gate speed and automated tracking speed were ≥ 0.99 ($P<0.001$), except the 20 m sprint, with 90° turn ($r > 0.7$). The results demonstrate good validity over a range of soccer specific movements and speeds, up to and including sprinting. In **Chapter 7a** multi-level regression revealed an inverted "u" shaped association between total distance covered and goal difference (GD), with greater distances covered when GD was zero and reduced distances when

GD was either positive or negative. A similar "u" shaped association was found with high speed distance covered at home. In addition, distance covered (both at home and away) were predicted by playing position. All activity profiles (with the exception of sprint distance at home) were predicted by pitch location and time scored. Lastly, distance away from home and high speed running at home were predicted by opposition ability. In **Chapter 7b** multi-level regression revealed a "u" shaped association between passing accuracy and goal difference (GD) with greater accuracy occurring at extremes of GD e.g., when the score was either positive or negative. The same pattern was seen for corner accuracy away from home e.g., corner accuracy was lowest when the score was close with the lowest accuracy at extremes of GD. Although free-kicks were not associated with GD, team ability, playing position and pitch location were found to predict accuracy. No situational variables were found to predict cross accuracy. The results of this thesis suggest that a number of variables are associated with both the physical and technical performance of players in difference score lines and that such effects may be related to the perception of events (as shown in Chapter 5) rather than fatigue, ability or opposition as previously thought. The current study also highlighted the need for more sensitive score line definitions in which to consider score line effects using technological advancements such as automated tracking systems.

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Grandad - this is dedicated to you.

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CHAPTER 1.0

Introduction

1.1 Introduction

Association football is played by 265 million people worldwide (Kunz, 2007), with the European football market revenue estimated at €25.5 billion for the 2016/17 season (Deloitte LLP Sports Business Group, 2018). At the highest level, teams earn in excess of €100 million per season (Deloitte LLP Sports Business Group) making the football industry a lucrative business for those who thrive within it. It is therefore not surprising, that in recent years, identifying the determinants of successful performance (defined as winning) has been a focus for football performance research in order to provide objective performance evaluations, comparisons and predictions (Hughes & Bartlett, 2002; Hughes & Franks, 2005; Jones, James & Mellalieu, 2004; Lago & Martin, 2007; Taylor, Mellalieu, James & Shearer, 2008; Taylor, Mellalieu, James & Barter, 2010; Tenga & Larsen, 2003).

Extensive research has investigated situational variables related to successful performance, such as game location (i.e. home or away) or quality of opposition (defined as either finishing position in the league table or progress in knock out competition) (Jones et al., 2004; Taylor, Mellalieu & James, 2005; Carling, Williams & Reilly, 2005; Lago & Martin, 2007; Lago, 2009; Lago-Peñas & Gomez, 2014; Lago & Dellal, 2010; Ridgewell, 2011; Redwood-Brown, Bussell & Bharaj, 2012) as well as key performance indicators (e.g. action related variables such as high speed distance completed or number or accuracy of passing) (Taylor et al., 2010). Advancements in technology (such as computerised tracking systems) have enabled researchers to analyse match performance in a more detailed manner helping professionals to identify these key attributes of success more readily (O'Donoghue & Robinson, 2009; Redwood-Brown et al., 2012; Lago-Peñas, Rey & Lago-Ballesteros, 2012).

In order to win a match, the successful team must score more goals than their opponent. Therefore, investigating how teams perform in different score lines, both in terms of scoring and conceding, could provide practitioners with vital information to avoid conceding goals and aid in scoring them. Adapted from Franks and Goodman's (1986) Systematic approach to analysing performance, Figure 1.1 highlights the key aspect of performance behaviour considered important in relation to the effect of score line. Commonly, the investigation of playing patterns

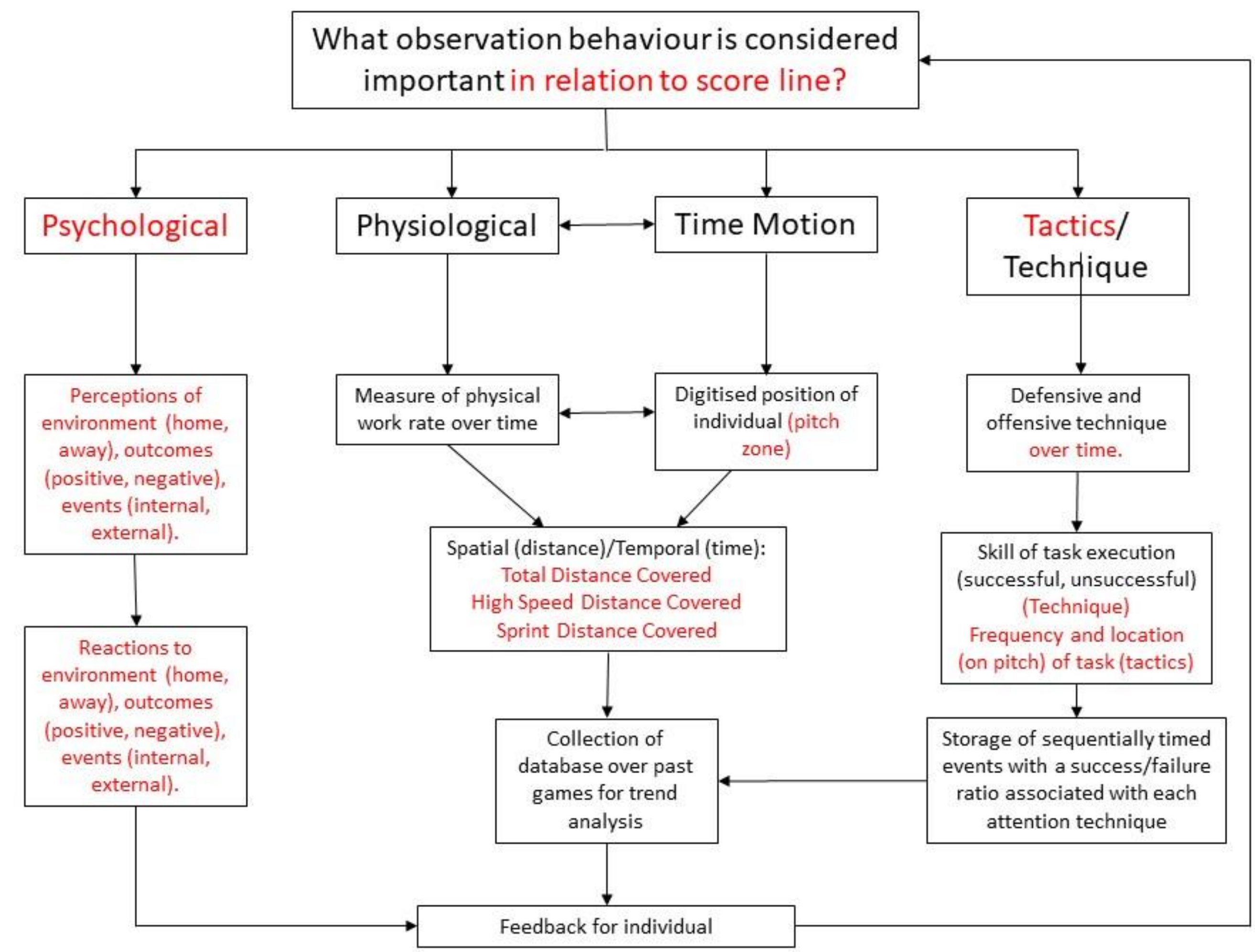

Figure 1.1 Model of Performance in relation to score line: *Note:* Adapted from From: Franks & Goodman (1986) A systematic approach to analysis sports performance. *Journal of Sports Science*, 4, 49-59.

(tactics) and success of performance variables (technique) such as shots on goal, crosses, corners, ball possession etc. (Lago-Peñas et al., 2012) has been used to distinguish between successful (winning match) and unsuccessful (losing match) teams, although the effect of score line on these performance variables is limited.

Although some studies (Al Haddad, Simpson, Bucheit, Di Salvo & Mendez-Villanueva, 2015; Bradley, Sheldon, Wooster, Olsen, Boanas & Krustrup, 2009; Dellal, Wong, Moalla & Chamari, 2010; Di Salvo, Gregson, Atkinson, Tordoff & Drust, 2009; Di Salvo, Baron, Tschan, Montero, Bachl & Pigozzi, 2007) have investigated the physiological performance of professional soccer players through activity profiles using time motion analysis, few to date have considered how successful and unsuccessful teams differ when winning, losing or drawing, when in different score lines states (e.g. 1-0, 2-0, 1-1 etc.) or when winning or losing by a certain number of goals. Understanding how players perceive score line from a psychological perspective may also help to explain the relationship and thus is an important addition to the model. The following sections give further justification for the inclusion of these variables in the model and thus the important of their investigation in the current thesis in relation to score line effects.

1.2 Effect of Score line on Technical and Tactical Factors

There has been much speculation about the influence of score line (i.e. scoring and conceding goals and/or whether a team is winning, losing or drawing) on player performance. Such speculation has motivated academic researchers to ascertain the influence of score line on different aspects of sports performance (Bloomfield, Polman & O’Donoghue, 2004a; 2004b; Lago & Dellal, 2010; O’Donoghue & Tenga, 2001; Paixão, Sampaio, Almeida & Duarte, 2015; Taylor et al., 2008). Score line is generally defined as a winning, losing or drawing state, however more recently smaller data sets (e.g. World Cup Tournaments) have included specific score lines or goal differences (e.g. 1:0, 1:1, 2:0) in an attempt to understand how the size of the lead or deficit affects player performance (Lago-Penas & Gomez-Lopez, 2014; O'Donoghue & Robinson, 2016; Ridgewell, 2011). In soccer the score line has been found to influence both technical (e.g. passing accuracy, successful possessions and successful throw-ins) (Bloomfield et al., 2004a; Jones et al., 2004; Lago & Martin, 2007; Lago-Penas & Gomez-Lopez, 2014; O'Donoghue & Robinson, 2016) and tactical performance (e.g. passing patterns, possession length and number of shots on target) (Taylor et al., 2008; Ridgewell, 2011). Although previous research has generally found passing accuracy and possession to vary depending on whether a team is winning, losing or drawing (Taylor et al., 2008), the omission of information pertaining to the methods and reliability of such observations (Wilson & Barnes, 1998), and the definitions used to investigate performance factors has led to questions over the accuracy of data collected (Hughes et al., 2002). The manual and somewhat time-consuming nature of previous systems used to measure performance variables has also limited the number of players observed. Both technical and tactical performance have also been found to vary as a function of several situational factors such opposition ability ((Bloomfield et al., 2004a; Lago & Martin, 2007), game location (Lago-Peñas & Lago-Ballesteros), team ability (Bloomfield et al., 2004) and pitch location (Ridgewell, 2011). However solemnly do studies consider score line effects taking into consideration multiply situational factors. There has also been a lack of consensus as to the cause of changes in performance in different score lines. Thus, there is a need for further work to investigate the effect of score line on both technical and tactical performance variables using more sophisticated, objective, reliable measurement systems that can compare multiple players, as well as different playing positions in different game situations (e.g. against different levels of opposition) across a number of score line conditions.

1.3 Effect of Score line on Activity Profiles

The score line has also been found to influence player activity profiles in team games, in terms of the amount of time players spend performing high speed activity (Buchheit, Modunoth, Stafford, Gregson & Di Salvo, 2018; Wallace & Norton, 2014); suggested as movement at or above 4 $m.s^{-1}$ (Robinson, O'Donoghue, & Wooster, 2011). A study of FA Premier League soccer players found that players spent a greater percentage of match time performing high speed running when the score was level than when their team was leading or trailing (O'Donoghue & Tenga, 2001). Shaw and O'Donoghue (2004) found similar effects of score line on the activity profiles of amateur soccer players as did Devlin and O'Donoghue (1999) in women's Gaelic football challenging the view that players chase the game when their team is losing. More recently Andrzejewski, Konefał, Chmura, Kowalczuk,and Chmura (2016) found difference in distances covered at high intensity across playing positions in different score line states. Although a number of score line effects have been found in relation to activity profiles, the methods used are generally time consuming and involve a high level of human intervention therefore limiting the number of players analysed per game and thus comparisons between players). Thus, there is a need for further research on the effect of score line on activity profiles with more valid and reliable measurement systems that can enable several players to be followed concurrently with limited human involvement.

1.4 Opposition ability

Although situational factors such as quality of opposition have been considered in a number of studies (Bloomfield et al., 2004a; Lago & Martin, 2007), these have generally considered performance factors without taking into consideration score line. Those that do consider the quality of opposition (e.g. Jones et al., 2004) have generally classified teams as successful or unsuccessful in relation to the game being observed without giving indication of the team's actual ability. Thus, score line effects, where the ability of each team has not been considered, may just reflect the fact that the opposition are better or worse.

It has previously been shown that teams increase their passing accuracy and ball possession when performing against middle ranked opponents in the English Premier League compared to top or bottom ranked opponents (Redwood-Brown, Bussell & Singh, 2012; Taylor et al., 2008). Similar patterns have also been shown in the Spanish Soccer League (La Liga) where the standard of opposition was shown to impact performance, as such the lesser the opponent the greater the possession (Lago & Martin, 2007). Although these studies suggest that differences in individual and team performance do change as a function of opposition standard, no account for match status (e.g. whether the team was winning drawing or losing) was considered. Due to the complex nature of soccer matches it has been suggested that soccer performance is influenced by a number of situational variables (Bradley & Noakes, 2013; Lago et al., 2010; (Redwood-Brown et al., 2012). For example, it has been found that most behaviours associated with "open play" are influenced by two or more situation variables, with match status (winning, drawing, losing) and match location being the two most pertinent. Although the "strong – weak" definition of the opposition used in Taylor et al's. (2008) study might have lacked the necessary sensitivity to show changes in behaviour as a function of the quality of opposition, investigating situational variables in isolation may be inappropriate given they can influence performance in a collective manner (i.e., playing at home against strong opposition may have an more of an effect on performance, than either variables alone). The nature of the sample size may also impact the ability to generalise findings, for example, case studies of individual teams allow patterns of play to emerge specific to that team in relation to the opposition, however using whole league data maybe more relevant to see more general patterns specific to certain situations (e.g. how teams react to the score line when playing against different opposition). Either way it is important that opposition ability is considered in future research to understand its impact on performance in different score line states.

1.5 Psychological Momentum

Although a number of score line effects have been highlighted in the research (Bloomfield, Polman & O'Donoghue, 2004a; 2004b; Lago-Peñas & Dellal, 2010; O'Donoghue & Tenga, 2001; Paixão, Sampaio, Almeida & Duarte, 2015; Ridgewell, 2011; Shaw & O'Donoghue, 2004; Taylor et al., 2008), there has been limited explanation as to what causes such effects. For example, the majority of studies have failed to consider the psychological impact of the score line or in fact the actual act of scoring or conceding a goal on performance from a psychological prospective. Hence the psychological impact of scoring and conceding has been included in the model of performance highlighted in Fig 1.1

The term momentum is frequently used to describe where the sequence of scoring has an influence on future performance success (Vallerand et al., 1988; Taylor & Demick, 1994; Gernigon, Briki, & Eykens, 2010; Briki, Den Hartigh, Markman, Micallef, & Gernigon, 2013) and therefore might be a possible explanation why a player's performance changes in relation to the score line. In sports where scoring is frequent, for example in racket sports, momentum is said to occur where there are sequences of winning points (Den Hartigh, Gernigon, Van Yperen, Martin & Van Geert, 2014; Gayton, Very, & Hearns, 1993; Raab, Gula & Gigerenzer, 2014; Silva, Hardy, & Crace, 1988). However, in lower scoring games, such as soccer; it is more difficult to measure momentum or to establish what creates momentum shifts and ultimately changes in player behaviour. Although research evidence suggests that perceptions of momentum exist and alter in response to gaining or losing ground in a competition (i.e. scoring and conceding) (Briki, Den Hartigh, Hauw & Gernigon, 2012a; Eisler & Spink, 1998; Iso-Ahola & Dotson, 2014; Moesch & Apitzsch, 2012; Perreault, Vallerand, Montgomery, & Provencher, 1998; Shaw, Dzewaltowski, & McElroy, 1992; Silva, Cornelius, & Finch, 1992; Stanimirovic & Hanrahan, 2004), many of the proposed mediators have not been empirically tested. Methods used to measure momentum have also lacked academic rigor with studies using a variety of different measurement techniques. A full discussion of the current trends in momentum literature will be presented in Chapter 2.7 to further justify the inclusion of psychological momentum within the performance model presented in Figure 1.1.

When discussing ‘perceptions’ of momentum the term ‘psychological’ is frequently used to describe momentum perceptions. Psychological momentum has frequently been measured via questionnaires using hypothetical scenarios and scales depending on whether the participants were ahead, behind or drawing to assess the effect on performance (see Briki et al., 2013; Briki, Den Hartigh, Hauw, & Gernigon, 2012a; Briki, Den Hartigh, Bakker, & Gernigon, 2012b; Den Hartigh, Gernigon, Van Yperen, Marin, & Van Geert, 2014; Perreault et al., 1998; Shaw et al., 1992; Vallerand et al., 1988). There is still some doubt as to how momentum affects performance in different score line states, but the strong belief from sports fans, athletes and media observers that momentum is key to performance success (Gernigon et al., 2010; Briki et al., 2012a; 2013; Briki, Den Hartigh, & Gernigon, 2015; Moesch & Apitzsch, 2012; Den Hartigh et al., 2014; Gayton et al., 1993; Jackson & Mosurski, 1997; Perreault et al., 1998; Vergin, 2000). As scoring goals is a key determinant of performance in soccer, and momentum has been seen as key to performance the relationship between the two should be further investigated and thus warrants its investigation in relation to score line. Thus, there is a need for carefully designed studies that examine the impact of score line on perceptions of psychological momentum in professional soccer players to further understanding of psychological momentum in team games and to draw out those factors that coaches and players can focus upon to enhance performance.

It is important for coaches, managers and sports professionals to understand performance changes that occur after scoring, especially if they can employ strategies to help players cope with such incidents. So far little research has demonstrated score line effects taking into consideration normal performance, opposition ability or enough matches to enable the findings to be generalised. Research has also failed to consider factors related to players' perceptions of the score line in determining how this may affect subsequent performance. Therefore, to gain a better understanding of score line effect it is firstly necessary to determine normal performance, for example during 0-0 drawn matches where no score line changes occurred. There is also a need for score line effect to be investigated using a greater volume of data as well as objective and reliable methods, such as semi-automatic player tracking systems now available to professional soccer clubs (Carling, Bloomfield, Nelsen, & Reilly, 2008). Using such systems would provide large data sets enabling other more detailed variables to be considered, for example opposition ability, positional role and multiple performance measures.

1.6 Rationale

The effect of score line on performance is poorly understood and although score line effects have been found in relation to changes in activity profile (O'Donoghue & Tenga, 2001; Shaw & O'Donoghue 2004; Bloomfield, Polman, & O'Donoghue, 2005) tactical and technical performance (Scully & O'Donoghue, 1999; O'Donoghue, 2006; 2007; Taylor et al., 2008), it is not clear whether these effects on performance are a consequence of natural fatigue, opposition ability or psychological factors (e.g. perceptions associated with gaining or losing momentum). Previously, due to the complexities of tracking player movement it has been difficult to access enough data to explore this effect in detail taking into account normalised patterns of behaviour (where no goals are scored). It has also been difficult to extrapolate data from different score line states or indeed for the time periods immediately preceding and immediately following a goal. By utilising semi-automated tracking systems not only will more data be generated, but the data can be specific to the time period required, enabling specific changes in performance in relation to score line to be observed (e.g. goals scored and conceded). Researchers (Carling et al., 2005) have also suggested using smaller time periods (e.g. 5 minutes) would allow a more comprehensive understanding of the impact of score line on performance giving us the opportunity to explore, in more detail reasons for such effects.

By investigating player's perceptions of psychological momentum it is hoped that a better understanding of the links between score line and performance can be established. Establishing whether psychological momentum can be used as an explanation for the score line effect will also be an important consideration. This may enable coaches, managers and practitioners to educate players on potential strategies to help gain momentum as well as overcome negative momentum in relation to either a positive or negative score line state. Thus, overall this thesis examines the impact of score line on technical, tactical, physical and psychological aspects of performance to better understand the impact of score line on the final match outcome.

1.7 Thesis Overview

Chapter 2 reviews the literature related to score line effects as well as the historical development of systems of measurement that have been employed to collect performance data in soccer. The review also considers the concept of momentum specifically in respect to its ability to explain score line effects from a psychological perspective.

Chapter 3 investigates the effect of score line on passing and movement in specific speed zones of English premier league soccer players. Specifically, it investigates how passing is affected in the 5 minutes before and after a goal is scored compared to normal performance. Chapter 4 reports on how high speed running is effected by score line state (winning, drawing and losing) taking into account normalised match fatigue (activity profile during 0-0 games) and player position (forwards/attackers, midfield and defenders).

Chapter 5 reports on the perceptions of psychological momentum in professional soccer players using both qualitative and quantitative methods. A mixed methods approach enabled a greater insight into players' experiences of both positive and negative momentum within soccer as well as the strategies used to maintain or gain positive psychological momentum and to cope with negative momentum. This provides evidence for the importance of goal scoring and conceding on player's perceptions of positive and negative psychological momentum.

Chapter 6 reports on the validation of an automated multiple camera tracking system (Venatrack™), for the measurement of movement activity during soccer matches. The aim of the study was to establish whether the Venatrack™ system was a valid and reliable motion analysis system for tracking player movement on a soccer pitch, thus providing a more comprehensive system for measuring player motion. The protocol from previous validation studies using semi-automated tracking systems (Di Salvo et al., 2006) was used to enable comparisons. Additional runs to those used by Di Salvo et al. (2006) were also included in the validation protocol to better represent match play as suggested by previous research (Carling et al., 2008). The sample size was also greatly increased to test the system under conditions similar to match day.

Chapter 7 reports on the effect of various situational factors on the performance of professional soccer players in different score line states. Specifically study 7a investigated the effect of opposition ability, team ability, playing position and pitch location on the passing accuracy, corner accuracy, crossing accuracy and free kick accuracy of players in the English Premier League as goal difference changed. Study 7b, investigated the same variables and their effect on the activity profiles (distance covered, high speed distance covered, sprint distance covered) in various goal differences.

Chapter 8 forms the general discussion. Key findings from the experimental chapters are discussed and implications of the findings for managers and coaches with professional soccer are highlighted. Directions for future research are also outlined.

CHAPTER 2

Review of Literature

2.1 Introduction

This review of literature will evaluate and discuss the effect of score line on technical, tactical, and physical (running speed and distances run at different speeds) aspects of performance in soccer. The effect of score line on perceptions of psychological momentum will also be examined, as psychological momentum is the term frequently used to describe the situation where the sequence of scoring (or score line) has an influence on future performance success (in terms of match outcome) (Briki et al., 2012a; Iso-Ahola & Dotson, 2014; Moesch & Apitzsch 2012; Vallerand et al., 1988).

2.2 Definitions

2.2.1 Definitions of Score line

There have been two main approaches to the study of score line effects. The first considers score line in relation to the match status (e.g. whether a team is winning, drawing or losing) (Andrzejewski et al., 2016; Bloomfield et al., 2004a; Clark & O'Donoghue, 2011; Jones et al., 2004; Lago & Martin, 2007; O'Donoghue & Tenga, 2001; Paixão et al., 2015; Shaw & O'Donoghue, 2004; Taylor et al., 2008), the second investigates the number of goals that have been scored for each team (e.g. 1-0, 2-0, 2-1 etc.) (Lago-Penas and Gomez-Lopez, 2014; O'Donoghue & Robinson, 2016; Ridgewell, 2011). The latter approach, although providing a more sensitive understanding of performance in relation to score line is far less popular, potentially due to the complexities in collecting data at individual score lines. One final approach that has been considered in Rugby is discriminating between different type of score line (e.g., winning and losing) using the difference in score, e.g., balanced (difference in score line of between 16 and 34 points), unbalanced (difference in score line of between 35 and 53 points) and close games (difference in score line of between 0 and 15 points) (Vaz, Mouchet, Carreras, & Morente, 2011). However, due to the low scoring nature of soccer this approach is limited. The introduction of automated tracking and associated software used within this thesis (Chapter 6) has however, made it easier to specify certain score lines within a match, thus enabling a greater volume of data to be explored. In order to make comparisons with previous findings the current thesis shall consider a series of score line definitions such as match status (winning, drawing, losing), specific score lines (e.g. 1-0, 2-0, 2-1 etc.) and under different goal differences (e.g., -2, +2 etc.).

2.2.2 Definitions of Momentum

The concept of psychological momentum (PM) was first reported in depth by Alder and Alder (1978), and in later studies they defined momentum as "a state of dynamic intensity marked by an elevated or depressed rate of motion, grace and success" (Alder, 1981 p.29). Alder (1981) saw momentum as a bipolar construct, operating in both a positive and negative direction, where individuals could perceive situations as having positive momentum, or negative momentum. Alder (1981) further suggested that the start of positive momentum could be characterised by an increase in effort (a building phase) followed by a 'cruising' phase where performers focus on economy of effort. Once the goal to be achieved is within reach, Alder (1981) suggested that performers would start to 'coast' reducing their efforts (see Briki et al., 2013; Den Hartigh et al., 2014).

In an early study examining the idea that success breeds success, the term 'momentum' was defined by Iso-Ahola and Mobily (1980) as "a gained psychological power which may change interpersonal perceptions and influence physical and mental performance" (p. 392). In relation to future success psychological momentum has been operationally defined as "the added advantage obtained when initial success in an athletic contest produces momentum which leads to future success" (Gayton et al., 1993 p. 121). Gayton et al. (1993) based their definition on investigations into scoring in the 1988-1989 American Hockey League. Similarly, Hubbard (2015) suggested psychological momentum as the tendency to believe that a subsequent behaviour is more likely to be consistent with previous behaviour. Specifically, psychological momentum involves the perception of whether success or failure is more or less likely based on recent success or failure. Taylor and Demick (1994) proposed a definition based on a more multidimensional approach, defining momentum as "an enhanced psychological power or state which facilities reaching a desired emotional state that impinges heavily on subsequent behaviour and performance" (p. 54). One of the most recent definitions, proposed by Gernigon et al. (2010) defined psychological momentum as "positive or negative dynamics of cognitive, affective, motivational, physiological and behavioural responses (and their couplings) to the perception of movement toward or away from either an appetitive or aversive outcome. Such a perception might emerge from both the feedback and feed forward that are provided by the specific ongoing history of events" (p.397).

As well as the most commonly cited definitions, a number of studies have suggested explanations of momentum describing it as a hidden 'force' perceived by players, coaches and spectators to control the flow of a sporting contest creating excitement and unpredictability (Burke, Aoyagi, Joyner, & Burke, 2003; Crust & Nesti, 2006; Higham et al., 2005). Higham et al. (2005) suggested that the lack of qualitative investigation examining individual subjective experiences of PM, has been the main driver behind terms such as this, depicting that PM is a "hidden force" felt by competitors and spectators but with limited explanation. A number of researchers (Alderman, 1974; Burke, Edwards, Weigand, & Weinberg, 1997; Taylor & Demick, 1994; Vallerand et al., 1988; Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001; Gernigon et al., 2010; Moesch & Apitzsch, 2012; Briki et al, 2013; Briki, Den Hartigh, Markman, & Gernigon, 2014) have also contributed several similar descriptions of this phenomenon; with most proposing that momentum has both positive (e.g., winning points, scoring goals, successful outcomes) and negative (e.g., losing points, conceding goals, unsuccessful outcomes) components. For example, Briki et al., (2014) suggested positive psychological momentum occurs when "athletes experience an upward spiral, a period in which everything appears to be going right while negative momentum is experienced as a downward spiral a period in which everything appears to be going wrong" [pg. 216]. Iso-Ahola and Dotson (2014; 2015) suggested that momentum is a psychological phenomenon which may mediate or moderate performance towards success (via positive momentum) or failure (via negative momentum).

In summary, even though psychological momentum has been studied since the early 1980s, no universal definition exists and there is still a lack of consensus with regard to the existence of the concept. Thus, for the purposes of this thesis, the definition proposed by Vallerand et al. (1988) that defines psychological momentum as a "perception that the actor is progressing towards his/her goal" (p. 94) will be used as it considers both the perceptions of performers as well as the end goal which is imperative to soccer performance.

2.3 Score line Effects

2.3.1 Impact of Score Line on Technical Performance

The effect of score line on technical effectiveness has been studied through the examination of both the number and or percentage of successful passes, shots on target and throw-ins (Liu, Hopkins & Gomez, 2016; Paixão et al., 2015; Ridgewell 2011; Taylor et al. 2008) (see Table 2.1 for a summary). Following a single football team over 40 matches, Taylor et al., (2008) found that the number of successful passes (pass reaching a team-mate) was higher when losing than when winning, shots on target (successful shots) decreased when the score was level, or the team was losing, compared to when they were ahead, and the number of successful throw-ins increased when the team was losing as opposed to drawing or winning. Taylor et al. (2008) also found a number of interactional effects, specifically successful throw-ins (resulting in maintaining possession) decreased when trailing against stronger opposition, decreased when playing at home against stronger opponents and increased when the score was level when playing stronger opponents at home. Successful passes were found to increase when leading against stronger opposition. Although Taylor and colleagues (2008) study was innovative in its approach to studying interactional effects, its results are difficult to generalise as only one team was used in the analysis. It was also suggested that limitations in the classification of opposition standard, as strong or weak, may have lacked sensitivity to differentiate changes in behaviour influenced by quality if opposition. The failure to account for pitch locations was highlighted as a possible explanation for the absence of more situational effects, however using a single camera viewpoint when generating on the ball activities could also be limiting.

Ridgewell et al. (2011) extended some of the previous work on technical effectiveness by investigating the effect of goals scored on passing success in specific areas of the pitch during the 2010 World Cup. For the 64 matches observed the percentage of successful passes was lower (72.9% ± 16.1%) in the five minutes after scoring compared to the average for the half (77.1% ± 7.0%). In support of previous literature it has been suggested that once a team score they are not aiming to score again immediately and therefore may sit on their lead perhaps explaining the decrease in the percentage of successful passes (Mohr, Krustrup, & Bangsbo., 2003; Kerick, Iso-Ahola, & Hatfield., 2000). No difference was found between the passing accuracy in 5 minutes before the goal was scored and the average for the half, however, the percentage of successful passes played in the attacking third was greater during the 5 minutes before a goal compared to the average for the half during which the goal was scored. The percentage of successful passes showed a different pattern for the conceding teams. Ridgewell (2011) found a decrease in the percentage of successful passes made by the conceding team in World Cup matches in the 5 minutes before a goal was conceded (69.9% ± 12.6%) compared to the average for the half (74.2% ± 6.2%). In contrast, in the 5 minutes after conceding a goal, teams showed an increased percentage of successful passes. It was suggested that the uncontested re-start by the conceding teams might explain this increase, which was also supported, by an increase in the number of successful passes in the middle third of the pitch. The percentage of successful passes was also found to decrease after teams extended their lead from 1-0 to 2-0 (70.2% ± 16.6% compared to the average for the half 77.8% ± 7.4%) and after they scored having trailed by two goals, 0-2 to 1-2 (61.7% ± 5.0%) compared to the average for the half (77.6% ± 3.6%). The findings from Ridgewell (2011) suggest that teams decrease their successful passing percentage immediately after taking the lead or extending their lead and increase their successful passing percentage immediately after they have conceded. However, this research only considered one tournament and therefore reduces the ability to apply these concepts further.

More recently, Paixão et al. (2015) investigated passing sequence in high-level teams (those that reached the knockout stages of the 2008-2009 UEFA Champions League) in winning, drawing and losing score line states. Long passing sequences were used more frequently in losing or drawing score lines whilst short passing sequences were more frequent in winning score lines, supporting the idea that teams' adopt a counterattacking style whilst in the lead (Lago-Penas & Dellal, 2010). However, these high-level teams significantly increased the number of passing actions and durations of pass possession prior to scoring opportunities when winning compared to drawing. Both Lago and Dellal (2010) and Carling et al. (2005) found that high-level teams are more likely to keep hold of the ball in an attempt to control play; this may explain why successful teams produced significantly more shots on goal using long passing sequences, (supporting Hughes & Franks, 2005) even though the strike to goal ratio from shots was better for direct play. Using specific score line states (1 goal up, level, 1 goal down) Lago-Penas and Gomez-Lopez (2014) also investigated the effect of score line on ball possession of English FA Premier League players. Across the entire 2012-13 season, ball possession decreased by 7.5% when teams were 1 goal up, further supporting previous research that has found possession decreases when in a winning state compared to losing (Bloomfield et al., 2005; Jones et al., 2004; Lago-Peñas, Lago-Ballesteros, Dellal, & Gómez, 2010; Lago &Martin, 2007; Lago-Penas & Dellal, 2010; Lago, 2009).

2.3.2 Impact of Score Line on Tactical Performance

The impact of scoring goals and score line on the total number of passes in different areas of the pitch, which may be considered a tactical rather than a technical characteristic has also been reported (Ridgewell, 2011). In the 2010 World Cup, Ridgewell (2011) found teams made fewer passes in the 5 minutes after scoring (20.2 ± 11.1), compared to the average for the half (27.5 ± 6.1) in which the goal was scored, in all three thirds of the pitch (defending: 4.2 ± 2.5, average half 7.9 ± 5.6; middle: 13.4 ± 9.5, average half 18.1 ± 4.9; attacking: 2.6 ± 3.2, average half 4.1 ± 2.0). No differences were found for conceding teams. Teams were also found to decrease the total number of passes after scoring when taking the lead from 0-0 to 0-1 (20.4 ± 11.8 compared to the average for the half 27.8 ± 6.9) and when equalising from 0-1 to 1-1 (21.9 ± 7.8 average half 28.1 ± 5.32). The same pattern was also observed when teams extended their lead from 1-0 to 2-0 (19.3 ± 3.6, average half 26.6 ± 6.7) and from 2-1 to 3-1 (13.0 ± 6.0, average half 23.8 ± 5.7). These findings highlight that teams do not necessarily change their tactics after conceding a goal, unlike teams who score, however as no consideration was given to the re-start (where the conceding team starts with possession of the ball) therefore further investigation is needed.

Ridgewell (2011) also reported that the possession time increased for the conceding team in the 5 minutes after a goal while it decreased for the scoring team. Once a team has scored, the team is not usually aiming to score again immediately, and as a result may sit back on their lead and 'coast' (Cornelius, Silva, Conroy, & Peterson, 1997; Kerick et al., 2000; Mohr et al., 2003). Such changes have been observed in Tennis where players have been found to reduce the percentage of points where they attack the net once they have achieved a break of serve (Scully & O'Donoghue, 1999). Attacking the net in tennis may be perceived as a positive but risky strategy, which players may avoid if they feel it could risk an opponent breaking back.

The effect of score line (defined by match status) on possession has also been investigated in relation to standard of opposition. Lago (2009) found the percentage of time spent in possession of the ball increased with the percentage of time in a losing state during a match. For example, possession was greater when losing than winning ($p < 0.01$) or drawing ($p < 0.05$). Playing against strong opposition was associated with a decrease in time spent in possession ($p < 0.01$) however the interactional effect between match status and standard of opposition was not analysed. Match status was also reported as episodes (e.g. periods of 10 minutes or more where a team was winning, drawing or losing) rather than an accumulated total time in each score line state. This could reduce the sensitivity of the score line effects investigated and decrease the number of interactional effects considered (e.g. in relation to opposition standard). The ability of a team has also been found to influence the effect score line has on tactical strategies such as keeping possession. Bloomfield et al. (2004a) found that successful teams in the English FA Premiership (tops 3 teams) were in possession of the ball less when the scores were level than when winning or losing during the 2003-2004 season. These successful teams also spent considerably more time attacking when behind suggesting their confidence to hunt down an equalizer and take control of the game might be more apparent than for a less successful team. Comparatively, the opposing teams were in possession of the ball more when the score were level than when ahead or behind. Findings also showed that there was more play in the attacking and defensive zones when the score was level. Similarly, Jones et al. (2004) found that successful teams had significantly longer possession than unsuccessful teams irrespective of game status (winning, losing or drawing). Both teams however had longer possession when they were losing matches than when winning. The latter was reported as a strategy employed by teams to regain possession in order to score to avoid defeat (Jones et al., 2004). In an attempt to further investigate the determinants of tactical performance Liu et al. (2016) included 16 performance-related match events in relation to winning and losing against different standards of opposition both at home and away. In accordance with previous research, ball possession, pass number and pass accuracy were found to increase the probability of winning. Additional variables such as crosses were also found to discriminate between winning and losing teams (Lago-Penas et al., 2010). Corners on the other hand, had minor within-team effects on the probability of winning even though they have been found to account for 20% of the total goals scores in tournaments (World Cup, 2006) (Yiannakos & Armatas, 2006).

Several studies more recently have considered the interactional effect of score line (defined as match status), match location (home or away) and ball possession. Lago and Martin (2007) found home teams had more possession when drawing than away teams and, in agreement with Bloomfield and co-workers (2004a) study, teams had more possession when they were losing matches than winning or drawing. Lago and Martin (2007) also found the standard of opposition had an impact on performance, as such the lesser the opponent the greater the possession. However, studies such as Bloomfield et al. (2004a) have been criticised for not including the standard of opposition in their analysis. For this reason, Lago-Penas and Dellal (2010) built on their work to investigate the influence of match location, match status, quality of opposition and level of team on ball possession over 380 games in the Spanish League First Division. Similar to previous work (Bloomfield et al. 2004a; Jones et al. 2004; Lago & Martin, 2007) possession was found to be greater when losing than winning or drawing. Playing away was characterised by a decrease in team possession as was playing against strong opposition. Top placed teams also experienced a greater ball possession than less successful teams, which supported the findings of previous studies (Jones et al. 2004; Lago & Martin, 2007). Although quality of opposition (defined as relative team quality based on the difference between the finishing positions in the league of the two teams) was considered in the regression equation no specific interactions between possessions, match status and opposition ability were highlighted.

The findings emphasise the importance of accounting for match location, quality of opposition and match status (winning, drawing, losing) when examining the effects of score line on performance. However, future research needs to consider the interactional effect of these variables on player performance as well as accounting for team ability given the volume of research (Grant, Williams, & Reilly, 1999; Jovanovic, Sporis, Omrcen, & Fiorentini, 2011; Kapidžić, Mejremić, Bilalić, & Bečirović, 2010; Szwarc, 2007), which has found differences between successful and unsuccessful teams in relation to these performance variables.

Table 2.1 Summary of studies investigating the effects of score line on technical performance factors in Soccer.

References	Sample	Research design	Situational Variables (Quality of Team, Opposition)	Performance Variables Considered	Main Findings
Bloomfield et al (2004a)	FA English Premier League Top 3 teams 2003/2004 season.	Noldus Observer Video pro 5.1 behavioural measurement package.	Level Ahead Behind Zones on pitch Defending 3rd, Middle 3rd, Attacking 3rd Home and Away	Time in possession Ball not in play	All teams dominated possession in all 3 score line states. Chelsea the most possession when scores level Man Utd the most when ahead and behind More play in attacking zones and defensive zones when score is level. When behind CFC and Man Utd spent more time attacking than Arsenal.
Jones et al (2004)	FA English Premier League 24 games – 12 from 3 successful teams and 12 from 3 unsuccessful.	Noldus Observer Information Technology 1996	Losing Winning Drawing	Time in possession. Also categories: 3-10s 10-20s 20+s	Successful team sig ($p<0.01$) longer possession than unsuccessful teams irrespective of match status. Both Successful ($p<0.05$) and unsuccessful ($p<0.05$) teams had longer durations possession when losing than winning. When categorized in possession length teams kept possession longer (10.2% above 20s) than unsuccessful teams (4.4% above 20s) ($p<0.001$).
Lago & Martin (2007)	Spanish Soccer League 2003-2004 170 matches	Multiple Camera System Gecasport.	Total Minutes Losing Winning Drawing Opposition considered but no details given on how included Home and Away	Time in possession (ball in play only)	Teams had greater possession when losing than winning or drawing. For every 11 mins losing – possession increased by 1%. Opposition did not have an effect on possession. But differences in possession did occur as a function of opponents. Playing at home increased possession by 6% compared to playing away.
Taylor et al (2008)	Professional Football 2002-2003 and 2003-2004 1 Team (40 Games)	Noldus Observer Video pro 4.1 behavioural measurement package. 20 Home 20 Away	Strong (finished 1-12 in league) Weak (finished 13-24 in league)	Pass reaching a team-mate Aerial Challenges Clearances Crosses Dribbles Interceptions Losses of Control	All on-the-ball behaviours (except set pieces) were influenced by at least one of the three situational variables. Set plays not influenced by any situational variables. Quality of opposition was excluded from models (except aerial challenges, dribbles and passes). Playing stronger opposition increase passes and decrease in dribbles also associated with an increase in odds of success, as was playing strong opposition and winning.

		Level – Ahead Level - Behind		Corners Free-Kicks Throw Ins Both frequency and outcome (e.g., successful and unsuccessful) Shots on target	Playing at home against strong opposition and playing strong opposition while losing were characterised by decreased odds of success. Throw-ins playing at home and winning, playing at home and losing and playing at home against string opposition and drawing all related to increase odds of success. Playing at home and drawing, playing at home against strong opposition and winning and playing at home against strong opposition and losing were all associated with a decrease in odds of throw-in success. Less shots successful when drawing or losing compared to winning. No improvements when playing at home. No effect of situation variables; match location, quality of opposition and match status.
Lago (2009)	Spanish Football League (2005-2006) 27 Matches	Amisco System	Losing Winning Drawing (split into 10 min episodes <10min excluded)	Time in possession	In 5 mins before scoring, the team appears to build up pressure by increasing possession in the attacking and middle thirds. Possession was greater losing than winning ($p<0.01$) or drawing ($p<0.05$). Team possession fell by 3% when scores were level and by 11% when ahead. Playing against strong opposition was associated with a decrease in possession ($p<0.01$). Each unit of distance between end of season ranking increased/decreased possession by 0.2%. No effect of match location on possession. Playing away against strong opposition decreased team possession compared with playing at home. Playing against weak opposition increased team possession compared with playing at home against same opposition. Possession in defensive zone increased by 10.3% and 3.0% when head and level respectively. Possession was greater in middle zone when losing than winning ($p<0.05$). Possession decreased in middle zone by 5.3% when ahead. Possession was greater when losing than winning ($p<0.01$) in attacking zone. Possession in attacking zone playing away decreased by 4.1% compared with playing at home ($p<0.01$).
Lago & Dellal (2010)	Spanish League First Division 2008-2009 Season 380 games	Multiple Camera System Gecasport	Minutes Losing Winning Drawing Weak (difference between the finishing position of the two teams). Divided into four groups: 1) Top five teams 2) 6th-10th 3) 11th – 15th and 4) 16th - 20th. Home and Away	Time in Possession	For each minute winning team possession decreased by 0.09% compared with each min losing. For each minute drawing team possession decreased by 0.04% compared with each min losing. Playing strong opposition was associated with reduction in possession ($p<0.01$). Each point of difference between end of season raking between teams increased/decreased corresponding teams' possession by 0.52%. Playing away reduction possession by 2.43% compared to playing at home. Group 2 and 3 showed 4.01% and 3.01% less possession respectively than group 1. No diff between group 1 and 4.
Ridgewell (2011)	2010 World Cup Sportscode Elite 58 Matches		5 minutes before and after a goal. Also at different score line (e.g., 1-0, 2-0 etc)	Pass reaching a team-mate Number of attempted passes	Conceding team sig. lower values for number of passes, % successful passes and % possession in the 5 mins. before the goal was scored than the half in which the goal was scored. Conceding team sig, increased its possession in both the middle ($p<0.001$) and attacking thirds (p,0.017) after the goal, whilst sig. reducing possession in its own defensive third ($p<0.001$).

			Zones on pitch Defending 3rd, Middle 3rd, Attacking 3rd All away (except for host nation)	Time in Possession	Scoring team sig. lower values for all 3 indicators in the 5 minutes after the goal was scored than the average for the half in which the goal was scored. In 5 mins before scoring, the team appears to build up pressure by increasing possession in the attacking and middle thirds.
Paixão, Sampaio, Almeida and Duarte (2015)	20 matches of the KO phase of the 2009-2009 UEFA champions league.	Passing sequences collected in clips using Camtasia Studio 7 (TechSmith, Michigan, USA). Winning Drawing Losing	4 different teams used (all reached the SF – so most successful). 6 matches from each team. 222 passing sequences analysed.	Passing sequences were based on – number of passes prior to a shot on goal and its corresponding duration.	The four teams investigated in this study used preferentially long passing sequences when they were losing or drawing, and short passing sequences when they were winning Teams significantly increased the number of passing actions and the duration of ball possession leading to scoring opportunities, when they were winning compared to drawing episodes. Although teams have performed fewer long passing sequences in winning situations, they sought to build-up more patiently their attacks irrespective of the group of passing sequence (long or short). Overall, when winning, teams substantially increased the number of goal-scoring opportunities through short passing sequences. Successful teams produced significantly more shots by long sequences of passes, even though the strike ratio of goals from shots was better for 'direct play'.
Liu, Hopkins & Gomez (2016)	380 matches of season 2012–2013 in the Spanish First Division Professional Football League (La Liga BBVA)	Data were obtained from OPTA Sportsdata Spain Company (Madrid) Probability of winning or losing	Strength of opposition (end of season rank - top, middle or bottom). Team ability (end of season rank - top, middle or bottom) Match location - Home or Away	Shot, Shot on Target, Shot Blocked Ball possession (%) Pass, Cross, Corner, Offisde, Aerial Advantage (%), Lost ball Ball recovery, Tackle, Foul, Yellow card, Red card	Passing showed positive between-team effects but negative within team effects on probability of winning. The scoring team reduced the number and accuracy of passes after scoring. Decrease in pass accuracy after scoring does not happen for high-level teams in close matches against low-level opponents. Pass had negative within-team effects for low-level teams when playing against oppositions of high level, but positive effects for high-level teams when facing low level opponents. Pass accuracy also showed negative within-team effects for low-level teams in the combination of low vs. high. Ball possession, pass, pass accuracy and aerial advantage had clear positive relationships, while cross, lost ball, ball recovery, tackle, foul, yellow card and red card had clear negative relationships on the probability of winning. Crosses showed negative between- and within team effects on probability of winning. The modelling accounted for different strength combinations showed that the negative within-team effect of cross was clear only for low-level teams when facing low level oppositions.

2.3.3 Impact of Score line on Physical Performance

Score line has also been shown to influence activity profiles of players in team games (see Table 2.2 for a summary). Activity profiles have been defined in a number of different ways by studies investigating the relationship between physical performance and score line. The most common definition used include high intensity activity (subjectively defined as all running, and sprinting movements) and high speed running (defined by running speed at or around $5m/s^{-1}$). The earliest studies of FA Premier League soccer players found that players spent a greater percentage of match time performing high intensity activity (subjectively defined as running/sprinting- purposeful running with obvious effort, on-the-ball activity – player is travelling with or alongside the ball and shuffling- movement backwards or sideways) when the score was level than when their team was leading or trailing (O'Donoghue & Tenga, 2001). Although effects in early studies were found, balancing the score line states (e.g. equal time winning, drawing and losing) has limited the application of such findings. For example, O'Donoghue and Tenga (2001) found only 3 out of 26 English FA Premier League players in their study experienced winning, losing and drawing for the designated time (at least 10 minutes) within the matches where they were observed, 8 other players experienced only one of the 2 score line states for the allotted time period. To try and account for this imbalance O'Donoghue and Tenga (2001) conducted two separate analyses; one on the 11 players who were level and ahead for at least 10 minutes and one for the 10 players who were level and behind for at least 10 minutes during the matches observed. Their study found that the first group spent a greater percentage of time performing high intensity activity when level than when ahead ($p < 0.05$) and that the second group spent a greater percentage of time performing high intensity activity when level than when behind ($p < 0.05$). It was suggested that teams who are winning may relax their work rate, allowing opponents back in the game, similarly teams that are losing may lose motivation to maintain a sufficient work rate (O’Donoghue & Tenga, 2001). This pattern, but with differing significance levels was also found by Clark and O’Donoghue (2011) for English FA Premier League players and by Shaw and O’Donoghue (2004) for Irish League players using the same activity categories. The major criticism of these three studies was the subjective nature and thus reliability used by all three studies in classifying player activity. All three studies found that players spent a greater percentage of time performing high intensity activity when the score was level than when leading or trailing. Although studies have shown that the percentage of time spent performing high intensity activity is lower during the second half of a soccer match than during the first (Bangsbo, Mohr & Krustrup, 1991; Carling & Dupont, 2011; Di Salvo et al., 2009; O’Donoguhe, 1998) it is possible that differences in percentage time spent performing high intensity activity may reflect score line rather than nature fatigue as suggested by the literature (Clark & O’Donoghue, 2011; O’Donoghue & Tenga, 2001; Shaw & O’Donoghue, 2004). Especially, as recent research (Hewitt, Norton & Lyons, 2014; Sparks, Coetzee & Gabbett, 2016) has suggested that teams pace themselves injecting periods of sub-max or max bursts late on in matches, therefore dismissing the previous thoughts that teams fatigue towards the latter stages of the match.

A more comprehensive study conducted by Bloomfield et al. (2004a) however, found no score line effect. They compared 59 midfielders and 82 forwards from the FA English Premier League who were observed for 15-minute periods in different score line states. Although a great number of players were observed, different sets of players were observed when level, ahead and behind. While this had the advantage of allowing more players to be included in the study, than was possible in the studies by O’Donoghue and Tenga (2001) and Shaw and O’Donoghue (2004), individual player and individual match effects may have contributed to the lack of support for a score line effect. In women's Gaelic football Devlin and O'Donoghue, (1999) found players spent a greater percentage of match time performing high intensity activity when the score was level than when their team was winning or losing. Although these studies give an insight into the effect of score line on player work rate the methods used permitted only one player to be observed per match limiting the numbers of players included. Furthermore, the methods in these studies lend themselves to poor reliability due to observer fatigue (Barris & Button 2003) and the subjective nature of classifying the movements observed, such as the complicated movement classification system used in the case of Bloomfield et al. (2004a).

In order to examine score line effects in relation to team opposition, Lago et al. (2010) investigated the effect of match location, quality of opposition, and match status on the distance covered at various speeds by players in a Spanish Premier League team during the 2005-2006 season, using a multiple-camera analysis system. The team performed less high-speed activity (> $19.1\ km \cdot h^{-1}$) when winning, than when they losing, but were walking and jogging more. They also observed that the longer the teams were winning, the distance covered at submaximal or maximal speeds (> $19.1\ km \cdot h^{-1}$) decreased by 0.95m per min. ($p< 0.05$) compared with each minute losing. For example, if the team were losing for the whole 90minutes, the predicted distance covered would be 86m higher than if winning for 90minutes (15.5%). This resulted in a 2.1m increase per minute ($p < 0.05$) walking and jogging, when winning compared to losing. Interestingly, Lago et al. (2010) found the higher the standard of opposition, the greater the distance covered walking and jogging compared to high speed running, although interaction with match status was not considered.

Hewitt et al., (2014) investigated the effect of opposition ability (teams were ranked 1-10 (top), 11-25 (middle) and 25+ (bottom) based on the FIFA ranking system) on movement patterns in women's soccer. They found more high-speed running (> 12 km · h^{-1}) was performed when playing against opposition of similar quality (middle) compared to teams ranked in the top group. No significant differences were found when playing against teams in the bottom group. The findings highlight the need to consider the quality of opponents when considering score line effects in relation to physical activity profiles as this clearly affects the percentage of time in these different activity zones.

Bradley and Noakes (2013) investigated the effects of score line and match importance on team strategies in FA Premier League teams. The score line alone was not found to influence the high speed (≥14.4 km · h^{-1}) distance covered at team level, however central defenders covered 17% less and attackers 15% more high speed running during matches that were heavily won, versus heavily lost (score differential ≥ 3 goals). Similarly, the importance of the match did not affect high speed running, with the exception of critical games (e.g. the outcome directly impacted upon Championships/European places or relegation, with local derby matches also included), where high speed running decreased in the second half of the match compared to the first. They concluded that high-speed running was influenced by score line and less so by match importance. The lack of findings between low and moderately important games and high-speed running poses questions with regards players' motivation when they perceive a game as unimportant (Karau & Hart. 1998). In contrast, Andrzejewski et al. (2016) found central defenders and full backs playing in the 2014-15 Bundesliga, covered shorter distances (both total and high intensity) in won matches than lost compared with attackers who covered longer distances when they won. It has generally been suggested teams work harder when pursuing a goal (losing) (Lago-Peñas, 2012), and thus do not always work to their capacity when winning.

Castellano et al. (2011) also studied player movement patterns in relation to score line in the Spanish Premier League, using a multi-camera tracking system. Although they did not differentiate between playing position, they did consider match location (home or away) and opposition ability as well as using effective playing time (e.g., the duration of play after subtracting time taken up by stoppages, substitutions, goals and injuries). They found players covered a greater distance per average half when playing at *home* (3931m versus 3887m away), when the *reference team* were losing (3975m versus 3837m drawing and 3921m winning) and when the *level of opposition* team was higher in ability (ranked in the top 6 league positions) (4032m versus 3938m (medium ranked 7th – 13th in the league) and 3736m (bottom ranked bottom 7 in the league). Garcia-Rubio, Gómez, Lago-Peñas, & Ibáñez, (2015) more recently, investigated match location, scoring first and quality of opposition, although the latter was not found to influence player performance. In the 475 matches analysed during 2009-2013 scoring first was found to be the strongest predictor of performance in both knock out and group matches. Match location was also featured but only in group stages. However, using a knock style competition may be more likely to elicit urgency in play (and thus a different reaction to score line) compared to a league game where the final league position is decided across a much larger number of games with no one game dictating the teams progression in the league. O'Donoghue and Robinson (2016) also included quality of opposition in their study investigating match type (won, drew or lost after being 1 goal up) and physical performance during the 2013-14 English Premier League. Alongside the more common movement categories (distance covered, high speed running, sprinting) O'Donoghue and Robinson (2016) also included V cut changes (where a player changes direction by more than 135^0), unlike previous studies investigating activity profiles of high level players, only sharp changes in directions (V cut changes) were influenced by match type and match period (before and after the first goal). These studies indicate that both the score line and standard of opposition influence the activity profiles of different playing positions. Although some interactional effects were considered, further investigation is needed in order to establish how the score line affects performance when considering different situational and player characteristics.

Table 2.2 Summary of studies investigating the effects of score line on physical performance factors in Soccer.

References	Sample	Research design	Situational Variables (Quality of Team, Opposition)	Performance Variables Considered	Main Findings
Devlin & O'Donoghue (1999)	1 player per match Women's Gaelic Football	Subjective Observation by trained observers	Not Considered – Although players were grouped depending on how much time they spend in each SL state.	% of time Running – purposeful running with obvious effort or all out sprinting. Walking – walking in a forward direction. Backing – walking backwards or sideways. Jogging – slow running in a forward direction without obvious acceleration Game related activity – where the player is involved in an on the ball event or travelling with the ball	The results were that players performed sig more high intensity activity when level than ahead ($p< 0.05$) There was also more high intensity activity performed when level and behind but not significant ($p > 0.05$). There was no statistical comparison of ahead and behind as LA and LB groups were used.
O'Donoghue & Tenga (2001)	FA English Premier League 26 players (only 3 players experienced all 3 states)	Subjective Observation by trained observers (verbally coded) Winning Drawing Trailing (Equal amounts in each).		Shuffling – a sideways, backwards or on-the-spot movement requiring effort and a shuffling movement of the feet. This category includes jogging backwards and sideways. Stationary – where the player is standing still, sitting, stretching or lying in a prone position. % of time Running – purposeful running with obvious effort or all out sprinting.	Players performed sig. less HIA (running, shuffling and game related activity) when winning than when score level ($P< 0.05$). Players also performed sig. less HIA when losing than when score level ($p< 0.01$).

Shaw & O'Donoghue (2004)	Amateur Irish League Players 24 games	Subjective Observation by trained observers (verbally coded) Level Ahead Behind	Only home or away	% of time Running – purposeful running with obvious effort or all out sprinting. Walking – walking in a forward direction Backing – walking backwards or sideways. Jogging – slow running in a forward direction without obvious acceleration Game related activity – where the player is involved in an on the ball event or travelling with the ball	Players less time stationary and walking when SL was level. Players who spent equal minutes in LA spent significantly more time HIA when level than ahead. Players in LB group no significant difference HIA. More jogging, backing, running and games related activity when level.
Bloomfield et al (2004b)	FA English Premier League 232 players observed	Noldus Observer Video pro 5.1 behavioral measurement package.	82 -Forward, 59 - Midfield	Exercise = any purposeful and deliberate movement made by the player to influence play. Rest = All other time	Venue had no effect on % exercises. No relationship between score line and % exercise or interactional effect of score line and position on % exercise.
Lago et al (2010)	Spanish Premier League 27 Matches 2005-2006 season (19 players)	Multiple-camera system (Amisco Pro) Total number of minutes in each score line state: Winning Drawing Losing	Five Groups: Central Defender External Defender Central Midfield External Midfield Forwards Difference in final ranking (in the season)	Standing walking Jogging 0-11 km.h-1 Low-Speed Running 11.1 – 14.0 km.h-1 Moderate Speed Running 14.1-19.0 High Speed Running 19.1 -23.0 km.h-1 Sprinting >23.0 km.h-1	Distance covered at Max and Sub max intensity was explained by match status. For every minute winning Max Intensity distance decreased by 0.95m and by 1.1m for sub max. Distance covered at low intensities was explained by match status, match location and quality of oppo. For each min winning distance covered walking and jogging increased by 2.2.m compared with losing. Low speed running also increase by 2.1m for each min winning. Players covered more distance when playing better ranked teams. Each position difference increased the total distance covered walking and jogging by 17m
Clark & O'Donoghue (2011)	FA English Premier League 20 Players	Subjective Observation by trained observers (verbally coded) Level Ahead Behind		% of time Running – purposeful running with obvious effort or all out sprinting. Backing – walking backwards or sideways.	LA group – similar % HIA when level and ahead. LB group % HIA sig greater than when behind ($p < 0.01$)

		Split into two groups 1) Level and Ahead (12) 2)		Walking – walking in a forward direction. Jogging – slow running in a forward direction without obvious acceleration Game related activity – where the player is involved in an on the ball event or travelling with the ball	
Castellano, Blanco-Villaseñor, & Alvarez (2011)	Spanish Premier League (2005-2006) 434 Players	Multiple Camera System Successful Teams (ranked in the top 6) Moderately successful (ranked 7th-13th) Least Successful (ranked bottom 7)	Match location Home or Away Opposition Ability	Standing intensity (0-11 km·h-1 Low-intensity running (11.1-14 km·h-1), Moderate-intensity running (14.1-17 km·h-1), HIR (17.1-21 km·h^{-1}), very HIR(21.1-24 km·h-1) Sprinting (>24 km·h-1)	No differences in home or away for distanced covered at any intensity. The poorer the quality of opposition the less distance covered. When playing against more successful teams the reference team covered greater distances at all intensities (except SpD – sprinting). When losing distances covered for all moderate intensities and above (> 14.1 km·h^{-1}) were greater than drawing or winning.
Bradley & Noakes (2013)	FA English Premier League (2006/2007 – 2008/2009) 169 Players	Prozone Sports Ltd Competitive (≥1 goal) Heavily won Heavily lost (Score differential (≥3 goals)	Central Defenders Full Backs Central Midfielders Attackers Game importance considered (e.g. derby playing for a European place etc.)	Standing 0-0.6 km.h^{-1} Walking 0.7-7.1 km.h^{-1} Jogging 7.2-14.3 km.h^{-1} Running 14.4-19.7 km.h^{-1} High speed running 19.8-25.1 km.h^{-1} Sprinting >23.0 km.h-1 High Intensity Running >14.4 km.h-1	HIR decreased in 2nd half in matches that were competitive or won. No changes when losing. Cen.def covered 10-17% less HIR during matches heavily won versus lost or competitive (p <0.01). Attackers covered 15% and 54% more HIR and sprinting in matches won versus lost (p <0.01). Match Running was unchanged. Tot.dist declined in the 2nd half of both critical and less important matches. Cen.def and full backs reduced HIR in 2nd half of matches that critically important. Also considered the impact of substitutes with regards activity profiles.
Coker, C (2014) Dissertation	Amateur players 20 outfield players	Computerised time motion analysis system. Level – Ahead Level - Behind	Central Defenders External Defenders Central Midfielders External Midfielders Forwards	% of time spent performing HIR.	No score line effect on percentage of time spent performing high intensity activity.
Hewitt, Norton & Lyons (2014)	International Soccer Players 15 players during 13 international matches	15 Minutes intervals (no score line) MinimaxX athlete tracking device	Top (1-10) Middle (11-25) Bottom (25+) Defenders Attackers Midfielders	% time spent in HIR (>12 km.h^{-1} (>0-0.4 km.h^{-1}) Standing (>0.5 - 6 km.h^{-1}) Walking low speed running (>6-12 km.h^{-1}). Sprinting (>19 km.h^{-1})	Playing against teams ranked 1-10 (top), 11-25 (middle) and 25+ (bottom) based on the FIFA ranking system. They found more high intensity running (>12 km.h$^{-1)}$. was performed when playing against opposition of similar quality compared to teams ranked in top group. NO significant differences were found when playing against teams in the bottom group. Sprint distance remained the same throughout the game.

					Decrease in HIR in the 60-75 min and 75-90 min periods compared to 0-15 min. HIR distances covered were significantly greater for midfielders versus defenders, while defenders had lower sprinting compared to both midfielders and attackers. Stronger opposition elicited less HIR and greater low-speed activity (LSA) compared to playing teams of similar or lower ranking.
Lago-Penas ad Gomez-Lopez (2014)	English FA Premier League players (2012-2013 season) All games and teams played in this season.	Match indicators = 1 goal up, 1 goal down and drawing. Data collected from Prozone Sports Ltd.	Info on the money spent by clubs was collected from Deloitte and Touche Annual Reports (4 different budget depending on the amount of money spent – range 180 euros to 43.6 euros).	Percentage of match ball possession, the percentage of entries into the final 3rd, the percentage of shots on goal.	Ball possession decreased when teams were 1 goal up. High budget teams and upper budget clubs dominated possession against their opponents whether winning, drawing or losing. Probability of reaching the final 3rd decreased when teams when 1 goal up. Low budget teams had less final 3rd entries than high budget teams. Team possession fell by 7.5% when teams were 1 goal up. Shots on target also decreased when team went up by one goal. Final 3rd entries decreased by 2.3% when scores were level and by 4.9% when teams were 1 goal up. Shots on goal decreased by 14.1% and 14.45% when teams were 1 goal up and when the scores were level respectively.
Andrzejewski, Konefal, Chmura, Kowalczuk and Chmura (2016)	350 soccer players competing in Bundesliga in 2014/15 season.	Used Impire AG motion analysis system (VIS TRACK – validated by Tiendermann et al., 2010) recording movement in all 306 matches. Winning Drawing Losing	Five roles: Central defenders, Full-backs, Central midfielders, Wide midfielders, Forwards	total distance covered, distances covered at low (less than <4m.s) and high intensity (>4m.s).	Central defenders and full backs covered shorter distances (both total and high-intensity) in won matches than in lost. Forward covered significantly longer distances (both total and high-intensity) in won matches than in drawn or lost matches. Whilst drawing all players conducted the greatest distance at low intensity (with exception of forwards). The shortest distance at low intensity was went players were losing
O'Donoghue and Robinson (2016)	The 380 English FA Premier League matches of the 2013-14 season.	Before and after goal was scored There were 135 matches that satisfied the criteria for inclusion that the first goal was scored between the 15th minute and the end of the first half.	Relative quality was represented by the number of points the teams had at the end of the 2013-14 season. The team that took a 1-0 lead within the match was classified as higher quality than the opposition	Distance covered (m.min-1). High speed running distance includes all movement at speeds of 5.5 m.s -1 (19.8 km.hour- 1) or faster Sprint distance includes all movement at speeds of 7 m.s-1 (25.2 km.hour- 1) or faster. Sprints counted in the current	The number of V-cut path changes decreased in matches won or lost than in drawn matches. Distance covered per minute and path changes of all types performed per minute declined for both teams after the first goal is scored. The largest decline in path changes was when the higher quality team was away from home, scored first and the match was drawn. There was also a relatively large decline in path changes after the first goal in matches where the teams were of similar quality, the away team scored first and went on to win. There was

	if their points total was 6 or more greater than that of the opponents, similar quality if their points total differed by no more than 5 to the opponent's points, and lower quality if their points total was 6 or more fewer than that of the opponents.	investigation had a duration of 0.5s or longer. The percentage of sprints that are explosive (as opposed to leading) sprints (acceleration to sprinting speed (7 m.s-1 (25.2 km.hour-1)) from a speed of less than 4 m.s-1 (14.4 km.hour-1) was achieved in less than 0.5s prior to the sprint. All other sprints were classified as leading sprints. Number of sprints per minute Total number of sprints, number of sprints of 0m to less than 10m, number of sprints 20m or further per minute Number of sharp path changes to the right, to the left and total number per min. Total number of path changes per minute. % time spent in each pitch zone (attacking, middle and defending 3rd)	also a relatively large decline in path changes after the first goal in matches where the away team was of a lower quality than the opponents, scored the first goal and went on to lose. Match type – matches where the team that took a 1-0 lead went on to win, draw or lose the match. · Team – the team that took a 1-0 lead and the team that conceded the first goal. · Period of the match – before the first goal and after the first goal. · Venue – whether the team scoring the first goal was playing at home or away. · Relative quality – whether the team scoring the first goal was of a higher, similar or lower quality than the team that conceded the first goal.

2.4 Limitations of Previous Research Concerning Score line and Performance

Although research has indicated the effects of different score lines and match statuses on performance factors such as activity profiles, technical and tactical game events, a number of questions still remain. Some of which have been limited by the methods used to collect data, others by the same size and some by definitions used to categorise performance. The main methodological criticism of previous research has been the failure to consider games where no score takes place, e.g. how teams perform when no goals are scored in order and what occurs when neither team changes match status. Even though a team may play better than their opponent without a score no win can be achieved. To understand how teams, react to changes in score line we much first understand how teams play when no score takes places in a game. Other situational factors may also mediate performances which have previously been mistaken for score line effects. For example, a soccer match starts with the score level at 0-0; one team may take the lead after 30 minutes and remain in the lead for the remainder of the match. In such a match the teams are level for the first 30 minutes with one team being ahead and the other team behind for the remaining 60 minutes of the match. Therefore, much of the difference in the activity profiles observed between different score line states have been attributed to the opposition's ability (e.g. one team is better than the other) or natural game fatigue rather than score line. This is supported by evidence from time-motion analysis studies which suggest that the percentage of time spent performing high speed running is lower during the second half of soccer matches than during the first half (Bangsbo et al., 1991; O'Donoghue, 1998; Di Salvo et al., 2009; Carling & Dupont, 2011). However, it is also possible that these declines in high speed running between the first and second halves of soccer matches may result from score line effects rather than player fatigue. Shaw and O'Donoghue (2004) speculated that if the outcome of a match becomes obvious during the second half (e.g., the opposition are of a higher standard), player motivation might be reduced, potentially leading to a reduction in effort. More recent research (Bradley & Noakes, 2013; Edwards & Noakes, 2009; Hewitt et al., 2014; Sparks et al., 2016) has proposed that players are more likely to pace themselves in order to maintain levels of high intensity activity in the latter stages of a match, therefore if decreases do occur it is important to understand the reasons why. Moving towards or away from the goal at hand as explained in the psychological momentum literature (see section 2.6) has been shown to have a strong impact on performance and effort (Briki et al., 2013; Den Hartigh et al., 2014; Stanimirovic & Hanrahan, 2004; Vallerand et al., 1988). Numerous studies have shown that performance changes when performers perceive they are moving towards or away from their goal. Using this concept as an explanation of performance changes in relation to score line maybe an important addition to the performance model proposed in Figure 1.1.

A secondary issue is the need to investigate score line effects on performance using a large sample size to provide appropriate power (Gregson, Drust, & Atkinson, 2010). Semi-automatic player tracking systems are a useful tools providing large volumes of objective and reliable movement data to professional soccer clubs (Carling et al., 2008; Di Salvo et al., 2006; O'Donoghue & Robinson, 2009). These systems have also been used in academic research into soccer performance allowing large numbers of players to be observed (Di Salvo et al., 2009; Gregson et al., 2010), although to date these commercially available systems have been limited in the analysis of score line effects. The majority of research (Lago & Martin, 2007; Lago & Dellal, 2010) that has been used to investigate score line effects have used privately owned systems such as Gecasport® (multiple camera system for analysing Spanish football) which are limited to domestic leagues or specific countries. The volume of player movement data available from commercially available semi-automatic player tracking would allow additional factors such as positional role to be considered which has not been possible in previous score line investigations. Access to data can also be problematic leading to many studies using a case study approach, with only one team analysed limiting the application of findings to wider populations.

The third issue is the lack of a gold standard (valid and reliable definitions) for defining activity profiles during the game (e.g. speeds associated with HSR, HIA and sprinting). Some findings have also been impaired by the subjective nature used to classify technical and tactical performance using indicators such as the number and percentage of passes, crosses etc. in different pitch areas. Specifically, the subjective nature of many performance factors has led to inaccuracies and errors when recording data. More recently researchers (Ridgewell, 2011; Bradley & Noakes, 2013) have used established industry definitions to try and give wider application to the findings. However, this does not eradicate the problems associated with human error when identifying events especially in real time. This subjective method of event identification is also time consuming, therefore limiting the number of games that can be used in meaningful analysis.

The use of computerised systems has been more apparent when investigating player movement, although with a number of different definitions. For example, Carling et al. (2008) listed 3 different threshold values for sprinting used in different time-motion studies in soccer. Di Salvo et al. (2009) used five different sub-ranges of speed (walking, jogging, running, high intensity running and sprinting) to represent movement of different intensities ranging from walking defined as speeds of under 2 $m.s^{-1}$ (7.2 $km.h^{-1}$) to sprinting defined as movement at 7 $m.s^{-1}$ (25.2 $km.h^{-1}$) or faster. In contrast, Abt and Lovell (2009) used the second ventilatory threshold (Beaver, Wasserman, & Whipp, 1986) to determine individual player thresholds for high-speed running. They found that the distance covered at 19.8 $km.h^{-1}$ or greater (845m) which was previously used as the high-speed running threshold under-estimated the distance covered when compared to the threshold value based on the second ventilatory threshold (2258m). It was suggested that using a running speed as a high speed running value does not consider the energy cost of moving at a full range of speeds, for example, when a player is in possession of the ball (Reilly & Ball, 1984). Secondly, high intensity running does not always include all high intensity movement as players perform many movements in backwards and sideways directions at much lower speeds or in possession of the ball (Bloomfield, Polman & O'Donoghue, 2004b; Reilly & Ball, 1984; Shaw & O'Donoghue, 2004). Therefore, investigating high speed activity using different speed threshold might provide a better estimate of the percentage of time spent performing high intensity activity. This more accurate representation of high speed activity combined with the use of an automated tracking systems could help to eradicate some errors, especially when recording player movement at higher speeds and in large number, which has previously been problematic.

2.5 Recommendations for Future Research Concerning Score line and Performance

From reviewing the literature to date, the following recommendations for future research assessing the effects of score line on performance can be made:

- Studies should focus on specific populations for example the English Premier League in order to make comparisons to previous literature and to eradicate inconsistencies in performance data due to lack of skill. Player position should also be considered in relation to score line.
- Performance data should be adjusted for fatigue to ascertain whether the score line effects occur irrespective of normal fatigue patterns (e.g. what activity profiles occur when no score takes place).
- Where possible opposition ability should be taken into consideration when accessing the effects of score line. Opposition ability should be considered by consistency (e.g. team's final league position) or individual game performance (e.g. ensuring each team

spends a significant period of time in each of the three score line states (level, ahead and behind) to ensure the game was evenly matched).

- Validated computerised tracking systems should be used where possible to ensure the accuracy and reliability of performance data. Automated tracking systems can also generate large volumes of data and more importantly data can be extrapolated at given time points and under specific conditions. Thus, enabling specific changes in performance in relation to score line to be observed (e.g. goals scored and conceded) at specific score line states (1-0, 2-0, 2-1 etc.) and goal difference.
- The subjective nature of many performance factors has led to inaccuracies and errors when recording data. Therefore, performance variables with clear definitions which can be quantified through a computerised system should be used over subjective performance variables.
- Previous studies (Carling et al., 2008; Di Salvo et al., 2009) have used different sub-ranges of speed to represent movement of different intensities resulting in inconsistent results. A standard measure should be used to assess the effect of score line on player movement using a speed threshold that incorporates movement in a number of directions.

2.6 Summary

Given the number of failings from previous research to consider these fundamental issues regarding; data collection methods, sample sizes and work rate definitions, this thesis aims to address these concerns to enable greater accuracy regarding the effect of score line on player performance. Establishing the specific nature of score line effects and their effect on technical, tactical and physical performance will enable researchers to establish the cause of score line effects beyond those already highlighted in the literature.

Whilst declines in physical performance (in-game activity profiles) have, generally been attributed to a player's physical capacity Smith, Marcora and Coutts (2015) recently investigated the effect of mental fatigue alongside physical performance measures. They found that mental fatigue increases the perception of effort – hence why players may continue to work only if there is sufficient reward for their efforts (Boksem & Tops, 2008). Additionally, as players are subject to constant pressure from opponents in most match scenarios it maybe that declines in match running performance could be determined from mental fatigue as well as physical (Boksem, Meijman & Lorist, 2006) and thus investigating the psychological impact of scoring and conceding goals in soccer may be helpful to understanding the relationships between score line and performance. The act of scoring has also been the most commonly cited variable in experimental studies to trigger emotional responses. Specifically, in both controlled scenarios (Briki et al., 2012b; Markman & Guenther, 2007; Vallerand et al., 1988) and when giving bogus feedback (Kerick et al., 2000; Perreault et al., 1998; Shaw et al., 1992; Silva et al., 1992; Stanimirovic & Hanranhan, 2004) scoring changes psychological momentum and thus, performance. The following section will discuss psychological momentum as a possible explanation of score line effects.

2.7 Psychological Momentum

One of the most common psychological concepts discussed in sport, yet poorly understood, is the concept of momentum (Briki, 2017; Taylor & Demick, 1994). Coaches commonly admit to adjusting their line-ups, game strategies, and tactics to take advantage of athletes with apparent momentum (Ingels, Fitzpatrick & Rhodius, 2016; Perreault et al., 1998;

Vergin, 2000). This may be especially pertinent in soccer where the outcome of the match has large financial implications (Hoffmann, Ging, & Ramasamy, 2002). There seems to be a strong belief by athletes (Jones & Harwood, 2008; Perreault et al., 1998), sports fans (Burke et al., 2003; Markman & Guenther, 2007), and media observers (Silva et al., 1992; Vergin, 2000) that momentum is an important determinant of success in sporting contests, even though there is evidence for (Burke et al., 2003; Cornelius et al., 1997; Dumangane, Rosati, & Volossovitch, 2009; Golding, Johnson & Sensenig, 2017; Jones & Harwood, 2008; Kerick et al., 2000; Vergin, 2000;) and against (Koehler & Conley, 2003; Miller & Weinberg, 1991; O'Donoghue & Brown, 2009; Schilling, 2009; Taylor & Demick, 1994; Stanimirovic & Hanranhan, 2004) the existence of the concept.

2.7.1 Conceptual Momentum Models

Several conceptual PM models have been proposed to explain the complex PM-performance relationship. The earliest was the Antecedents-Consequences model (AC) proposed by Vallerand et al. (1988), which was followed by the Multi-dimensional model (MD) (Taylor & Demick, 1994), and the most recent Projected Performance model (PP) of momentum (Cornelius et al., 1997). Each of these three models is discussed in more detail in the following sections as well as recent theoretical developments (e.g., Iso-Ahola & Dotson's, 2014 theoretical framework and Markman & Guenther, 2007 theory of mass x velocity) in relation to explaining the momentum-performance relationship.

2.7.1.1Antecedents-Consequences Model

Vallerand and his colleagues introduced the first conceptual model of psychological momentum in 1988. Their Antecedents-Consequences Model (Figure 2.1) was developed to try and better understand the cause/antecedents of momentum and the effect/consequences momentum had on performance. Vallerand et al. (1988) suggested that in order to understand the momentum-performance relationship it was first essential to discover whether momentum was in fact the cause or effect of performance changes. The model proposed that when an athlete or actor was progressing towards their goal they would experience positive momentum and as a consequence of this, heightened levels of motivation and enhanced perceptions of control, confidence, energy, and synchronism (Vallerand et al., 1988). In contrast, moving away from this goal could reduce these factors.

The Antecedents-Consequences model states that psychological momentum perceptions are produced by interplay between situational and personal (intra-individual) variables and essentially the importance that one places on the event/s. In certain instances, situational variables may be so salient that most individuals will perceive psychological momentum in that given situation; for example, a goal scored in soccer. However, in other instances the situation maybe such, that only certain individuals will perceive psychological momentum, particularly when the situation is ambiguous enough to permit differential perceptions; e.g., when a bad refereeing decision is made.

According to the AC model, the perceived control one has over the situation in question is fundamental in influencing psychological momentum (Vallerand et al., 1988). Specifically, if the performer perceives he or she is in control of the situation they will most likely experience positive psychological momentum. Vallerand et al. (1988) also suggested that these feelings could be enhanced if the feelings of control were attributed to the athlete's own abilities and actions as proposed by Weiner's (1985) attribution theory. For example; a soccer player is more likely to experience positive PM in a penalty or free kick situation than during open play because the player is in more control of the direction of the shot in the set piece scenario. The importance of the event is also important in terms of the impact it has on PM perceptions (Vallerand et al., 1988). For example; a goal keeper who blocks a shot in the last minute of the game when the team is currently winning by one goal is more likely to experience positive PM, than when blocking a shot when the team is leading by three goals.

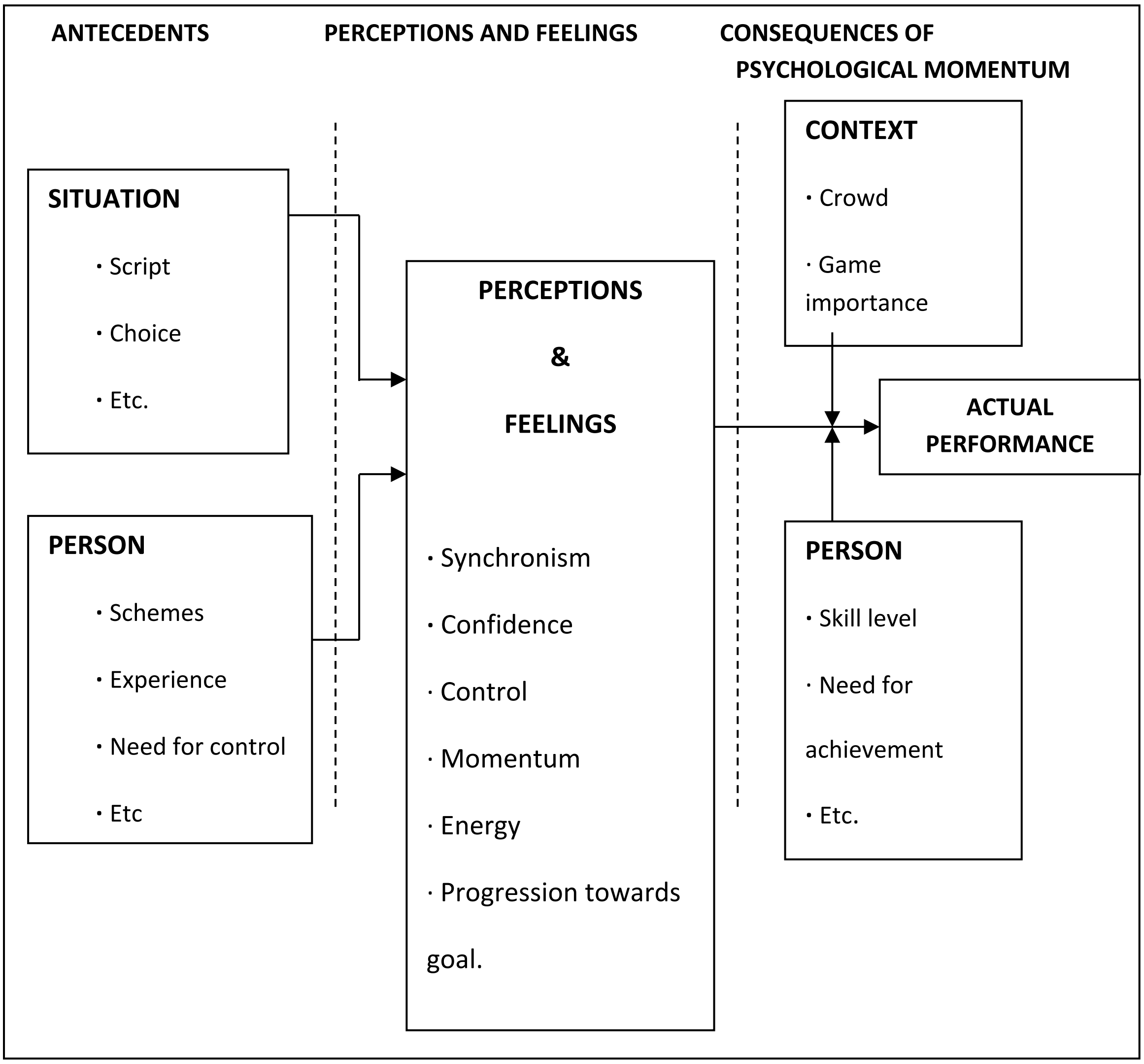

Figure 2.1 The Antecedents – Consequences Model of Psychological Momentum
Note. Adapted from "Psychological momentum and performance influences: a preliminary test of the antecedents' consequences psychological momentum model," by R.J. Vallerand, P.G. Colavecchio, and L.G. Pelletier, (1988). *Journal of Sport and Exercise Psychology, 10,* 92-108.

Vallerand and colleagues (1988) provided support for their conceptual model using a hypothetical tennis game. Two scenarios were presented which depicted either the presence or absence of a PM pattern. In the PM condition, one player was said to have taken a five–to–one lead prior to their opponent winning four consecutive games to level the set at five games all.

In the ‘no PM’ condition the game was said to ebb and flow with neither player taking an advantage.

A series of questions relating to the scenarios, such as, who had momentum and who would win the next set were asked to a two groups (one with high and one with low tennis experience). Results revealed that the scenario depicting the presence of PM led to enhanced PM perceptions in both the experienced and inexperienced tennis players. In addition, both the score configuration and the experience variables led to inferences that the player with PM should win the first set, thus supporting the Antecedents-Consequences model which suggests that players’ coming from behind are more likely to win the set if they had won previous games. However, the results were founded on hypothetical scenarios which may lack ecological validity, as participants do not necessarily experience PM directly and, therefore, may base their answers on the perceived performances of others rather than their own experiences.

Although not directly related to actual performance, Smisson, Burke, Joyner, Munkasy, & Blom (2007) reported similar findings relating to internal control and positive momentum in relation to spectators when testing the Antecedents-Consequences model. Specifically, spectators perceived external events (such as crowd noise) to have the biggest impact on starting momentum, whereas internal control and god-mediated (weather etc.) were not even moderately related to momentum. As crowd effects have been shown to have large effects on both player momentum and performance (Balmer, Nevill, Lane, Ward & Williams, 2007; Nevill Balmer & Williams, 2002) knowledge of what events trigger momentum are of great importance. Markman and Guenther (2007) attempted to explain the social aspects of momentum using the variables mass and velocity in Newtonian physics. The speed at which a performer moved towards or away from their goal was associated with changes in velocity whereas the strength or ‘mass’ was associated with contextual variables such as the value, immediacy or importance of the situation. For example, as proposed by Vallerand et al. (1988)

psychological momentum would develop at a faster rate if a situation is more important to an individual (Markman & Guenther, 2007; Iso-Ahola & Dotson, 2014). Their mass x velocity model predicts that psychological momentum would develop more when the goal the performer is progressing towards is more important to them (Markman & Guenther, 2007). Along with others (Vallerand et al., 1988; Iso-Ahola & Dotson, 2014) this highlights the need to consider the context of the situation (e.g. the value, importance etc.) when investigating momentum effects.

2.7.1.2 Multidimensional Model of Momentum

The second conceptual model, the Multidimensional Model of Momentum (Figure 2.2) was introduced by Taylor and Demick (1994). They defined momentum as "a positive behaviour caused by an event or series of events that will result in a shift in performance and competitive outcome" (p. 54). The Multi-Dimensional model expands on the Antecedents-Consequences Model suggesting that PM is created through a complex 6-Stage process resulting in a momentum chain. The model proposes that the momentum-performance chain starts with a critical precipitating event such as a goal being scored (Jones & Harwood, 2008). In order to start the momentum chain, the player must perceive this event to be significant enough that it could influence factors such as their confidence, control and behavioural responses (Taylor & Demick, 1994). For example; a player taking a well-timed shot at goal could create feelings of confidence and control depending on the timing of the shot in the context of the game. Miller and Weinberg (1991) found the effects of psychological momentum to be stronger if they occur at critical points in the game. The event might then cause a change in cognition, affect, and physiology which the model postulates as Stage-2. For example, a change in physiology may occur where positive PM would require a shift towards an optimal level of arousal, and negative PM requires a shift away from optimal levels in response to the precipitating event.

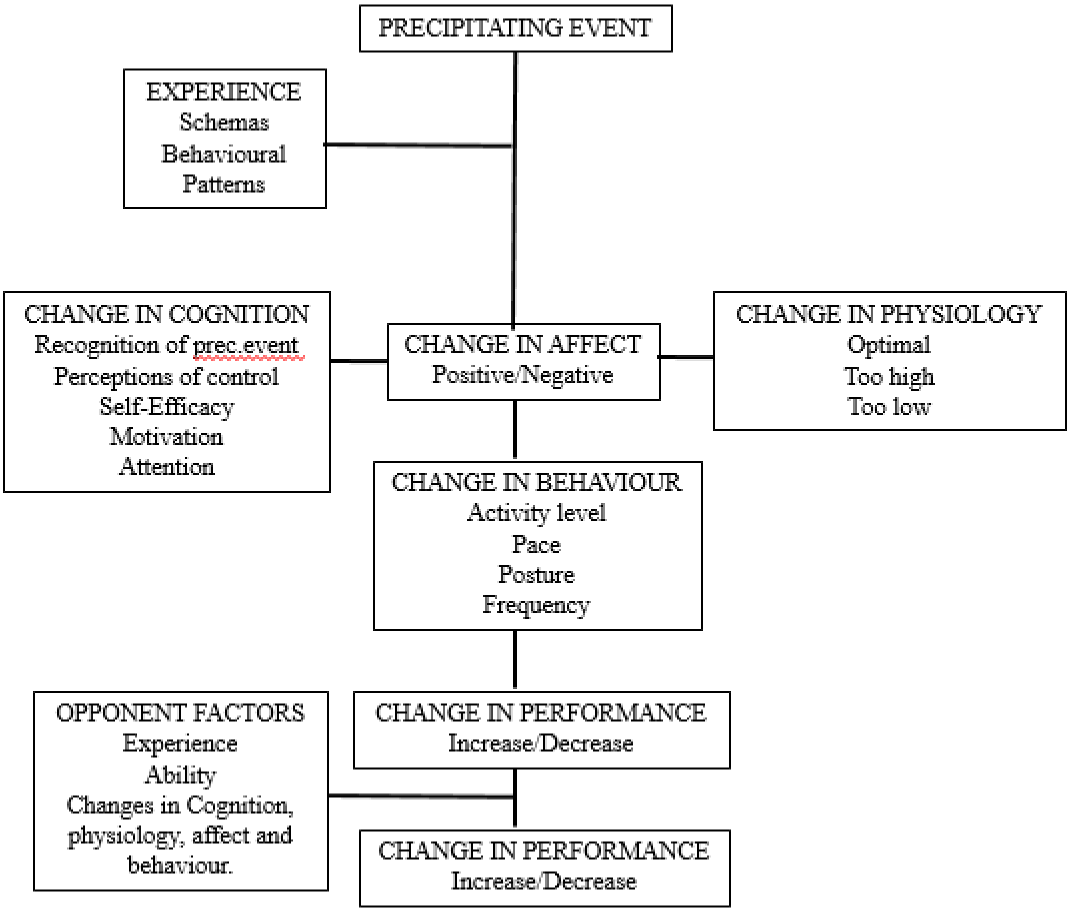

Figure 2.2. Multidimensional Model of Momentum in Sports.
Note. Adapted from "A multi-dimensional model of momentum in sports," by J. Taylor, and A. Demick, (1994). *Journal of Applied Sport Psychology, 6,* 51-70.

As with the Antecedents-Consequences Model (Vallerand et al., 1988), the event may be perceived differently by players' depending on their subjective opinions of the situation. Therefore, the extent to which the event changes the player's behaviour expressed as Stage 3 of the model is defined by the importance placed upon it. The change in player behaviour expressed in Stage 3 can be either positive (increased frequency of successful performance) or negative (increase frequency of unsuccessful performance) depending on the perception of the precipitating event and, thus, creates a performance change (Stage 4) consistent with Stages 1-3. Stages 5 and 6 in the chain are proposed to relate to equal and opposing changing in the players' opponent/s in relation to Stages 1-3. For example, the model proposes that in order for the athletes to experience positive momentum, their opponent must be experiencing negative momentum (Stage 5) resulting in a change in performance (Stage 6) (Taylor & Demick, 1994).

Due to the complexities of momentum, Taylor and Demick (1994) state that a number of other factors need to be considered when using the model to explain the momentum-performance relationship. For example, it is proposed that the experience of the athlete in terms of their skill level may influence the momentum chain, where athletes with positive experiences (related to maintaining momentum) are more likely to act upon precipitating events with the aim of creating momentum in their favour. Inexperienced athletes (with limited positive experiences of maintaining positive momentum) are more likely to be overwhelmed by the situation and subsequently more likely to experience negative momentum (Alder, 1981; Silva et al., 1988; Taylor & Demick, 1994).

Taylor and Demick (1994) found support for their model when they investigated the impact of precipitating events on immediate match outcomes in basketball and tennis. Significant differences were found between winning and losing players for valences of precipitating events (events reported by participants that may cause changes in momentum). Specifically, winning players produced more positive precipitating events (81.3%) and fewer negative precipitating events (18.7) than losing players (68.9% and 21.1 respectively) and were also better able to successfully act on the positive events and restrict negative events. Differences between the sports were also found; for example, the basketball players only changed their outcome immediately following a precipitating event whereas, in tennis, changes in momentum occurred even with the absence of a precipitating event. It was suggested that in team sports, aspects of momentum may become ‘contagious’, thus spreading from player to player and facilitating the progress of momentum (Taylor & Demick, 1994). The higher the number of players on a team, more likely it is that one or more of them will recognise a precipitating event and, in turn, change their (and others) behaviour in response.

Mack and Stephens (2000) also provided partial support for the Multi-Dimensional model (MD) using a basketball shooting task. Players were asked to shoot from 12 different positions around the basket, having three shots at each station. Momentum (positive, neutral or negative) was measured by examining the score configuration immediately prior to the conclusion of the performance (players could either be eliminated or voluntarily cease their involvement). Player’s self-efficacy (confidence of making the next shot), arousal and persistence (willingness to carry on) were measured prior to each shot. The results indicated that players experiencing negative momentum as a result of their score configuration (points scored) had significantly lower self-efficacy compared to players experiencing positive or neutral momentum. Players experiencing positive momentum also reported more positive thoughts and feelings than those experiencing negative momentum. Findings of Mack and Stephens (2000) lend support for the first three stages of the MD model however, no relationship was found between PM (positive, neutral, negative) and persistence, thus providing no support for the model’s prediction that positive momentum should lead to higher levels of persistence and ultimately performance (Stage 4) (Taylor & Demick, 1994). Kerrick et al. (2000), however, suggested that less behavioural changes may occur as participants reach their desired goals; therefore, highlighting that it might be the gap between participants’ desired goals and their current level of performance that will have more of an effect than their level of psychological momentum. For example; if a team is losing 3-0, their reaction to a scoring a goal may not have the same perceived response as scoring a goal when the team was level (Vallerand et al., 1988). Most recently, Mortimer and Burt (2014) used a similar method to

Taylor and Demick (1994) to investigate the existence and effect of behavioural momentum in 45 handball matches. Momentum patterns were present in a number of matches and in the majority of cases (86%) momentum had a positive effect on match outcome.

2.7.1.3 Projected Performance of Momentum

The most recent conceptual model, the Projected Performance Model (Figure 2.3), was established by Cornelius et al. (1997). Unlike the previous two models, the Projected Performance Model suggests that perceptions of momentum have little influence on performance. According to the model, Cornelius and his colleagues (1997) propose that positive and negative momentum are a result of an extremely good or poor performance rather than the cause of the performance outcome. The model also suggests that fluctuations in performance, often perceived as momentum, are in fact nothing more than normal performance variation. Therefore, for momentum to occur performance must be maintained over an extended period of time (Cornelius et al., 1997). The longer a person or team can maintain positive momentum the more likely success, or victory may become (Hamberger and Iso-Ahola, 2004). According to the model, positive and negative inhibitions have an important impact on performance. For example, when a team scores in the first few minutes of a soccer game they may experience positive inhibition (when a successful performance leads to a negative change in subsequent performance) as they start to 'coast' or take their 'foot off the gas' as a desired goal has been reached early in the competition. In contrast, negative facilitation is said to occur following a negative performance or a mistake (Cornelius et al., 1997; Perreault et al., 1998). For example, a team maybe motivated to 'up their game' and play with more aggression and assertion to get them 'back in the match' which is generally more likely when two opponents are relatively equal in skill level (Higham et al., 2005).

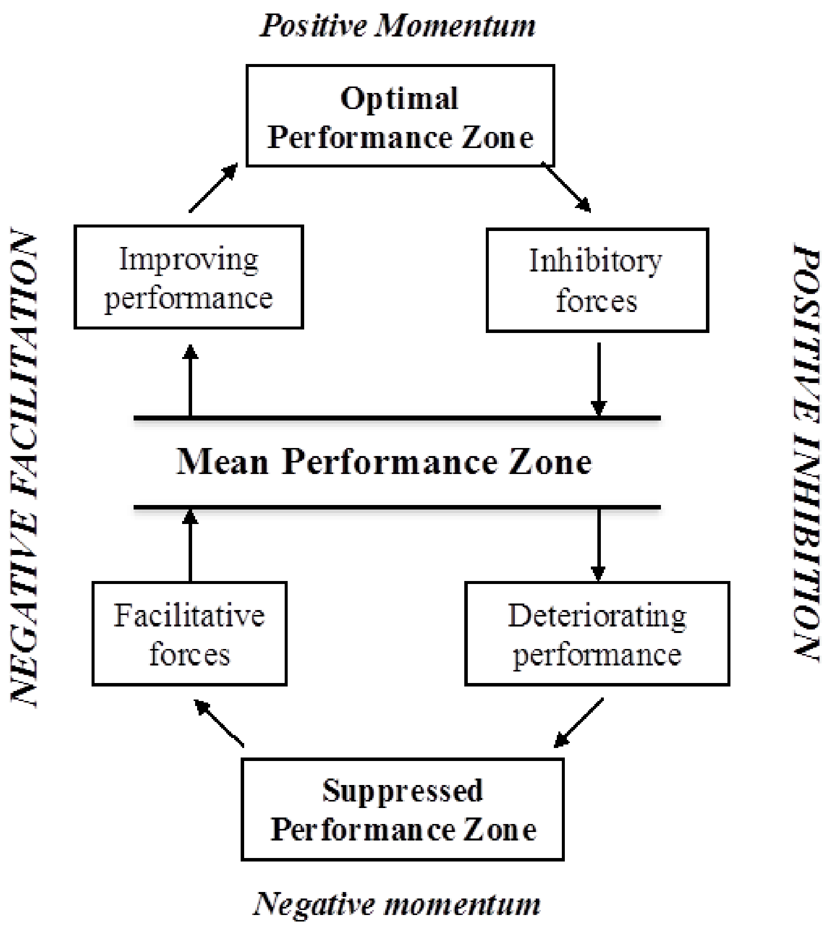

Figure 2.3 The Projected Performance Model
Note. Adapted from "The projected performance model: Relating cognitive and performance antecedents of psychological momentum," by A.E. Cornelius, J.M. Silva, D.E. Conroy, and G. Petersen, (1997). *Perceptual and Motor Skills, 84,* 475-485.

Unlike the Antecedents-Consequences model (Vallerand et al., 1988) which used hypothetical scenarios in a sport related task and the Multi-Dimensional model (Taylor & Demick 1994), which used data from actual sporting performances, Cornelius et al. (1997) used a lab-based competitive task to test the Projected Performance Model. A total of 132 Physical Education students were included in the study. They were asked to complete a series of questionnaires at varying times during their participation. Initially, students were told the nature of the task (basketball free throw shooting) and asked to complete a questionnaire assessing their confidence (Trait Sport Confidence Inventory). They were then informed that the task would take place against an opponent before completing a second questionnaire assessing their levels of confidence in relation to the task (State Sport Confidence Inventory). During the task, students were asked to attempt to make as many successful free throws in 90 seconds whilst their opponent did the same at the other end of the court. Following the completion of the first round, each student was informed of his/her score and asked to complete a post-game performance questionnaire (rating their performance above average (+3) or below average (-3) on a 7-point scale) as well as reporting whether their experienced any PM (anchored by strongly negative (-3) to strongly positive (+3)). Participants were then brought together and informed of the score (e.g., whether they were winning or losing, and by how much) and asked to complete a second post-game performance questionnaire. The process was repeated after the second round of shooting with the addition of three questions relating to PM (do you think PM exists?, do you think PM had a direct positive effect on your performance?, do you think PM had a negative effect on your performance?) to the second completed post-game questionnaire. These additional questions related specifically to their assessment of whether PM had an impact on their performance. The results revealed that higher ratings of performance in the first round were related to higher perceptions of PM; however, regardless of whether participants rated their performance above or below average (which translated to positive or negative PM), no subsequent changes in performance occurred in the second round (Cornelius et al., 1997). The study provided support for the concepts of positive inhibition and negative facilitation, since the number of baskets made in round one was negatively related to the number made in round two (i.e., a greater number of baskets made in round one was associated with a lower number of baskets made in round two and vice versa). Cornelius et al. (1997) concluded that performance fluctuations are most likely a consequence of normal performance variation (as shown by the high perceptions of PM in round one with no subsequent increase in performance), and that positive inhibition and negative facilitation are important aspects to consider in relation to the PM-performance relationship. Although this model gave an interesting explanation for why teams may increase their effort when in a negative scoring scenario, it dismisses the causal relation of PM and thus makes it difficult to apply to sporting situations where PM has been found to be both a cause and effect of performance.

2.7.1.4 Psychological Momentum as a Dynamical System

Gernigon et al., (2010) proposed that PM could be described as a dynamical system, where the system or team in the case of most sporting examples does not vary as a function of one or two independent variables but as a function of its preceding state (Van Geert, 1997; Van Geert, 2009). For example, if teams are in a stable state, with one desperate to score after conceding a goal, one or two events may not be enough to boost psychological momentum, however if the system is in an unstable state (a weaker team are currently in the lead), one positive event can be enough to generate psychological momentum. Thus a small change to an unstable system could result in dramatic changes in the system, and vice versa, a rather large change to a stable system may not change the system at all (Briki et al., 2012a).

Gernigon et al. (2010) examined the influence of increasing (i.e. positive momentum) versus decreasing (i.e. negative momentum) scoring sequences on several psychological components (e.g. self-confidence, competitive anxiety and achievement goals) during observed tennis matches. Negative events were found to have a more powerful psychological impact than positive events of the same value, supporting previous research (Baumeister et al., 2001). Both somatic and cognitive anxiety were lower in the increasing scenario than the decreasing, whereas self-confidence was higher in the increasing scenario. Previous studies have shown that moving towards (or away from) a goal has positive (or negative) consequences on affects (Stanimirovic & Hanrahan, 2004) and feelings of self-confidence (Shaw et al., 1992;

Stanimirovic & Hanrahan, 2004). The more abrupt the change, in moving toward, or away from the goal in question, the more sudden the change in affect (Carver & Scheier, 1990; Hsee, Salovey, & Abelson, 1994). Several other studies have also found competitive anxiety and self-confidence (as well as collective efficacy) to have an important role in characterising psychological momentum (Briki et al., 2012a; Gernigon et al., 2010; Shaw et al., 1992). For example, the majority of research has found increased self-confidence (Briki et al., 2012b; Den Hartigh et al., 2014; Gernigon et al., 2003; Woodman & Hardy, 2003; Jones & Harwood, 2008; Taylor & Demick et al., 1994) and decreased cognitive anxiety (Briki et al., 2012b; Eisler & Spink, 1998; Miller & Weinberg, 1991) to be related to positive momentum and the reverse in the case of negative momentum.

Briki et al (2012a) extended Gernigon et al.'s (2010) findings using actual cyclists competing against each other on home trainers. Bogus feedback was given showing either a positive momentum (i.e. evolving from lagging behind to leading) or negative momentum sequence (i.e. evolving from leading to lagging behind). Supporting the findings of Gernigon et al. (2010) the negative momentum scenario elicited an abrupt decrease in PM perceptions, whereas in the positive scenario PM perceptions increase gradually suggesting negative momentum is a stronger attractor than positive momentum. Gernigon et al., (2010) along with others (Briki et al., 2013; 2012a) also proposed that once the state of a system has changed there is a resistance in it returning to its previous state and thus recovery may be delayed; a state known as hysteresis.

The most recent study to attempt to support the dynamical system theory was conducted by Den Hartigh et al. (2014) and was the first study to consider the dynamics of team momentum. Their aim was to explain how behavioural states change during positive and negative momentum. Rowing pairs were asked to compete against a virtual opponent, whose performance was manipulated to either put the rowers in a positive or negative momentum scenario; collective efficacy, task cohesion, effort exerted and coordination were also measured. Den Hartigh et al.'s (2014) results revealed that exerted effort decreased dramatically in the negative momentum scenario along with perceptions of collective efficacy and task cohesion compared to the positive scenario. The history of progress or regress was also important, for example, the same levels of task cohesion and collective efficacy were seen by the team who gained the lead at the start (negative scenario) as having gained the lead having been behind (positive scenario). Meanwhile, lagging behind at the start of the race did not have as much of a negative impact on task cohesion and collective efficacy than losing the lead when being close to achieving the goal at hand (Den Hartigh et al., 2014). In terms of invasion games, specifically soccer where scores are infrequent, gaining the lead early on in a game may have less of an impact on performance than losing the lead later on in a match.

2.7.1.5 Success Breeds Success Theoretical Framework

The most recent attempt to explain momentum was conducted by Iso-Ahola and Dotson (2014) who proposed a model to explain why success breeds success, specifically by incorporating intensity, frequency and duration effects of initial success on subsequent success. In its most basic form they propose that initial success can trigger psychological momentum which in turn triggers future success, the greater the perceived initial success the greater the psychological momentum and the greater the likelihood of future success. Similarly, if the initial success is intense e.g. a team score in the first minute of the game, psychological momentum is likely to be stronger than if the success is small, e.g. a well-timed tackle. Thus highlighting the intensity component of the model. It is well known that a number of smaller, successes can trigger psychological momentum (Gernigon et al., 2010), thus the second component proposed by the framework is related to frequency of events. For example, Iso-Ahola and Dotson (2014) highlight that rather than a single intense event, a series of smaller but frequent events may also generate psychological momentum resulting in the same perceptions of psychological momentum as one intense event. The closer the events are, and the more frequent they are, the more likely psychological momentum will be generated.

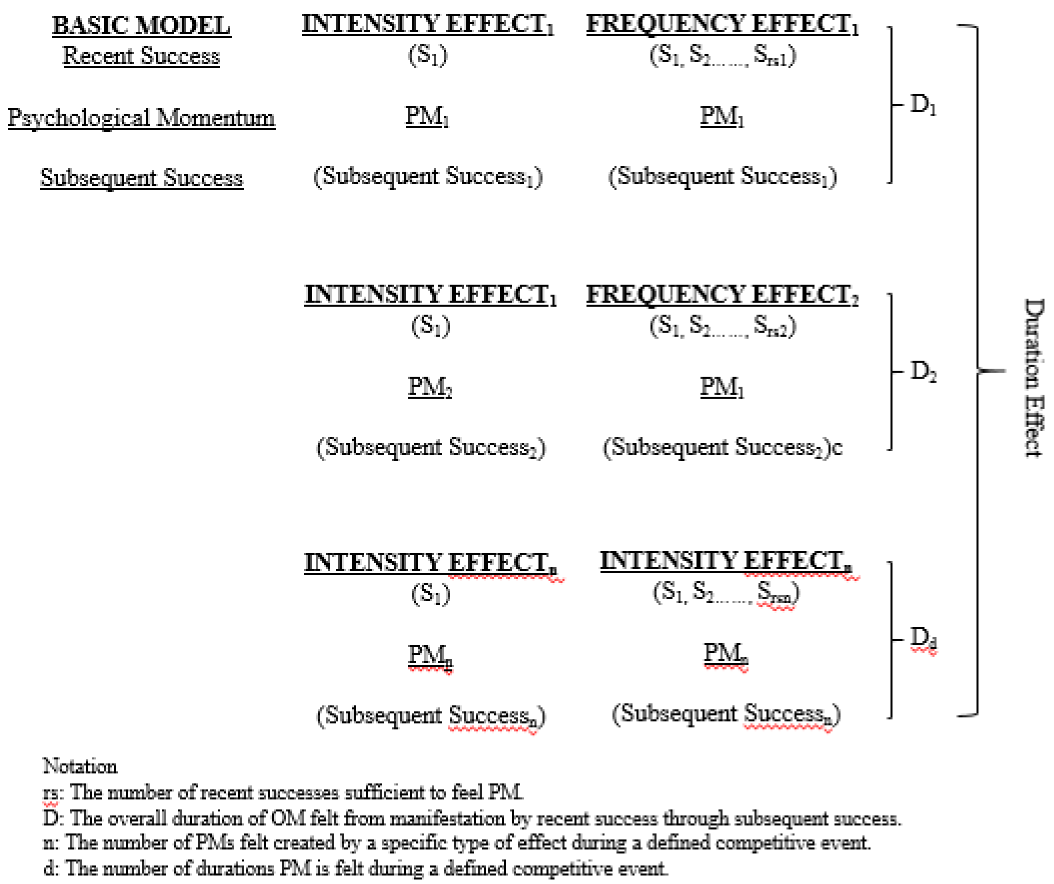

Figure 2.4. Frequency, intensity and direction effects of Psychological Momentum
Note. Adapted from "Psychological Momentum: Why Success Breed Success," by S.E. Iso-Ahola and C.O.Dotson, (2014). *Review of General Psychology,* Vol 18, No1, 19-33.

The model also considers duration, for example an element can be determined by both the number of small events that accumulate to give a psychological momentum effect or one large effect. Figure 2.4 shows how independently intensity and frequency may evolve during a game, although in reality the momentum sequences generated may come from a mixture of small events with larger more intense events enhancing the effect of psychological momentum. For example, a time out or conceding a goal, may rapidly decrease perceptions of psychological momentum, whereas a small event such as losing the ball to your opponents would be unlikely change perceptions of PM. The model also postulates that perception of oneself and one's opponents can alter how a team may start and ultimately generate psychological momentum (e.g. psychological momentum may only occur if the performer's perception of themselves is greater than their perception of their opponent) however, the specifics of this go beyond the scope of this current review (See Ahola-Dotson, 2014).

Although pertinent in helping to explain the PM-performance relationship, these models are limited in their applicability for practitioners as they provide minimal insight into individual perceptions with regard to specific events that initiate momentum. This is especially true in team sports where the individuality of players' perceptions for concepts such as this have been found to be sacrificed for the collective norm (Jones & Harwood, 2008). Support for the models have however highlighted a relationship between perceived PM and performance and thus a closer examination of the PM-Performance relationship is warranted.

2.7.2 Momentum and Performance

Understanding the relationship between momentum and performance is of critical importance to coaches, practitioners and researchers. However, empirically testing this relationship has been a challenge. Initial approaches to studying the momentum-performance relationship used archival data from various sports such as basketball (Vallone, & Tversky, 1985), tennis (Silva, Hardy, & Crace, 1988) and minor league hockey (Gayton et al., 1993). Hypothetical scenarios where perceptions of performance were manipulated have also been used to investigate the PM-performance relationship (Eisler & Spink, 1998; Miller & Weinberg, 1991; Perreault et al., 1998; Vallerand et al., 1988). More recently, Jones and Harwood (2008) used a novel qualitative (semi-structured interviews) approach to examining participants' perceptions of PM (to be discussed later in this chapter).

The majority of the momentum-performance research has attempted to support the notion that success breeds success especially that performance increases with positive momentum (Miller & Weinberg, 1991; Iso-Ahola & Dotson, 2014) and deteriorates with negative momentum (Stanimirovic & Hanrahan, 2004; Taylor & Demick, 1994). A number of studies have attempted to identify the 'hot hand' (where athletes' performance during a particular period is significantly better than expected) concept in sports such as basketball using archival game data (Vergin, 2000; Koehler & Conley, 2003) with limited findings. Bar-Eli, Avugos, & Raab (2006) reviewed 28 papers investigating the 'hot hand' phenomenon and found over half (16 in total) found no evidence to suggest performance that followed previous successes or failures was different than would be expected by chance. It was proposed that one of the reasons for limited support based on archival data was related to the inability to establish whether momentum was the cause or effect of performance changes (Alder, 1981; Silva & Hardy, 1985) or in many cases whether the opponents were just better (Hubbard, 2015). More recently Arkes (2013) suggested that given that psychological momentum is short lived (Hamberger & Iso-Ahola, 2004) it may be difficult to detect especially in small data sets (Arkes, 2010) especially as the 'hot hand' effect occurs infrequently (Iso-Ahola & Dotson, 2014). Raab, Gula, and Gigerenzer, (2012) also proposed that an increase in effort from opponents my mask 'hot hand' effects as opponents attempt to increase their effort to overcome this apparent positive streak.

Although support for momentum in basketball is limited, more promising support for the concept using archival data has been obtained in sports such as ice hockey (Gayton & Hearn, 1993), tennis (Silva et al., 1988; Jackson & Mosurski, 1997), volleyball (Raab et al., 2012) and racquetball (Iso-Ahola & Mobily, 1980). Generally, results from these studies indicate that winning the first set or period leads to future success and therefore predicted game outcome (Gayton et al., 1993; Iso-Ahola & Mobily, 1980; Raab et al., 2012; Silva et al., 1988).

Suggesting that teams who performance well early on in a game/performance are more likely to continue to perform well. Further studies have reported that positive score configuration or performing well early-on may also lead to enhanced perceptions and feelings of confidence (Briki et al., 2013; Gernigon et al., 2010; Iso-Ahola & Blanchard, 1986; Taylor & Demick, 1994), competence (Vallerand & Reid, 1984), and self-efficacy (Bandura & Schunk, 1981), as well as increased expectations of future success (Burke et al., 1997; Mack, Miller, Smith, Monaghan, & German, 2008) and heightened levels of motivation (Weiner, 1985).

Several recent studies have shown further support for the "hot hand" hypothesis using much larger data sets from basketball. Yaari and Eisenmann (2011) analysed five seasons of NBA free throw shots and reported that the second free throw shot success rate was significantly higher if the first shot had been made. Consequently, initial success was likely to stimulate psychological momentum and thus a greater likelihood of subsequent success. A number of other studies have also found self-confidence to increase in positive PM scenarios and decrease when participants experience negative PM (Briki, Den Hartigh, Bakker, & Gernigon, 2012; Den Hartigh et al., 2014). Both Briki, Den Hartigh, Hauw, and Gernigon (2012) and Gernigon et al. (2010) found that progressing toward (or away from) a desired outcome (e.g., victory or defeat) increased (decreased) self-confidence and therefore further supports the idea that success breeds success. Although there is inconclusive evidence to ascertain whether momentum is the cause or effect of performance change, there is evidence of a momentum–performance relationship across a number of sports, therefore future exploration is required to ascertain the relationship between momentum and performance and vice versa.

2.7.3 Perceptions of Psychological Momentum

The momentum-performance relationship has also been explored by assessing participants' perceptions of PM using post-game questionnaires (Iso-Ahola & Blanchard, 1986; Mack et al., 2008; Perreault et al., 1998). One of the most common approaches to studying perceptions in this way has been to use hypothetical or contrived scenarios where perceptions of PM are induced in a controlled setting (Cornelius et al., 1997; Eisler & Spink, 1998; Mack & Stephens, 2000; Taylor & Demick, 1994; Vallerand et al., 1988). For example, both Eisler and Spink (1998) and Miller and Weinberg (1991) investigated perceptions of PM within different hypothetical volleyball scenarios. Findings indicated that teams who were described as coming from behind to tie the game were reported to be more confident, have greater PM, and, thus, be more likely to go on to win the game than the team described as having no PM (Eisler & Spink, 1998; Miller & Weinberg, 1981).

These results are consistent with research in tennis conducted by Vallerand et al. (1988), which revealed that participants believed a player coming from behind was more likely to win the set if they had won previous games. One issue, however, with findings that are founded on hypothetical scenarios is their lack of ecological validity, as participants do not necessarily experience PM directly and, therefore, may base their answers on the perceived performances of others. Although no research of this kind has been conducted in soccer, similar patterns have been reported by spectators watching the game. Specifically, Higham et al. (2005) highlighted that spectators were much more likely to perceive their team would win the game if they came from behind. It is therefore likely that players' perceptions may also follow similar patterns, especially as scoring has been shown to be a key determinant of PM in soccer (Higham et al., 2005; Jones & Harwood, 2008).

To increase the ecological validity and extend understanding of the momentum-performance relationship, Perreault et al. (1998) measured participants' actual performance (average power output) whilst giving false feedback during a bogus bicycle race. Results indicated that participants' average power output was highest when they were experiencing both positive (being in the lead) and negative momentum (being behind) as opposed to drawing the race. The latter findings, in particular, support the concept of negative facilitation (Silva et al., 1988; Taylor & Demick, 1994) where performers work harder when they perceive they are behind.

Crust and Nesti (2006) suggested that qualitative methods should be employed to examine individual perceptions and experiences of PM to better understand the momentum-performance relationship. To address this, Jones and Harwood (2008) interviewed soccer players to investigate triggers, experiences, and potential consequences (e.g., behavioural affect) related to PM, and strategies used to control perceptions of PM within competitive soccer matches. Their findings gave support for existing research (Eisler & Spink, 1998; Higham et al., 2005) and PM models (e.g., Taylor & Demick, 1994; Vallerand et al., 1988) with regard to the importance of antecedents that trigger positive and negative momentum. In particular, a high level of confidence, scoring a goal, and seeing negative body language in opponents were all factors that were perceived as key triggers of positive PM, whilst negative momentum was triggered by incidents where opponents played to their strengths or maintained possession.

Although Jones and Harwood (2008) gave an initial insight into the perceptions of PM of soccer players, their sample size and population was limited. Only one group of university soccer players were interviewed limiting the ability to generalize findings across a wider population. Due to the difficulty of gaining perceptions of psychological momentum during actual sporting competitions a number of studies have investigated the perceptions of supporters in an attempt to understand the momentum-performance relationship. Both Briki et al (2013) and Briki et al. (2015) asked supporters to watch a simulated cycling race in which they were assigned to either a positive or negative momentum scenario (supporting one of two cyclists). Bogus feedback was given showing either an ascending performance scenario (i.e., positive momentum) or a descending performance scenario (i.e., negative momentum). Abrupt changes were found at the beginning of both scenarios, followed by a period of stability supporting the negative hysteresis theory (see Gernigon et al., 2010). The negative momentum scenario elicited an abrupt decrease in PM perceptions, whereas in the positive scenario PM perceptions increased gradually. This finding indicates that negative momentum was entered relatively rapidly compared to positive momentum

Briki et al., (2012b) interviewed table tennis players and swimmers regarding their experiences of both positive and negative momentum, with both groups stating they increased their effort as momentum started either positively (to improve performance) or negatively (to regain control over the situation). However, athletes also reported decreasing their effort once it was clear they would either win or lose, supporting the decrease in performance for negative momentum (Taylor & Demick, 1994; Vallerand et al., 1988) as well as the concept of coasting (reducing effort towards the end goal) for positive momentum (Briki et al., 2015; Carver, 2003). A similar pattern was found by Moesch and Apitzsch (2012) who interviewed coaches about their experiences of psychological momentum. Coaches proposed that performing well would lead to increased self-efficacy which would trigger a willingness in performers to put in more effort. These studies also support the theory proposed by Alder (1981) that suggests that the start of positive momentum can be characterised by an increase in effort (a building phase) followed by a 'cruising' phase where performers focus on economy of effort. Once the goal to be achieved is within reach, Alder (1981) suggests that performers will start to 'coast' reducing their efforts (see Briki et al., 2013). In reverse as performers experience negative momentum Alder (1981) proposes that a surge in effort will occur in an attempt to overcome this, however if this negative momentum persists, performers will normally abandon the activity as the goal becomes further away from them.

2.7.4 Psychological Momentum and Soccer

Although specific research into PM and soccer has been limited, the existence of critical incidents, such as scoring or conceding goals in sport games has been one of the key areas of research in momentum (Eisler & Spink, 1998; Higham et al. 2005; Jones & Harwood 2008; Vallerand et al. 1988). Two studies have, however, addressed the concept of PM in soccer. Firstly, Higham et al. (2005) interviewed a selection of high profile players, managers and coaches in an attempt to understand how PM was perceived by soccer professionals. More recently, Jones and Harwood (2008) interviewed ten university soccer players regarding their experiences of PM. Both studies reported a number of key factors perceived to influence both momentum and performance within soccer.

The players interviewed by Higham et al. (2005) stated that they perceived momentum to build upon itself; for example, if their team started well, it was likely that they would continue to perform well and everything would go right for them. Similarly, if they started poorly they perceived their performance would snowball into 'one bad thing after another' (Higham et al., 2005). The findings support a number of early studies using archival data (Arkes, 2013; Hamberger & Iso-Ahola, 2014; Hardy & Silva, 1985; Moesch et al., 2014; Ransom & Weinberg 1985; Silva et al., 1988;; Weinberg, Richardson, & Jackson 1981; Weinberg, Richardson, Jackson, & Yukelson, 1983; Weinberg & Jackson 1989; Yaari & Eisemann, 2011) who found that teams who were successful early in competition would develop momentum and, thus, be successful later in the competition. The timing of key events (such as goals, shots, periods of positive play) was also highlighted as important in relation to the impact that they had on the perceived momentum (Higham et al., 2005). This has also been shown in a number of other studies (Krustrup, Mohr, Ellingsgaard, & Bangsbo, 2005; Mohr et al., 2003) who found some game periods in soccer to be more susceptible to momentum shifts due to changes in performance. These periods include; the first fifteen minutes of the game (Rahnama, Reilly, & Lees, 2002), just after half time (Mohr et al., 2003) and towards the end of the game (Bangsbo et al., 2006; Carling et al. 2002; Mohr et al., 2003; Reilly, 1997). Burke, Edwards, Weigand, & Weinberg (1999) also found that gaining momentum during the closing minutes of a game was more advantageous than having momentum early in the contest, as a score is more likely towards the end of the game as players become fatigued and make more mistakes (Mohr et al., 2003). Some of the players interviewed by Higham et al. (2005) highlighted that the main reason for the loss in momentum in the latter stages of a game was due to player fatigue, as they were more likely to reduce their work rate and persistence (Higham et al., 2005). A number of the players proposed that during these periods extra effort may be needed to attack advances from the opposition or to take advantage of their mistakes or drop in performance. For example, players reported that mistakes by a team, or a flash of brilliance at these critical times had a greater impact on their cognitions. This could ultimately create a series of knock-on effects and influence performance (Higham et al., 2005); thus, supporting stages three and four of the momentum chain proposed by the Multi-Dimensional model (Taylor & Demick, 1994).

The way that the players and teams deal with momentum changes during games can be attributed to various personality factors and individual differences (Vallerand et al., 1988). For example, teams can create momentum in different ways; some go off hard and attack from the start, whilst other take time to get into the game, slowly building momentum as the game proceeds (Higham et al., 2005). However, through their responses, players, teams and managers can create momentum as well as lose it (Vergin, 2000). As Higham et al. (2005)

highlighted from coach interviews, the pattern by the end of the match is often a reflection of how the players dealt with momentum, as it acted either for or against them.

To help coaches, managers and practitioners to understand individual players' perceptions of PM, Jones and Harwood (2008) conducted a series of interviews and subsequent focus groups asking university soccer players about their experiences of PM. 'Feeling confident' was reported as one of the most common triggers of positive momentum, alongside 'scoring a goal' and 'seeing negative body language from opponents'. The most common triggers of negative momentum were 'opponents playing to their strengths', 'opponents maintaining possession' and 'conceding a goal' (Jones & Harwood, 2008). The results also highlighted specific individual and team strategies that players used to maintain or develop positive PM and overcome negative PM. These included changing tactics, maintaining a positive attitude, encouraging teammates, executing basic ball skills well and maximising effort.

It is important for teams to develop strategies to maintain positive PM and overcome negative PM so coaches and managers need to be aware of not only what triggers the momentum changes, but also when momentum may be changing. They need to recognise when the flow may be starting to go against them and make the necessary changes to avoid this happening (e.g., change tactics or make a change to the line-up through a substitution or play). Salitsky (1995) observed that volleyball players called time-outs to break up positive momentum of the opposition. They found that following a time-out, the opposition with positive psychological momentum reduced the number of points scored. As most invasion games do not allow time-outs, having possession (feeling superior) may act as a momentum breaker and allow a team to re-configure after a period of negative momentum or a drop in performance (Higham et al., 2005). As much of the literature has shown PM to have an impact on performance, knowing when momentum is most likely to change (and what causes it to change) could have implications on how coaches and players employ strategies to deal with negative momentum and facilitate positive momentum.

2.8 Limitations of Previous Research Concerning Momentum and Performance

Despite considerable research into psychological momentum and sports performance, there is still a divide as to whether the concept is real or illusionary (Burke et al., 1997). One of the main criticisms of previous research investigating the existence of PM has been the failure of researchers to provide clear definitions of the concept. This has made comparing findings challenging as methodologies differ in relation to the nature of the definition used (Taylor & Demick 1994; Vallerand et al., 1988). There has also been speculation as to whether psychological momentum is the cause or effect of performance changes. For example, does PM cause teams to perform well and create goal scoring opportunities or does scoring a goal create positive PM?

Secondly, the majority of studies reporting PM effects have used archival data over a series of matches and a number of these have also focused on a single team limiting the ability to generalise findings. The ability of the teams analysed in relation to their opponents was also not frequently considered and, thus, possibly explains why there is a lack of consistency across those studies that have used archival data to support the existence of PM (e.g., point scoring sequences often described as momentum may just be a function of better teams taking control). Momentum shifts are said to occur throughout the game or performance (Higham et al., 2005), therefore defining whether a team has momentum based on overall game outcome rather than in relation to game events does not provide a complete picture. The nature of each athletic competition is unique in its rules, time frame, and outcomes. Thus, comparisons among sports and even games are difficult and debatable, and drawing inferences becomes even more problematic.

With regards to research examining the perceptions of PM using hypothetical scenarios, a number of limitations are present. For example, in the majority of studies participants based their perceptions of momentum on scoring patterns which reflected predictions of momentum through hypothetical scenarios and not actual sporting experiences. However, examining perceptions of PM within a laboratory setting essentially detached the participant from real experiences. As PM is considered a subjective experience (Vallerand et al., 1988), only athletes experiencing PM within a 'real life' situation can attempt to give a true account of their experiences and even then, experiences maybe reconstructed inaccurately. The structured nature of the questionnaires used also does not allow participants to fully express their thoughts and feelings regarding their experiences of PM.

More recently, qualitative methods of enquiry have provided more sustainable support for its existence (Jones & Harwood, 2008) but this type of research is scarce. One of the reasons for a lack of research, especially with concepts such as momentum, maybe the inability to access players directly at the point at which they are experiencing momentum. That is, reporting thoughts and feelings concerning their perceptions of the score line is done in retrospect, if at all. Although Jones and Harwood (2008) gave an initial insight into the perceptions of PM of soccer players, their sample size and population are limited. Only one group of university soccer players were interviewed, limiting the ability to generalise findings. There has increasingly been more consistency in the methods used to investigate perceptions of PM, but research is still limited in terms of understanding the complexities of PM (e.g., why behaviour was changed in a particular way).

2.9 Recommendations for Future Research Concerning Momentum Perceptions and Performance

From reviewing the literature to date, the following recommendations for future research assessing athletes' perceptions of PM on performance can be made:

- Studies have previously used archival data of a single team over a series of games or a season to assess psychological momentum and performance. However, momentum shifts are said to occur throughout the game or performance (Higham et al., 2005); therefore, psychological momentum should be examined on a game-by-game basis or within specific game periods across a number of teams to establish if momentum is changing.
- Research examining the perceptions of PM using hypothetical scenario; has based athletes' perceptions of momentum on scoring patterns, which reflect predictions of momentum and not actual experiences. Examining perceptions of PM within a laboratory setting or using hypothetical scenarios detaches the participant from real experiences. Therefore, examining the perceptions of psychological momentum should be based on real life experiences.
- The low scoring nature of soccer does not lend itself to much of the previous momentum research as the majority of the methods used to measure momentum are based on points won or scores during a game (Gayton et al., 1993; Silva et al., 1988). Therefore, due to the low scoring nature of soccer games, alternative performance measures should be considered to measure momentum patterns during matches, for example ball possession and frequency of good play (e.g., passing accuracy, shots of target, corners).
- Qualitative methods of enquiry that have investigated perceptions of psychological momentum have provided a better understanding of the existence of PM (Jones & Harwood, 2008), but this type of research is scarce and is limited by sample size and

population reducing the ability to generalize findings across a wider population. Using a mixed methods approach to investigate player's perceptions of psychological momentum should be used to further our understanding of the relationship between score line and performance from a psychological perspective.

Taking into consideration the recommendations of previous literature investigating both score line effects and PM on performance, this thesis addresses the following:

a) The effect of score line on performance when adjusted for normal performance,

b) The relationship of score line and psychological momentum perceptions,

c) The effect of score line on performance across a number of physical (distance covered, high speed distance covered, sprint distance covered) and technical (passing, corners, free kicks and crosses) performance measures taking into consideration a number of situational factors such as opposition ability, team ability, pitch position and playing position.

2.10 System of Measurement

One of the biggest developments in relation to the study of soccer performance has been the use of technology to track player movement and measure game variables (e.g., passing, corners, crosses). The following section will review the different systems of measurement available in the commercial market to measure both technical and physical (e.g. activity profiles) performance in invasion games as well as those that have been used for academic research. Support for the systems in terms of their reliability and validity for measuring player performance in soccer and other team sports will also be discussed as well as practical considerations.

2.11 Measuring Soccer Performance

Soccer is a high-intensity intermittent sport that provides unique challenges for coaches and sports scientists alike with regard to tracking performance changes across matches (Gregson et al., 2010). Being able to identify both the physiological and technical demands on players during game play is essential to enable coaches to adapt training and recovery strategies accordingly, to ensure adequate preparation to achieve optimal performance (Carling et al., 2009; Drust, Atkinson, & Reilly, 2007). A number of studies (MacLeod, Morris, Nevill, & Sunderland, 2009; Rampinini, Impellizzeri, Castagna, Coutts, & Wisløff, 2009; Reilly & Thomas, 1976, Varley, Di Salvo, Modonuth, Gregson & Mendez-Villanueva, 2018; Varley, Gregson, McMillan, Boanno, Stafford, Modonuth & Di Salvo, 2017) have investigated the activity profiles of soccer players in an attempt to understand the demands placed upon them during matches. Methods used to analyse player movement have progressed rapidly from manual notation systems (Reilly & Thomas, 1976) to human operated computer based systems (O'Donoghue & Tenga, 2001) and more recently automatic player tracking with limited need for human interaction (Di Salvo et al., 2006; 2009; O'Donoghue & Robinson 2009). Such video-based time motion analysis has been applied widely in the soccer world providing useful information regarding the work capacity of players during competitive matches (Castellano et al., 2015; Krustrup, Mohr, Amstrup, Rysgaard, Johansen, Steensberg, Pedersen, & Bangsbo, 2003; Mallo, Mena, Nevado, & Paredes, 2015; Mohr et al., 2003; Rampinini Bishop, Marcora, Ferrari Braco, Sassi, & Impellizzeri, 2007; Varley et al., 2017; 2018). Over the past 15 years the influx of computer based technology has allowed new methods of assessing movement in soccer; such as multiple camera methods (Di Salvo et al., 2009; Rampinini et al., 2007; 2009), global positioning systems (GPS) (Bucheit et al., 2010; Coutts & Duffield 2008; Edgecomb & Norton 2006; Goto, Morris & Nevill, 2015; Kirkendall, Leonard, & Garrett, 2004; Saward, Morris, Nevill, Nevill & Sunderland, 2015) and systems using microprocessor technology

(Frencken, Lemmink, & Delleman, 2010).

More recently fully automated tracking systems such as TRACAB, with no human operator input have introduced the concept of live tracking during games (Carling et al., 2009). Such physical performance data related to the activity profile of players has become so sophisticated that performance analysts can now retrieve data corresponding to specific speed zones to evaluate the performance of various players. Companies such as Prozone (Leeds, UK), Amisco (Nice, France), TRACAB (Stockholm, Sweden) and SportsTec (SportsTec, Warriewood, Australia), have all provided systems to the commercial market which allow tracking data to be collected and used for post-match analysis. Computer based coding systems have also been available for live analysis and half-time review such as Focus (Elite Sports Analysis, Fife, Scotland), Dartfish (Fribourg, Switzerland), Digital Soccer (Italy) and Sportscode (SportsTec, Warriewood, Australia). The aim of this chapter is to highlight the development of player tracking, in terms of capturing both event data and player movement for the purposes of investigating score line effects.

2.12 Human Operated Notation Systems

Notation systems are often recommended as an inexpensive way of providing an insight into the physiological and technical demands of game play by recording and quantifying player movement patterns that are characterised as skilled performance (Duthie, Pyne, & Gabbett, 2003).

A number of systems exist on the commercial market which enable such analysis (Sportscode, Warriewood, Australia; Dartfish, Fribourg, Switzerland; Focus, Elite Sports Analysis, Fife, Scotland; Digital Soccer, Italy), all with varying features and associated costs. The main benefits of manually operated systems compared to automated systems is the vastly reduced costs in gathering data, however, due to speed at which team games are played, collecting large amounts of live data can be difficult, incurring numerous errors (Barris & Button, 2008). Therefore, although human operated notation systems are convenient, practical and usually inexpensive, the validity and reliability of such systems has been questioned (Barris & Button, 2008). The following section details some of the most utilised computerised notation systems used in Soccer together with research that has been conducted using such systems.

2.13 Computerised Generic Systems

2.13.1 MatchViewer –ProZone

ProZone MatchViewer, was developed as a sophisticated notation system which enables on-the-ball events to be notated using a computer led process (Di Salvo et al., 2006; Robinson & O'Donoghue, 2009). The event, the time of event, the players involved and pitch location, using X/Y co-ordinates, are notated for each game event recorded as well as X, Y, Z co-ordinates of the ball. This allows event details to be recorded and associated with frames within match videos in a similar way to other commercial systems such as Focus X2 (Elite Sports Analysis, Fife, Scotland) and SportsCode (SportsTec, Warriewood, Australia). The added benefit of the MatchViewer system is the ability to specify pitch location of events to give tactical as well as technical outputs at player level (Bradley, O'Donoghue, Wooster, & Tordoff, 2007). The multiple levels at which the data is collected also allows for inter game and inter player comparison and interactive information such as passing matrices and player formation strategy (Di Salvo et al., 2009). Although the data is collected manually and inputted by a team of human operators, a number of studies have tested this system for validity and reliability. Bradley et al, (2007) tested the reliability of the Prozone MatchViewer system and found high levels of inter-observer reliability; however, this was attributed to the quantity of user training and the strict use of the systems precise operational event definitions. The most common source of error was found when one observer considered an event to be a single event, while the other considered it to be composed of two separate events (e.g. touches). However, the largest error occurred when entering event position; 95% of the events were agreed by the 2 observers to within 8.5m with a mean absolute error of 3.6m (Bradley et al, 2007). Although this study reported the system as reliable when operated by observers that had undergone the necessary training (Bradley et al. 2007) the large positional errors may be considered differently when compared to more recent tracking technologies. Therefore, there is still some doubt over the quality of the data due to the volume of human validation needed. And, as O'Donoghue (2007) highlights, if coaches and players are making important decisions about how they will prepare for competition using such data, it is important that the data is reliable and accurate.

2.13.2 OPTA – Sportsdata

OPTASPORTS (formerly known as OPTA Sportsdata) has been the world leader in collecting, compiling, analysing, storing, distributing and supplying live sports data on a wide variety of sports for the last 20 years. Sold in 2013, it now sits as a subsidiary within the PERFORM group. OPTA has two main products within the soccer industry for performance analysis; *OPTA Client System* and *OPTA Pro.* OPTA's unique infrastructure enables over 40 soccer leagues to be analysed by their extensive team of analysts, producing some of the most comprehensive scouting and recruitment data in the business. Their core strength however lies in their depth of data with over 2000 events collected per game which can be packaged to suit the end user (Sportingstatz, 2008). This depth of match data has helped to advance both the field of performance analysis and academic research investigating event data.

Within OPTA's system analysts use a set of rigid definitions to code every possible type of ball touch and on the ball activity within the match. The OPTA Client System has recently been investigated in terms of its reliability in collecting live soccer match statistics

(Liu, Hopkins, Gomez, & Molinuevo, 2013). Liu et al. (2013) tested the OPTA *Client system* using data from a game in the 2012-13 Spanish Soccer League. A team of experienced operators independently coded the game both in relation to the event and the time it took place. Results indicated a good level of agreement (kappa values were 0.92 and 0.94) with an average difference of event time 0.06 ± 0.04 s suggesting that the OPTA Client system is reliable as a tool to collect live soccer data by trained operators. The following section details some of the most common of the systems used to track the activity of soccer players during matches.

2.14 Video- Based Semi-Automated Player Tracking Systems

Semi-automatic player tracking systems are used by sports professionals to provide objective and reliable movement data. Unlike manual notation systems, these systems have the ability to track a large number of players within the same game (Di Salvo *et al*., 2009; Gregson et al., 2010) and thus allow researchers to investigate both team and individual player performance.

2.14.1 Sport Universal –Amisco

Sport Universal's major product Amsico Pro, enables users to view player movements, as well as tactical and technical performance data (Liebermann, Katz, Hughes, Barlett, McClements & Franks., 2002). The Amisco system (Amisco Pro, Nice, France) uses a series of video cameras and sensors (approximately 4-6) installed around the playing surface to track player movement. This is achieved through sophisticated software that compares predicted trajectory paths of both the players and the ball with the data acquired via the multi-camera system (Liebermann et al., 2002). Through this process an interactive representation of player actions is generated via graphical reconstruction and thus provides digital replays of all players and the ball from a range of positions. The system tracks all 22 players at a rate of up to 25Hz

(AmsicoPRO, Nice, France) whilst human operators note all game events such as fouls, off-sides and cautions that occur during the game (Liebermann et al., 2002; Randers et al., 2010). Although the reliability and validity of the coded output from AMISCO system has been tested (Rodriguez, Croisier & Bury, 2010), no formal validation of the system has been completed, questioning the reliability of the data. The volume of data generated by the system, means only trained analysts, who are able to extract relevant data are able to effectively use the system. The positioning of the camera system also means it is not portable and limited to the stadium in which it is fixed which makes it a costly system to install and utilise (Liebermann et al, 2002).

2.14.2 Prozone3

PROZONE® offers a semi-automatic tracking system able to analyse movement patterns quantifying both motion characteristics and work rate ratios of professional football players during games (Prozone, Leeds, UK). The system uses a number of fixed cameras, positioned strategically around the stadium to produce a complete view of the pitch. To ensure accuracy, occlusion, resolution and resilience each area of the pitch is covered by at least 2 cameras (Di Salvo et al., 2006) and up to as many as 8. On receipt of the video files, human operators transfer the media onto dedicated file servers which instigates the automatic tracking of the videos (Di Salvo et al., 2006). Each video is tracked independently determining image coordinates and continuous trajectories for each player. Once the automatic tracking is complete, the output from all 8 cameras is automatically combined to produce a single dataset. The video's image co-ordinates can then be converted into world pitch co-ordinates via a calibration process (computer vision homography) (Di Salvo et al., 2006).

In order to test the system's tracking accuracy Di Salvo and his colleagues (2006) conducted a validity study on the Prozone system. Four separate tests were completed across a number of speeds and distances and compared to a measured benchmark. The mean differences and limits of agreement between the two systems ranged from 0.05-0.23 $km.h^{-1}$ and 0.05-0.85 $km.h^{-1}$ respectively, with the CV ranging from 0.2-1.3%. Although the study highlighted Prozone to be a valid system for tracking player movement, with only 30 individual runs tracked this is not a true reflection of the number of runs conducted during a standard soccer match and thus further testing on this system should be undertaken. As well as testing the accuracy of the system to track player speeds and distances, O'Donoghue and Robinson (2009) investigated its ability to track the location of path changes and transitions between different areas of the pitch. Their observations supported the systems accuracy in tracking player movement however, like with previous validation studies only a small portion of the game was tested.

Although Di Salvo and colleagues (2006; 2009) have reported this system as reliable with good inter- and intra-operator agreement for the distance covered at different speed ranges (Di Salvo et al., 2006; 2009), they reported that as much as 42% of player time was required to undergo a verification process in order to achieve the required level of accuracy. This is perhaps a lot less since publication of these stats, however clubs are still undergoing several hours of re-analysis to individualise data outputs post game (Strudwick, 2016). The system of coding events can also be a lengthy process, resulting in client clubs waiting as much as 24 hours for match data after the final whistle (O'Donoghue & Robinson, 2009). A lot of manual work is also required to register all the relevant events which occur during the game; such as free-kicks, corners and passes (Mylvaganam, Ramsay, & De Graca, 2002). Although a time consuming process, the system does enable all 22 players to be tracked simultaneously with no disruption or necessity to wear tracking devices. Although previous camera-based systems have successfully tracked players, they were unable to track more than one player at a time

(Castagna, et al., 2004) and generally required a large investment from human operators to follow the individual analysed during the course of the game.

2.15 Automatic Player Tracking Systems

With no human operators needed to gather data, automated tracking allows a greater amount of time to be spent on real-time analysis investigating tactical and technical aspects of play. Automatic tracking in this way allows sports science and medical personnel to make detailed observations of player movement in order to evaluate agility and injury risk respectively (O'Donoghue & Robinson 2009). In addition, having this information live during matches can allow the appropriate personnel to assess whether players are performing to their individual targets, informing tactical aspects of play such as substitutions; which can be critical during a game (Hirotsu & Wright 2002). The cost of image processing technology and fixed installation is generally much higher than using GPS systems which are relatively inexpensive and do not require a fixed base (e.g. stadium) on which to place cameras (MacLeod et al., 2009; Witte & Wilson 2004). However, if the intervention is able to assist in injury prevention by highlighting player movement issues live during a game, a large part of the cost of the technology could be justified, especially if the overall incidence of injury in a team is reduced (O'Donoghue & Robinson 2009). Due to the fully automated nature of the systems a greater volume of data can be collected on individual player movement, allowing more relative analysis responding to movements that may involve sharp turns or cutting movement, associated with ankle and other such injuries (O'Donoghue & Robinson 2009; Simpson, Shewokis, & Alduwaisan, 1992). The following sub-section details some of the key automatic tracking systems currently available in the commercial market for tracking player movement.

2.15.1 TRACAB

TRACAB is a semi-automatic computerised player tracking system **(**TRACAB Image Tracking System™, Solna, Sweden) that uses a multiple camera system to passively track player movement in real-time. Using eight pairs of cameras, the video stream captured by the cameras is analysed by the TRACAB Image Tracking System™, capturing player movement at 25Hz. This generates X,Y,Z coordinates as well as speed and acceleration for all objects (Lago-Penas et al., 2012). The system has been found to measure player location to less than < 0.1 m (Castellano et al., 2011) making it an accurate and useful tool for player analysis.

2.15.2 Venatrack

Venatrack's Visual-AI technology (Venatrack, Slough, UK) allows players to be monitored in real time (at 25 Hz) providing identification through recognition algorithms (based on x, y, z coordinates for hands, feet, head and the pelvis and shoulder lines; Venatrack, UK). Between 24 and 28 HD colour cameras are installed in each stadium to maximise accuracy. As visual acuity of any camera image based system is limited by the number of video pixels provided to either the human operator (in the case of most semi-automated systems) or the computer algorithm (in the case of the Venatrack system) using a greater number of cameras results in a greater number of pixels with which to quantify the pitch area and thus provide a greater accuracy for measuring each point. Venatrack's automated system therefore uses 28 HD cameras in up to 10 locations compared to most semi-automated systems which use between 4 and 10 HD cameras in up to 4 locations (Di Salvo et al., 2006; O'Donoghue & Robinson 2009). Accordingly, the estimated visual acuity for the current system is in the range 5–25 mm compared to previous systems which are estimated at between 500 mm–1500 m depending on the region of the pitch. The cameras position, orientation and field of vision are determined and fixed when installed using a Theodolite (Nikon NPL 362, Japan). The cameras are thus positioned to give a full view of the pitch using the systems unique configuration co-ordinates (unique to each ground). This allows each position on the pitch/player to be covered by at least 5 cameras at any one time (Venatrack Ltd, UK). Calibration of the automatic tracking system is completed by a team of technical experts. Although the system is fixed for the duration of the game, only 8 of the 28 cameras are permanently fixed due to their location (generally on the stadium roof). Each installation process takes up to 4 hours, with a further 2 hours required for calibration to be completed. The running and installation costs are comparable to both the Prozone and Amisco systems but with much less human operation once calibrated therefore reducing the delay on data extraction. The cost of image processing technology and fixed installation is generally much higher than using other more portal positioning systems such as GPS which are relatively inexpensive and do not require a stadium for camera positions (Libermann et al., 2002; O'Donoghue & Robinson 2009). However, having immediate feedback on player performances has many potential benefits, which would arguably out way the initial costs of installation. It is however essential that methods used for match analysis are reliable and valid (Drust et al. 2007). The validity of the Venatrack automated system therefore needs determining before it is used to determine performance changes in professional soccer players.

2.16 Limitations

At present, no fully automated valid '3D' system is currently commercially available to the soccer market that tracks live, and requires no human operator; therefore, the amount of information that is currently analysed in real-time within clubs is limited by the method of collecting the data, rather than the way in which the data is used. Information that is produced by current providers has had its validity questioned, and is based somewhat on human perception and observation where it is proposed that on average 42% of player tracking is manually verified in the case of some systems (Di Salvo et al., 2009). More research is needed to evaluate such methods of player tracking as it is essential that the data is reliable and valid if it is to be used to make important game decisions (Drust et al., 2007). Carling et al., (2008) also suggested more relevant movements should also be included in validation studies to best replicate 'in-game' player movements to ensure match play can be accuracy reported.

2.17 Recommendations for Future Research Concerning Automated Tracking Systems

From reviewing the literature to date, the following recommendations for future research regarding the use and validation of automated tracking systems can be made:

- Although validations have taken place on some of the systems available on the commercial market, no system has undergone validation across a wide range of soccer specific motion. Future validations of automated tracking systems should include walking, jogging, running and sprinting test runs as well as game specific runs to represent the demands of an automated tracking system during match play (Carling et al., 2005; MacLeod et al., 2009).
- The majority of current systems are based on human perception and observation (Franks & Miller, 1986) where it is proposed that on average 42% of player tracking is manually verified in the case of some systems (Di Salvo et al, 2009). New systems are required that enable accurate and reliable data which require limited or no human intervention in order to generate the performance data. Therefore future research should consider using automated, validated tracking systems.
- Due to the cost of fitting and supplying tracking systems within soccer stadiums and

the sensitivity of data, there are a limited number of suppliers in the English Premier League and access to the data can be difficult. Having access to teams across a season would enable a more comprehensive analysis of the soccer leagues in relation to score line effects.

2.18 Conclusions

AmiscoPRO (www.sport-universal.com) and Prozone3 (www.p3football.co.uk) revolutionized the analysis of player performance in professional football. Although these companies have now merged at present no fully automated valid '3D' system is currently commercially available to the soccer market that tracks live, and requires no human operator. Therefore, the amount of information that is currently analysed in real- time within clubs is limited by the method of collecting the data, rather than the way in which the data is used. Information that is produced 'live' during games by current providers has had its validity questioned, and is based somewhat on human perception and observation where it is proposed that on average 42 % of player tracking is manually verified in the case of some systems (Di Salvo et al., 2009) – although this is difficult to access without validation. More research is needed to evaluate such methods of player tracking as it is essential that the data is reliable and valid if it is to be used to make important game decisions (Drust et al., 2007). As Carling et al. (2008) also suggested more relevant movements should also be included in validation studies to best replicate 'in-game 'players' movements to ensure match play can be accurately reported.

Taking into consideration the recommendations of previous literature investigating both automated tracking systems and computerised notation systems for collecting player's event data this thesis aims to validate a real-time video analysis system specifically for soccer across multiple speeds and game specific movements.

2.19 Statement of Purpose

The purpose of the work in this thesis is to address three major research questions:

1. Does score line effect technical, tactical and physical performance?

2.19.1 Hypotheses to be tested to address Question 1:

- Score line (winning, drawing and losing) will influence activity profiles of soccer players.
- Score line (wining, drawing and losing) will influence activity profile of players in different playing positions.
- Score line (winning, drawing and losing) will influence technical team performance (passing accuracy).
- Score line (winning, drawing and losing) will influence tactical team performance (number of passes and passing patterns).

2. Is the score line an important factor in players' perceptions of both positive and negative momentum?

2.19.2 Hypotheses to be tested to address Question 2:

- Scoring a goal is a key trigger of positive psychological momentum.
- Conceding a goal is a key trigger of negative psychological momentum.

3. Does score line effect the technical, tactical and physical performance when, opposition ability, team ability, playing position and pitch zone are taken into consideration?

2.19.3 Hypotheses to be tested to address Question 3:

- Score line (number of goals winning or losing by) will influence the activity profiles (distance covered, high intensity distance covered and sprint distance covered) of players in different playing positions.
- Score line (number of goals winning or losing by) will influence the activity profiles of players in different pitch zones.
- Score line (number of goals winning or losing by) will influence the activity profiles of players when playing against different standard of opposition.
- Score line (number of goals winning or losing by) will influence the activity profiles of players of different abilities.
- Score line (number of goals winning or losing by) will influence the technical (passing accuracy, corner accuracy, crossing accuracy and free kick accuracy) performance of players in different playing positions.
- Score line (number of goals winning or losing by) will influence the technical performance of players in different pitch zones.
- Score line (number of goals winning or losing by) will influence the technical performance of players when playing against different standard of opposition
- Score line (number of goals winning or losing by) will influence the technical performance of players of different abilities.

2.19.4 Hypotheses to be tested to address Question 3:

- Venatrack automated tracking system is a valid method of measurement for tracking player movement and player performance during professional soccer games.

CHAPTER 3

The Effects of Score Line on the Technical and Tactical Performance of Professional Soccer Players.

3.1 Introduction

It has been shown from the literature reviewed in Chapter 2, score line has been shown to influence tactical (Taylor et al. 2008; Bloomfield et al. 2004b; Ridgewell 2011; Lago and Dellal 2010) and technical aspects of play (Taylor et al., 2008; Ridgewell 2011). This research, however, has been somewhat limited by small data sets using a single team, limiting the ability to generalise findings. This chapter aims to further the understanding of the effects of score line on technical and tactical performance in line with the model proposed in Figure 1.1 using a larger data set and considering what occurs in periods where no goals are scored.

3.1.1 Technical Effectiveness

Taylor et al (2008) took a novel approach to studying situational effects on performance. They investigated the effect of the three situational variables on a number of performance measures for a single soccer team over 40 matches. They found the number of successful passes was higher when losing than when winning, whilst shots on target decreased when the score was level and the number of successful throw-ins increased when the team was losing. As well as these individual effects, Taylor et al. (2008) found a number of interactional effects, specifically successful throw-ins decreased when trailing against stronger opposition, decreased when playing at home against stronger opponents and increased when the score was level when playing stronger opponents at home. Although Taylor et al's. (2008) study was innovative in its approach to studying interactional effects, its results are difficult to generalise as only one team was used in the analysis.

Ridgewell et al. (2011) extended some of the previous work on technical effectiveness by investigating the effect of goals scored on passing accuracy in specific areas of the pitch during the 2010 World Cup. From the 64 matches observed the study found that passing accuracy was significantly lower in the five minutes after scoring compared to the average for the half. No significant difference was found between the passing accuracy in 5 minutes before the goal was scored and the average for the half, however, the percentage of successful passes played in the attacking third was significantly greater during the 5 minutes before a goal compared to the average for the half during which the goal was scored. The percentage of successful passes showed a different pattern for the conceding teams. Ridgewell (2011) found a significant decrease in the percentage of successful passes made by the conceding team in World Cup matches in the 5 minutes before a goal was conceded compared to the average for the half and a non-significant increase in the 5 minutes after a goal was conceded compared to the average for the half. The increased passing percentage in the 5 minutes after a goal was conceded was however significant for those passes made in the middle third of the pitch compared to the average in that area for the half. It was suggested this may be attributed to possession after conceding, where the conceding team begin the five-minute period with uncontested possession because they have the re-starting kick off (Ridgewell, 2011). However, no account for tactics was considered.

3.1.2 Tactical Aspects

Previous research investigating the complex nature of soccer (James et al., 2002; Taylor et al., 2008; Ridgewell, 2011) has highlighted the need to investigate performance taking into consideration interactional effects of situational variables (e.g. match status, match location and quality of opposition). Taylor et al. (2008) incorporated this into their study by first investigating the influence of match location, quality of opposition and match status of on-the-ball behaviours in soccer. They highlighted that most ‘open-play’ behaviours were influenced by two or more situation variables, with match status having the greater effect. However, set plays (e.g., free-kicks, corners, throw-ins) were not found to vary as a function of any of the situational variables (Taylor et al., 2008). The second stage of their study investigated the effect of the three situational (match location, quality of opposition and match status) variables on a number of performance measures for a single soccer team over 40 matches. They found the number of successful passes was higher when losing than when winning, the number of throw-ins also increased when losing whereas the number of shots on target decreased when the team was drawing. Taylor et al. (2008) also found interactions between score line and opposition standard, specifically successful passes increased when leading against stronger opposition. Successful throw-ins were found to decrease when trailing against stronger opposition, decrease when playing at home against stronger opponents and increase when the score was level when playing stronger opponents at home. Although this study addressed a number of previous limitations, it was suggested that limitations in the classification of opposition standard, as strong or weak, may have lacked sensitivity to differentiate changes in behaviour influenced by quality of opposition. The failure to account for pitch locations was highlighted as a possible explanation for the absence of more situational effects, however using a single camera viewpoint when generating on the ball activities could also be limiting.

Ridgewell (2011) studied the effect of goals scored on passing in specific areas of the pitch during the 2010 World Cup. He found teams made significantly less passes after scoring compared to the average of the half in which the goal was scored. This difference was significant for all three thirds of the pitch (defending; 4.24 ± 2.52 average half 7.90 ± 5.62, middle; 13.42 ± 9.52 average half 18.16 ± 4.94, attacking; 2.56 ± 3.19, average half 4.1 ± 1.97). There was also a lower number of passes made by the scoring team in their own defending third in the 5 minutes before a goal was scored than during the half in which the goal was scored. The conceding team showed decreased passing in the 5 minutes prior to conceding a goal (21.0 ± 9.41) compared to the average for the half (24.7 ± 5.37). This difference was also significant for passes made in the defending (4.67 ± 2.54, half-average 8.49 ± 6.64) and middle thirds (13.07 ± 7.53, half-average 15.89 ± 4.14) of the pitch. Ridgewell (2011) also found that the possession time increased for the scoring team in the 5 minutes before a goal while it decreased for the conceding team. Conversely, the possession time increased for the conceding team in the 5 minutes after a goal while it decreased for the scoring team. Once a team has scored, the team are not usually aiming to score again immediately and as a result may sit back on their lead (Cornelius et al., 1997; Kerick et al., 2000; Mohr et al., 2003).

Lago, Rey, Lago-Ballesteros, Casais, & Dominquez. (2009) examined the effect of venue and score line, and found the percentage of time spent in possession of the ball increased with the percentage of time a team experienced trailing during a match. However, the study used values for the match as a whole and did not actually look at possession at the specific times when teams were experiencing different score line states. Strategy in FA Premier League soccer has also been found to be influenced by score- line. Bloomfield et al. (2004a) found that successful teams in the English FA Premiership (tops 3 teams) increased possession when ahead or behind, suggesting they try and “control” the game by dictating play. Findings also showed that there was more play in the attacking and defensive zones when the score was level. These successful teams also spent considerably more time attacking when behind suggesting their confidence to hunt down an equaliser and take control of the game might be more apparent than for a less successful team.

Jones et al. (2004) found that successful teams had significantly longer possession than unsuccessful teams irrespective of game status (winning, losing or drawing). Both teams however had longer possession when they were losing matches than when winning. The latter was reported as a strategy employed by teams to regain possession in order to score to avoid defeat (Jones et al., 2004). Lago and Martin (2007) investigated the interaction between match status and match location on ball possession duration. They found home teams had more possession when drawing than away teams and in line with Bloomfield et al's. (2004a) study teams had more possession when they were losing matches than winning or drawing. However, both Bloomfield et al. (2004a) and Lago and Martin (2007) have been criticised for not including the standard of opposition in their analysis. For this reason, Lago and Dellal (2010) expanded their work to investigate the influence of match location, match status, quality of opposition and level of team on ball possession over 380 games in the Spanish League First Division. Similar to previous studies (Bloomfield et al., 2004a; Jones et al., 2004; Lago & Martin, 2007) they found possession was greater when losing than winning or drawing. Playing away was characterised by a decrease in team possession and top placed teams reported higher percentage ball possession than less successful teams as found by previous studies (Jones et al., 2004; Lago & Martin, 2007). More recently, Paixao et al. (2015) found teams during knock out stages of the UEFA Champion's league preferentially used long passing sequences when they were losing or drawing and short passing sequences when they were winning.

3.1.3 Limitations of previous studies

Technical effectiveness in the form of passing success and possession has been considered by previous research (Bloomfield et al., 2004a; Jones et al., 2004; Lago et al., 2009), although the former has been limited to knockout competitions (Ridgewell, 2011) with small sample sizes. Accounting for normal performance has also been neglected, making it difficult to ascertain whether changes to passing accuracy or possession in relation are a function of the score line or simply the opposition's ability. The reliability of some findings has also been questioned due to the lack of objective and reliable data collection methods. Given the number of failings from previous research to consider these fundamental issues, this chapter aims to address these concerns to enable a greater understanding of the effect of score- line on player performance.

3.1.4 Rationale

The effect of score line on performance is poorly understood and although score line effects have been found in relation to changes in technical performance (O'Donoghue., 2006; 2007; Scully & O'Donoghue, 1999; Taylor et al., 2008) it is not clear whether these effects on performance are a consequence of normalised patterns of play or other factors such as motivation or momentum. It has also been suggested (Carling et al., 2005) that using smaller time periods (e.g. 5 minutes) to identify the effect of specific changes in score line (e.g. goals scored and conceded) would allow a more comprehensive understanding of the impact on performance. For this reason, passing performance was chosen due to the frequency of actions per 5 minutes compared to other technical aspects of performance (e.g. tackles, crosses, corners etc.)

This chapter aims to use clear objective definitions to investigate the effects of scoring and conceding defined as 5 minutes before and 5 minutes after a goal, on the technical (percentage of success passes) and tactical (number of passes) performance of soccer players. Specifically, the effect of scoring on both the number of passes and the accuracy of passes for both the scoring and conceding team within the English Premier League. This chapter will also build upon previous work taking into consideration normal performance behaviour and specific time periods around goals scored and conceded.

3.2 Methods

3.2.1 Data Set

In total, 285 goals scored in 120 FA Premier League matches from the 2004-2005 season were used in the current investigation. Both the percentage of successful passes (passing accuracy) and the frequency of passes in each 5 minute period were observed at team level only. Normal performance (defined as a period where no goals were scored) was established by calculating the mean average passes and pass accuracy per five minute game periods. This was then used to calculate changes in pass number and pass accuracy before and after a goal was scored. Goals scored before 5 minutes of play had elapsed and goals scored with less than 5 minutes remaining before the end of the match were excluded from the current investigation. Passing was used due to the frequency at which it occurs within a match (no other technical or tactical performance variables would enable the same level of analysis in relation to goals scored). The study was approved by the Nottingham Trent University's School of Science and Technology non-invasive Ethical Advisory Committee.

3.2.2 Data Gathering

All 120 matches were from the 2004-2005 English Premiership League and were recorded using video from a series of cameras positioned strategically around each team's stadium and analysed by three trained observers with the computerised match analysis system developed by OPTA Sportingstatz. The mean passing accuracy (measured as successful passing %) and mean number of passes made in each 5-minute period of the game were compared to the number of passes and accuracy of passing that occurred in the 5 minutes before and after a goal was scored. In total 285 goals were analysed recording both the passing variables before and after a goal was scored and conceded for both the scoring and conceding team. The definitions used can be seen in table 3.1. OPTA's system of data collection has been firmly established as valid and reliable and is consistently used by a number of high profile teams and commercial agents in soccer (Setterwell, 2003). Data for the current study were retrieved from an event query data base produced by OPTA Sportingstatz which holds data on a number of key match events for each Premiership Game (see appendix A).

Table 3.1 Operational definitions

EVENT	SECOND	THIRD	DEFINTION (Study 8a)	DEFINTION (Study 4)
PASS	SUCCESSFUL		The act of passing the ball with part of the body (other than the head) which goes to a team mate.	"the act of passing the ball with any part of the body which is received by a teammate".
	INTERCEPTED		The act of intercepting an intended pass from the opposition	"the act of passing the ball with any part of the body which is received by the opposition or goes out of play (unsuccessful)"
	OUT OF PLAY		The act of passing the ball with a part of the body (other than the head) which goes straight out of play resulting in a throw in, goal kick, corner.	
	HEADED	SUCCESSFUL	The act of heading the ball which goes to a team mate.	
	HEADED	INTECEPTION	The act of heading the ball which is intercepted by an opposition player.	
	HEADED	OUT OF PLAY	The act of heading the ball which goes out of play.	

3.2.3 Data Analysis

The current investigation analysed performances under three conditions relating to goals (the current half of the match, the 5 minutes preceding the goal and the 5 minutes following the goal – in line with suggestions from previous research (Carling et al., 2005)). The passing frequency for the given half of the match was scaled to be equivalent for 5 minutes of play. These were investigated for both the team that scored the goal and the team that conceded the goal resulting in six samples of related data for passing frequency and for the percentage of passes that were successful. Kolmogorov Smirnov tests were used to assess the distribution of both passing frequency data and the percentage of successful passes. As 5 out of 6 of the samples analysed in the current investigation (p < 0.05) were not normally distributed it was decided to apply non-parametric tests to compare the samples. A series of Spearman's correlations were used to evaluate the association between the performance indicators under various conditions. For the scoring team and conceding team a Friedman test was used to compare the two performance indicators of interest between the half of the match where the goal was scored, the 5 minutes before the goal and the 5 minutes after the goal. A p value of less than 0.05 would indicate a significant difference between these conditions and where such differences were found, Bonferroni adjusted pot hoc Wilcoxon signed ranks tests were used to compare individual pairs of conditions (p values of less than 0.017 were used to indicate significance here). The Friedman tests and Bonferroni adjusted pot hoc Wilcoxon signed ranks tests were also used to compare these conditions for different score lines at the time the goal was scored. There were 2 goals that occurred at score lines that only occurred once in the current data set; once where the score went from 4-1 to 5-1 and once where the score went from 3-2 to 4-2. These two goals were excluded from the individual score line analysis.

3.3 Results

There were no correlations between the number of passes made in the 5 minutes before a goal and the 5 minutes after a goal for the scoring team (p = 0.124) or the conceding team (p = 0.132). There were no significant correlations between the number of passes made between the scoring team and the conceding team before a goal was scored (p = 0.000) or after a goal was scored (p = -0.037). Similarly, there were no meaningful correlations between the percentage of successful passes made in the 5 minutes before a goal and the 5 minutes after a goal for the scoring team (p = 0.183) or the conceding team (p = 0.140). There were no significant correlations between the percentage of successful passes made between the scoring team and the conceding team before a goal was scored (n = -0.039) or after a goal was scored (n = 0.023). Table 3.2 shows that there were significant effects of goals on passing frequency for both the team scoring the goal and the team conceding the goal. Scoring a goal significantly related to a decrease in the percentage of passes that were successful, for the team that scored the goal (P=0.017) but not the team that conceded the goal.

Table 3.2 Passing performance (mean ± SD) in the 5 minutes before and after a goal is scored in relation to the overall half of the match where the goal was scored.

Sample /Performance Indicator	Half of match goal was scored in	5 mins before goal	5 mins after goal	Friedman test
Scoring team				
Number of passes	23.2 ± 5.2	22.5 ± 8.8	21.5 ± 11.1 ^	p < 0.001
%Successful passes	70.2 ± 7.5	72.4 ± 12.7 ^	67.3 ± 14.7 ^&	p < 0.001
Conceding team				
Number of passes	22.9 ± 4.3	19.3 ± 8.4 ^	22.1 ± 9.4 &	p < 0.001
%Successful passes	69.3 ± 6.0	67.8 ± 13.6	66.0 ± 14.0	p = 0.118

^ Bonferroni adjusted post hoc Wilcoxon signed ranks test revealed significant difference to mean for the half in which the goal was scored (p < 0.017).
& Bonferroni adjusted post hoc Wilcoxon signed ranks test revealed significant difference to the 5 minutes before the goal was scored (p < 0.017).

Table 3.3 shows that there were only two individual score lines where passing frequency was significantly affected for the scoring team (0-1 to 1-1 and 1-0 to 2-0), while there were four score lines for the conceding teams where the goal had a significant influence (0-0 to 1-0, 0-1 to 1-1, 0-2 to 1-2 and 2-1 to 3-1). Teams scoring to level the score line at 1-1 had significantly more passes in the 5 minutes before a goal was scored compared to the average 5 minutes for that half. This was in contrast to teams scoring to extend their lead to 2-0, where a significant decrease in passes was seen in the same period.

Table 3.3 Passing frequency (mean ± SD) before and after goals under different score-lines.

Score- line	Half of match goal was scored in	5 mins before goal	5 mins after goal	Friedman test
<u>Scoring Team</u>				
0-0 to 1-0 (n=119)	22.8 ± 4.7	22.2 ± 8.3	19.6 ± 8.2	p = 0.149
0-1 to 1-1 (n = 34)	24.2 ± 5.6	27.8 ± 9.9 ^	17.5 ± 8.5	p = 0.031
0-2 to 1-2 (n = 14)	23.3 ± 2.6	23.1 ± 7.3	17.4 ± 7.7	p = 0.683
1-0 to 2-0 (n = 48)	23.1 ± 4.9	21.2 ± 8.7 ^	22.1 ± 8.6	p = 0.020
1-1 to 2-1 (n = 24)	22.4 ± 5.6	19.2 ± 8.2	18.2 ± 8.2	p = 0.213
1-2 to 2-2 (n = 8)	21.3 ± 2.0	22.3 ± 7.5	15.6 ± 7.8	p = 0.206
1-3 to 2-3 (n = 2)	23.6 ± 3.1	20.0 ± 2.8	11.5 ± 6.4	p = 0.607
2-0 to 3-0 (n = 10)	25.1 ± 7.6	20.9 ± 5.5	24.7 ± 9.3	p = 0.407
2-1 to 3-1 (n = 11)	25.3 ± 8.6	22.2 ± 11.8	14.3 ± 7.0	p = 0.159
2-2 to 3-2 (n = 6)	22.0 ± 2.1	23.5 ± 12.1	16.2 ± 8.5	p = 1.000
3-0 to 4-0 (n = 3)	27.5 ± 9.0	27.3 ± 10.0	17.7 ± 5.5	p = 0.717
3-1 to 4-1 (n = 4)	24.9 ± 10.4	19.3 ± 10.0	19.3 ± 11.1	p = 0.420
<u>Conceding team</u>				
0-0 to 1-0 (n=119)	22.5 ± 4.0	21.3 ± 10.5 ^	22.4 ± 8.9 &	p = 0.038
0-1 to 1-1 (n = 34)	22.4 ± 4.4	22.3 ± 9.7	20.6 ± 8.5 ^	p = 0.041
0-2 to 1-2 (n = 14)	23.3 ± 6.5	20.7 ± 9.5 ^	21.8 ± 12.4	p = 0.022
1-0 to 2-0 (n = 48)	23.3 ± 3.9	20.4 ± 7.9	23.3 ± 8.5	p = 0.167
1-1 to 2-1 (n = 24)	23.0 ± 3.8	19.4 ± 11.1	23.4 ± 11.0	p = 0.180
1-2 to 2-2 (n = 8)	21.4 ± 2.7	17.0 ± 5.0	21.8 ± 10.4	p = 0.093
1-3 to 2-3 (n = 2)	23.2 ± 8.0	18.0 ± 12.7	10.0 ± 5.7	p = 0.13
2-0 to 3-0 (n = 10)	25.8 ± 5.4	24.9 ± 14.8	19.7 ± 9.8	p = 0.092
2-1 to 3-1 (n = 11)	24.1 ± 5.4	22.4 ± 13.1 ^	22.5 ± 11.5	p = 0.002
2-2 to 3-2 (n = 6)	22.3 ± 3.1	23.7 ± 10.4	21.8 ± 9.3	p = 0.311
3-0 to 4-0 (n = 3)	24.9 ± 8.1	32.0 ± 30.5	22.3 ± 14.6	p = 0.717
3-1 to 4-1 (n = 4)	25.7 ± 6.8	22.8 ± 24.3	27.8 ± 6.3	p = 0.174

^ Bonferroni adjusted post hoc Wilcoxon signed ranks test revealed significant difference to mean for the half in which the goal was scored ($p < 0.017$). & Bonferroni adjusted post hoc Wilcoxon signed ranks test revealed significant difference to the 5 minutes before the goal was scored ($p < 0.017$).

For the conceding teams, regardless of the score line teams played significantly less passes in the 5 minutes before they conceded compared to the average for that half. Losing the lead to bring the score level at 1-1 was related to teams significantly reducing their passes in the 5 minutes after a goal was scored compared to the average for the half.

Table 3.4 shows that goals scored by teams who were drawing (0-0 or 1-1) before they scored increased their passing accuracy in the 5 minutes before they scored and decreased in the 5 minutes after, compared to the average (for that half). Teams who conceded goals at points of the match where they had been leading 1-0 or 2-1 also exhibited a significant change in the percentage of passes that were successful. Specifically teams passing accuracy was lower in the 5 minutes before they conceded at 1-0 to 2-0 but higher from 2-1 to 3-1 compared to the average for that half.

Table 3.4 Percentage of successful passes (mean ± SD) before and after goals under different score lines.

Score- line	Half of match goal was scored in	5 mins before goal	5 mins after goal	Friedman test
Scoring Team				
0-0 to 1-0 (n=119)	69.7 ± 7.3	70.2 ± 13.8 ^	66.4 ± 13.8 ^	p = 0.047
0-1 to 1-1 (n = 34)	70.3 ± 6.9	74.9 ± 9.4	63.4 ± 13.8	p = 0.086
0-2 to 1-2 (n = 14)	69.2 ± 5.1	73.9 ± 8.2	71.6 ± 12.4	p = 0.109
1-0 to 2-0 (n = 48)	71.6 ± 7.6	72.9 ± 11.6	73.3 ±12.2	p = 0.864
1-1 to 2-1 (n = 24)	68.5 ± 7.9	73.3 ± 12.2 ^	71.3 ± 14.0 ^	p < 0.001
1-2 to 2-2 (n = 8)	66.8 ± 5.4	69.7 ± 12.1	63.1 ± 9.9	p = 0.325
1-3 to 2-3 (n = 2)	68.6 ± 2.4	79.8 ± 2.8	80.4 ± 7.6	p = 0.135
2-0 to 3-0 (n = 10)	70.5 ± 10.1	70.1 ± 17.5	71.2 ± 10.6	p = 0.905
2-1 to 3-1 (n = 11)	72.2 ± 9.6	75.8 ± 13.1	56.7 ± 13.8	p = 0.695
2-2 to 3-2 (n = 6)	69.0 ± 5.8	72.7 ± 17.3	61.5 ± 15.7	p = 0.846
3-0 to 4-0 (n = 3)	74.3 ± 10.5	82.4 ± 5.7	77.7 ± 8.0	p = 0.368
3-1 to 4-1 (n = 4)	74.4 ± 11.9	87.4 ± 7.5	72.2 ± 5.7	p = 0.368
Conceding team				
0-0 to 1-0 (n=119)	68.8 ± 6.4	67.7 ± 13.9	65.8 ± 13.6	p = 0.794
0-1 to 1-1 (n = 34)	68.1 ± 5.8	67.7 ± 13.6	62.8 ± 14.9	p = 0.239
0-2 to 1-2 (n = 14)	70.6 ± 7.8	64.3 ± 18.2	65.9 ± 15.1	p = 0.880
1-0 to 2-0 (n = 48)	70.3 ± 5.4	69.5 ± 13.1 ^	70.5 ± 11.1 ^	p = 0.016
1-1 to 2-1 (n = 24)	69.1 ± 5.3	59.1 ± 14.0	64.9 ± 14.1	p = 0.515
1-2 to 2-2 (n = 8)	66.7 ± 7.7	57.8 ± 14.0	64.3 ± 13.2	p = 0.607
1-3 to 2-3 (n = 2)	68.2 ± 11.5	66.7 ± 0.0	46.5 ± 5.0	p = 0.223
2-0 to 3-0 (n = 10)	70.7 ± 6.3	70.4 ± 18.3	60.2 ± 25.2	p = 0.146
2-1 to 3-1 (n = 11)	70.3 ± 4.0	72.7 ± 17.2 ^	66.9 ± 13.4 &	p = 0.003
2-2 to 3-2 (n = 6)	69.8 ± 2.9	67.9 ± 12.5	63.5 ± 11.8	p = 0.183
3-0 to 4-0 (n = 3)	74.6 ± 4.2	77.6 ± 14.9	76.0 ± 9.2	p = 0.717
3-1 to 4-1 (n = 4)	70.8 ± 5.7	64.2 ± 26.7	72.1 ± 5.9	p = 0.779

^ Bonferroni adjusted post hoc Wilcoxon signed ranks test revealed significant difference to mean for the half in which the goal was scored (p < 0.017).
& Bonferroni adjusted post hoc Wilcoxon signed ranks test revealed significant difference to the 5 minutes before the goal was scored (p < 0.017).

3.4 Discussion

Although research has considered the effect of score line on player behaviour in terms of strategy (Bloomfield et al., 2004a; Bradley & Noakes, 2013; Lago-Peñas & Gomez-Lopez, 2014) and work rate (O'Donoghue & Tenga, 2001; Bloomfield et al., 2004a), no research to date has considered the effect of score line on performance variables such as passing (expect within knock-out competition). The current study aimed to highlight the effect of scoring on both the number of passes made and the accuracy of passes for both the scoring and conceding teams within the English Premier League.

Scoring teams showed a higher passing success rate in the 5 minutes before scoring a goal than for the overall half of the match in which the goal was scored. However, after scoring both the number of passes made and the percentage success rate of those passes decreased compared to the average for that half of the match. One interpretation may be that once a goal is scored, the team is not aiming to score again immediately and therefore change tactics. However, the opposition may also step up their possession in an attempt to take control of the game and score (Castellano et al., 2011; Lago et al., 2010). Research (Lago, 2009; O'Donoghue & Tenga, 2001; Paul et al., 2015) suggests that teams who are winning may relax their work-rate, potentially allowing opponents back in the game. Alternatively, although losing teams may initially increase their work-rate (Castellano et al., 2011; Lago et al., 2010) to get back in the games, they may quickly lose motivation to maintain a sufficient work-rate which maybe especially true when teams play away from home. Mohr et al. (2003) found a 12% drop in performance, in the 5 minutes after a period of high intense play, suggesting that a scoring team may "sit back on their lead" once in front (rather than decrease efforts due to fatigue as previously thought). Especially, as recent research (Hewitt, Norton & Lyons, 2014; Sparks, Coetzee & Gabbett, 2016) has suggested that teams pace themselves injecting periods of sub-max or max bursts late on in matches, therefore dismissing the previous thoughts that teams fatigue towards the latter stages of the match or after intense periods. Lago-Penas & Dellal (2010) and Lago (2009) found that as teams extend their lead they tend to revert to a counterattack or direct style of play, resulting in a reduction in the number of passes in the middle third of the pitch as play is confined to the attacking and defending thirds, supporting the drop in pass number and accuracy in the current study.

The reduction in passing accuracy may be related to player's motivation. For example, Alder's (1981) theory suggests that once teams have gained positive momentum through scoring or performing well, they start to 'cruise' in an attempt to economise efforts and eventually coast when the goal has been achieved or is perceived within reach, supporting the lowest accuracy seen as teams increased their lead in the current study. Taylor et al. (2008) also found that the number of successful passes was higher when losing than when winning in their analysis of one team across 40 games. Although their case study approach allows for sensitive measures this patterns maybe not be true of all teams and warrants further investigation. There have also been numerous studies which have reported that a losing match status was associated with greater ball possession (thus suggesting greater passing accuracy) where teams on the back foot may be searching for an equalizer (Lago and Martin, 2007; Lago, 2009; Lago-Penas and Dellal, 2010).

Conceding teams were found to pass less in the five minutes before conceding a goal compared to their average for that half of the match and compared to the 5 minutes after a goal was conceded. O'Donoghue and Tenga (2001) found that players performed less high-intensity activity when losing and winning than when the score was level. The effect of conceding a goal, may be determined by the stage in the game at which the goal is conceded and the score line at the time. The results in the present study can be partially explained by the fact that trailing teams may lose motivation to maintain the high-intensity work rate, as speculated by O'Donoghue and Tenga (2001). However, they did not investigate individual score lines so their results do not explain why teams who are drawing would pass less before they concede. For this reason, a closer look at the passing frequency and accuracy was needed to further understand this effect.

When equalising after trailing 0-1, teams completed more passing in the 5 minutes before equalising compared to their average for the given half of the match; this could be explained by teams trying to push forward to create scoring opportunities. Initial research into scoring (Ali, 1988) found that plays involving a great number of passes increased the likelihood of a goal. After scoring the equalizer to make it 1-1, teams made less passes than their average for that half of match, possibly to avoid becoming exposed to opposition counter-attacks. Olsen and Larsson (1997) described how the success of counter attacks was associated with the balance of the opposition's defence once possession changed. The team conceding the goal after being 1-0 up also made less passes after the goal was scored. After losing the lead, the conceding team may be concerned with conceding again and, therefore, the reduction in the number of passes made might be a change to a defending strategy; as the ball is played into their defensive area, it may be cleared to avoid danger rather than passing the ball out of the defensive area. Regaining possession in defensive positions has also been shown to be crucial to success in soccer (Carling et al., 2005).

When teams scored a second goal to go from a 1-0 lead to a 2-0 lead they played a lower number of passes in the 5 minutes before they scored compared to their average for that half of the match. Research conducted during the 1998 and 2002 World Cups showed that the majority of goals were scored following short passing sequences and possessions lasting between 6s and 15s (Carling et al., 2005). This was also supported by data collected from the 1997 – 1998 English Premiership season (Carling et al., 2005). The short build up time before scoring suggests that English Premiership teams play a more direct attacking style (less passes), which has been suggested to lead to a higher scoring ratio (Franks, 1996). Carling and his colleagues (2005) suggested that successful teams have the ability and technical proficiency to take control over play, allowing them to maintain possession until suitable attacking opportunities arise. Being comfortable on the ball may result in players making more runs and dribbles and less passes when leading and in control of play (Grant et al., 1999; Jones et al., 2004). The teams conceding the second goal were significantly less accurate in their passing in the 5 minutes before they conceded compared to their average for their half of the match. This may suggest that the conceding teams, in their quest to score an equaliser, were adopting a direct style of play, leaving themselves open to a fast break counter attack (Armatas, Yiannakos, & Silelogou, 2007). Such fast breaks would explain the lower number of passes shown by the scoring team in the 5 minutes before they scored. Superior teams, are more in control after taking the lead and are also more likely to make less passes if they are comfortable dribbling the ball (Bate, 1988; Jones et al., 2004; Hughes & Franks, 2005a). When attacking teams are also more decisive, making short sharp moves, it often results in less passes before a shot on target (Olsen & Larsson, 1997). Jones et al. (2004) found that both successful and unsuccessful teams kept the ball for longer periods when they were losing compared to winning. This may be explained by a greater effort to regain possession by a team when losing (i.e. needing a goal to avoid defeat). They also found that successful teams had longer possession than unsuccessful teams when in winning situations.

An interesting passing profile was found when teams scored at 0-0 to take a 1-0 lead. The scoring team made more passes before they scored compared to their average for that half of the match. Rahnama et al. (2002) found that the majority of critical game incidents and the highest intensity of activities occurred in the first 15 minutes of a game. Therefore, a team’s response to the first goal may depend on the timing of that goal. Numerous studies have also shown that cognitive function and physical performance is diminished in a fatigued (Bangsbo, 2006) or dehydrated state (Fortes, Nascimento-Jùnior, Mortatti, Lima-Jùnior & Ferreira, 2018) which may lead to a decrease in decision making ability and thus a decrease in the accuracy of passing (Fortes et al., 2018). When the score went from 2-1 to 3-1 the conceding team played more passes before and fewer passes after they conceded this goal. Armatas et al. (2007) suggested that eventual losing teams push play to create scoring opportunities, often conceding further goals. Hughes and Franks (2005) found that teams who made longer passing sequences had a better chance of scoring, suggesting a slower build up style may be more appropriate to gain an equaliser. If sufficient time remains in the game, trailing by a single goal is not a desperate situation. Therefore, a direct passing style in this situation with fewer passes may not be the most productive way of gaining scoring opportunities especially given the number of studies supporting the relationship between possession length and success (Bate, 1988; Hughes, Evans, & Wells, 1988; Hook & Hughes, 2001; Jones et al., 2004). However, after conceding to go two goals down, the reduction in passes may highlight the need to score two goals and thus a more direct style of play where fewer passes and more long balls are played in the attempt to score.

Although teams included in the current study spent an equal amount of time in a winning, drawing and losing state no account for team ability was considered. Bloomfield et al. (2004a) found that successful teams in the English FA Premiership generally tried to increase possession when ahead or behind, suggesting they try and "control" the game by dictating play. Bloomfield et al. (2004a) also showed that there was more play in the attacking and defensive zones when the score was level. These successful teams also spent considerably more time attacking when behind suggesting their confidence to hunt down an equalizer and take control of the game might be more apparent than for a less successful team.

3.5 Conclusions

This study has revealed significant differences in technical player performance specifically; passing frequency and passing accuracy before and after goals are scored when compared to the average for that half. In the 5 minutes that preceded a goal, the scoring team played a significantly greater percentage of passes accurately than the average for the half, while the conceding team played significantly fewer passes. The accuracy of passing for the scoring team may have not only contributed to the scoring opportunity being created but reduced opposition possession by not losing the ball. After a goal, the scoring team made less passes and had a lower percentage of accurate passes. Score line was also found to effect individual score lines for both the scoring team (0-1 to 1-1 and 1-0 to 2-0) and conceding team (0-0 to 1-0, 0-1 to 1-1, 0-1 to 1-2 and 2-1 to 3-1). The findings support the idea that players may reduce their effort when a goal is achieved (Briki et al., 2013; Den Hartigh et al., 2014). However, to understand why players may reduce their effort, additional information such as the time of the goal, the ability of the team and the opposition ability need to be considered. Further highlighting the need to consider players perceptions and behaviours when scoring and conceding goals.

CHAPTER 4

The Effects of Score Line on the Physical Performance of Professional Soccer Players.

4.1 Introduction

The previous chapter considered the effect of goal scoring in soccer matches on the technical (passing accuracy) and tactical (passing frequency) performance of premier league players in line with the model of performance proposed in Figure 1.1. It was highlighted that the score line effected both player's, technical and tactical performance, specifically; players reduced their passing accuracy as well as their possession after a goal was scored. It was suggested that players reduced their efforts after a goal, supporting previous research (Briki et al., 2013; Den Hartigh et al., 2014; Shaw & O'Donoghue, 2004), however without considering players physical performance it is difficult to make these conclusions. The aim of the current chapter is to expand our understanding of the effects of score line (specifically match status) on the physical activity of professional soccer players, within different playing positions.

4.1.1 High Intensity Activity

There have been a number of studies that have considered the effect of score line on the work-rate (defined as either high speed activity or high intensity activity) of soccer teams. A study of FA Premier League soccer players found that players spent a greater percentage of match time performing high intensity activity when the score was level than when their team was leading or trailing (O'Donoghue & Tenga, 2001). Although effects were found, limitations in balancing the score line states (equal time winning drawing and losing) have been problematic; a team maybe in a losing state for 10 minutes and a winning state for 80 minutes. O'Donoghue and Tenga (2001) found only 3 out of 26 English FA Premier League players in their study experienced winning, losing and drawing for at least 10 minutes within the matches where they were observed. Eight other players experienced only one of the three score line states for at least 10 minutes. To try and account for this imbalance O'Donoghue and Tenga

(2001) conducted two separate analyses; one on the 11 players who were level and ahead for at least 10 minutes during the match observed and one for the 10 players who were level and behind for at least 10 minutes during the matches observed. The study found that the first group spent a significantly greater percentage of time performing high intensity activity when level than when ahead and that the second group spent a significantly greater percentage of time performing high intensity activity when level than when behind. This pattern, but with differing significance levels was also found by Clarke and O'Donoghue (2011) for English FA Premier League players and by Shaw and O'Donoghue (2004) for Irish League players. In terms of activity profiles Castellano, Blanco-Villaseñor, and Alvarez (2011) found players covered a greater distance per average half when playing at *home* (3931m versus 3887m away), when the *reference team* were losing (3975m versus 3837m drawing and 3921m winning) and when the *level of opposition* team was higher in ability (ranked in the top 6 league positions) (4032m versus 3938m (medium ranked 7^{th} – 13^{th} in the league) and 3736m (bottom ranked bottom 7 in the league).

The major criticism of these studies was the failure to consider the score line effect observed might actually be down to other factors such as player effort or match fatigue. The majority of studies have found that players spent a greater percentage of time performing high intensity activity when the score was level than when leading or trailing. As matches commence with the score being level, changes in the score line may diverge as the match progresses. Therefore, leading and trailing score lines are more likely to be experienced during the second half of a match than during the first half. As many studies have shown that work-rate is higher during the first half of matches than in the second half (Bangsbo et al., 1991; O'Donoghue, 1998; Di Salvo et al., 2009; Carling & Dupont, 2011) this is something to consider in future research. Although studies have shown that the percentage of time spent performing high intensity activity is lower during the 2^{nd} half of matches than the first, it is possible that differences may result from score line effects rather than fatigue. Especially, as more recent research has suggested that teams pace themselves injecting periods of sub-max and maximal bursts late in matches (Hewitt et al., 2016; Sparkes et al., 2016) therefore dismissing the previous notion that teams fatigue towards the latter stages of a game.

A more comprehensive study conducted by Bloomfield et al. (2004a) however found no score line effect. They compared 59 midfielders and 82 forwards from the FA English Premier League who had been observed for 15-minute periods in different score line states. Although a greater number of players were observed, different sets of players were observed when level, ahead and behind. While this had the advantage of allowing more players to be included in the study than was possible in the studies by O'Donoghue and Tenga (2001) and Shaw and O'Donoghue (2004), individual player and individual match effects may have influenced the results. In women's Gaelic football (Devlin & O'Donoghue, 1999), players were found to spend a greater percentage of match time performing high intensity activity when the score was level than when their team was winning or losing. These studies can be criticised because the methods only permitted one player to be observed per match limiting the numbers of players included. Furthermore, the methods used in these studies had limited reliability due to observer fatigue and the subjective nature of classifying movement.

4.1.2 Limitations of previous studies

The main methodological criticism of previous research into score line effect on the volume of high intensity activity performed in soccer is that any differences between score line states may be due to other situational factors. For example, a soccer match could start with the score being level at 0-0 and one team may take the lead after 30 minutes and remain in the lead for the remainder of the match. In such a match the teams are level for the first 30 minutes of the match with one team being ahead and the other team being behind for the remaining 60 minutes. Therefore, it is not clear whether the difference in work-rate observed between different score line states is due to match fatigue, opposition or other situational factors rather than score line (Bangsbo et al., 1991; Carling & Dupont, 2011; Di Salvo et al., 2009; O'Donoghue, 1998). The lower percentage of time spent performing high intensity activity in the second halves of soccer matches may be due to reduced ball-in-play time (Hughes & Barlett, 2002). There is also evidence of a reduction in 'ball in play' time over successive 15 minute periods within the first and second halves of soccer matches with differences between the first 5 minutes, the last 5 minutes and the remainder of the match (Carling & Dupont, 2011). However, it is also possible that differences in the percentage of time spent performing high intensity activity between the first and second halves of soccer matches may result from score line effects rather than fatigue. Shaw and O'Donoghue (2004) speculated that if the outcome of a match becomes obvious during the second half, player motivation might be reduced potentially leading to a reduction in effort. Therefore, to gain an understanding of score line effect on the percentage of time spent performing high intensity activity in soccer it is firstly necessary to determine the pattern of high intensity activity in 0-0 drawn matches where no score line changes occur. Secondly, matches where goals are scored can be analysed to compare the high intensity activity observed in different score line states with that performed during the equivalent periods within 0-0 drawn matches.

A secondary issue is the need for score line effect on the percentage of time spent performing high intensity activity to be investigated using a greater volume of data as well as objective and reliable methods. Semi-automatic player tracking systems are used to provide objective and reliable movement data to professional soccer clubs (Carling et al., 2008; Di Salvo et al., 2006; O'Donoghue & Robinson, 2009). These systems have also been used in academic research into soccer performance allowing large numbers of players to be observed (Di Salvo et al., 2009; Gregson et al., 2010).

A final issue with previous research into work-rate is there is currently no standard variable established for high intensity activity in time-motion studies in soccer. For example, Carling et al. (2008) listed 3 different threshold values for sprinting used in different time-motion studies in soccer. Whereas, Di Salvo et al. (2009) used different sub-ranges of speed to represent movement of different intensities. Movement was classified as walking at speeds of under 2 $m.s^{-1}$ (7.2 $km.h^{-1}$), jogging at 2-4 $m.s^{-1}$ (7.2-14.4 $km.h^{-1}$), running at 4-5.5 $m.s^{-1}$ (14.4-19.8 $km.h^{-1}$), high intensity running at 5.5-7 $m.s^{-1}$ (19.8-25.2 $km.h^{-1}$) and sprinting if at 7 $m.s^{-1}$ (25.2 $km.h^{-1}$) or faster. Abt and Lovell (2009) used the second ventilatory threshold (Beaver et al., 1986) to determine individual player thresholds for high intensity running. This indicated that the distance covered at 19.8 $km.h^{-1}$or greater (845m) under-estimated the distance covered using a threshold value based on the second ventilatory threshold (2258m). There are two further issues with using 19.8 $km.hr^{-1}$as a threshold value for high intensity running. Firstly, the energy cost of moving at a full range of speeds is elevated when a player is in possession of the ball (Reilly & Ball, 1984). Distance covered at high speed alone may underestimate energy expenditure by 6-8% (Gaudino et al., 2013; Osgnach et al., 2010; Özgünen et al., 2010) whilst not accounting for accelerations. Secondly, high intensity running does not include all high intensity movement with players performing high intensity movement in backwards and sideways movements at much lower speeds. Therefore, a lower speed threshold such as 4 $m.s^{-1}$ (14.4 $km.hr^{-1}$) might provide a better estimate of the percentage of time spent performing high intensity activity as it includes player movement on and off the ball (at high intensity).

4.1.3 Rationale

The effect of score line on performance is poorly understood and although score line effects have been found in relation to changes in high intensity activity (O'Donoghue & Tenga, 2001; Shaw & O'Donoghue 2004; Bloomfield et al., 2004a) and technical performance (Chapter 4, O'Donoghue., 2006; 2007; Scully & O'Donoghue, 1999; Taylor et al., 2008) it is not clear whether these effects on performance are a consequence of normalised fatigue or other factors such as motivation or momentum. Previously, due to the complexities of tracking player movement it has been difficult to access enough data to explore this effect in detail taking into account normalised patterns of behaviour.

This chapter aims to use innovative tracking technology to investigate the effects of score line on the physical performance of soccer players in line with the model of performance highlighted in Figure 1.1. We aim to investigate the effect of match status and goal incidents under various conditions and at both team and unit level taking into consideration normal performance (where no score is present) and specific time periods.

4.2 Methods

4.2.1 Data Set

Data from the 2007-2008 FA Premier Leagues matches were used in this study. Data were analysed at player level and by position where players were divided into forward (attacker), midfield and defending players. High speed running/activity was classified as *"the percentage of time spent moving at 4 $m.s^{-1}$ or faster"*, The specific threshold value of 4 $m.s^{-1}$ was justified because the movement included sideways and backwards movement, movement with the ball as well as forward movement (O'Donoghue & Shaw, 2004). The percentage of time spent moving at this speed (4 $m.s^{-1}$) or faster has been found (O'Donoghue &Shaw, 2004) comparable with the percentage of match time spent performing high speed running in previous time motion studies of soccer (7-8%) (Bangsbo et al., 1991; Clark, 2010; Gaudino, Iaia, Alberti, Struckwick, Atkinson & Gregson, 2013; Osgnach, Poser, Bernardini, Rinaldo & Prampero, 2010; Özgünen, Kurdock, Maughan, Zeren, Korkmaz, Yazici & Dvorak, 2010). Previous studies have avoided using higher speed thresholds due to the greater variability of time spent moving at higher speed ranges than lower speed ranges (Gregson et al., 2010). This has generally been associated with inaccuracies in the measurement systems and the inability to determine the reliability and validly of a system tracking at speeds associated with sprinting (e.g. speeds greater than 7 $m.s^{-1}$). The measurement system used in the current chapter has been shown to be valid and reliable at speeds up to 23$km.h^{-1}$ (Di salvo et al., 2006).

The criteria for a match to be included in the study (where high intensity activity was adjusted for normal running performance) was that both teams had to be level, ahead and behind for at least 15 minutes each during the match and that the Prozone3® system was installed at the stadium. In the 2007-08 season there were 5 out of 380 English FA Premier League matches that satisfied these criteria (Figure 3.1). Player performances from all 5 of these matches played in the 2007-08 season were used in the second part of the study with no team being involved in any more than one match. The criteria for including a player in the study were that the player had to be an outfield player who had been on the field for at least 15 minutes when the score was level, ahead and behind for the player's team. There were 90 players that satisfied these criteria; 36 defenders, 37 midfielders and 17 forwards. Ethical approval was granted by the Nottingham Trent University's School of Science and Technology non-invasive Ethical Advisory Committee.

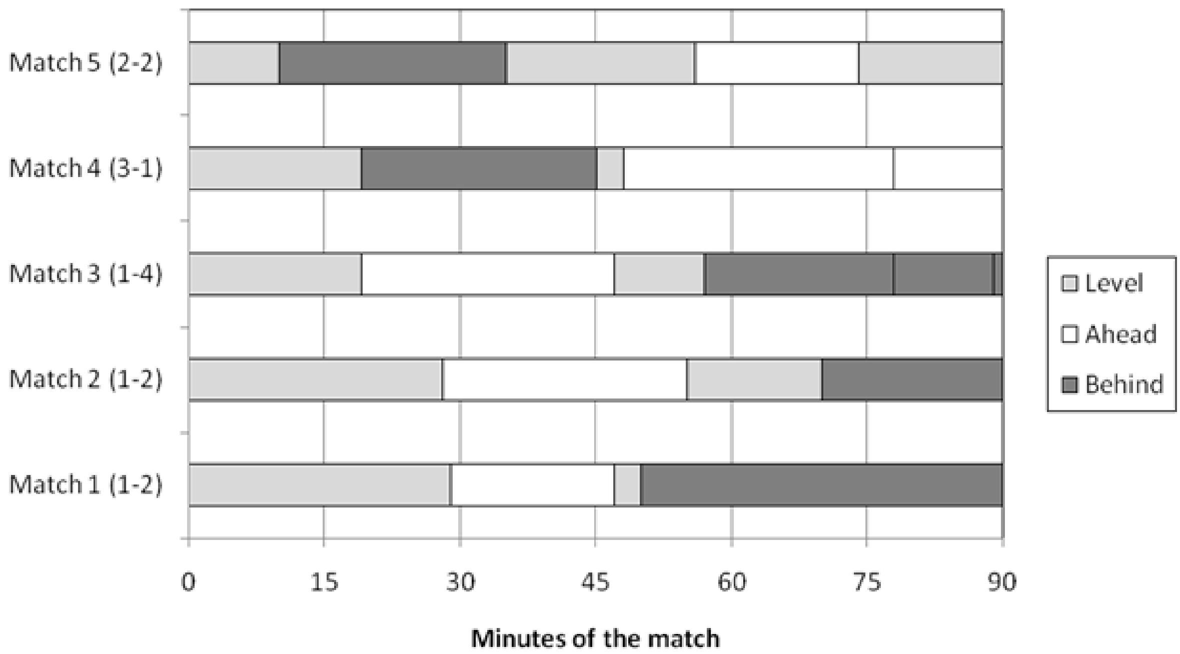

Figure 4.1 Score line state for home team within each match.

In order to establish normal work rate patterns when no score line was present the total distance covered at 4m.s^{-1} or above, for 79 outfield player performances was collected from 5 FA Premier League matches played in the 2007-08 season that ended 0-0. No individual player was included more than once in the data and all players played at least 90 minutes. Adjusted values for work rate were determined by producing an expected value for normal fatigue (TExp), using work rate values from five games that ended 0-0 for each playing position. These expected values were then subtracted from the raw data to find out how much time was spent moving at 4 m.s^{-1} or faster (TAdj) in different score line states.

4.2.2 Data Gathering

High speed activity was recorded using Prozone3®'s player tracking system with pitch location of the player having been determined every 0.1s. Data were requested from PROZONE® that fitted the criteria for game inclusion (for more details see www.sportingstatz.co.uk). Successive player locations were used to determine distance travelled every 0.1 s and speed of movement each 0.1s allowing raw data to be determined for the periods of matches that were of interest. Data from 5 games where no goals were scored were recorded to give the percentage of distanced covered at 4 $m.s^{-1}$ or above where no goals were scored (defined as a normal fatigue pattern). Distance run at 4 $m.s^{-1}$ or above, for 79 outfield player performances that fitted the required criteria, where players were ahead, level and behind for at least 15 minutes in the same game were compared to high speed running distance from the five 0-0 draws to determine the percentage of time that players of different positional roles would be expected to move at 4 $m.s^{-1}$ or faster if goals had no influence on activity profile.

Reliability of the PROZONE® system has been demonstrated with good inter- and intra-operator agreement for the distance covered at different speed ranges (Di Salvo et al., 2009). The distance and velocity data produced have also been validated against values derived from electronic timings made during a stadium test experiment (Di Salvo et al., 2006).

4.2.3 Data Analysis

The times at which each team was level, ahead and behind in each of these matches was noted and the data from the five 0-0 draws were used to determine the percentage of time that players of different positional roles would be expected to move at 4 $m.s^{-1}$ or faster if goals had no influence on work-rate, TExp (Table 4.1). For example, if a midfield player's team were ahead for the 20 minutes between the 10 and 30 minute points of a match, then the expected work-rate would be the same as the work rate during a 0-0 draw if no effect of score line occurred. The expected values for home team players who competed for the full duration of a match are shown in Table 4.2. The expected values for players of the away team were the same as those shown in Table 4.2 except the ahead and behind values were exchanged.

Table 4.1 Percentage of raw time spent moving at 4 $m.s^{-1}$ or faster during different periods of the match (mean+SD)

Period	Positional Role			
	Defenders (n=39) (%)	Midfielders (n=30) (%)	Forwards (n=10) (%)	All Players (n=79) (%)
0 – 15 mins	6.9 ± 2.5	9.0 ± 3.3	8.1 ± 3.0	8.6 ± 3.4
15 – 30 mins	5.6 ± 2.6	9.7 ± 3.3	7.8 ± 2.0	7.5 ± 3.4
30 mins – Half Time	5.8 ± 2.3	8.8 ± 3.1	7.7 ± 2.0	7.2 ± 2.9
45 – 60 mins	6.4 ± 2.5	9.9 ± 3.4	7.9 ± 2.0	8.0 ± 3.2
60 – 75 mins	5.9 ± 2.5	9.6 ± 3.4	7.1 ± 2.8	7.5 ± 3.4
75 mins – Full Time	5.8 ± 2.2	9.3 ± 2.1	6.9 ± 2.6	7.3 ± 2.7

Table 4.2 Expected percentage of time that home team players would be expected to be moving at 4 $m.s^{-1}$ or faster.

Match	Positional Role								
	Defender (%)			Midfielder (%)			Forward (%)		
	Level	Ahead	Behind	Level	Ahead	Behind	Level	Ahead	Behind
1	6.31	5.91	5.97	10.28	9.05	9.57	7.95	7.70	7.19
2	6.24	6.02	6.00	10.15	9.29	9.59	7.78	7.75	7.24
3	6.57	5.82	5.90	10.42	9.29	9.51	7.98	7.75	7.08
4	6.60	6.00	5.74	10.52	9.59	9.21	8.00	7.24	7.73
5	6.20	6.01	5.93	9.71	9.71	9.75	7.54	7.29	7.84

Kolmogorov Smirnov tests were used to assess whether the adjusted work rate data and 0-0 game data was normally distributed or not. Kolmogorov Smirnov tests revealed that during the 0-0 games, the first, third and sixth 15 minute periods were normally distributed ($p > .05$) with the second ($p = .046$), fourth ($p = .018$) and fifth 15 minute periods ($p = .032$) being positively skewed (zSkew > 1.96). Given that three of the six repeated measures were normally distributed and the desire to analyse the interaction with positional role, parametric procedures were employed. A two-way ANOVA test was applied to the 0-0 data set including 15-minute period of the match as a repeated measure measured at 6 levels and position as a between subject's effect measured at 3 levels. Where a significant effect was found, Bonferroni adjusted post hoc tests were employed to explore differences between pairs of 15 minute periods or pairs of positions. The data failed Mauchly's test of sphericity ($p = .016$) and so results only indicated significant differences where p values of less than .05 were obtained when the degrees of freedom were adjusted using the Greenhouse Geisser epsilon value of .868. Kolmogorov Smirnov tests revealed that the adjusted value was normally distributed when players' teams were level and ahead ($p > .05$) but not when their teams were behind ($p = .040$). Given that the adjusted value was normally distributed for two of the three score line states and the desire to analyse the interaction of position and score line state, parametric procedures were employed. When positional role and score line were included within a two-way ANOVA test, Mauchly's test of sphericity was satisfied ($p = .928$).

Therefore, the two-way ANOVA test was applied to adjusted high speed running distances (observed distance minus normal fatigue from 0-0 games) including score line as a repeated measure, measured at 3 levels (winning, losing, drawing) and positional role as a between subjects' effect measured at 3 levels (forwards, defenders, midfielders). Where score line or positional role had a significant influence on the adjusted work rate values ($p < 0.05$), Bonferroni adjusted post hoc tests were used to compare pairs of samples. Partial values were also determined for each of the effects. A two-way ANOVA test was applied to the 0-0 data set including 15-minute period of the match as a repeated measure measured at 6 levels and position as a between subjects' effect measured at 3 levels. Where a significant effect was found, Bonferroni adjusted post hoc tests were employed to explore differences between pairs of 15 minute periods or pairs of positions.

4.3 Results

Table 4.1 summarises the 0-0 games (T0-0) during different periods of the match by players of different positional roles. Positional role had a significant effect on T0-0 ($F(2, 76) = 25.6$, $p < .001$) with midfielders spending a greater percentage of time 4 $m.s^{-1}$ than defenders ($p < .001$) and forwards ($p = 0.019$). There was no significant difference between defenders and forwards for T0-0 ($p =0 .142$). Fifteen-minute period also had a significant effect on T0-0 ($F(4.3, 330.0) = 3.7$, $p = 0.005$) with values being higher during the first 15-minute period of the match than during the last 15 minutes of the first half ($p = 0.042$) and the last 15 minutes of the second half ($p = 0.035$). There was no other pair of 15 minute periods with significantly different values for T0-0 ($p > 0.05$). There was no significant interaction between positional role and 15 minute period on T0-0 ($F(10,380) = 0.6$, $p = 0.802$).

Figure 4.2 shows the actual percentage of time spent moving at 4 $m.s^{-1}$ or faster (TRaw) and Figure 4.3 shows the adjusted values (TAdj). Figure 4.3 shows that the midfielders in the second study had lower TRaw values than the midfielders in the first study. Figure 4.3 also shows adjusted values (TAdj) due to score line that are additional to expected values (TExp) derived from matches where no goals were scored. TAdj is therefore a relative work-rate in relation to what would be expected in a 0-0 drawn match. TAdj was neither influenced by score line ($F(2,174) = 0.8$, $p = 0.449$) nor by positional role ($F(2,87) = 1.6$, $p = 0.205$). However, the interaction between score line and positional role had a significant influence on TAdj ($F(4,174) = 3.4$, $p = 0.010$) with defender's higher values when their team was behind, while forwards had higher values when their team was ahead. The difference in the adjusted values (TAdj) when leading and trailing was -0.72+2.15% for the defenders, -0.05+2.12% for the midfielders and +1.30+1.19% for the forwards. A one-way ANOVA revealed a significant positional effect on this difference ($F(2,87) = 5.9$, $p = 0.004$) with Bonferroni adjusted post hoc tests showing that the behind-ahead difference was significantly greater for the forwards than it was for the defenders (p =0.004).

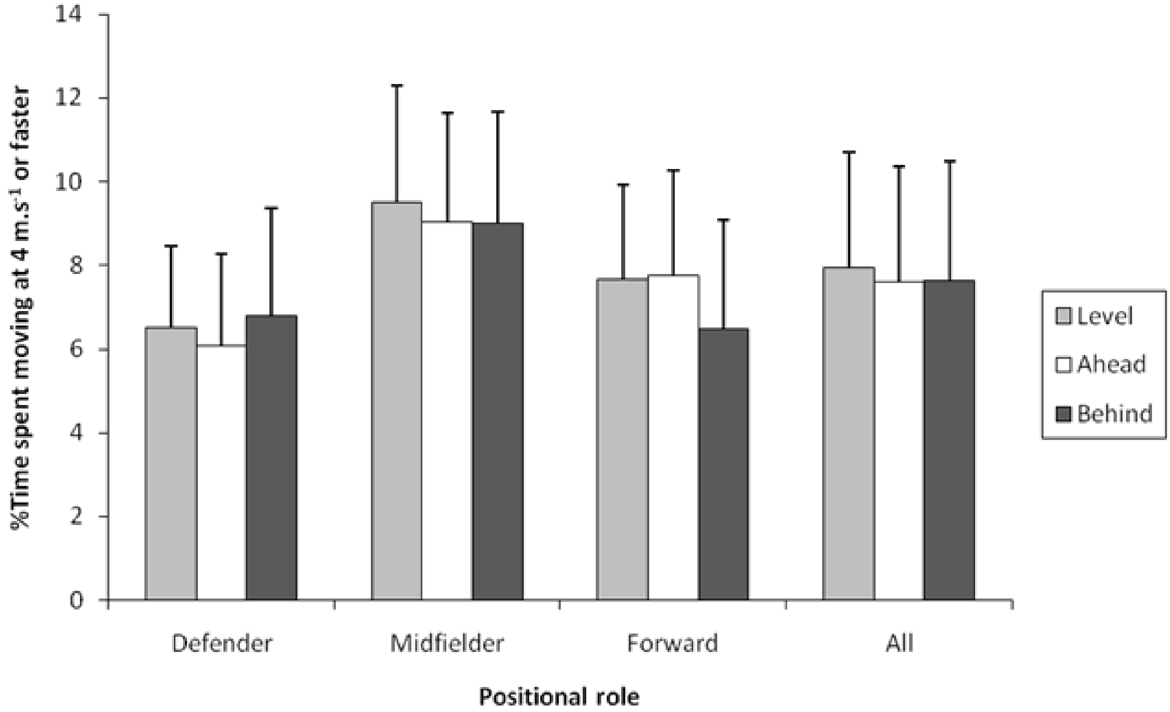

Figure 4.2 Percentage of raw time (mean ± SD) spent moving at 4.m.s^{-1} or faster in different score line states.

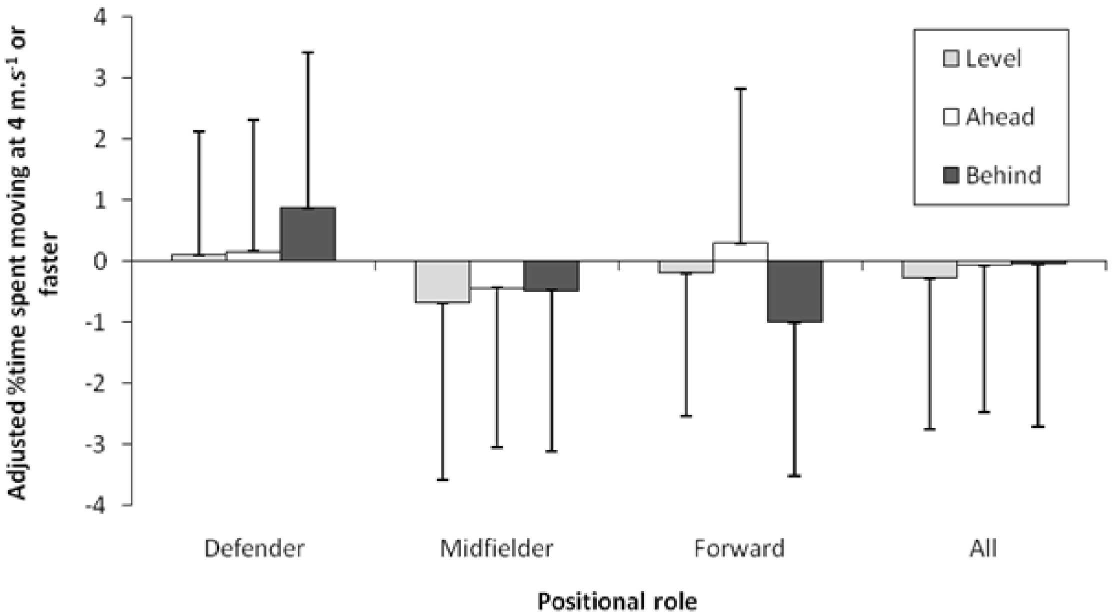

Figure 4.3 Adjusted percentage of time (mean ± SD) spent moving at 4m.s^{-1} or faster in different score line states.

4.4 Discussion

The first part of this study aimed to develop an understanding of high intensity activity in matches where no goals were scored. This allowed the second part of the study to investigate how high intensity activity changed between score line states and to see if such changes were different to the pattern observed in 0-0 draws. When adjusted for these 0-0 profiles the study found a significant interaction between player position and score-line ($p = .010$) with forwards spending a greater percentage of time moving at 4 $m.s^{-1}$ or faster when their team was leading than when level while defenders spent a greater percentage of time moving at 4 $m.s^{-1}$ or faster when their team was trailing than when level.

This discussion offers explanations for the pattern of high intensity activity observed in 0-0 draws, the need to adjust work-rate variables in score line studies, the lack of an overall score line effect when players are considered as a single group and the interactive effect of position and score line on work-rate. Some limitations of the two studies are acknowledged before practical recommendations are made and areas for future research are proposed.

4.4.1 Adjustment for pattern of high intensity activity during 0-0 draws

Previous research has found that players spent a higher percentage of time performing high intensity activity when the score was level than when their teams were ahead or behind (; Clark & ’Donoghue, 2011; O’Donoghue & Tenga, 2001; Shaw & O’Donoghue, 2004). In the first part of this study work-rate was found to be higher in the first 15 minutes of matches than during other periods. This was in agreement with a number of studies that found second half decrements in total distances covered and the percentage of time spent performing high intensity work (Barros et al., 2007; Mohr et al., 2003; Hennig & Briehle 2000; Bangsbo et al.

1991). Teams may work harder in the first 15 minutes to gain control of the game and gain positive momentum. Vallerand et al. (1988) found that many of the effects of the score configuration, and the extent of the effects experienced by the performer would be attributable to psychological momentum perceptions. Therefore, in order to gain advantage from winning the first part of the game or scoring first, it would appear important that these events or successes are attributed to one's self and not to external causes (Weiner, 1985). Although no goals were scored in the five 0-0 draws analysed in the first study, the higher work-rate values in the first 15 minutes may still be explained by the intention to take the lead as early as possible. It is, therefore, important to understand high intensity activity in different score line states, taking into account (or adjusting for) activity profiles when no goals are scored. The approach of using the performances from 0-0 draws to provide a pattern of work-rate, where the scoring of goals has not had an effect, extended the approaches used in previous score line research.

4*.4.2 Score Line*

The players in the second part of the study did not have significantly higher TRaw or TAdj values when their team was level than when behind or in front. This is in contrast to previous investigations where players were found to spend a greater percentage of time performing high intensity activity when the score was level (O'Donoghue & Tenga, 2001; Shaw & O'Donoghue, 2004; Clark & O'Donoghue, 2011). This contrast to previous research may be due to the different dependent variables used to represent high intensity activity. The lack of a score line effect is also in contrast to previous research comparing winning and losing teams within matches. Rampinini et al. (2009) observed greater distances were covered in high intensity speed ranges by losing teams in the Italian league matches. This suggests that losing teams may chase the ball and work harder to regain possession, whereas the winning teams may pass the ball around and control the game with a more possession / passing game involving less running activity (Bloomfield et al., 2004a). Di Salvo et al., (2009) also suggested that high intensity activity was higher for less successful teams.

4.4.3 Position and Score Line Interaction

The adjusted work-rate values shown in Figure 5.3 shows an interesting contrast between forwards and defenders with forwards exhibiting a higher work-rate when their team was ahead than when behind while the defenders had a higher work rate when their team was behind than when level. The forwards in the current investigation were playing in the same matches as the defenders such that when forwards' teams were leading the opposing teams' defenders were trailing (and vice versa).

One possible explanation of this interaction is through efficacy expectation (Bandura, 1977). Performance accomplishments are a source of efficacy expectation that can motivate players for subsequent competitions, similar to the concept of "success breeds success" (Iso-Ahola & Dotson, 2014). Psychological momentum has also been used to explain situations where a team builds upon successful performances, e.g., success breeds success (Hubbard, 2015). Specifically, PM involves the perception of whether success or failure is more or less likely based on recent success or failure. Research (Briki et al., 2015; Carver, 2003) has also found teams increase their efforts to overcome score deficits. This may also explain why the defenders show an increased relative work-rate when their team is behind. The defenders' work-rate is to some extent dictated by the forwards of the opposing team. Therefore, when one team is leading and their forwards are motivated to maintain a high work-rate, the other team's defenders will be required to maintain a high work-rate while their team is losing.

Although limited research has considered team momentum, Den Hartigh et al. (2014) found that exerted effort, collective efficacy and task cohesion decreased dramatically in the negative momentum scenario compared to the positive scenario. Interestingly, lagging behind at the start of the race (positive momentum scenario) did not have as much of a negative impact on task cohesion and collective efficacy as losing the lead did when being close to achieving victory (negative momentum scenario) (Den Hartigh et al., 2014).

The results of the second study partially agree with the finding of Zubillaga, Gorospel, Mendo, and Villaseñor (2007) that the losing teams cover less ground in the second half of matches compared to the first half while winning teams covered more ground in the second half compared to the first. Although the general consensus is that players spend a greater percentage of time performing high speed activity when level, than when behind or ahead (O'Donoghue & Tenga, 2001; Shaw & O'Donoghue, 2004). In support of previous research (O'Donoghue & Shaw, 2004) the current findings suggest that some players may maintain their efforts to overcome negative momentum (e.g., losing or conceding) whilst they perceive the goal to still be in reach (e.g., conceding only 1-2 goals).

Winning teams are typically in the lead for longer than losing teams and their lead would be during later stages of matches. This could increase efficacy expectation and motivation of the winning teams during the latter stages when they are leading as has already been discussed. However, the current investigation only observed such an effect for the forwards of leading teams and the opposite effect was only observed for the defenders of the trailing teams.

4.5 Limitations of the Study

There are some limitations to the normal fatigue pattern during 0-0 draws that was determined in the preliminary study. Firstly, the 79 player performances came from 5 matches where particular stoppages in play may have influenced the observed work-rates. Secondly, the method did not account for expectation, for example for a higher placed team to draw against a lower placed team, a draw may be a disappointing result; on the other hand, their opposition may see this as a good result. Therefore, work rate and motivation may well be affected as a consequence. Kerick et al. (2000) found that deviations in performance, thought to be above that of the performers' subjective norms, could have the capacity to function as a precipitating event of momentum. Therefore, a team, who are performing better than they are expecting, could gain psychological momentum and even effect the momentum of the opposing team (Kerick et al., 2000). Given the number of games that were available that resulted in 0-0 draws; variables such as this are difficult to eradicate. Movement variables during soccer are not stable characteristics of performers (O'Donoghue, 2004) and there can be greater within player variability than between player variability for distances covered using high speed movement (Gregson et al., 2010). Such variability makes it more difficult to find significant differences especially when related samples are used. Therefore, investigating such factors related to score line across much larger sample sizes, taking into consideration both player and match variability would be a valuable addition to future research.

4.6 Conclusions

This study has revealed a significant interaction between score line and positional role in relation of physical player performance. Specifically, there was a significant interaction between player position and score-line ($p = .010$) with forwards spending a greater percentage of time moving at 4 $m.s^{-1}$ or faster when their team was leading than when level while defenders spent a greater percentage of time moving at 4 $m.s^{-1}$ or faster when their team was trailing than when level. The explanations for this have been drawn from sports psychology literature but remain speculative in the absence of direct accounts from players in relation to their perceptions of momentum in different score lines. Score line may affect different players in different ways. Vallerand et al. (1988) proposed that the most important cognitive change that occurs with events that may lead to negative momentum is an individual's perceptions of control over the event or situation. Therefore, individuals who perceive that they can cope with the situation may actually not experience a reduction in performance through negative momentum (Kerick et al., 2000). Higham et al. (2005) also supported this, proposing that in football that momentum per se is not what affects performance and outcome of players, but how the players on the pitch perceive the momentum and therefore warrants further investigation in Chapter 5.

CHAPTER 5

Perceptions of Psychological Momentum in Professional Soccer Players

5.1 Background

Chapter 3 reported on the effect of score line on the technical and tactical performance and chapter 4 the physical performance of professional soccer players based on the model of performance highlighted in Chapter 1. In both chapters, performance periods where no goals were scored were compared to performances in different score lines. Score line effects were found in both studies suggesting that changes in performance could be attributed partly to psychological factors, specifically changes in momentum. Given the wealth of literature that has found scoring/performing well to elicit changes in momentum through emotional responses (Briki et al., 2013; Gernigon et al., 2010; Taylor & Demick, 1994) it is important to understand players perceptions of PM specifically in relation to key events such as socring. To further investigate this in line with the model of performance highlighted in Figure 1.1, the following chapter aims to investigate the perceptions of psychological momentum in professional soccer players using a combination of both qualitative and quantitative methods.

5.2 Introduction

There seems to be a strong belief that PM is an important determinant of success in sporting contests, even though there is both evidence for (Cornelius et al., 1997; Jones & Harwood, 2008) and against (Koehler & Conley, 2003) a positive relationship between PM and sport performance. Research suggests that perceptions of PM exist and alter in response to gaining or losing ground in a competition (i.e., scoring or conceding) (Briki, et al., 2012; Eisler & Spink, 1998; Iso-Ahola & Dotson, 2014; Moesch & Apitzsch, 2012; Perreault et al., 1998; Stanimirovic & Hanrahan, 2004) and therefore might be a possible explanation why a player's performance changes in relation to the score line. Therefore, in this study the definition of PM as a "perception that the actor is progressing towards his/her goal" (Vallerand et al., 1988, p. 94) will be used, as it considers the perception of the performer, as well as the act of scoring, the score line itself and the overall match status. All of which have been shown to be a key determinants of PM in soccer (Higham et al., 2005; Jones & Harwood, 2008).

Several conceptual models have been proposed to explain PM. The earliest was the antecedents-consequences model (AC) proposed by Vallerand et al. (1988), which was followed by the multi-dimensional model (MD) (Taylor & Demick, 1994), and the projected performance model (PP) (Cornelius et al., 1997) (see chapter 2.6.1). More recently, Gernigon et al. (2010) proposed that PM could be described as a dynamical system, where the system or team, in the case of most sporting examples does not vary as a function of one or two independent variables (e.g., triggers) but as a function of its preceding state (e.g., whether the team is in a stable or unstable state). The view is supported by qualitative research (Briki et al., 2012; Jones & Harwood, 2008) which reported a number of PM variables as both determinants and consequences of PM states. Such variables pertaining to PM have generally been classed as internal (complacency, psychological states, fatigue), environmental (scoring, dramatic actions, opponents) or social (team cohesion, staff influences, crowd influences) (Taylor & Demick, 1994) which influence performance either independently or as a complex interaction depending on the stability of the system.

Employing the dynamical systems theory, Gernigon et al. (2010) examined the influence of increasing (i.e., positive momentum) versus decreasing (i.e., negative momentum) scoring sequences on several psychological components (e.g., self-confidence, competitive anxiety, achievement goals) during observed tennis matches. Negative events were found to have a more powerful psychological impact than positive events of the same value. Both somatic and cognitive anxiety were lower in the increasing scenario than the decreasing, whereas the reverse was found for self-confidence. Previous studies have shown that moving towards (or away from) a goal has positive (or negative) consequences on emotions such as competitive anxiety and self-confidence (as well as collective efficacy) (Briki et al., 2012; Gernigon et al., 2010; Den Hartigh et al., 2014; Stanimirovic & Hanrahan, 2004).

To test the dynamical systems theory in practice, Briki et al. (2013) extended Gernigon et al.'s (2010) findings using actual cyclists (as opposed to observers) competing against each other on home trainers. Bogus feedback was given showing either an ascending performance scenario (i.e., positive momentum) or a descending performance scenario (i.e., negative momentum). Supporting the findings of Gernigon et al. (2010), the negative momentum scenario elicited an abrupt decrease in PM perceptions, whereas in the positive scenario PM perceptions increased gradually. This finding indicates that negative momentum was entered relatively rapidly compared to positive momentum and, thus, from an applied perspective it would be essential to develop strategies to overcome negative PM (e.g., conceding a goal) or create positive PM (e.g., scoring opportunities).

The most recent study to attempt to support the dynamical system theory was conducted by Den Hartigh et al. (2014) and was the first study to consider the dynamics of team momentum. Their results revealed that exerted effort, collective efficacy and task cohesion decreased dramatically in the negative momentum scenario compared to the positive scenario. Interestingly, lagging behind at the start of the race (positive momentum scenario) did not have as much of a negative impact on task cohesion and collective efficacy as losing the lead did when being close to achieving victory (negative momentum scenario) (Den Hartigh et al., 2014). This may explain why soccer teams suffer dramatic performance decreases after a score against the run of play (Higham et al., 2005).

In summary, these studies (Briki et al., 2013; Gernigon et al., 2010; Den Hartigh et al., 2014) have shown that progressing toward or away from victory causes changes in various psychological and behavioural states. However, with relatively few variables investigated and a focus on the characteristics of the PM state, this previous work provides only a brief overview of the experiences and perceptions of PM.

Crust and Nesti (2006) suggested that qualitative methods should be employed to examine individual perceptions and experiences of PM to better understand the psychological momentum phenomenology. To address this, Jones and Harwood (2008) interviewed university soccer players to investigate triggers, experiences, and potential consequences (e.g., behavioural affect) related to PM, and strategies used to control perceptions of PM within competitive soccer matches. A high level of confidence, scoring a goal, and seeing negative body language in opponents were all factors that were perceived as key triggers of positive PM, whilst negative momentum was triggered by incidents where opponents played to their strengths or maintained possession (Jones & Harwood, 2008). More recently, Briki et al. (2012) interviewed senior table tennis players and swimmers regarding their experiences of both positive and negative momentum. Although similarities in player responses between Jones and Harwood (2008) and Briki and his colleagues (2012) were found, it was highlighted that PM experiences could have been dependent on the context of the situation which can differ depending on the sport in question (Higham et al., 2005). For example, Briki et al. (2012) found that reducing effort (i.e., coasting) when winning (gaining PM) had more of an impact (increase in cognitive anxiety) on swimmers than the table tennis players interviewed. This would make sense as once a swimmer takes a lead there is an expectation of future success as, unlike table tennis, a swimmer cannot stay still and let opponents catch up. It would appear that some sports may have greater demands in some areas than others (e.g., physical versus psychological), and although some PM experiences are standard (e.g., self-confidence) others may be reflective of the sport and age group being analysed.

Qualitative methods were also used by Moesch and Apitzsch (2012) who interviewed handball coaches about their perceptions of PM. Coaches reported that they perceived positive

PM to be associated with joy, happiness, and pride in their athletes and negative PM with anxiety and stress, which is similar to players' perceptions in the previous studies. Confidence (or lack of) was also a major factor perceived to lead to continued positive performance (or negative performance) and increased (or decreased) effort in their players. Unlike the findings of both Jones and Harwood (2008) and Briki et al. (2012) coaches in Moesch and Apitzsch's (2012) study perceived that players' opponents had a large impact on their players, influencing both positive and negative PM. These contrasting findings may be explained by the nature of the coaches interviewed. All coaches interviewed by Moesch and Apitzsch (2012) were females, suggesting that males and females may perceive PM differently (e.g. females are more affected by the ability of opponents than males) and therefore should be considered when investigating PM perceptions.

Although there is no single best method for investigating PM, manipulating perceived progress toward or away from a goal to simulate positive or negative PM may lack ecological validity, as progress is not based on actual performance. Lab-based studies are also limited with regards to the depth of information reported about positive and negative PM scenarios. As an alternative, qualitative methods are useful for exploring experiences of negative and positive PM in more depth; however, such methods have generally relied on small sample sizes. The purpose of the current study was to investigate professional male soccer players' experiences of psychological momentum in relation to key events using a mixed methodological approach. Due to the depth of information available from qualitative methods, interviews focused on both the triggers and characteristics of PM as well as strategies used to gain positive PM and overcome negative PM. It was proposed that if both methods produced similar results, the quantitative methods may provide coaches with a more proximal (e.g., closer to the game) way of collecting PM data to help understand how players respond to different situations.

5.3 Method

5.3.1 Data Set/Participants

Professional male soccer players, with at least two years of experience in a professional academy, were recruited to participate in interviews and focus groups and/or subsequent completion of a questionnaire to assess perceptions of PM. Consistent with previous researchers (e.g., Ford & Williams, 2012), athletes were considered professional if they held a professional contract with their club. Ten English U18 League One academy players (six defenders, three midfield players, and one striker) were recruited for interviews, focus groups, and completion of the questionnaire (M_{age}= 17.10 years, *SD* = 0.56 years). Four additional teams from professional English Soccer Leagues were recruited to complete the questionnaire only (*N* = 65), resulting in a total of 75 respondents (across all positions) for the questionnaire data (M_{age}= 22.8 years, *SD* = 3.12 years).

Prior to data collection, participant information sheets were distributed, and individuals were briefed about the research purpose, data confidentiality, and their right to withdraw. Informed consent was obtained for adult players as described in appendix B, and for U18 athletes was obtained both through their club contracts and via an opt-out consent from each player's respective parent or guardian (see appendix C). Ethical approval for the study was granted by Nottingham Trent University's School of Business, Law, and Social Sciences Ethics Committee.

5.3.2 Data Gathering

Players' perceptions of psychological momentum (PM) were generated in two ways (via player interviews and via a PM questionnaire). For the players completing both an interview and questionnaire (N=10), data was collected over 4 weeks to allow two-week gaps between the first and second interviews, and again between the second interview and questionnaire completion. The questionnaire data for those completing only the questionnaire (n = 65) was collected immediately after a specified match with each team, whereby dates were agreed with each club's coach, and questionnaires were administered during the respective clubs' feedback sessions to minimise conferring between participants. The PM measure (see appendix D) was administered by either the Head of Performance Analysis from each respective club, or one of the key coaching team who had been initially involved in the development of the measure. Individual semi-structured interviews, with an identical set of questions asked in a similar manner (Hanton, Fletcher, & Coughlan, 2005) were conducted first to investigate players' perceptions and experiences of PM in soccer.

Interviews included main questions to initiate conversation, and probe questions to encourage elaboration (e.g., asking for specific examples where these situations had occurred in matches). Focus groups were conducted two weeks after completion of initial interviews, with a convenience sub-sample of players in groups of two to four, follow-up questions were used as a means to further explore emergent themes and to clarify, summarise, and ensure the interviewer accurately interpreted the responses. The process facilitated exploration of identified themes and relevant issues and ensured fluent discussion and richness of the data (Patton, 2002). A full copy of the interview guide can be seen in Appendix E.

Questionnaires (N = 75), were administered two weeks after the completion of focus groups during the respective clubs' feedback sessions. The quantitative measure allowed data to be collected within 48 hours of the match being played, with the potential to reduce memory decay that could occur if data collection were delayed. The PM measure (further discussed below) was administered by either the Head of Performance Analysis from each respective club, or one of the key coaching team who had been involved in the development of the measure. Administration guidelines were provided to ensure consistency across teams and to ensure players completed the questionnaire without conferring with teammates. Due to club confidentiality issues, responses were recorded only according to position type and club.

5.3.3 Instrumentation: Interviews and focus groups.

The individual interview questions were adapted from Jones and Harwood's (2008) interview guide which, after clarifying PM, asked players about their general experiences and perceptions of PM (e.g., triggers and characteristics of PM as well as strategies used to gain or overcome PM). Interviews included three types of question: main questions, probe questions and follow-up questions. Main questions were used to initiate conversation and probe questions were used to encourage elaboration (e.g. asking for specific examples where these situations had occurred in matches). Using Patton's (2002) recommendations for conducting interviews, the use of clarification, elaboration, and general probes was essential for expanding on issues raised by participants. Interviews were recorded using a digital voice recorder (SONY ICD-BX140) and then transcribed verbatim. Each interviews included 39 questions and lasted on average 26 minutes (*SD* = 3 min) and ranged from 20 – 35 minutes.

Focus groups (*N* = 2) were used to encourage further discussion amongst peers and to clarify themes that had previously emerged from individual interviews. They lasted on average 18 minutes (*SD* = 2 min) and ranged from 14 to 23 minutes. No formal guide was used as participants were prompted to expand on themes emerging from the initial interviews (Sparkes, 2000). For example, players were asked to highlight specific situations that had been recalled in the first interviews and asked for elaboration and/or clarification on these themes. Interviews and focus groups, respectively, were concluded once data saturation was reached (i.e., no new information was being provided by interviewees in relation to the focus of the study) in line with recommendations of previous researchers (e.g., Jones, Hanton, & Connaughton, 2002). Member checking was used to ensure robustness of the data, whereby each participant was given a copy of their transcribed interview and asked to confirm its accuracy (Jones et al., 2002). The process was conducted to allow for identified themes and relevant issues to be explored, and to ensure fluent discussion and richness of the data (Patton, 2002). A full copy of the interview guide can be seen in Appendix E.

5.3.4 Instrumentation: Psychological momentum measure

Due to the timing of the access granted, the new PM measure was developed using the "raw themes" (*N* = 61) generated from previous interviews conducted regarding players' perceptions of PM in soccer (Jones & Harwood, 2008). These modifications were guided in part, by way of discussion and feedback from coaches, athletes, and relevant experts (e.g. football managers with 15 years' experience; academics in the field with over 20 years' applied experience). Modifications were made as follows: (1) re-wording of items (e.g., "positive attitude" was changed to "you have a positive attitude"); (2) clarification of items (e.g., including bracketed examples at the end of items as for "use of time (e.g., slowing down or speeding up the game)"); and (3) deletion of items (e.g., questions related to team strategies or team performance). The resulting 49 items comprised of four sub-scales including; triggers of positive PM (*N* = 14); triggers of negative PM *(N* = 14); strategies to maintain positive PM (*N* = 15) and strategies to overcome negative PM (*N* = 6). As with previous measures used to assess athletes' experiences and behaviours (Lonsdale, Hodge, & Rose, 2008), players used a Likert scale ranging from 1 (not a lot) to 7 (very much so) to rate the extent that the item applied to their own experiences. Players were encouraged to be open and honest in their responses.

5.3.5 Data analysis: Qualitative

Interview and focus group data were manually analysed using a combination of inductive and deductive approaches (see Patton, 2002). The previously identified four dimensions; experiences of positive PM, which included both triggers and characteristics, experiences of negative PM, which included both triggers and characteristics, strategies to gain or maintain positive momentum, and strategies to overcome negative momentum were used to guide the deductive analysis process, but there was flexibility for discovering new factors, themes, and/or dimensions from the current investigation. For inductive analysis, the primary investigator read and re-read 40 pages of transcribed verbatim individual interviews and four pages of focus group interview data several times to ensure familiarity and promote accuracy of data interpretation. Given that focus groups did not yield additional themes and, instead, provided clarification and useful insight to previous discussions with interviewees, qualitative data analysis was derived from the content of individual interviews ($N = 10$) only.

Based on principles of inductive qualitative analysis as identified by Patton (2002), themes were categorised using a four-stage process: (a) Raw data were systematically extracted from transcriptions. (b) Raw data were then clustered into units according to similarity of meaning. (c) First order themes were then established through further systematic organisation of broader, overarching concepts. (d) Finally, higher order themes were ultimately positioned by common factors according to the four previously-specified dimensions. Although the current study yielded more first order and higher order themes compared to findings of Jones and Harwood (2008), no new dimensions were identified.

5.3.6 Trustworthiness of data analysis

One of the co-authors, who was both familiar with PM research and experienced in qualitative data analysis, was presented with 25% of the transcribed data and the entirety of the extracted raw data, first order themes, and higher order themes for the purpose of verification. Similar to the process used by Mellalieu, Neil, Hanton, and Fletcher (2009), the second researcher acted as "devil's advocate" to read and re-read the findings and to discuss the initial analysis conducted by the principal researcher. For each stage of analysis, feedback from the second researcher informed discussions with the primary researcher, and revisions were made accordingly. The two authors met regularly during the analysis to check coding decisions and to check the emerging higher order themes.

The reliability of the coding process was assessed in line with the methods used by Briki et al. (2012). Agreement rating [(number of same findings)/(number of same findings + number of divergent findings)] was calculated resulting in agreement ratings of 86.9%, 85% and 87.5% for raw themes, 1st order themes and higher order themes, respectively. Reliability for all three inter-coder agreements were above the minimal percentage of 70% as recommended by Van Someren, Barnard, and Sandleberg (1994).

5.3.7 Data analysis: Quantitative

A series of five Chi-square tests of independence were performed to assess differences between responses to the 49 questions both individually and for the set of questions as a whole. Alpha was set at $p < .05$ for all statistical tests. In line with recommendations of Fallowfield, Hale, and Wilkinson (2005) for two of the four dimensions (triggers of positive PM and strategies to overcome negative momentum), frequency data for the first two points (1 and 2) of the 7-point Likert scale were combined when performing Chi-square tests to ensure that the data satisfied the assumption of an expected frequency of at least 5.0 in at least 80% of the cells.

5.4 Results: Qualitative Analysis

Inductive content analysis yielded a total of 848 raw data extracts from the verbatim transcriptions across the four dimensions of PM (players' experiences of positive PM (N = 300); experiences of negative momentum (N = 193); players' strategies for maintaining positive momentum (N = 108); strategies to overcome negative momentum (N = 247)). These were then categorised into first order (N = 58) and, in turn, higher order (N = 24) themes according to the four above specified dimensions. When reporting the interview data, higher order themes are listed at the beginning of each section in descending order (based on frequency totals in parentheses; see Figures 5.1 & 5.2), followed by key first order themes, and finally their respective supporting quotes (coded as P1, P2…P10 throughout) in order to contextualise the depth and finer detail of this research.

5.4.1 Experiences of Positive Psychological Momentum

Players revealed several factors (higher order themes) associated with experiences of positive PM, including *performance factors, external influences, confidence, general feelings and emotions, group factors,* and *recognise the need for PM* (Figure 5.1). When considering performance factors, all players interviewed associated experiences of positive momentum with scoring a goal; for example, a player explained that, "If the team has just scored, they feel a lot more confident and positive, especially when they see their opponents' heads go down" (P10).

Within the higher order themes of general feelings and emotions and confidence, the first order themes of positive feelings and confidence were highly salient features for the players, as evidenced by their prevalence and the depth of discussion by players. For example, players noted, "When you have momentum you feel confident, you are positive and your whole attitude changes. You want to score and it's likely" (P8), and, "when it's going

1st order themes	Higher order themes	Dimension
External Influence Coach/ Manager/Captain (19) Crowd (12) Opponents (12) Referee (7) Encouragement (25)	External Influences (75)	Players Experiences of Positive PM (300)
Recognise the need for PM (2)	Recognise the need for PM (2)	
Effort (10) Starting the game (10) Scoring (42) Individual performance (20)	Performance Factors (82)	
Positive feelings (51) No pressure calm (3)	General Feelings & Emotions (54)	
Upper hand (10) Confidence (35) Positive body language/attitude (19)	Confidence (64)	
Group efficacy (6) Teamwork (11) Group performance (6)	Group Factors (23)	
Body language (24) Feelings and emotions (61)	Psychological Aspects of PM (85)	Players Experiences of Negative PM (193)
Negative group performance (8) Negativity within team (23)	Group Experiences of Negative PM (31)	
Facilitates performance (20)	Positive Effects on Performance (20)	
Crowd Effects (3) Opponent Effects (5) Referee (3) Conceding (2)	External Influences (13)	
Loss of Confidence (18) Ability (7)	Confidence Issues (25)	
Debilitates Performance (12) Effort (7)	Negative Effects on Performance (19)	

Figure 5.1: Inductive Analysis: Players Experiences of PM (*N*=10)

our way and we are on top, we feel good, we feel more confident and composed on the ball – lots of positive thoughts" (P4).

5.4.2 Experiences of Negative Psychological Momentum

The perception of negative PM was associated with a number of interesting factors, categorised under the following higher order themes; *psychological aspects of negative PM, group experiences of negative PM, confidence issues, negative effects on performance, external influences*, and *positive effects on performance* (Figure 5.1). Similar to positive experiences of PM, within the psychological aspects higher order theme, feelings and emotions and body language were both first order themes that were highly salient features for the interviewed players. Specifically, players frequently reported visible changes in their body language (and confidence) when they conceded a goal with 'heads going down (when you concede)' the most frequently reported raw data extract. In addition, there was a wide range of feelings and emotions that players associated with experiences of negative momentum such as feeling under pressure, and being worried, nervous, and angry. For example, one player recalled, "[When you perceive momentum is against you,] head goes down, 50/50, [you feel] frustrated, angry, feel fatigued and under pressure" (P9).

Within group experiences of negative PM, players commonly referred to their negative interactions with other teammates when they perceived that momentum was not on their side; for example*;* "[When momentum is against us, the] communication goes out the window, negative comments like shouting at each other arguing, like everyone is against you blaming you" (P4).

5.4.3 Strategies for Building and Maintaining Psychological Momentum

Strategies used to maintain and develop positive PM included *tactical, technical, and individual strategies, being better prepared,* and *teamwork* (Figure 5.2). More so than the other three dimensions, this area provided a wide range of raw data relative to its first order themes, suggesting that players use a variety of strategies to maintain and develop positive PM. Various technical and tactical related factors (e.g., keeping possession of the ball and making more passes) and use of psychological skills (e.g., maintaining concentration and focus) were highly prevalent in comparison to other factors or strategies, and overall elicited a far greater depth of discussion in the individual interviews.

With regard to psychological skills, keeping focused and maintaining concentration were reported as strategies used frequently by players especially after scoring; for example, a player noted:

> I feel [that] especially after we score, we need to be focused, because as everyone knows this is the time when you are most vulnerable as people tend to switch off (P1).

5.4.4 Strategies for Overcoming Negative Psychological Momentum

Players revealed several strategies used to overcome negative momentum, including *keeping a positive attitude, external influences, technical strategies, increasing effort, tactical strategies, performance strategies*, and *working as a team* (Figure 5.2). Within the higher order themes of keeping a positive attitude and external influences, the first order themes of staying positive and keeping going, and encouragement from teammates and coaches were highly salient features for the players. For example, players frequently noted, the importance of looking and feeling optimistic, "[When you start to lose momentum] keep your head up, keep tracking back, be more positive" (P9).

1st order themes	Higher order themes	Dimension
Tactical Objective (14) Tactical Strategy (General) (5) Tactical Strategy (Individual) (13) Tactical Choice (15)	Tactical Strategies (47)	Strategies Used to Maintain/Gain Positive PM (108)
Technical Choice (22) Technical Objective (7)	Technical Strategies (29)	
Psychological Skills Mind-Set (14) Increasing Effort (Individually) (6)	Individual Strategies (20)	
Teamwork (3)	Teamwork (3)	
Fitness (5) Preparation (4)	Being Better Prepared (9)	
Staying Positive (39) Don't let it get to you (9) Just keep going (26)	Keeping a Positive Attitude (74)	Strategies Used To Overcome Negative PM (247)
Opponents (11) Crowd (7) Encouragement (33)	External Influences (51)	
Teamwork (22)	Working as a Team (22)	
Effort (26)	Increasing Effort (26)	
Tactical Objective (6) Opponents (tactical) (6) Controlling Pace (13)	Tactical Strategies (25)	
Technical Choice (13) Technical Objective (14)	Technical Strategies (27)	
Psychological Skills (15) First Chances (2) Performance (positive) (5)	Performance Strategies (22)	

Figure 5.2: Inductive Analysis: Strategies Used to Maintain/Gain/Overcome PM (*N*=10)

With regard to encouragement, players noted, “[You’re always] telling them 'keep head up', keep on going, don't give up, you got him, and keep putting 100% in” (P6). In terms of keeping going, a number of players reported it was important to “Keep doing what you can” (P7) in order to overcome negative momentum.

5.5 Results: Quantitative Analysis

The PM measure was completed by 75 participants. Descriptive statistics from their responses are presented in Tables 5.1 and 5.2. Chi-square results highlight differences within each of the four dimensions when analysed individually (triggers of positive momentum χ^2 (65, N = 75) = 449.0, p < .001), triggers of negative momentum χ^2 (78, N = 75) = 376.5, p < .001, strategies used to maintain positive momentum χ^2 (78, N = 75) = 445.7, p < .001, and strategies used to overcome negative momentum χ^2 (25, N = 75) = 44.72, p < .001), and also for the set of 49 questions as a whole χ^2 (228, N = 75) = 1440.64, p < .001). Thus, differences were found between the distribution of responses across both individual questions and the four specified dimensions (e.g., some statements/dimensions apply to the 75 players more than others).

Table 5.1 Questionnaire Responses for Players' Experiences of PM (*N*=75)

Experience of positive PM	Question	1	2	3	4	5	6	7	Mean	SD	Median	Mode	Rank
You or your team score a goal	6	0	0	0	3	5	18	49	6.51	0.79	7	7	1
You feel confidence	4	0	0	0	1	11	26	37	6.32	0.77	6	7	2
The team feels cohesion/united	13	1	0	3	10	18	21	22	5.60	1.27	6	7	3
You have a positive attitude	14	0	1	3	10	17	24	20	5.60	1.21	6	6	3
Opponents make mistakes	3	3	4	1	5	18	25	18	5.41	1.56	6	6	5
Opponents weaknesses are highlighted	2	0	3	5	10	20	16	21	5.39	1.40	5	7	6
You see negative body language from opponents	1	0	2	6	12	20	18	17	5.29	1.34	5	5	7
You receive encouragement from coach	10	0	2	4	16	24	23	6	5.07	1.14	5	5	8
You receive encouragement from teammates	9	0	1	10	17	27	17	3	4.77	1.11	5	5	9
Good luck/fortune	5	5	8	7	19	15	14	7	4.35	1.68	4	4	10
Referees decisions going your way	7	3	5	11	24	19	11	2	4.23	1.35	4	4	11
Previous experiences/achievements	8	8	11	6	12	17	16	5	4.16	1.82	5	5	12
You receive encouragement from crowd	11	8	14	14	14	14	9	2	3.63	1.64	4	2,3,4,5	13
You receive encouragement from captain	12	8	16	13	17	14	6	1	3.47	1.54	4	4	14

Experience of negative PM	Question	1	2	3	4	5	6	7	Mean	SD	Median	Mode	Rank
You or your team concede a goal	20	0	0	0	1	18	24	32	6.16	0.84	6	7	1
Lack of perceived ability	25	1	2	4	5	19	27	17	5.51	1.33	6	6	2
Feeling nervous and/or anxious	24	2	2	4	13	15	24	15	5.25	1.46	6	6	3
When you feel fatigue	26	1	3	5	12	21	18	15	5.17	1.43	5	5	4
Loss of concentration	23	2	1	6	16	17	21	12	5.08	1.42	5	6	5
Bad luck/fortune	19	1	8	5	13	21	17	10	4.81	1.54	5	5	6
Uncontrollable response of opponent	18	1	3	11	19	18	11	12	4.75	1.47	5	4	7
Bad Refereeing decisions	21	1	6	7	19	16	20	6	4.69	1.44	5	6	8
Feelings that members of team are being complacent	22	1	3	12	18	21	15	5	4.60	1.34	5	5	9
When you feel under pressure	28	4	7	10	16	18	10	10	4.43	1.68	5	5	10
Negative criticism	27	4	8	9	22	13	17	2	4.21	1.53	4	4	11
Playing opponents of a higher ability	15	8	8	11	17	10	13	8	4.12	1.83	4	4	12
Opponents strengths are highlighted	16	18	14	14	16	9	4	0	2.95	1.53	3	1	13
Opponents reputation	17	17	15	22	13	5	3	0	2.77	1.37	3	3	14

Note. Table is arranged by descending mean scores according to each dimension.

Table 5.2 Questionnaire Reponses for Players' Experiences of PM – Strategies (*N*=75)

Strategies to maintain/create positive PM	**Question**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Mean**	**SD**	**Median**	**Mod**	**Rank**
Maintaining concentration	38	0	0	1	4	15	20	35	6.12	1.00	6	7	1
Physical preparation (training preparation)	33	0	0	2	3	14	28	28	6.03	0.99	6	6,7	2
Preparation	30	0	3	1	5	19	23	24	5.73	1.24	6	7	3
Maximising effort	39	0	1	2	8	22	22	20	5.63	1.15	6	5,6	4
Retaining possession	41	0	2	4	12	20	22	15	5.35	1.27	5	6	5
Targeting opponent's weaknesses	43	0	3	4	15	13	22	18	5.35	1.39	6	6	5
Giving encouragement to team mates	42	3	4	4	7	18	18	21	5.28	1.66	6	7	7
Controlling pace	40	1	2	9	19	15	20	9	4.88	1.39	5	6	8
Relaxation	31	4	3	7	15	20	16	10	4.76	1.58	5	5	9
Use of time (slowing down/speeding up the game)	35	3	5	8	15	16	17	11	4.75	1.63	5	6	10
Goal setting	29	7	8	6	19	16	12	7	4.24	1.74	4	4	11
Changing tactics	34	1	7	8	15	17	10	7	4.04	1.86	4	5	12
Going back to basics	36	1	11	1	12	10	6	5	3.31	1.89	3	1	13
Using confidence building strategies	37	1	17	7	15	6	8	5	3.27	1.91	3	1,2	14
Trigger words (which help to stay focused,	32	2	20	9	11	4	5	3	2.73	1.75	2	1	15

Strategies to overcome negative PM	**Question**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Mean**	**SD**	**Median**	**Mode**	**Rank**
Changing tactics	44	0	0	5	13	19	21	17	5.43	1.21	6	6	1
Encouraging team mates	49	2	3	5	13	16	16	20	5.21	1.58	5	7	2
Frustrating opponents	46	2	5	7	14	15	19	13	4.92	1.60	5	6	3
Managing pressure	47	5	3	8	10	15	23	11	4.87	1.70	5	6	4
Controlling pace	45	0	5	7	20	17	20	6	4.77	1.34	5	4,5	5
Managing anxiety	48	8	8	1	12	9	16	10	4.25	1.92	4	6	6

Note. Table is arranged by descending mean scores according to each dimension.

5.6 Discussion

The purpose of the current chapter was to investigate professional soccer players' experiences (triggers, characteristics and strategies) of psychological momentum (PM) using a mixed methodological approach. As the majority of experimental studies have not focused on the different kinds of triggers and strategies of PM, the questionnaire aimed to provide further insight into this aspect of PM. A number of the experiences reported were highlighted by players in their interviews as both triggers and effects of PM. For this reason, unlike previous models (Taylor & Demick, 1994; Vallerand et al., 1988) which have separated these experiences, the current study reports on players' experiences combined with a focus on triggers of PM, specifically those that were consistent across both methods. Strategies highlighted as important to either maintaining/creating positive PM or overcoming negative PM are discussed separately due to variation across players.

The act of scoring or conceding a goal yielded the highest average scores from players' questionnaire responses for positive and negative PM. This is in agreement with previous research that has highlighted the importance of goal scoring (Gernigon et al., 2010; Higham et al., 2005; Jones & Harwood, 2008) and positive score configuration (Briki et al., 2013; Stanimirovic & Hanrahan, 2004; Vallerand et al., 1988) in relation to PM experiences. Scoring a goal was also reported most frequently within the performance factors higher order theme by players interviewed. Indeed, all players interviewed referred to goal scoring as a factor related to positive PM, reporting that a positive PM state would often result in progression toward a goal/scoring and that progressing toward a goal/scoring also triggered positive PM. With regards to negative PM, body language - specifically when athletes described their heads going down after conceding a goal - accounted for 12.4% of all raw data extracts in player interviews. Although goal scoring was highlighted by Jones and Harwood (2008) as a trigger of positive PM, it is difficult to establish the strength of its importance as the authors, unlike the current study, provided no details with regard to the number of respondents who reported each theme.

Feeling confident was also an important factor related to positive PM and was reported second-most frequently across player interviews as both a trigger and characteristic of positive PM, and this also yielded the second highest questionnaire average score. Jones and Harwood (2008) found confidence to be the most frequently cited trigger of PM in their interviews with soccer players. A number of other studies have also found self-confidence to increase in positive PM scenerios and decrease when participants experience negative PM (Briki, Den Hartigh, Bakker, & Gernigon, 2012; Den Hartigh et al., 2014). Both Briki, Den Hartigh, Hauw, and Gernigon (2012) and Gernigon et al. (2010) found that progressing toward (or away from) a desired outcome (e.g., victory or defeat) increased (decreased) self-confidence. This further supports the prominent findings regarding scoring in the current study, especially as having a lack of ability was reported as the second highest average score related to negative PM on the PM measure.

Although confidence was an important aspect of positive PM in the current study, its importance was proceeded by goal scoring, unlike previous studies which have found self-confidence (Jones & Harwood, 2008) and opponent ability (Moesch & Apitzsch, 2012) to be the most salient factor relating to PM experiences. It is plausible to suggest that the prescence of self-confidence in the current study may facilitate the development of PM but also that a positive PM scenerio may enhance self-efficacy at the same time - especially as teams progress toward their goal. Recently Den Hartigh, Van Geert, Van Yperen, Cox, and Gernigon (2016) demonstrated that athletes who enter a match with relatively high levels of self-efficacy were better able to maintain their levels of self-efficacy, PM perception, and efforts whilst in a negative PM scenerio. It is possible that the experienced players recruited in the current study may be better able to moderate PM perceptions compared to the less experienced athletes interviewed by Jones and Harwood (2008).

It would seem that confidence, experience, and belief in one's ability are key factors affecting how PM is perceived, and from a practical perspective, should be developed through positive reinforcement and mastery during training sessions (Vallerand & Reid, 1984). The use of confidence-building strategies, however, was reported as one of the least popular strategies for maintaining positive PM in the player measure, giving further support for the notion that players at this level may have a lower need to build confidence as they already have a high level of perceived ability. Maintaining concentration was the highest reported strategy for maintaining PM; therefore, it may be more advisable for coaches to channel energy into strategies that focus attention on creating positive PM.

Supporting previous studies (Jones & Harwood, 2008; Moesch & Apitzsch, 2012), results from the current study indicate that having a positive attitude was one of the highest reported experiences of positive PM in the player questionnaires, and it was frequently cited in player interviews. Interestingly, although feeling anxious/nervous was reported as one of the highest experiences of negative PM, managing anxiety as a strategy was the lowest reported item on the measure with regard to strategies to overcome negative PM. It would appear that although increases in competitive anxiety are related to negative PM and decreases to positive PM (Briki, Den Hartigh, Bakker, & Gernigon, 2012; Gernigon et al., 2010), there may be a number of factors that interact in order for either positive or negative PM to evolve. This provides further support for Gernigon et al.'s (2010) suggestion that PM manifests itself as a series of complex interactions that create changes in behaviour. It may therefore be more appropriate for coaches to focus on strategies that maximise the chances of success (e.g., adequate preparation, which was reported one of the highest strategies by the PM measure and a positive attitude) as a way to perhaps mediate unfavourable scenarios.

Although research often indicates the detrimental effects of negative PM on performance (Stanimirovic & Hanranhan, 2004; Taylor & Demick, 1994), the findings from this study show that players may perceive negative PM as facilitative for performance. Notably, this was also found by Perreault et al. (1998) who concluded that losing and experiencing negative momentum did not necessarily result in a decrease in performance. The latter findings, in particular, support the concept of negative facilitation (Cornelius et al., 1997; Stanimirovic & Hanrahan, 2004), whereby performers work harder when they perceive that they are behind. More recently however, studies have found that although athletes may increase their efforts when experiencing negative momentum, this gradually decreases once they are convinced they will lose (e.g., after a period of resisting negative PM) (Briki, Den Hartigh, Hauw, & Gernigon, 2012; Briki et al., 2013). This could explain why some studies have found that performers increase their efforts immediately after conceding in the hope of scoring on the counterattack (Ridgewell, 2011).

For maintaining positive PM, athletes' questionnaire responses indicated the most frequently reported strategy was maintaining concentration which was also reported by players interviewed. Being prepared was also reported as an important strategy for creating positive momentum, with physical preparation (training preparation) and preparation representing the second and third highest mean scores from the questionnaire, respectively. Similarly, Jones and Harwood (2008) reported that feeling prepared put players in a more positive frame of mind and helped them to gain momentum and develop a positive attitude, which has already been established as key to positive PM experiences. Coaches interviewed by Moesch and Apitzsch (2012) considered being well-prepared to be a concentration enhancing strategy that could also be used during matches to build PM or refocus. It is important, therefore, that coaches understand the importance of perceived preparation -

especially as these two factors were also the most frequently reported strategies in the current study to maintain positive PM.

Changing tactics was the highest reported strategy from the questionnaires for overcoming negative PM with tactical and technical strategies featuring frequently in player interviews. Interestingly, controlling the game by keeping possession has been shown as a key attribute of successful soccer teams (Jones, James, & Mellalieu, 2004) and was a key strategy reported by players interviewed by Jones and Harwood (2008) for overcoming negative PM. Chapter 3 found that teams increased their passing accuracy in the 5 minutes prior to scoring, yet reduced their passing accuracy after scoring. The opposite pattern was found for conceding teams. Although no account of team ability or opposition was made, the increase/decrease in passing accuracy and passing number suggest that teams changed their tactics in line with the changing score line. Therefore players and coaches should practice changing tactics to overturn the balance of momentum (if in a negative PM state) in training matches, as the change itself maybe more important than any particular tactic enforced (Higham et al., 2005).

Coaches and managers need to be aware of not only what triggers the momentum changes, but also when momentum may be changing. They need to recognise when the flow may be starting to go against them and make the necessary changes to avoid this happening (e.g., change tactics or make a change to the line-up through a substitution or play). For example, in volleyball, Salitsky (1995) observed that following a time-out, the opposition with positive psychological momentum reduced the number of points scored. Having possession (e.g., feeling superior/in control) may act as a similar strategy and allow a team to re-configure after a period of negative momentum or a drop in performance (Higham et al., 2005). Knowing when momentum is most likely to change (and what causes it to change) could have implications on how coaches and players employ strategies to create positive and overcome negative PM.

In terms of external strategies, athletes frequently reported encouragement, specifically from teammates, as a valuable strategy used to overcome negative PM. Similarly, on the questionnaire, encouragement from teammates yielded the second highest average score within this dimension. Den Hartigh et al. (2014) found team cohesion increased alongside collective-efficacy when teams experienced positive PM, but decreased with negative PM. It is possible that teams who have a strong sense of unity and support are able to use such encouragement to foster a positive outlook to overcome negative PM or produce positive momentum (Vallerand et al., 1988). Facilitating positive group dynamics within team training sessions where negative momentum is experienced may also be a useful way to help players create team strategies to cope with such situations, especially as teams who are cohesive and confident are more likely to remain united in the face of failure and vice versa (Stanimirovic & Hanrahan, 2004). Coaches have also reported not sticking to one's role and not taking responsibility as key actions for the onset of negative PM (Moesch & Apitzsch, 2012). Ensuring team goals and roles are set out clearly and with measurable targets may be one strategy for coaches to adopt to ensure teams remain on target and focused on the desired outcome.

In conclusion Chapter 5 has helped to justify the inclusion of a psychological component in the study of score line (Figure 1.1) by highlighting the perceived importance of scoring and conceding on the development toward a positive performance outcome (PM in the case of this study). The use of both quantitative and qualitative methods also gives options to coaches, managers and practitioners to collect data on players PM perceptions in different ways in order to establish and help develop key experiences and strategies for different players.

CHAPTER 6

Validation of a real-time video analysis system for soccer

6.1 Background

The previous three chapters have found score line or the act of scoring or conceding a goal to have an important effect on the technical, physical and psychological performance of professional soccer players. In order to establish to what extend score line effects are related to each of these three components of performance further situational factors must be considered which have been suggested as mediators of performance (e.g., previous relationships between score line and performance maybe a function of the opposition ability, the match location, the time goals are scored etc.). In order to include numerous factors such as team ability, opposition ability, pitch location and playing position large volumes of data are required. The volume of accurate data that can be obtained from automatic player tracking systems allows such research due to the reduction in time and the accuracy of collecting data. The following chapter aims to assess the validity of an automated multiple cameras system to track soccer player's movement in real-time using a range of soccer specific runs.

6.2 Introduction

Soccer is a high-intensity intermittent sport, which provides unique challenges for the players and sports scientist alike with regards to tracking performance changes from match to match (Gregson et al., 2010). Being able to identify the physiological demands of players during games has enabled coaches to adapt training and recovery strategies accordingly, to ensure maximum performance and preparation (Carling et al., 2009; Drust, Atkinson & Reilly 2007). There have been a number of studies that have investigated the activity profiles of soccer players (Rampinini et al., 2009; Reilly 1976) in an attempt to understand the demands placed upon them during matches.

Methods used to analyse player movement have progressed rapidly from manual notation systems (Reilly, 1976) to human operated computer based systems (O'Donoghue & Tenga, 2001) and more recently automatic player tracking with limited need for human interaction (Di Salvo et al., 2006; Di Salvo et al., 2009; Gamble, Young & O'Donoghue, 2007; O'Donoghue & Robinson, 2009). Such video-based time motion analysis has been applied widely in the soccer world (Bangsbo et al., 1991; Krustrup et al., 2003; Mohr et al., 2003; Reilly., 1976) and such analyses have provided evidence that the distance covered at high intensity depends on playing position, standard of competition, physical capacity of the players and physical performance of the opponent (Krustrup et al., 2003; Mohr et al., 2003; Rampinini et al., 2007a).

Over the past 15 years the influx of computer based technology has allowed new methods of assessing movement in soccer; such as multiple camera methods (Di Salvo et al, 2007, Rampinini et al., 2007a, Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2007b), global positioning systems (GPS); (Coutts & Duffield, 2010; Edgecomb & Norton, 2006; Kirkendall et al., 2004) and systems using microprocessor technology (Frenken et al., 2010). More recently the introduction of fully automated tracking systems with no human operator input has allowed live tracking to be demonstrated during games by companies such as TRACAB (Carling et al., 2009). Such physical performance data related to the activity profile of players has become so sophisticated that performance analysts can now retrieve data corresponding to specific speed zones to evaluate the performance of various players. Data relating to the activity profile of players can give indications of training effects (Reilly & Williams, 2003), injury (Rahnama et al., 2002) and fatigue (Bangsbo, et al., 1991).

Companies such as Prozone (Leeds, UK), Amisco (Nice, France), TRACAB (Stockholm, Sweden) and Verusco (Palmerston, New Zealand), have all provided systems to the commercial market which allow tracking data to be collected and used for post-match analysis. Computer based coding systems have also been available for live analysis and half time review such as Focus (Elite Sports Analysis, Fife, Scotland) and Sportscode (SportsTec, Warriewood, Australia). Although validations have taken place on some of the systems available on the market, no system has undergone validation across a wide range of soccer specific motion. Therefore, no gold standard test in soccer has been found (O'Donoghue & Robinson, 2009). This has generally been attributed to the unpredictable nature and variability in the sport (O'Donoghue, 2004; Randers, Mujika, Hewitt, Santisteban, et al., 2010) and the lack of agreement about the speed ranges to be used to represent different classes of movement such as walking, jogging, running and sprinting (Carling et al., 2005). A study by Randers and colleagues (Randers et al., 2010) found significant differences between various time motion analysis systems with regards to distances covered at various speeds. Total distance covered ranged from 10.83 ± 0.77km (semi-automatic multiple camera system) to 9.51 ± 0.74km (video based time motion analysis system) and high intensity running distances ranged from 2.65 ± 0.53km (semi-automatic multiple camera system) to 1.61 ± 0.37km. The large differences between systems, further supports the need for validation data to be available for all systems on the market to allow direct comparisons to take place.

At present no fully automated '3D' system is currently commercially available to the soccer market that tracks live, and requires no human operator, therefore, the amount of information that is currently analysed in real-time within clubs is limited by the method collecting the data, rather than the way in which the data is used. Information that is produced "live" during games by current providers has had its validity questioned, and is based somewhat on human perception and observation where it is proposed that on average 42% of player tracking is manually verified in the case of some systems (Di Salvo et al., 2009). It is essential that methods used for match analysis are reliable and valid (Drust et al., 2007). Therefore, the aim of the present study was to assess the validity and reliability of a fully automated multiple camera system to track soccer players' movement in real-time, using a range of soccer specific runs.

6.3 Methods

6.3.1 Participants/Data Set

Eighteen male recreationally active soccer players (mean age ± SD, 27 ± 8.6 years) volunteered for the study. All participants were members of a Premiership soccer team's staff and were required to be physically active and have a good level of soccer skill. All participants were given test schedules and schematic diagrams of each test prior to testing to allow for familiarisation and to reduce the amount of practise time needed on the day. All tests were conducted on the same day, over an 8 hour period.

6.3.2 Data Gathering

Previous soccer validation studies together with suggestions from previous motion analysis research in soccer were used as the basis to the movement patterns determined as key movements to test the tracking system (Di Salvo et al., 2006; Di Salvo et al., 2009). Using this information, a series of test runs were developed that required participants to perform a variety of soccer-related movements these included a straight shuttle run (60m; Test 1) at various pre-defined speeds (7 $km \cdot h^{-1}$, 11 $km \cdot h^{-1}$, 14 $km \cdot h^{-1}$, 19 $km \cdot h^{-1}$and 23 $km \cdot h^{-1}$) and curved shuttle run (50m with a 45 degree curve at 30m; Test 2) at the same target speeds (Figure 6.1). These targets were chosen as they are seen to represent the classification speed thresholds (slow jog, jog, run, high speed run and sprint) used in both previous related validity (Di Salvo et al., 2006) and player movement studies (Bangsbo et al., 1991). Players were also asked to perform an acceleration shuttle (15m jog followed by a 15m sprint; Test 3), a dribble shuttle (30m dribble with a standard size 5 soccer ball ; Test 4), and a right angled turn (10m straight followed by a 90 degree turn either left or right followed by 10m straight; Test 5).

As well as these standard runs; used in the validation of previous soccer specific tracking systems (Di Salvo et al., 2006) game specific runs were added to represent the demands of an automated tracking system during match play as suggested by previous validation studies in other invasion games (Carling et al., 2005; MacLeod et al., 2009). These runs included a T-Test (80m; Test 6), a ZigZag shuttle (60m in and out of cones 10m apart; Test 7) and a Distance Run (8-12 half laps of the pitch; Test 8). See Figure 6.1 for details of the layout of each run.

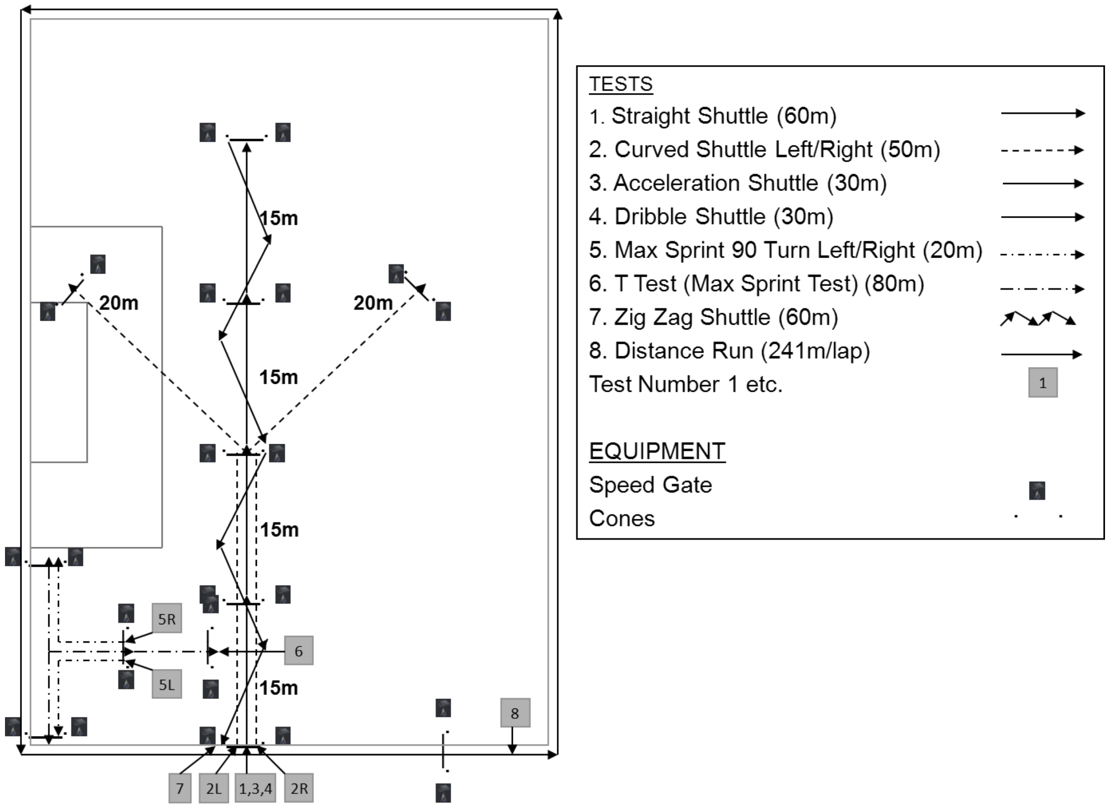

Figure 6.1 Schematic of all test runs performed.

Participants were given details of each of the tests including the speeds at which they need to be completed. Times were also provided and feedback (time recorded) was given after each run so participants could judge their speed correctly.

6.3.3 Instrumentation

Each test was manually measured using a tape measure (30m RST Fibreglass Long Tape, Rollins, UK) and a Theodolite (Nikon NPL 362, Japan) using known co-ordinates on the pitch. Each test was set out using flat and straight markers to indicate a mid-test timing point, the test layout and where change of speed were required by participants. A lazer square (Bosch GTL3 Tile Lazer, Germany) was used to make sure adjacent markers were parallel. Timing gates (Brower Timing, USA) were used to record the time taken to complete each of the test runs and to measure mid-test times. All timing gates were positioned and aligned at approximately waist height (fixed at 1 meter – in line with previous research (MacLeod, Morris, Nevill, & Sunderland, 2009)) to ensure consistency between the time measurement point for both the timing gates and the system (the system measures at waist point).

6.3.4 Automated Tracking System

The Visual-AI (Venatrack, UK) technology used to track the players allowed the players to be monitored in real time (at 25 Hz) providing identification through recognition algorithms (based on x,y,z coordinates for hands, feet, head and the pelvis & shoulder lines; Venatrack, UK). The video capture was performed at Etihad Stadium, Manchester, where 28 HD colour cameras (model and manufacturer withheld by company) were installed.

The twenty-eight HD cameras were used to ensure maximum positional accuracy (visual acuity) was provided to the computer algorithm. By using a greater number of cameras a greater number of pixels with which to quantify the pitch area and thus provide a greater accuracy for measuring each point were achieved. The estimated visual acuity for the current system was in the range 5 – 25mm compared to previous systems which have been estimated at between 500mm – 1500m depending on the region of the pitch (Di Salvo et al., 2006). The cameras position, orientation and field of vision were determined and fixed using a Theodolite (Nikon NPL 362, Japan) during installation.

The cameras were positioned to give a full view of the pitch using the systems unique configuration co-ordinates (unique to each ground), which allowed each position on the pitch to be covered by at least five cameras at any one time (Venatrack Ltd, UK). Calibration of the automatic tracking system was completed by a team of technical experts who have collectively over eighteen years of experience of visual AI technology, such as that used by the system in question.

6.3.5 Data Analysis

Criterion validity was assessed using the Bland and Altman 95% limits of agreement (Bland & Altman, 1986). The data were tested for heteroscedasticity by plotting a figure of absolute difference against the mean and computing the correlation (Atkinson & Nevill, 1998). To assess the validity of the speed measurements recorded during each of the tests, mean difference, typical error, Pearson product-moment correlation and coefficient of variation were all calculated using a specific spread sheet (Hopkins, 2000). Paired *t*-tests were used to compare speed recorded by the timing gates with that derived from the automated tracking system in order to detect large systematic bias (Atkinson & Nevill, 1998). For the Bland and Altman analysis 391 data points were included, which incorporated all the runs from all the tests for the 18 players. All data were reported as the mean ±SD unless otherwise stated. Statistical significance was set at $P<0.05$.

6.4 Results

In total 391 runs were performed and tracked by the automated tracking system. Mean recorded speeds from the timing gates and from the automated tracking system are shown in Table 6.1. The speeds ranged from 6.03 $km \cdot h^{-1}$to 29.03 $km \cdot h^{-1}$. For all the tests combined (n=391) the mean timing gate speed was 15.2±5.4 $km \cdot h^{-1}$ and the mean speed for the automated tracking system was 15.4±5.5 $km \cdot h^{-1}$. Figure 6.2 shows a mean difference and 95% limits of agreement of 0.25±0.64 $km \cdot h^{-1}$. Table 6.1 provides a summary of validity for the different speed measurements made for all the tests combined and for each test separately including individual speeds for the straight shuttle.

The correlation (r) for the mean speed recorded by the timing gates and the automated tracking system was ≥0.99 for all the tests except test 5, the 20 m sprint with 90^{o} turn. Although tests 5a (left) and 5b (right) showed a good correlation between the mean speed recorded by the automated tracking system and the speed gates (r = 0.80 and r = 0.72 respectively) some errors occurred during the calibration of these tests due to speed gate positioning effecting validity.

Table 6.1 Validity for the speed measurements recorded by both the speed gates and the automated tracking system during the 10 difference tests.

Test No.	**Test Description**	**No. of Runs**	**Actual Speed Timing Gate** (km. h^{-1})	**Speed System** (km. h^{-1})	**Mean Difference (Limits of Agreement)** (km. h^{-1})	**Pearson Correlation Coefficient** (*r*)	**Typical Error as a CV (%)**	**TTest (p)**
1	Straight Shuttle	68	14.7 ± 6.2	15.0 ± 6.4	-0.26 (0.47)	1.00	0.5	0.81
1	Straight Shuttle (7 km. h^{-1})	12	7.9 ± 0.8	8.0 ± 0.8	-0.07 (0.08)	1.00	0.4	0.83
1	Straight Shuttle (11 km. h^{-1})	13	10.0 ± 0.9	10.1 ± 0.9	-0.11 (0.04)	1.00	0.2	0.76
1	Straight Shuttle (14 km. h^{-1})	11	13.1 ± 1.1	13.3 ± 1.2	-0.17 (0.13)	1.00	0.4	0.73
1	Straight Shuttle (19 km. h^{-1})	14	17.0 ± 1.1	17.2 ± 1.1	-0.27 (0.19)	1.00	0.6	0.5
1	Straight Shuttle (Max speed)	14	24.9 ± 2.0	25.6 ± 2.1	-0.64 (0.47)	0.99 (0.98-1.00)	0.9	0.41
2	Curved Shuttle Left	74	14.2 ± 5.7	14.4 ± 5.8	-0.22 (0.41)	1.00	1.3	0.82
2	Curved Shuttle Right	79	15.0 ± 6.3	15.4 ± 6.5	-0.32 (0.50)	1.00	0.7	0.76
3	Acceleration Shuttle	25	14.6 ± 1.7	15.2 ± 1.8	-0.61 (0.35)	1.00	1	0.22
4	Dribble	28	9.1 ± 1.4	9.30 ± 1.4	-0.18 (0.22)	1.00	1.3	0.64
5	20m Sprint (90 degree turn left)	26	17.4 ± 0.8	17.7 ± 1.0	-0.30 (1.18)	0.80 (0.60-0.91)	2.8	0.24
5	20m Sprint (90 degree turn right)	27	18.3 ± 0.6	18.1 ± 0.7	0.22 (0.94)	0.72 (0.47-0.86)	2.5	0.22
6	T Test (Max Sprint Test)	16	16.5 ± 0.6	16.6 ± 0.6	-0.11 (0.16)	0.99 (0.97-1.00)	0.5	0.62
7	Zig Zag shuttle	33	20.8 ± 3.4	21.2 ± 3.5	-0.50 (0.45)	1.00	1	0.59
8	Perimeter Run	15 sets	11.3 ± 1.1	11.3 ± 1.1	-0.04 (0.02)	1.00	0.1	0.93
ALL	All Tests (Excluding 5)	338	14.8 ± 5.7	15.1 ± 5.8	-0.28 (0.49)	1.00	1.2	0.52
ALL	All Tests	391	15.2 ± 5.4	15.4 ± 5.5	-0.25 (0.64)	1.00	1.8	0.52

For all the tests combined excluding test 5a and 5b (n=338) the mean timing gate speed was 14.7 ± 5.7 km·h^{-1} and the mean speed for the automated tracking system was 15.0 ± 5.8 km·h^{-1}. Figure 6.3 shows a mean difference and 95% limits of agreement of -0.28 ± 0.49 km·h^{-1}. The *t*-test for the mean speed recorded by the automated tracking system and the timing gates during the tests showed no significant difference with *p* values ranging from 0.22 to 0.93. The data was heteroscedastic.

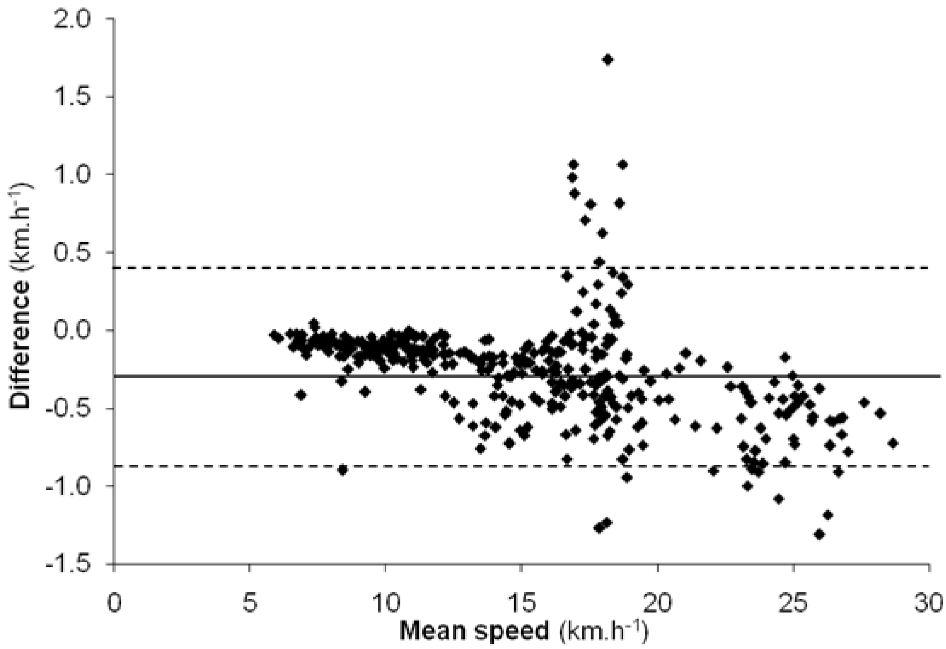

Figure 6.2 Bland-Altman plot for all speeds (n=391; mean difference ± limits of agreement: -0.25 ± 0.64 km·h^{-1}).

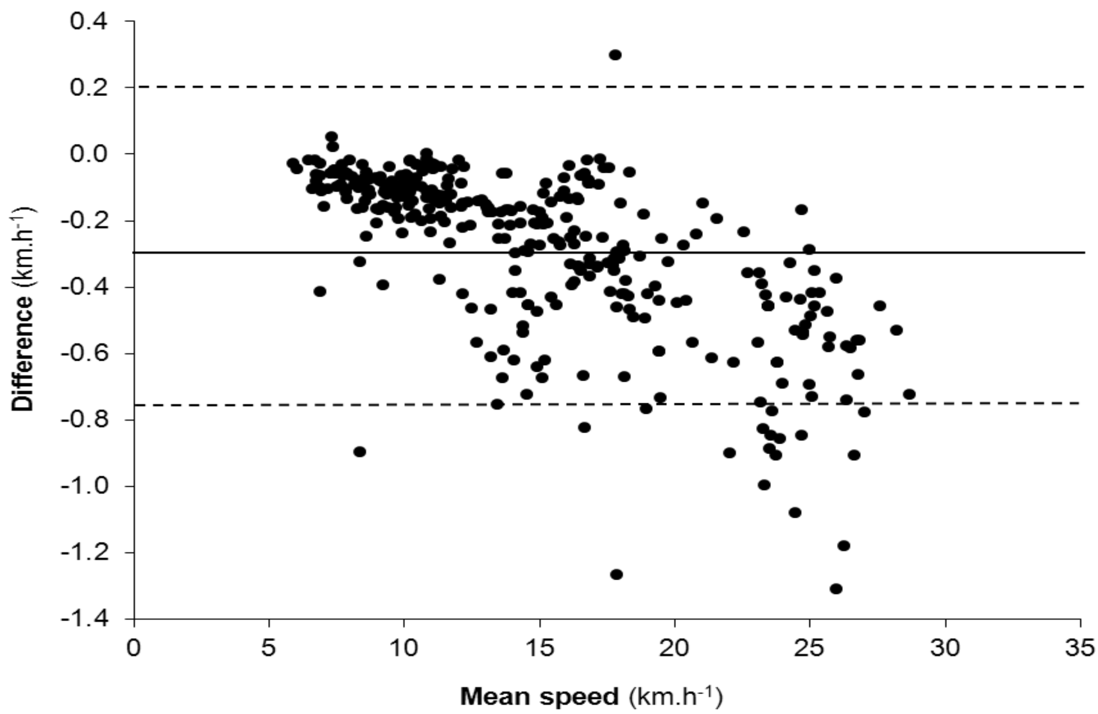

Figure 6.3 Bland-Altman plot for all speeds, excluding test 5 (n=338; mean difference ± limits of agreement: -0.28 ± 0.49 km·h^{-1}).

Both test 1 and test 2 were conducted over a range of speeds, specifically in test 1 speeds ranged from 6.92 to 28.67 km·h^{-1}and 5.88 to 28.22 km·h^{-1} in test 2. For all speed ranges combined in test 1 (n=68) the mean timing gate speed was 14.7 ± 6.2 km·h^{-1} and the mean speed for the automated tracking system was 15.0 ± 6.4 km·h^{-1}. Figure 6.4 shows a mean difference and 95% limits of agreement of -0.26 ± 0.47 km·h^{-1}. In test 2 (n=153) the mean timing gate speed was 14.6 ± 6.0 km·h^{-1} and the mean speed for the automated tracking system was 14.9 ± 6.1 km·h^{-1} across all speed ranges from both the left and right tests combined. Figure 6.5 shows a mean difference and 95% limits of agreement of -0.27 ± 0.47 km·h^{-1}.

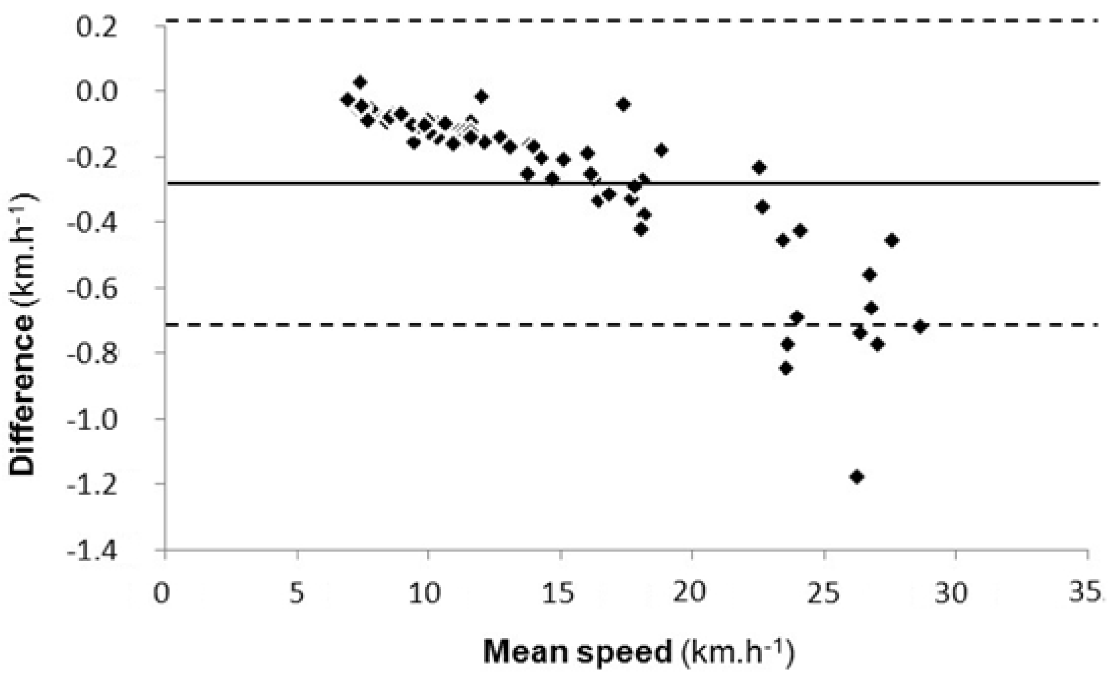

Figure 6.4 Bland-Altman plot for all speeds in Test 1, (n=68; mean difference ± limits of agreement: -0.26 ± 0.47 km·h^{-1}.

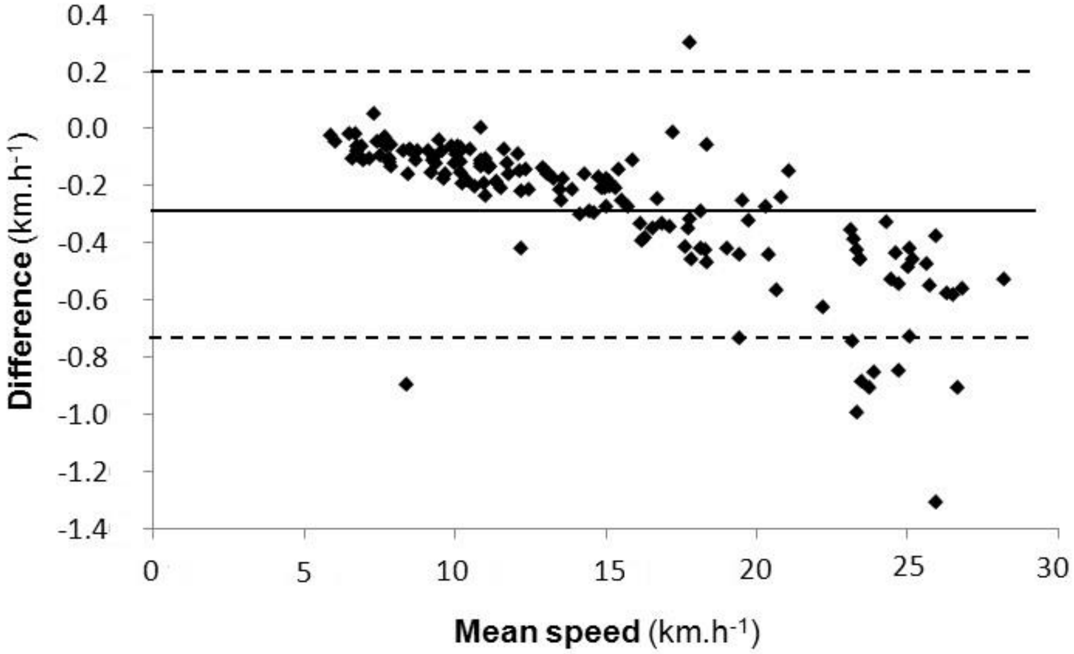

Figure 6.5 Bland-Altman plot for all speeds, excluding test 5 (n=153; mean difference ± limits of agreement: -0.27 ± 0.47 km·h^{-1}).

6.5 Discussion

The purpose of this study was to examine the criterion validity of an automated tracking system to measure soccer specific motion. The correlations between the speeds participants recorded via the timing gates and those recorded by the automated tracking system were all strong (r ≥ 0.99) with the exception of one test. The study also demonstrated the potential capabilities of such a system in its ability to deliver accurate tracking information across a number of soccer related movements in real time. This was demonstrated by the mean difference ± limits of agreement of 0.25 ± 0.64 km·h^{-1} for the combined speeds measured across all tests at different speeds. The automated tracking system also generated accurate tracking whilst players conducted a simulated acceleration or fast change of speed; previously highlighted as problematic for video operator controlled (Di Salvo et al., 2006) or GPS tracking systems (Witte & Wilson, 2004). Evidence from field and laboratory tests have shown that running with the ball in soccer increases energy expenditure and should be taken into account when evaluating player efforts (Reilly & Williams, 2003). Thus the small differences and strong correlation (r=1.0) found between the timing gates and the automated tracking system during the dribble shuttle are of key importance for accurately monitoring player intensity which has previous been difficult to conduct with accuracy.

The mean difference ± limits of agreement and CV for the zigzag shuttle and acceleration shuttle were -0.50 ± 0.45 km.h^{-1} and 1.0% and -0.32 ± 0.35 km.h^{-1} and 1.0% respectively. Similarly the mean difference ± limits of agreement for the sprint portion of the straight line shuttle between the timing gates and the system at maximum speed (24.9 ± 2.0, 25.6 ± 2.1, respectively) was -0.64 ± 0.47 km.h^{-1}. The automated tracking system clearly demonstrates very good validity during maximal sprints and multiple turning movements, which have previously been highlighted as important to fully understand the demands placed upon players during a game (O'Donoghue & Robinson, 2009) and have either not been investigated comprehensively in previous validation studies (Carling et al., 2005; Di Salvo et al., 2006) or have been shown to have lower validity than slower movements with other tracking systems (Barbero-Álvarez, Coutts, Granda, Barbero- Álvare, & Castagna, 2010; Witte & Wilson, 2004).

The validity of the real-time multiple camera system is similar to that for semi-automatic tracking systems and GPS which have undergone validation studies and are regularly used in research. The semi-automated tracking system AMISCO has been highlighted as a useful tool to investigate valid descriptions of game performance (Liebermann et al., 2002) and has since been used to track player activity profile in a number of studies (Di Salvo et al., 2007; Randers et al., 2010) however no formal reliability or validity testing has been published on the system. In contrast, Di Salvo and colleague (Di Salvo et al., 2006) conducted a validity study on the Prozone system. Of the four separate tests completed the mean difference and limits of agreement ranged from 0.05 -0.23 $km.h^{-1}$ and 0.05-0.85 $km.h^{-1}$ respectively, with the CV ranging from 0.2-1.3%. Although Prozone was shown to be a valid system for tracking player movement, only 30 individual runs were completed, compared to 391 in the current study.

The validity for GPS have demonstrated CV ranging from 1.3 - 3.1% and mean difference ± limits of agreement of 0.0 ± 0.9 $km.h^{-1}$ (MacLeod et al., 2009; Portas, Harley, Barnes, & Rush, 2010; Rampinini, Alberti, Florenza, Riggio, Sassi, Borges & Coutts, 2014). Although speeds beyond 15$km.hr^{-1}$ have been tested (Rampinini et al., 2014) error at these speeds has been reported in excess of 10% questioning the usability of GPS at these high end speeds. Given the number of clubs using GPS systems in training to monitor player movement, it is important that the systems used on match day are able to report data with the same or better accuracy for training and match day comparisons. Clearly the automated tracking system can detect both complex and high-speed movements accurately, demonstrating validity that is comparable if not better than previous validations studies and is thus appropriate for research and applied use.

As well as providing evidence for the system's ability to track sprint events and turns it was important to highlight its ability to track over longer periods of time and thus longer distances. Half laps of the pitch were conducted by players in pairs, with a total of 15 runs completed ranging from 1920m to 3120m. The mean speeds measured by the tracking system and the timing gates during each lap showed a strong correlation and low CV ($r = 0.999$; CV=0.2%) providing evidence that the system accurately tracks movement over longer distances. Longer periods of time and distance are often used by sports scientists and physiotherapists to provide an overall indication of the demands on players during specific periods of matches (Carling et al., 2009; Kirkendall et al., 2004; Mohr et al., 2003).

Di Salvo and colleagues (2009) reported that certain tracking systems undergo a verification process of around 42% of player match time. This can be a lengthy process meaning client clubs may have to wait as much as 24 hours for match data (O'Donoghue & Robinson, 2009). With no human operators needed to gather data, the automated tracking system allows a greater amount of time to be spent on real-time analysis and thus more time can be spent investigating tactical and technical aspects of play. Automatic tracking in this way allows sports science and medical personnel to make detailed analysis of player movement in order to evaluate agility and injury risk respectively (O'Donoghue & Robinson, 2009). In addition, having this information live during the match can allow the appropriate personnel to assess whether players are performing to their individual targets, thus informing tactical play such as substitutions which can be critical during a game (Hirotsu & Wright, 2002). The cost of image processing technology and fixed installation is generally much higher than using GPS systems which are relatively inexpensive and do not require a stadium for camera positions (MacLeod et al., 2009, Witte & Wilson, 2004). However, if the intervention is able to assist in injury prevention by highlighting player movement issues live during a game, a large part of the cost of the technology could be justified, especially if the overall incidence of injury in a team is reduced (O'Donoghue & Robinson, 2009). Due to the fully automated nature of the system a greater volume of data can be collected on individual player movement, allowing more relative analysis responding to movements that may involve sharp turns or cutting movement which are associated with ankle and other such injuries (Simpson, Shewokis, Alduwaisan, & Reeves, 1992).

CHAPTER 7

Effects of Playing Position, Pitch Location, Opposition Ability and Team Ability on the Performance of English Premier League Soccer Players in Different Score Line States.

7.1 Background

The effects of score line, on the passing (Chapter 3), activity profiles (Chapter 4), and on the psychological perceptions of players' momentum (Chapter 5) have been considered in this thesis in line with the model of performance proposed in Figure 1.1. Although relationships have been found between score line states it is not clear how key situational factors influence this relationship. For example, chapter 3 and 4 found that score line had an effect on passing accuracy, passing number and high speed activity, however neither study took into consideration team ability, opposition ability or situational factors relating to the time goals were scored or the position on the pitch performance took place. Chapter 3, also failed to address differences in playing position in relation to the effect of score line on performance. The current chapter aims to address a number of these limitations using the automated tracking system validated in **Chapter 6** which has been shown as a valid system for collecting late volumes of tracking data on players performances.

7.2 Introduction

The main methodological criticism of previous research examining score line effects in soccer has been the failure to consider how teams perform when no goals are scored, or when playing against different standards of opposition, (e.g. whether the team were considered top, middle or bottom of the league in question). Other temporal factors may also have mediated performances which have previously been mistaken for score line effects. For example, a soccer match starts with the score level at 0-0; one team may take the lead after 30 minutes and remain in the lead for the remainder of the match. In such a match the teams are level for the first 30 minutes with one team being ahead and the other team behind for the remaining 60 minutes of the match. If a team scores in the first 5 minutes of a game and spend the remaining time defending their lead, their passing success rate maybe a function of the teams strategy rather than a representation of performance. Similarly, much of the difference in work-rate observed between different score line states may be due to the opposition's ability or simply fatigue rather than score line. This is supported by evidence from time-motion analysis studies which suggest that the percentage of time spent performing high intensity activity is lower during the second half of soccer matches than during the first half (Bangsbo et al., 1991; O'Donoghue, 1998; Di Salvo et al., 2009; Carling and Dupont, 2011). Although studies have shown that the percentage of time spent performing high intensity activity is lower during the second half of a soccer match than during the first (Bangsbo, Mohr & Krustrup, 1991; Carling & Dupont, 2011; Di Salvo et al., 2009; O'Donoguhe, 1998) it is possible that differences in percentage time spent performing high intensity activity may reflect score line rather than fatigue. Especially, as recent research (Hewitt, Norton & Lyons, 2014; Sparks, Coetzee & Gabbett, 2016) has suggested that teams pace themselves injecting periods of sub-max or max bursts late on in matches, therefore dismissing the previous thoughts that teams fatigue towards the latter stages of the match.

Shaw and O'Donoghue (2004) speculated that if the outcome of a match becomes obvious during the second half (e.g. the opposition are of a higher standard), player motivation might be reduced, potentially leading to a reduction in effort. This was supported in Chapter 5 which found across both quantitative and qualitative data collection methods, individual perceptions of momentum were affected by scoring and conceding. Although this was considered in both Chapter 3, investigating score line in relation to passing success rate and Chapter 4 in relation to player's activity profiles, the current study will help to expand the findings, and thus application by using a larger data set across a number of additional situational factors.

A secondary issue has been the technological barriers in data collection methods that have limited the ability to generalise findings for both physical and technical performance factors. Categorising players by position (defenders, midfielders, attackers) in relation to score line effects has been considered for activity profiles (chapter 4) only and with very small data sets (5 games) using overall match status (winning, drawing, losing) rather than by how much the team were winning or losing by. There is however, a need to investigate score line effects on performance using a greater volume of data as well as objective and reliable methods. Semi-automatic player tracking systems are a useful tool providing large volumes of objective and reliable movement data to professional soccer clubs (Carling et al. 2008; Di Salvo et al. 2006; O'Donoghue and Robinson, 2009). These systems have also been used in academic research into soccer performance allowing large numbers of players to be observed (Di Salvo et al. 2009; Gregson et al. 2010) although to date, no such system has been used in the analysis of score line effects within soccer. The volume of player movement data available from semi-automatic player tracking would allow further investigation of how different playing positions react to score line changes, as found in chapter 4. Access to data can also be problematic leading to many studies using a case study approach, with only one team analysed limiting the application of findings to wider populations.

It is also important to consider match location when discussing the impact of both physical and technical factors on player performance given the volume of research that has considered this as a factor relating to success in soccer. For example, Lago and Martin (2007) found home teams had greater possession than their opposition, a pattern found by numerous studies across a wide range of playing abilities (Thomas et al., 2004; Bloomfield et al., 2005; Jones et al., 2004; Tucker et al., 2005; Taylor et al., 2008). Tucker et al. (2005) and Taylor et al. (2010) also suggested that home teams tended to perform a higher number of attacking actions (goal scored, shots on goal, passes, crosses etc.) which is not surprising given research investigating match location effects has suggested that the home team have a number of advantages over the visiting team (Carling et al., 2005; Tucker et al., 2005). Home advantage has also been found to produce triggers for positive momentum (e.g. crowd effects) (Agnew & Carron, 1994; Harville & Smith, 1994; Nevill, Balmer & Williams, 2002) as supporters are typically in a win frame (e.g. focused on achieving success), thus motivate teams to perform (Briki et al., 2015). Lago-Penas and Dellal (2010) found that higher ranked teams had less variation in performance than lower ranked teams suggesting that higher ranked teams are able to maintain their performance regardless of the environment and situation (playing at home or away/losing, winning, drawing). In terms of activity profiles Castellano et al. (2011) found players covered a greater distance per average half when playing at *home* (3931m versus 3887m away), when the *reference team* were losing (3975m versus 3837m drawing and 3921m winning). However, in contrast Bloomfield et al. (2004a) found no effect of match location on player activity in the English Premier League, thus warranting further investigation. Technical and tactical factors may also vary as a function of the opposition's ability especially as previous research (Lago-Peñas & Gómez-López, 2014; Ridgewell, 2011; Lago-Peñas & Dellal, 2010) has found that teams decrease their passing accuracy when winning and increase passing accuracy after conceding.

The third issue with previous studies into score line is the lack of a gold standard for defining both performance events that occur during the game (such as tackles, passes etc.) and work rate. Specifically the subjective nature of many performance factors has led to inaccuracies and errors when recording data, for example where human operators have coded matches with little or no confirmation of the accuracy of the data. This has led to inaccuracies and errors when recording data, questioning the reliability of findings from these studies. More recently, researchers (Ridgewell, 2011; Bradley & Noakes, 2013) have used established industry definitions to try and give wider application to the findings. However, this does not eradicate the problems associated with human error when identifying events especially in real time. This subjective method of event identification is also time consuming, therefore limiting the number of games that can be used in meaningful analysis.

The use of computerised systems has been more apparent when investigating player movement, although with a number of different definitions used, this has led to difficulty in comparing findings. For example, Carling et al. (2008) listed 3 different threshold values for sprinting used in different time-motion studies in soccer. Di Salvo et al. (2009) used five different sub-ranges of speed (walking, jogging, running, high intensity running and sprinting) to represent movement of different intensities ranging from walking defined as speeds of under 2 $m.s^{-1}$ (7.2 $km.h^{-1}$) to sprinting defined as movement at 7 $m.s^{-1}$ (25.2 $km.h^{-1}$) or faster. In contrast, Abt and Lovell (2009) used the second ventilatory threshold (Beaver et al., 1986) to determine individual player thresholds for high intensity running. They found that the distance covered at 19.8 $km.h^{-1}$ or greater (845m) which was previously used as the high intensity threshold under-estimated the distance covered when compared to the threshold value based on the second ventilatory threshold (2258m). It was suggested that using a running speed as a high intensity value does not consider the energy cost of moving at a full range of speeds, for example when a player is in possession of the ball (Reilly & Ball, 1984). Secondly, high intensity running does not always include all high intensity movement as players perform many movements in backwards and sideways directions at much lower speeds. Therefore, a lower speed threshold might provide a better estimate of the percentage of time spent performing high intensity activity. This more accurate representation of high intensity combined with the use of an automated tracking systems could help to eradicate some errors, especially when recording player movement at higher speeds and in large number which has previously been problematic. The automated tracking assessed in Chapter 6 was found to have good validity over a range of soccer specific movements and speeds, suggesting it as a valid real-time motion analysis system for tracking player movement. The benefit of this system is highlighted in its ability to produce and store data on a much larger scale and to a greater accuracy than seen in previous studies.

Therefore the aim of the present study was to investigate the effect of the interaction of a number of situational factors (playing position, opposition ability, team ability, pitch location) on player performance (either activity profiles, technical performance or both) in different score line states. The use of the automated tracking system validated in Chapter 6 can also allow the aggregated data of several teams to be analysed rather than a single team thus creating more normative data to improve team performance in a collective way (Lago-Penas et al., 2011).

STUDY 7a – EFFECTS OF OPPOSITION ABILITY, TEAM ABILITY, PLAYING POSITION AND PITCH LOCATION ON THE TECHNICAL PERFORMANCE OF ENGLISH PREMIER LEAGUE SOCCER PLAYERS IN DIFFERENT SCORE LINE STATES.

7.3 Methods

7.3.1 Data Set

In total 376 of the 380 games played during the 2011-2012 English Premier League season were used in the current study which included 570 players and 35,000 rows of data. The omission of four games was due to a number of technological incidents outside of the operators' control, which disabled the system and resulted in the tracking data becoming unusable. This resulted in 20 teams who played against each other at both their own ground and that of their opponents, with the exception of the teams affected by the excluded games. The ability of each team and their respective opponents was calculated using their final league position at the end of the season once all games had been played (ranked 1-20, i.e. 1st in the league to 20th in the league). For accuracy player position (striker, midfielder, defender) was determined at the start of each game using the official team sheets provided to the press association by each respective club. This ensured players who may change positional role each game or between games depending on the playing formation adopted by the team were accurately defined for each game. In line with previous research (Ridgewell, 2011) the pitch was split evenly into three sections (attacking third, middle third and defensive third) using a theodolite and calibrated pitch dimensions (specific to each individual stadium). Consent to use the data for research purposes was provided by both Venatrack Ltd (Appendix F) and the English Premier League.

Ethical approval was granted by Nottingham Trent University's School of Science and Technology non-invasive Ethical Advisory Committee.

7.3.2 Data Gathering

Data were recorded using the live OB feed provided by the host broadcaster and Venatrack's live eventing system. Two trained observers, event analysis A (EAA) and event analysis B (EAB) used the live eventing system to code game events alongside the automated tracking system (Venatrack Ltd).

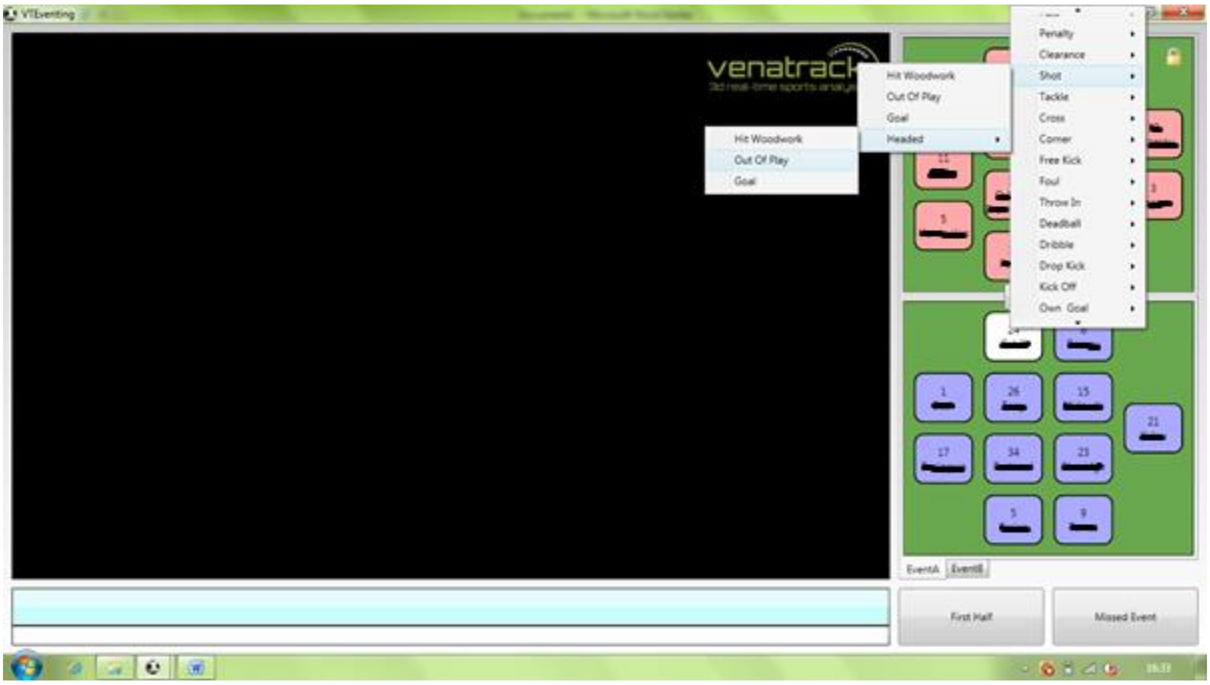

Figure 7.1 EAA system interface (Example, player highlighted (white) has possession and has had a headed shot, which has gone out of play).

For each action, EAA coded the event using the EAA interface (Figure 7.1). The automated tracking system gave a time code, which was then aligned with the positional tracking data. Calibration of the automated tracking system was completed by a team of technical experts who had collectively over 18 years of experience of visual artificial intelligence (AI) technology, such as that used by the system in question. The system was also found to be valid and reliable for tracking player movement at both high speed and sprinting distances. Using the same OB video feed EAB (event analysis B) verified the action and the players involved in the action using EAB interface (see Figure 7.2) and the event and all relevant details associated with it were sorted and stored on a master server. Any ambiguous outcomes were flagged on the system and discussed with the team of analysts at the end of the game prior to submitting the final eventing report to ensure reliability, and validity of the data.

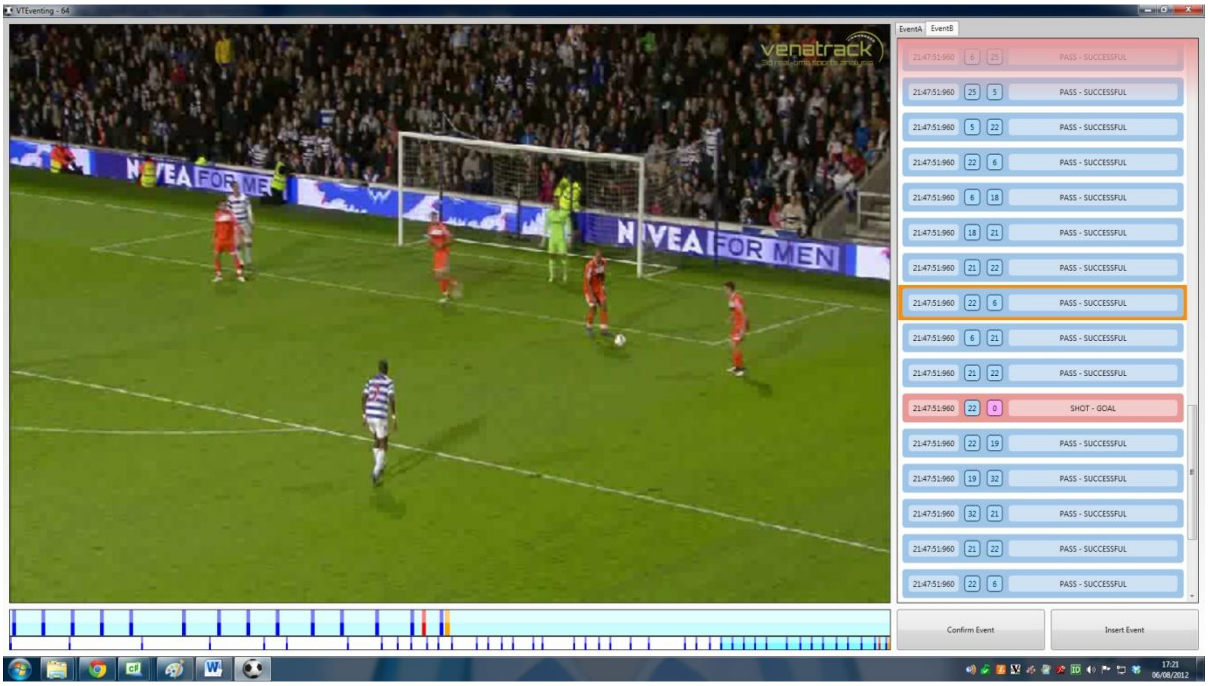

Figure 7.2 EAB system interface (Example, urgent event highlighted on time line).

7.3.3 Performance Indicators (Technical)

Due to the automated nature of the tracking system used in this study a number of different types of passes, crosses, corners and free-kicks were included in the overall categories. For the purpose of the study these were combined to make two distinct categories;

successful and unsuccessful (see appendix G). The outcome of each technical factor (successful or unsuccessful) was categorised by a team of two trained observers. Therefore, ambiguous outcomes were subjectively defined by the expert panel to ensure reliability and validity of the data. A full list of definitions can be seen in Table 7.1.

Table 7.1 Operational definitions used in Study 3 and Study 7a.

EVENT	**SECOND**	**THIRD**	DEFINTION (Study 8a)	DEFINTION (Study 4)
PASS	SUCCESSFUL		The act of passing the ball with part of the body (other than the head) which goes to a team mate.	"the act of passing the ball with any part of the body which is received by a teammate".
	INTERCEPTED		The act of intercepting an intended pass from the opposition	"the act of passing the ball with any part of the body which is received by the opposition or goes out of play (unsuccessful)"
	OUT OF PLAY		The act of passing the ball with a part of the body (other than the head) which goes straight out of play resulting in a throw in, goal kick, corner.	
	HEADED	SUCCESSFUL	The act of heading the ball which goes to a team mate.	
	HEADED	INTECEPTION	The act of heading the ball which is intercepted by an opposition player.	
	HEADED	OUT OF PLAY	The act of heading the ball which goes out of play.	
CROSS	SUCCESSFUL		The act of crossing the ball in a danger area (attacking third) that creates a goal scoring opportunity that goes to a team mate.	Not considered
	INTERCEPTION		The act of crossing the ball with the aim of creating a goal scoring opportunity which is intercepted by an opposition player.	
	OUT OF PLAY		The act of crossing the ball with the aim of creating a goal scoring opportunity that goes directly out of play.	
	CLEARED		The act of crossing the ball with the aim of creating a goal scoring opportunity which is cleared out of the danger area by the opposition. A clearance is not controlled and is "hoofed" away from a danger area (every clearance is successful).	
	SHOT	PARRIED	The act of crossing the ball which results in a direct shot at goal that is parried (deflected by an open hand/s) by the goal keeper to stop the shot.	
	SHOT	BLOCKED	The act of crossing the ball which results in a direct shot at goal that is blocked by the goal keeper or defender to stop the shot (a block is the act of stopping the shot, that is not caught, punched or parried by the goal keeper or cleared by an outfield player).	
	SHOT	CAUGHT	The act of crossing the ball which results in a direct shot at goal that is caught by the goal keeper to stop the shot (the ball must be controlled/held).	

	SHOT	PUNCHED	The act of crossing the which results in a direct shot at goal that is punched (fist/s must be closed) by the goal keeper to stop the shot.	
	SHOT	HIT WOODWORK	The act of crossing the ball which results in a direct shot at goal that hits the woodwork.	
	SHOT	OUT OF PLAY	The act of crossing the ball which results in a direct shot at goal which goes out of play (wide or over the cross bar) which is not handled by the goal keeper.	
	SHOT	CLEARED	The act of crossing the ball which results in a direct shot at goal which is cleared by the opposition.	
	SHOT	GOAL	The act of crossing the ball which results in scoring a direct goal which increases your team's goal tally.	
CORNER	SUCCESSFUL		The act of taking a corner which goes to a team mate.	Not considered
	INTERCEPTION		The act of taking a corner which is intercepted by an opposition player.	
	OUT OF PLAY		The act of taking a corner which goes directly out of play.	
	SHOT	PARRIED	The act of taking a corner which results in direct shot at goal that is parried (deflected by an open hand/s) by the goal keeper to stop the shot.	
	SHOT	BLOCKED	The act of taking a corner which results in a direct shot at goal that is blocked by the goal keeper or defender to stop the shot (a block is the act of stopping the shot, that is not caught, punched or parried by the goal keeper or cleared by an outfield player).	
	SHOT	CAUGHT	The act of taking a corner ball which results in a direct shot at goal that is caught by the goal keeper to stop the shot (the ball must be controlled/held).	
	SHOT	PUNCHED	The act of taking a corner which results in a direct shot at goal that is punched (fist/s must be closed) by the goal keeper to stop the shot.	
	SHOT	HIT WOODWORK	The act of taking a corner which results in a direct shot on goal that hits the woodwork.	
	SHOT	OUT OF PLAY	The act of taking a corner which results in a direct shot on goal which goes out of play (wide or over the cross bar) which is not handled by the goal keeper.	
	SHOT	CLEARANCE	The act of taking a corner which results in a direct shot on goal which is cleared by the opposition.	
	SHOT	GOAL	The act of taking a corner which results in a direct goal which increases your team's goal tally.	
FREEKICK	SUCCESSFUL		The act of taking a free kick which goes to a team mate which is not a goal.	
	INTERCEPTION		The act of taking a free kick which is intercepted by an opposition player.	Freekick
	OUT OF PLAY		The act of taking a free kick which goes directly out of play or an in-direct kick that goes into the back of the net (not allowed/foul).	
	CLEARANCE		The act of taking a free kick into which goes into the danger area and is cleared from a danger area (attacking third).	

	SHOT	PARRIED	The act of taking a free kick which results in a direct shot at goal that is parried (deflected by an open hand/s) by the goal keeper to stop the shot.	
	SHOT	BLOCKED	The act of taking a free kick which results in a direct shot at goal that is blocked by the goal keeper or defender to stop the shot (a block is the act of stopping the shot, that is not caught, punched or parried by the goal keeper or cleared by an outfield player).	
	SHOT	CAUGHT	The act of taking a freekick which results in a direct shot at goal that is caught by the goal keeper to stop the shot (the ball must be controlled/held).	
	SHOT	PUNCHED	The act of taking a freekick which results in a direct shot at goal that is punched (fist/s must be closed) by the goal keeper to stop the shot.	
	SHOT	HIT WOODWORK	The act of taking a freekick which results in a direct shot on goal that hits the woodwork.	
	SHOT	OUT OF PLAY	The act of taking a free kick which results in a direct shot on goal which goes out of play (wide or over the cross bar) which is not handled by the goal keeper.	
	SHOT	CLEARANCE	The act of taking a free kick which results in a direct shot on goal which is cleared by the opposition.	
	SHOT	GOAL	The act of taking a freekick which results in a direct goal which increases your team's goal tally.	

7.3.4 Data Analysis

Firstly, due to the hierarchical structure of the data, multi-level modelling was use to predict the technical performance across different score lines with each of the match related and performance related variables (MLwiN v 2.22, Bristol University, Bristol, UK). For each variable, a two-level hierarchical structure was defined with repeated measures (level 1) nested within match ID (level 2). The benefit of this hierarchical structure means that, unlike traditional longitudinal data analysis techniques such as repeated measures ANOVA, the same number of measurement points per individual are not required. Therefore, due to the variation that occurs between matches in the current data set, this statistical technique is well suited to the current data structure. A multilevel model of this nature is also able to describe the underlying trends of a particular component in the population (the fixed part of the model), as well as modelling the unexplained variation around the mean trend for that component due to individual differences (the random part of the model) (Twist, 2003).

The first stage in this multi-level model statistical analysis approach was to create a model that explained changes in the various different performance variables selected. These were, passing accuracy; pass total count, free kick accuracy, free kick total count, corner accuracy, corner total count, cross accuracy and cross total count. Each performance variable was modelled in turn. Relevant parameters were systematically added to the null model and were accepted or rejected on the basis of firstly changes in the model fit; as indicated by a difference in log likelihood between models, and the effect of the variable on the performance variable of players, indicated by z-scores. Firstly, to investigate the variance between players the intercept was allowed to vary randomly between players. The effect of score line defined by goal difference (centered at 0 goals) on each of the performance variables of players was modelled. Quadratic goal difference terms were then modelled. Subsequently, the effect of playing position, the zone on the pitch the activity took place where applicable (e.g. corner only took place in the attacking third); the time scored; the opposition's ability and the team's ability were modelled. Following each analysis, the assumption that variations in intercepts were normally distributed with an average of zero was checked (Twisk, 2013). Statistical significance was accepted at the 95% confidence level ($p < 0.05$). Mean ± SD were used to describe the average and variability of the technical profile data.

7.4 Results

A total of 570 players across 376 games were analysed, with the maximum number of appearances from one player being 38 and the minimum being 1 game. Table 7.2 presents the technical performance for each of the teams included in the analysis across the three match statuses (winning, drawing, losing). The average passing accuracy per player per games was 73.6 ± 5.5% per game. With regards to corners, crosses and free-kicks players performed on average 19.7 ± 2.6%, 45.4 ± 8.3% and 63.9 ± 12.1% accuracy respectively. Table 7.3, 7.4 and 7.5 display the mean ± SD of all technical variables for player position, pitch location and team ability in relation to goal difference.

Table 7.6-7.8 presents the final multi-level models for the development of the match-performance characteristics of passing accuracy, free kick accuracy and corner accuracy, for players of different playing positions, in different pitch zones, across different abilities and against different standards of opposition of players in the 376 English Premier League games analysed. The random part of the multi-level models predicted that the fit of all models was improved when the intercept was allowed to vary randomly ($p < 0.05$), as indicated by the between game standard error displayed in Table 7.6, 7.7 and 7.8.

Table 7.2 Mean Percentage Accuracy for Corners, Crosses, Free-kicks and Passes for each Club included in the Analysis in a winning, drawing and losing score line state

			WINNING				DRAWING				LOSING				ALL			
Team	Number Games Played	Number of Players Included	Corner	Cross	Freekick	Pass	Corner	Cross	Freekick	Pass	Corner	Cross	Freekick	Pass	Corner	Cross	Freekick	Pass
1	38	32	17.4	35.6	76.7	79.9	19.6	69.7	80.0	83.1	28.1	38.6	88.9	81.9	20.4	49.6	79.8	81.9
2	38	27	20.0	51.2	44.2	60.9	20.9	40.3	62.9	67.3	11.9	59.5	64.9	67.4	17.5	50.2	61.0	65.8
3	38	31	20.6	56.7	29.3	62.1	18.9	52.6	32.9	65.6	18.9	42.1	38.2	69.4	19.1	48.1	34.7	66.7
4	38	30	18.3	57.6	52.2	68.9	17.1	24.6	49.1	67.4	19.3	39.2	48.2	74.3	18.4	36.9	49.2	71.1
5	35	29	26.3	46.7	97.8	78.9	14.5	45.7	71.5	78.3	20.4	43.3	75.6	75.0	18.6	45.6	74.1	77.9
6	38	30	20.2	60.0	66.4	71.9	21.9	25.0	62.2	72.9	28.7	32.5	81.1	70.1	23.0	33.8	63.0	71.8
7	37	29	25.5	53.1	76.3	76.7	21.5	34.6	83.4	77.5	15.6	44.7	81.1	79.8	20.4	43.1	79.6	78.1
8	37	25	26.3	50.0	59.6	74..8	19.3	41.8	73.1	76.8	16.2	48.4	65.8	78.5	19.8	45.9	67.6	76.2
9	38	26	19.3	55.6	75.2	78.9	15.7	46.7	75.3	78.9	10.0	40.0	42.9	82.7	16.6	49.2	73.2	79.3
10	38	32	23.4	60.6	79.4	82.3	24.7	55.9	79.3	83.3	15.6	58.3	85.7	77.3	23.8	63.7	77.9	82.6
11	37	27	18.5	37.3	54.8	68.3	24.1	41.7	56.4	69.7	28.1	48.2	62.6	74.3	23.8	41.9	57.5	70.4
12	38	28	19.8	64.1	62.1	70.3	23.9	68.9	46.8	67.0	21.0	35.7	62.5	71.1	21.5	52.4	57.9	69.8
13	38	36	16.1	42.7	38.5	69.0	22.9	32.6	44.4	68.0	15.9	23.8	53.9	71.9	18.1	29.4	47.8	70.2
14	38	23	25.0	40.0	58.1	58.8	18.6	43.8	59.0	59.7	19.5	40.0	58.6	67.5	20.2	41.6	58.7	62.8
15	38	28	16.7	28.8	56.7	63.1	16.9	40.3	54.3	61.1	16.4	22.2	50.0	72.2	16.7	32.9	54.1	68.1
16	38	25	33.8	79.8	59.7	72.1	19.0	52.2	81.0	77.6	20.8	51.9	67.6	79.2	22.5	55.9	72.5	76.4
17	38	31	19.1	56.6	72.8	80.9	13.7	43.1	80.6	78.3	11.7	52.1	69.6	79.1	14.8	50.8	75.0	79.7
18	37	25	24.3	71.1	64.9	73.1	21.9	32.7	59.6	72.2	15.1	37.9	62.1	77.1	20.1	46.9	62.0	74.6
19	38	24	20.2	60.0	64.6	73.7	17.7	49.9	73.7	72.6	13.1	47.5	77.6	75.6	16.3	50.9	73.7	74.2
20	37	32	20.0	58.3	38.5	67.2	33.3	40.5	65.7	73.7	16.1	32.3	56.2	77.1	21.7	38.4	57.7	74.9
Mean	**376**	**570**	**21.5**	**53.3**	**61.4**	**71.4**	**20.3**	**44.1**	**64.6**	**72.6**	**18.1**	**41.9**	**64.7**	**75.1**	**19.7**	**45.4**	**63.9**	**73.6**
SD	0.8	3.3	4.3	12.3	16.2	7.1	4.4	12.0	14.3	6.7	5.4	10.0	14.1	4.6	2.6	8.3	12.1	5.5

Table 7.3 Mean ± SD for all technical performance variables of different playing positions in different goal differences.

		Home	Away	Home	Away	Home	Away	Home	Away
Goal Difference		Passing Accuracy (%)		Cross Accuracy (%)		Corner Accuracy (%)		FreeKick Accuracy (%)	
-5	Striker	84.9 ± 24.9	77.5 ± 35.3	0.0 ± 0.0	100 ± 0.0		100.0 ± 0.0		
	Midfielder	90.0 ± 13.6	75.4 ± 36.3	30.6 ± 40.0	40.0 ± 54.8	50.0 ± 70.7	50.0 ± 70.7	75.0 ± 35.3	33.3 ± 57.8
	Defender	87.1 ± 24.4	82.6 ± 24.0	0.0 ± 0.0	13.3 ± 29.8			100.0 ± 0.0	77.8 ± 44.1
-4	Striker	80.7 ± 31.3	73.5 ± 35.6	0.0 ± 0.0	14.3 ± 37.8			100.0 ± 0.0	100.0 ± 0.0
	Midfielder	87.8 ± 26.5	81.7 ± 29.0	0.0 ± 0.0	13.6 ± 32.3	0.0 ± 0.0	20.0 ± 44.7	58.3 ± 49.2	62.5 ± 43.3
	Defender	84.5 ± 28.9	83.8 ± 27.0	12.5 ± 35.4	15.0 ± 33.7			100.0 ± 0.0	72.2 ± 44.1
-3	Striker	72.1 ± 34.9	72.1 ± 35.8	28.6 ± 48.8	0.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	25.0 ± 50.0
	Midfielder	82.7 ± 29.4	80.5 ± 28.5	34.6 ± 46.5	9.3 ± 23.6	30.9 ± 46.1	46.7 ± 47.9	65.0 ± 47.4	59.2 ± 49.1
	Defender	82.5 ± 26.9	79.7 ± 27.8	15.4 ± 37.6	10.0 ± 30.5		50.0 ± 70.7	75.0 ± 46.2	78.6 ± 40.7
-2	Striker	69.8 ± 35.8	70.9 ± 35.3	6.7 ± 23.2	22.5 ± 39.8	0.0 ± 0.0.	65.4 ± 42.2	66.7 ± 57.8	81.8 ± 40.4
	Midfielder	77.3 ± 29.2	77.4 ± 30.2	18.4 ± 32.9	13.0 ± 30.5	45.2 ± 45.7	49.6 ± 47.9	40.9 ± 46.9	55.0 ± 47.5
	Defender	78.5 ± 27.8	75.3 ± 29.1	15.3 ± 34.2	20.4 ± 38.1	66.7 ± 57.7	66.7 ± 44.4	79.8 ± 39.9	83.2 ± 35.1
-1	Striker	69.7 ± 34.1	67.0 ± 34.6	12.2 ± 30.7	16.9 ± 35.7	31.1 ± 42.2	19.7 ± 34.3	46.4 ± 49.9	25.0 ± 42.9
	Midfielder	76.2 ± 29.6	77.2 ± 29.3	17.7 ± 32.9	21.1 ± 37.3	33.1 ± 40.9	45.3 ± 46.4	60.5 ± 47.7	58.1 ± 48.0
	Defender	74.7 ± 29.4	74.3 ± 30.4	20.6 ± 35.7	22.6 ± 39.2	35.9 ± 46.2	25.0 ± 46.2	76.7 ± 41.6	81.6 ± 37.5
0	Striker	67.2 ± 31.3	64.6 ± 32.5	17.2 ± 34.2	18.7 ± 36.4	43.3 ± 43.2	50.4 ± 44.0	43.8 ± 47.6	40.4 ± 48.5
	Midfielder	75.4 ± 27.2	74.8 ± 27.8	19.6 ± 34.7	21.3 ± 38.1	46.0 ± 38.9	44.4 ± 43.7	60.4 ± 46.6	61.6 ± 45.5
	Defender	74.9 ± 26.5	71.2 ± 27.9	22.4 ± 37.6	17.0 ± 32.7	28.9 ± 40.9	40.2 ± 48.3	80.1 ± 38.3	74.0 ± 40.9
1	Striker	68.4 ± 34.3	65.1 ± 35.7	29.6 ± 44.0	14.1 ± 33.1	61.1 ± 50.2	67.9 ± 46.4	59.5 ± 49.0	50.0 ± 51.6
	Midfielder	76.1 ± 30.7	73.2 ± 32.0	21.9 ± 37.1	23.7 ± 38.9	52.9 ± 45.6	48.2 ± 45.5	64.5 ± 46.7	65.9 ± 45.4
	Defender	72.9 ± 31.2	70.0 ± 31.1	25.8 ± 40.3	20.7 ± 37.8	60.0 ± 51.6	50.0 ± 50.0	72.3 ± 42.9	72.8 ± 43.3
2	Striker	71.1 ± 33.1	68.1 ± 37.9	14.2 ± 33.7	35.0 ± 46.1	80.3 ± 35.6	57.1 ± 53.5	33.3 ± 51.6	50.0 ± 54.8
	Midfielder	78.7 ± 29.5	76.9 ± 32.0	26.9 ± 41.8	16.4 ± 35.7	62.6 ± 44.1	65.5 ± 41.4	72.6 ± 41.5	82.0 ± 37.2
	Defender	74.8 ± 31.8	72.7 ± 32.4	23.1 ± 39.9	18.5 ± 37.1	62.5 ± 47.9	12.5 ± 17.7	77.6 ± 40.4	76.6 ± 41.5
3	Striker	73.7 ± 32.7	69.6 ± 36.2	14.3 ± 36.3	0.0 ± 0.0	76.7 ± 25.1		50.0 ± 57.7	100.0 ± 0.0
	Midfielder	82.7 ± 28.2	85.8 ± 26.4	14.9 ± 35.2	15.6 ± 35.2	44.0 ± 47.8	81.2 ± 37.2	74.1 ± 44.7	100.0 ± 0.0
	Defender	80.4 ± 29.7	76.3 ± 33.2	23.7 ± 38.8	0.0 ± 0.0			90.9 ± 29.4	84.6 ± 37.6
4	Striker	69.8 ± 40.7	70.5 ± 35.4	20.0 ± 44.7	25.0 ± 50.0	0.0 ± 0.0	100.0 ± 0.0	33.3 ± 57.7	100.0 ± 0.0
	Midfielder	88.1 ± 21.9	87.5 ± 23.4	36.4 ± 45.2	50.0 ± 57.7	31.3 ± 45.8	50.0 ± 70.7	87.5 ± 34.2	100.0 ± 0.0
	Defender	82.2 ± 28.3	76.1 ± 37.1	16.7 ± 40.8	33.3 ± 57.7			75.0 ± 45.2	75.0 ± 41.8
5	Striker	74.3 ± 37.6	72.5 ± 41.4	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	
	Midfielder	83.3 ± 25.4	85.6 ± 26.7	16.7 ± 40.8	0.0 ± 0.0	66.7 ± 51.6	100.0 ± 0.0	75.0 ± 35.4	100.0 ± 0.0
	Defender	83.0 ± 28.6	74.4 ± 34.5	25.0 ± 35.4				80.0 ± 44.7	

Table 7.4 Mean ± SD for all technical performance variables of different pitch locations in difference goal differences.

Goal Difference		Passing Accuracy (%) Home	Passing Accuracy (%) Away	Cross Accuracy (%) Home	Cross Accuracy (%) Away	Corner Accuracy (%) Home	Corner Accuracy (%) Away	FreeKick Accuracy (%) Home	FreeKick Accuracy (%) Away
-5	Attacking 3rd	87.1 ± 21.7	87.4 ± 32.5	26.2 ± 38.3	48.9 ± 38.9			50.0 ± 0.0	0.0 ± 0.0
	Middle 3rd	91.5 ± 15.5	89.5 ± 28.6	0.0 ± 0.0					89.5 ± 28.6
	Defending 3rd	82.8 ± 26.6	78.4 ± 29.8						75.0 ± 50.0
-4	Attacking 3rd	86.9 ± 26.3	81.3 ± 31.2	0.0 ± 0.0	18.2 ± 36.3			75.0 ± 35.4	64.3 ± 47.6
	Middle 3rd	89.2 ± 20.1	86.3 ± 22.7		0.0 ± 0.0			71.4 ± 48.8	67.9 ± 42.1
	Defending 3rd	74.0 ± 39.2	75.2 ± 33.0					100.0 ± 0.0	64.3 ± 47.6
-3	Attacking 3rd	86.6 ± 22.5	76.7 ± 31.5	26.0 ± 43.1	8.7 ± 24.8			56.3 ± 49.6	35.2 ± 47.7
	Middle 3rd	85.9 ± 20.7	82.5 ± 24.2	40.0 ± 54.8	14.3 ± 36.3			81.8 ± 40.5	79.8 ± 39.9
	Defending 3rd	75.4 ± 35.2	72.9 ± 34.9					50.0 ± 54.8	72.6 ± 40.8
-2	Attacking 3rd	79.2 ± 29.1	71.5 ± 34.2	15.5 ± 31.7	32.9 ± 15.5			38.9 ± 46.5	32.1 ± 44.7
	Middle 3rd	84.4 ± 24.0	81.1 ± 24.4	13.9 ± 33.5	29.6 ± 46.5			60.4 ± 47.9	76.4 ± 39.9
	Defending 3rd	67.6 ± 35.4	67.3 ± 35.7	0.0 ± 0.0	0.0 ± 0.0			64.5 ± 43.9	71.6 ± 41.1
-1	Attacking 3rd	74.8 ± 31.3	74.0 ± 32.5	16.1 ± 31.4	22.3 ± 38.1			29.4 ± 42.9	36.3 ± 46.4
	Middle 3rd	83.0 ± 19.2	79.2 ± 25.3	22.3 ± 41.6	21.1 ± 40.3			75.7 ± 41.5	76.8 ± 40.8
	Defending 3rd	69.7 ± 33.7	67.3 ± 34.3	5.0 ± 15.8	12.0 ± 31.6			73.9 ± 59.7	67.3 ± 42.0
0	Attacking 3rd	72.9 ± 29.1	71.7 ± 31.3	20.2 ± 34.9	18.8 ± 34.9			37.9 ± 44.9	36.2 ± 44.9
	Middle 3rd	80.6 ± 18.0	76.5 ± 23.8	22.3 ± 41.2	26.9 ± 43.9			75.5 ± 41.1	73.9 ± 40.7
	Defending 3rd	67.7 ± 31.9	64.1 ± 30.8	30.2 ± 44.8	8.2 ± 24.5			74.8 ± 38.1	67.1 ± 39.6
1	Attacking 3rd	73.9 ± 32.9	72.5 ± 35.0	23.8 ± 38.6	20.6 ± 36.7			45.8 ± 47.9	44.6 ± 47.8
	Middle 3rd	81.5 ± 23.1	76.3 ± 26.6	30.2 ± 45.8	25.7 ± 44.3			76.8 ± 40.4	70.2 ± 43.8
	Defending 3rd	64.5 ± 35.3	61.7 ± 33.9	0.0 ± 0.0	0.0 ± 0.0			58.7 ± 44.1	54.1 ± 43.7
2	Attacking 3rd	73.9 ± 33.1	77.3 ± 32.3	23.3 ± 39.7	23.4 ± 40.4			51.6 ± 47.9	60.0 ± 50.3
	Middle 3rd	81.2 ± 25.8	80.6 ± 27.5	28.9 ± 45.1	0.0 ± 0.0			80.6 ± 36.9	76.8 ± 40.7
	Defending 3rd	69.3 ± 34.9	64.9 ± 36.5	0.0 ± 0.0	33.3 ± 57.8			63.7 ± 42.3	50.9 ± 46.8
3	Attacking 3rd	76.8 ± 34.5	76.1 ± 35.9	18.6 ± 36.9	8.3 ± 25.7			43.8 ± 51.2	100 ± 0.0
	Middle 3rd	83.7 ± 26.0	83.2 ± 28.3	33.3 ± 57.8	0.0 ± 0.0			90.0 ± 30.3	90.0 ± 30.8
	Defending 3rd	71.4 ± 34.4	66.2 ± 36.8	0.0 ± 0.0				58.3 ± 47.9	54.2 ± 49.8
4	Attacking 3rd	77.7 ± 36.5	76.5 ± 35.0	28.6 ± 43.5	36.4 ± 50.5			42.9 ± 53.5	
	Middle 3rd	84.5 ± 28.0	84.3 ± 25.7					90.0 ± 30.8	95.0 ± 15.8
	Defending 3rd	69.3 ± 38.9	66.6 ± 42.0					57.1 ± 53.4	65.7 ± 57.8
5	Attacking 3rd	83.2 ± 27.3	76.4 ± 32.6	13.6 ± 32.3	14.3 ± 37.8			16.7 ± 28.9	100.0 ± 0.0
	Middle 3rd	87.2 ± 20.5	85.6 ± 27.3	0.0 ± 0.0				66.7 ± 57.8	
	Defending 3rd	70.8 ± 39.3	67.1 ± 40.4					100.0 ± 0.0	

Table 7.5 Mean ± SD for all technical performance variables of different ranked teams in difference goal differences.

Goal Difference		Passing Accuracy (%)		Cross Accuracy (%)		Corner Accuracy (%)		FreeKick Accuracy (%)	
		Home	Away	Home	Away	Home	Away	Home	Away
-5	Rank 1								
	Rank 10								
	Rank 20	83.3 ± 24.4	81.9 ± 33.7	8.3 ± 20.4	0.0 ± 0.0			75.0 ± 35.3	
-4	Rank 1								
	Rank 10		78.8 ± 23.7		0.0 ± 0.0		50.0 ± 70.7		75.0 ± 50.0
	Rank 20	83.2 ± 35.6	71.3 ± 39.8	0.0 ± 0.0	0.0 ± 0.0		50.0 ± 70.7		0.0 ± 0.0
-3	Rank 1								
	Rank 10		84.4 ± 27.0		3.7 ± 11.1		66.7 ± 57.7		66.7 ± 31.6
	Rank 20	75.5 ± 36.9	74.4 ± 39.0	9.1 ± 30.2	20.8 ± 40.1	33.3 ± 51.6		62.5 ± 51.8	50.0 ± 70.7
-2	Rank 1	84.3 ± 20.1		25.0 ± 50.0		33.3 ± 57.7		50.0 ± 70.7	
	Rank 10	81.9 ± 21.9	77.7 ± 29.3	50.0 ± 70.7	16.7 ± 40.8	33.3 ± 57.7	44.4 ± 50.9	66.7 ± 47.1	58.3 ± 49.2
	Rank 20	77.0 ± 28.2	70.6 ± 34.5	17.7 ± 34.8	14.3 ± 37.8	33.3 ± 51.6	50.0 ± 0.0	61.4 ± 45.0	35.7 ± 47.6
-1	Rank 1	89.7 ± 21.7	80.9 ± 33.1	8.1 ± 16.2	0.0 ± 0.0	25.0 ± 31.9	66.7 ± 57.7	60.0 ± 54.8	28.6 ± 48.8
	Rank 10	73.7 ± 33.8	76.2 ± 27.2	30.0 ± 48.3	7.9 ± 25.0	0.0 ± 0.0	41.7 ± 49.2	33.3 ± 43.3	68.8 ± 46.2
	Rank 20	69.5 ± 35.6	71.1 ± 31.8	25.4 ± 42.0	14.4 ± 34.9	0.0 ± 0.0	34.7 ± 45.2	57.4 ± 49.6	56.8 ± 46.6
0	Rank 1	81.8 ± 23.9	75.3 ± 24.0	16.4 ± 31.1	16.7 ± 34.8	46.5 ± 48.6	46.1 ± 45.1	70.9 ± 44.3	76.2 ± 40.6
	Rank 10	74.3 ± 26.3	68.8 ± 34.2	22.2 ± 38.1	20.0 ± 42.2	24.2 ± 31.4	50.0 ± 47.4	57.7 ± 46.5	66.1 ± 43.4
	Rank 20	69.4 ± 33.5	71.7 ± 31.3	35.8 ± 44.8	29.5 ± 43.0	54.5 ± 47.2	25.0 ± 42.5	76.1 ± 38.7	52.8 ± 46.2
1	Rank 1	79.4 ± 26.6	72.1 ± 32.8	20.1 ± 36.3	20.0 ± 36.8	61.1 ± 46.9	33.3 ± 57.7	80.7 ± 39.2	65.9 ± 45.1
	Rank 10	69.6 ± 32.9	69.9 ± 28.3	21.7 ± 36.4	28.1 ± 40.7	50.0 ± 50.0	66.7 ± 47.1	62.6 ± 46.4	66.2 ± 42.3
	Rank 20	68.3 ± 32.1	66.8 ± 35.7	14.3 ± 24.4	28.5 ± 48.8	33.3 ± 57.7	50.0 ± 44.7	53.3 ± 50.6	20.0 ± 44.7
2	Rank 1	78.8 ± 29.8	81.8 ± 33.4	30.0 ± 48.3	100.0 ± 22.3	50.0 ± 57.7	50.0 ± 0.0	70.0 ± 44.7	75.0 ± 50.0
	Rank 10	74.3 ± 34.9	73.7 ± 29.2		33.3 ± 57.7	100.0 ± 0.0	50.0 ± 0.0	87.5 ± 25.0	62.5 ± 47.9
	Rank 20	66.8 ± 28.6		0.0 ± 0.0		66.7 ± 57.7		41.7 ± 49.2	
3	Rank 1	81.8 ± 30.4	85.5 ± 26.7	11.1 ± 33.3	0.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0	100.0 ± 0.0
	Rank 10	72.9 ± 34.6	70.0 ± 44.7	16.7 ± 40.8		0.0 ± 0.0		41.7 ± 52.0	
	Rank 20								
4	Rank 1	80.9 ± **29.9**	85.6 ± 30.9	16.7 ± 28.7	100.0 ± 0.0	0.0 ± 0.0		0.0 ± 0.0	100.0 ± 0.0
	Rank 10	75.1 ± 33.0	77.8 ± 34.2						100.0 ± 0.0
	Rank 20								
5	Rank 1		66.7 ± 57.8						
	Rank 10								
	Rank 20								

7.4.1 Passes

Analyses indicated that player passing accuracy both at home and away in relation to goal difference was non-linear and best described with a quadratic term. In general, models predicted that passing accuracy has a “U” shape association with goal difference. Pass accuracy was greatest as teams conceded more goals and the lowest when goal difference was close, specifically when teams increased their goal difference by 1 or 2 goals. When looking at the effect of goal difference on passing accuracy across pitch zone, players passing accuracy was greatest in the middle third, with the defending third reporting the lowest accuracy. Across all three-pitch zones, passing accuracy was highest when teams were losing by the largest margin, with the lowest accuracy highlighted when teams were winning by 1 to 3 goals. This pattern was also predicted for playing position with regards to goal difference. Across positions, strikers reported the lowest passing accuracy, with midfielders showing slightly better accuracy than defenders across all goal differences. Passing accuracy was lowest for the lowest ranked teams across all GD’s.

The estimated parameters of passing accuracy that included goal difference as an independent factor can also be seen in Table 8.5. The table shows that for both at home and away from home, passing accuracy, goal difference, goal difference^2, playing position, pitch zone and team ability significantly improved the model fit. It is possible to calculate the performance of players of different playing positions, in different pitch locations in different goal differences, against different opposition, for different ranked teams, playing either at home or away using the coefficients from Table 8.5. For example, the prediction equation for pass accuracy for a midfielder in the middle 3rd, playing for a team ranked 10th, who are losing by 2 goals, away from home is: Pass Accuracy = Constant + (β_1 * goal difference centered at 0) + (β_2 * goal difference centered at 0^2) + (β_3 * midfielder) + (β_4 * middle 3rd) + (β_5 * team ability centered at rank 10) which is: 0.793 + (-0.012*-2) + (0.003*-2^2) + (0.025) + (0.050) + (-0.006*9) = 0.838. This results in a passing accuracy of 83.8%

Table 7.6. Estimated models for passing accuracy recorded as a percentage.

Passing Accuracy Home		
Fixed Effects	Coefficient	SE
Constant	0.812	0.010
Goal Difference	-0.014	0.002
Goal Difference^2	0.005	0.001
Midfielder	0.016	0.005
Striker	-0.071	0.006
Goal Keeper	-0.103	0.012
Middle 3rd	0.048	0.005
Defending 3rd	-0.047	0.006
Team Ability	-0.007	0.001
Random Effects	Variance	SE
Between Game (Repeat)	0.083	0.001
Within Game (Match ID)	0.005	0.000

Passing Accuracy Away		
Fixed Effects	Coefficient	SE
Constant	0.793	0.011
Goal Difference	-0.012	0.002
Goal Difference^2	0.003	0.001
Midfielder	0.025	0.005
Striker	-0.064	0.007
Goal Keeper	-0.115	0.012
Middle 3rd	0.050	0.006
Defending 3rd	-0.067	0.006
Team Ability	-0.006	0.001
Random Effects	Variance	SE
Between Game (Repeat)	0.086	0.001
Within Game (Match ID)	0.005	0.001

Notes. Independent intercepts estimates (centered at Goal Difference 0) for each playing position (reference defender), pitch location (reference attacking 3rd), team ability (centered at rank 10) and opposition ability (centered at rank 10).

Figure 7.3, 7.4 and 7.5 display the predicted goal-difference related changes in passing accuracy for each playing position, pitch zone and team rank respectively for matches played both at home and away.

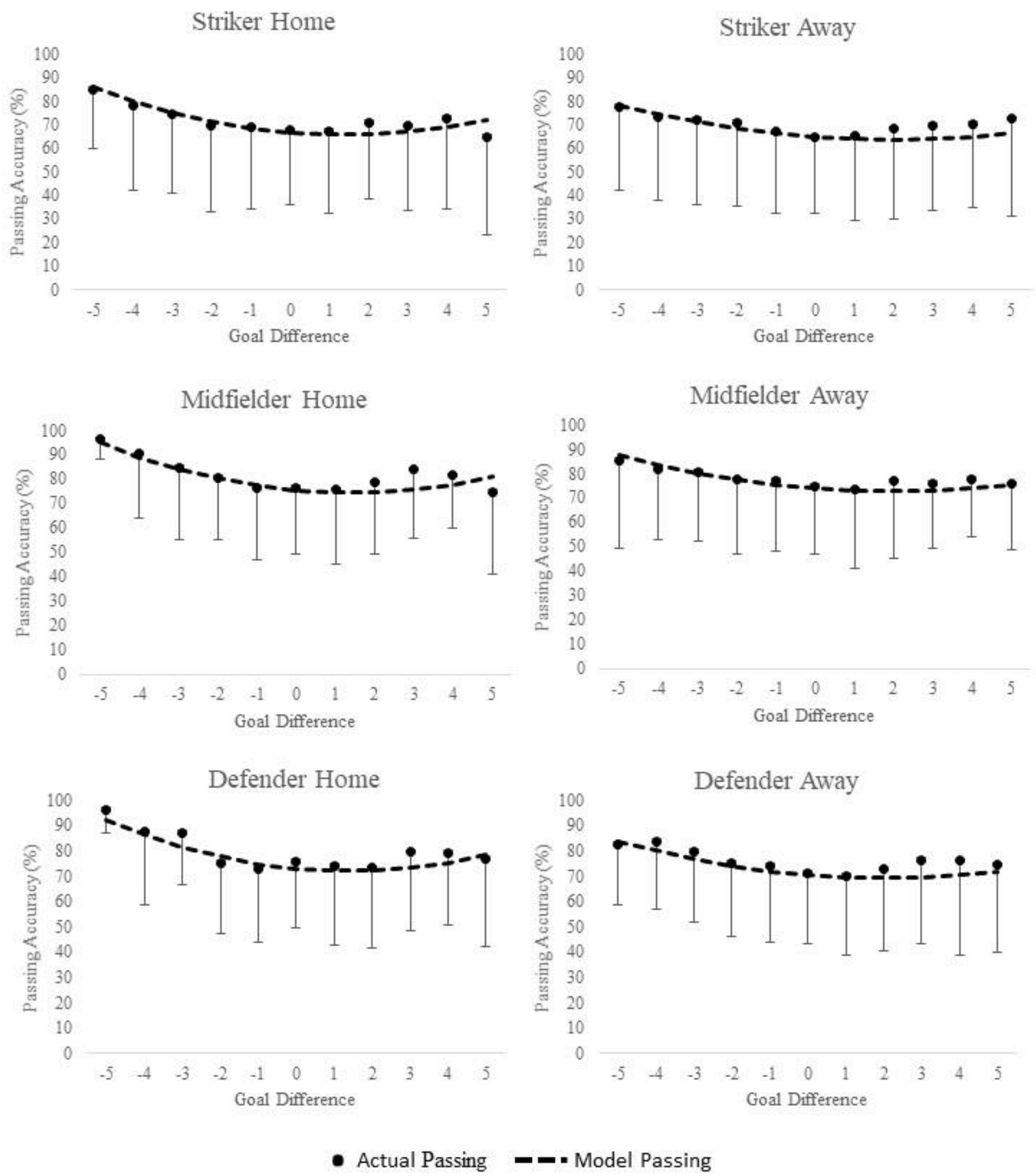

Figure 7.3: Passing Accuracy (%) during match-play in English Premier League across difference goal differences. Curves are based on predicted passing accuracies from multi-level models of longitudinal data. Points are based on the 'raw' passing accuracy data (mean ± SD). Data are presented by playing position both at home and away during match-play.

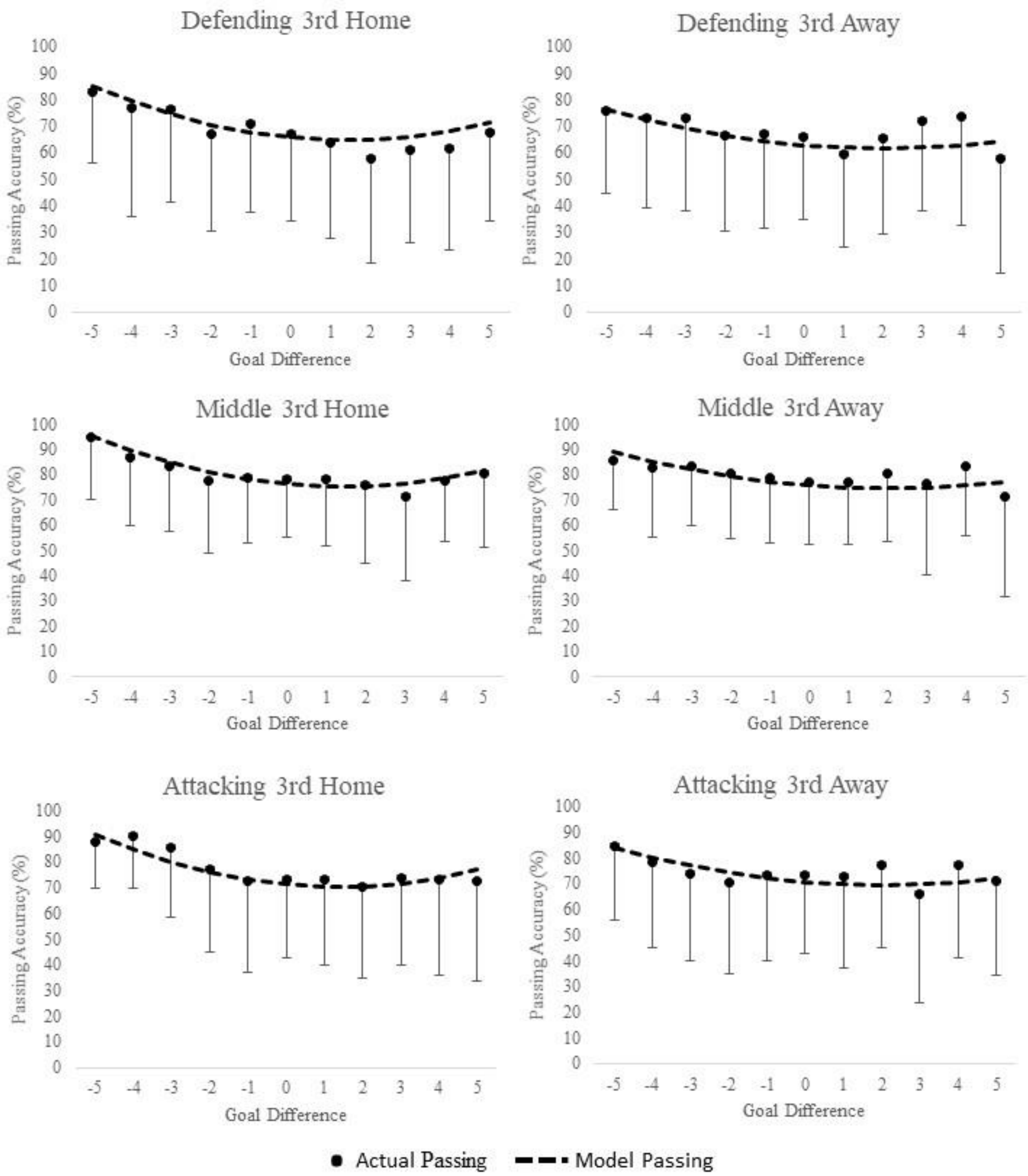

Figure 7.4: Passing Accuracy (%) during match-play in English Premier League across difference goal differences. Curves are based on predicted passing accuracies from multi-level models of longitudinal data. Points are based on the 'raw' passing accuracy data (mean ± SD). Data are presented by pitch location both at home and away during match-play.

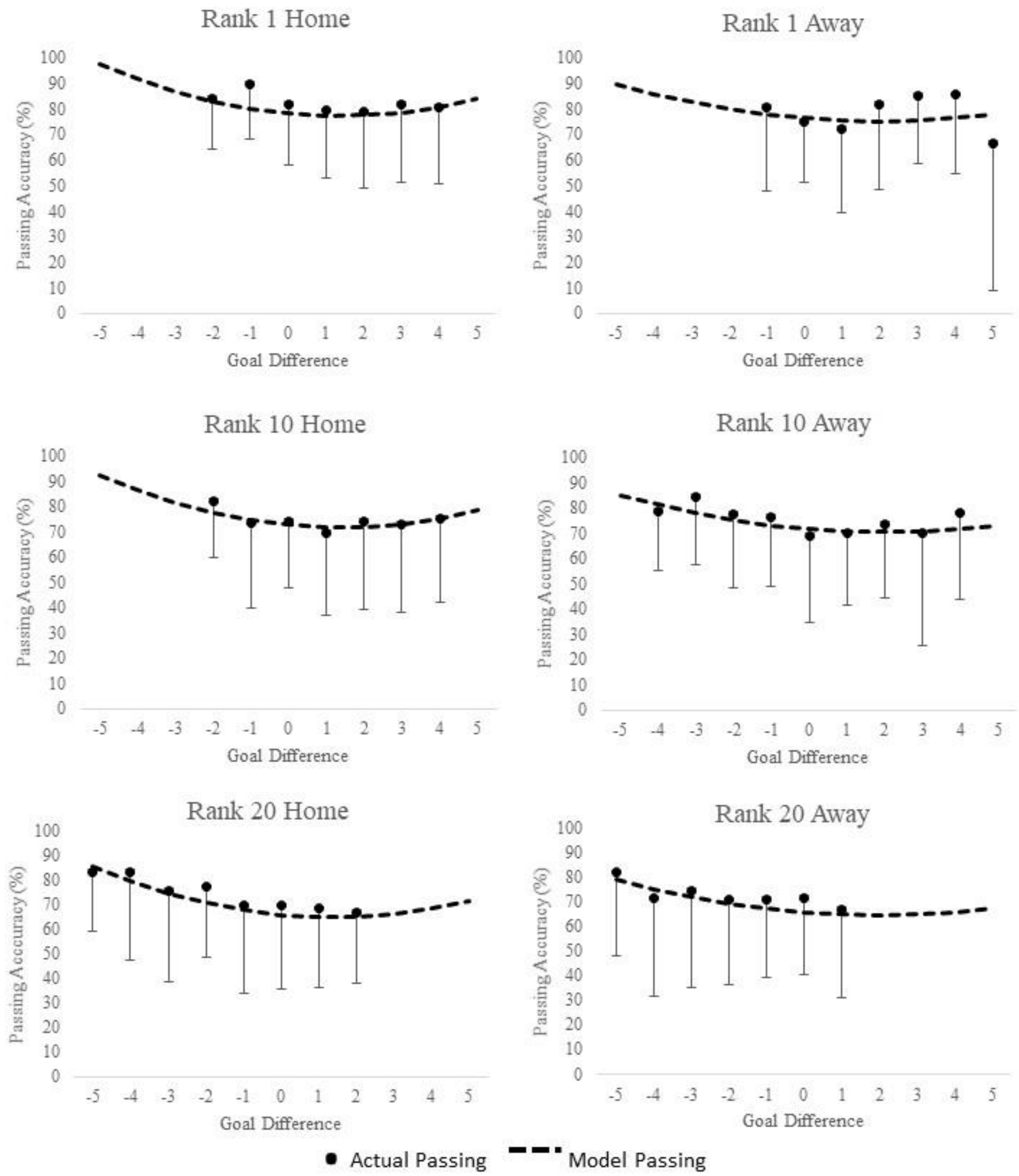

Figure 7.5: Passing Accuracy (%) during match-play in English Premier League across difference goal differences. Curves are based on predicted passing accuracies from multi-level models of longitudinal data. Points are based on the 'raw' passing accuracy data (mean ± SD). Data are presented by Team Rank (final league position) both at home and away during match-play.

7.4.2 *Crosses*

Analyses indicated that unlike passing, cross accuracy was not predicted by any of the variables entered into the model (playing position, pitch location, opposition ability, team ability and time scored) in relation to goal difference. Cross accuracy was not associated with change in GD.

7.4.3 *Corners*

Analyses indicated that corner accuracy, in relation to goal differences was non-linear and best described with a quadratic term when playing away from home and linear when playing at home. Models predicted that when playing away from home corner accuracy was lowest when the goal difference was close, increasing as teams either scored or conceded goals. Winning teams were found to increase their corner accuracy more rapidly than conceding teams, away from home. When playing at home teams were found to increase their passing accuracy in a linear fashion with the lowest passing accuracy occurring when teams were losing by 5 goals and the greatest when teams were winning by 5 goals.

The estimated parameters for corner accuracy that included goal difference as an independent factor can also be seen in Table 8.6. The table shows that for corner accuracy away from home, goal difference, goal difference^2, team ability significantly improved the model fit. For corner accuracy at home only goal difference was found to significantly improve the model fit. Table 8.4 displays the mean ± SD of corner accuracy for teams of different abilities in relation to goal difference.

Table 7.7. Estimated models for corner accuracy recorded as a percentage.

Corner Accuracy Home			Corner Accuracy Away		
Fixed Effects	Coefficient	SE	Fixed Effects	Coefficient	SE
Constant	0.440	0.017	Constant	0.516	0.041
Goal Difference	0.049	0.012	Goal Difference	0.018	0.015
			Goal Difference^2	0.017	0.006
			Team Ability	-0.008	0.004
Random Effects	Variance	SE	Random Effects	Variance	SE
Between Game (Repeat)	0.186	0.013	Between Game (Repeat)	0.193	0.015
Within Game (Match ID)	0.000	0.008	Within Game (Match ID)	0.003	0.009

Notes. Independent intercepts estimates (Centred at Goal Difference 0) for each playing position (reference defender), pitch location (reference attacking 3rd), team ability (centred at 10) and opposition ability (centred at 10).).

It is possible to calculate the performance of players of different playing positions, in different goal differences, against different opposition, for different ranked teams, playing either at home or away using the coefficients from Table 7.7. For example, the prediction equation for corner accuracy for a midfielder playing for a team ranked 10th, who are winning by 2 goals away from home is: Corner Accuracy = Constant + (β_1 * goal difference centered at 0) + (β_2 * goal difference centered at 0^2) + (β_3 * team ability centered at rank 10) which is: Corner Accuracy = 0.516 + (0.018 * 2) + (0.017 * 2^2) + (-0.008*9) = 0.481. This results in a corner accuracy of 48.1%.

7.4.4 Free-Kicks

Modelling indicated that free kick accuracy was not predicted by goal difference, however a number of other variables were found to significantly improve the model, when playing at both home and away. In both match environments models predicted that teams free kick accuracy was greatest in the defending 3rd and the lowest in attacking 3rd midfielders were found to have the highest free kick accuracy with strikers the least. Higher ranked teams were also found to have the highest free kick accuracy. The estimated model for free kick accuracy at both home and away from home can be seen in Table 7.8. The table shows that for free kick accuracy; team ability, pitch zone and playing position significantly improved the model fit.

Table 7.8. Estimated models for free kick accuracy recorded as a percentage.

FreeKick Accuracy Home			FreeKick Accuracy Away		
Fixed Effects	Coefficient	SE	Fixed Effects	Coefficient	SE
Constant	0.508	0.033	Constant	0.555	0.034
Middle 3rd	0.378	0.024	Middle 3rd	0.345	0.026
Defending 3rd	0.482	0.033	Defending 3rd	0.408	0.035
Midfielder	0.004	0.023	Midfielder	-0.020	0.024
Striker	-0.106	0.049	Defender	-0.154	0.050
Goal Keeper	-0.311	0.029	Goal Keeper	-0.305	0.030
Team Ability	-0.010	0.002	Team Ability	-0.012	0.002
Random Effects	Variance	SE	Random Effects	Variance	SE
Between Game (Repeat)	0.150	0.005	Between Game (Repeat)	0.159	0.006
Within Game (Match ID)	0.009	0.003	Within Game (Match ID)	0.003	0.002

Notes. Independent intercepts estimates (Centred at Goal Difference 0) for each playing position (reference defender), pitch location (reference attacking 3rd), team ability (centred at 10) and opposition ability (centred at 10).

It is possible to calculate the performance of players of different playing positions, in different pitch locations, for different ranked teams, using the coefficients from Table 8.7. The prediction equation for free kick accuracy playing at home, in the middle 3rd, for a striker playing for a team ranked 10th in all goal differences is: Constant + (β_1 * middle 3rd) + (β_2 *striker) + (β_3 * team ability rank 10) which is: 0.508 + (0.378) + (-0.106) + (-0.010*9) = 0.69. Resulting in a free kick accuracy of 69.0%. Figure 7.6 displays the predicted changes in free kick accuracy for playing position, pitch location and team ability for matches played at both home and away from home.

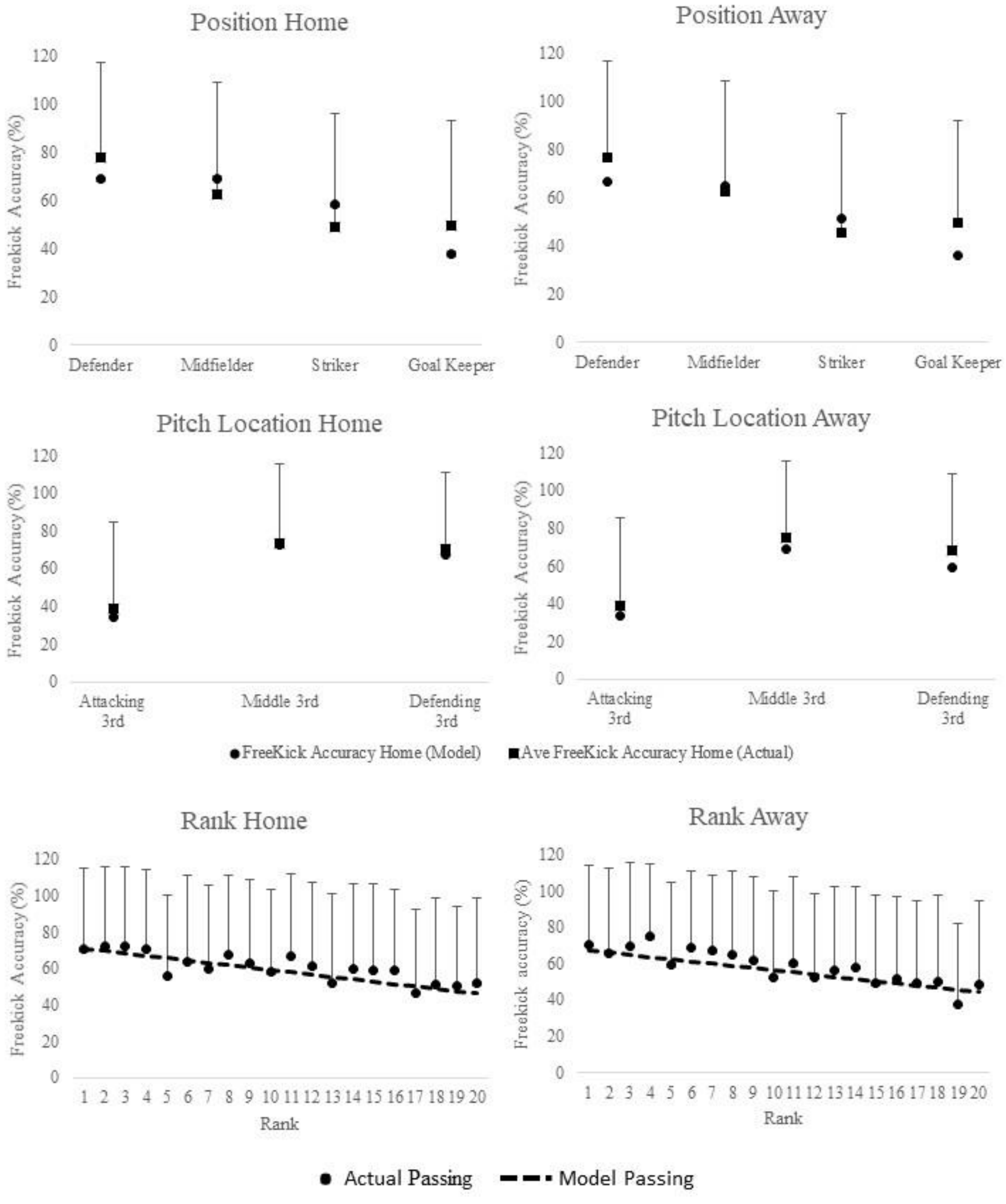

Figure 7.6: Freekick Accuracy (%) during match-play in English Premier League across playing position, pitch location and team ability. Curves are based on predicted passing accuracies from multi-level models of longitudinal data. Points are based on the 'raw' freekick accuracy data (mean ± SD). Data are presented by playing position, pitch location and team ability playing both at home and away during match-play.

7.5 Discussion – Technical Performance Factors

The aim of the present study was to investigate the effect of playing position, pitch location, team ability and opposition ability on the technical performance of English Premier League players across various goal differences (GD). The results suggested that passing accuracy (when playing both at home and away) and corner accuracy (when playing away from home) changed systematically with differences in GD in a non-linear manner and there was significant difference between matches, specifically teams showed higher passing accuracies in extremes of GD (e.g., -5 and +5) and the lowest when winning by only a smaller number of goals (e.g., +1 to +3). On the other hand teams were found to have the lowest corner accuracy (away from home) when losing by a small margin (e.g., 1 to 2 goals). Although free kick accuracy was varied across pitch location, playing position and team ability no association was found with goal difference. Crossing accuracy was not found to vary across goal difference or any of the temporal factors considered in the model.

7.5.1 Score line/Goal Difference

In general, predictive modelling suggested that passing accuracy increased as GD increased either positively (scoring team) or negatively (conceding team) across all playing positions and pitch locations. At home this increase in passing accuracy was greater when teams conceded goals than when teams scored (e.g., passing accuracy was higher at -4 than +4). Away from home the increase was similar whether teams scored or conceded. The lowest pass accuracy was seen when teams had a small lead specifically a GD of +2 at home and +1 away from home. A number of contrasting results have been highlighted regarding the effect of score line on technical performance variables with studies finding both a winning score line (Evangelos et al., 2014; Grant et al., 1999; Jankovic et al., 2011; Kapidzic et al., 2010; Reed,

2004) and losing score line promoting enhanced play specifically with regards possession and passing success (Lago-Penas and Dellal, 2010; Lago, 2009; Bloomfield et al., 2005; Jones et al., 2004; Lago and Martin, 2007). This may explain why at extremes of GD (-3 /+3 and greater), accuracies were similar especially for passing accuracy and corner accuracy away from home (e.g., different teams may react differently to different score lines as shown in the contrasting results of previous studies). Lago-Penas & Dellal (2010) and Lago (2009) found that as teams extend their lead they tend to revert to a counterattack or direct style of play, resulting in a reduction in the number of passes in the middle third of the pitch as play is confined to the attacking and defending thirds. Teams have also been found to increase their possession when in a losing state suggesting that they attempt to work harder to get back in the game (Bloomfield et al., 2005; Jones et al., 2054; Lago and Dellal, 2010; Lago and Martin, 2007; Sasaki et al., 1999). Alder's (1981) theory suggests that once teams have gained positive momentum through scoring or performing well, they start to 'cruise' in an attempt to economise efforts and eventually coast when the goal to be achieved or is within reach, supporting the lowest accuracy seen as teams increased their lead in the current study. Taylor et al. (2008) also found that the number of successful passes was higher when losing than when winning, although only one team was analysed for the duration of the 40 matches included. There have also been numerous studies which have reported that a losing match status was associated with greater ball possession (thus suggesting greater passing accuracy) (Lago and Martin, 2007; Lago, 2009; Lago-Penas and Dellal, 2010).

The term negative facilitation has often been used to describe when teams increase their efforts after failure (e.g. conceding a goal) to overcome negative momentum and get themselves back in the game and could explain the increase in passing seen in the current study as teams concede more goals. In contrast to this, positive inhibition is said to explain when teams reduce their effort after periods of success, thus describing the reverse as teams reduce their passing accuracy as they score (Cornelius et al., 1997; Perreault et al., 1998). These contrasting results may explain why for passing accuracy in the current study, both winning and losing by a large margin were found to have the highest passing accuracy, compared to when the GD was close. Using a more sensitive method for measuring score line (-5 to +5) and including a complete season of games may explain why the current study found that both a winning by a large amount (e.g., goal difference of +3 onwards) and losing (e.g., a goal difference of -1 onwards) score line elicited a higher passing accuracy, where teams change tactics depending on the size of the goal difference. This also supports why the lowest passing accuracy occurred when teams were leading by only a goal or 2 (e.g., reverting back to a counterattack style of play to protect their lead, but once the lead was well established +3 teams start to increase passing accuracy again) (Lago-Penas & Dellal, 2010; Paixao et al., 2015).

Corner accuracy, when playing away from home was also found to increase at extremes of goal difference (e.g., as teams either extended their lead or conceded more goals). The lowest corner accuracy was reported when the GD was close (e.g., +/- 1 goal). Corner accuracy was also found to increase more rapidly as teams scored goals as opposed to conceding goals. Delgado-Bordonau et al. (2013) found teams demonstrate higher averages for offensive variables when they are winning; supporting the increase in successful corners as teams increased their lead. Is it plausible however, that higher successful rates are a function of a team's superior ability, (hence the winning state) rather than an effect of the match status. Especially as research has also found reductions in attacking variables when teams are in a winning score line (Lago-Penas & Dellal, 2010; Paixao et al., 2015). The nature of definitions used for score line could explain contrasting results, as most studies have considered score line as an overall status rather than by how many goals a team are winning or losing by.

Although the score line was not found to affect; free kick accuracy both at home or away or corner accuracy playing at home, a number of the temporal factors were significant predictors of technical performance in the respective models and therefore will be discussed later.

The effects of score line were similar whether teams were playing at home or away from home, in terms of significant performance predictors, although teams generally performed better at home (e.g., higher passing, corner, cross, free kick accuracy). This is in support of previous research (Bloomfield et al., 2005; Jones et al., 2004; Lago & Martin, 2007; Thomas et al., 2004; Taylor et al., 2008; Tucker et al., 2008) who found home teams had greater possession than their opponents across a range of abilities. Tucker et al. (2005) and Taylor et al. (2010) also suggested that home teams tended to perform a higher number of attacking actions (goal scored, shots on goal, passes, crosses etc.) which is not surprising given research investigating match location effects has suggested that the home team have a number of advantages over the visiting team (Carling et al., 2005; Tucker et al., 2005). Home advantage has also been found to produce triggers for positive momentum (e.g. crowd effects) (Agnew & Carron, 1994; Harville & smith, 1994) as supporters are typically in a win frame (e.g. focused on achieving success), thus motivate teams to perform (Briki et al., 2015), further supporting the findings of the current study.

7.5.2 Playing Position - Technical Factors

According to the predictive models, playing position influenced passing accuracy both at home and away across all GD’s. Midfielders performed more accurate passes when playing at both home and away from home than either strikers (10.8% less at home and 7.8% less away from home than midfielders) or defenders (1.6% less at home and 2.5% less away from home). This was consistent across all GD’s.

Although research investigating technical performance differences between positions is scarce, especially in different score line states Redwood-Brown et al. (2012) did find midfielders and defenders made more passes than attacking players in a case study of one English Premier League team. It was thought attackers maybe less accurate as they have less at stake, if a defender makes a bad pass their error could lead to the opponents scoring, whereas attacking players are able to attempt riskier options in their own attacking third (Redwood-Brown et al., 2012; Ridgewell, 2011). Redwood-Brown et al. (2012) also found passing accuracy varied within position (e.g., some midfielders performed better when losing whereas others better when winning). Due to the association between score line, passing accuracy and playing position, there is clearly a need to investigate the performance of individual players in relation to technical performance factors such as passing accuracy. This would enable managers and coaches to apply effective strategies when in each match situation as well as picking the most appropriate team for the predicted match outcome, especially as Redwood-Brown et al. (2012) suggested, some players perform better when chasing a lead whereas others like to defend a lead.

Similar to Taylor et al. (2008) no differences between playing positions were found for corner success rate and cross success rate. The lack of difference between playing position and cross accuracy were also in contrast to Evangelos et al. (2014). Evangelos et al. (2014) found midfielders decreased the number of crosses made as they increased their positive goal difference but did not decrease the number of crosses made as they conceded goals (e.g. from a level score no decrease in cross count was seen as teams conceded). They also found winners and losers of short-range results (less than one goal difference) had higher rates of corners than wide range results (3 goal difference or more). Thus suggesting teams, who are losing by a small margin, may still adopt an attacking strategy to search for an equaliser.

With regards to free-kicks, midfielders performed more successful free-kicks when playing at home than either strikers (10.9% less than midfielders) or defenders (0.4% less than midfielders). Away from home it was defenders who performed the most free-kicks closely followed by midfielders (2.2% less than defenders) with strikers performing the least (15.4% less than defenders).

7.5.3 Pitch Zone

Both passing accuracy and free kick accuracy were found to vary across pitch location although free-kicks were not affected by goal difference. Teams recorded the highest passing accuracy both at home and away from home in the middle third ahead of both the defending third (16.3% less at home and 9.7% less away from home) and attacking 3rd (9.3% less at home and 3.1% less away from home). Although research investigating the interaction of score line and pitch locations is scarce, Lago (2009) found teams passing accuracy was greatest in the middle third with the worst passing accuracy occurring in the defending third similar to the current study. Lago (2009) also found teams changed the amount of time spent in each pitch zone depending on the score line, e.g., when teams were behind they spent more time in the attacking third than when in the lead suggesting teams alter their tactics depending on the evolving score. Research has also suggested (Hughes & Franks, 2005; Lago & Martin, 2007) that successful teams are less likely to deviate from their strategy than unsuccessful teams regardless of the score line and thus possession across pitch location does not change. James et al. (2002) outlined that teams react to the opposition strategy rather than dictating their own, although the absence of opposition ability in any of the predicting models in the current study suggests performance is more closely related to other factors (e.g. team ability, GD, position etc.)

The current study found that teams higher in ability performed better than lower ability teams across a number of the variables investigated across all goal differences. It has been suggested that higher ranked teams are more likely to react to changes in play compared to lower ranked teams (Lago-Penas & Dellal., 2010). Therefore, future research would benefit from linking observed strategy (e.g. formation/style of play) with score line and thus performance changes in order to establish how teams respond and thus perform across different GD's. In contrast to passing accuracy, free-kicks were most accurate in the defending third than either the attacking (48.1% less at home and 40.8% less away from home) and middle third (10.3% less at home and 6.3% less away from home). Possibly, when in the defending third, there is more at stake if the free kick is not cleared by the defending team. In the defending third the opposition is most likely to be down field in anticipation of the ball being cleared as opposed to the attacking third where attacking teams are likely to be setting up for a shot on target. Although pitch location was added to the predictive models of both cross accuracy and corner accuracy it was not found to have a significant effect on these technical performance variables and was thus not included in the final models.

7.5.4 Team Ability

Team ability was found to predict passing and freekick accuracy at home and away as well as corner accuracy away from home. With all three technical performance variables, as expected, higher ranked teams were more accurate than lower ranked teams. This equated to 0.9% less accurate per rank for passing at home, 0.6% less accurate per rank for passing away from home, 1.0% less accurate per rank for free-kicks at home, 0.8% less accurate per rank for free-kicks away from home and 1.2% less accurate per rank for corners away from home. Although studies (Hughes & Franks, 2005; Jones et al., 2004; Lago & Martin, 2007; Taylor et al., 2008) have found higher ranked teams perform significantly better than lower ranked teams this has generally been limited to passing accuracy and/or possession strategies. These studies have generally found successful teams have longer possessions (Bloomfield et al., 2005; Lago, 2009) and perform more successful passes (due to increase in possession) than unsuccessful teams (Jankovic et al., 2011, Szawarc, 2007; Reed, 2004; Berkris et al., 2014). Hughes and Franks (2005) and Harrop and Nevill (2014) found teams of lower ability find it harder to achieve success using a possession style of play, potentially due to their inability to keep hold of the ball, and thus adopt more of a direct style of play which is indicative of a lower passing accuracy. Lago-Penas and Dellal (2010) found that higher ranked teams had less variation in performance than lower ranked teams suggesting that higher ranked teams are able to maintain their performance regardless of the environment and situation (playing at home or away/losing, winning, drawing). They also suggested that teams tended to employ different tactics depending on the characteristics of the players, team formation and philosophy of the team. This may explain why teams in the current study decreased their passing accuracy once they had a convincing lead, adopting a counterattack style to protect their lead. Losing teams on the other hand increase their passing accuracy as GD increased, suggesting they maintain possession and attacking play in search for goals (Jones et al., 2004).

In support of previous research (Taylor et al., 2008), set plays (corners, free-kicks) did not vary as a function of the situation and maintained a stable accuracy across all GD’s. Perhaps highlighting that teams higher in ability are more likely to maintain their strategy regardless of the evolving score line.

7.5.5 Opposition Ability

Opposition ability was not found to influence any of the technical performance variables across different score line states. This is not surprising given that the majority of studies investigating successful and unsuccessful teams have found that winning teams show greater passing accuracy regardless of the level of opposition played (Bloomfield et al., 2005; Lago, 2009; Jankovic et al., 2011, Szawarc, 2007; Reed, 2004; Berkris et al., 2014).

Taylor et al. (2008) also found no effect of quality of opposition on the technical aspects of performance (aerial challenges, clearances, passes, crosses, dribbles interceptions, tackles, free-kicks, throw ins, corners, shots on target). However, it was suggested that their strong-weak dichotomy was not sensitive enough to show changes in behaviour of the one team used. The sensitive opposition definition used in the current study continue to further cement that opposition ability does not affect technical performance variables regardless of score line. The findings suggest that teams may alter their game strategy (e.g. number of passes, crosses made etc.) in relation to the standard of opposition played but not necessarily their performance accuracy of these technical variables. Future research should therefore consider both frequencies and accuracies of technical performance variables in relation to score line in order to establish how the opposition strategy may effect team's performance. Considering the psychological impact of important game events (such as goals) is also important, as weaker opponents generally perceive events to have a bigger impact on performance than stronger teams (Miller & Weinberg 1991). This is especially important for managers and coaches as negative events (such as conceding goals) have been reported to have a much greater impact on performance than positive events of the same value (Baumeister et al., 2001; Gernigon et al., 2010) and thus could influence team performance as shown in the findings of Chapter 5.

STUDY 7B – EFFECTS OF OPPOSITION ABILITY, TEAM ABILITY, PLAYING POSITION AND PITCH LOCATION ON THE ACTIVITY PROFILES OF ENGLISH PREMIER LEAGUE SOCCER PLAYERS IN DIFFERENT SCORE LINE STATES.

7.6 Methods

7.6.1 Data Set

As with chapter 7a, a total of 376 games played during the 2011-2012 English Premier League season were used in the current study. The same situational variables from study 8a were used for team and opposition ability, player position and pitch location. Consent to use the data for research purposes was given by both Venatrack Ltd and the English Premier League (via Venatrack contractual terms).

7.6.2 Data Gathering

Visual-AI (Venatrack, UK) technology was used to track the players in the current study in the same way as the previous study. This allowed players to be monitored in real time (at 25 Hz) providing identification through recognition algorithms (based on x,y,z coordinates for hands, feet, head and the pelvis & shoulder lines; Venatrack, UK). A full explanation of the system and the data gathering procedure can be seen in the validation study (chapter 6).

7.6.3 Performance Indicators (Activity Profiles)

For each player the total playing time was used to calculate how much relative time the player spent in each activity zone. Initially the zones were presented as incremental categories and then further categorised into high speed running and sprinting based on previous literature (Di Salvo et al., 2006; Clark, 2010). High speed activity in Chapter 4 was defined as *"the total distance covered at 4 $m.s^{-1}$ or faster (measured in $m.s^{-1}$)"*. The specific threshold value of 4 $m.s^{-1}$ was justified because the movement included sideways and backwards movement, movement with the ball as well as forward movement. The percentage of time spent moving at this speed or faster averages about 7-8% of match time which is comparable with the amount of match time spent performing high speed activity in previous time motion studies of soccer (Bangsbo et al., 1991; Clark, 2010). Previous studies have avoided using higher speed thresholds due to the greater variability of time spent moving at higher speed ranges than lower speed ranges (Gregson et al., 2010). This has generally been associated with inaccuracies in the measurement systems. The measurement system Venatrack used in the current study has been shown valid and reliable at speeds in excess of 8$m.s^{-1}$ (Chapter 6). Therefore, high speed running was defined as *"the total distance covered at 5.5$m.s^{-1}$ or faster"* in line with recent research (Miñano-Espin et al., 2017) which have established this as a represented threshold for high speed activity in professional soccer players. A sprinting threshold was also included as a work rate performance measure. Sprinting was defined as *"the total distance covered at 8$m.s^{-1}$ or faster"*. This resulted in three values for each player; total distance covered, total distance covered in high speed zone (5.5$m.s^{-1}$) and total distance covered in sprinting zone (8$m.s^{-1}$).

7.6.4 Data Analysis

Data analysis in this study followed the same process of multi-level modelling as study 7a (see section 7.3.4). Each activity profile (total distance covered, high speed distance covered, sprint distance covered) performance characteristic was modelled in turn. The effect of score line defined by GD (centered at 0 goals) on each of the three activity profiles of players was modelled. GD was introduced to the model as a quadratic term to establish whether the data would be better explained by a curve. Subsequently, the effect of playing position, the zone on the pitch the activity took place; the time the goal was scored; the opposition's ability and the team's ability were added to the model (fixed components). These fixed components were accepted or rejected on the basis of firstly, changes in the model fit; as indicated by a difference in log likelihood between models, and the effect of the variable on the activity profiles of players, indicated by z-scores. Statistical significance was accepted at the 95% confidence level ($p < 0.05$). Mean ± SD were used to describe the average and variability of the activity profile data.

7.7 Results

A total of 570 players across 376 games were analysed, with the maximum number of appearances from one player being 38 games and the minimum 1 game. Table 7.9 presents the activity profiles for each of the teams and table 7.10 presents activity profiles across the three match statuses (winning, drawing, losing). The average distance covered per player per game (Mean ± SD) was 10020.2m ± 141.7m, with players covering on average 395.6 ± 33.9m of high speed running per game and 107.0 ± 21.3m sprinting distance.

Tables 7.11 and 7.12 present the final multi-level models for the development of the match-running performance characteristics of total distance covered, high speed distance covered and sprint distance covered for players of different playing positions, in different pitch zones, across different abilities and against different standards of opposition of players in the 376 English Premier League games analysed. The random part of the multi-level models predicted that the fit of all models was improved when the intercept was allowed to vary randomly ($p < 0.05$), as indicated by the between game standard error displayed in Tables 7.11

and 7.12. Only variables that were significant when added to the model are presented in the tables.

Table 7.9 Mean activity profiles for each club included in the analysis.

Team Ranked	Number Games Played	Number of Players Included	DC/90mins	DC/Min	HSR/90mins	HSR/Min	SD/90mins	Sprint/Min
1	38	32	10031	111.5	400	4.4	128	1.4
2	38	27	9965	110.7	393	4.4	118	1.3
3	38	31	9908	110.1	415	4.6	134	1.5
4	38	30	9814	109.0	413	4.6	139	1.5
5	35	29	9967	110.7	403	4.5	87	1.0
6	38	30	10299	114.4	419	4.7	112	1.2
7	37	29	9984	110.9	370	4.1	86	1.0
8	37	25	9915	110.2	397	4.4	116	1.3
9	38	26	10031	111.5	336	3.7	99	1.1
10	38	32	10239	113.8	409	4.5	120	1.3
11	37	27	10099	112.1	466	5.2	109	1.3
12	38	28	10260	114.0	419	4.7	103	1.1
13	38	36	9880	109.8	377	4.2	104	1.2
14	38	23	10072	111.9	337	3.7	72	0.8
15	38	28	9977	110.9	452	5.0	150	1.7
16	38	25	10071	111.9	406	4.5	113	1.3
17	38	31	9896	110.0	364	4.0	80	0.9
18	37	25	9923	110.3	387	4.3	96	1.1
19	38	24	9855	109.5	345	3.8	74	0.8
20	37	32	10220	113.6	404	4.5	99	1.1
TOTAL	**376**	**570**	**10020.2**	**111.3**	**395.6**	**4.4**	**107.0**	**1.2**
SD		3.3	141.7	1.6	33.9	0.4	21.3	0.2

NB: DC = Distance Covered, HSR = High Speed running, SD = Sprint distance

Table 7.10 Mean Activity Profiles for each Club included in the Analysis in a winning, drawing and losing score line state.

			WINNING						DRAWING						LOSING					
Team	Number Games Played	Number of Players Included	DC/ 90 mins	DC/ min	HSR/ 90 mins	HSR/ min	Sprint DC /90 mins	Sprint/ min	DC/90 mins	DC/min	HSR/ 90 mins	HSR/ min	Sprint DC /90 mins	Sprint/ min	DC/90 mins	DC/min	HSR/ 90 mins	HSR/ min	Sprint DC /90 mins	Sprint/ min
1	38	32	9885	110	423	4.7	170	1.9	10332	115	397	4.4	98	1.1	9896	110	373	4.1	118	1.3
2	38	27	9822	109	403	4.5	136	1.5	10295	114	387	4.3	88	1.0	9827	109	386	4.3	126	1.4
3	38	31	9777	109	424	4.7	138	1.5	10078	112	371	4.1	114	1.3	9890	110	468	5.2	161	1.8
4	38	30	9600	107	440	4.9	157	1.7	10153	113	403	4.5	115	1.3	9685	108	387	4.3	148	1.6
5	35	29	9801	109	396	4.4	95	1.1	10338	115	396	4.4	78	0.9	9693	108	431	4.8	91	1.0
6	38	30	10266	114	440	4.9	127	1.4	10540	117	400	4.4	93	1.0	10008	111	416	4.6	125	1.4
7	37	29	9797	109	382	4.2	85	0.9	10218	114	356	4.0	85	0.9	9929	110	371	4.1	91	1.0
8	37	25	9555	106	380	4.2	120	1.3	10199	113	405	4.5	100	1.1	9928	108	404	4.5	139	1.5
9	38	26	9920	110	355	3.9	98	1.1	10426	116	317	3.5	93	1.0	9684	108	336	3.7	109	1.2
10	38	32	10073	112	424	4.7	144	1.6	10385	115	384	4.3	79	0.9	10239	114	429	4.8	168	1.9
11	37	27	9806	109	325	3.6	200	2.2	10530	117	570	6.3	105	2.4	9981	111	369	4.1	119	2.6
12	38	28	10056	112	383	4.3	106	1.2	10505	117	436	4.8	106	1.2	10199	113	445	4.9	94	1.0
13	38	36	9796	109	413	4.6	131	1.5	10005	111	346	3.8	68	0.8	9807	109	371	4.1	135	1.5
14	38	23	9888	110	349	3.9	74	0.8	10366	115	338	3.8	69	0.8	9905	110	308	3.4	75	0.8
15	38	28	9691	108	393	4.4	102	1.1	10340	115	449	5.0	185	2.1	9869	110	542	6.0	150	1.7
16	38	25	9929	110	414	4.6	106	1.2	10179	113	387	4.3	103	1.1	10118	112	429	4.8	147	1.6
17	38	31	9791	109	322	3.6	104	1.2	10188	113	435	4.8	60	0.7	9647	107	339	3.8	66	0.7
18	37	25	9652	107	362	4.0	112	1.2	10267	114	400	4.4	78	0.9	9893	110	400	4.4	101	1.1
19	38	24	9854	110	377	4.2	80	0.9	9967	111	317	3.5	63	0.7	9730	108	342	3.8	84	0.9
20	37	32	10110	112	351	3.9	80	0.9	10482	117	405	4.5	88	1.0	10078	112	452	5.0	135	1.5
TOTAL	**376**	**570**	**9853.5**	**109.5**	**387.6**	**4.3**	**118.1**	**1.3**	**10289.6**	**114.3**	**394.9**	**4.4**	**93.3**	**1.1**	**9900.2**	**109.9**	**399.8**	**4.4**	**119.1**	**1.4**
SD		3	174.7	1.9	35.6	0.4	32.6	0.4	166.8	1.9	54.9	0.6	26.9	0.4	169.6	1.9	54.2	0.6	29.4	0.4

NB: DC = Distance Covered, HSR = High Speed running, SD = Sprint distance

Table 7.11 Estimated models for total distance covered per minute both home and away.

Distance Covered – Home		
Fixed Effects	Coefficient (m)	SE (m)
Constant	118.527	0.646
Goal Difference	0.601	0.189
Goal Difference^2	-0.462	0.072
Midfielder	7.275	0.554
Striker	1.116	0.557
Time Scored	-0.069	0.01
Defending 3rd	-7.884	0.558
Middle 3rd	-12.082	0.553
Random Effects	Variance	SE
Between Game (Repeat)	349.365	6.146
Within Game (Match ID)	27.199	3.589

Distance Covered – Away		
Fixed Effects	Coefficient (m)	SE (m)
Constant	123.625	1.088
Goal Difference	1.388	0.217
Goal Difference^2	-0.362	0.083
Midfielder	6.75	0.601
Striker	0.433	0.605
Time Scored	-0.087	0.011
Defending 3rd	-11.436	0.606
Middle 3rd	-14.081	0.602
Opposition Ability	-0.204	0.078
Random Effects	Variance	SE
Between Game (Repeat)	407.802	7.215
Within Game (Match ID)	44.289	5.217

Notes. Intercept estimates at (Goal Difference 0) for each playing position (reference defender), pitch location (reference attacking 3rd), team ability (rank 1), opposition ability (rank 1) and time scored (minute 1).

Table 7.12 Estimated models for total high speed distance covered per minute both home and away.

High Speed Running – Home		
Fixed Effects	Coefficient (m)	SE (m)
Constant	6.654	0.238
Defending 3rd	-1.971	0.174
Middle 3rd	-4.011	0.168
Opposition Ability	-0.035	0.017
Time Scored	0.011	0.003
Random Effects	Variance	SE
Between Game (Repeat)	29.707	0.554
Within Game (Match ID)	1.279	0.232

High Speed Running – Away		
Fixed Effects	Coefficient (m)	SE (m)
Constant	7.376	0.289
Goal Difference	0.21	0.103
Goal Difference^2	-0.112	0.042
Defending 3rd	-3.221	0.302
Middle 3rd	-4.904	0.294
Time Scored	0.01	0.005
Random Effects	Variance	SE
Between Game (Repeat)	88.651	1.664
Within Game (Match ID)	6.298	0.904

Notes. Intercept estimates at (Goal Difference 0) for each playing position (reference defender), pitch location (reference attacking 3rd), team ability (rank 1), opposition ability (rank 1) and time scored (minute 1).

7.7.1 Distance Covered

Modelling indicated that the distances covered at both home and away in relation to GD were non-linear and best described with a quadratic term. The estimated models of distance covered for home and away teams that included GD as an independent factor can also be seen in Table 8.10. The table shows that for distance covered at home; GD, GD^2, playing position, time scored and pitch zone significantly improved the model fit. For distance covered away from home, the same was true, with the addition of opposition ability. It is possible to calculate the performance of players, playing either, at home or away using the coefficients from Table 7.12. For example, the prediction equation for distance covered at home for a midfielder in the middle 3rd of the pitch, who are in a +2 GD at half time (45 minutes) is: Constant + (β_1 * GD centered at 0) + (β_2 * GD centered at 0^2) + (β_3 * midfielder) + (β_4 * middle 3rd) + (β_5 * time scored) which is: 118.53+ (-0.601 * 2) + (-0.462 * 2^2) + (7.275) + (-12.082) + (-0.069 * 45) = 107.6 $m \cdot min^{-1}$ (9681.1m per 90 min. game).

7.7.2 High Speed Running

Modelling indicated that high speed running distance covered away from home in relation to GD was non-linear and best described with a quadratic term. Goal difference was not found to significantly influence distance covered whilst playing at home. The estimated models of high speed distance covered for home and away teams can be seen in Table 7.12. The table shows that for high speed distance covered at home, pitch zone, opposition ability and time scored significantly improved the model fit. For high speed running distance covered away from home, GD, GD^2, the time goals were scored and pitch zone significantly improved the model. The prediction equation for high speed distance covered away from home for all players in the middle 3rd of the pitch, who are in a +2 GD at half time (45 minutes) is: Constant + (β_1 * GD centered at 0) + (β_2 * GD centered at 0^2) + (β_3 * middle 3rd) + (β_4 * time scored) which is: = 7.376 + (0.21 * 2) + (-0.112 * 2^2) + (-4.904) + (0.001 * 45) = 2.9 $m \cdot min^{-1}$ (260.5m per 90 min. game).

7.7.3 Sprint Distance

Modelling indicated that sprint distance covered at both home and away was not affected by GD. In fact the only parameter that was found to explain this activity was pitch zone and time scored and only when playing away from home. The prediction equation for sprint distance covered away from home for all players in the middle 3rd of the pitch, who score at half time (45 minutes) is: Constant + (β_3 * middle 3rd) + (β_4 * time scored) which is: 2.742 + (-2.002) + (0.015 * 45) = 1.42 m·min^{-1} (127.4m per 90 min. game).

7.7.4 Goal Difference Effects

Figures 7.7 – 7.9 display the predicted goal difference related changes in activity (per player per 90 minutes) for each playing position, pitch zone and opposition ability (ranked 1st, 10th and 20th) respectively. Tables 7.13 – 7.16 display the mean ± SD of match-running performance for each of the categories (playing position, pitch location, team ability rank and opposition ability rank).

Models predicted that for all playing positions and across all pitch zones, the total distance covered both at home and away from home was greatest when GD was close (-1 to +1) decreasing towards the extremes of GD (+5 or -5). Players also tended to decrease their activity more when losing heavily as opposed to winning, this was more prominent when playing away from home. Goal difference was only found to predict high speed running when playing away from home showing a similar pattern to total distance covered. Teams covered less distance (both total distance covered away and high speed distance at home) when playing lower ranked teams (e.g. rank 20), whereas in comparison a team's own ability was not found to predict any physical performance across GDs. Although time scored appeared in the majority of predictive models, its impact was small. Across all performance parameters (except sprint distance at home) models predicted that the later into the game a goal was scored the less total distance, high speed distance and sprint distance away from home that was covered.

Table 7.13 Mean ± SD match-running performance characteristics by goal difference related to position and match location (home or away).

		HOME			AWAY		
Goal Difference	Playing Position	Total Distance/ 90 minutes (m)	High-Speed Distance / 90 minutes (m)	Sprint Distance/ 90 minutes (m)	Total Distance/ 90 minutes (m)	High-Speed Distance / 90 minutes (m)	Sprint Distance/ 90 minutes (m)
-5	Striker	7658 ± 3786	561 ± 454	106 ± 116	8047 ± 2897	248 ± 220	76 ± 95
	Midfielder	8430 ± 3111	400 ± 242	97 ± 70	8485 ± 720	380 ± 281	77 ± 73
	Defender	7948 ± 2313	414 ± 279	80 ± 73	7761 ± 3059	279 ± 256	57 ± 67
-4	Striker	9232 ± 1576	545 ± 577	283 ± 280	8813 ± 2912	357 ± 217	162 ± 364
	Midfielder	9461 ± 1159	367 ± 255	92 ± 56	9177 ± 2052	389 ± 358	71 ± 77
	Defender	9059 ± 1626	414 ± 361	108 ± 186	8689 ± 2411	438 ± 597	95 ± 128
-3	Striker	9089 ± 1924	346 ± 401	233 ± 501	8973 ± 2387	351 ± 304	107 ± 164
	Midfielder	9712 ± 1809	473 ± 524	194 ± 301	9395 ± 2533	384 ± 342	102 ± 175
	Defender	9222 ± 1502	414 ± 330	114 ± 160	9120 ± 2735	386 ± 523	128 ± 176
-2	Striker	9486 ± 2680	343 ± 419	97 ± 124	9440 ± 2530	376 ± 662	185 ± 943
	Midfielder	10076 ± 1766	395 ± 368	108 ± 166	9973 ± 2167	359 ± 330	134 ± 360
	Defender	9585 ± 1831	407 ± 359	106 ± 133	9684 ± 2027	396 ± 475	456 ± 1328
-1	Striker	9475 ± 1982	367 ± 511	118 ± 371	9372 ± 2004	352 ± 498	138 ± 422
	Midfielder	10212 ± 1824	363 ± 384	147 ± 683	10080 ± 1749	360 ± 285	96 ± 195
	Defender	9633 ± 1641	345 ± 334	107 ± 133	9601 ± 2007	389 ± 616	151 ± 928
0	Striker	10058 ± 1665	393 ± 532	104 ± 293	9928 ± 2858	473 ± 700	116 ± 254
	Midfielder	10682 ± 1375	389 ± 317	134 ± 686	10640 ± 1632	398 ± 397	118 ± 844
	Defender	10055 ± 1383	352 ± 289	153 ± 485	10060 ± 1691	371 ± 659	128 ± 627
1	Striker	9926 ± 1626	426 ± 439	145 ± 249	9898 ± 1333	414 ± 563	128 ± 166
	Midfielder	10383 ± 1536	414 ± 728	253 ± 269	10594 ± 1621	438 ± 583	130 ± 315
	Defender	9774 ± 1870	398 ± 512	133 ± 170	9708 ± 1586	335 ± 393	112 ± 200
2	Striker	9866 ± 1492	426 ± 520	146 ± 194	9724 ± 1521	508 ± 552	191 ± 299
	Midfielder	10380 ± 1445	387 ± 337	87 ± 97	10396 ± 1525	438 ± 464	323 ± 1208
	Defender	9653 ± 1440	416 ± 366	112 ± 170	9780 ± 1971	422 ± 745	159 ± 336
3	Striker	9541 ± 2166	507 ± 548	157 ± 225	9791 ± 2135	652 ± 647	228 ± 214
	Midfielder	10387 ± 1607	482 ± 504	189 ± 368	10433 ± 1506	520 ± 630	200 ± 331
	Defender	9661 ± 1626	390 ± 384	163 ± 286	9946 ± 1788	414 ± 507	279 ± 638
4	Striker	9464 ± 2057	474 ± 535	137 ± 161	9126 ± 2589	519 ± 561	255 ± 472
	Midfielder	9687 ± 1835	389 ± 358	71 ± 77	10150 ± 1386	469 ± 435	165 ± 254
	Defender	9083 ± 1879	345 ± 360	125 ± 180	9730 ± 2207	348 ± 343	237 ± 280
5	Striker	9087 ± 661	330 ± 249	68 ± 79	9380 ± 2073	409 ± 232	179 ± 141
	Midfielder	9814 ± 696	480 ± 369	149.± 161	9902 ± 1535	404 ± 381	89 ± 100
	Defender	8970 ± 903	337 ± 305	97 ± 156	8941 ± 2350	310 ± 298	46 ± 28

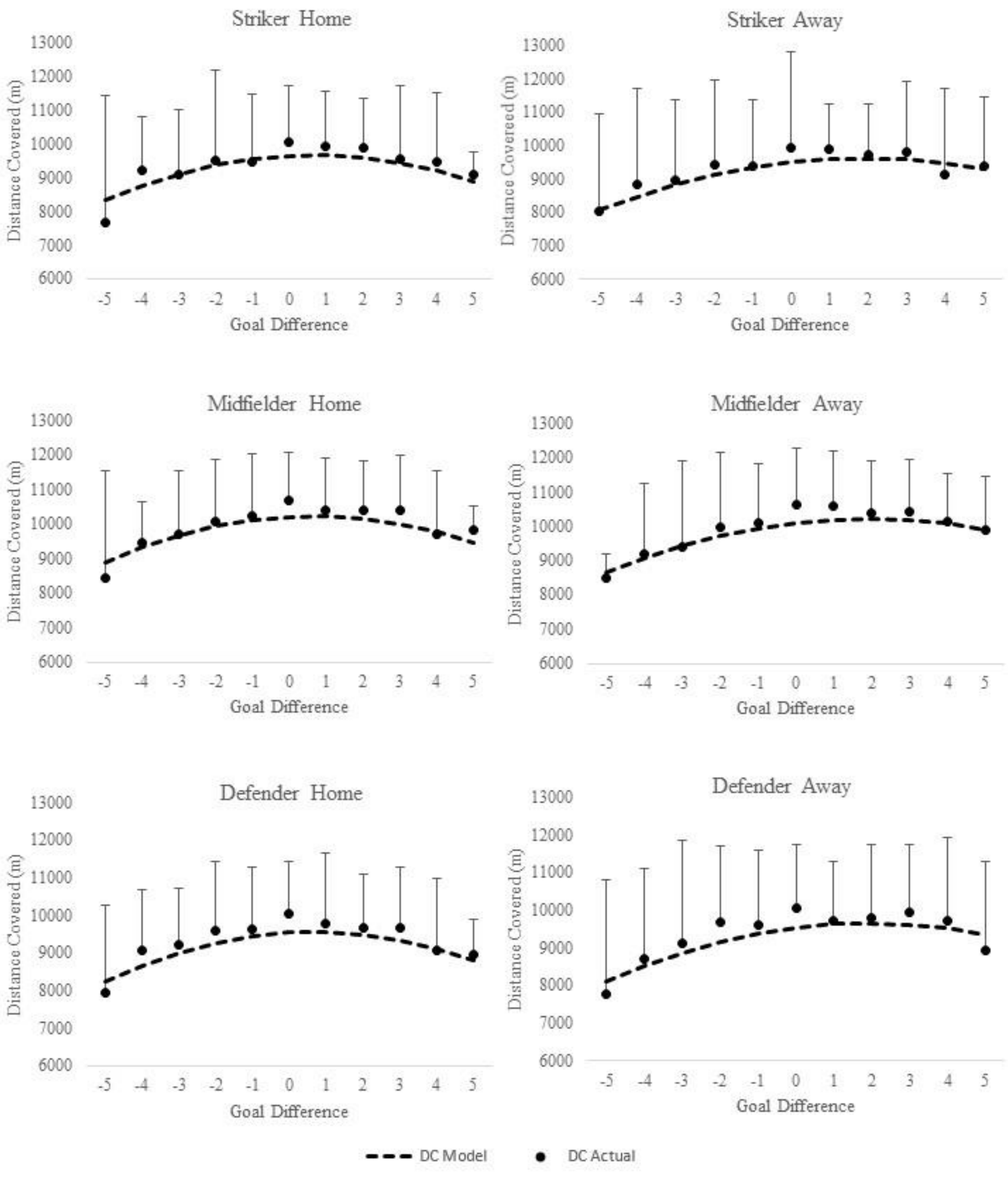

Figure 7.7: Total distance covered(m) during match-play in English Premier League across difference goal differences. Curves are based on predicted distances covered from multi-level models of longitudinal data. Points are based on the 'raw' distance covered data (mean ± SD). Data are presented by playing position both at home and away during match-play.

Table 7.14 Mean ± SD match running performance characteristics by goal difference related to pitch location and match location (home and away).

		HOME			AWAY		
Goal Difference	Pitch Position	Total Distance/ 90 minutes (m)	High-Speed Distance / 90 minutes (m)	Sprint Distance/ 90 minutes (m)	Total Distance/ 90 minutes (m)	High-Speed Distance / 90 minutes (m)	Sprint Distance/ 90 minutes (m)
	Attacking	9531 ± 1521	425 ± 186	132 ± 79	9132 ± 2200.4	417 ± 323	110 ± 157
-5	Middle	8027 ± 2471	106 ± 133	45 ± 42	8603 ± 975.6	81 ± 83	43 ± 35
	Defending	8647 ± 2276	149 ± 231	89 ± 70	9065 ± 1444.6	146 ± 125	43 ± 28
	Attacking	10313 ± 1322	511 ± 234	161 ± 173	10263 ± 1790.8	452 ± 235	130 ± 130
-4	Middle	8771 ± 1243	157 ± 130	46 ± 64	8574 ± 1690.3	128 ± 127	35 ± 60
	Defending	9186 ± 1702	268 ± 237	173 ± 186	8149 ± 2010.6	223 ± 192	68 ± 57
	Attacking	10159 ± 1759	443 ± 401	157 ± 145	10338 ± 1817.0	498 ± 412	161 ± 226
-3	Middle	9146 ± 1459	201 ± 160	114 ± 281	8993 ± 1343.2	174 ± 164	54 ± 80
	Defending	9454 ± 1955	355 ± 254	231 ± 400	9692 ± 2159.9	309 ± 201	122 ± 142
	Attacking	10554 ± 2025	469 ± 404	111 ± 139	10755 ± 1780.0	528 ± 439	207 ± 423
-2	Middle	9075 ± 1521	215 ± 155	57 ± 92	9285 ± 1266.8	216 ± 135	54 ± 80
	Defending	9540 ± 2510	413 ± 285	152 ± 177	9236 ± 1573.6	326 ± 210	120 ± 297
	Attacking	10575 ± 2149	459.± 435	117 ± 211	10586 ± 2228.1	568 ± 539	158 ± 252
-1	Middle	9300 ± 1203	219 ± 134	50 ± 74	9221 ± 1410.12	206 ± 142	51 ± 155
	Defending	9455 ± 1798	378 ± 363	124 ± 166	9259 ± 1794.5	360 ± 309	85 ± 289
	Attacking	10655 ± 1539	522 ± 354	163 ± 362	10798 ± 1907.8	587 ± 508	196 ± 358
0	Middle	9983 ± 1160	228 ± 134	45 ± 67	10023 ± 1258.7	228 ± 141	49 ± 154
	Defending	10157 ± 1699	383 ± 529	103 ± 318	10142 ± 1896.8	329 ± 295	67 ± 103
	Attacking	10679 ± 1814	658 ± 547	210 ± 273	10742 ± 1734.4	616 ± 485	219 ± 249
1	Middle	9517 ± 1244	223 ± 147	54 ± 70	9557 ± 1236.9	228 ± 157	60 ± 148
	Defending	9881 ± 1780	318 ± 331	85 ± 179	10036 ± 1746.2	334 ± 398	136 ± 382
	Attacking	10267 ± 1322	583 ± 404	182 ± 176	10769 ± 1839.4	736 ± 660	320 ± 333
2	Middle	9527 ±1219	233 ± 146	55 ± 66	9488 ± 1384.4	234 ± 171	78 ± 137
	Defending	10110 ± 1778	355 ± 564	91 ± 179	9917 ± 2176.2	333 ± 367	114 ± 214
	Attacking	10894 ± 1710	640 ± 408	222 ± 195	10819 ± 1970.1	739 ± 462	383 ± 419
3	Middle	9367 ± 1160	233 ± 145	79 ± 101	9627 ± 1348.5	286 ± 202	86 ± 96
	Defending	9832 ± 2098	380 ± 504	151 ± 343	9590 ± 1361.8	369 ± 390	121 ± 159
	Attacking	10163 ± 2211	594 ± 406	197 ± 183	10771 ± 1992.6	641 ± 382	380 ± 423
4	Middle	8874 ± 1376	219 ± 127	51 ± 49	9293 ± 1200.8	207 ± 119	69 ± 44
	Defending	9753 ± 2470	388 ± 563	71 ± 151	10034 ± 2109.5	301 ± 203	149 ± 369
	Attacking	10282 ± 1364	443 ± 279	185 ± 177	10784 ± 1126.6	544 ± 394	218 ± 130
5	Middle	8882 ± 1007	163 ± 139	39 ± 37	9341 ± 2166.0	110 ± 136	58 ± 49
	Defending	9795 ± 1135	330 ± 228	153 ± 164	9477 ± 2596.5	262 ± 146	69 ± 84

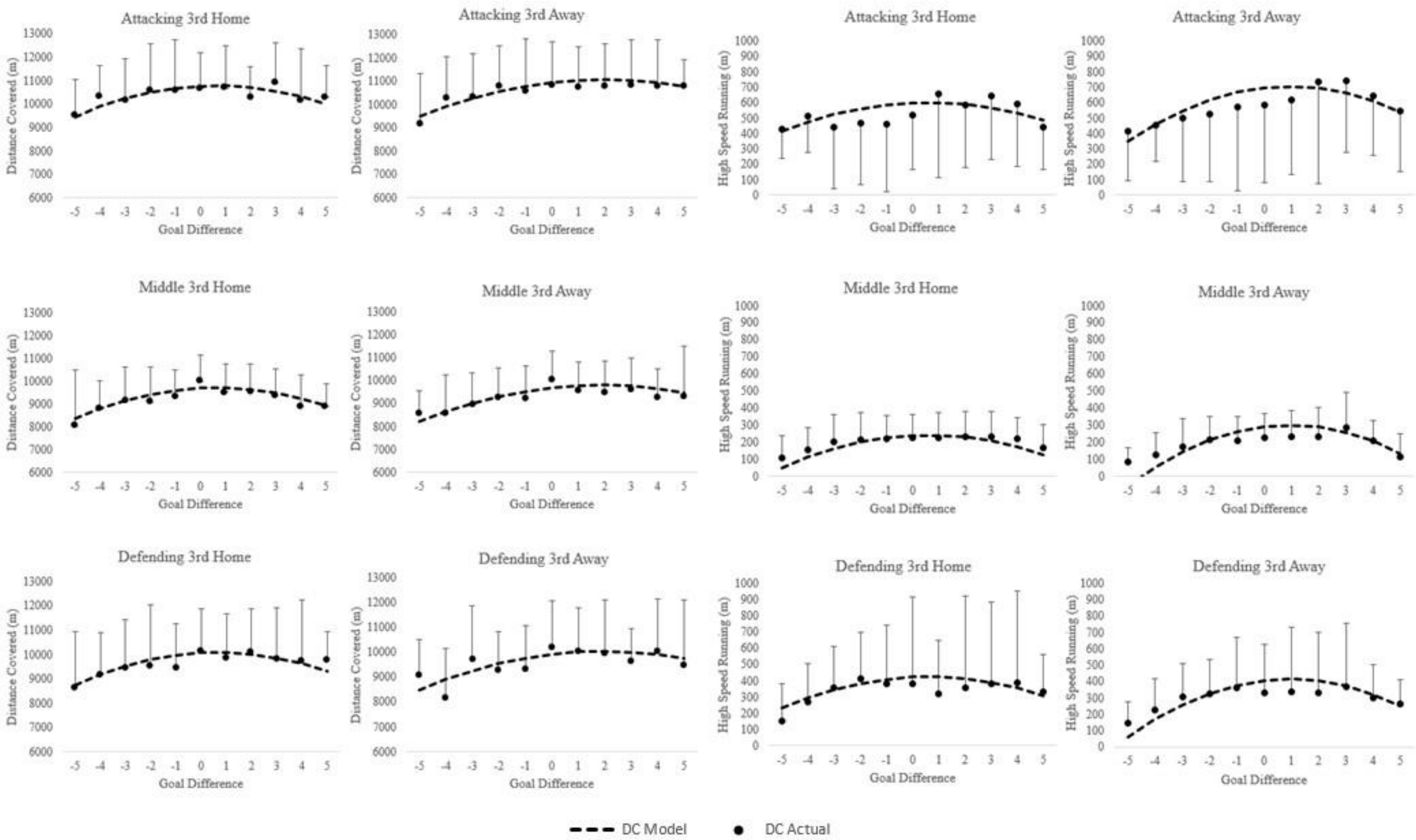

Figure 7.8: Total distance covered (m) and total high speed distance covered (m) during match-play in English Premier League across difference goal differences. Curves are based on predicted distances covered from multi-level models of longitudinal data. Points are based on the 'raw' distance covered data (mean ± SD). Data are presented by pitch location during match-play.

Table 7.15 Mean ± SD match-running performance characteristics by goal difference and opposition ability (finish position in the EPL).

		HOME			AWAY		
Goal Difference	Rank Opposition Ability	Total Distance/ 90 minutes (m)	High-Speed Distance / 90 minutes (m)	Sprint Distance/ 90 minutes (m)	Total Distance/ 90 minutes (m)	High-Speed Distance / 90 minutes (m)	Sprint Distance/ 90 minutes (m)
	Rank 1	6788 ± 3196	145.± 216	234 ± 0			
-5	Rank 10						
	Rank 20						
	Rank 1	9579 ± 2269	249 ± 299	213 ± 265	9065 ± 3059	346 ± 219	138 ± 161
-4	Rank 10	9643 ± 2700	272 ± 229	130 ± 155	9112 ± 2461	303 ± 0	0 ± 0
	Rank 20						
	Rank 1	9586 ± 1434	321 ± 231	106 ± 139	9848 ± 2033	466 ± 591	148 ± 269
-3	Rank 10	9563 ± 2233	235 ± 203	253 ± 359	10158 ± 956	426 ± 259	63 ± 58
	Rank 20						
	Rank 1	9946 ± 1417	374 ± 543	83 ± 70	10145 ± 2787	435 ± 332	128 ± 188
-2	Rank 10	10398 ± 1678	288 ± 187	165 ± 359	10396 ± 2277	334 ± 364	85 ± 89
	Rank 20				9874 ± 877	350 ± 216	99 ± 149
	Rank 1	9845 ± 1595	349 ± 350	101 ± 166	10067 ± 2442	415 ± 502	97 ± 139
-1	Rank 10	9684 ± 1317	351 ± 286	99.± 154	10102 ± 2738	277 ± 230	70 ± 73
	Rank 20	9625 ± 2287	274 ± 164	75 ± 104	9471 ± 1757	337 ± 355	62 ± 51
	Rank 1	10320 ± 1039	368 ± 224	91 ± 102	10637 ± 1562	481 ± 683	104 ± 158
0	Rank 10	10381 ± 1443	353 ± 242	75 ± 108	10153 ± 1073	340 ± 193	88 ± 123
	Rank 20	10149 ± 1359	370 ± 258	107 ± 157	10627 ± 1307	421 ± 285	120 ± 235
	Rank 1	9848 ± 2473	368 ± 306	224 ± 221	10726 ± 1862	368 ± 352	121 ± 158
1	Rank 10	10015 ± 927	314 ± 192	160 186	10557 ± 1606	482 ± 538	160 ± 186
	Rank 20	10304 ± 1542	396 ± 293	128 ± 151	10420 ± 1991	462 ± 574	186 ± 449
	Rank 1						
2	Rank 10	10039 ± 1130	346 ± 228	93 ± 81	11009 ± 1687	321 ± 233	122 ± 121
	Rank 20	10254 ± 1511	343 ± 271	174 ± 199	10224 ± 1871	436 ± 397	170 ± 254
	Rank 1						
3	Rank 10	10379 ± 1986	357 ± 293	225 ± 246			
	Rank 20	11104 ± 1749	294 ± 310	273 ± 213	10444 ± 2189	394 ± 382	258 ± 378
	Rank 1						
4	Rank 10	10600 ± 2542	315 ± 153	57 ± 26			
	Rank 20	10520 ± 1344	284 ± 225	122 ± 153	10646 ± 1369	295 ± 307	45 ± 0
	Rank 1						
5	Rank 10						
	Rank 20	10390 ± 1793	161 ± 136	61 ± 83	10574 ± 2163	332 ± 148	108 ± 99

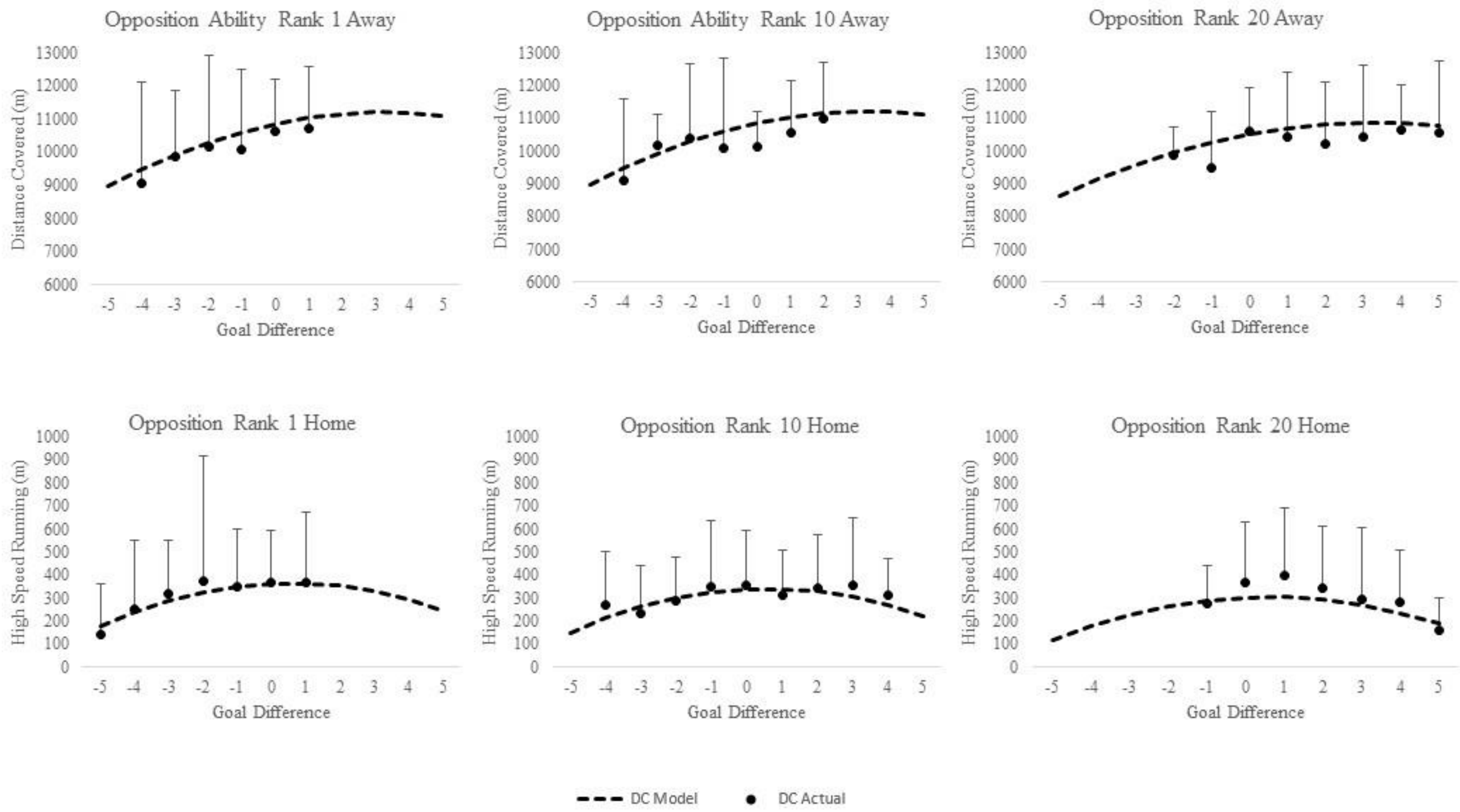

Figure 7.9: Total distance covered (m) during match-play in English Premier League across difference goal differences. Curves are based on predicted distances covered from multi-level models of longitudinal data. Points are based on the 'raw' distance covered data (mean ± SD). Data are presented for opposition ability rank that were significant predictors of performance variables during match play within the model.

Table 7.16 Mean ± SD match-running performance characteristics by goal difference and team ability (finish position in the EPL).

		HOME			AWAY		
Goal Difference	Rank Team Ability	Total Distance/ 90 minutes	High-Speed Distance / 90 minutes	Sprint Distance/ 90 minutes	Total Distance/ 90 minutes	High-Speed Distance / 90 minutes	Sprint Distance/ 90 minutes
-5	Rank 1						
	Rank 10						
	Rank 20	10408.6 ± 1512.8	409.6 ± 219.3	73.6 ± 52.3	9826.8 ± 1509.8	136.9 ± 71.7	15.8 ± 10.3
-4	Rank 1						
	Rank 10				9928.8 ± 1023.1	401.8 ± 210.9	104.6 ± 147.5
	Rank 20	10071.4 ± 2442.6	460.1 ± 525.9	57.5 ± 26.4	9856.7 ± 971.8	406.2 ± 167.6	48.5 ± 29.4
-3	Rank 1						
	Rank 10				9878.9 ± 1142.2	416.4 ± 336.0	145.9 ± 192.2
	Rank 20	9732.8 ± 1483.1	409.6 ± 368.1	155.1 ± 188.9	11285.7 ± 2345.9	359.9 ± 269.9	119.1 ± 150.1
-2	Rank 1						
	Rank 10	8586.4 ± 3251.2	329.5 ± 146.9	97.9 ± 75.3	10265.3 ± 2404.0	313.3 ± 211.9	110.8 ± 156.4
	Rank 20	10164.7 ± 2181.5	493.5 ± 602.1	124.6 ± 188.9	10309.9 ± 1607.4	335.7 ± 231.3	70.9 ± 81.7
-1	Rank 1	9517.9 ± 1043.2	343.3 ± 315.9		8886.7 ± 1650.6	303.5 ± 231.0	158.6 ± 138.5
	Rank 10	10237.5 ± 2078.4	379.1 ± 282.1	121.7 ± 173.4	9962.6 ± 1332.3	321.6 ± 260.6	71.1 ± 74.8
	Rank 20	10082.4 ± 2353.9	405.6 ± 330.3	90.5 ± 83.3	9914.2 ± 1956.1	362.5 ± 238.2	86.4 ± 89.6
0	Rank 1	10418.1 ± 1334.4	424.7 ± 308.4		10250.5 ± 1116.9	371.9 ± 261.6	98.9 ± 167.7
	Rank 10	10271.1 ± 1260.1	363.1 ± 276.3	75.9 ± 91.1	10487.7 1516.9	359.5 ± 277.0	80.8 ± 137.9
	Rank 20	10513.7 ± 1144.9	411.7 ± 265.1	79.2 ± 80.7	10448.9 ± 1373.3	397.7 ± 312.2	96.4 ± 160.6
1	Rank 1	10126.8 ± 1533.4	418.8 ± 318.6		10015.7 ± 1324.3	359.1 ± 252.9	83.3 ± 96.4
	Rank 10	10321.2 ± 2163.3	346.2 ± 431.4	97.8 ± 192.3	10144.7 1390.4	393.1 ± 338.8	109.1 ± 148.3
	Rank 20	9897.0 ± 1659.4	358.6 ± 403.7	63.5 ± 68.1	10122.6 ± 1725.0	412.1 ± 414.8	135.3 ± 218.9
2	Rank 1	9979.8 ± 1565.9	426.4 ± 317.8		10040.4 ± 1505.3	350.3 ± 252.3	93.1 ± 86.8
	Rank 10	9814.2 ± 1274.5	185.5 ± 147.8	93.8 ± 86.4	10747.9 1268.8	327.5 ± 242.6	82.5 ± 101.9
	Rank 20	10039.2 ± 1279.9	360.2 ± 240.6	74.6 ± 130.4			
3	Rank 1	10133.8 ± 1913.1	358.2 ± 313.9		9977.1 ± 1137.8	416.2 ± 424.9	142.5 ± 163.5
	Rank 10	10384.3 ± 650.2	379.7 ± 208.8	128.9 ± 76.6	11165.7 2165.4	396.3 ± 371.0	283.1 ± 155.5
	Rank 20						
4	Rank 1	9909.9 ± 2186.7	351.5 ± 322.3		10078.9 ± 2007.5	431.3 ± 368.3	160.1 ± 142.8
	Rank 10	9161.8 ± 1529.2	230.0 ± 204.9	191.9 ± 0.0	10585.8 ± 1729.5	180.1 ± 234.2	0.0 ± 0.0
	Rank 20						
5	Rank 1				9001.9 ± 2121.3	304.2 ± 426.3	26.1 ± 0.0
	Rank 10						
	Rank 20						

7.8 Discussion

The aim of the present study was to investigate the effect of playing position, pitch location, team ability and opposition ability on the activity profiles of English premier league players across various goal differences (GD) to extend the work done in previous chapters (specifically chapter 3 and 4). By using an automating tracking system (validated in chapter 6) the studies in this chapter we able to take into consideration limitations of the previous chapters, namely limitations in amount of data/games used, the situational variables included in analysis, the positional variables as well as match to match and player to player variability. The multi-level model suggested that activity profiles changed with changes in GD in a non-linear manner and there was significant variation between matches, specifically teams covered more distance and more high speed distance (at home) when the score was close (e.g., ± 2 goals). Modelling also suggested that activity profiles were influenced by playing position, pitch location and opposition ability, as well as the time at which goals were scored.

7.8.1 Goal Difference/Score line

In general, predictive modelling suggested that distance covered decreased as GD increased either positively (scoring team) or negatively (conceding team), across all playing positions and all pitch locations. Playing away from home this decrease was greater when teams conceded goals than when teams scored (e.g. less distance was covered at -3 compared to +3 GD), whereas at home the decrease was even for both the scoring and conceding teams. Research (Lago, 2009; O'Donoghue & Tenga 2001; Paul et al., 2015) suggests that teams who are winning may relax their work rate, potentially allowing opponents back in the game. Alternatively, although losing teams may initially increase their work rate (Castellano et al., 2011; Lago et al., 2010) to get back in the game, they may quickly lose motivation to maintain a sufficient work rate which maybe especially true when teams play away from home as shown in the findings here. From a psychological perspective, it has been suggested (Alder, 1981; Briki et al., 2015) that teams move through a period of building momentum as they work towards scoring through positive play to cruising (where teams try and economise effort). This often results in a decrease in effort (Briki et al., 2015; O'Donoghue & Tenga, 2001) once the goal has been achieved as shown in the current study. The reverse maybe true when teams are losing and experiencing negative momentum, i.e., although an initial surge in effort is sometimes seen to overcome this deficit (as teams search for a goal to get back in the game), if the negative momentum persists, teams tend to abandon the activity and reduce their effort dramatically (Alder, 1981; Briki et al., 2015; Carver, 2003, see Chapter 5) as seen when teams conceded more goals in the current study. The current findings further support the misconception that physical activity profiles are related to purely fatigue, rather than the psychological effects of the score line. This is especially pertinent as recent research (Hewitt et al., 2014; Sparkes et al., 2016) has found little support for decreases in physical activity as a function of fatigue.

High speed running also decreased as GD increased either positively (scoring team) or negatively (conceding team). Away from home, this decrease was more rapid for the conceding team, whereas when playing at home the decrease was similar for both conceding and scoring teams. As previous research considering GD as opposed to match status has been limited, it is difficult to compare results from this current study, however in general, high speed running was at its highest when the GD was small (e.g. -1 to +1) supporting previous studies which have shown that players spend a greater percentage of time performing high speed activity when level, than when behind or ahead (O'Donoghue & Tenga, 2001; Shaw & O'Donoghue, 2004). In support of previous research (O'Donoghue & Shaw, 2004) the current findings suggest that players may maintain their efforts to overcome negative momentum (e.g., losing or conceding) whilst they perceive the goal to still be in reach (e.g., conceding only 1-2 goals). However, once this goal is perceived out of reach (e.g., -3 and beyond in the current study) findings suggest teams decrease their effort, especially when playing away from home. This therefore suggests that although GD is a major factor in influencing player activity, the 'size' of the GD and the environment (playing at home or away) may also play a role in predicting player movement activity and thus should be considered by managers and coaches (see Chapter 5).

7.8.2 Playing Position

According to the predictive models, playing position influenced total distance covered both at home and away from home across all GD's. Midfielders covered more meters per minute when playing both at home and away from home than either strikers (1.1 $m \cdot min^{-1}$ less at home and 0.43 $m \cdot min^{-1}$ less away from home than midfielders) or defenders (7.3 $m \cdot min^{-1}$ less at home and 6.8 $m \cdot min^{-1}$ less away from home than midfielders). This was consistent across all GD's. No significant differences were found between playing positions for either high speed running or sprint distance. Indeed, it is commonplace for midfielders to cover more distance due to their interlinking role between attack and defence within a team (Di Salvo et al., 2009). Strikers, on the other hand have generally been found to cover more high speed running and sprint distance than defenders and in some cases midfielders in an attempt to capitalise on goal scoring opportunities (Faude et al., 2012). The lack of significant differences between players in the current study is most likely related to the higher frequency of the automated tracking system used ensuring more accurate estimates of both high speed running and sprint distance, which has previously been problematic.

In relation to score line Redwood-Brown et al. (2012) found midfielders covered more high speed running when level, defenders more when losing and attackers more when winning. A similar pattern was reported by Bradley and Noakes (2013) who found central defenders covered 17% less and attackers 15% more high speed running during matches that were heavily won versus heavily lost (score differential ≥3 goals). The lack of sensitivity to the playing positions maybe the reason for no significant effect of high speed running or sprint distance in the current study. For example, many researchers have now found position specific roles go deeper than the striker, midfielder and defender categorisation used in the current study (Andrzejewski et al., 2016; Bush et al., 2015; Coker, 2014; Lago-Penas et al., 2010). Even when using specific playing positions, many teams now seem to adopt individualised playing strategies, with team specific positional roles, which evolve in relation to the match itself (Bloomfield et al., 2005; Lago-Penas & Dellal, 2010). Thus making it difficult to 'group' playing positions in relation to their physical activity profiles and suggesting that individual player comparisons maybe more relevant when investigating the effect of score line in relation to physical activity profiles.

7.8.3 Pitch Zone

All playing positions were found to cover more distance per minute in the attacking 3rd both at home and away from home than either the middle 3rd (12.1 $m \cdot min^{-1}$ less at home and 14.1 $m \cdot min^{-1}$ less away from home than attacking 3rd) or defending 3rd (7.9 $m \cdot min^{-1}$ less at home and 11.4 $m \cdot min^{-1}$ less away from home) across all GDs. High speed running followed a similar pattern with more covered in the attacking 3rd both at home and away than either the middle 3rd (4.0 $m \cdot min^{-1}$ less at home and 4.9 $m \cdot min^{-1}$ less away from home than attacking 3rd) or defending 3rd (2.0 $m \cdot min^{-1}$ less at home and 3.2 $m \cdot min^{-1}$ less away from home) across all GDs. No significant differences were found between pitch location for sprint distance covered at home, however when playing away from home, more distance was covered in the attacking 3rd than either the middle 3rd (2.0m less away from home than attacking 3rd) or defending 3rd (2.01m less away from home than attacking 3rd) across all GDs.

Although research considering the interactional effect of pitch location and score line is scarce, Lago (2009) did find when teams were behind they spent more time in the attacking third than when in the lead potentially in search of a consolation goal if the opportunity arises. Similarly, García-Rubio et al. (2015) found that when teams are winning they tend to play less risky options, and with a more structured defence strategy placing more players between the ball and their own goal thus reducing the amount of time, and thus distance covered in the defending and middle thirds. This supports the idea that winning teams are more likely to adopt a counterattack style of play (Andrzejewski et al., 2016; Lago, 2009) and therefore helps to explain why the middle 3rd had the lowest values for distance covered in the current study as the majority of games end with one dominant team.

The strategy (e.g., time spent in each pitch location) teams employ when either winning or losing maybe somewhat determined by the ability of that team. For example, winning teams have been found to maintain ‘control’ of the game by keeping possession especially if higher in ability (Jones et al., 2004; Taylor et al., 2005), which contradicts the idea that teams adopt a direct style of play when winning (Andrzejewski et al., 2016; Lago, 2009). This therefore suggests that there is a need to investigate activity profiles and technical performance together especially, when considering the pitch location during different score line states as higher ability teams may be able to maintain their style of play despite other variables (e.g., match location or evolving score) (Bloomfield et al., 2005; Lago-Penas & Dellal, 2010).

7.8.4 Team Ability

Models predicted that the ability of the team did not predict activity profiles of players across GDs. Even though research has found teams higher in ability covered more distance than lower ranked teams, especially in higher speed zones (Mohr et al., 2003; Andersen, Randers et al., 2010). A possible explanation for this maybe that teams are more capable than previously thought at adapting their strategy based on the evolving score. A more plausible explanation is that there may not be much difference between the top and bottom ranked teams in the English Premier League in terms of physical activity profiles and 'ability' is better explained by a team's technical performance (Rampinini et al., 2008, see Chapter 7a). This provides additional support for the need to investigate both physical and technical performance together in line with individual teams, playing formations and strategies in order for managers and coaches to maximum team performance.

7.8.5 Opposition Ability

Models predicted that when playing away from home, teams covered 0.09m per minute, less total distance and when playing at home, 0.04m less high speed distance for every decrease in rank position of their opposition. For example when playing against opposition who finished second in the league, teams would cover 0.09m total distance and 0.04m high speed distance per minute less than when playing the top ranked team. Whereas when playing opposition ranked 10th in the league teams covered 0.81m total distance and 0.36m high speed distance less per minute. This was in support of previous research (Hewitt et al., 2014; Mohr et al., 2003; Randers et al., 2010) which has found players cover more ground when their opposing team is higher in ability compared to medium or bottom ranked teams (Castellano et al., 2011). No significant differences were found for total distance covered at home, high speed running away from home or sprint distance either home or away. Lago and Dellal (2010) suggested when playing against higher or lower ranked opposition, teams may bunch together at either end of the pitch reducing the total distance covered, but increasing sub-maximal and maximal activity profiles. Lago-Penas and Lago-Ballesteros (2011) suggested that match location and quality of opposition have equal importance, for example if a lower rank teams plays at home against higher ranked opposition the influence of both these variables maybe compromised accounting for the small effect shown in the current findings.

Teams consistently reported the highest distance covered and high speed distance when the game was close (e.g., -1 to +1). Although it is not always the case that these games will end in a close final score, previous research has found teams cover more high speed running when they play opposition of similar ability compared to lower ranked or higher ranked teams (Hewitt et al., 2014). These findings also support the idea that the technical performance of a team maybe more indicative of their overall ability (final league position) than how far they run during a match (Rampinini et al., 2008; Castellano et al., 2011). This is especially true, as recent research has shown teams are able to inject sub-maximal and maximal runs towards the end of the match, showing no signs of physical fatigue (Sparkes et al., 2016).

7.9 Conclusion

A number of previous studies have investigated the effect of score line on activity profile of players, yet few have considered score line outside of match status (i.e., winning, drawing, and losing). Only a handful of studies have considered score line in relation to technical performance factors and those that have usually failed to consider team ability, opposition and goal difference. The studies in this chapter considered a greater number of matches across one season in an attempt to eradicate the high match-to-match variation in total distance covered and more specifically high speed running distance that has been found in previous work (Gregson et al., 2010). By using only one validated system and an entire season of games more generalisations could also be made by reducing the error seen when trying to compare multiple measurement systems (Randers et al., 2010). In support of the majority of previous research (Bloomfield et al., 2005a; 2005b; Jones et al., 2004; Lago & Martin, 2007; O'Donoghue & Tenga, 2001; Sasaki et al., 1999; Shaw & O'Donoghue, 2004; Tucker et al., 2005) which has only examined situational factors independently, **Study 7a** extends our understanding of the complex dynamic nature of soccer in relation to technical performance. Specifically, that teams performed more accurate passes in extremes of GD (e.g., when the score was heavily positive or heavily negative) than when the score was close highlighting once the outcome of the game becomes obvious teams reduce their work rate (DC and HSR) and thus are more likely to increase the accuracy of their technical play (Shaw & O'Donoghue, 2004).

. The same pattern was seen for corner accuracy away from home (e.g., corner accuracy was lowest when the score line was close and highest at extremes of GD). Although freekick accuracy was not associated with GD changes, team ability, playing position and pitch location were found to predict freekick performance. More research using GD/score line as a foundation is needed to understand the interaction of technical performance variation in different score line states (Lago & Martin, 2007). There is also a great deal of contrasting research with regards to how teams perform when in different score line states, which suggests players may not play the same across all matches (James et al., 2002; Lago & Martin, 2007; Lago, 2009; Taylor et al., 2008; Tucker et al., 2005).

In **Study 7b** goal difference was found to have a large and varied impact on the activity profiles of premier league soccer players where total distance both at home and away and high speed distance covered at home were greatest when the goal difference was close. Pitch zone was found to have the biggest effect on activity profiles across GD being present in all but one model, this was followed by playing position. Opposition ability was found to effect teams but on a much smaller scale – supporting the findings that the difference in ability maybe negated when teams are on their own territory (Rampinini et al., 2008). The absence of team ability in all models suggests that the physical movement of players is less of a predictor of overall team performance than technical performance and thus both aspects should be considered when modelling player and team performance.

8.0 GENERAL DISCUSSION

8.1 Overview

The aim of this thesis was to investigate how teams perform in different score lines, both in terms of scoring and conceding to provide practitioners with vital feedback to avoid conceding goals and aid in scoring them. Adapted from Franks and Goodman's (1986) Systematic approach to analysing performance, Figure 1.1 was used to highlight the key aspect of performance behaviour considered important in relation to score line. The first 2 chapters of this thesis (Chapter 3 and 4) aimed to clarify previous findings in relation to the

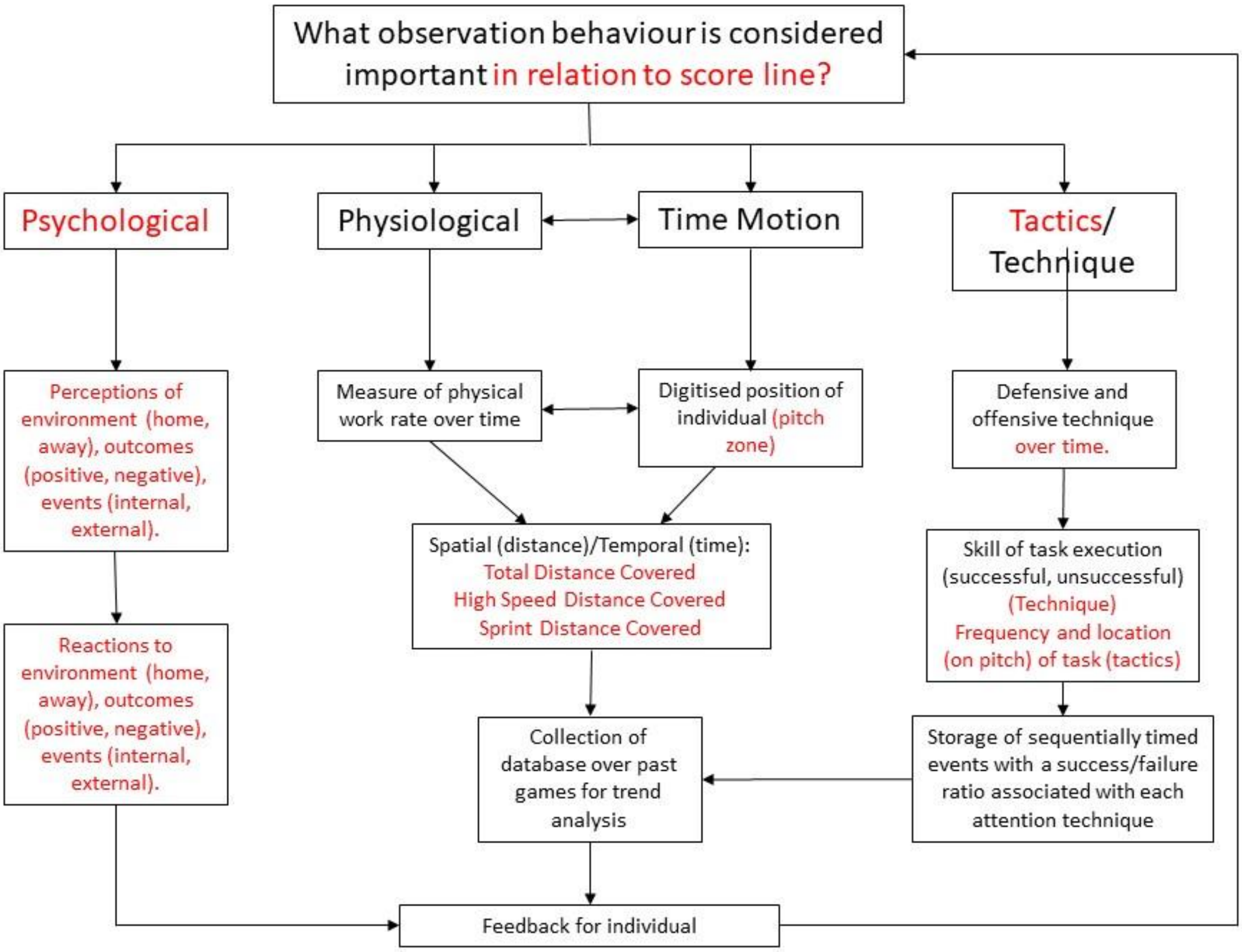

Figure 1.1 Model of Performance in relation to score line: Adapted from From: Franks & Goodman (1986) A systematic approach to analysis sports performance. *Journal of Sports Science*, 4, 49-59.

effect of scoring and conceding on aspects of tactical (passing frequency), technical (passing accuracy) (Chapter 3) and physical performance (activity profiles) (Chapter 4). Although previous research (Al Haddad et al., 2015; Bradley et al., 2009; Dellal et al., 2010; Di Salvo et al., 2009; Di Salvo et al., 2007, Jones et al., 2004; Lago-Penas & Gomez-Lopez, 2014; O'Donoghue & Robinson, 2016; Ridgewell, 2011; Taylor et al., 2008) has investigated the technical, tactical and physiological performance of professional soccer players few have considered how performances differ when in different score lines states (e.g. 1-0, 2-0, 1-1 etc.) and even when included have used relatively small sample sizes, with limited control over the time spent in each score line (e.g., a team could score in the first 5 minutes, spending 5 minutes in a drawing state and 85 minutes in a winning state or score in the last 5 minutes and spend 85 minutes in a drawing state and 5 minutes in a winning state even though the overall result is the same). The addition of a psychological component to the model (Figure 1.1) required justification, therefore Chapter 5 used both interviews and questionnaires to investigate the concept of psychological momentum; given the body of literature supporting psychological momentum and performance. Specifically, key experiences of psychological momentum (PM) and the strategies associated with positive and negative momentum were investigated.

8.2 Effects of Score Line – Chapter 3 and 4

Both **Chapter 3** and **Chapter 4** used novel approaches to studying score line specifically, as recommended by previous research, playing position (Chapter 4) and performance periods where no goals were scored were considered as well as a more sensitive definition of score line. This provided further evidence that changes in performance observed can be related to score line effects rather than other factors such as fatigue, which had previous been used as an explanation.

8.2.1 Effects of Score line on Technical and Tactical Performance Factors

Chapter 3 revealed significant differences in passing frequency and passing accuracy before and after goals were scored when compared to the average for that half of the match. In the 5 minutes that preceded a goal, the scoring team played a significantly greater percentage passes accurately than the average for the half, while the conceding team played significantly fewer passes. The accuracy of passing for the scoring team may have not only contributed to the scoring opportunity being created but reduced opposition possession by not losing the ball. After the goal was scored, the scoring team played significantly fewer passes and a lower percentage of passes were played accurately than the average for the half of the match where the goal was scored. In the 5 minutes that preceded a goal, the scoring team played a significantly greater percentage of passes accurately (72.4 ± 12.7) compared to the average for the half (70.2 ± 7.5) ($P<0.017$) while the conceding team played significantly fewer passes before (19.3 ± 8.4) compared to the average for the half (22.9 ± 4.3) ($P<0.017$). After the goal was scored, the scoring team played significantly fewer passes (21.5 ± 11.1) and a lower percentage of passes were played accurately (67.3 ± 14.7) than the average for the half of the match where the goal was scored (23.2 ± 5.2) (70.2 ± 7.5) ($P<0.017$).

One interpretation was that once a goal is scored, the scoring team are not aiming to score again immediately and therefore change tactics, reverting to a counterattack style of play. This supports the findings of Lago-Penas & Dellal (2010) and Lago (2009) who found a reduction in the number of passes in the middle third of the pitch by the scoring team as the counterattack style of play is confined to the attacking and defending thirds. The opposition (conceding team) may also step up their possession in an attempt to take control of the game and score (Castellano et al., 2011; Lago et al., 2010). This supports previous research (Lago, 2009; O'Donoghue & Tenga, 2001; Paul et al., 2015) which suggests that teams who are winning relax their work-rate, potentially allowing opponents to take control of the game.

Additionally, it has been suggested that although losing teams may initially increase their work-rate (Castellano et al., 2011; Lago et al., 2010) to get back in the game, they may quickly lose motivation to maintain a sufficient work-rate which seems to be more prevalent when teams play away from home.

The psychological component of the model would suggest the reduction in passing accuracy may be related to player's motivation. For example, Alder's (1981) theory suggests that once teams have gained positive momentum through scoring or performing well, they start to 'cruise' in an attempt to economise efforts and eventually coast when the goal has been achieved or is perceived within reach, supporting the lowest accuracy seen as teams increased their lead in the current study.

The findings of Chapter 4 helped to establish the relationship between score line and technical and tactical factors and support previous research in relation to the idea that players change their behaviour once a goal has been scored. However, several factors may also need to be considered in order to give a better understanding of this effect, namely the opposition, the playing position and the time of the goal, thus justifying their inclusion in Chapter 7.

8.2.2 Effects of Score line on Physical Performance Factors

Chapter 4 established a typical fatigue pattern using data from 79 player performances during five 0-0 drawn English FA Premier League matches. This typical fatigue pattern was used to adjust the work-rate of 90 player performances in five English FA Premier League matches. Players were found to spend a greater amount of time moving at 4 $m.s^{-1}$ or faster in the first 15 minutes of matches than any other period. This was in agreement with a number of previous studies (Barros et al., 2007; Mohr et al., 2003; Hennig & Briehle 2000). There was also a significant interaction between player position and score-line (p = .010) with forwards spending a greater percentage of time moving at 4 $m.s^{-1}$ or faster when their team was leading than when level while defenders spent a greater percentage of time moving at 4 $m.s^{-1}$ or faster when their team was trailing than when level. Research (Briki et al., 2015; Carver, 2003) found teams increase their efforts to overcome deficits, thus explaining why defenders showed an increase in work-rate when their team was behind. The defenders work-rate is also to some extent dictated by the forwards of the opposing team, therefore when one team is leading, and their forwards are motivated to maintain a high work-rate the other team's defenders will be required to maintain a work-rate to counteract this. Investigating this further using a greater number of games, details of where on the pitch players are moving in relation to the opposition and the time of goals would help to understand the effect of scoring on team's physical performance. Tus justifying the inclusion of these factors in Chapter 7.

8.2.3 Psychological Effect of Score Line on Performance

In order to justify the inclusion of a psychological component to the study of score line, Chapter 5 provided insight into the key experiences of psychological momentum (PM) and the strategies associated with positive and negative momentum using both questionnaires and interviews. The majority of key responses reported in the interviews were supported by the questionnaire data. The similarity of results from both methods support the measure as a useful tool for coaches to collect data pertaining to players' experiences and perceptions of PM.

Scoring or conceding a goal was highlighted as an important factor that affected players' perceptions of positive and negative momentum, respectively thus supporting its inclusion when studying score line. In support of previous research (Gernigon et al., 2010; Higham et al., 2005; Staminmirovic & Haranhan, 2004; Vallerand et al., 1988) it was reported that goal scoring and more specifically a positive score configuration was important for the development of positive PM and thus progress towards their end goal. In addition to this, "feeling confident", "having a positive attitude" and "being cohesive as a team" were important aspects of positive PM. It is plausible to suggest that the presence of self-confidence in the current study may facilitate the development of PM but also that a positive PM scenarios may enhance self-efficacy at the same time – especially as teams progress towards their goal. In reverse to this a "perceived lack of ability" and "feeling anxious" were the most frequently reported experiences of negative PM. A number of these factors have been established as influencing one another, for example a lack of confidence can lead to perceived lack of ability (and vice versa). Investigating this relationship is beyond the scope of this thesis but would be a valuable addition in the future.

8.2.4 Conclusions

Chapter 3, 4 and 5 established score line effects across technical, tactical and physical performance as well as highlighted scoring and conceding goals as an important component of player's perceptions of PM. A number of situational factors (opposition ability, team ability, time scored, pitch location etc.) were proposed as potential reasons for changes in performance in relation to score line. Although some account for playing position was considered in Chapter 4, the small sample size limits the ability to generalise these findings.

Identifying score line effects across multiple situational variables requires volumes of accurate data that only automated player tracking systems can provide. Such systems can also take into consideration stoppage time when calculating physical and technical variables performed. Therefore Chapter 7 aimed to investigate the effect of scoring and conceding goals on other the technical and physical performance of players taking into consideration situational factors such as, pitch location, playing position, team and opposition ability and time scored using an automated tracking system. To ensure the accuracy of the system, Chapter 6 tested the validated of the automated tracking. The system was compared to calibrated speed gates within a stadium environment. For all the runs combined the mean speed recorded by the automated system was 15.4 ± 5.5 $km \cdot h^{-1}$ compared with the recorded mean speed of 15.2 ± 5.4 $km \cdot h^{-1}$ and the mean difference and 95% limits of agreement were -0.25 ± 0.64 $km \cdot h^{-1}$. Pearson correlations (r) among timing gate speed and automated tracking speed were ≥ 0.99 ($P<0.001$), except the 20 m sprint, with 90° turn ($r > 0.7$). The results demonstrate good validity over a range of soccer specific movements and speeds, up to and including sprinting.

8.3 Effects of Score line – Using Automated Tracking System

Chapter 7 used the automated tracking system validated in **Chapter 6** to investigate score line effects incorporating the suggestions of **Chapters 3 and 4**. The use of this system allowed for a greater number of matches, across an entire season to be analysed in an attempt to account for the high match-to-match variation in total distance covered and more specifically high speed running distance that has been found in previous literature (Gregson et al., 2010). A number of situational factors were included in the analysis specifically, team ability, opposition ability, player position; pitch location, match location and time scored. The system also allowed for greater sensitivity in relation to score line; where the number of goals a team were winning or losing by was considered. By using only one validated system and an entire season of games more generalisations can also be made by reducing the error seen when trying to compare multiply measurement systems (Randers et al., 2010).

8.3.1 Effects of Score line on Technical Performance Factors

In **Chapter 7b** multi-level regression revealed a "u" shaped association between passing accuracy and goal difference (GD) with greater accuracy occurring at extremes of GD e.g., when the score was either positive or negative. The same pattern was seen for corner accuracy away from home e.g., corner accuracy was lowest when the score was close with the lowest accuracy at extremes of GD. Specifically teams showed higher passing accuracies in extremes of GD (e.g., -5 and +5) and the lowest when winning by only a smaller number of goals (e.g., +1 to +3). On the other hand teams were found to have the lowest corner accuracy (away from home) when losing by a small margin (e.g., 1 to 2 goals). Although free kick accuracy was varied across pitch location, playing position and team ability no association was found with goal difference. Crossing accuracy was not found to vary across goal difference or any of the situational factors considered in the model. The effects of score line were also similar whether teams were playing at home or away from home, in terms of significant performance predictors, although teams generally performed better at home (e.g., higher passing, corner, cross, free kick accuracy). According to the predictive models, playing position influenced passing accuracy both at home and away across all GD's. Midfielders performed more accurate passes when playing at both home and away from home than either strikers (10.8% less at home and 7.8% less away from home than midfielders) or defenders (1.6% less at home and 2.5% less away from home). This was consistent across all GD's. Both passing accuracy and free kick accuracy were found to vary across pitch location although free-kicks were not affected by goal difference. Teams recorded the highest passing accuracy both at home and away from home in the middle third ahead of both the defending third (16.3% less at home and 9.7% less away from home) and attacking 3rd (9.3% less at home and 3.1% less away from home).

Team ability was found to predict passing and freekick accuracy at home and away as well as corner accuracy away from home. With all three technical performance variables, as expected, higher ranked teams were more accurate than lower ranked teams. This equated to 0.9% less accurate per rank for passing at home, 0.6% less accurate per rank for passing away from home, 1.0% less accurate per rank for free-kicks at home, 0.8% less accurate per rank for free-kicks away from home and 1.2% less accurate per rank for corners away from home. Opposition ability was not found to influence any of the technical performance variables across different score line states. This is not surprising given that the majority of studies investigating successful and successful teams have found that successful teams show greater passing accuracy regardless of the level of opposition played. (Bloomfield et al., 2004a; 2004b; Evangelos et al., 2014; Jankovic et al., 2011; Lago, 2009; Reed, 2004; Szwarc, 2007).

8.3.2 *Effects of Score line on Physical Performance Factors*

In **Chapter 7b** multi-level regression revealed an inverted “u” shaped association between total distance covered and goal difference (GD), with greater distances covered when GD was zero and reduced distances when GD was either positive or negative. A similar “u” shaped association was found with high speed distance covered at home. Specifically, teams covered more distance when the score was close (e.g., -1 to +1) than at extremes of GD (e.g., -5 and +5). Away from home the decrease in running performance was greater when teams conceded goals (e.g., -2 and greater) whereas at home the decrease was similar whether teams scored or conceded. Similarly, to distance covered, high speed running decreased as goal difference increased for both the scoring and conceding team with the exception of those ranked lowest. At home this decrease was more rapid for the conceding team, whereas when playing away from home the decrease was similar for both conceding and scoring teams. High speed running was at its highest when the goal difference was small (e.g. -1-+1) supporting previous studies which have shown that players spend a greater percentage of time performing high speed activity when level then when behind or ahead (O'Donoghue & Tenga, 2001; Shaw & O'Donoghue, 2004; Devlin & O'Donoghue, 1999). Research (Lago, 2009; O'Donoghue & Tenga 2001; Paul et al., 2015) suggests that teams who are winning may relax their work rate, potentially allowing opponents back in the game. Alternatively, although losing teams may initially increase their work rate (Castellano et al., 2011; Lago et al., 2010) to get back in the game, they may quickly lose motivation to maintain a sufficient work rate which maybe especially true when teams play away from home as shown in the findings here.

Pitch zone was found to have the biggest effect on activity profiles across GD being present in all but one model, this was followed by playing position. Specifically, more distance was covered in the attacking 3rd than either the middle or defending 3rd. In terms of playing position, midfielders covered more meters per minute than either strikers or defenders across all GD's. Opposition ability was found to effect teams but on a much smaller scale – supporting the findings that the difference in ability maybe negated when teams are on their own territory (Rampinini et al., 2008). The absence of team ability in all models suggests that the physical movement of players is less of a predictor of overall team performance than technical performance and thus both aspects should be considered when modelling player and team performance.

The results of **Chapter 7** suggest that a number of variables are associated with both the physical and technical performance of players in difference score lines and that such effects may be related to the perception of events (as shown in Chapter 5) rather than fatigue, ability or opposition as previously thought. The current studies also highlighted the need for more sensitive score line definitions in which to consider score line effects using technological advancements such as automated tracking systems.

8.4 Practical Implications

Across all experimental chapters this thesis found players technical (**Chapter 3 and 7a**) and physical (**Chapter 4 and 7b**) performance was affected by the score line. These effects were found when score line was considered as winning, drawing, losing (Chapter 4), as well in specific score lines or goal differences (-5 to +5) (Chapter 3 and Chapter 7). It is important for coaches, managers and sports professionals to understand performance changes that occur after scoring/conceding, especially if they can employ strategies to help players cope with such incidents (as highlighted in Chapter 5). Prior to this thesis limited research investigating score line effects had taken into consideration performances where no score was present, opposition/team ability or enough matches to enable the findings to be generalised and account for match-to-match variability. Research had also failed to consider factors related to players' perceptions of the score line in determining how this may affect subsequent performance. By investigating the psychological perceptions of player's, specifically perceptions of psychological momentum (**Chapter 5**) this thesis was able to provide further understanding of how the psychological components of PM may help to explain score line effects in relation to technical and physical performance with the performance model proposed in Figure 1. Given that no previous studies have examined the effects of score line across multiple situational variables at the same time, the present studies add to the existing literature by documenting these effects. Thus, enabling coaches, managers and practitioners to use this information to pin point situations where groups of players maybe more at risk of performance declines as well as educating players on potential strategies to help gain momentum as well as overcome negative momentum in relation to either, a positive or negative score line state.

Supporting this psychological component and previous research (O'Donoghue & Shaw, 2004), the findings of Chapter 7b suggested that players maintain their efforts to overcome negative momentum (e.g., losing or conceding) whilst they perceive the goal to still be in reach (e.g., conceding only 1-2 goals). However, players also decreased their effort once it was clear they would either win or lose (+/-2 goal difference), supporting the decrease in performance for negative momentum (Taylor & Demick, 1994; Vallerand et al., 1988) as well as the concept of coasting (reducing effort towards the end goal) for positive momentum (Briki et al., 2015; Carver, 2003). Identifying how players respond to the score line in terms of their technical and physical performance allows coaches and managers to change tactics and thus help to optimise performance (Chapter 5). Therefore, players and coaches should practice changing tactics (e.g. different attacking plays and formations) to overturn the balance of momentum (if in a negative PM state) in training matches, as the change itself maybe more important than any particular tactic enforced (Higham et al., 2005, Chapter 5). Changing tactics was also the most frequently cited strategy in **Chapter 5** for overcoming negative momentum further supporting this as a strategy. Maintaining concentration and being well prepared were the most frequently cited strategy for creating/maintaining positive momentum. Coaches interviewed by Moesch and Apitzsch (2012) considered being well-prepared to be a concentration enhancing strategy that could also be used during matches to build PM or refocus. It is important, therefore, that coaches understand the importance of perceived preparation. Ensuring team goals and roles are set out clearly and with measurable targets may be one strategy for coaches to adopt to ensure teams remain on target and focused on the desired outcome.

Given the nature of goal scoring in low-scoring sports such as soccer, it would seem sensible to address players' coping strategies (e.g. concentration techniques, set plays, sequences which can be developed in training matches) surrounding both scoring and conceding and to assess how each scenario affects their performance. Developing clearly defined roles in such situations and identifying key personnel to lead the team in each situation may also be beneficial (Higham et al., 2005). Nurturing confidence by providing both situations in training to develop confidence, and strategies to help build confidence in competitive matches should also be employed to help players maximise their performance especially as this was one of the most frequently cited themes associated with positive PM behind scoring in **Chapter 5**. Given the relation between confidence and anxiety (Hanton et al., 2005) this may also help to assuage negative feelings and emotions associated with negative PM.

Although perceived ability was one of the most frequently reported factors in creating positive PM in **Chapter 5,** team ability did not predict activity profiles of players across GDs in any of the models in **Chapter 7b**, even though research has found teams higher in ability covered more distance than lower ranked teams, especially in higher speed zones (Mohr et al., 2003; Andersen, Randers et al., 2010). A possible explanation for this maybe that teams are more capable than previously thought at adapting their strategy based on the evolving score. A more plausible explanation is that there may not be much difference between the top and bottom ranked teams in the English Premier League in terms of physical activity profiles and 'ability' is better explained by a team's technical performance (Rampinini et al., 2008, see **Chapter 7a**). This was further supported in **Chapter 7a** where team ability was found to effect passing and freekick accuracy both at home and away and corner accuracy away from home, whereas no effect was found for opposition ability. These findings provide evidence for the need to investigate both physical and technical performance together in line with individual teams, playing formations and strategies in order for managers and coaches to maximum team performance in different score line states. It would seem that score line may also affect different players in different ways for example Vallerand et al. (1988) proposed that the most important cognitive change that occurs with events that may lead to negative momentum/performance is an individual's perceptions of control over the event or situation. Therefore, addressing individual player perceptions of the score line (e.g. picking teams based on their ability to thrive in different score lines) in relation to performance maybe more beneficial for managers and coaches to use in order to maximise team performance.

8.5 Limitations

8.5.1 Limitations – Chapter 3 and 4

Although Chapter 3 revealed significant differences in passing frequency and passing accuracy before and after goals are scored when compared to the average for the half, no account for ball in play was considered therefore stoppage time could vary between each 5-minute segment. The conceding team would also take possession on the kick off after the goal was scored, therefore creating an advantage in the analysis of passing frequency in that 5 minutes period. Including the area of the pitch in which passing took place could also help to understand the changes in tactics teams make when in different score line states, especially as this has been found to be a significant factor of score line effects (Ridgewell, 2011). Future research should consider not only ball in ball time, but also the patterns of play beyond the immediate goal event (e.g. consider timing beyond 5 minutes). The timing of goals should also be added as a factor, to establish whether the effect of scoring impacts players differently at different points in the game. The effect of scoring and conceding goals on other aspects of play would also be useful but would require large volumes of data across multiple games and teams in order to account for match-to-match variability. For this reason, Chapter 7 included the time the goal was scored as a factor of analysis as well accounting for only ball in play time, pitch location and adding additional performance factors.

In Chapter 4 one of the major limitations was the limited number of games used to generate performance profiles when no score was present (0-0 games). Stoppage time was also not accounted for and thus may have influenced the observed work-rates. Secondly, the method did not account for expectation, for example for a higher placed team to draw against a lower placed team, a draw may be a disappointing result; on the other hand, their opposition may see this as a good result. Therefore, work rate and motivation may well be affected as a consequence. Kerick et al. (2000) found that deviations in performance, thought to be above that of the performers' subjective norms, could have the capacity to function as a precipitating event of momentum. Therefore, a team, who are performing better than they are expecting, could gain psychological momentum and even effect the momentum of the opposing team (Kerick et al., 2000). Given the number of games that were available that resulted in 0-0 draws; variables such as this are difficult to eradicate. Movement variables during soccer are not stable characteristics of performers (O'Donoghue, 2004) and there can be greater within player variability than between player variability for distances covered using high speed movement (Gregson et al., 2010). Such variability makes it more difficult to find significant differences especially when related samples are used. Although teams included in Chapter 4 spent an equal amount of time in a winning, drawing and losing state no account for team ability was considered. Successful teams in the English FA Premiership have been found (Bloomfield et al.,2004a) to increase possession when ahead or behind, suggesting they try and "control" the game by dictating play. Therefore, Chapter 7 addressed these limitations including a much larger sample size, taking into consideration both player and match variability as well as team ability.

8.5.2 Limitations - Chapter 5

Chapter 5 extended the qualitative work of researchers who have attempted to gain an understanding of the perceptions of PM in sport. Although only one team was used in the qualitative part of the study, the use of quantitative methods greatly increased the number of players who reported their experiences and perceptions of PM. However, using a case study approach with only one team may have influenced players' responses as all players were coached by the same coaching team and were drilled in the same manner, and therefore may share similar perceptions with regard to success and failure. Although individual perceptions would still occur, this does not allow for the data to be generalised across teams. Case studies do however, allow us to see how a small population react within a given scenario/s, in this case how academy players report experiences of PM. Individual player data analysis was also limited as only the accumulated player responses were recorded within the PM measure. Future research should therefore consider using more than one team for individual player interviews, and also compare responses across a number of positions and levels to provide a clearer picture of the entire team, each player's PM experiences, and subsequent strategies that can be used to control PM.

Although Chapter 5 built upon previous research by including athletes' experiences of PM across multiple teams, no account for match outcome (e.g., after a win or after a loss) was considered, which may have positively or adversely influenced athletes' responses, especially as this has been a key feature of several studies. Conducting both interviews and questionnaires with players following different match outcomes may help to eradicate this problem as well as to establish how momentum manifests itself in different score line conditions.

8.5.3 Limitations Chapter 6

The main limitation of the validation study conducted in Chapter 6 was the lengthy calibration of each measurement point required by the system. Normally prior to a match the cameras that are situated around the stadium undergo a calibration process taking between three to four hours from fixed points. Which although not a direct limitation of the validation study undertaken in Chapter 6, could affect the ability for teams to use this system on match day.

Secondly, as the speed gates that were used to compare speeds were not fixed it was highlighted prior to testing that if a speed gate got knocked by a player during a run, the gate would need to be re-calibrated in order to ensure maximum accuracy and eradicate any potential errors that may occur. Fortunately, only one such incident occurred, however errors occurred whilst re-calibrating the speed gate, meaning there was a slight disparity (test 5). Although the cost of this system is high, it is comparable to the current computer based systems which track players but with a delay on data extraction.

8.5.4 Limitations Chapter 7

Although the studies conducted in Chapter 7 included playing position in the multi-level modelling, unlike more recent studies only 3 categories were used. Splitting these categories further (e.g., into wide and central midfielder) would further highlight any variation between playing position. It would however, be interesting to investigate the extent that individual differences contribute to the overall team, or in this case, the overall mean of their playing position given the amount of research (Redwood-Brown et al., 2012; Iso-Ahola & Dotson, 2014) that suggests variability between players with regards performance accomplishments and success and failure. Another consideration/limitation of these studies was the definition used for score line, although the current study used a more sensitive score line definition to the traditional win, loss, draw it did not give an indication to the actual evolving score line; e.g. 2-0 could be perceived by players differently to 4-2 but would have the same goal difference (GD).

Across all studies data was collected across a wide time frame with the earliest data used collected from the 2004-2005 season and the latter from the 2011-2012 football season. Although all data was obtained from professional soccer leagues, collecting data across a long-time frame can have implications when comparing findings, especially to modern day. The evolution of physical, technical and tactical capabilities of elite soccer players is enviable and is evidenced in the paper of Bush et al., (2015) where performance parameters were analysed over the course of 7 seasons. Although Bush et al., (2015) found differences across the 7 seasons, these differences were gradual, with the smallest differences in the most reason seasons. Care must also be taken when interpreting findings in an applied setting, for example a significant different clinically could mean only a 150m difference in reality. Similarly, small differences in performance which are not significant could mean the difference between winning and losing in a narrow margin event. A review of magnitude-based inferences could be considered if the data set was small in nature however, as an entire season across all 380 games was included in the analysis it is appropriate that the statistical differences found here would be of relevance to managers and coaches in an applied setting as long is care is taken when interpreting them.

8.6 Future Investigation

Due to the variety of novel results found in this thesis, future research should also consider adopting a case study approach in order to maximise player and ultimately team performance in relation to situational factors. This would enable managers and coaches to apply effective strategies when in each match situation as well as picking the most appropriate team for the predicted match outcome, especially as Redwood-Brown et al. (2012) suggested, some players perform better when chasing a lead whereas others like to defend a lead. Therefore, addressing individual player perceptions of the score line in relation to performance maybe more beneficial for managers and coaches to use in order to maximise team performance.

- **Systems of Measurement:** Future research should aim to test automated tracking technologies in a range of different climates and lighting conditions. Although the system has been internally tested for accuracy and consistency in such conditions, no formal validation has taken place.

  Comparisons between tracking systems used by professional clubs, such as Prozone and Amsico and GPS 15Hz systems (GPS Sports) should also be undertaken to enable coaches and sports scientists to compare movement player data. Similarly using professional players would support the use of such a system in the professional field.

  Although new player movements have been included in the current study incorporating more specific movements such as jumping and falling as well when occlusions occur should be considered in future validation studies.

- **Psychological Momentum Perceptions:** The use of quantitative methods greatly increases the depth of understanding regarding players experiences of PM, however future studies should consider more than one team in order to establish patterns beyond those of teams who are all coached by the same coaching staff and thus share similar perceptions with regard to success and failure.

  Further research should further test quantitative methods of measuring perceptions of psychological momentum. This would allow a greater volume of data to be collected in a more efficient and timely manner in order to coaches and managers to understand the concept further.

  To avoid environmental bias (Jones et al., 2002), specifically in the age group in question (e.g., academy players), utilising a greater number of players across multiple teams, age groups, and abilities may also help to address this issue by providing a more general account of players’ perceptions of PM.

Chapter 5 built upon previous research by including athletes experiences of PM across multiple teams, however no account for match outcome (e.g., after a win or after a loss) was considered, and this may have positively or adversely influenced athletes' responses. Conducting both interviews and questionnaires with players following different match outcomes may help to eradicate this problem as well as to establish how momentum manifests itself in different score line conditions.

- **Score Line on Technical Performance Factors:** In terms of technical factors only accuracy was considered in the current study, which does not always give a true reflection on the performance of players. Considering additional attacking and defensive variables both in terms of frequency and accuracy would give further understanding to the impact of score line on the technical performance of soccer players.

  Incorporating the evolving score line would give a greater indication of score line effects; e.g. 2-0 could be perceived by players differently to 4-2 but would have recorded the same goal difference in the current study.

- **Score Line on Physical Performance Factors:** Although the current study included individual data in the multi-level modelling analysis, no results were presented to this level. Future research may wish to consider both technical and physical performance at individual player level given that empirical research (Vallerand et al., 1988; Redwood-Brown et al., 2012) suggests variability between players with regards performance accomplishments and success and failure.

  Incorporating the evolving score line would give a greater indication of score line effects; e.g. 2-0 could be perceived by players differently to 4-2 but would have recorded the same goal difference in the current study.

8.7 Conclusion

In support of the majority of previous research which has only examined situational factors independently, this thesis has extended our understanding of the complex dynamic nature of soccer in relation to technical (Alder, 1981; Bloomfield et al., 2004a; Jones et al., 2004; Lago, 2009; O'Donoghue & Tenga, 2001; Shaw & O'Donoghue, 2004; Tucker et al., 2005) and physical (REF) soccer player performance. The number of contrasting findings across the literature with regards to how teams perform when in different score line states, suggests players may not play the same across all matches (James et al., 2002; Lago, 2009; Lago & Martin, 2007; Taylor et al., 2008; Tucker et al., 2005). Approaching soccer performance as a physical, technical or tactical concept may be 'outdated' and considering the psychological impact of situational factors on individual players and score line may provide more information for managers and coaches to use in order to maximise team performance.

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EFFECTS OF SCORE LINE ON MATCH PERFORMANCE IN PROFESSIONAL SOCCER PLAYERS

APPENDICES

ATHALIE REDWOOD-BROWN

APPENDIX A

QueryTool

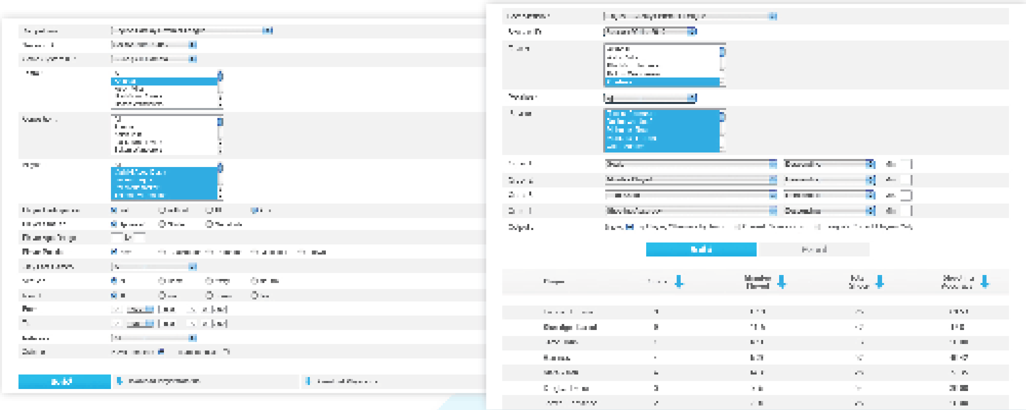
Product Overview

Opta's collection systems and methodologies have enabled us to build the most comprehensive and high definition database in the industry, with all match actions from all major football leagues analysed and recorded. The QueryTool is a powerful online propriety application which provides sports book marketers, quants teams and traders with direct access to the Opta database allowing them to interrogate datasets in an insightful and meaningful manner.

The QueryTool permits users to select from a range of competitions followed by specific teams, players or positions and create multivariate ranking tables.

The rankings are customisable based on over 120 different performance variables across single or multiple seasons. The tool provides a simple yet effective way to compare teams and players and extract bespoke data outputs.

The QueryTool permits marketing teams to offer unique, quirky and targeted promotional campaigns with complementary odds deduced from accurate historical datasets and trends. Trading and quants teams can utilise the QueryTool to development innovative products and specials markets differentiating brands in a crowded market place.



Product Detail

- Powered by industry leading Opta data.
- All major international football leagues and competitions are available.
- Entirely online solution accessed via any platform including iPhone and iPad.
- Export datasets for further analysis.
- Fully customisable searches and outputs.
- Multi-season searches and rankings.

Coverage

- *Premier League*
- *Champions League*
- *Europa League*
- *La Liga*
- *Serie A*
- *Bundesliga*
- *2. Bundesliga*
- *Ligue 1*
- *Eredivisie*
- *MLS*
- *Copa Libertadores*
- *Mexican Primera*
- *Spanish Segunda*
- *Russian Premier League*
- *Norwegian Tippeligaen*
- *Portuguese Primeira Liga*

Features & Benefits

- Simple and intuitive application.
- Innovative market leading product.
- Offers the ability to offer innovative new products and markets differentiating brands.
- No need to integrate XML feeds or develop in house databases and interrogation tools.
- Full training and ongoing support provided.

London +44 (0)20 7902 0600
Leeds +44 (0)113 236 8810
Madrid +34 91 536 38 38
München +49 89 200014 310
Sydney +61 (0)2 8060 3661
Bassano +39 (0424) 219 828
Milan +39 02 820 227 234
Paris +33 (0)144 641 376
New York +1 (212) 460 1482
Montevideo +598 2411 2774

optasports.com info@optasports.com

Table of Definitions – Pass Type

Second Assist/Key Pass	A pass/cross that is instrumental in creating a goal-scoring opportunity, for example a corner or free-kick to a player who then assists an attempt, a chance-creating through ball or cross into a dangerous position.
Key Pass	The final pass or pass-cum-shot leading to the recipient of the ball having an attempt at goal without scoring.
Passes	An intentional played ball from one player to another.
	Chipped pass - a lofted ball where there is a clear intended recipient
	Headed pass - a header where there is a clear intended recipient
	Launch - a long high ball into space or into an area for players to chase or challenge for the ball
	Cross - a pass from a wide position into a specific area in front of the goal
	Flick-on - a glancing pass with head or foot onto a team mate where the ball is helped on in the same general direction
	Pull back - a pass inside the penalty area which is pulled back from the goal-line to the centre of the penalty area
	Lay-off - a ball returned back to where it came from (usually by a forward) with one touch
	Through Ball - a pass splitting the defence for a team-mate to run on to.
	Each pass is logged with X and Y co-ordinates for its point of origin and destination. This allows Opta to log the following:
	Passes broken down area of the pitch for example by own half/opposition half or defensive/middle/final third or left/right/centre
	Passes broken down by half, for example short/long, short medium/long
	Pass direction, for example backwards/sideways/forwards.
Pass completion	This is simply a formula where Successful passes are divided by Total attempted passes in whichever combination of passes is selected.

APPENDIX B

PARTICIPANT INFORMATION SHEET

STUDY 1

Investigating perceptions of psychological momentum of elite soccer players, during competitive match situations.

You are being invited to take part in a research study. Before you decide, it is important for you to understand what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Please ask if there is anything that is not clear or if you would like more information.

Protocol and requirements

You will be required to answer a series of questions relating to your experiences of both positive and negative psychological momentum. These responses will be compared to previous research investigating perceptions of psychological momentum in soccer players to enhance our understanding of the area. The responses will also be used to generate themes or experiences which are most common in the following four areas:

1. Triggers/experiences of positive psychological momentum
2. Triggers/experiences of negative psychological momentum
3. Strategies to maintain positive psychological momentum
4. Strategies to overcome negative psychological momentum.

Benefits of taking part

From the information obtained I will be able to give both yourself and your manager feedback on the four areas above - namely, the experiences that are most likely to elicit both positive and negative momentum. I will also be able to give feedback highlighting which strategies are perceived to be used most often to maintain positive psychological momentum and overcome negative psychological momentum.

Risks of taking part

Thinking back to situations where you may have been experiencing negative momentum, may in very rare occasions cause you some discomfort if you were particularly affected by that situation (e.g. you played badly or lost a game). However this is not posed as a major risk and if at any point you feel uncomfortable answering such questions you may withdraw or "pass" on that question.

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you may also withdraw your data up to the 28th February 2012 without giving a reason.

Investigator contact information:

If you would like any further information about this study, then please contact:

Athalie Redwood-Brown Tel: 0115 84883229 Athalie.Redwoodbrown@ntu.ac.uk

*Primary contact

STATEMENT OF INFORMED CONSENT

I ……………………………..……… provide my full written informed consent to take part in the study entitled: *"Investigating perceptions of psychological momentum of elite soccer players, during competitive match situations."*

I am fully aware of the protocols I am to undertake, the potential risks and benefits associated with the procedures involved and understand that I may be under risk of injury if exercises are not carried out correctly. I also understand that I must follow the instructions of the researcher regarding alcohol consumption and the listening of music prior to training sessions.

I understand that I have had opportunity to ask any questions or communicate and discuss any additional concerns and queries associated with the trials. I understand that I have the right to withdraw from the trial(s) at any time with no obligation to provide reasons for the decision to withdraw.

Finally, I am assured that all information which I have provided and any that is obtained during the course of the testing will be treated as private and confidential and only communicated to others with my identity concealed.

Participant's signature:……………………………………………………… Date:……………………………

Witnessed by:..……….………………………………………………………. Date:……………………………

PARTICIPANT INFORMATION SHEET

STUDY 2

Quantifying perceptions of psychological momentum of elite soccer players, during competitive match situations.

You are being invited to take part in a research study. Before you decide, it is important for you to understand what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Please ask if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Protocol and requirements

You will be required to complete a short psychological momentum questionnaire, which will ask you to highlight your experiences of both positive and negative psychological momentum. These responses will be used to identify which items on the questionnaire are perceived to have the greatest impact on either positive or negative momentum. The questionnaire will also ask you to identify what strategies you use to maintain positive momentum and what strategies you use to overcome negative momentum. The questionnaire will take no longer than 15 minutes to complete.

Benefits of taking part

From the information obtained I will be able to give both yourself and your manager feedback on the experiences that are most likely to elicit both positive and negative momentum. I will also be able to give feedback highlighting which strategies are perceived to be used most often to maintain positive psychological momentum and overcome negative psychological momentum.

Risks of taking part

Thinking back to situations where you may have been experiencing negative momentum, may in very rare occasions cause you some discomfort if you were particularly affected by that situation (e.g. you played badly or lost a game). However this is not posed as a major risk and if at any point you feel uncomfortable answering such questions you may withdraw or "pass" on that question.

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you may also withdraw your data up to the 28th February 2012 without giving a reason.

Investigator contact information:

If you would like any further information about this study, then please contact:

Athalie Redwood-Brown Tel: 0115 84883229 Athalie.Redwoodbrown@ntu.ac.uk

*Primary contact

Statement of Informed Consent

I …………………………….……… provide my full written informed consent to take part in the study entitled: *"Quantifying perceptions of psychological momentum of elite soccer players, during competitive match situations."*

I am fully aware of the protocols I am to undertake, the potential risks and benefits associated with the procedures involved and understand that I may be under risk of injury if exercises are not carried out correctly. I also understand that I must follow the instructions of the researcher regarding alcohol consumption and the listening of music prior to training sessions.

I understand that I have had opportunity to ask any questions or communicate and discuss any additional concerns and queries associated with the trials. I understand that I have the right to withdraw from the trial(s) at any time with no obligation to provide reasons for the decision to withdraw.

Finally, I am assured that all information which I have provided and any that is obtained during the course of the testing will be treated as private and confidential and only communicated to others with my identity concealed.

Participant's signature:……………………………………………………… Date:……………………………

Witnessed by:..……….…………………………………………………………. Date:……………………………

APPENDIX C

NOTTINGHAM TRENT UNIVERSITY

Date: To Be Confirmed

Dear Parent or Guardian:

I am currently lecturing at Nottingham Trent University whilst conducting my PhD in the area of Performance Analysis and Sports Science in football. The focus of my research is on psychological momentum in football (i.e., how we build on positive and negative experiences). The aim of the research is to identify key triggers of psychological momentum, and these will be used to help coaches improve individual and team playing performance. The research will also be able to give feedback about strategies that are used most often to maintain positive psychological momentum and overcome negative psychological momentum.

Players will be asked a series of questions about their experiences of positive and negative psychological momentum in their sport.

There are no right or wrong answers to the questions. Your son will participate only if they are willing to do so. Only the relevant coaches and I will have access to the information gathered. Each of the questionnaire responses will be kept confidential by replacing names with numbers. At the end of the study, player responses will be reported as a group, and individuals can obtain a summary of findings after the study is complete by contacting me via the below email address.

Participation in this study is voluntary. Even if you give your permission for your child to participate, your child is free to refuse to take part. If your child agrees to participate, he or she is still free to withdraw at any time. Please note that your child can withdraw their data until one week following the final date of data collection (TO BE CONFIRMED FOLLOWING ETHICAL APPROVAL) .

If you are happy for your child to participate, then you do not need to do anything further. ONLY if you do NOT give consent to your child taking part in the study, please fill in the relevant information at the bottom of the page and return it to me via the club. Should you have any questions or desire further information please contact me, Athalie Redwood-Brown on Athalie.Redwoodbrown@ntu.ac.uk.

Kind Regards,

Athalie Redwood-Brown (Senior Lecturer, Nottingham Trent University)

Please indicate ONLY if you do NOT wish to allow your child to participate in this project by stating your child's surname followed by your signature and return this form to **(your coach)** by (TO BE CONFIRMED)

I do not grant permission for ________________________ to participate in the study.

________________________________ ________________________________

Signature of Parent/Guardian Printed Parent/Guardian Name

Date: XX XX XXXX

To Whom It May Concern:

As part of a postgraduate research project I am looking for participants to take part in a study related to psychological momentum in Soccer. As you are a current collaborator with the University in relation to support placements, I would be very grateful if you would consider your team in taking part in this study. Please find below information on the purpose and subject requirements of the study.

Objectives and Purpose of the research

The study aims to investigate the perceptions of psychological momentum of elite soccer players during competitive match situations.

Expected starting and completion dates

Start date: February 2012 Completion date: May 2012

Subjects required

Members of your team who are classed as professional (e.g., playing/training full time within the team as their main source of income). Participation is dependent upon the clubs approval, and the passive consent of parents if the player is under 18 (i.e., if they do not want their child to participate, they can return a form to 'opt-out' their child/ren), and also the player's willingness to take part. Players can withdraw at any time during data collection. Once data collection is complete each participant has 1 week to remove their data from the study.

Methods and Procedures

If the study receives your approval each player will receive an informed consent form with information of the study (see attached), if the player is under 18 the parent/guardian will receive the informed consent form along with a passive consent form (see attached). Any player under 18 who does not return the passive consent form to you will be deemed available to take part in the study. All players must complete the informed consent prior to taking part in the study. Players will be required to answer a series of questions relating to their experiences of both and negative psychological momentum. These responses will be compared to previous research investigating perceptions of momentum in soccer players to enhance or understanding of the area. Once all of the responses have been collated players will be required to complete a short psychological momentum questionnaire based on the collective responses given, specifically relating to triggers/experience of positive momentum, negative momentum and strategies to maintain positive and negative momentum.

Steps to guard anonymity of subjects and the confidentiality of their responses

Anonymity and confidentiality of participants and their responses will be maintained by changing names into numbers (participant IDs will be assigned to each player). Only my supervisor and I will see the data and all results will be reported collectively as most frequent responses from the group.

If additional information is required about the study please contact Athalie Redwood-Brown via email, **Athalie.Redwoodbrown@ntu.ac.uk**

If your club is happy to participate in the study, I would be grateful if the section below could be returned.

Kind Regards,

Athalie Redwood-Brown
Nottingham Trent University

I have read and approve the research study entitled, "Investigating perceptions of psychological momentum of elite soccer players during competitive match situations."

I give consent for the study to be conducted at:

____(Name of Club & Section).

Signature:	Date:

APPENDIX D

Psychological Momentum Questionnaire: Briefing statement: The following set of questions will ask you to highlight the extent to which certain things give you positive or negative momentum and to what extent you use certain strategies to alter this momentum. It is important that you take your time to answer the questions as honestly. Please ask if you do not understand any of the questions/terminology. After completing the interview you have the right to withdraw your responses in accordance with the consent form you have signed.

Psychological Momentum Questionnaire							
Positive Momentum is defined as; " a gained psychological power or state that gives us a feeling that we have an edge over oppoents". Please read each element below and answer to what extent it gives you ***positive momentum*** *(when it occurs during the game)*							
	Not at all						Very much so
You see negative body language from opponents	1	2	3	4	5	6	7
Opponents weaknesses are highlighted	1	2	3	4	5	6	7
Opponents make mistakes	1	2	3	4	5	6	7
You feel confidence	1	2	3	4	5	6	7
Good luck/fortune	1	2	3	4	5	6	7
You or your team score a goal	1	2	3	4	5	6	7
Referees decisions going your way	1	2	3	4	5	6	7
Previous experiences/achievements	1	2	3	4	5	6	7
You receive encouragement from team-mates	1	2	3	4	5	6	7
You receive encouragement from coach	1	2	3	4	5	6	7
You receive encouragment from crowd	1	2	3	4	5	6	7
You receive encouragement from captain	1	2	3	4	5	6	7
The team feels cohesion/united	1	2	3	4	5	6	7
You have a positive attitude	1	2	3	4	5	6	7
Negative Momentum is defined as; "psychological state of mind affecting performance in a negative direction where most everything seems to go wrong where we may feel frustrated, disapointed and angry" Please read each comment below and answer to what extent it gives you ***negative momentum*** *when it occurs during the game.*							
	Not at all						Very much so
Playing opponents of higher ability	1	2	3	4	5	6	7
Opponents strengths are highlighted	1	2	3	4	5	6	7
Opponents reputation	1	2	3	4	5	6	7
Uncontrollable response of opponent	1	2	3	4	5	6	7
Bad luck/fortune	1	2	3	4	5	6	7
You or your team conceed a goal	1	2	3	4	5	6	7
Bad Refereeing decisions	1	2	3	4	5	6	7
Complacency	1	2	3	4	5	6	7
Loss of concentration	1	2	3	4	5	6	7
Feeling nervous and/or anxious	1	2	3	4	5	6	7
Lack of perceived ability	1	2	3	4	5	6	7
When you feel fatigue	1	2	3	4	5	6	7
Negative critism	1	2	3	4	5	6	7
When you feel under pressure	1	2	3	4	5	6	7
Below is a list of strategies used to develop or mantain ***positive psychological momentum*** *. On the scale below please answer to what extent you use each strageties to maintain poistive momentum during a game*							
	Not at all						Very much so
Goal setting	1	2	3	4	5	6	7
Preparation	1	2	3	4	5	6	7
Relaxation	1	2	3	4	5	6	7
Trigger words (which help to stay focused, motivated etc)	1	2	3	4	5	6	7
Physical preparation (training preparation)	1	2	3	4	5	6	7
Changing tactics	1	2	3	4	5	6	7
Use of time (alowing down or speeding up the game)	1	2	3	4	5	6	7
Going back ot basics	1	2	3	4	5	6	7
Building confidence	1	2	3	4	5	6	7
Maintaining concentration	1	2	3	4	5	6	7
Maximisming effort	1	2	3	4	5	6	7
Controlling pace	1	2	3	4	5	6	7
Retaining possession	1	2	3	4	5	6	7
Giving encouragement to team mates	1	2	3	4	5	6	7
Targeting opponent's weaknesses	1	2	3	4	5	6	7
Below is a list of strategies used to overcome ***negative psychological momentum*** *. On the scale below please answer to what extent you use each strageties to overcome negative momentum during a game*							
	Not at all						Very much so
Changing tactics	1	2	3	4	5	6	7
Controlling pace	1	2	3	4	5	6	7
Frustrating opponents	1	2	3	4	5	6	7
Managing pressure	1	2	3	4	5	6	7
Managing anxiety	1	2	3	4	5	6	7
Encouraging team mates	1	2	3	4	5	6	7

APPENDIX E

NOTTINGHAM TRENT UNIVERSITY

Study 1 Interview Guide:

Briefing statement:

The following set of questions will ask you to recall your experiences of both positive and negative psychological momentum. These responses will be compared to previous research to enhance our understanding of the area. It is therefore important that you take your time to answer the questions as honestly and as fully as possible. Please ask if you need any of the questions repeated or if you do not understand what is being asked. Similarly if you do not feel comfortably answering any of the questions, you can move on. You may terminate the interview at any time and if you wish, you may withdraw your responses in accordance with the consent form you have signed.

Main Questions	Probes	Follow-Up
<u>Introduction</u> 1. Name, D.O.B, highest playing standard, experience 2. Describe your involvement in football at the moment		
Players Perspective 3. What do you understand by the phrase psychological momentum? 4. How does it feel when you have the upper hand in the game? 5. What goes through your mind when you have the upper hand? 6. How does it feel when you are on the back foot in a game? 7. What goes through your mind when you are under the cosh 8. How does it feel when the game is balanced? 9. What goes through your mind when the game is balanced 10. Why do you think the tide turns in matches, why does momentum swing your way? 11. What are trying to accomplish when begin to feel like you have the upper hand? 12. What thoughts go through your mind when you feel like you are starting to lose the upper hand? 13. How do you try and overcome this? 14. What's the difference between these situations (positive momentum / negative momentum) and when the game appears to be in balance? 15. Can you describe the gaining of the upper hand as a process? Does something have to happen for you to gain or lose momentum?		
Responses 16. How do you respond if the run of play is going against you? 17. How do you respond if you are on the front foot, for example your team has just scored?		
Team 18. How do your team-mates react when you are on the back foot 19. How do your team-mates react when you have the upper hand? 20. How does your team effect how you respond to having the upper hand? 21. How does your team effect how you respond when the run of play is going against you? 22. Do you think that individual players can have an effect on how the team deals with and reacts to gaining or losing the balance of power during games? How, why, why not?		
Control 23. Do you think it is important to control momentum in games? Why, why not		

24. Can you give examples of strategies used to control the balance of power within a game? 25. What strategies do you use to weather the storm if you are on the back foot? 26. What factors help you control the balance of power? 27. What factors affect you controlling the balance of power? 28. What would you suggest to another player who feels like the run of play is always against him? 29. What would you suggest to another player who feels they lose the upper hand after a run of success? 30. When the game is in balance what can be done to tilt the play in your direction 31. What can be done to prevent the opposition doing the same?		
Other factors 32. After scoring are you (as in either yourself or your team) more likely to score another goal or more likely to concede one? Why? 33. After conceding are you (as in either yourself or your team) more likely to concede another goal or more likely to score? Why? 34. Does the coach/manager affect you gaining or losing momentum? How, why, why not? 35. Does the crowd affect you gaining or losing momentum? How, why, why not? 36. Are there any other factors that affect the balance of power? Explain? 37. Do stoppages affect you gaining or losing momentum? How, why, why not? 38. Does momentum change during half time? Why, how, why not? 39. How does the score line going into the final 15 minutes affect in the closing minutes?		

APPENDIX F

venatrack
3d real-time sports analysis

Venatrack Limited
938 Yeovil Road
Slough
Berkshire
SL1 4NH

15 September 2011

To Whom It May Concern:

RE: ATHALIE REDWOOD-BROWN

Venatrack have been working with Athalie Redwood-Brown for the past 4 years in conjunction with her research in academia. We are fully supportive of her research proposals and studies that will form her PhD thesis. As part of these studies I understand that she will require data, currently owned by Venatrack Limited. Athalie Redwood-Brown will have full access to any physical, technical and player data that she requires for the purposes of either her PhD or research, providing all publications are discussed prior to their submission to academic journals or such like.

Kind regards,

Paul Schenk
Managing Director Commercial

APPENDIX G

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3d real-time sports analysis

Eventing Concept

Eventing Guidance

Document reference	
Authors	Jonathan Davis Athalie Redwood-Brown
Pages	21
Revision	0.4
Status	Draft

Definitions Of Prozone's Football Events

ProZone