GAME ANALYSIS IN RUGBY UNION

by

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Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or material which to a substantial extent has been excepted for the award of any other degree or diploma of a university or other institution of higher learning, except where due acknowledgement is made in the acknowledgements.

Signed……

Marcus S B Agnew (Thesis candidate)

Date……

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Dedication

This project is dedicated to my late sister Marie. She ultimately responsible for me starting my sport science education and has been my main source of inspiration over the last five years.

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Preface

Background

From my early childhood I have had a passion for sport, both as a keen participant and a spectator. As a spectator I have had a particular fascination with highly skilled individuals and their graceful execution of difficult tasks. This interest continued into university undergraduate studies, in which I focused on biomechanics, thus combining biomechanical learning with my passion for analysis of sporting performance.

This pathway led me to the discovery of performance analysis, which is an exciting new scientific field, seemingly perfectly suited to my interests. Performance analysis involves the examination of athletic actions, and integrates the scientific disciplines of biomechanics, notational analysis, and motor control.

Although I have played many sports, rugby has been my passion from an early age, and therefore it seemed logical to pursue a research direction to foster my expertise and passion, for both rugby and the analysis of human movement.

The initial motivation for the direction of this project was to provide quantified performance measures of individuals and teams, rather than relying on subjective opinion. Also, I felt accurate analysis of elite performance could be used in the development of lesser players, by using the elite performers as coaching models and benchmarks in talent identification.

I approached the New Zealand Rugby Union (NZRU) with my research proposal, seeking feedback on the research rationale and to enquire if they would assist with the project. The NZRU endorsed the project and agreed to provide match analysis software, video files of games, primary data collected by their analysis organisation, and financial support via the Enterprise Scholarship scheme.

The aim of the project was to develop a method of interpreting the NZRU data into useable information for coaches, players, and other interested parties. A secondary analysis system was created, enabling the breakdown of rugby into all logical units of play. From this breakdown reports were developed as a means to demonstrate the structured account of all play that this analysis approach can provide, and the potential the system has for further more advanced analysis research.

Organisation of the Thesis

This thesis is presented as three chapters: a literature review, the research manuscript, and a summary including the limitations and future research. The focus of the literature review is game analysis in rugby union. Rugby is known for its complex laws and unique game structures, which render research from other sports as largely inapplicable (De Lacy & Fox, 2000). I have further narrowed the focus to game constructs and strategies by excluding research on individual athlete technique analysis.

The review first explains methodological approaches pertaining to performance analysis, before considering analysis conducted specific to rugby. The review concludes with recommendations for future research, including a more systematic advancement of theory and practice.

It is evident from my literature review that there is a lack of a comprehensive analysis method categorizing all active play within the game. The second chapter is a report on the development of such a method. This research has developed an instrument that can provide primary information to coaches and form a foundation from which more detailed analysis can be extracted in a systematic manner.

Chapter Three consists of a plain language summary of the methodological paper, discussing limitations and future research directions. An Appendix is attached, providing a list of errors in the New Zealand Rugby Union data.

Chapter 1 - Game Analysis in Rugby Union: A Review of the Literature

Abstract

Due to rugby's increasing level of professionalism, rugby union performance analysis is in a rapid state of evolution. Coaches, media, administrators and players are demanding greater access to more detailed analysis of team and player performance. Owing to the dynamic nature of the game and high frequency of events, nobody can adequately recall all aspects of the game; therefore performance analysts are playing an increasingly important role in rugby. The ability of analysts to meet this demand is being enhanced by technological advancements world wide, including the integrated capabilities of digital video, computer systems and video analysis software. Most analyses are conducted post-match by reviewing video footage and coding events of interest. Sound methodological approaches exist to develop performance indicators, which, if appropriately collated, can be used to create performance profiles indicative of player and/or team abilities. Sufficient data should be collected to ensure valid profiles, which can then be compared against population norms for more objective interpretation. Rugby research has focused on a range of performance indicators related to game structures and tactical aspects, including lineout tactics, differences between winning and losing performances, which side of the field try scoring predominates, and the number of passes per try. Research has included analysis of the world's top teams to assess the effect of law changes on the game and rates of foul play across different competitions. Despite the range of detailed analysis in the literature, there is a need for a structured account of all logical units of play, defined and quantified in accordance with coaching language and concepts. Player interactions, and off the ball player formations, also present future research potential.

Introduction

The ranking of individuals is a necessary part of the selection process for professional sports teams (Cameron, 2004). In the professional environment team selection can have a significant financial impact on the lives of the individuals involved. Although accurate observation and evaluation is a key objective in coaching, it is practically impossible for the coach to identify and remember all key events in rugby games (Parsons & Hughes, 2001).

Performance analysts therefore are becoming increasingly prevalent in professional rugby organizations, providing coaches and players with valuable support through the use of modern technological resources.

The purpose of this review is to summarise the game analysis literature applicable to rugby union. The review begins by addressing key methodological approaches of performance analysis, before discussing analysis specific to rugby, and is concluded by identifying areas for future research. Literature has been sourced from Sports Discuss, International Journal of Performance Analysis in Sport, conference proceedings, and analyses released by the International Rugby Board (IRB, the governing body of rugby union).

What is game analysis?

Game analysis involves quantifying performance and strategies of teams or individuals in sport. Game analysis falls within a relatively new sports science discipline called performance analysis, which is concerned primarily with investigating various aspects of player and/or team performance (O'Donoghue, 2005). Performance analysis has also been described more simply as a combination of biomechanics and notational analysis in the study of how movements relate to sport performance (Bartlett, 2001). Performance analysis generally involves analysis a match performance; however, if a particular skill is critical to the sport (for example, the golf swing or tennis serve), then performance analysis can also be conducted in a practice setting (O'Donoghue, 2005). I consider performance analysis as a continuum ranging from technical analysis of an individual's closed skills at one end through to game analysis at the other. Where technical analysis focuses on the mechanics of specific skills, game analysis measures the outcomes, and strategies, employed by the individual, team unit, or whole team.

In 1998 the British Olympic Association's Biomechanics Steering Group was expanded to include notational analysts, and redefined as the Performance Analysis Steering Group (Bartlett, 2001; Hughes, 2004b). A few years later motor control specialists were added, further enhancing the scope of the group (Hughes, 2004b). The steering group has subsequently been disbanded, but the discipline of performance analysis continues to be driven, at least at an academic level, by the team at the Centre for Performance Analysis, University of Wales Institute Cardiff (UWIC). Mike Hughes is leader of the centre, and has

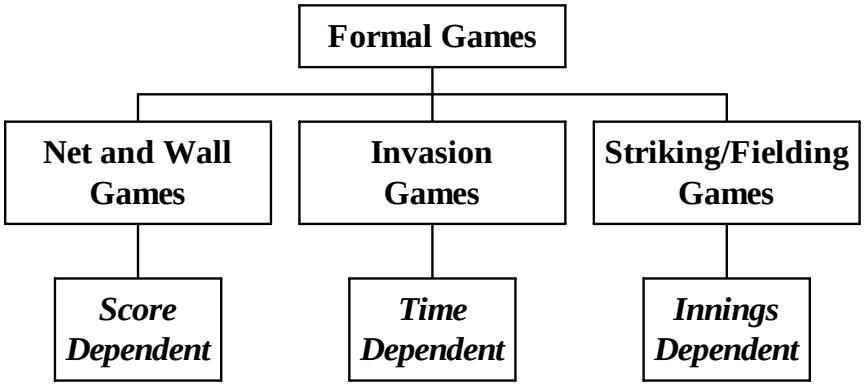
plans to formalize the International Society of Performance Analysis as a support body for the increasing number of young people working within sporting institutions around the world (Hughes, 2005). Other performance analysis units have been established, including divisions within the Australian Institute of Sport and the national sporting academies/institutes of Britain and Ireland.

Performance analysis in sport also has its own world congress; the inaugural event was in England in 1992 with the seventh to be staged in Hungary in 2006. An academic e-journal dedicated to Performance Analysis has also been established: the International Journal of Performance Analysis in Sport, with the first issue published in July 2001. To date there have been eight issues. The International Journal of Computer Science in Sport and the new Journal of Quantitative Analysis in Sports also carries performance analysis articles although very few specific to rugby. The Journal of Sports Sciences has run a special issue on performance analysis (2002; volume 20, issue 10).

To obtain expertise in sport, athletes must excel in no less than four domains: physiological, technical, cognitive, and emotional. Cognitive refers to the *strategic* awareness of an individual, and their ability to implement preordained strategies through effective in-the-moment *decision-making* (Starkes & Ericsson, 2003). Performance analysis focuses primarily on two of the four domains; technical and the strategic component of cognitive, and to a lesser extent physiological by way of time-motion analysis.

Before investigating the methods of sports analysis that apply to rugby, I will consider the different categories into which sports can be classified. As depicted in Figure 1, formal games have been defined as falling into one of three categories: net or wall games, invasion games, and striking or field games (Read & Edwards 1992 as cited in, Hughes & Bartlett, 2002). Rugby is a form of invasion game, as it involves entering the opponent’s territory in an attempt to score points and is time dependent.

Figure. 1. Game classification (Read & Edwards 1992 as cited in Hughes & Bartlett, 2002).



Coding

Notational analysis is a technique used by coaches and sport scientists to gather objective data on the performance of athletes, and has existed in a rudimentary form for centuries (Hughes & Franks, 2004). Coding is the current term for the modern-day equivalent of notational analysis, whereby a performance is viewed on computer with key events electronically recorded for statistical purposes, or simply for convenient review of selected video clips.

The following concepts deal with issues related to the data collected from coding. First volatility discusses the variable nature of rugby and the effects this can have on match data; validity, stability and variability then describe approaches designed to create data and performance measures that are true; followed by normalization which is designed to give perspective to make the data more meaningful (Hughes, 2004a; Hughes & Bartlett, 2002).

Volatility

Match volatility is a term used by Bracewell (2001) to describe the effect that varying match constraints can have on the performance of a subject (for the remainder of this literature review the term “subject” will refer to the subject of the analysis, regardless of whether the subject is an individual, unit, or team). Constraints on performance include the dynamic and chaotic structure imposed by all the competing individuals and referee, varying match conditions including weather and psychological pressures, and issues of “non-performance”. Non-performance is a performance by an individual that is lower than

expected for that player, and importantly, the non-performance does not always relate to the individual's ability. Two areas of non-performance are effected by match volatility: player superiority, which relates to a superior player being heavily marked by the opposition and thus having a lower performance rating than they would otherwise; and game structure, which can effect a player's performance measure due to team tactics, weather or performances of other players (Bracewell, 2001).

To account for volatility and produce a reliable measure of ability, Bracewell (2003) believes past performance should be included by using an exponentially weighted moving average. An exponentially weighted moving average allows greater importance to be assigned to more recent performances, and provides a more stable measure of an individual's playing ability than simply looking at single performances. It also provides a measure that more closely reflects an individual's more recent performances than merely taking a long-term average. In addition the performance of individual tasks within a game is especially vulnerable to match volatility (Bracewell, 2001). However, by combining a sufficient range of tasks a robust measure of match performance is obtained (Bracewell, 2003).

Validity

A range of definitions exist for validity, and even its sub-categories, including internal, external, construct and statistical conclusion validity (Domholdt, 2000). However, regardless of all various situations in which it needs to be considered, ultimately validity is only concerned with the relationship between an observed or practical measurement and its true or criterion value (Hopkins, 2004).

Stability

Hughes, Evans and Wells (2001) used the term "stability" to explain the variation in performance measures about the mean. Hughes et al. (2001) described a method of establishing "normative" profiles in performance analysis. Firstly the mean for a given task (or performance indicator) is established over a large number of matches, with the mean value deemed to be a typical performance. Then the analysed matches are collated in sequential order, with the calculated mean updated with each subsequent match. An evolving mean is created and tracked to establish after how many matches it falls within

acceptable (they haven't defined acceptable) limits of the typical performance, at which point the indicator is deemed to be stable. Different performance indicators may require data to be gathered over varying numbers of matches before a stable value is achieved. Once all the indicators are stable, the analyst can construct a performance profile that reflects the typical performance, rather than specific to an individual match (Hughes et al., 2001).

Use of the term normative by Hughes et al. (2001) in reference to stable profiles has since been challenged. Normative suggests the subject data has been related to normative percentiles for the performance indicators, which it has not (O'Donoghue, 2005). Hughes' method of using multiple data are effective in reducing variability and for determining how many matches need to be analysed before the value for a given indicator has stabilized, but the method of achieving stable measures of performance could be refined by giving more weight to the most recent matches (O'Donoghue, 2005).

Bracewell's (2003) approach to developing performance measures uses an exponentially weighted moving average, which provides a more current representation of the subject's ability than using either individual values or the average for a person over time. Using the average overtime can be useful to compare with the equally weighted moving average to examine whether the person is playing at, above or below their historical performance levels. Bracewell also used the term stability in a similar context to that of Hughes and O'Donoghue (Hughes et al., 2001; O'Donoghue, 2005). However, the relationship between the individual tasks and team success still needs to be evaluated. For example, counts of particular actions may have a positive, negative or negligible effect on match outcome.

Bracewell (2003) also felt that his method of using dimension reduction techniques to combine various tasks into a single measure created a more stable measure of performance, as single measures of task performance were more likely to vary match to match than a combined measure. The principle of the two uses for the term stability are the same; although one refers to combining multiple performances measures over a number of matches (Hughes et al., 2001; O'Donoghue, 2005), and the other combining multiple task measures within a single match (Bracewell, 2003).

Variability

Although Hughes' method of using multiple data are effective for reducing variability, variability is not something we should ignore (O'Donoghue, 2005). Variability relates to the consistency of the subject, which is an important attribute of sporting performance that needs to be measured, as coaches look for consistently high performances from their players, rather than fluctuating levels of performance from week to week. Therefore as an advancement on Hughes' use of the mean to assess typical performance, O'Donoghue (2005) developed an approach to also measure a subject's level of consistency by calculating the spread of performances.

The mean is the average value of the performance, while the standard deviation represents the typical spread around the average performance. Where the subject's values are normally distributed, 68% of the values will fall within one standard deviation of the mean. However, it is argued that as the distributions of performance indicators in sport are often skewed, one standard deviation either side of the mean may be even greater than the maximum or minimum values for that subject. The inter-quartile range, on the other hand, represents 50% of the performances of the subject, regardless of the distribution of the values. Therefore O'Donoghue (2005) proposed the use of upper and lower quartiles to represent the spread of performance (the consistency of the subject), rather than the mean ± SD. The mean is still used to represent the average performance rather than the median, as the mean is calculated from the full range of recorded values and therefore will reflect any skewness in the results.

Normalisation

It is important that any performance measure is normalized either to appropriate population norms, the opposition or to their own previous performances, and represented as ratios or percentages (Hughes, 2004a; Hughes & Bartlett, 2002). Hughes and Bartlett (2002) highlight this point with an example from rugby union. If team A conceded 12 turnovers and team B 8 turnovers, one may assume that team B performed better in this department. However if team A had 48 possessions and team B 24 possessions, then team A could be deemed to be performing better as their ratio of possessions per turnover conceded was better than team B. As this example illustrates, the data are more meaningful for the coach when normalized appropriately.

Another means of normalising data is with graphical charts, which can be used to plot the subject's performance measure against a control value. Bracewell (2003) proposed control charts that compare the performance of the subject against an unattainable level of perfection, arguing that athletes seek perfection, and therefore they should be compared against perfection rather than average performance for their population.

Performance indicators

A performance indicator is a variable, or combination of variables, aimed at defining some aspect of performance, and to be useful, should relate to a successful performance or outcome (Hughes & Bartlett, 2002). The level of success achieved in each performance indicator, is usually normalised relative to some predetermined desired outcome. Notational analysis techniques are used to collect key performance indicator data, which are then stored for subsequent analysis (Hughes & Bartlett, 2002).

Four categories of performance indicators have been proposed for use in performance analysis of sport: match classification indicators, tactical indicators, technical indicators, and biomechanical indicators (Hughes & Bartlett, 2002). Such indicators can be applied to an individual, team unit, or an entire team.

Match classification indicators report the frequency of key structural events within a game. Examples within rugby union include: tries, shots at goal, lineouts, scrums, and turnovers.

Tactical indicators should reflect the style of play of the individual, unit, or team, by indicating the options taken at certain junctions of the game. Within rugby union, percentages or ratios to represent the options of pass, kick, and run, particularly by key decision makers of the inside back unit, could be established. Tactical analysis would be particularly relevant to the inside backs, who are key decision-makers of a rugby team, and could be further scrutinized by assessing indicators in relation to field position, or forms of possession.

A soccer scenario provided by Hughes and Bartlett (2002), serves as a good practical example to highlight how various depths of analysis can shed light on a performance. Match indicators for two players show that players, A and B, had four and six shots on goal respectively, which suggests player B had the better game. Further analysis though, revealed that player A had four shot attempts, while player B had 12 shot attempts,

representing indices of 4/4 and 6/12 respectively, which now suggests player A had the better game. Even further analysis showed that both players had 12 shooting opportunities; however player A decided to pass the ball on eight of these occasions, while player B shot on every opportunity, thus highlighting tactical differences between the two players. If additional analysis was carried out on the outcome of player A's eight passes, the results would be indicative of the success of that player's option taking.

Technical indicators reflect the level of success at performing a specific skill. Any error or success frequencies should be normalized against the total number of times the technical skill was attempted, and represented as a percentage or ratios (Hughes, 2004a). Examples include percentage of: lineout throws won, successful shots on goal, tackles missed, successful passes, total match turnovers.

There is also potential for team sports to develop more use of biomechanical indicators, particularly of the qualitative nature. Gymnastics and diving judges use qualitative biomechanical analysis, which is a skill sports coaches and technical analysts should also develop (Hughes & Bartlett, 2002). Critical features (also known as key elements) of the skill are used as performance indicators, with acceptable ranges of correctness established (Knudson & Morrison, 2002). Athletes are then advised with respect to, not only the outcome of the performance, but also the key elements within the skill. Technical skills that could potentially benefit from such analysis within rugby include: Tackling, lineout jumping, lineout lifting, throwing, kicking, and passing.

Performance profiles

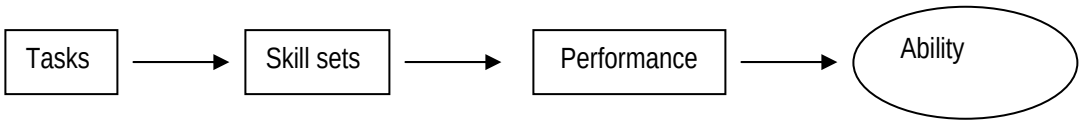
Key performance indicator values can be used to build performance profiles, which represent the performance or ability of the subject (Bracewell, 2003; Hughes et al., 2001). Values from the performance profile should be based on the typical performance rather than an individual performance (O'Donoghue, 2005). Creating and using performance profiles has been described as a six-step process (Hughes, 2004a).

1. Defining performance indicators,
2. Determining which are important,
3. Establishing reliability in the data collected,
4. Ensuring that enough data have been collected to define stable performance profiles,
5. Comparing sets of data,

6. Modeling performances, predicting outcomes.

Steps 1 and 2 establish the performance indicators to be used, with step 3 ensuring the data collected is reliable. Step 4 is expanded on in the stability section below, and is about collecting enough data so that the profile is more representative of the subject's current ability, rather than reflective of one-off performances. Step 5 is expanded on in the normalization section below, and addresses the task of putting the performance into context against relevant benchmarks. Step 6 refers to the potential to experiment with manipulation of performance indicators and profiles, to investigate the effects they may have on performance outcomes.

Figure. 2. Construction of performance and ability profiles (adapted from Bracewell, 2001).



A similar approach that has used aspects of that above combines discrete tasks into skill sets, which are then merged into one single profile value (Bracewell, 2003). Firstly, tasks (factors) that are related to successful performance are identified. Dimension reduction techniques are then used to reduce groups of similar tasks into skill sets (key performance indicators). Examples of tasks in rugby union include goal kicking and cover tackling, which could then be grouped with other like actions, into skill sets such as kicking and defence. Groups of four or five key performance indicators can then be reduced into a single performance measure for a given match. Ability however cannot be assessed from one performance due to various situational constraints and sampling variability. Ability is a longer-term accumulation of performances commonly referred to as form (Bracewell, 2003).

What is Rugby Union?

Rugby is a tough physical contact sport played by 15 players divided into eight forwards and seven backs. The IRB Playing Charter states the object of the game is that two teams each of fifteen players, observing fair play according to the laws and sporting spirit should,

by carrying, passing, kicking and grounding the ball, score as many points as possible (IRB, 2003a). The main object of the game is to score a “try”, which is achieved by grounding the ball in a controlled manner over the opposition goal line. Other means of scoring involve kicking the ball through and over the goal posts; either from a penalty, a drop goal, or when “converting” a try.

The primary job of the forwards is to compete for possession of the ball, while the backs then attempt to use the ball provided to advance down field and score points. The main areas where possession is contested are at the “Set-piece” and the “breakdown”. The term Set-piece refers to the main restarts in play; kick-offs, lineouts and scrums, which are relatively structured portions of play. The breakdown (also called “tackle ball” area) occurs after play has moved on from the Set-piece, and a tackle is made which evolves into a ruck or maul (Johnson, 2001). The breakdown involves the ball carrier or tackled player, and one or more players from each team contesting for the ball. The breakdown is either a ruck if the tackled player is on the ground or a maul when the ball carrier is held up off the ground. The object for competitors at these contests for possession, both Set-piece and broken play, is to provide good quality ball as a platform to assist the backs to execute successful “moves”. Research to date has not provided a specified definition for move, but the term is generally used to describe a deliberate sequence of events carried out to run or kick the ball, through or around the opposition.

The inside backs (halfback, 1st five and 2nd five), particularly the 1st five, are responsible for the majority of the team’s tactical decision-making. Once the inside backs receive possession of the ball, the general options are to either kick the ball, or to keep it in hand and execute attacking back-line moves either individually or in combination with their outside backs (De Lacy & Fox, 2000).

Aside from winning possession, and then implementing strategies to advance down field, all players, forwards and backs, backs must be adept at defending/tackling. The defensive ability of the team is vital in countering the attacking moves and strategies of the opposition.

Professional rugby analysis systems

The use of performance analysis techniques is increasing within professional rugby union. ProZone is a system that allows tracking of players, producing a large amount of

data of the team performance, and has been used for some time by the England Rugby Union and English premier division football clubs (Hughes, 2004b). In 2005 ProZone was employed by the South African Rugby Union. South Africa's purchase of the ProZone system gained media attention due to its great expense that is in part due to the required installation of 18-36 fixed cameras into the stadium. The system needs many cameras to allow the continuous tracking of all players on the field.

"TryMaker" is another rugby analysis product, which is owned by the New Zealand company Verusco Technologies. Verusco has two types of rugby software: TryMaker Pro and TryMaker+, which are used by 11 of the Super 14 franchises, New Zealand's provincial unions, and the All Blacks. TryMaker Pro is particularly useful as it provides pre-coded games so the end user can instantly access and review video replays of a comprehensive range of coded actions, performed by any player involved in a given match. In addition TryMaker Pro calculates a range of key performance indicators and player profiles, although these features are not utilized as much, probably due to the end-users not knowing how the indicators are calculated and therefore what they represent. TryMaker+ is widely used by the New Zealand teams. TryMaker+ allows the teams to code their own games, thereby accessing specific actions of interest for subsequent review, and enabling the creation of their own key performance indicators and player profiles.

IRB Analysis of Rugby Union

The IRB has its own Centre for Analysis of Rugby Union, within the Centre for Performance Analysis, University of Wales Institute Cardiff (UWIC). Since the inception of the centre in 1997, data has been gathered on the game of Rugby Union throughout the world, with video and data archived on database (Martin, Thomas, & Williams, 2001). The IRB is distinct from other professional rugby bodies in that they are less concerned with intellectual property issues regarding their game analysis. All the other national and provincial organizations are in competition, and as such much of their analysis remains confidential.

The IRB game analysis is the vehicle through which the IRB tracks at any period in time, how the game of rugby is being played at the highest levels (Thomas, 2004). Corris Thomas, head of the Centre for Analysis of Rugby Union, provided a technical report to the

IRB in November of 2004 (Thomas, 2004), in which he explains the role of the centre, giving examples of the benefits such analysis provides.

The IRB Centre for Analysis documents a record of all major matches, which enables it to:

- Track changes in the game
- Assess the extent to which the game is meeting the objectives set out in the IRB charter
- Track the effects of law changes
- Examine the accuracy of commonly held perceptions relating to the game
- Produce analysis and reports on specific elements of play
- Produce videos and CDs for illustrative and training purposes

(Thomas, 2004)

The IRB Centre for Analysis document of record provides comparative review across different seasons and competitions, as well as annual reviews for the following tournaments:

- 6-Nations (Northern Hemisphere)
- Tri Nations (Southern Hemisphere)
- Under21 World Championship
- Under19 World Championship
- Womens World Cup
- IRB Sevens (Sevens Rugby World Series)
- Heinekin Cup (6-Nations club championship)
- Super 12 (Tri Nations club championship)
- Rugby World Cup

(Thomas, 2004)

Due to the confidential nature of analysis conducted within the various national and provincial professional rugby organizations, the IRB reports form a valuable source of information for this review.

Performance indicators

Jones, Mellalieu and James (2004) created and analysed 22 team performance indicators over 20 matches played by a professional male rugby union team in Britain. Fifty-four percent of the squad had played international rugby, with a combined total of 231 test appearances. The aim was to examine the differences between winning and losing performances. They measured team performance as proportions of successful events such as scrums, lineouts, rucks, mauls and tackles. Of the 22 team performance indicators, only percent tries scored and percent lineouts stolen exhibited statistically significant differences between winning and losing performances. Additionally, there was a practical difference between the percentages of total turnovers won. The higher number of tries for winning teams is not surprising, but the higher values for gaining possession through stolen lineouts and turnovers is of interest. Turnovers and stolen lineouts are forms of possession where the opposition defence can be caught by surprise; these data suggest that coaches should select and coach their players to optimize the amount of lineouts stolen and turnovers won per match.

James, Mellalieu, and Jones (2005) developed position specific key performance indicators and performance profiles for 10 different rugby positional clusters. They found intra-positional variability, and concluded that there is a need for more than one profile per playing position. Their conclusion is not surprising for someone familiar with rugby as there are many different playing styles within given positions, each of which can be equally effective for their team (De Lacy & Fox, 2000).

The remaining performance indicators discussed in the review don’t necessarily relate directly to individual or team performance outcomes. Some of the indicators relate to various game strategies and structures.

Possession

Possession is a term used to describe which team has control of the ball. Most possession is contested at set-pieces, which are restarts in play. Possession can also be acquired when the team A kicks the ball to team B, or when team A commits a handling error resulting in possession being turned-over to team B. The set-piece are important sources of possession as they are restarts in play where ball is contested, and consist of lineouts, scrums and kickoffs. As they are the restarts in play, possession gained at the set-

piece provides the opportunity to dictate play. The following IRB analyses show how infrequently this important source of possession is forfeited.

The 2004 6-Nations had an average of 21 scrums per match with 87% possession retained, while the 2004 Tri Nations also averaged 21 scrums per match, in which 92% possession was retained. The 2004 6-Nations had 36 lineouts per match with 80% possession retained, while in the 2004 Tri Nations 32 lineouts resulted in 81% possession retained. At kick-offs 1 in 4 were contestable (i.e. short kick offs as opposed to long kicks), and of these 1 in 4 were regathered in the 6-Nations and 1 in 2.5 in the Tri Nations (Thomas, 2004).

Dominating possession has traditionally been a fundamental requisite to winning rugby. In the final stages of the 2003 World Cup, seven of the last eight matches were won by the team with the greatest amount of possession (Thomas, 2004). South Africa however, proved possession was not essential by winning the 2004 Tri Nations even though New Zealand and Australia had 40% and 11% more possession respectively (Thomas, 2004).

It would be interesting to analyse what type of possession South Africa and their opponents had, as it may be that certain types of possession are more useful than others. It may be too simplistic to lump all forms of possession together into one statistic. Usually if one team is reported to have more possession than another it is assumed that it is due to the superior ability of that team in contesting possession at the set-piece, and in retaining possession by not kicking the ball away and by not committing handling errors. However, it may be that a team has had more possession (e.g. New Zealand and Australia above) but not good set-piece possession; rather they have only gained scrappy possession via kicks and handling errors from the opposition. Therefore two separate measures for possession may be applicable: “set-piece” possession, and “other” possession.

In the 2004 Tri Nations South Africa used far more open play kicks and kicked at a far greater rate than New Zealand and Australia, yet they scored more tries than their opponents combined (Thomas, 2004). Analysis of the source of possession could reveal what percentages of set-piece possession the 2004 South African side won. Simply measuring the amount of possession does not necessarily reflect the amount of control a team has had over the game.

Turnovers

The 2004 Tri Nations victory by South Africa clearly heralded a new style of play, one which was not only at odds with the predominant style of winning rugby in recent years, but also with the directions of the IRB Charter. The IRB charter states that "It is the aim of the team in possession to maintain continuity by denying the opposition the ball and, by skillful means, to advance and score points. Failure to do this will mean the surrendering of possession to the opposition either as a result of shortcomings on the part of the team in possession or because of the quality of the opposition defence" (IRB, 2003a). However Thomas (2004) showed South Africa used a greater amount of kicking (rather than denying the opposition the ball), and certainly scored more tries from turnovers (rather than by advancing by maintaining continuity). South Africa seemed to prefer to wait for turnover possession to attack from, rather than attack from conventional forms of possession.

By kicking the ball away, South Africa clearly did not have the aim of maintaining continuity by denying the opposition the ball. Further, their failure to deny the opposition the ball was not due to any of their shortcomings, and was not a direct result of the opposition defence resting the ball from them. South Africa's kicking may have been a preordained strategy, designed to avoid the strong opposition defence from set play, followed by an attempt to gain possession from other platforms (such as kicks and handling errors by the opposition) where the opposition defence may not be quite as organised.

Potter and Carter (1996a) conducted specific analysis of turnovers. They referred to a turnover as a ruck or maul which yields either possession or a scrum feed to the opposition, and found that in the 1995 World Cup, the side which conceded fewer turnovers, in proportion to the rucks and mauls they set up, won the match 72% of the time (in 23 of the 32 matches). The resulting percentage is not particularly surprising, but the use of such a statistic is something that teams should utilize as a measure of performance. The definition used for turnover could also include turnovers mid-phase resulting from handling errors.

Lineouts

Martin et al. (2001) examined lineouts in the senior international fixtures during 1999 and 2000. Interestingly, New Zealand had the lowest equal rate for winning their own lineout throws of the eight teams analysed in 1999, and the lowest outright of the nine teams in 2000. New Zealand also had one of the higher rates of crooked throw-ins by any

country; Wales had the greatest proportion of 1:17, and New Zealand third lowest after Italy with 1:19, compared with Australia's ratio of 1:53, Scotland 1:80, and Ireland with no crooked throws in two years having the best record (Martin et al., 2001). These data suggest that not only did the New Zealand hookers have trouble throwing the ball straight, but their general ability to accurately find their jumpers was deficient.

Differing strategies were also highlighted by the percentage of opposition lineouts that each team contested. Often teams not throwing in the ball decide not to contest the lineout, as they believe they will be better organized to defend lineout drives if they do not jump for the ball. This strategy often frustrates commentators and supporters, as they believe teams are more effective if they challenge for possession. In 2000, the World Champions Australia contested 84% of the opposition throws, while rivals New Zealand contested just 48%, trailed only by Wales with 33%. Australia obtained possession once in every three opposition lineouts (a success rate almost twice as good as any other country), compared with Wales who successfully challenged just 5 of 137 lineouts (Martin et al., 2001). These findings suggest the more often a side contests lineout possession, not only does this obviously increase their chance of winning the ball, but the forward unit actually improve their skill in contesting opposition throws. The importance of contesting opposition lineouts is further magnified when the findings of Jones et al. (2004) are considered, which showed winning teams stole significantly more ball off opposition throws.

In further lineout analysis, there is a perception that winning a lineout within 5-10 Meters of the opposition goal line is ideal possession for the forwards to drive over the line and score a try. Subsequently, a regular attacking strategy is to kick a penalty out close to the opposition try line to set up an attacking lineout. However, analysis of a sample of games from the 2003 World Cup revealed that of 78 penalties kicked into touch only 7 tries resulted from the ensuing lineout possession. Of those 7 tries only 2 came from lineouts within 10 Meters of the opposition goal line, and only on one occasion was the ball caught and driven over the try line directly from the lineout (Thomas, 2004).

Points scoring

Thomas (2004) provided historical data to illustrate trends in the four modes of scoring points, during selected seasons over the past six decades. Seasons were selected at 10-year intervals from 1954 through to 2004, with comparisons made between the average number

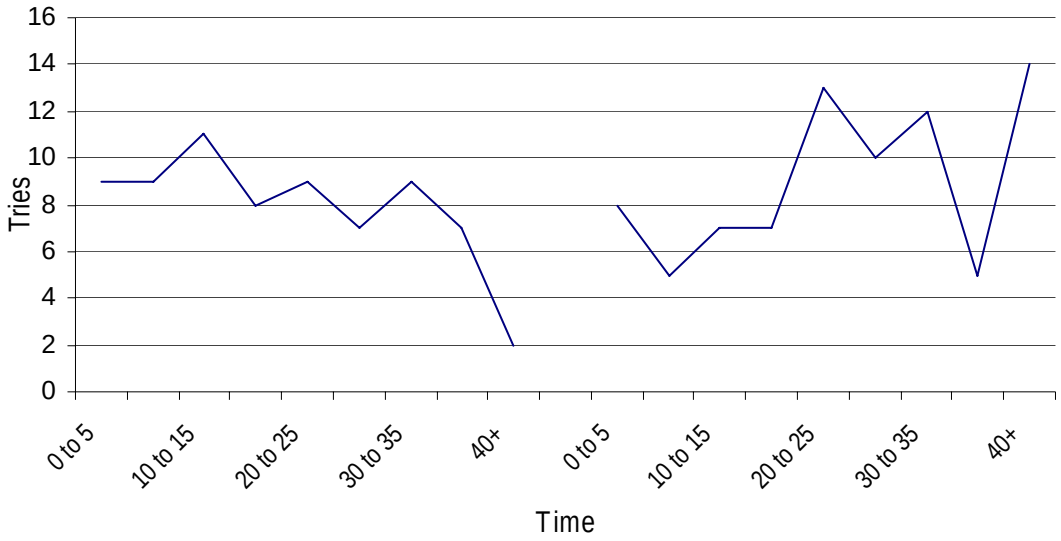
of tries, conversions, penalties and drop goals scored per match. The most dramatic changes have occurred in the last 10 years. 1994 had the lowest average tries scored per match (2.0) and highest number of penalty goals (6.1) per match of the five decades analysed, which is a trend that contravenes the IRB desire for points to be scored through tries (IRB, 2003a). The trend has reversed over the last 10 years, with 2004 having the highest recorded average of 4.5 tries per match, and the lowest rate of 4.5 penalty goals since the 1974.

Of the 76 matches played in the 2004 6-Nations, Tri Nations, Under19 World Cup and Under21 World Cup, only 4 games were won by the side scoring fewer tries, which suggests that scoring more tries than the opposition will generally win rugby. However in only three of the six 2004 Tri Nations matches did the winning team score more tries (Thomas, 2004). The Tri Nations is played between three of the top five teams in the world, and it may be that at the very elite level defenses are so good that goal kicking becomes more important in winning games. These findings show that even basic analysis, if well directed, can provide useful information. Conversely though, analysis of any degree of sophistication, if poorly directed and applied could yield misleading information.

Timing of tries

Analysis was conducted on the timing of tries throughout the course of games, in matches played between the top 10 international sides of 2003 (IRB, 2003b). During injury time at the end of the first half just two tries were scored, but during injury time in the second half 14 tries were scored. These results suggest that fatigue toward the end of the game results in more tries, although it is surprising that the period just before half time has the slowest rate of try scoring. Part of the reason more tries are scored at the end of the game may be that the result is already assured, and that defences relax knowing the game is effectively over. However this doesn't explain the lowest rate of scoring tries occurring at the end of the first half; it may be that teams are playing too conservatively at this time, and should recognize that with fatigue setting in there is an opportunity to push for tries.

Figure 3. Timing of tries during games played between the top 10 international sides of 2003 (adapted from IRB, 2003b).



Possession platforms and tries

In their review of the 2003 season, the IRB game analysis centre provided the possession source (I prefer the term platform) of the 152 tries scored during fixtures between the top 10 international sides (see table 1). Lineout possession from own throw in had a high proportion with 50 tries, followed by own scrum and opponents kick with 22 and 21 tries respectively (IRB, 2003b). Opponents handling error and turnover are listed as two separate categories, but if they were grouped together then turnovers would total 27 tries.

Table 1. Frequency of tries scored in possession platforms in games played between the top ten international sides of 2003 (adapted from IRB, 2003b).

Possession source	Tries
Lineout - own	50
Scrum - own	22
Opponent's kick	21
Penalty/Free kick	18
Opponents handling error	14
Turnover	13
Lineout - opposition	6
Opponent's restart	5
Own restart	2
Scrum - opponents	1
TOTAL	152

Field position and tries

Boddington and Lambert (2004) conducted an evaluation of the try scoring opportunities for South Africa during the 2003 Rugby World Cup. Points were plotted on a grid matching the dimensions of the field to indicate: where points were scored, where movements began, and the net distance the ball moved across field. Their findings revealed that 86% of scoring opportunities resulting in points began from within the attacking 25, with the two wing zones accounting for 65% of these, and that scoring opportunities began most frequently from the attack/mid zone (between 25 and halfway).

Laird and Lorimer (2004) examined try scoring statistics gathered by the IRB on games played among the top ten internationally ranked rugby teams of 2003. They found that 39% of tries were scored from possession gained within the opposition 22, which isn't surprising considering the 22 is nearly one quarter of the field and it is closer to the try line than any other sector. Further research could be carried out to establish what portion of the 39% of tries scored from possession obtained within the 22, came from forward moves, executed either from a scrum or lineout close to the opposition goal line, as opposed to back moves.

The real question is: From what part of the field is it most effective to launch attacking back moves? Traditionally teams kick for territory when they gain possession in their own half, and attack when possession is gained within the opposition territory, however analysis of attacking moves launched from the various parts of the field would provide more clarity to the above question, and may produce surprising results.

One trend that should be recognized was observed in matches played between the top 10 international teams in 2003. Of the 79 tries scored within 15 m of the sideline, 62% were scored on the left side and 38% on the right (IRB, 2003b), which is a large contrast that coaches may be interested in. No attempt was made to explain this trend, but possibilities include: the tendency of scrums to screw around to the left, which makes attacking down the left side easier, and the predominant right-handedness of players that makes passing to the left easier and side stepping off the right foot more effective, both resulting in more breaks in the defence to the left side of the field.

Passes per try

In their analysis of IRB statistics Laird and Lorimer (2004) found that 48% of tries were scored using three or less passes, and concluded that the higher the number of passes in a given move the less likely a try will be scored. It is a surprisingly high percentage, and suggests that teams should not bother to hold onto the ball for too long. But if a denominator was established then the number of tries could be expressed as a percentage of the number of possessions containing three or less passes. A ratio could also be calculated for possessions containing greater than three passes, to allow a more accurate relationship to be established between the number of passes and the scoring of tries

Options: pass, kick, run

The ability of a team to control the ball with accurate passing would seem an obvious requisite to success. The total number of passes within a given game could be used to indicate the level of control teams have over the ball, and/or strategies employed. However a particularly surprising statistic arising from analysis of the knockout stages of the 1995 Rugby World Cup tournament (i.e. the last eight matches) was that the losing side actually passed the ball more than the winners (Potter & Carter, 1996a). Similarly Potter and Carter (1996b) found that the winners of the three World Cups at that point in time, had less of the

passing share than their opponents in the final, with New Zealand 39% of the passing share in 1987, Australia 26% in 1991, and South Africa 39% in 1995. As the authors suggested, this may be due to the team trailing on the scoreboard playing “catch-up rugby”, which generally involves passing the ball more than they would otherwise, in a risky attempt to score tries.

Potter and Carter (1996b) also used passing statistics to create a ratio of kicks to passes that is a simple but very effective means for assessing strategies of individuals and teams. They used the ratio to compare the trend across the two of Rugby World Cups of 1991 and 1995. The ratio revealed an increase from 1:1.9 (kick to pass) in 1991 to 1:2.2 in 1995. On the surface these ratios suggest a definite shift in playing styles over the four-year period, however such statistics should be viewed with caution. The World Cup in 1991 was played in Britain, whereas the World Cup of 1995 was played in the much drier conditions of South Africa, which is more conducive to the running and passing style of play (Potter & Carter, 1996b).

Carter and Potter (1996a) showed that during the plays leading to the 187 tries scored in the 1995 World Cup, there was 39 kicks and 885 passes, which equates to a much higher kick to pass ratio of 1:23. These analyses suggest that teams should not be kicking the ball away, but rather use more passing to gain an advantage; again a valuable statistical indicator for coaches determining strategies for their team.

An advancement of this analysis technique also counted the run option (Parsons & Hughes, 2001). The frequency ratios of these fundamental ball-in-hand options could shed useful information, particularly on the play making inside backs within a team. In this project the Welsh international first-five was analysed over 10 matches during which he: received the ball 204 times, passed 145, kicked 46, and ran 13 (Parsons & Hughes, 2001). The ratio of the three ball in hand options of the first-five directly affects the team’s style of play, and therefore should receive significant attention from the coaching staff regarding what kind of ratio is most desirable against specific opposition.

Performance profiles

Vivian et al. (2001) conducted analysis of players across three different levels of competition: Cardiff league (local), European Cup (regional), and Wales’ (national) fixtures were analysed. Active involvement of the three loose forwards and halfback were notated

and compared across the three levels of competition. The number of actions carried out by each player was recorded, and results showed a steady increase in the number of actions from the league level, through European Cup, and up to International level. Flankers showed an increase from 31 to 37 actions per game, interestingly attacking actions consistently comprised 57% to 58% of the total actions. Of further interest is that the international flankers made relatively fewer tackles than their counterparts in lower competition; this may be a reflection of the greater tackling ability of the players surrounding the flankers at international level. The number of actions recorded for the halfback increased rather more dramatically, from 29 at league level, 36 at European to 50 at International level (Vivian et al., 2001).

Comparing profiles across different levels of competition clarifies different playing styles, which may be useful when identifying players suitable for a various levels of play. The concept that players may vary in their ability within different levels of competition is one that talent scouts and selectors may want to consider.

In a related study data was collected from the same sample of matches, with the information presented forming part of individual player performance profiles (Parsons & Hughes, 2001). For the Welsh international results, data were collected over 10 matches. Data were collected for on the ball skills, which were defined as attacking or defensive action. The attacking actions were defined as either ‘with ball’, or ‘without ball’. The ‘with ball’ actions were divided into the fundamental options of pass, catch, and run.

The results highlighted the need for players in certain positions to be practicing skills without the ball, particularly the flankers who had 128 “without ball” attacking actions, compared against 90 with ball actions. Although the specific skills of these attacking actions are not identified, it can be assumed that many of them would have been supporting the ball carrier, involving collisions at the tackle ball area. To give these numbers some context, the locks had the second most without ball attacking actions of 90, and by contrast the halfback had zero; all the halfback’s 310 attacking actions were with the ball (Parsons & Hughes, 2001).

Time-motion analysis

Research within rugby has also been conducted using time motion analysis, which tracks the movement intensity of players in space and time, and is aimed at gaining information

for trainers to provide greater specificity in training prescription (Bloomfield, Polman, & O'Donoghue, 2004). The Bloomfield Movement Classification system (Bloomfield et al., 2004) was designed for dynamic movement invasion sports, and includes 17 modes of motion, 14 directional categories, 4 intensity types and other specific instantaneous movement and sport-specific events including turns, swerves and on the ball activity. Other time-motion analysis methods have been developed specifically for research within rugby (Duthie, Pyne, & Hooper, 2005; Roberts, Stokes, Trewartha, Higgitt, & El-Abd, 2005).

Duthie et al. (2005) reported that forwards completed greater total work than backs, and that backs were involved in more sprinting, which in itself is not surprising. However, the ability of the method to identify that forwards work was followed by rest periods of <20 s, while the backs work was followed by rest periods of >100 s, shows the insightful detail the analysis can provide to aid training prescription. Roberts et al. (2005) also provided specific and relevant detail, finding that the work to rest ratio was 1:7 for forwards, and 1:18 for the backs, and that 70% of forwards high intensity work was in static exertion, while 65%-75% of high intensity work for the backs was cruising or sprinting.

Law changes and game structure

Analysis can also be conducted to quantify important game structures to indicate what effect law changes have had on the game. A significant change in the game from the 1991 to 1995 World Cup occurred in the number of second phase possessions, which rose 44% from 48 to 69 per match. The term second phase is possibly an inaccurate term, as the researchers are actually referring to all phases beyond the first. This type of possession can simply be called “phase play”, that is, all phases emanating from rucks and mauls rather than from the possession platform. In any case, the increase in phase play possession appears to be a positive outcome of the “use it or lose it law” the IRB implemented in 1994. The use it or lose it law discourages teams from letting play end in a maul or collapsed maul with the ball in their possession, by ruling that in this situation the ensuing scrum will be awarded to the opposition (Quarrie & Hopkins, 2006).

Carter and Potter (1996b) analysed time elapsed when ball is not in play during the 80 min of running time per match. Such analysis provides useful information for Rugby’s administrators, identifying which areas of the game lead to the greatest amount of wasted time. The wasted time during stoppages in play occurs mainly during preparation for set

pieces (scrums, lineouts and kickoffs) and shots at goal. Carter and Potter (1996b) reported that in three matches during the 1995 World Cup, preparation for shots at goal took over twenty minutes, with the greatest amount of time wasted being 26 min 46 sec during the match between New Zealand and Scotland. Such information may have led to the introduction of the rule giving goal kickers a maximum of 1 min to take their shot at goal.

IRB analysis has since shown that the average “ball in play” time per game has dramatically increased over the last 15 years. In 1991 it was 25 minutes, and has gradually increased through to an all time high in 2003 of 34 minutes (IRB, 2003b).

Foul play

Game analysis can also be useful for monitoring levels of foul play, which is an important aspect for administrators to manage in such a physically confrontational sport. Martin et al. (2001) reported statistics compiled at the IRB Centre for Analysis of Rugby Union. They reported on the incidence of foul play, penalties, red and yellow cards, examining trends primarily by comparing statistics from years 1999 and 2000.

Penalties for foul play (kicking, stamping and punching etc) were analysed in games played in the 5 Nations, Tri Nations, and matches played between teams from those respective tournaments. The analysis concept was useful for showing trends in foul play (or at least the referees interpretation), and showed a marked decrease from 23 fouls in 1999 (21 matches), to 14 in 2000 (20 matches). This type of statistic would be of interest to administrators involved in managing and marketing the games image in this professional era. The administrators may also be interested to note that there is a proportionally higher incidence of foul play penalties when team from the 6-Nations play matches against teams from the Tri Nations, rather than the standard matches against teams from within their own hemispheric competition.

Thomas (2004) also monitored the level of foul play in 2004, by comparing the number of penalties conceded within the main international competitions during the year. Surprisingly there was less than one penalty for foul play per game, and one illegal tackle penalty per game, minimal injuries resulting, and overall there is a reducing trend for foul play penalties. These results can be seen to conform well to the IRB Charter, which states that while it is perfectly acceptable to exert extreme physical pressure on an opponent, it is not acceptable to, willfully or maliciously, inflict injury (IRB, 2003a).

Historical comparisons

Analysis can also be useful for making comparisons across different eras of the game. Total time that the ball is in play per match has been a concern for administrators wanting to make the game more attractive to spectators, particularly since the advent of professionalism in 1995. Total playing time from the World Cups of 1991, 1995, 1999, and the 6-Nations of 2004 was compared. Results revealed a steady increase from 31% of the total match time in 1991, to 46% in 2004 (Thomas, 2004). It is unknown why the report included the 6-Nations of 2004 rather than the 2003 World Cup, which would have seemed more appropriate; however this type of analytical approach is obviously useful for structural changes in the game over time.

Long held opinions (particularly in the Southern Hemisphere) accusing the English of playing a boring style of rugby may be outdated. Analysis compared two comparatively successful eras of English rugby: 1993-96 where they played 16 matches and won two championships, and 2002-2004 where they played 15 matches and also won two championships. From 1993-1996 they scored 15 tries and 58 penalty goals, but clearly changed their style to score 58 tries and 35 penalty goals in the years 2002-04 (Thomas, 2004).

Conclusions

Game analysis within rugby union organizations is growing due to the increasing professionalism of the game, coaches' needs for analytical assistance, and advancements in performance analysis technology. Data for game analysis is gathered by the computerized coding of matches. Methodological approaches have designed to account for match volatility and produce valid and reliable performance indicators and performance profiles.

Rugby research has focused on a range of performance indicators related to game structures and tactical aspects. Practical differences have been shown to exist between winning and losing performances for percent lineouts stolen and percent total turnovers. In the 2004 Tri Nations the team throwing the ball in won 81% of lineouts and 92% of scrums. However South Africa showed that possession was not essential by winning the tournament with 40% and 11% less possession than New Zealand and Australia respectively.

Of the 76 matches played in major international tournaments in 2004 only four matches were won be the team scoring less tries, although in only three of the six Tri Nations matches did the winning team score more tries. Of the tries scored in 2004, 48% involve three or less passes. Most tries of the senior internationals in 2003 were scored off lineouts, 39% of tries were scored from possession gained within the opposition 22, and of the 79 tries scored with 15 Meters of the sideline, 62% were scored on the left side and 38% on the right.

Analysis has examined the work to rest ratios of both forwards and backs, providing useful information for fitness trainers. Research into game structure highlighted the amount of time wasted during stoppages in play; one game between New Zealand and Scotland at the 1995 World Cup had over 26 minutes wasted during shots taken at goal. Historical comparisons related to time wasted have also been made; showing that total playing time has steadily increased from 31% at the 1991 World Cup through to 46% in the 2004 6-Nations. Foul play is another focus of analysis, with research showing an average of less than one penalty per match for foul play occurred during senior international fixtures of 2004.

However, despite the range of detailed analysis there is no obvious structure or progressive evolution to the development of analysis methods and there are still large gaps in rugby literature. The available research has tended to focus on individual aspects, without taking a global approach to summarizing the main structures of the game. Such analysis could provide the theoretical base, from which further more detailed research can advance in a systematic manner. Player interactions, and off the ball player formations, also present future research potential.

Chapter 2 – A Synthesis of Game Structure in Rugby Union

Abstract

In this methodological study we developed secondary analyses of data provided by the New Zealand Rugby Union (NZRU) from Super 12 rugby games. The primary data were files of all "on the ball" events. The files were examined in conjunction with matching video to identify and characterize logical units of play. The "move" was identified as the fundamental unit for analysis, and was defined as a controlled period of possession delineated by breakdowns in play, changes in possession, and kicks. Although this term is used frequently in rugby circles, it lacked a precise definition. From the move evolved another key component of play, the "possession", defined as a period of continuous play in which one team has controlled possession of the ball. Twenty match situations called "platforms" were identified from which moves and possessions are initiated. All moves and possession were then categorized dependent upon their initiating platform. A computer programme was developed to create match listings defining and quantifying these units of play. An iterative process evolved between examining match listings in conjunction with videos of nine games, and rectifying errors in identification of moves via adjustments to the programme. In a subsequent validity study with a sample of five new games, only 1.9% (90% confidence limits 1.3-2.5%) of the 1328 moves were not identified correctly, and more than half these errors were due to errors in the primary data. To illustrate the game structure provided by the programme simple statistics for the units of play were derived from the 69 games of the 2005 Super 12 season. The average game consisted of 110 possessions and 247 moves; 57% of moves emanate from rucks and mauls; the mean meters gained in any given possession was 20; kick receptions provided 23% of all possessions, and lineouts and scrums provided 73% of all possessions that start play. With matches now able to be broken down into all units of play, potential exists for further research into the systematic dissection of the game.

Introduction

Rugby is a dynamic fast-moving 80-minute game consisting of a variety of concentrated player actions. No person can be expected to adequately recall all events, which range from

individual technical skills through to complex whole team interactions. Therefore performance analysts are playing an increasingly important role in the extraction and interpretation of data from rugby games.

The global development of rugby union and its increasing level of professionalism are resulting in growing demands for accurate analysis from coaches, media, administrators and players (Bracewell, 2003; Vivian et al., 2001). The demand for information coupled with technological advancements world wide, including the integrated capabilities of digital video, computer systems and video analysis software is driving a rapid evolution in performance analysis practice.

Performance analysis can be viewed as a continuum ranging from technical analysis of closed skills at one end through to broad game analysis at the other. Game analysis forms the focus of this project and concentrates on the performance and strategies of teams and individuals.

Coding is the term given to the technique whereby a match is viewed on computer with key events electronically noted for statistical purposes or to allow convenient review of the selected video clips at a later date. The volatile and chaotic structure of rugby (Bracewell, 2001) means that individual and team performances are often unstable (Hughes et al., 2001; O'Donoghue, 2005). Approaches designed to provide valid and reliable data have been developed that enable the creation of performance indicators.

A performance indicator is a variable, or combination of variables, aimed at defining some aspect of performance, and to be useful should relate to a successful performance or outcome (Hughes & Bartlett, 2002). It is important that any performance measure is normalized either to appropriate population norms, the opposition performance, or to the subject's own previous performances, and represented as a ratio or percentage (Hughes & Bartlett, 2002; Hughes & Franks, 2004). Performance indicators can be collated into "performance profiles" to provide measures representative of the subject's performance or ability, and should be based on the average performance rather than an individual performance (Bartlett, 2001; Hughes et al., 2001; O'Donoghue, 2005).

Rugby is a physical contact sport played by two teams of 15 players divided into eight forwards and seven backs. The object of the game is by observing fair play according to the laws and sporting spirit, to carry, pass, kick and ground the ball over the opposition goal-line, score as many points as possible (IRB, 2003a). Commercial rugby analysis systems

are available, and provide services to all the major professional rugby organisations around the world. TryMaker is such a system, which provides analysis for the New Zealand All Blacks, as well as 11 of the Super 14 franchises. The IRB (International Rugby Board) has its own Centre for Analysis of Rugby Union, which allows the IRB to track how the game is being played at the highest level (Thomas, 2004).

Rugby research has focused on a variety of performance indicators related to game structures, tactical aspects, and performance of individuals and whole teams. Possession of the ball is an obvious requisite to winning rugby, and the ability to win the ball at the contests for possession that restart play are traditionally considered vital. Possession won from restarts in play during the 2004 6-Nations was examined and it was found that 87% of scrums and 80% of lineouts were won by the team throwing the ball in (Thomas, 2004). Teams can therefore plan strategies with reasonable confidence that they are going to win the ball. However stolen possession has been shown to be particularly useful. Jones, Mellalieu and James (2004) identified 22 team performance indicators and found statistical differences between winning and losing performances for percent lineouts stolen, as well as practical differences in percent turnovers won.

Try scoring remains important to winning rugby; of 76 major international fixtures in 2004 only four matches were won be teams scoring less tries than their opposition (Thomas, 2004). Of the 79 tries scored within 15 Meters of the sideline in games between the top 10 international sides of 2003, 62% were scored on the left side of the field and 38% on the right (IRB, 2003b). Laird and Lorimer (2004) found that 48% of the tries were scored in the same 2003 sample used three or less passes.

Analysis has also been conducted to assess the effects of law changes on rugby. Potter and Carter (1996b) studied the amount of time wasted while the ball is not in play during international matches. Analysis of the 1995 World Cup revealed that preparation for shots at goal where the primary source of time wasted with over 26 minutes wasted in the game between New Zealand and Scotland. In later research the proportion of match time that the ball is in play was analysed, and showed an increase from 31% of total match time at the 1991 World cup, to 46% of total match time in the 6-Nations of 2004 (Thomas, 2004). Rates of foul play (kicking, stamping, punching etc) have also been monitored, within the senior international competitions of 2004 having a surprisingly low average of one such penalty per game (Thomas, 2004).

Despite the range of detailed analysis in the literature, there is a need for a structured account of all play within the game. Thus the aim of this project was to create an analysis method that defines and quantifies all logical units of play. Coaches could then be provided with reports summarizing all constructs of the game, from which further more detailed analysis can also emanate.

Methods

Primary data

Primary data from the entire 2005 Super 12 season was provided by the NZRU. The data includes all "on the ball" events coded by Verusco Technologies, who are the providers of analysis services to the NZRU.

An event is a single occurrence in the game that has been coded by Verusco. Each event includes detail such as: how the play started, how the phase started, the team and player in possession, how the player obtained and/or released the ball, whether a turnover occurred, the x-y coordinates of each event, and the time at which the event occurred. A "controlled" event is where a handling error has not been coded against the player. If one player has two consecutive controlled events we deem the player to have controlled possession.

Units of Play

A focus of this project was, by studying rugby video, to identify and characterise controlled periods of possession suitable for the analysis of performance and strategies. The following sub-sections provide a description of the identified units.

It should be noted that the majority of match analysis would likely only include active play. Active play as coded by Verusco is recorded as all time in which the ball is in play, as opposed to elapsed time. Elapsed time includes (for example) the time taken from the ball going over the side-line to the time of the following lineout throw in.

Play

A "play" is the largest unit of play in the game, and is coded by Verusco. A play is simply the period of time that the ball is in play, from the moment the referee starts, or restarts play, until referee blows the whistle for a stoppage. For the purposes of this project only plays that continue beyond their initiating events until a team has possession of the

ball in a state of continuous action are included in the analysis. Therefore as no active play has occurred, and no meaningful analysis can be extracted, the following plays are excluded: penalty/fair catch/free kicks that go directly into touch; penalty shots at goal that either result in points, carry directly out of play, or are received and forced immediately by the opposition for a restart 22; conversion attempts; or restarts in play that are stopped by the referee for an infringement before either team has claimed possession of the ball.

Possession

A possession is a period of play during which one team has possession of the ball. A possession is delineated by changes in possession and/or start and end points of a play; a new play always heralds the start of a new possession. While a team has possession of the ball they have the opportunity to execute moves. Verusco used the term “move” to define a possession; however we felt this term was not appropriate. “Move” is usually used in rugby to describe a deliberate sequence of events, in smaller portions of play than what possessions can extend to.

Phase

A phase is a natural unit of play, and is traditionally and frequently used by rugby people when describing aspects of the game. A phase is the period of play extending from the re/start of play until the next breakdown in play, which can either be a ruck, maul, or the end of the play itself. Verusco code phase, however, the phase is not suitable for our analysis, as a whole phase is sometimes too long to distinguish smaller isolated sequences of events. A phase as coded by Verusco can contain several changes in possession, either via mid-phase turnovers or kicking the ball to the opposition. Such phases of play become too long and chaotic to legitimately relate performance indicators at the start of the phase, to eventual phase outcomes.

Move

A move involves the interaction of one or more players during a period of controlled possession. A move is not only delineated by breakdowns in play (as is the case with the phase), but also changes in possession, and kicks. Therefore if there are no changes in possession during a given play, the increasing number of moves will replicate Verusco’s

incrementing tally of phases. For example, if three phases have been completed without any changes in possession, then three moves would have also been completed. However, when there is a possession change in the middle of a phase, moves will start being counted for the new team in possession, whereas Verusco's phase count will continue to increase up until the completion of the play. Thus the main benefit of counting moves is that individual units of play occurring mid-phase can be isolated, which means all practical sequences of play can be analysed.

In the traditional sense of the word a move involves the execution of a deliberate tactic designed to gain territory, produce forward momentum, or score points. Such moves are generally orchestrated by the inside backs, and classically involve members of the backline, however forward runners can also be employed among the backs in any move. Forwards can also execute their own moves, which are generally designed to gain momentum for an ensuing backline move, or are executed close to the opposition goal line in a direct attempt to score a try.

Although not all moves as defined in this project will involve a rehearsed sequence of events, ideally each move should involve efficient execution of tactics to gain positive outcomes for the team. Therefore the term move was deemed the most appropriate name for this unit of play.

Sets of hands

Sets of hands is a term that has traditionally been used to count the number of players who have handled the ball in a given move, or phase of play. Once a team is in possession of the ball the sets of hands will count incrementally each time a different player touches the ball. It doesn't matter what type of event is coded to the player, so long as that team is has controlled possession of the ball. If the same player touches the ball on two separate occasions in the one move that will counts for two sets of hands.

Meters gained

Although Meters gained is not a unit of play as such, it is a unit used to measure performance in this project, and it is appropriate that it be defined in this section. Meters gained are calculated from the x-coordinates provided in the NZRU data. The x-coordinates represent the length of the field, and the y-coordinates represent the width of the field. The

calculation is only made in the x-direction, which represents Meters gained toward the opposition goal line.

Move platforms

The move became the most obvious unit to use for the systematic breakdown of rugby union. As well as isolating each individual move, we wanted to classify the moves into appropriate groups to enable more detailed future analysis. The moves were categorized dependant upon the event in play from which they originated, that is, their "platform".

As the name suggests, a platform is the base from which moves begin, and is the source of the ball that is being used in a given move. It is often said that the forwards need to provide a good platform from which the backs can work. Although the term platform can by used to describe the beginning of a move, it is more often associated with the origin of a possession. Technically though, moves also start from a platform, and therefore the various categories of move identified within this project have been given the name of their respective platform. Twenty platforms were identified and characterized. The following is a description of each platform:

Lineout won

The purpose of a lineout is to restart play quickly, safely and fairly, after the ball has gone out of play, with the ball thrown in between to lines of opposition players contesting possession (IRB & NZRU, 2005). A lineout is won when a player from the team throwing the ball in has two consecutive controlled events after the ball has been thrown in.

Lineout stolen

A lineout is stolen when a player from the team not throwing the ball in has two consecutive controlled events after the ball has been thrown in.

Scrum won

The purpose of a scrum is to restart play quickly, safely and fairly, after a minor infringement or stoppage. A scrum is formed when eight players from each team bind together and engage by interlocking with the heads of the opposition eights front row. The halfback feeds the ball into the tunnel between the two teams, and the front row players compete for possession (IRB & NZRU, 2005). A scrum is won when one player from the

team feeding the ball in has two consecutive controlled events after the ball has been thrown in.

Scrum stolen

A scrum is stolen when one player from the team not feeding the ball in, has two consecutive controlled events, after the ball has been thrown in. That player's team is deemed to have control of the ball, and therefore stolen the scrum.

Start half reception

In general rugby parlance start halves and start 22s are commonly referred to as kick-offs. It has suited our means to use the terms start half and start 22 as Verusco code the events in this manner, but also as an easy means of distinguishing between the two forms of kick-off.

A start half occurs at the start of a match, at the restart of play after halftime or after a score. The team kicks off with a drop kick, which must be taken at or behind the centre of the halfway line (IRB & NZRU, 2005).

A start half reception is when one player from the team not kicking off, has two consecutive controlled events, after the ball has been kicked off. That player's team is deemed to have control of the ball, and therefore received the kick-off.

Start half regather

A start half regather is when one player from the team kicking off, has two consecutive controlled events, after the ball has been kicked off. That player's team is deemed to have control of the ball, and therefore regathered the kick-off.

Start 22 reception and Start 22 regather

A start 22, also known as a dropout 22, is used to restart play after the attacking team has played the ball into the in-goal area and a defending player has made the ball dead. The defending team drops out with a drop kick anywhere on or behind the 22-metre line (IRB & NZRU, 2005).

To avoid unnecessary repetition, the principles applied to start half reception and regather are the same for start 22.

Tap penalty

Penalties and free kicks are awarded to the non-offending team, for infringements by their opponents. To restart play any player can take the free kick or penalty awarded with any type of kick (except a place kick in the case of free kicks), including a small tap to him/herself (IRB & NZRU, 2005). In this project tap penalty refers to penalties and free kicks where the player has tapped the ball and run with it, rather than kicking it down field or into touch.

Penalty kick reception

A penalty kick in this project refers to a penalty kick or free kick that has been kicked directly down field (rather than being tapped first), usually with the intention of kicking the ball out. A penalty kick reception occurs when the ball does not go out, and the opposition receive possession of the ball.

Penalty shot reception

A penalty shot is when the team that has been awarded the penalty opt to take a shot at goal. A penalty shot reception occurs when the shot misses the goal, and the opposition receive possession of the ball.

Kick reception

Kick receptions occur when a player receives the ball from a kicked by the opposition. If the kick has travelled far enough, beyond the specified dimensions of the appropriate ellipse (see Table 2), and the receiving player gains controlled possession, then the receiving team is deemed to have a kick reception.

Kick regather

Kick regathers occur when a player kicks the ball downfield toward the opposition goal line, and any player from the same team regains controlled possession. If the kick has travelled far enough, beyond the specified dimensions of the appropriate ellipse (see Table 2), and the regathering player gains controlled possession, then the receiving team is deemed to have a kick reception.

Beyond the fundamental kicks downfield that result in a kick reception, or a kick regather, a range of other more complicated scenarios occur surrounding one or more kicks.

As well as kicks, single event touches can also be involved before the ball is bought under control by one of the competing teams. On the following page Table 2 outlines the various scenarios that had to be accounted for by the analysis programme.

Table 2. Schema to determine move platform in different scenarios after a kick during active play.

Kick-1	Kick-2	Final Possession	Move name
A	_	A	Regather if K1>Ellipse1.
			Otherwise same as previous move.
A	A	A	Regather if K12>Team A kick-1 ellipse.
			Otherwise same as previous move.
A	B	A	Reception if K2>Team B ellipse.
			Regather if K2<Team B ellipse and K1>Ellipse.
			Otherwise same as previous move.
B	_	A	Reception if K1>Team B ellipse.
			Otherwise same as previous move.
B	A	A	Regather if K2>Team A kick-2 ellipse.
			Reception if K2<Team A kick-2 ellipse and K1>Team B ellipse.
			Otherwise same as previous move.
B	B	A	Reception if K12>Team B ellipse.
			Otherwise same as previous move.
A	_	B	Reception if K1>Ellipse.
			Otherwise mid-phase turnover.
A	A	B	Reception if K12>Team A kick-1 ellipse.
			Otherwise mid-phase turnover.
A	B	B	Regather if K2>Team B ellipse.
			Reception if K2<Team B ellipse and K1>Team A kick-1 ellipse.
			Otherwise mid-phase turnover.
B	_	B	Regather if K1>Team B ellipse.
			Otherwise mid-phase turnover.
B	A	B	Reception if K2>Team A kick-1 ellipse.
			Regather if K2<Team A kick-1 ellipse and K1>Team B ellipse.
			Otherwise mid-phase turnover.
B	B	B	Regather if K12>Ellipse.
			Otherwise mid-phase turnover.

[a] Initial team in possession is always Team A.

[b] K1=distance first kick; K2=distance last kick; K12=distance both kicks plus intervening kicks or touches.

[C] Dimensions forming the three ellipses are with respect to position and playing direction of kicker:

Team A kick-1 ellipse: 5 m forward, 5 m backwards and 10 meters laterally

Team B kicks ellipse: 15 m forward, 5 m backwards and 20 meters laterally

Team A kick-2 ellipse: Same size as team B kicks.

Fair catch

A fair catch is also known as a “mark”. To take a fair catch a player must be on or behind his/her own 22-metre line, whilst making a clean catch direct from an opponent’s kick and at the same time shout mark. Play is restarted with any kick other than a place kick; the player claiming the fair catch must take the kick (IRB & NZRU, 2005).

Ruck

A ruck is where one or more players from each team who are on their feet, are in physical contact, competing over the ball on the ground. Open play has ended (IRB & NZRU, 2005). The platform is deemed a ruck if the same team that has taken the ball into the ruck is the first team to have controlled possession after the ruck.

Maul

A maul consists of at least three players bound together on their feet, including the ball carrier plus one player from each team; open play has ended (IRB & NZRU, 2005). The platform is deemed a maul if the same team that has taken the ball into the maul is the first team to have controlled possession after the maul.

Ruck turnover

The ruck turnover occurs when one team takes the ball into the ruck, and the opposition is the first team to have controlled possession after the ruck.

Maul turnover

The maul turnover occurs when one team takes the ball into the ruck, and the opposition is the first team to have controlled possession after the maul.

Mid-phase turnover

A mid-phase turnover occurs when there is a change in the team in possession in the middle of a phase, rather than within a ruck or maul. A mid-phase turnover occurs after some form of handling error from the original team in possession.

Kick regather turnover

A kick regather turnover is an unusual circumstance, and is not a term used in rugby language. However a special set of circumstances can take place, which result in a turnover that does not fall with the criteria of the previous three forms of turnover.

Kick regather turnovers eventuate when one team's possession of the ball is interrupted by a single event kick by an opposition player. The second team is not deemed to have possession of the ball until an individual player has gained control of the ball. Therefore the ball cannot be deemed to be turned-over until the kick is regathered, at which point a turnover kick regather has occurred. As can be seen in the results section this scenario rarely happens, and for practical usage will be grouped with other forms of turnover.

Possession platforms

The same criteria used for move platforms, was then used to define the start of a possession, i.e. the possession platform. Possession of the ball is important in rugby; therefore analysis of the possession platforms is necessary.

All of the above move platforms will also be the possession platform, when they are the first move in a given possession. The three moves that cannot be the first move of a possession are ruck, maul and kick regather, as these three move platforms are not means of gaining possession. Subsequently there are 17 platforms to defining possession.

As will be shown in the results section, some of the 17 possession platforms are similar enough that they can be grouped together to create a refined and more pragmatic list of 12 platforms. The list of possession platforms can also be refined further to a group of 10 platforms that start a play.

Development of computer programme

The aim of this analysis approach was to convert the primary data into listings of all match events, grouped into appropriate units of play. To achieve this aim a computer programme was developed to process the NZRU data. The programme became more complex over a period of time; due to the iterative process of checking the programme outputs against the match video, and if necessary NZRU data, and making alterations to rectify any incorrect listings of match events.

Development of the analysis programme required the coordinated input from two knowledge domains. A statistician expert in the use of statistical software, coupled with an individual who has in-depth understanding of rugby laws, structures, and strategies.

Two groups of games were used during the development process: three games from the 2004 Super 12, and four games from the 2005 Super 12. The programme was developed using one group of games until there was a low number of errors, before processing the second group of games to further test for errors. Invariably, new problems (incorrect listings of match events) arose as a result of alterations intended to fix the previous group of games. Further adjustments would then be carried out to repair the second group of games accordingly, before processing the original group again. This iterative process continued until both groups of games were eventually free of errors, at which point the programme was deemed to be finished for the purpose of this research project, and ready to be subjected to a validity test.

Validity study

The validity study was conducted on a sample of five previously unseen games. The analysis listings for the five games were checked for correctness against the corresponding video. The observed errors were attributable to three types: incorrect NZRU data, programme error, or "either". Errors attributable to either are those that would have been avoided by either correct NZRU data, or if the programme had worked as intended. The number of incorrectly listed moves was tallied up and calculated as a proportion of the total number of moves for the five games (1328 moves). The percent error was calculated for each of the three types of error, and a total error; 90% confidence limits for the error rates were derived by assuming the sampling distribution of the counts was a normal approximation of the binomial.

Analysis of units of play

To illustrate the structured account of all play provided by the programme, some statistics for moves and possessions were derived from the 69 games of the 2005 Super 12 season. Estimation of confidence limits and of likelihood of practically important differences in magnitudes would require application of repeated-measures mixed and

generalized linear modeling, which was beyond the scope of the present methodological study.

Results and Discussion

Validity study

Table 3 shows an overall error for identifying moves in the analysis programme of 1.9%. The majority of the errors (1.1%) stemmed from errors in the NZRU data. The upper range of the confidence limits for incorrectly identified moves is 2.5%, which presents a negligible impact on match statistics. Most of the errors were the last moves in a play after possession had changed teams, only for the referee to call play back for a prior infringement that nullified the possession change. The programme is designed to detect such moves and classify them as "non-moves". The detection of non-moves is important as it enables illegitimate moves and possessions to be excluded from the analysis.

Table 3. Frequency and rate of incorrectly identified moves in a total if 1328 moves in five games randomly selected from the 2004 Super 12 season, showing errors attributable to: NZRU data, the programme, or either.

	Frequency	Rate (%)	90%CI (%)
NZRU Data	15	1.1	0.7-1.6
Programme	6	0.5	0.1-0.8
Either	4	0.3	0.1-0.5
Total	25	1.9	1.3-2.5

90%CI: confidence interval

The main effect the errors had on performance measures was with the possession count. Of the 25 errors, 19 resulted in incorrect possessions; 15 new possessions that should not have occurred, and four instances where a new possession was not detected. All of the incorrect possessions occurred at the end of a play, lasting only one move. The fifteen incorrect new possessions represented failure to identify handling errors and penalties that would have led to non-moves, and thus the averting of new possessions.

Fifteen errors were attributable to NZRU data; of these eight were due to the absence of a handling error listed in the data, which results in the last move of a play having the wrong move platform name. Another five were due to a missing event that on four occasions resulted in a mid-phase turnover being listed as a ruck turnover, or visa versa.

Of the six programme errors, two were lineout throws not straight, which the programme will identify with further minor modification. A further two errors that occurred on the last event of a play appear to be due to a systematic error that can be eliminated.

Units of play

Units of play used to synthesize game structure are identified in Table 4. There is an average of 36 more moves than phases per match, therefore an extra 36 units of play are able to be accessed and analysed using analysis by move, rather than analysis by phase (a limitation of the primary data).

Table 4. Number of plays and their components in all games of the 2005 Super 12.

	Mean	Standard Deviation	Minimum	Maximum
Plays	70	5.6	56	83
Possessions	110	11	86	135
Phases	211	19	161	258
Moves	247	21	200	295
Sets of hands	572	52	461	696

Move platforms

The full list of move platforms are presented in Table 5. The ruck is the most frequent platform, and when combined with ruck turnover, maul and maul turnover, moves from ruck and maul total 57% of all moves. Coaches therefore could prepare their team's accordingly, to ensure strategies reflect the high proportion of moves emanating from ruck and maul platforms.

The mean number of hands is highest for the maul platform. The high number of hands attributed to the maul is likely to be due to transfers of the ball between players in the maul itself, rather than any extra passes in open play.

Table 5. Frequency of move platforms in all games of the 2005 Super 12 (n=69) and simple statistics for the number of hands and meters gained in each move platform.

	Moves		No. hands		Meters gained	
	Total	Total (%)	Mean	SD	Mean	SD
Ruck	8107	48	2.4	1.2	7	13
Line-out Won	1857	11	2.4	1.5	3	10
Kick Reception	1748	10	1.6	1	20	20
Scrum Won	1369	8	2.4	1.3	9	14
Maul	971	5.7	3.9	1.8	10	15
Start Half Reception	605	3.6	1.4	0.7	7	14
Ruck Turnover	508	3	2.7	1.5	15	19
Mid-Phase Turnover	489	2.9	1.9	1.1	13	19
Line-out Stolen	351	2.1	2.3	1.5	7	15
Tap Penalty	291	1.7	2	1.3	13	12
Kick Regather	242	1.4	1.6	1.1	10	12
Start 22 Reception	150	0.88	1.7	0.9	25	16
Start Half Regather	94	0.55	2.1	1.3	2	11
Scrum Stolen	59	0.35	2	1.5	10	15
Fair Catch	49	0.29	1.5	0.9	35	17
Penalty Kick Reception	43	0.25	1.8	0.9	29	20
Maul Turnover	42	0.25	3.2	2	16	19
Penalty Shot Reception	19	0.11	1.5	1	19	20
Start 22 Regather	18	0.11	1.7	1.2	14	20
Kick Regather Turnover	5	0.03	2.2	0.4	13	24
TOTAL	17017	100	2.3	1.4	9	15

SD, standard deviation.

The highest Meters gained values are for fair catch, penalty kick reception, start 22 reception and kick reception, all of which are receiving some form of kick from the opposition. These highest values for Meters gained are likely a result of players who have received the kick from the opposition replying by immediately kicking the ball back, either into touch or to the opposition, both scenarios which result in relatively large Meters

gained. Kick reception, mid-phase turnover and kick regather are platforms that would not be available if analysis was conducted by the phase provided within NZRU data, which is the traditional unit of rugby world wide.

Kick regather turnover eventuated on just five occasions during the entire 69 games of the 2005 Super 12 season. Unfortunately it didn't fall adequately within the criteria of other turnovers and had to remain a separate move platform. However for practical purposes it can be grouped with other forms of turnover.

Possession platforms

Table 6. Frequency of possession platforms in all games of the 2005 Super 12 and simple statistics for the number of moves, number of hands and meters gained in each possession.

	Possessions		No. moves		No. hands		Meters gained	
	No.	%	Mean	SD	Mean	SD	Mean	SD
Lineout Won	1836	24	2.8	2	7.4	5.3	14	17
Kick Reception	1703	22	1.7	1.2	3.2	3.3	26	21
Scrum Won	1331	18	2.3	2	5.5	5.3	17	18
Start Half Reception	605	8	2.1	1.2	4.2	3.4	25	18
Ruck Turnover	507	6.7	1.9	1.4	4.8	4	22	21
Mid-Phase Turnover	488	6.4	1.8	1.4	3.9	3.8	20	22
Lineout Stolen	353	4.6	2.4	1.8	5.9	5	18	20
Tap Penalty	292	3.8	2.9	1.9	6.6	5	21	20
Start 22 Reception	150	2	2.2	1.7	4.7	4.5	34	20
Start Half Regather	94	1.2	3.2	2.5	7.6	6	8	15
Scrum Stolen	58	0.76	1.7	1.1	3.7	3.5	15	19
Fair Catch	49	0.65	1.2	0.8	2	2.5	35	17
Penalty Kick Reception	43	0.57	1.5	1	3.3	3	35	20
Maul Turnover	41	0.54	2.4	1.8	6.5	5.5	28	23
Penalty Shot Reception	19	0.25	1.8	1.4	3.5	4	21	21
Start 22 Regather	18	0.24	2.3	1.2	4.7	3.3	25	19
Kick Regather Turnover	5	0.07	1	0	2.2	0.4	13	24
TOTAL	7592	100	2.2	1.7	5.2	4.8	20	20

SD, standard deviation.

Table 6 shows the full list of possession platforms. Ruck, maul and kick regather platforms cannot occur at the start of a possession and therefore do not occur here. The main sources of possession are usually considered to be the set-pieces, particularly lineout and scrum, so it is surprising to see kick reception as the second highest proportion of possession platforms. Coaches could therefore design specific team strategies and commit sufficient preparation time to optimize their teams ability of kick reception platforms.

Table 7 contains a more practical list of grouped possession platforms. Seven of the possession platforms within Table 6 are grouped into two platform groups: kick reception, penalty kick reception, and penalty shot reception are grouped as kick reception; ruck turnover, mid-phase turnover, maul turnover and kick regather turnover are grouped as turnover.

Possession platform groups

Table 7 presents the possession platform groups, as opposed to the full list of possession platforms. Only three of the move platforms cannot also be possession platforms: ruck, maul and kick regather, as these three moves do not represent the start of a new possession. Of the 17 remaining platforms the four forms of turnover have been grouped together as turnovers, and penalty shot reception and penalty kick reception have been grouped together with kick reception.

It is not surprising that lineout won and scrum won are primary sources of possession, given that they are a common means of restarting play. However, it is surprising to me that turnovers rank so highly as a proportion of total possessions. Turnovers represent an unstructured facet of play, compared with lineouts and scrums, thus presenting a challenge for coaches to design effective means to develop their team’s ability off this platform.

Table 7. Frequency of possession platform groups in all games of the 2005 Super 12 and simple statistics for the number of moves, number of hands and meters gained in each possession.

	Possessions		No. moves		No. hands		Meters gained	
	No.	%	Mean	SD	Mean	SD	Mean	SD
Lineout Won	1836	24	2.8	2	7.4	5.3	14	17
Kick Reception	1765	23	1.7	1.2	3.2	3.3	26	21
Scrum Won	1331	18	2.3	2	5.5	5.3	17	18
Turnovers	1041	14	1.9	1.4	4.4	4	21	22
Start Half Reception	605	8	2.1	1.2	4.2	3.4	25	18
Lineout Stolen	353	4.6	2.4	1.8	5.9	5	18	20
Tap Penalty	292	3.8	2.9	1.9	6.6	5	21	20
Start 22 Reception	150	2	2.2	1.7	4.7	4.5	34	20
Start Half Regather	94	1.2	3.2	2.5	7.6	6	8	15
Scrum Stolen	58	0.76	1.7	1.1	3.7	3.5	15	19
Fair Catch	49	0.65	1.2	0.8	2	2.5	35	17
Start 22 Regather	18	0.24	2.3	1.2	4.7	3.3	25	19
TOTAL	7592	100	2.2	1.7	5.2	4.8	20	20

SD, standard deviation.

Apart from platforms that start with a received kick, turnovers and tap penalty are the only other possessions to average greater than 20 meters gained per possession. Unlike possessions starting from a received kick, the ball is more likely to be kept in hand during turnovers and tap penalty possessions; therefore the high values for meters gained indicate that these possessions are effective attacking platforms. The overall average territory gain from any given possession is 20 meters, lasts for just two moves, and involves five sets of hands.

Possession platform groups that start play

Possession platforms that start play consist of possession won or lost from each of the four set-piece platforms (lineout, scrum, start half, and start 22), as well as tap penalty and fair catch. The quality of possession that teams can gain from set-piece platforms is considered vital to successful team performance, and Table 8 shows why. Lineout won and

lineout stolen combined, together with scrums won, produce 73% of possessions that start play. Traditionally teams spend a lot of time rehearsing lineouts and scrums, and the data from Table 8 supports that practice. With 13% of possessions start half receptions are also a significant possession platform warranting priority from coaches, particularly given that failure to claim the ball from a start half reception can present the opposition with excellent attacking opportunities.

Table 8. Frequency of possession platform groups that start play in all games of the 2005 Super 12.

	Number of possessions	Number of possessions (%)
Line-out Won	1836	38
Scrum Won	1331	28
Start Half Reception	605	13
Line-out Stolen	353	7.4
Tap Penalty	292	6.1
Start 22 Reception	150	3.1
Start Half Regather	94	2
Scrum Stolen	58	1.2
Fair Catch	49	1
Start 22 Regather	18	0.38
TOTAL	4786	100

Conclusions

In comparison to previous research this project has taken a more comprehensive approach to whole game structure by synthesizing all events into coherent units of play; moves and possessions. The major outcome from this project was the creation of a game analysis system suitable for immediate use in rugby at the elite level, particularly with an error rate in the order of just 2%. Furthermore, with this analysis tool, potential now exists for the development a range of exciting new analysis possibilities.

Chapter 3 - Conclusions

Strengths and Limitations

Strengths

The aim of producing an analysis system suitable for application at the elite level has driven the design and construction of the programme. Throughout this project I have had both rigorous statistical direction from my primary supervisor, and practical rugby guidance in the first instance from my secondary supervisor. In addition comments regarding specialist rugby direction could also be called on from the All Black coaches.

In addition to the human resources, the equipment available for the project was also excellent. The primary data used in the project was gathered on professional rugby players. High-powered statistical analysis software was used to process the large data files. Cutting edge rugby specific video analysis software was utilized, without which the project could not have been completed on the same scale. Over seventy Super 12 games were available, and utilized at various stages. Financial support was also provided to allow the large amount of time that was necessary to be spent analyzing the programme listings, the games, and NZRU data.

Limitations

Access to NZRU data

It would have been preferable if we had access to all forms of data the NZRU have available to them. By having access to more match variables we may have created a more complete analysis programme. Also, instead of writing parts of the programme to interpret certain events during the game, the data may already have been available.

Having only limited contact with Verusco, the company that codes matches and provides the NZRU with data, was not ideal. It was difficult to establish if errors in the data we were easily fixed from their end, or whether we had to try and account for the errors with specific programming. This situation led to unnecessary work attempting to overcome apparent problems in the data, only to find out at a later date that the data could be easily fixed at the coding centre (for example rucking incorrectly listed as kicking).

Due to commercial sensitivity, the limited interaction with the Verusco, and restricted access to the range of NZRU data Verusco manage is understandable. Verusco code data for the NZRU, some of which is specific to All Black analysis requirements, and may contain information to provide the NZRU with a competitive advantage over their opposition. At the same time Verusco are expanding their analysis services to other nations within the world of professional rugby. Therefore, it may be in the NZRU's interests to not only ensure that researchers such as ourselves are protected from certain types of data they use to analyse games, but also that further developments such as the concept of utilizing Verusco data for secondary analysis, and the specific techniques we developed in this project, remain confined within the NZRU.

Incorrect NZRU data

During the course of developing the analysis system match listings produced by the programme were checked for correctness against match video, and if necessary, NZRU data. The data Verusco provide for the NZRU is in the main accurate and organized. However incorrect data can affect our analysis programme, and during the process of checking match listings instances of data that I perceived to be errors were identified; examples of which are included in Appendix I.

Three potential reasons for the perceived errors include:

1. Incorrect definitions and terminology in the template that coders use to describe match events (provide examples).
2. Faults in the programme used to filter information from the main database, which holds all coded match data.
3. Incorrect coding due to human error.

Analysis programme limitations

Most of the limitations in the programme are related directly to errors identified in the validity study. However the major limitation was time. With more time the programme could have continued to be refined. With a greater proportion of errors attributable to the primary data than the programme itself, continued development should first focus on aspects related to improving the NZRU data. Also, the programme deals only with events on the ball. Therefore if additional NZRU data including off the ball events if to be

processed further programming would be required. Such programming will provide more information on how possessions are won and lost how meters are gained and how points are scored.

Future Research

Most of the limitations acknowledged above form the basis of ideas for future research directions. The ability of the analysis programme to synthesize active play into logical units is clearly a useful tool for the analysis of rugby. However, the following improvements could be developed in future research.

- Establishing a close relationship with the individuals who are responsible for designing and providing the primary data would speed the programme development and improve analysis outputs.
- To develop the ability of the programme to detect errors in the Verusco data. This would be particularly useful, as it would not only improve our analysis programme, but improve the quality of the Verusco data.
- Analysis and comparison of individual teams.
- Analysis and comparison of different levels of competition, e.g. provincial, Super 12 and international.
- Identify differences between winning and losing performances.
- Develop more performance indicators, consistent with rugby language and concepts
- Correlations between performance indicators and winning games.
- A method to quantify player interactions, and how they are related to important outcomes.
- Individual player performance measures, and player ranking systems.
- Identifying “off the top” lineout possession, which is where the lineout forward passes the ball straight down to the halfback the moment he catches the ball in the lineout, rather than bringing the ball to ground before clearing it to the halfback.
- Measure sets of hands in open play, distinct from sets of hands with a maul.

By bridging a gap between elite rugby knowledge and scientific expertise, I believe I have helped to develop an important partnership that should continue to grow for the mutual benefits of the domains.

References

Bartlett, R. (2001). Performance analysis: can bringing together biomechanics and notational analysis benefit coaches? *International Journal of Performance Analysis in Sport, 1*(1), 122-126.

Bloomfield, J., Polman, R., & O'Donoghue, P. (2004). The 'Bloomfield Movement Classification': Motion Analysis of Individual Players in Dynamic Movement Sports. *International Journal of Performance Analysis in Sport, 4*(2), 20-31.

Boddington, M., & Lambert, M. (2004). Quantitative and qualitative evaluation of scoring opportunities by south africa in world cup 2003. *International Journal of Performance Analysis in Sport, 4*(2), 32-35.

Bracewell, P. (2001). Perception of Individual Rugby Player Performance and the Impact of Non-Performance on Statistical Analyses. *Research Letters in the Information and Mathematical Sciences, 2*, 19-22.

Bracewell, P. (2003). Monitoring meaningful rugby ratings. *Journal of Sports Sciences, 21*, 611-620.

Cameron, M. (2004). *Using performance or results to measure the quality of sports competitors.* Paper presented at the Seventh Mathematics and Computers in Sport Conference, Palmerston North, New Zealand.

Carter, A., & Potter, G. (1996a). *The 1995 rugby world cup finals. 187 tries.* Paper presented at the Third World Conference of Notational Analysis of Sport, Antalya, Turkey.

Carter, A., & Potter, G. (1996b). *The 1995 rugby world cup finals. Where does all the time go?* Paper presented at the Third World Conference of Notational Analysis of Sport, Antalya, Turkey.

De Lacy, H., & Fox, G. (2000). *Think and play winning rugby*. Auckland: Harper Collins.

Domholdt, E. (2000). *Physical therapy research*. Philadelphia: W.B. Saunders Company.

Duthie, G., Pyne, D., & Hooper, S. (2005). Time motion analysis of 2001 and 2002 super 12 rugby. *Journal of Sports Sciences, 23*, 523-530.

Hopkins, W. (2004). How to interpret changes in academic performance test. *Sportscience, 8*, 1-7.

Hughes, M. (2004a). Notational analysis: a mathematical perspective. *International Journal of Performance Analysis in Sport, 4*(2), 97-139.

Hughes, M. (2004b). Performance analysis - a 2004 perspective. *International journal of performance analysis in sport, 4*(1), 103-109.

Hughes, M. (2005). Editorial. *International Journal of Performance Analysis in Sport, 5*(2), i-ii.

Hughes, M., & Bartlett, R. M. (2002). The use of performance indicators in performance analysis. *Journal of Sports Sciences, 20*(10), 739-754.

Hughes, M., Evans, S., & Wells, J. (2001). Establishing normative profiles in performance analysis. *International Journal of Performance Analysis in Sport, 1*(1), 1-26.

Hughes, M., & Franks, I. (2004). Notational analysis - a review of the literature. In M. Hughes & I. Franks (Eds.), *Notational analysis of sport* (2nd ed., pp. 59-106). London: Routledge.

IRB. (2003a). IRB charter on the game (pp. 20). Dublin: International Rugby Board.

IRB. (2003b). *Review of the game 2003*. Dublin: International Rugby Board (IRB).

IRB, & NZRU. (2005). *The laws of the game of rugby union*.

James, N., Mellalieu, S. D., & Jones, N. M. P. (2005). The development of position-specific performance indicators in professional rugby union. *Journal of sports sciences, 23*(1), 63-72.

Johnson, P. (2001). *Rugby union: tactics, techniques and training*. Wiltshire: Crowded press Ltd.

Jones, N. M. P., Mellalieu, S. D., & James, N. (2004). Team performance indicators as a function of winning and losing in rugby union. *International Journal of Performance Analysis in Sport, 4*(1), 61-71.

Knudson, D. V., & Morrison, C. S. (2002). *Qualitative analysis of human movement*. Champaign: Human Kinetics.

Laird, P., & Lorimer, R. (2004). An examination of try scoring in rugby union: a review of international rugby statistics. *International Journal of Performance Analysis in Sport, 4*(1), 72-80.

Martin, M., Thomas, C., & Williams, J. (2001). *Mapping the world game of rugby union.* Paper presented at the Pass.com: Fifth World Congress of Performance Analysis of Sport, Cardiff, UK.

O'Donoghue, P. (2005). Normative profiles of sports performance. *International Journal of Performance Analysis in Sport, 5*(1), 104-119.

Parsons, A., & Hughes, M. (2001). *Performance profiles of male rugby union players.* Paper presented at the Pass.com: Fifth World Congress of Performance Analysis of Sport, Cardiff, UK.

Potter, G., & Carter, A. (1996a). *The 1995 rugby world cup finals. From whistle to whistle: A comprehensive breakdown of the total game contents.* Paper presented at the Third world conference of notational analysis of sport, Antalya, Turkey.

Potter, G., & Carter, A. (1996b). *The 1995 rugby world cup finals. The four year cycle: A comparison of the 1991 and 1995 rugby world cup finals.* Paper presented at the Third world conference of notational analysis of sport, Antalya, Turkey.

Quarrie, K., & Hopkins, W. (2006). Changes in bledisloe cup rugby union from 1972 to 2004.

Roberts, S. P., Stokes, K., Trewartha, G., Higgitt, T. J., & El-Abd, J. (2005). An objective time-motion analysis of elite rugby union. *Journal of Sports Sciences, 23*, 213-214.

Starkes, J. L., & Ericsson, K. A. (Eds.). (2003). *Expert performance in sport: advances in research in sport expertise*. Champaign: Human Kinetics.

Thomas, C. (2004). *IRB game analysis, IRB technical committee Nov 2004*: IRB Game Analysis Centre.

Vivian, R., Mullen, R., & Hughes, M. (2001). *Performance profiles at league, european cup and international levels of male rugby union players, with specific reference to flankers, no 8 and no 9.* Paper presented at the Pass.com: Fifth World Congress of Performance Analysis of Sport, Cardiff, UK.

Appendix I – Problems with NZRU Data

These were identified in 2004 and 2005 Super 12 season.

- Wrong player names
- Scrums listed as lineouts.
- No differentiation in the data between a pass within a maul, and a pass in general play. Any transfer of the ball between players within the maul is coded as a pass, in exactly the same manner as a normal pass in open play. There are occasional instances where a turnover occurs within a maul after a number of "passes" (what could be termed transfers); in this circumstance the maul turnover is interpreted by the programme as a mid-phase turnover. It is envisaged that in future interactions with the NZRU amendments will be able to enable the coding of this type of pass.
- Missing events, in particular the "catch" when receiving an opposition kick (which Verusco fixed) and immediately prior to the "place" before a ruck.
- Important handling errors not appearing in the data. This effects our definitions of move and possession platforms.
- From lineout platforms the end of the first phase is sometimes coded too early, before the first phase has finished. The policy seems to be to code the end of the first phase as soon as the lineout degenerates into a ruck or maul, which I believe is too early. The counting of the phases is related to our move count; therefore this is an issue that would need to be clarified in any future research.
- A significant problem we had to work to overcome were rucking actions incorrectly listed as kicking. Eventually toward the end of the project we established that Verusco were able to fix the problem, by adjusting their programme that filters out data from the main database.
- Excessive use of the term turnover; events listed as turnovers that are not turnovers in rugby language, e.g. ball kicked to the opposition in open play, or kick offs that the opposition receive. Turnovers in the data averaged approximately 100 per game, which is far in excess of the 15 per game we calculated.
- Conversely classic turnover events where the ball is stolen off the tackled player are not coded at all.

- Inaccuracies in the order of 2-3 Meters were visible in the distance measurements. The smaller the total distance in the given measurement the larger the percent error. This is problematic when defining some of our move and possession platforms, as their definitions involve distance criteria.
- No events existing for charge downs.
- Free kicks are not coded (this was confirmed by Verusco). Therefore there is no differentiation between free kicks and penalties.
- The data do not distinguish between fair catches that have been tapped, and those that have been kicked directly down field.
- A handling error is often coded when a player carries the ball over the sideline, even if they have maintained complete control of the ball.