CHAPTER 1

1.1 INTRODUCTION

There are pertinent factors that play a part in attacking play, in particular the collision site where the ball carrier and defender meet. In all aspects of the game, the players or teams that are able to manage and dominate this facet of play to their advantage should be more adept at moving up the field in order to get into a scoring position (Meyer, 2005).

This study will primarily be empirical in nature making use of analytical research methods. According to Thomas and Nelson (1996), a danger of such a study is that relying too much on personal experience may be a pitfall as one's own experience may be limited, furthermore, one's retention depends substantially on how the events agree with ones past experiences and beliefs, on whether things "make sense", and on the state of one's motivation to remember.

In order to guard against this possible danger, notational analysis will be done in order to attempt to analyse these collisions in the sport. This will be done using a specifically defined analysis process so that a biomechanical explanation is able to be made thus making it possible to use this information in a coaching environment (James & Bates, 1997; Mullineaux, Bartlett & Bennett, 2001; Bracewell, 2002).

Biomechanics and notational analysis both involve the analysis and improvement of sport performance. They make extensive use of video analysis and technology. They require careful information management for good feedback to coaches and performers and systematic techniques of observation. They do differ however in that biomechanists analyse, in fine detail, individual sports techniques and their science is grounded in mechanics and anatomy. Notational analysis studies gross movements or movement patterns in team sports and is primarily concerned with strategy and tactics (James & Bates, 1997; Bartlett, 2001; Mullineaux et al., 2001, Bracewell, 2002).

Traditionally, coaching intervention has been based upon subjective observations of athletes. However, several recent studies have shown that such observations are not only unreliable but also inaccurate. Franks and Miller (1986) compared coaching observations to eyewitness testimony of a criminal event. Using methodology gained from applied memory research, they showed that international-level soccer coaches could only recollect 42% of the key factors that determined successful soccer performance during one match.

In another study, a forced choice recognition paradigm was used by Franks (1993), who found that experienced gymnastic coaches were not significantly better than novice coaches in detecting differences in two, sequentially presented, front hand-spring performances (Hughes & Franks, 1997).

The evidence from these studies leads one to believe that the processing of visual information through the human information processing system is extremely problematic, if one requires an objective, unbiased accounting of past events. Hence, the solution is to collect relevant details at the termination of that event, analyse them in order to give the most accurate evaluation of movements or play possible, and to make this information available to the players as feedback for optimal performance improvement (Magill, 1993; Hughes & Franks, 1997).

1.2. MOTIVATION AND BACKGROUND

> *"Know your enemy, and know yourself, and you will win a 1000 battles"*
>
> Ancient Chinese proverb

As a professional rugby coach, it has always been a passion to always try and stay ahead of the opposition. This, with having been employed as Technical Advisor of The Bulls Super 12 team in 2004 has further fuelled this ambition to get ahead. This passion and opportunity to hone one's analysis skills has resulted in the desire to pursue the exploration of this topic of collisions in rugby.

During post graduate studies, two dissertations where completed where an analysis of the components of rugby has taken place. The two dissertations being firstly; “The significance of the level of attack and possession on the outcome of a rugby match” (Evert, 2000), and the second; “A Scientific Analysis of Running Lines in Rugby” (Evert, 2003), have both played a major role in the coaching techniques that have been employed since the completion of these two dissertations.

The information gained from these two studies has since been used in all aspects of the coaching that has taken place and have mostly definitely seen how it has positively influenced the success of the teams that have been worked with. The path of rugby is so dynamic and the cross pollination of information from various codes and sporting types has resulted in the game becoming an even closer contested spectacle.

It is for this reason that this study has been initiated. It is the authors view that if a player is able to dominate the collision site, the team as a whole will be able to be more successful, irrespective of the water tight defensive systems that are in place. This study will therefore form the basis of the methodology identified for coaching players in the “art” of how to approach a body on body collision in rugby.

1.3. FORMULATING THE RESEARCH PROBLEM

1.3.1 The unit of analysis

The research will follow a structure which will set the boundaries of the study. The discussion will take place in an ordered fashion beginning with a historical background of both rugby and notational analysis in sport followed by the necessity of notational analysis in the coaching of teams or players. It stands to reason that in order to know where you are going, you need to know where you have been.

Thereafter, a detailed look at attacking play will be made. In order to understand the concept of collisions in a rugby context, a complete understanding of how an attacking play will take place is needed. Each attack is based on the premise that an

objective is sought to be achieved thus a full understanding of all the components involved is needed.

The next step will be to look at those aspects of defensive play that can be seen as a defensive error. The reason for this is that there could be either a breakdown in the defensive system or a fault made by player within the system which could lead to the defensive line being broken.

Thereafter, a detailed look at the principles of notational analysis which are specifically applicable to rugby will be analysed. The reason for this is that each sporting code has unique factors that affect the way their notational analysis takes place. It thus becomes important that the study shows how the detailed analysis of this aspect of play, i.e., collisions, is to be approached.

The analysis sheets will focus on the following key areas;

1. post contact evaluation;
2. in contact evaluation;
3. pre contact – attacking qualities;
4. pre contact – defensive qualities; and
5. velocity change evaluation.

1.4 THE RESEARCH GOAL

The research goal is to gain a better understanding of the factors that play a role in a dominant collision in rugby as well as the relative significance of dominant collisions as an indicator of success in rugby. The hypothesis stands to reason that if a team is aware of the factors that lead to a dominant collision, are able to execute them in a match situation, the team should thus be able to dominate collisions and be more adept at getting “go forward” resulting in more tries being scored. The final step will then be to analyse the collision making use of various biomechanical principles. This will be done making use of notational analysis sheets specially designed in order to evaluate the key concepts to be evaluated during the course of the study and that are important in order to explore the above mentioned factors (see CD Appendix).

Once the notational analysis process has been completed, links and reasons will be attempted to be explained as to the significance of successfully executed collisions in match situations. Key factors associated with collisions will also be evaluated in the light of, and in comparative ratios to the mentioned collisions. This will include the following;

1. The average number of collisions for the try to be scored. The collisions mentioned here, includes the number of rucks / phases, off-loads in the tackle and a forced missed tackle;
2. The ratio of dominant collisions versus the number of passes executed for the try to be scored. (number of collisions / number of passes);
3. The average number of forced missed tackles for the try to be scored;
4. The average positive velocity change of the dominant collisions for the try to be scored. (momentum of the ball carrier – momentum of the defender)
5. The comparison of whether a try is scored from a clean line break, or from extra players in support, versus the percentage of tries scored where a dominant collision took place by the try scorer before the try was in fact scored; and
6. The ratio of forced missed tackles per phase for the try to be scored. (forced missed tackles / number of phases).

If the study does in fact show that the above mentioned factors associated with successful dominating ball carrying collisions do positively influence the outcome of a match, reasons will be researched as to why this in fact does occur.

1.4.1 The research strategy

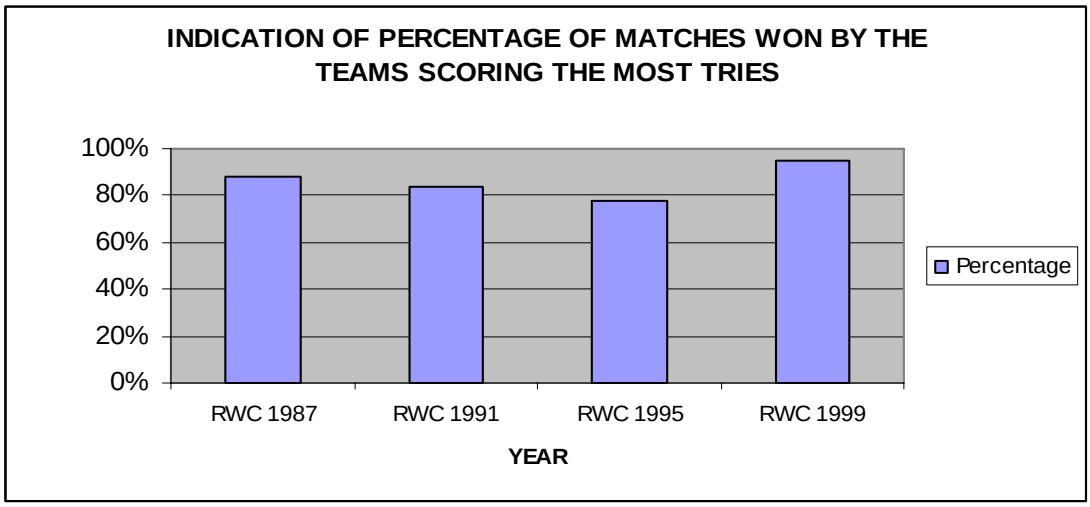
The research strategy will take the form of an in-depth analysis of specific factors that occur in real-life match situations. A notational analysis sheet will be developed which will identify pertinent factors to be looked for during a collision, (See Appendix A, B and C found on the accompanied CD). The research will be primarily statistical in nature and the author will make use of this statistical information in order to make deductions as to why or why not the identified contributing factors played a role in the dominant collision.

A quasi-experimental design will be used where a multiple regression analysis will be done identifying the correlation between log position and the four key measurements. Although no intervention will be possible from the researcher, the change will be measured between teams within a competition, and from a competition to competition basis. The number of tries scored will be seen as the indication of success. This assumption can be made due to the research done by Thomas (2003) when comparisons were made between the 1987 and 1999 IRB Rugby World Cup's as can be seen in Table 1.1 and Chart 1.1.

Table 1.1: Table indicating the percentage of teams winning matches by scoring more tries than the opposition

Year	Number of matches	Won by team scoring the most tries	Percentage
RWC 1987	32	28	88%
RWC 1991	32	27	84%
RWC 1995	32	25	78%
RWC 1999	41	39	95%

(Adapted from: Thomas, 2003)



(Adapted from: Thomas, 2003)

Figure 1.1: Graph showing the relative percentages of teams winning matches by scoring more tries than the opposition

As can be seen from the respective Table 1.1 and Graph 1.1, a summary of the above shows that of the 137 matches played in the four Rugby World Cups, 119 or 87% were won by the team scoring the most tries, and only two were won by the team that scored the fewest number of tries but kicked more penalties (Thomas, 2003).

The three competitions in question are the Super 12 of 2003, Super 12 of 2004 and Super 12 of 2005. The reason that these competitions have been identified is that they are firstly the most recent, and are recognised as the pace setting competitions in world rugby due to these Super 12 players making up the National teams that have won four of the last five Rugby World Cups. It would also be foolish to try and go too far back in history as, as previously mentioned, the game evolves from year to year and the information would be outdated.

The data that is collected will thus be compared in the following way:

- as ranked from winners, to position 12 on the log.

Once this comparison has been made, links will be attempted to be found so that a clear, correct deduction and prediction can be made. Finally, a philosophical comparison and discussion will take place.

1.5 METHODS OF RESEARCH

1.5.1 Data collection

The task is to obtain data which enables one to get an accurate and detailed description of the concepts that are specific to rugby, in particular the collision site. The data used will be collected from video footage of tries scored in the following competitions; the 2003, 2004 and 2005 Super 12 Competitions. All in all 784 tries were evaluated over the three years with 2003 Super 12 having 280 tries, 2004 Super 12 having 234 tries and 2005 Super 12 having 270 tries. During these three years 405 matches were played made up of each team playing eleven pool matches followed by a semi-final and a final. The discussion will be made by means of making use of

scientific articles, relevant books on the subject, and interviews with coaches and the researcher's own deductions.

1.5.2 Data organisation

The data will be organised in such a way that when incorporated into the discussion it will add to the exploration of the research goal. The analysis will be done manually however the researcher will attempt to develop a computer program in order to be able to log and recall information that will be able to be used in the future as a notational analysis tool. A computer program called "Verusco Systems®" will also be used. This program will aid in the biomechanical analysis of the technical aspects of the study.

1.5.3 Analysis and interpretation of data

The analysis of this subject will rely heavily on statistical evaluations and descriptions of the relevant topics. The information will follow a systematic description of the concepts needed to understand the object of the study, namely collisions in rugby.

It will involve working with data, organising the data, systematically ordering the information into understandable, easy to read components, searching for patterns and links between concepts, discovering what is important and what can be learnt, and finally identifying key principles that are applicable to the concept.

CHAPTER 2

2.1 THE DEVELOPMENT OF RUGBY FOOTBALL

The early history of rugby football has been researched by a South African teacher, writer and rugby administrator and is described in two books which show the history of rugby in South Africa and at a Cape Town private school for boys (Noakes & Du Plessis, 1996).

According to Dobson (2003), the origin of all ball games, being played between two teams on a field with two goal posts for example rugby, soccer and hockey, can be traced back to the Middle Ages in England. In these "games" the inhabitants of two neighbouring villages would meet halfway between the two villages on an open piece of ground. The goal of the game was to get a ball or a similar like object through the poles of the house owned by the opposition's town "chief'.

There are many accounts of these games being very gruesome as the game Brigand was played with the heads of Danish Vikings, which was unceremoniously kicked through the streets by the local towns' people. The game began as soon as the "ball" was let loose in the middle of the two teams. Thereafter anything was acceptable as there were no rules concerning clothing, equipment, the number or the age of players taking part. These games were often so savage that Royal Proclamation banned them 30 times in three centuries (Gallaher & Stead, 1906; Noakes & Du Plessis, 1996).

Later in the 19th Century in the English Public Schools, especially Rugby, Westminster, Eton, Marlborough, Winchester, Charterhouse and Cheltenham a form of the game of rugby developed. The schools accepted these "manly" games as an opportunity for their pupils to relax and to prepare the "muscled Christians" physically, in order to take the British values to the far corners of the British Empire. The football games that developed in these famous schools each had different characteristics and there were no fixed rules. The reason for this was that each school developed their own particular rules based on the facilities available to them. The playing area at Rugby School was much larger than the others, therefore it allowed for

the ball to be able to be carried. Eton school had a much smaller area available and they therefore developed a form of "dribbling" game (Noakes & Du Plessis, 1996).

When these pupils left school to attend the University of Cambridge, the first rugby club in 1839 was founded by an old boy from Rugby School. The old boys from Eton got upset when in the middle of games the players from Rugby School picked up the ball instead of kicking it. Thereafter a new set of rules was set up in 1846 at a meeting of the University of Cambridge. There were more old boys from Eton, therefore, the rules favoured the "dribbling' game. In 1863 these Cambridge rules formed the basis of the rules developed for football (soccer) (Noakes & Du Plessis, 1996). It therefore happened that in 1863 the differences between rugby and soccer became more defined. Teams in these early days of rugby consisted of up to 300 players per side, obviously to ensure no goals were scored! The ball was kicked downfield towards the opposition's goal posts and players then moved by means of dribbling and scrums, which were called *hots*. Lineouts were formed if the ball landed outside the field of play. Handling of the ball was first allowed at Rugby School and only if the ball was cleanly caught. Out of a historical perspective William Webb Ellis was the first person to take a clean catch and then ran forwards with the ball in possession. Rugby School then introduced a rule that a player could only run forwards if he was trying to score a goal himself. At this stage he still wasn't able to pass the ball to another player (Noakes & Du Plessis, 1996).

On 26 January 1871, a meeting was ordered for the 21 rugby-playing clubs in London and the surrounding areas in the Pall Mall Restaurant. At this meeting the Rugby Football Union was founded and 59 laws were set out for the playing of the game rugby (Noakes & Du Plessis, 1996). In 1875 the number of players was limited to 15 a side for the match between Cambridge and Oxford and in 1877 international teams also had teams of 15 players. These 15 players consisted of 10 forwards, two attacking halves and three defending backline players. From here the play developed through changes in the scrum formations to what we see in modern day rugby, a 3-5-1 formation. The positions also became specialised and lately the laws have been adjusted in order to make the game more exciting so that viewer audiences can increase (Noakes & Du Plessis, 1996).

Although the first style of rugby played in South Africa at Bishops School in Cape Town conformed to the rules of Winchester School (the headmaster was a former pupil of the English School) by the time the first governing body of the sport - England's Rugby Football Union (RFU) - was founded in 1871, Rugby's rules held sway. That same year the first international match was played between England and Scotland. Wales and Ireland followed onto the international calendar shortly afterwards and by the end of the century South Africa, New Zealand and two Australian states were also part of the international community. Since that time the game has evolved slowly. The game's international governing body, the International Rugby Football Union (today the International Rugby Board) was founded in 1886 although England declined to take part in a dispute over the number of representatives they would be permitted to supply. It was agreed that games would be played according to the rules of the Rugby Football Union but it was not until 1930 that the way the game was played was standardised across the world.

The first match in South Africa took place between the "Officers of the Army" and the "Gentlemen of the Civil Service" at Green Point in Cape Town on 23 August 1862 and ended as a 0-0 draw (van der Merwe, 2001). The game spread with British colonisers through the Eastern Cape, Natal and along the gold and diamond routes to Kimberley and Johannesburg. The first union to be formed in South Africa was Western Province, which came into being in 1883; Griqualand West followed in 1886 and Eastern Province in 1888 (Dobson, 2003).

South Africa played its first international in 1891 against a touring side from Britain although it was not until the side toured Britain in 1906 that they became known as the Springboks. The sport quickly gripped the imagination of many South Africans and the country's success fuelled the enthusiasm (Dobson, 2003; Unknown Author, 2005a). South Africa won their third series in 1903 and it was not until the 1956 tour of New Zealand that they were to be defeated in a series as they established themselves as arguably the world's leading rugby nation. Their most dangerous rival was invariably New Zealand whom they met for the first time in 1921 to establish what is regarded as rugby's most bitter rivalry (Dobson, 2003; Unknown Author, 2005a).

The game remained strictly amateur until 1995 when the inevitable decision to allow players to be paid was made. Up until then anyone caught taking money for playing the game was banned for life. In the years since that decision the game has changed more rapidly than in the previous century and a half. New competitions such as the Vodacom Super 12, Vodacom Tri-Nations and the Heineken Championship in Europe have hugely increased the game's revenues and spectator interest (Dobson, 2003; Unknown Author, 2005a).

2.2 Background to The South African Rugby Football Union (SARFU) and SA Rugby (Pty) Limited

The South African Rugby Football Union (SARFU) is the custodian of the Game of rugby in South Africa. SARFU was established in 1992 following the unification of the former SA Rugby Board (SARB) and SA Rugby Union (SARU), paving the way for South Africa's readmission to the international arena after eight years of isolation (Dobson, 2003; Unknown Author, 2005b).

SARFU has as its members the 14 Provincial Unions - the Blue Bulls (Pretoria), Boland (Wellington), Border (East London), Eastern Province (Port Elizabeth), Falcons (Springs), Free State (Bloemfontein), Golden Lions (Gauteng), Griffons (Welkom), Griqualand West (Kimberley), Leopards (Potchefstroom), Mpumalanga (Witbank), Natal (Durban), South Western Districts (George) and Western Province (Cape Town) (Unknown Author, 2005b).

The unified SARFU was founded on three core principles:

1. The establishment of a non-racial, non-political and democratic rugby community, both on and off the field to ensure the levelling of the playing fields at all levels;
2. The development of infrastructure and human resources potential in order to uplift the game in disadvantaged areas and establish it in areas where it was not being played;
3. To ensure that South Africa reclaimed its place amongst the world's top rugby playing Nations (Unknown Author, 2005b).

Over the past decade much progress has been made in growing and transforming the game in South Africa and there have been many notable achievements. The SARFU Game Development Programme was successfully launched in 1993 with the aim of creating opportunities for all South Africans to play the game and ensuring that the sport is representative of the population at all levels. Over the last nine years the programme has ensured the on-going growth of the game, especially in local communities through the schools and clubs network. The SARFU investment in community rugby over the past 10 years has been extensive and has provided much needed financial assistance to the 14 Provincial Unions, allowing the growth and transformation of the game at grassroots level on a National scale. Community rugby and the support of the 14 Provinces rely heavily on income generated through the sale of broadcast rights, as well as sponsorship income. This is enabling the continuance of a host of activities annually at all levels, including Youth Weeks, talent identification programmes, elite squads, fast-tracking and excellence programmes, rugby academies, coaching and referee development, club assistance programmes, school and club tournaments and the establishment of women's rugby. It is obvious that rugby has had to adapt to the needs of players and in so doing has developed into the spectacle that we are able to experience now two centuries later (Unknown Author, 2005b). Today's Rugby Coaches are thus better prepared, better organised and more understanding of the needs of their athletes in their care. They are skilful, resourceful, confident and caring in their role as responsible coaches (Levy & Ponissi, 1993).

As is evident South African rugby has undergone many changes from isolated governing bodies to a now unified South African Rugby Union. This path has allowed for a successful transition and as long as dialogue and unity prevail, South African rugby can again become the world force it was in the last century.

CHAPTER 3

3.1 THE NECESSITY OF FEEDBACK FROM NOTATIONAL ANALYSIS

Information that is provided to the athlete about action is one of the most important variables affecting the learning and subsequent performance of a skill (Mento *et al.*, 1987; Alexander *et al.*, 1988; Hughes *et al.,* 1989; Young & Schmidt, 1992; Bouthier *et al.,* 1996; Franks, 1996; Partridge & Franks, 1996; Mosteller, 1997; McGarry *et al.*, 2002; Hughes *et al.*, 2003).

The term feedback should thus be viewed as a general term that refers to information that comes from a source and goes to a mechanism that uses the information to make error corrections (Alexander *et al.*, 1988; Alderson *et al.*, 1990; Young & Schmidt, 1992; Magill, 1993; Partridge & Franks, 1996; Bracewell, 2002; Glazier *et al.*, 2003).

The practical value of performance analysis is that well-chosen performance indicators highlight good and bad techniques or team performances. They help coaches to identify good and bad performances of an individual or a team member and facilitate comparative analysis of individuals, teams and players (Alexander *et al*., 1988; Sprigings, 1988, Hughes *et al*., 1989; Alderson *et al*., 1990; Young & Schmidt, 1992; Partridge & Franks, 1996; Mosteller, 1997; Bartlett, 2001; Bracewell, 2002; McGarry *et al.*, 2002; Glazier *et al.*, 2003; Hughes *et al.*, 2003; Hughes & Franks, 2004).

Knowledge about the proficiency with which athletes perform a skill is critical to the learning process and in certain circumstances a failure to provide such knowledge may even prevent learning from taking place (Sprigings, 1988; Hughes *et al*., 1989; Alderson *et al*., 1990; Young & Schmidt, 1992; Bouthier *et al.*, 1996; Partridge & Franks, 1996; Potgieter, 1997; McGarry *et al.*, 2002; Glazier *et al*., 2003).

In addition, the nature of the information that is provided has been shown to be a strong determinant of skilful performance, i.e., precise information about the

produced action will yield significantly more benefits for the athletes than feedback that is imprecise (Hughes et al., 1989; Young & Schmidt, 1992; Bracewell, 2002; Glazier *et al*., 2003).

3.2 TYPES OF FEEDBACK

The question now arises as to how does the athlete acquire this vital information?

First, a major contributor to the athlete's knowledge base about the performance of a skill is that of intrinsic or sensory feedback. Intrinsic feedback can be defined as information that is gained from the body's own proprioceptors, such as muscle spindles, joint receptors, etc. (Alexander *et al.*, 1988; Sprigings, 1988; Hughes *et al.*, 1989; Alderson *et al*., 1990; Young & Schmidt, 1992; Magill, 1993; Bouthier *et al*., 1996; Partridge & Franks, 1996; Hughes & Franks, 1997; Mosteller, 1997; Hughes & Franks, 2004).

A second source of feedback is that which augments the feedback from within the individual. This can be thought of as extrinsic information or Knowledge of Results (KR). The term Knowledge of Performance (KP) has also been used to differentiate between information about the outcome of the action (KR) and information about the patterns of actions used to complete the skill (KP) (Alexander *et al.*, 1988; Sprigings, 1988; Alderson *et al*., 1990; Young & Schmidt, 1992; Magill, 1993; Partridge & Franks, 1996; Bracewell, 2002).

Perhaps the best global definition of KR would be, "… *information provided to an individual after the completion of a response that is related to either the outcome of the response or what performance characteristics produced that outcome*" (Magill, 1993).

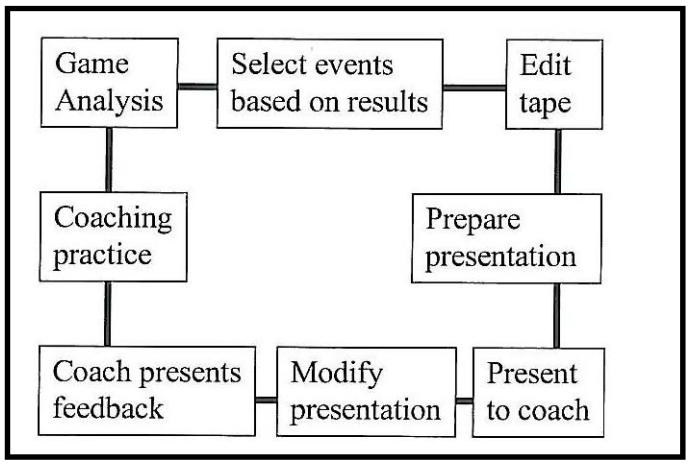
3.3 THE ROLE OF THE COACH IN USING FEEDBACK

Although intrinsic feedback is of vital importance to the performance of a skill, there is very little that coaches can do to improve upon this "hardwired" system (Zatsiorski, 1995).

It thus remains the responsibility of the coach to offer the best possible extrinsic feedback that will enable the athlete to accurately compare "*what was done*" with "*what was intended*" (Alexander *et al*., 1988; Bouthier *et al*., 1996; Partridge & Franks, 1996; Bracewell, 2002).

Clearly, the use of video footage as a medium of feedback has irreplaceable potential in this regard. The benefits are intuitively obvious. In the case of video, the information can be played back on a TV screen only a few seconds after the event has taken place. There is no delay period that may hamper the comparison of performances being made by the athlete, the motivation to perform is enhanced by individuals wanting to see themselves on TV and, in addition, the whole performance can be stored in its entirety or edited for later analysis.

The following Figure 3.1, shows that the coach provides the information to the players based on the results of match analysis.



(Adapted from O' Donoghue et al., 2005)

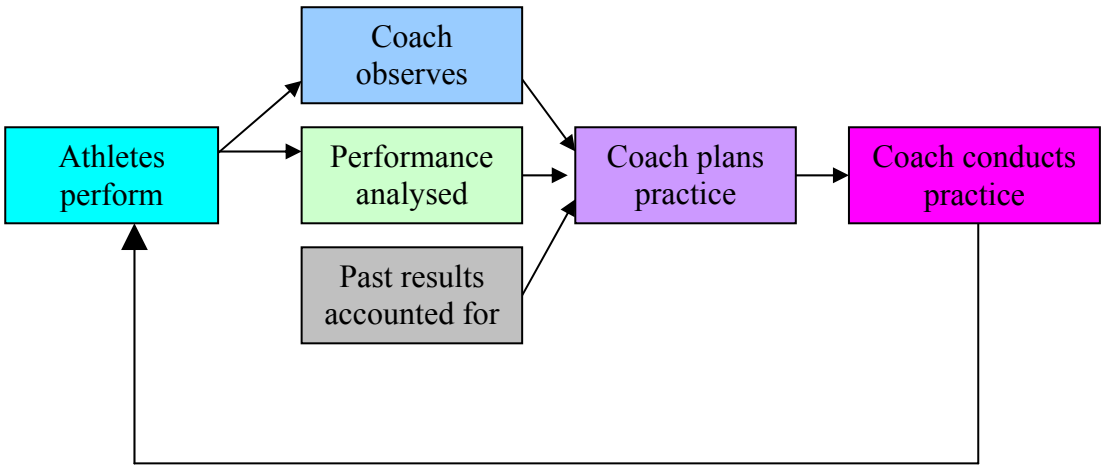
Figure 3.1: A schematic diagram representing how the coaching process can be improved by means of feedback

The videotape can therefore provide error information, can be a reinforcer when performance is correct and can be a strong motivating force (Sprigings, 1988; Young & Schmidt, 1992; Hughes & Franks, 1997; Mosteller, 1997; O' Donoghue *et al.*, 2005).

3.4 THE NEED FOR OBJECTIVE INFORMATION

The essence of the coaching process is to instigate observable changes in behaviour. The coaching and teaching of skill depends heavily upon analysis in order to effect an improvement in athletic performance. It is clear that informed and accurate measures are necessary for effective feedback and hence improvement of performance. This feedback should include qualitative as well as quantitative analysis (Alexander *et al,* 1988; Sprigings, 1988; Hughes *et al.*, 1989; Alderson *et al.*, 1990; Young & Schmidt, 1992; Bouthier *et al.*, 1996; Partridge & Franks, 1996; Hughes & Franks, 1997; Mosteller, 1997; Bracewell, 2002; McGarry *et al.*, 2002; Glazier *et al.*, 2003; Hughes *et al.*, 2003; Hughes & Franks, 2004; O' Donoghue *et al.*, 2005).

In most athletic events analysis of the performance is guided by a series of qualitative assessments made by the coach. Franks *et al.* (1983a, b) defined a simple flowchart of the coaching process (see Figure 3.2).



(Adapted from: Franks et al., 1983a, b)

Figure 3.2: A schematic diagram representing the coaching process

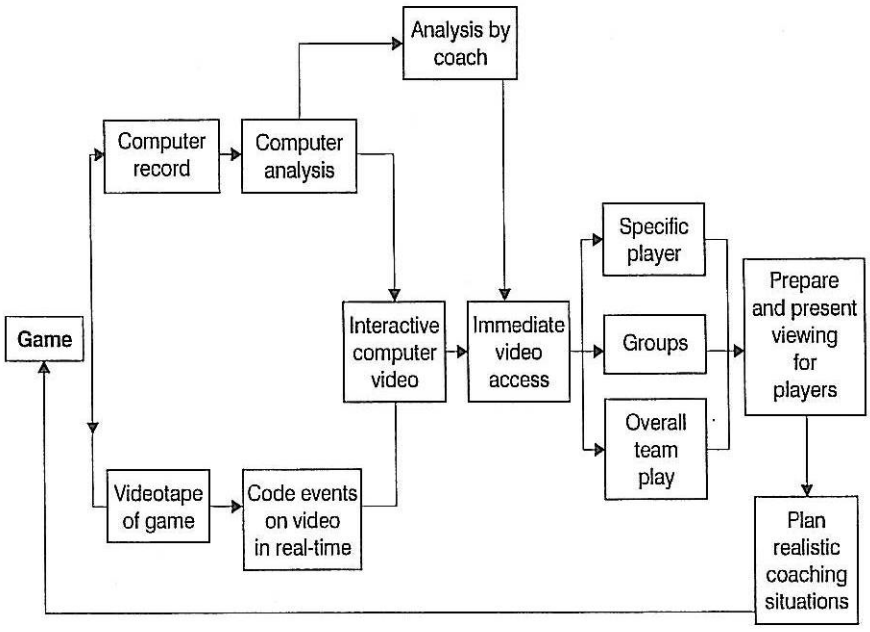
The schema in Figure 3.2 outlines the coaching process in its observational, analytical and planning phase. The game is watched and the coach will form a conception of positive and negative aspects of the performance. Often the results from previous games, as well as performances in practice, are considered before planning in

preparation of the next match (Alexander *et al*., 1988; Hughes *et al*., 1989; Alderson *et al*., 1990; Young & Schmidt, 1992; Partridge & Franks, 1996; Hughes & Franks, 1997; Mosteller, 1997; Lynch, 2001; Bracewell, 2002; McGarry *et al*., 2002; Glazier *et al*., 2003; Hughes *et al*., 2003; Hughes & Franks, 2004; O' Donoghue *et al*., 2005).

The next game is played and the process repeats itself. There are, however, problems associated with a coaching process that relies heavily upon the subjective assessment of game action. During a game many occurrences stand out as distinctive features of action. These range from controversial decisions given by officials to exceptional technical achievements by individual players. While these types of occurrences are easily remembered, they tend to distort the coaches' assessment of the game in total. Human memory systems have limitations and it is almost impossible to accurately remember all the events that take place during an entire competition. Studies by Franks and Miller (1986) have shown that soccer coaches are less than 45% correct in their post-game assessment of what occurred during 45 min of a soccer game. While there is considerable individual variability, this rapid forgetting is not surprising, given the complicated process of committing data to memory and subsequently retrieving it. Events that occur only once in the game are not easily remembered and forgetting is rapid. Furthermore, emotions and personal biases are significant factors which affect storage and retrieval processes of memory. In most team sports an observer is unable to view, and assimilate, all the action taking place on all the playing area. Since the coach can only view parts of game action at any one time (usually the critical areas), most of the peripheral play action is lost. Consequently, the coach must then base post-match feedback on only partial information about a team's, unit's or individual's performance during the game. This feedback is often inadequate and, as such, the opportunity is missed to fully aid the possible improvement of players and teams (Young & Schmidt, 1992; Bouthier *et al*., 1996; Partridge & Franks, 1996; Hughes & Franks, 1997; Bracewell, 2002; McGarry *et al*., 2002; Hughes & Franks, 2004; O' Donoghue *et al*., 2005).

Problems that are associated with subjective assessments would seem to present the coach with virtually insurmountable difficulties. The whole process of coaching, i.e., gaining improvement of performance of the athlete, hinges on the observational abilities of the coach (Partridge & Franks, 1996; Hughes & Franks, 1997; O'

Donoghue *et al*., 2005). Despite the importance of observation within the coaching process, very little research has been completed in the specific area of observational accuracy. Despite this dearth in the literature of the sport science discipline, there has been a considerable body of applied research that quantitatively measured the accuracy of observers in criminal eyewitness situations. There are a number of similarities between the situation of the coach observing an athletic performance and that of the eyewitness to the criminal event. Testimony by an eyewitness can be an event of profound importance; this is equally true for both criminal and sporting situations. The accurate analysis of competition is thus fundamental to the entire coaching process and underlies improvement in performance; see Figure 3.3 (Alderson *et al*., 1990; Bouthier *et al*., 1996; Hughes & Franks, 1997; Lynch, 2001; O' Donoghue *et al*., 2005).



(Adapted from Hughes & Franks, 1997)

Figure 3.3: A schematic diagram representing the coaching process, utilising some of the computer-aided analysis and feedback technology

3.5 NOTATIONAL ANALYSIS – A REVIEW OF THE LITERATURE

Notational analysis is the systematic gathering, analysis and communication of detailed information relating to competitive sport. Notational analysis provides accurate information in quantifiable terms that allows misperceptions by coaches to be avoided. Notational analysis allows progress to be monitored and accurate feedback to be provided to players. This assists decisions about training and tactics and improves the coaching process by directing the coach to those facets of the game that require attention.

General, rudimentary and unsophisticated forms of notation have existed for centuries. Hutchinson (1970) cited evidence indicative of the fact that for at least five centuries attempts had been made to devise and develop a system of movement notation. Further, the Egyptians, thousands of years ago, made use of hieroglyphs to read dance, and the Romans employed a primitive method of notation for recording salutary gestures. Research shows that the earliest recorded form of music notation was conceived in the 11th century (Hutchinson, 1970; Thornton, 1971), although it did not become established as a uniform system until the 18th century. Historical texts give substantial evidence pointing to the emergence of a crude form of dance notation much later, in about the 15th century. Thornton (1971) stated that the early attempts at movement notation may well have "*kept step*" with the development of dance in society and as a consequence the early systems were essentially designed to record particular movement patterns as opposed to movement in general. It becomes apparent, then, that dance notation actually constituted the "*starting base*" for the development of a general movement notation system. Arguably the greatest development in dance notation was the emergence of the system referred to as "*Labanotation*" or "*Kinetography-Laban*", so called after its creator Rudolph Laban, in 1948 (Hughes & Franks, 1997).

Laban highlighted three fundamental problems encountered in the formulation of any movement notation system:

1. recording complicated movement accurately;
2. recording this movement in economical and legible form; and

3. keeping abreast with continual innovations in movement (Hughes & Franks, 1997).

It was these three fundamental problems that left dance in a state of flux incapable of steady growth, for centuries (Hutchinson, 1970). The next "*step*" in the development of movement notation came in 1947 with the conception of another form of dance notation, Choreology, published in 1956, by Jean and Rudolph Benesh (Hughes & Franks, 1997).

In this form of notation five staves formed the base or matrix for the human figure, i.e.,

_____ Top of head
_____ Top of shoulder
_____ Waist
_____ Knees
_____ Floor

All notation was completed on a series of these five-line grids with a complex vocabulary of lines and symbols (Hughes & Franks, 1997).

The major underlying disadvantage of both Benesh and Laban methods of notation in terms of sport is that they are both primarily utilised for the recording of patterns of movement rather than its quantification (Hughes & Franks, 1997). There were numerous attempts to develop a system of movement notation based entirely on the mathematical description of movement in terms of the degrees of a circle in a positive or negative direction. However, as with the systems of Labanotation and Choreology, these systems did not allow the description of movement in terms familiar to sport or everyday life. As Brooke and Knowles (1974) stated:

> "*The Benesh and Laban methods of notation are more suitable for recording expressive movement and articulate skills than for gross motor activity of major team games*".

Movement notation systems, developed primarily in the field of expressive movement, gradually diversified into game analysis, specifically sport. However, ensuing research proved severely limited both in variety and detail, as reported by Sanderson & Way (1977):

> *"The majority of little-published research that there is in game analysis is concerned with basketball and soccer – and at a fairly global and unsophisticated level".*

There are a number of texts that contain sections devoted to research in notational analysis. The best of these are copies of proceedings of conferences on football (two) and racquet sports respectively (Reilly *et al.*, 1988, Reilly *et al.*,1993; Reilly *et al.*, 1995).

Finally, there are the proceedings of the three world conferences on notational analysis of sport. The presentations of the first two conferences are compiled in one book, Notational Analysis of Sport I & II (Hughes, 1996), and the first section has a number of keynote speakers who present a varied but enlightened overview of different aspects of notational analysis. Croucher (1996) presents a lucid and clear analysis of the way in which notational analysis can be used in a practical and real setting. To complement this practical presentation, Winkler (1996a, b) introduces all the problems associated with computer analysis of a sport, using his experiences with German soccer as a source of practical examples. From a philosophical point of view, Treadwell (1996) presents an educational aspect to the potential uses of notational analysis. Lyons (1996) completed what must be the first historical piece of research in notational analysis highlighting the work and life of Lloyd Messersmith, one of the earliest pioneers of notation in sport, also clearing up some of the misconceptions about his research (Hughes & Franks, 1997).

3.6 THE DEVELOPMENT OF SPORT – SPECIFIC NOTATION SYSTEMS (HAND NOTATION)

Probably one of the first attempts to devise a notation system specifically for sport analysis was that of Messersmith and Corey (1931), who attempted to notate distance covered by specific basketball players during a match (Hughes & Franks, 1997). Notation systems were commercially available for American football play-analysis as early as 1966 (Purdy, 1977), and the Washington Redskins were using one of the first in 1968 (Witzel, cited by Purdy, 1977).

Interestingly, American football is the only sport that has as part of its rules a ban on the use of computerised notation systems in the stadium. How this could be enforced is not clear; however, all clubs that have been contacted have been helpful. All claim to use a similar hand notation system, the results of which are transferred to computer after the match (Hughes & Franks, 1997).

3.7 A HISTORICAL REVIEW OF HAND NOTATION SYSTEMS FOR RUGBY UNION

Rugby union presents unique problems for analysis with its primary phase facets, i.e., scrums, lineouts and restarts, and the activity ensuing from a tackle in either rucks or mauls. Lyons (1988) has gathered data by hand on the Home International Championship for a period of ten years and has created a sound database. From this database he claimed to predict the actions, e.g., the number of scrums, lineouts, passes, kicks, penalties, etc., in the England – Wales match in the 1986-87 season to within three passes and two kicks (Hughes & Franks, 1997).

Treadwell (1992) presented a summary of work completed at Cardiff by the team working there, demonstrating that game models were clearly tenable for rugby union regardless of weather, selection, refereeing or even coaching style. Over 40 different action variables were defined and data collection was completed live using hand notation. This was validated using a computerised system to analyse matches from video, post-event. Data from the Five Nations championships over four years were presented to confirm the hypothesis that the game of rugby union provides a rhythm for prediction of certain variables (Hughes & Franks, 1997).

Du Toit (1989) made a time, movement and skill analysis for rugby union at senior level in South Africa in 1987. Three video cameras were used. One followed the match, one followed a forward and one followed a back in each of 12 matches. Their methodology provided the possibility to compare between positions and over a period of time and take into account the game situation (Hughes & Franks, 1997).

Their results included:

1. the length of an average match was 88 min 37 s;
2. 77% of each playing periods were below 20 s;
3. average play to rest ratio for forwards was 14:22 and backs was 12:24;
4. scrums lasted 5 s; lineouts 4 s, loose play situations 6 s;
5. forwards moved 3730 m; backs 3900 m;
6. average of 9 scrums, 45 lineouts, 49 loose-play situations; and
7. average of 35 tackles, 24 running skills, 169 handling skills, 82 hand kicks (Du Toit, 1989).

There is however a need when comparing time-and-motion studies to consider whether every researcher's definition of each activity is the same. For instance, Grehaigne *et al.* (1996) used the following measurements: stop (0 m/s), walk (0-2 m/s), jog (2-4 m/s), cruise (4-6 m/s) and sprint (greater than 6 m/s). Research into movement analysis and definition of fitness profiles is of value to rugby union coaches, players and others but it does have its limitations, and there is a need for some other important aspects to be considered (Hughes & Franks, 1997).

For any fitness or training norms to be taken from such studies there is a need to ensure that:

1. a specific player / position is tracked for the entire match and for a series of matches. This will then give a global figure which will also have accounted for environmental factors such as weather and pitch conditions, importance of the match and personal attitude of the player; and

2. the nature of the game is accounted for. The work-rates of the player may vary from position to position according to whether the game is fast and fluid or whether they are on the winning or losing side (Hughes & Franks, 1997).

Carter (1996) did combine quantitative and qualitative information in a time-and-motion analysis and heart rate monitoring of a back-row forward. The results showed that the requirements for playing in each of the three back-row positions did vary. The qualitative recording of game incidents and training methods did add another dimension to the research. A clear analysis of the performance of England (Potter, 1996), as an example of one of the international teams in the Five Nations championship (1992-1994), demonstrated the power of notational analysis in a team sport, but this type of research might benefit from a directed hypothesis rather than just reporting data (Alexander *et al*., 1988; Hughes & Franks, 1997).

Hand notation systems are in general very accurate but they do have some disadvantages. The more sophisticated systems involve considerable learning time. In addition, the amount of data that these systems produce involve many hours of work in processing them into forms of output that are meaningful to the coach, athlete or sports scientist (Alexander *et al.*, 1988; Hughes & Franks, 1997; O' Donoghue *et al.*, 2005).

The introduction of computerised notation systems has enabled these two problems, in particular the data processing, to be tackled in a positive way. Used in real-time analysis or in post-event analysis in conjunction with video recordings, they enable immediate, easy access to data (Alexander *et al.*, 1988; Alderson *et al*., 1990; Maclean, 1992; Hughes & Franks, 1997; O' Donoghue *et al*., 2005).

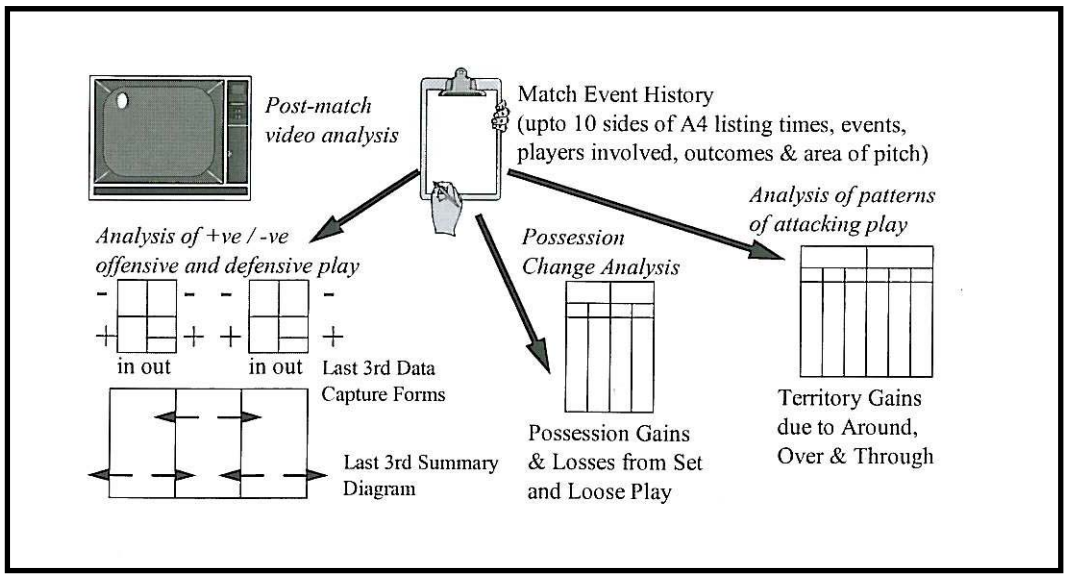
They also enable the sports scientist to present data in graphical forms more easily understood by the coach and athlete. The increasing sophistication and reducing cost of video systems has greatly enhanced the whole area of post-event feedback, from playback with subjective analysis by a coach to detailed objective analysis by means of notation systems (Maclean, 1992; Hughes & Franks, 1997; O' Donoghue *et al*., 2005).

A description follows of a manual method of notational analysis used during the 1995 Rugby Union World Cup, see Figure 3.4. The project studied the quarter-finals, semi-finals, 3rd and 4th place play off as well as the final of the 1995 World Cup for Rugby Union (O' Donoghue *et al*., 2005).

The methodology systematically reduced match information into a quantified form. Initially, the video-recording of each match was observed and a history of match events was recorded onto paper (up to 10 sides of A4) including the time of each event, the players involved, territorial position of the event and the outcome of the event (possession lost, touch found, penalty scored or missed, etc).

After consultation with academics and practitioners of rugby union, it was decided to concentrate on the following areas;

- offensive and defensive play;
- possession changes; and
- patterns of attacking play (O' Donoghue *et al*., 2005).



(Adapted from O' Donoghue et al., 2005)

Figure 3.4: A schematic diagram representing a hand notation system used during the 1995 Rugby World Cup.

To analyse offensive and defensive play, each team's last third of the pitch was considered. A last third capture form was used to note occurrences of various examples of good attacking or poor defensive play leading to the ball entering the last third. The form was also used to capture details of whether play in the last third resulted in a score or whether the ball left the last third as a result of good defensive play or poor offensive play. For each side, the occasions where possession of the ball was gained were identified by examining the match history. These possession changes were classified as coming from set play or loose play. Similarly, to analyse patterns of attacking play those occasions where a team gained territory were identified and classified into around (running and passing, etc), over (chipping, up and under, etc) and through the opposition (rucking, mauling and driving) (O' Donoghue *et al*., 2005).

Four sides competed in three matches each during the knockout stages (South Africa, New Zealand, France and England). The performances of these teams were analysed. Of these, the Possession Gain to Loss Ratio turned out to be the most promising predictor of performance, reflecting the four team's rankings in the tournament (South Africa 1.24:1, New Zealand 1.19:1, France 1.03:1 and England 0.64:1) (Eaves & Hughes, 2003; O' Donoghue *et al*., 2005).

3.8 THE USE OF COMPUTERISED NOTATION

Using computers does introduce extra problems of which systems users and programmers must be aware. Increases in error possibilities are enhanced by either operator errors or hardware and software errors.

The former type of error is when the system user unintentionally enters incorrect data, e.g., presses the wrong key on the keyboard. Any system is subject to perception error where the observer misunderstands an event or incorrectly fixes a position but the computer-operator interface can result in the operator thinking the correct data is being entered when it is not (Hughes & Williams, 1988; Hughes *et al*., 1989; Alderson *et al.*, 1990; Maclean, 1992; Bouthier *et al*., 1996; Partridge & Franks, 1996; Hughes & Franks, 1997; Glazier *et al.*, 2003; O' Donoghue *et al.*, 2005).

Hardware and software errors are introduced by the machinery itself, or the programs of instructions controlling the operation of the computer. To minimise both of these types of problems, careful validation of computerised notation systems must be carried out. Results from both the computerised system and a hand system should be compared, and the accuracy of the computerised system quantitatively assessed (Hughes *et al*., 1989; Alderson *et al*., 1990; Maclean, 1992; Bouthier *et al*., 1996; Partridge & Franks, 1996; Hughes & Franks, 1997; Hughes, 1999; Glazier *et al*., 2003; O' Donoghue *et al*., 2005).

Computers have only been recently impinged on the concept of notation analysis. Franks *et al*. (1983b) maintained that this form of technology is likely to enhance manipulation and presentation due to improved efficiency. This postulation is supported by the work of Hughes (1985).

Four major purposes of notation have been delineated:

1. analysis of movement – time motion analysis involves the collection of more information than match analysis as the movement activity of each competitor must be recorded for the full duration of the match. This is particularly challenging for team sports;
2. tactical evaluation – analysis of the moment to moment decisions made during the game and the cognitive which cannot be directly analysed but which must be inferred from the application of technical skills;
3. technical evaluation - is the quantification and assessment of technical skills. Technique refers to those psychomotor aspects of behaviour used by the individual players. These are often recorded independently of the playing context of the technical events;
4. development of databases for performance modelling, and
5. statistical compilation (Hughes & Franks, 1997; O' Donoghue *et al*., 2005).

Many of the traditional systems outlined above are concerned with the statistical analysis of events which previously had to be recorded by hand. The advent of on-line computer facilities overcame this problem, since the game could then be digitally

represented, first via data collection directly onto the computer and then later documented via response to queries pertaining to the game. The major advantage of this method of data collection is that the game is represented in its entirety and stored in ROM or on disk. A database is therefore initiated and is a powerful tool once manipulated (Franks *et al*., 1983a; Alderson *et al*., 1990; Partridge & Franks, 1996; Hughes & Franks, 1997; Hughes, 1999; Glazier *et al*., 2003; O' Donoghue *et al.*, 2005).

Team sports have the potential to benefit immensely from the development of computerised notation. The information derived from this type of computerised system can be used for several purposes as suggested by Franks *et al.* (1983a):

1. immediate feedback;
2. development of a database;
3. indication of areas requiring improvement;
4. evaluation; and
5. as a mechanism for selective searching through video recording of the game.

All the above functions are of paramount importance to the coaching process. The development of a database is a crucial element, since it is sometimes possible, if the database is large enough, to formulate predictive models as an aid to the analysis of different sports, subsequently enhancing future training and performance (Hughes & Franks, 1997).

3.9 THE USE OF COMPUTERISED NOTATION IN RUGBY UNION

Rugby union presents slightly different problems for analysis, with its set-piece moves, the scrum and the lineout, and also the ensuing action after a tackle: either rucks or mauls. Treadwell (1987) developed software that utilises the concept keyboard to analyse rugby union. Hughes and Williams (1987) developed software using a similar system of hardware. The system was designed to notate the matches' post-event using videotapes. Four computer programs were written. The data

collection program was constructed with the help of an international coach, who helped define the most important variables to be recorded (Hughes & Franks, 1997; Hughes, 1999).

The other three programs analysed the data and provided the output. Once again the concept keyboard was used to help gather the data. The pressing of the sub-routine keys, i.e., "scrum", "lineout", "ruck", or "maul", caused the software to direct the input back to the QWERTY keyboard where additional data was entered, such as: the order in which the players arrived (ruck or maul), quality of ball (scrum, ruck or maul), etc (Bouthier *et al*., 1996; Hughes & Franks, 1997; Hughes, 1999).

The developed system was used to notate five matches from the Home International Series over the previous two years, involving all the participating nations. A comparison was made for each match between two playing sides and then the results were collated and analysed statistically for differences in the patterns of play between the French, Scottish and Irish compared to the English and Welsh sides. No significant differences were found between the patterns of play for successful and unsuccessful teams, although a number of differences were found between the patterns of play of the three nations compared to the other two ($\rho < 0.05$). France, Scotland and Ireland have played, for the previous two seasons, in different patterns to England and Wales (Hughes & Williams, 1987; Bouthier *et al*., 1996; Hughes & Franks, 1997).

Docherty *et al*. (1988) analysed 27 players during matches to assess the time spent in the various activities of the game. Computerised notation of the frequency and total, mean and percentage times of six activities was undertaken. The players selected were either centres or props; eight players were tracked by four cameras in 5 min intervals for a minimum of 40 min per match. The players spent:

1. 47% of the time walking and jogging;
2. 6% of the time running and sprinting;
3. 9% of the time tackling and competing for the ball;
4. 38% of the time standing;

5. centres sprinted for 3% of the time, the props for less than 1% of the time; and
6. players spend 85% of the match in low-intensity activity (Docherty et al., 1988).

The system of Hughes and Williams (1987) was upgraded and transferred to IBM software architecture and used to investigate the effects of the rule changes in rugby union in the 1991-92 seasons. It was found that the ball in play time actually decreased, and the only other significant changes were to the rucks and mauls (Maclean, 1992; Bouthier *et al.*, 1996; Hughes & Franks, 1997).

These systems were also used to investigate the 1991 World Cup (Hughes & White, 1996; Stanhope & Hughes, 1996); comprehensively analysing the way in which points were scored, the way the successful and unsuccessful teams used their respective three-quarters and forwards. The whole analysis of the tournament also placed all the data onto a database, which will be invaluable as it will enable longitudinal comparisons across tournaments to be made (Hughes & Franks, 1997).

Hughes et al., (1996) used some of this data as a comparative norm with which to compare similar analyses of women's international rugby matches taken from the Five Nations championship. This data showed clearly the result of the stark physiological differences between male and female rugby players in the comparative figures in distances gained from kicks and yardage gained, in all positions, in running with the ball. There were also indications that the women's game is still in the early stages of technical development and further studies should be repeated in years to come to help the coaches remain aware of shortcomings.

3.10 THE FUTURE OF NOTATIONAL ANALYSIS IN SPORT

In terms of technological development, notational analysis will undoubtedly move as rapidly as the developments in computer technology and video technology. There are two developments that will most certainly happen over the next few years. The first will be the development of "all-purpose", generic software. Work in some centres has

almost reached this point now (Alderson *et al.*, 1990; Bouthier *et al*., 1996; Hughes & Franks, 1997; Glazier *et al*., 2003; Hughes, 2004).

Another technological advance that will make computerised notation more easily handled by the non-specialist will be the introduction of "voice-over" methods of data entree. Taylor and Hughes (1988) have demonstrated that this is possible now, but relatively expensive at present day prices. These are expected to drop rapidly over the next couple of years and voice interaction should therefore be a natural extension of any computing hardware system (Hughes & Franks, 1997). The integration of both these technological developments with computerised video feedback will enable both detailed objective analysis of competition and the immediate presentation of the most important elements of play. Computerised systems now enable the analysis, selection, compilation and re-presentation of any game on video to be processed in a matter of seconds. The coach can then use this facility as a visual aid to support the detailed analysis (Alderson *et al.,* 1990; Partridge & Franks, 1996; Hughes & Franks, 1997; Bracewell, 2002; Glazier *et al.*, 2003; O' Donoghue *et al*., 2005).

As these systems are used more and more, and larger databases are created, a clearer understanding of each sport will follow. The mathematical approach, typified by Eom (1988) and McGarry and Franks (1994, 1995), will make these systems more and more accurate in their predictions (Hughes, 2004). At the moment the main functions of the systems are analysis, diagnosis and feedback; few sports have gathered enough data to allow prediction of optimum tactics in set situations. Where large databases have been collected (e.g., soccer and squash), models of the games have been created and this has enabled predictive assertions of winning tactics (Hughes & Franks, 1997; O' Donoghue *et al.*, 2005).

Technological advances aside, the real future of notational analysis lies in the growing awareness by coaches, athletes and sports scientists of its potential applications to sport. Whether the most sophisticated and expensive of systems is being used, or a simple pen and paper analysis, as long as either system produces accurate results that are easy to understand, then coaches, athletes and sport scientists will increase their insights into sport performance (Alderson *et al*., 1990; Bouthier *et al.,* 1996; Partridge & Franks, 1996; Hughes & Franks, 1997; Bracewell, 2002).