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MOMENTUM PROFILING USING PERTURBATIONS IN ELITE FEMALE SQUASH

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ACKNOWLEDGEMENTS

I would like to take this opportunity to express my gratitude to the people who have made my University years and dissertation a success.

Many thanks to Professor M.D. Hughes for his continual assistance throughout this study, and without his guidance or contacts it would not have been possible.

Thanks to England Squash, especially Stafford Murray for their help in supplying video footage.

Also many thanks to my parents Roger and Lynne, for their endless support.

Final thanks to my friends at University, for their continual support through some of the best and hardest times.

Abstract

Momentum in sport is classified as a 'rhythmic reinforcement' where the energy generated becomes recycled through a loose cybernetic feedback system of upwardly spiralling elation and achievement (Adler and Adler, 1978). Positive momentum can be characterised by a winning streak, for example, in squash, by a player hitting a succession of winners, thus attaining a psychological state of mind where most everything 'goes right' for the performer (Burke et al., 1997). Fenwick et al. (2006) found that the World number ones, both men and women, managed their momentum swings better than their peers, as they exhibited significantly greater lengths of positive momentum. Fuller (2007) extended this study and examined how momentum calculated from perturbations might complement traditional methods of compiling performance profiles from winners and errors. The aims of this study were to create momentum profiles using perturbations for elite female players, and examine how these perturbation momentum curves might complement traditional methods of compiling performance profiles from winners and errors.

Data from competitive matches (N=3 for each player) on the WISPA circuit were analysed from DVD post event, on four elite female players ranked within the top five of the World. Intra-operator reliability test was performed, the overall highest error being 9.1%, which was deemed acceptable due to the subjective nature of the data.

Perturbations were identified from all areas of the court with the backhand back corner the most predominant. Drop shot (34%), volley drop (15%) and boast (13%), were identified as the likeliest of causes of perturbations reinforcing the findings of Hughes et al. (2005) with the cross-court volley drop (11%) and cross-court drives (9%), narrowly following. The distribution of perturbations were significantly different (***P***<0.001) from the distributions of winners and errors. It was strongly felt that the curves are best used with their individual match sequentiality retained – enabling an insight into the particular changes in momentum in each match. In this way the use of perturbation momentum curves does complement and inform the traditional methods of compiling performance profiles.

CHAPTER I

NATURE OF THE STUDY

1 Introduction

Notation analysis within sport has amplified with sport science teams integrating performance analysis within their set up. Yet notational analysis is a procedure that can be used in any discipline that requires assessment and analysis of performance (Hughes and Franks, 2004) not only in sport. The nature of feedback whether qualitative or quantitative, is equally important, although research (Franks et al., 1983) has shown that more objective feedback, for example, quantitative, the greater the effect on performance.

A number of studies have been conducted investigating 'pattern of play'; Sanderson and Way (1979) examined the hypothesis that an individual exhibits a pattern of play, which is relatively stable over time and independent of the opponent, whilst additionally analysing the similarities of stroke frequencies for individual players in different matches against different opponents. More recent research further indicates that it is essential to have an understanding of your opponent's tactical strengths and weaknesses (Murray and Hughes, 2001) as well as your own. In continuation of this statement Murray and Hughes (2001) carried out consultancy work with England Squash, developing a performance technique in belief that players adhere to set patterns, 'by modelling performance in this way tactical plans can be based upon empirical evidence' (Murray and Hughes, 2001). McGarry and Franks (1994) suggested that a player exhibits greater consistency, when matched against the same opponent, rather than against a different opponent. As a result it is believed that establishing a normative profile is critical, and an important question to bear in mind when reviewing research is, how many matches were exploited to construct this profile? Evans (1998) stated 'ideally a good player profile can be established by using a collection of five matches, the more matches that one can notate the more accurate an emerging pattern will be'. Contrary to this finding Hughes et al. (2001) suggested that if data collection becomes too large it might become insensitive to slight changes making it imprecise, in that it will not reflect current 'form', for example, a recent performance will not be reflected accurately, within a large database that has been constructed over a number of years. As limited research has been conducted in the field of momentum profiles in female squash it is essential to create a normative profile for this study. One previous study, (Hurst, 2007) found that it was necessary to notate four matches, on each elite female player.

The feedback provided, by winner and error analysis of a player's game is fundamentally important with regards to player development, as a simple system illustrates both shot and court positioning of the final ball played. Sanderson and Way (1979) introduced a simple system utilising symbols for 17 shots, in addition to court plans for accurate positional information. Winner and error statistics are most advantageous when conducted during event, enabling coaches to interact with the performer at game intervals, generating instructions and feedback based on data gathered. Within this study winner and error tallies will enable a comparison to be carried out between player momentum and winner and errors played.

Research acknowledges that perturbations exist in sport (Hughes et al., 1998) and more specifically in squash (McGarry et al., 2002; Hughes et al., 2005). A standard rally will incorporate a succession of length shots played deep to the back of court, whilst waiting for an opportunity to attack. This type of rally demonstrates the typical rhythm of a squash match, yet once a disturbance in open play arises it is known as a perturbation placing the player in a disadvantaged position, with extreme changes in velocity being observed in an attempt to recover the shot. Hughes and Reed (2005) stated that a perturbation exists when 'the usual stable rhythm of play is disturbed by extreme elements of high or low skill' and may even lead to a critical incident such as a winning shot in squash or a shot on goal in football. Nevertheless, it must be noted that not all perturbations lead to critical incidents occasionally normal rhythm can be restored by quick movement or good defensive shots, yet research by Hughes et al. (2005) indicate that there is an increased opportunity of winning rather than losing a rally, subsequent to playing a perturbation.

Squash is a dynamic game showing evidence of a stable rhythm – a game played between two players where one's action affects the behavior of the opponent and consequently the rhythm of play shifts from bouts of stability to instability. Kelso (1999) defined two main categories that may adjust a dynamic system: environmental conditions (stability), and internal and external conditions (adaptability). Pearson (2001) specified that in order to control the rhythm of a squash game, it is vital to control the ‘T’ and attempt to keep your opponent under constant pressure, a tactic occupied by both players. McGarry (2006) stated, ‘the nature of squash is that, typically as one player leaves the T-position to make the next shot the other player returns to the T-position, and vice versa as the shot sequence progresses’.

Momentum is a physical term that refers to the quantity of motion that an object has, and can be defined as ‘mass in motion’ (Henderson, 2004). It has been proven (Fenwick et al., 2006) that elite players at the higher tier of the rankings illustrate improved momentum than those below. Despite Fenwick et al. (2006) utilising winner and error tallies to generate their profiles, research acknowledges that the final shot is not the most important, flooring the results of momentum profiles using winner and error tallies. Hughes and Murray (2001) further analysed the distribution of shots that preceded the end shot (N-1)W and (N-1)E, and shots preceding these (N-2)W and (N-2)E, enabling the researcher to scrutinise which shot types contributed the most to the frequencies, in the important areas of the court.

Momentum results displayed in graphs provide a visual representation of performance, for both the player and coach to assess in post-event, whilst winner and error tallies can be compared to profiles assessing their contribution to momentum. Opponent profiles can additionally be created analysing a player’s strength and weakness; precise tactics can then be employed when playing the opponent, and as a consequence of ‘modelling the oppositions’ performance, it is possible to predict certain outcomes and patterns’ (Fenwick et al., 2006) before they occur.

Player momentum determined through perturbations will further enable participants and coaches to understand the importance of ‘game control’ and improve their game through feedback and tactical interventions (Reed and Hughes, 2005). Factors such as fatigue and concentration, nonetheless may affect the momentum of a player (Fenwick et al., 2006), and a question to consider when comparing momentum profiles in the latter stages of a match is; does player momentum using perturbations decrease as a player becomes fatigued?

Fuller (2007) conducted a similar investigation to this study on elite male players. He concluded that no comparisons were found between momentum profiles using winner and error tallies, to the momentum profiles using perturbations. He further concluded that player momentum was not affected by the use of perturbations, yet the physiological characteristics of the body have an effect upon the amount of perturbations played as players become fatigued.

The aim of this investigation is to generate momentum profiles of a number of elite female squash players by means of perturbations, and analyse these in a series of comparative case studies

1.2 Aims

1. To create momentum profiles of elite female squash players using perturbations.
2. To investigate if perturbation momentum profiles of a number of games for a particular player can be added to give an ‘aggregated momentum profile’ and examine what this informs about the player.
3. To compare perturbation momentum data to winner and error momentum data, and examine whether these analyses complement the profiling process.
4. To compare the momentum profiles of female elite squash players with those of male elite squash players.

1.3 Hypothesis

1

$\mathbf{H}^0$ Momentum profiles created by positive and negative perturbations by elite female squash players will be significantly different to profiles for the same players created from winners and errors.

$\mathbf{H}^1$ No difference in profiles will be found.

2

H^0^ Momentum of elite squash players will not be affected by the use of perturbations.

H^1^ Momentum of elite squash players will be affected by the use of perturbations.

1.4 Limitations

One of the main constraints of this study is the lack of research developed in the area of momentum and perturbations combined. Another limitation is the time constraint within the academic year.

1.5 Delimitations

A delimitation of the study includes the population of elite female performers. Word count is also a restriction, as all aspects may not be analysed thoroughly.

1.6 General definition of terms

Table 1.1: General definition of terms

General terms	**Definition**
Perturbation	A sudden movement away from the 'T'- as a sudden disturbance has occurred changing the tempo of the game.
Stability	Games' ability to regain its original rhythm once a perturbation has occurred.
Critical incident	A critical incident is simply a winning shot in squash, or a shot on goal in football.
Performance indicator	A performance indicator is a selection, or combination, of action variables that aims to define some or all aspects of a performance (Hughes et al., 2004).

CHAPTER III

METHODOLOGY

3 Methodology

3.1 Introduction

Hughes et al. (2005) devised a system in order to collect perturbation data for elite male squash players. It was seen adequate to utilise a similar data collection procedure to collect raw data, calculating momentum profiles using perturbations for 4 elite female players ranked in the top ten in the World.

This system enabled the researcher to analyse:

- Whether a perturbation occurred for or against a player
- What shot and court position it occurred at
- Where in the rally the perturbation occurred
- Whether or not the rally re-gained stability

Further the rally ending shot, total number of shots and whether it was a winner or error were recorded. Additionally to this system, a decision was made to include the score following each rally.

The matches were analysed in post-event on DVD through a DVD player, in order to allow the use of pause and re-wind minimising the amount of errors within the data.

3.2 Equipment

- Pens
- Hand notation system

3.21 Hardware

- ACER laptop
- Windows media player
- Panasonic TV/DVD combo
- Excel

3.22 The system

3.221 Pilot Study

Initially, before data collection began a pilot study was conducted. A two-hour training block was set-up in order for the researcher to practice data gathering, and therefore minimise any future errors. A practice run not only for the researcher but also the system, to check it is free from limitations.

3.222 Final Data Collection System

Twelve matches in total, three for each subject were notated in post event from a DVD, which were originally recorded from a video camera placed behind yet above the court in a central position. Once a disturbance in open play occurred, changing the rhythm of the rally, the shot causing the perturbation was notated, along with details regarding whether the perturbation was for or against the player, the number of shots pre and post- perturbation, and position on court when the shot was played.

Rally No.	Perturbation for	Perturbation against	No. of shots at that point	Shot	Stability gained	No of shots taken to gain stability	Momentum for	Momentum against	Rally ending shot	Winner or Error	Player	Total no. of shots in rally

Figure 3.1: Hand notation system used to collect Perturbation data.

Table 3.1: Symbols utilised to notate the shot perceived during the match.

Shot type	**Symbol**
Serve	S
Drive	D
Cross Drive	XD
Volley	V
Cross Volley	XV
Drop	d
Volley drop	Vd
Cross drop	Xd
Cross Volley Drop	XVd
Boast	B
Volley Boast	VB
Reverse Boast	RB
Back wall Boast	BB
Triple Boast	TB
Lob	L
Cross Lob	XL
Kill	K
Volley Kill	VK
Cross Volley Kill	XVK

Table 3.2: Operational definitions for the investigation

Skill	Definition
Perturbation	When a disturbance in open play occurs, identified from a sudden movement from the 'T', or a sound.
Stability	Once a rally has become volatile, stability was only regained when two consecutive shots were played restoring and returning the rally to equilibrium.
Boast	The ball is played into a sidewall, then the front wall towards opposite sidewall.
Drive	Strike the ball to the back of the court.
Lob	The ball is played high and softly to the back of the court.
Drop	A short shot played softly to the front of the court.
Volley Boast	The ball is played in the air prior to it bouncing, into a sidewall, then the front wall towards opposite sidewall.
Volley	The ball is played in the air prior to it bouncing.
Serve	Played to begin a rally - hit above service line, from one side of court to the other, bouncing behind mid-court line.
Back wall boast	A shot hit off the back wall so that it hits the front wall before bouncing.
Skid Boast	Initially the ball is hit high onto the side wall, then onto front wall and returning to the opposite back corner.
Reverse Boast	A shot, which hits the opposite sidewall, then strikes the front wall.
Triple boast	Similar to the boast, yet a soft shot played at the front of the court.
Kill	A ball played low and hard, at the front of the court aiming for the nick.
Stroke	The opponent wins the rally, due to a circumstance where interference arose during the rally.
Let	A situation where the rally is replayed

Position (cell): Squash court divided into 4 x 4 cells, labelled 1–16.

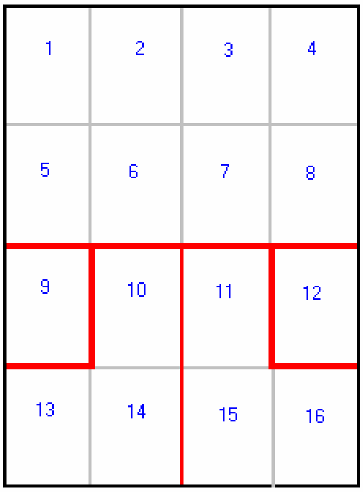

Figure 3.2: Squash court diagram, utilised to distinguish position of the shot.

3.223 Reliability

An intra-operator reliability test was performed to assess if the operator was identifying perturbations correctly, a procedure completed by analysing a single game on four separate occasions. Once the games had been notated the results were entered onto a spreadsheet and analysed for difference. It was decided that a percentage error of 10% would be acceptable for this study.

$\sum(\text{mod}(V1 - V2)) / \text{Vtot mean} \times 100\%$

Where mod is the modulus and $\sum$ indicates the sum of the overall percentage error, and Vtot mean is the mean of the total variables measured.

3.3 Data Population

Four international players were analysed in this study, all ranked in the top 10 of the World. Matches of a competitive nature on the professional circuit were analysed all during the past two years, removing the likelihood that players may have adapted their playing patterns, further as the DVD's were provided by England Squash no informed consent was necessary. Data was assumed to be homogeneous, as most of the women's matches were against each other. Fenwick et al. (2006) recognised that male data was heterogeneous as a number of matches were against lower ranked opponents consequently skewing results. An in-depth study was conducted on one subject, due to the quantity of data gathered and processed it was unfeasible to conduct studies on all subjects, nevertheless all four subjects were included in the overall profile.

3.4 Procedure

A quiet working environment must be occupied, in order to conduct a reliable test where no interruptions will distract the researcher. Once an adequate workspace has been established the data gathering procedure began.

The first stage of analysis began with the researcher counting the number of shots from when the rally began. When a perturbation occurred the DVD was paused whilst the perturbation was noted for the particular player. Once noted, the DVD was replayed from the beginning of the rally, where the operator identified whether the perturbation occurred for or against the player, including at what stage in the rally the perturbation arose and identifying the shot type. Following a perturbation the DVD was resumed and the operator continued by counting the number of shots, if the rally continued for two or more then it was deemed to have regained stability. On the contrary if the rally terminated, the ultimate and total number of shots of the rally were recorded and whether it was a winner or an error for the player. Finally player momentum was calculated by giving '-1' for a perturbation against the player and a '+1' for a perturbation for the player, a procedure that was continued throughout the analysis.

3.5 Data Processing

The raw data gathered utilising the hand-notation system was placed in Microsoft Excel, where data analysis was conducted. Here, percentages of shots causing perturbations for and against the player were calculated, along with the court position of where perturbations were likely to occur. It was further investigated whether rallies regained stability following a perturbation. Chi-Square Test was conducted, between the cell perturbations were played from, and the England Squash winners and error profiles.

Secondly, momentum graphs were created using perturbations for and against the player. In conjunction with the match and game scores, the peaks and troughs of momentum were investigated identifying playing patterns and a player’s reaction within a winning and losing environment. Positive momentum peaks were also analysed, with regards to length, whilst investigating the number of points scored during a bout of positive momentum.

CHAPTER V

CONCLUSIONS

5.0 Conclusion

It was concluded that:-

- Perturbations were identified reliably from all areas of the court with the backhand back corner the most predominant. Drop shot (34%), volley drop (15%) and boast (13%), were identified as the likeliest of causes of perturbations.

- The distribution of perturbations were significantly different (***P***<0.001) from the distributions of winners and errors.

- Aggregating momentum curves produced some interesting data, but it is strongly felt that the curves are best used with their individual match sequentiality retained – enabling an insight into the particular changes in momentum in each match.

- In this way the use of perturbation momentum curves does complement and inform the traditional methods of compiling performance profiles.

5.1 Future Investigations

Using voice interaction systems now available, for use in performance analysis, a full in-event analysis could be conducted. Leading onto the possibility of in-event perturbation analysis, where feedback related to perturbations can be transferred between games.

Image-recognition tracks linking perturbations to velocity, is a possible future research project. Using a method created by Vuckovic et al. (2004), perturbations maybe quantified as a physical measurement, rather than a quantitative method, by categorising perturbations, and linking to a change in velocity.

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APPENDICIES

APPENDIX A

Cumulative momentum curves for subjects 2,3 and 4

APPENDIX B

Chi-squared Test results for winner and error profiles against perturbation profiles for subjects 1 and 2

APPENDIX A
Subject two

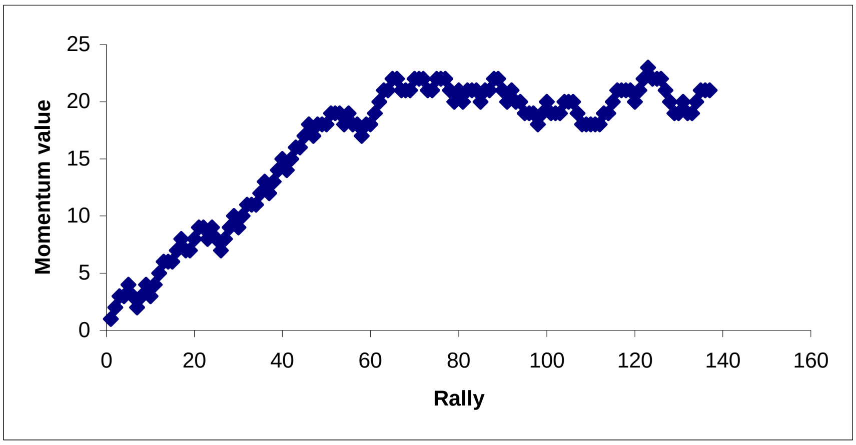

Figure 7.1: Graph showing cumulative momentum using perturbations for subject two vs. Opponent B

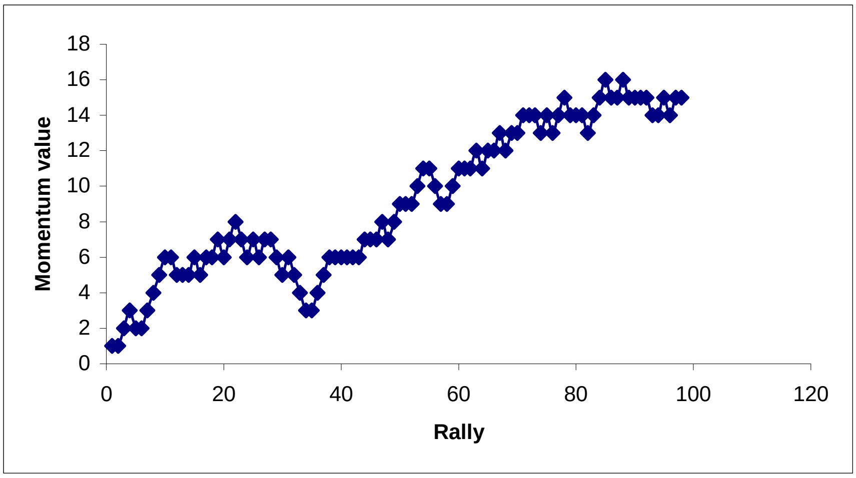

Figure7.2: Graph showing cumulative momentum using perturbations for subject two vs. Opponent C.

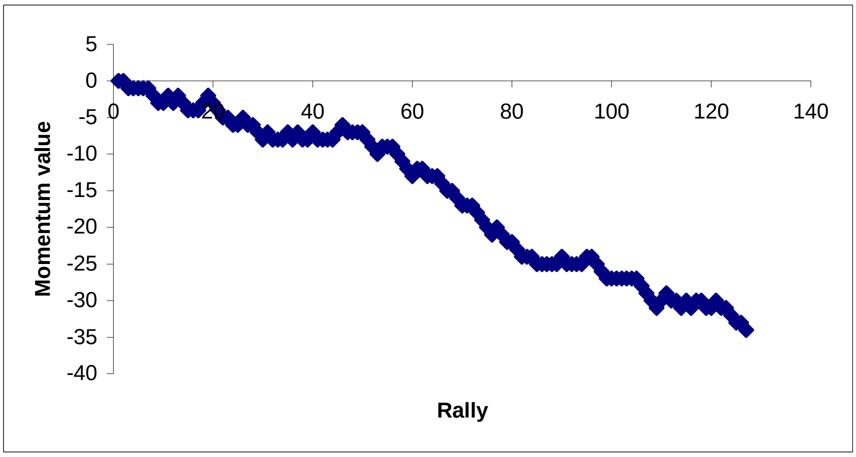

Figure7.3: Graph showing cumulative momentum using perturbations for subject two vs. subject four

Subject three

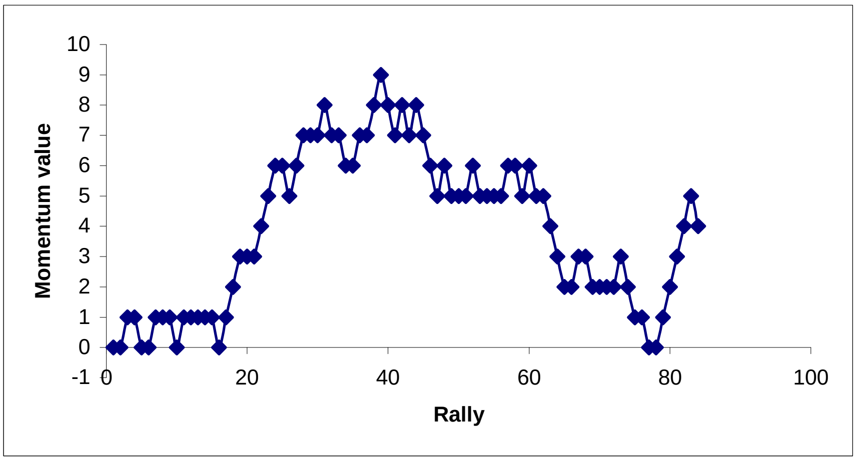

Figure 7.4: Graph showing cumulative momentum using perturbations for subject three vs. subject one.

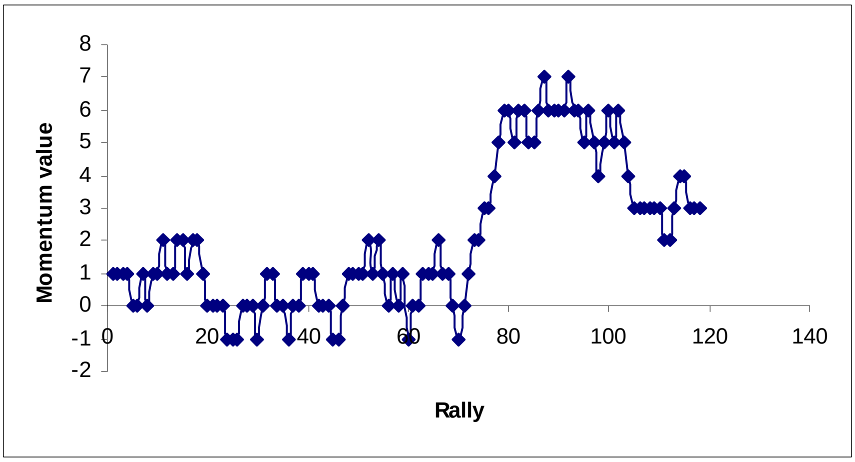

Figure7.5: Graph showing cumulative momentum using perturbations for subject three vs. Opponent D

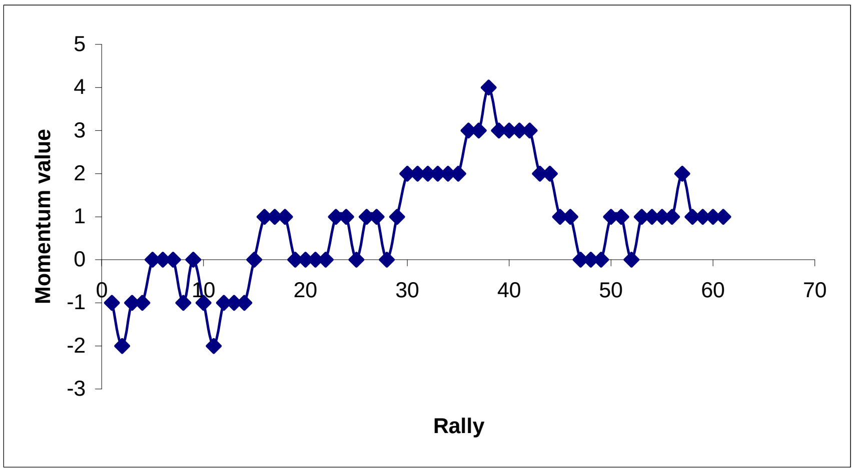

Figure7.6: Graph showing cumulative momentum using perturbations for subject three vs. subject four.

Subject four

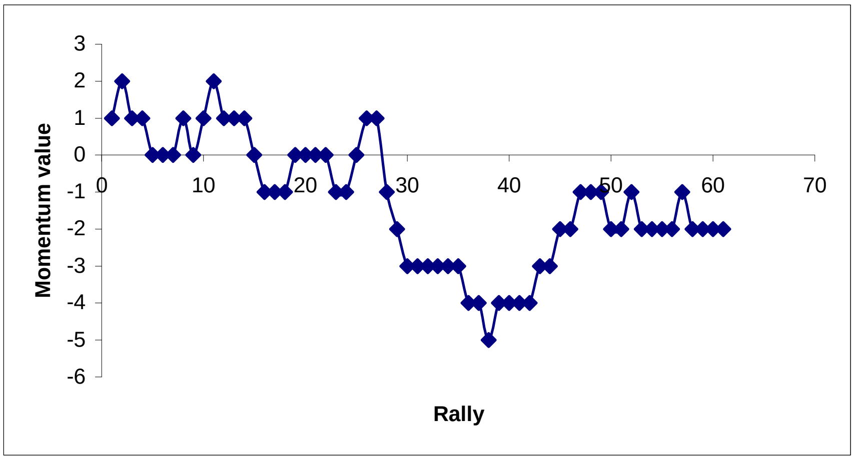

Figure7.7: Graph showing cumulative momentum using perturbations for subject four vs. subject three.

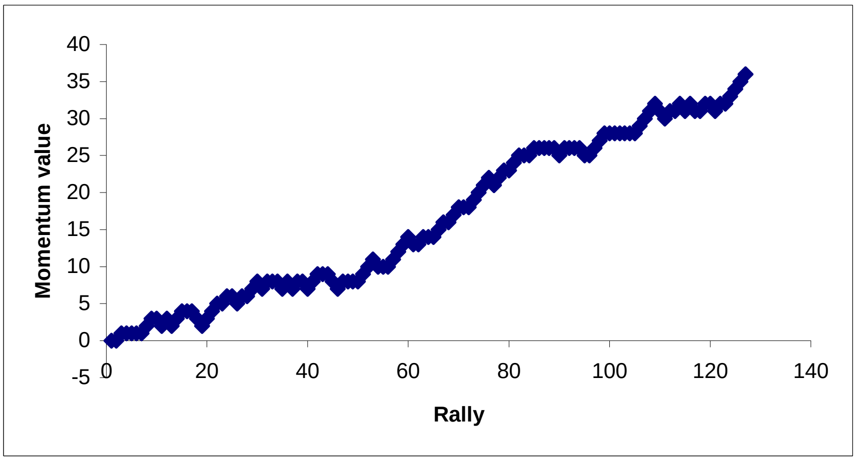

Figure 7.8: Graph showing cumulative momentum using perturbations for subject four vs. subject two.

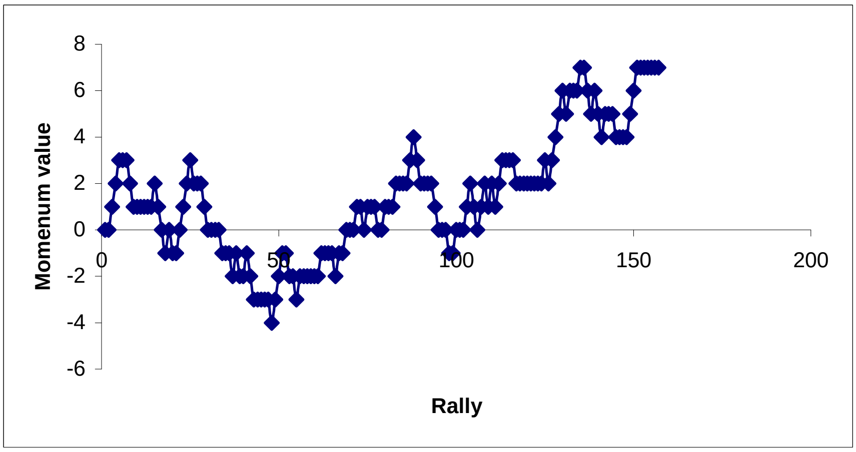

Figure 7.9: Graph showing cumulative momentum using perturbations for subject four vs. Opponent E

APPENDIX B

Table 7.1: Chi-Squared output for subject one and two, for winners played compared to England Squash Winner and Error profile

Subject 1

Cell	Pertubations	Winners
1	1	3
2	2	1
3	1	3
4	3	1
5	12	5
6	5	5
7	7	5
8	4	1
9	17	6
10	29	10
11	15	2
12	7	3
13	18	2
14	10	4
15	3	3
16	1	2

Chi-Squared 32.675
$p<0.001$

Subject 2

Cell	Pertubations	Winners
1	2	1
2	0	0
3	1	0
4	1	4
5	16	4
6	3	3
7	3	4
8	1	4
9	13	8
10	10	3
11	9	7
12	9	1
13	26	7
14	8	6
15	4	1
16	12	1

Chi-Squared 23.814
$p<0.001$