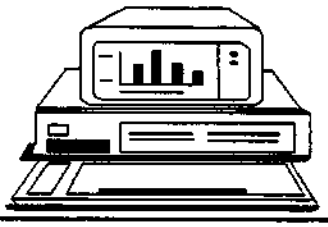
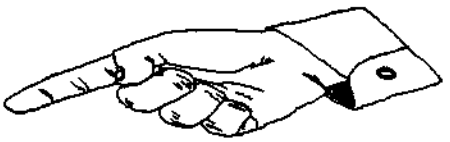
FIRST WORLD CONGRESS of NOTATIONAL ANALYSIS of SPORT





A 3—DAY CONFERENCE

November 22nd—25th 1992

BURTON MANOR,
WIRRAL, MERSEYSIDE.

Co-sponsored:

THE INTERNATIONAL SOCIETY OF NOTATIONAL ANALYSIS
BRITISH ASSOC. OF SPORTS SCIENCES

KEYNOTE PRESENTATIONS

COMPUTER/VIDEO ANALYSIS IN GERMAN SOCCER

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By utilising measuring and computer/video equipment to analyse training and real game situations, soccer coaches and physical education experts gain important insights with regard to the performance and behaviour of both their own as well as opposing players.

For purposes of analysis scenes from a German National Soccer League game between Borussia Dortmund and Bavaria Munich (9/25/92) will be presented. Those aspects of such an analysis which are especially revealing will be introduced and discussed. It will be demonstrated that - even with low-cost computer/video equipment - exact information can be obtained on typical playing systems, marking behaviour, tactical mistakes, transition situations, etc. These insights can be used to improve

1. the structure of practice sessions,
2. methods of working on individual technical/tactical skills, and
3. preparations for single games.

THE USE OF NOTATIONAL ANALYSIS IN DETERMINING OPTIMAL STRATEGIES IN SPORTS

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The use of notational analysis in sport is not new. For many years scientists, statisticians, mathematicians and just plain sport enthusiasts have been collecting data with the hope that it will provide some magic insight to increase the chance of success of individuals or teams in sport.

The advent of computers has been of immeasurable value in this regard with modern machines now being able to process enormous amounts of information at the touch of a key. The recording of game data is now big business with professional teams in almost all sports having their own technique to have access to facts relating both to their own performance and that of the opposition.

The number of sports using computerised statistics is seemingly endless and examples include all codes of football, hockey, basketball, water polo and baseball to mention just a few. Without such evidence players and coaches would have to rely on their own impressions and prejudices in developing their game plans.

However, the way in which the information is recorded varies greatly between sports and the notational analysis used is dependent upon a number of factors. This paper examines some of the techniques used to achieve this in several sports including rugby league, cricket, netball and tennis and looks at future directions for this increasingly important area.

ANALYSIS IN RACKET SPORTS

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During the 1980s the use of systems of notation to record data for analysis has developed in a number of sports. Unfortunately it still does not provide a comprehensive account of human performance in sports. It provides only an analysis based on primary observations and does not take into account secondary and tertiary observations, analysis and evaluation.

As the task of the coach is primarily to improve the performance of his players in order to optimise the chances of winning then it is most important that all aspects of performance are recorded and analysed. To do this it would be necessary to obtain general agreement on the logical nature of a game and on the logical structure of a game. By doing so it would become possible to establish the contexts in which performance can be described and evaluated.

Such descriptions and evaluations that are made will depend on a multidisciplinary approach to the recording and analysis of performance. These will include philosophy, aesthetics, psychology, social psychology, exercise physiology, statistics and biomechanics.

It will involve the use of computer and video in recording the data and require more sophisticated and comprehensive means of analysing the data if coaches are to obtain a deeper understanding of their players and help to maximise their performances.

ANALYSIS OF COACHING PERFORMANCE

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One of the primary goals of coaching is to effect a permanent improvement in the performance of athletes. In order to achieve this goal the coach provides information to athletes, structures the learning environment, and allows adequate time for practice. During this process it is necessary for the coach to interact with the athlete using various methods of analysis and communication. It is this intervention process that has been the object of several research studies at the University of British Columbia and will be the central focus of this particular presentation.

Methods of notating various coaching behaviours have been developed and tested. Most recently, a computer-aided, systematic observation instrument that analysed the verbal comments provided by the coach during practice was modified. The ultimate aim of this research was to develop a notational analysis system that could be used by coaches of varying experience and ability (Canadian National Coaching Certification Programme, Level 1 to Level 4). These Coaches would use the computer-video interactive system to analyse their own performance. A limited amount of user training would be required that the coaches completed a structured interactive training programme. The results from both intra and inter reliability studies that were conducted on the instrument and its use helped structure the basic framework of this training programme.

This presentation will focus on the rationale for developing such a notational analysis system and the possible utility of the system. In doing so, several practical research studies will be described. In addition, the relevance of this research, with respect to the notational analysis of athletes, will be described in some detail.

USING COMPUTERS IN NOTATIONAL ANALYSIS

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Notation analysis can have an important role to play in sport. It is the fulcrum of the coaching process; it must ultimately provide information for virtually all decisions made with respect to long-term and short-term strategies, training, selection, scouting and so on. This applies to analysis of movement, actions and skills for both individual and teams.

Notation systems have been used in various disciplines for a long time: e.g. the early Egyptians useda notation system to record troop manoeuvres and music notation was employed in the Middle Ages.

More recently, sophisticated methods were developed for choreographic notation in ballet. It was only in the 1970s that notation analysis made an impact in the sport literature. The first systems were designed for racket games but these were soon extended and modified for a variety of other sports. Developments in power and sophistication of the microcomputer in the 1980s, along with a decrease in cost, enabled sports analysts to simplify data handling and processing. Parallel work in Australia, Canada and U.K. in computerized analysis of field games demonstrate similarities in the hardware and software used. Advantages and disadvantages of the various computerized systems can be detailed. The main problem centres on three areas data input, analysis and data output. The development of some of the solutions to these problems can be traced by examples of work done by researchers in the field.

Likely developments in future notation systems can be estimated, given the place of progress within the micro-electronics industry. These may be extended for ergonomic applications to areas other than sport.

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ORAL PRESENTATIONS

A COMPARISON OF HEART RATE - OXYGEN UPTAKE RELATIONSHIPS IN THREE TESTS INVOLVING A REGULARLY INCREMENTING WORKLOAD, A FREQUENTLY AND VARIABLY CHANGING LOAD AND A STEADY STATE LOAD

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By using compact monitors, heart rate is perhaps the only physiological variable which can be measured during competition in many sports (typically the team sports) without in any way disrupting the participation of the subject in the game. Frequently, progressive maximum oxygen uptake tests have also been performed in the laboratory in conjunction with such field monitoring, and by equating heart rates from the test and during the game, the oxygen cost of the sport has been assessed. Game heart rates have also been used to determine targets for conditioning work involving constant prolonged effort.

However, heart rate is a reflector of a variety of stressors, including anxiety, thermal stress, recovery after anaerobic effort, and changes in modes of movement. Consequently heart rates may not reflect accurately the oxygen cost of the game, thereby both distorting the assessment of the role of the aerobic system in the sport, and causing players to be set inappropriate conditioning sessions.

One distorting factor may be the constant changes in intensity of activity typical of many sports. Therefore, this study attempts to determine the heart rate - oxygen uptake relationship occurring under conditions of constantly changing velocity and to compare the relationship to that pertaining during a progressive maximum oxygen uptake test and also during constant page efforts.

Subjects were highly trained junior soccer players. They performed three separate tests on a treadmill in each of which heart rates and oxygen uptakes were measured throughout. The first test was a progressive test to maximum with minute increases in effort. The second test consisted of 4 five minute blocks of movement with a 1 minute rest between each block; each block comprised 50 six second movement modes. There were 5 modes, each of a different speed ranging from 4 to 20 km/h. The mode changed every 6 seconds so that their overall proportion and the number of mode changes in the test simulated that in a typical game of soccer. The third test consisted of 3 ten minute constant pace runs, the speeds being chosen to elicit heart rates within 3 ranges frequently occurring in the variable speed test.

THE USE OF COMPUTER-VIDEO INTERACTIVE ANALYSIS IN THE SPORT OF SOCCER: CHANGING TEAM AND INDIVIDUAL PERFORMANCE BY PROVIDING QUANTITATIVE AND QUALITATIVE FEEDBACK

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Recent years has seen the development of a number of computer-aided analysis systems. These systems have been used to analyze a variety of sports, e.g. Volleyball (Eom, 1989), Squash (Hughes & McGarry, 1988), Australian Rules Football (Patrick & McKenna, 1988) and Association Football (Partridge, Mosher & Franks, 1990). Consequently an extensive data base has been produced about the nature of performance in each of these sports. As yet, however, little work has been done in using the information provided by these analysis systems as feedback for athletes in order to change either a team or an individuals performance.

In this paper results from two pilot studies will be presented. Firstly, a computer-aided team analysis system (Partridge & Franks, 1992) was used to undertake a comprehensive analysis the Canadian National Youth (U20) Soccer Team as it attempted to qualify for the CONCACAF World Youth Soccer Finals. In the second study a computer-aided time motion analysis system (Franks & Nagelkerke, 1989) was used to collect data on the performance on an individual player, namely a forward playing for a university men's soccer team. In both these systems the computer analysis made it possible to search for and edit several video examples of acceptable and non-acceptable performance.

Both studies followed the same protocol. After a series of baseline measures quantitative information along with video excepts were compiled and given back to the team or individual. After this initial intervention, quantitative (digital) and qualitative (video) feedback were provided between subsequent performances. In each study the analysis focused on particular key factors associated with successful performance. The methods used to provide the feedback and the problems encountered with this process will be discussed, along with the time series analysis data.

A MODEL FOR TECHNICAL AND TACTICAL ANALYSIS IN SOCCER

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The computerized notation analysis pioneered by Hughes in 1988, using a concept keyboard, has provided a detailed analysis of the activity of each player when in possession of the ball. However, information on the degree of difficulty of the action is not provided by this analysis. Thus, the aim of the present study was to develop a coding system to describe the difficulty and success of each action with the ball occurring during a soccer game. In addition, individual time when in possession of the ball (dribbling) was measured. A video tape of a game is viewed and each technical action (P = pass, I = interception, S = shot) is described and rated in terms of its difficulty (1 = easy, 2 = moderate, 3 = complicated) and outcome (success, failure). The coding system was used to evaluate the Danish National Team and its opponents during the 1992 European Championship. The mean number of passes per team per match was 388 of which 252 (range: 144-352) were 1-P, 116(90-139) 2-P and 20(9-32) 3-P. The success in 1-P, 2-P and 3-P was 93 (89.6-95.2)%, 42 (34.4-50.8)% and 45 (22.2-66.7)%, respectively. The mean number of 1-P per minute was observed to decrease ($p<0.05$) from 3.1, in the first half, to 2.4 in the last 15 minutes of the game, whereas no differences were observed throughout the match for 2-P and 3-P. On average, a team was in possession of the ball for 7.6 min during the first half of a match compared to 6.7 min during the second half. The mean number of shots per team in a game was 12.2 and the ratio of goals per shot was 1:12. The number of interceptions during the game was 159 per team. The Danish Team had significantly ($p<0.05$) fewer 1-P when playing France (151), Germany (157) and Holland (211) compared to the matches against England (319) and Sweden (352). The number of passes per minute within any of the three categories and their success were not different in the overtime played between Denmark and Holland as compared to the preceding 90 minute period. Total dribbling time for the Danish Team in the matches against England and Sweden was 17.0 and 17.1 min, respectively, which was longer ($p<0.05$) than against France (11.0 min), Holland (13.5 min) and Germany (11.6 min). The mean time per dribble (2.9s) was similar during all matches. Middle defenders, defensive midfielders and target players dribble the ball less ($p < 0.05$) compared to players assigned to other areas of the field (2.7 vs 3.1 s). The mean number of success in 3-1 was larger ($p < 0.05$) for Denmark (4.6) than for its opponents (2.4). The coding system presented can give an impression of a team's style of play and particularly evaluate the technical performance of individual players.

A WEIGHTED MODEL TO ANALISE THE CONDITIONS OF SCORING IN SOCCER

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In this paper, we shall particularly insist on the specific conditions of scoring in a soccer match which lead up to a goal being scored in order to try and isolate the constant factors in this phase of the game. Using video recordings of soccer matches, we have noted on a diagram, second by second, the positions taken up by all the players who participated in the attack or the defense preceding goals being scored. For each second, we obtain a cloud of points. To process those configurations of the game, we have used a weighted model to sum up the characteristics of the cloud of points of the attack and of the defense based on three criteria: the position of the ball; the center of gravity; the principal axes. For this purpose, we have created a program for an APPLE-MACINTOSH™ which permits automatic numeric calculations.

The goals studied have been collected from the World Soccer Championship of Italy in 1990.

QUANTITY OR QUALITY?

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TEAM A: 10 shots - nil goals

TEAM B: 5 shots - 5 goals

Quantitative analysis set against goals (or targets) does provide an effective monitoring system of team and individual performance. Such goals can be set following very large samples of analysis, a requirement of Probability Theory. However, quantitative analysis and MBTO (Management by Tactical Objectives) can be misleading. The above example of Team A v Team B demonstrates this.

The team manager/coach wants to know what he/she has to do to achieve seasonal and match objectives.

In order for analysis and monitoring of games against match objectives to be meaningful, it is necessary to carry out qualitative analysis in addition to, or integrated within, the quantitative analysis. This allows for assessment of individual and team quality of performance in comparison to that of opponents.

Qualitative analysis carried with it certain problems. It involves highly subjective observations. To validate such qualitative analyses it requires the use of such techniques as concordance of observation using for instance Kendalls coefficient of correlation.

As yet qualitative analysis is to the author's knowledge still in need of considerable development in sports performance.

An example of MBTO

A study of previous English Soccer 1st Division winners revealed that the winners and runners up achieved:

2 goals for 1 goal against - on average.

Two different examples of how qualitative analysis can add in a meaningful way to the interpretation of match performance analysis in relation to the Assist and the Shot are given.

This allows for constant monitoring of offence and defence performance throughout the season.

The Assist

The way in which assists in Basketball have been defined is of little value ie. a player can make 10 assists to another player's 5 assists. Yet the latter 5 assists could have created and simplified the task of scoring, whereas the former 10 assists could have merely been giving possession from which the receiver then manoeuvred and scored. The definition - "A pass to a scorer" is in the author's view also

inappropriate. A superb pass leading to a simple scoring attempt that is then missed is not given any credit. Thus the definition – "A pass to a person who shoots" is seen as being more appropriate. The quality of assist can be categorised as follows:

POSSESSION ASSIST: A pass from which the shooter manoeuvres to make the shot (Lowest Quality).

SHOT ASSIST: A pass which enables the shooter to make an immediate attempt to shoot,with no certainty of scoring.

SCORE ASSIST: A pass from which the receiver should score.

The Shot

The mere recording of shots and goals tells us little with regard to the quality of the chance created and the subsequent shot made.

SHOT OPPORTUNITY (1-5 Scale)

1 No chance scoring
2 little chance of scoring
3 a 50:50 chance of scoring
4 a very good chance of scoring
5 should score

SHOT QUALITY (1-5 Scale)

1 No chance of a goal
2 a little chance of a goal
3 a 50:50 chance of a goal
4 a very good chance of a goal
5 a goal

These techniques can be developed to cover all of the key tactical events which occur during a game of both individual and team performances.

It is possible to develop an index of performance from such techniques.

COMPUTERIZED ANALYSIS OF COMPETITOR'S MOVEMENT BY TELEVISING THE WHOLE PITCH AND TRACK

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Competitor's movement analysis on the whole pitch and track is possible by placing TV camera at an elevated level and in some distance from the field. In addition, camera is equipped with wide-angle (130°) lens (half-fish eye). Side and end lines playeda role of the reference system. On the monitor's screen they are rounded as a result of deformation given by wide-angle lens.

On the edges of the video monitor a set of sliders is mounted in a shape of rectangle. In this set two movable sides can be displaced according to two other sides (immovable). In a place of joining of two movable sides a transparent cursor exists. It is used for the running following the moving competitor on the video monitor's screen. During the running, movable arms cause rotation of rotating device in a computer mouse connected permanently with the immovable arms. Every movement of the cursor along X or Y axis gives a transmission of a proper number of impulses to the computer.

After the inputing of the field data to the computer's memory, it calculates curved co-ordinates onto the rectangle co-ordinates. Then, computer defines a position of the subject in the real time according to the reference system, calculates displacement, velocity, acceleration. If a mass is inputting, forces are calculated too. These quantities are calculated for one subject and for group of subjects, e.g. soccer team. In this case a team point of position is analysed, obtained by calculating a mean value of co-ordinates of 11 players of a team. Computer program gives a possibility of printing out kinematic data, their mean, minimal and maximal values. It is also possible to obtain computerized animation.

OUR AIM - THE REALISATION OF TRUTH

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The aim of those working under the auspices of the Notational Analysis of Sport should be the realisation of truth. But what is this truth and how do we achieve it, and know that it is the truth?

If we look to philosophy for direction, we are told that what is in people's minds and reality can be two different things. Thomas Nagel in his book 'The View fro Nowhere', Chapter VI, 'Thought and Reality', explains this, and the recent Channel 4 series, 'The Real Thing', took up the argument for reality from the truth of science.

Philosophy furthermore warns us to be wary of language. Some say that mathematics is the only true language.

There can be much prejudice from both supporter and from many within the profession of soccer to what we do.

If we consider that our measurement reflects the truth and reality, what is it then that is in the minds of those that do not wish to share our view?

The aim of this paper is to endeavour to understand what is it that is in the mind of everyone that would prevent us from seeing reality and how we should stand detached with a 'view from nowhere' if we can.

A TIME, MOVEMENT AND SKILLS ANALYSIS OF RUGBY UNION AT SENIOR CLUB LEVEL IN SOUTH AFRICA

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The purpose of the study was to make a time, movement and skills analysis of the game rugby union as played at senior club level in South Africa. The specific objectives of the study, aimed at the attainment of the above objective, were to determine:

a) what the actual playing time was in a match lasting 80minutes;

b) what the time duration was of set scrums, lineouts and facets of loose play;

c) what the average proportion of play to resting time was;

d) what average distance the players in various positions covered in the course of a match;

e) how many set scrums, lineouts and loos play situations occurred in a game on average; and

f) how many individual skills (including the different kicks, handling skills, running skills and crash tackles) occurred on average in the course of a match and what their frequency of use had been by the different players on the team.

The subjects consisted of the eight best senior rugby club teams in the country which participated in the 1987 Rugby Club Championships, an event which is held annually.

Three persons were responsible for the recordings. Two video cameras filmed one back and one forward player for the full duration of a match. In this way three recordings were made of each playing position during the tournament. Each one of the twelve matches played at the tournament was filmed by a third video camera.

Following the tournament the information as contained on the video tapes was analysed. The different types of analyses were made with the aid of specially designed data cards, viz. in a series time study, movement and individual skills analyses.

1. The total time duration of matches came to an average of 88 minutes 37 seconds.

2. There were an average of 142 playing periods per match, of which 77% lasted shorter than 20 seconds.

3. The average rest-to-play ratio for a single rest-to-play period was 22 seconds rest: 14 second play.

4. The rest-to-play proportion for forwards was 61:39 percent and for backs 68:32 percent.

5. There were an average 39 set scrums, 45 lineouts and 49 loose play situations per match.

6. Set scrums lasted an average of 5 second, lineouts lasted an average of 4 seconds and loose play situations lasted an average of 6 seconds per match.

7. Forwards moved an average of 3,730 metres as against the 3,901 metres of backs per match.

8. There were an average of 34 crashtackle skills per match, an average of 24 running skills, 169 handling skills, 82 hand kicks and 33 place kicks.

As a result of the specific demands made on each position of play, it is felt that specific positional training programmes are essential for rugby players.

POINT-SCORING IN THE 1991 WORLD CUP FOR RUGBY UNION (MALE)

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The aim of the study was to analyse the points attempted during the Second Rugby Union World Cup, 1991. The points were scored from four different methods; Tries (value 4 points). Conversions (2 points), Drop Goals (3 points) and Penalty Kicks (3 points).

The sixteen participating countries were subdivided into two sections. The successful countries, the eight that progressed from the pool matches and the unsuccessful countries, the eight that failed to do so.

The analysis observed how the points were attempted and from which area of the pitch the attempts came. This was further analysed to record which phase of play was the most productive, in regard to the attempts and to observe the breakdown in the patterns of play which led a coring opportunity. A time base of ten minute intervals was incorporated to observe which stage of the match produced the most scoring attempts.

A computerised notation system written in the Microsoft Windows software package was used to notate and store the match analysis. Matches were also hand notated to measure the validity of the system $r = 0.98$. This proved the reliability and accuracy of the system.

The successful and unsuccessful teams recorded no significant difference in the positions that the tries were scored, i.e. either left or right hand side of the posts. Both groups of countries attempted significantly more, $p < 0.05$, Drop Goals and Penalty Kicks in the opponents half between the halfway line and the 25 metre line. Further the unsuccessful teams attempted significantly, $p < 0.05$, more Drop Goals from the left of that section. There was no significant difference for the Penalty Kicks.

The first phase plays produced the most scoring attempts 59.43%, however, after normalising the data for number of attempts per play per phase, both the successful and unsuccessful countries registered an increase in the chance of scoring a try for each phase.

The breakdown patterns of the Rucks compared to the Mauls showed a significant, $p < 0.05$, increase in Rucks, from 59.63% in second phase plays up to 67.25% in fifth phase plays. The comparison of passes to other actions did not significantly change from 25% for any phase.

Time did not significantly contribute to any scoring attempt or its starting point. This was due to time being a match based variable and the compiled data consumed any significant results.

DATA ANALYSIS OF 1991 RUGBY WORLD CUP

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In this I would like to discuss some of the data gathered during the Rugby World Cup. In particular, I would like to say something about:

1. A profile of the tournament winners

2. Try-scoring

In general I would like to discuss the significance we can attach to world championships as benchmarks for analysis of performance.

FROM A DISTANCE: THE PERSUASIVE RHETORIC OF ANALYSIS

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In this paper I would like to contribute to the second-order debate about the process and product of notational analysis. I will discuss issues that have been addressed in other disciplines, particularly anthropology and ethnography, about the representation of research evidence. I would like to share with delegates the challenges we face in developing "analytical transparencies".

BUILDING KNOWLEDGE IN SPORTS SCIENCE - THE POTENTIAL OF SPORTS NOTATION

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Academics have begun to question the dominant methodologies for studying the phenomenon in our field of sports science. (Hartens, R. 1987).

This paper focuses on the reductionism surrounding sports science and raises questions as to how knowledge is constructed. It suggests that sports science needs practitioners that understand the 'narrative' that overlays and surrounds sports performance. As such it argues for a heuristic philosophy of sports science. Sports notation, and in particular, the way in which researchers place themselves in a central position alongside the principal 'actors' (i.e. performers, coaches, spectators), offers sports science an exemplar for 'applied' science.

A COMPUTERISED NOTATION ANALYSIS OF GAELIC FOOTBALL

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In 1990, the G.A.A., with a view to speeding up the flow of play, implemented a change in the rules of the competition. The aim of this study was to develop a computerised notation system to analyse the effect of the rule changes on playing patterns within the game.

A concept keyboard with an overlay was used in conjunction with a television and video recorder to view the matches and record the information from them. The software was developed from previous team notation systems. Sixteen All-Ireland senior Championship games were notated, 8 either side of the rule changes.

Combinations of Chi-square and 't' tests were performed on the data to highlight changes in the frequency and field positions of the action variables.

The Chi-square analysis showed significant differences, ($p<0.01$), for frees, possessions gained, tackles, hand and kick passes, hops and solos. The 't' test analysis produced non-significant results involving the sidelines and shots on goal. The average action variable totals, per game, for both rule structures are shown in Table 1.

Table 1. Average Variable Totals, per Game, for both Rule Structures

Action Variable	Old Rules	New Rules
Frees	51	53*
Poss. Gained	41	74*
Tackles	51	97*
H/Passes	103	97*
K/Passes	120	130*
Hops	99	111*
Solos	61	66*
Sidelines	12	14**
Shots	49	47**

1 Significant ($p<0.01$)
** Non-Significant

A greater percentage of unretained possession from frees, 56.6% compared to 42%, and sidelines, 51% compared to 32%, was recorded in the new rules, resulting in a significant increase in possession gained for the opposing team. In this regard a greater number of actions per game was notated for the new rules. A further significant difference was recorded during the games for distribution of hops, solos and hand passes, with the new rules illustrating a more event distribution throughout the field as opposed to right side laterality in the old rules.

It was concluded that the rule changes significantly increased the continuity of the game, as evident in the frequency of hops and solos. The greater amount of play would enhance the spectators perceived view of the game.

A WORK-RATE AND TIME-MOTION ANALYSIS OF GAELIC FOOTBALL PLAYERS

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The aim of this study was to develop an accurate method of assessing and analysing the work rates' of Gaelic football players. The technique adopted was based on the method of Reilly and Thomas (Journal of Human Movement Studies, 1976), and updated using video equipment and computer aided data analysis. Sixteen competitive matches were video-taped. Each of these concentrated on a different playing position, so that one player was filmed during a match.

Mean total distance covered was 8594m, of which 35% was covered while walking, 32% jogging, 12% striding, 4% sprinting, 2% while in possession of the ball, 6% moving sideways, 8% walking backwards, and 3% jogging backwards. Mean distance covered per discrete event, when moving forward ranged from 10.6m to 13.5m, with the greatest distance being covered when sprinting. Each competitive game, on average, was made up of 925 $\pm$ 50 discrete activities, including 875 movement activities. The least amount of time was spent in possession of the ball (29s) when compared with the other movement activities.

No major differences were found to exist between the movement patterns of the backs (6), forwards (6) and mid-fielders (4) or between the central (6), wing (6) and mid-field (4) positions. This may be in part due to the small sample size, or alternatively it may reflect high positional role versatility.

When Gaelic football was compared with other sports, it was found to have the highest movement rate (133m/min). However, no signs of fatigue, based on total distance covered in the second half of the matches, was found.

It can be deduced that Gaelic Football mainly taxes the aerobic energy systems as 77% of the movement time was spent in low intensity activities. In contrast to this only 16% of the time was spent in high intensity activities.

THREE TOUCHES AND ITS OVER: ADDRESSING THE PROBLEMS OF PERFORMANCE ANALYSIS IN VOLLEYBALL

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This paper describes the development and validation of a computer based analysis system for volleyball. Through the work of the Sport Science Education Programme (SSEP) involving the English Volleyball Association (EVA) the national coaches of England and Great Britain identified the need for a sensitive and objective measure of strategic and technical aspects of performance. This need was primarily stimulated by a requirement for data that could be used effectively for scouting and goal setting. An evaluation of existing computer-based systems revealed a number of shortcomings and it became apparent that a programme was required which combined the best features of these systems together with options tailored to the specific questions posed by the coaches. Development of the system emphasised three major points throughout. Firstly, coaches were actively involved in the design and operation of the system at various levels in an attempt to identify those aspects of match analysis and data presentation which they considered important. Secondly, data collection initially concentrated on analysis from video record with some development of a version suitable for 'live' data collection which imposes significant limitations on the operator when working in real-time. The software was structured such that data input was based on the expected sequence of events together with a constantly updated screen display of players rotational position and set score. Input involves a qualitative assessment of a performance based on the effectiveness of each action derived from ratings developed by a panel of expert judges and International Volleyball Federation (FIVB) criteria. Finally, sophisticated programming skills were employed to prepare the required software, paying particular attention to menu driven options, context sensitive help, and, comprehensive error-trapping and escape routines. Data output takes advantage of high quality graphical displays, time series data and multidimensional screen images to present complex technical and strategical information to the coach in an easily understandable format. The facility to generate match reports containing all team and individual data permits the rapid feedback of information to coaches and players, a process which the authors view as fundamental to the success of coordinated developments in computer assisted notational analysis.

COMMERCIALISATION
THE ROUTE TO FUNDING AND THE FUTURE SUCCESS OF SPORTS NOTATION

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We are on the verge of notation explosion into the sports market place.

Large numbers of academic institutions have developed high quality notation systems. With minor adjustments to the presentation of these systems the leap from academic to commercial success will be made. With this leap will come increased funding and a snowballing of the success.

The desired success can be achieved by applying well established commercial concepts to sports notation.

The necessary concepts and their application is demonstrated.

THE CUBE
A NEW APPROACH TO THE PRODUCTION AND MANAGEMENT OF PLAYER STATISTICS FOR THE EUROPEAN PROFESSIONAL GOLF TOUR

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Golf's a funny game. You're on your own. Just you and the elements ... and a stationary ball! When things go well invariably there is someone else that has done better. When things are bad it was because there was too much wind, not enough wind, it rained, it was too hot, the fairways were too soft and had no run, the greens were too hard and had too much bounce.

Perhaps if you ask a golfer why he scored badly he may reply that he three putted four greens so his putting needs more practice. Ask him why he three putted so often and the chances are that he would say that his first putts were not getting close enough to the hole to give him a chance of getting the next one in. Perhaps the real problem was not the putting. Perhaps he was failing to put his 8-irons, 9-irons and wedges close enough. He will probably be totally unaware of his real weaknesses and can only identify the symptoms, not the causes.

Notational analysis is his only option.

This paper does not attempt to provide the definitive answer to the problems of notational analysis in golf. Indeed, until the last year or so I did not even know of the term 'Notational Analysis' let alone the fact that it was an exact science to measure performance. So I will leave the technical bits to the experts, to the professors and doctors of science. Instead, I want to examine the problems of assessing performance in golf from a golfer's perspective.

A COMPARATIVE COMPUTERISED ANALYSIS OF FEMALE COACHING BEHAVIOUR WITH MALE AND FEMALE ATHLETES

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The coach is a key factor in the development of an athlete's potential. Much of this development and subsequent success hinges on the behaviour of a coach during the training session. However, until recently little research has been done in this area.

The aims of the study are to analyse female coaching behaviour via computer; determine if there is any significant difference in the behaviour towards male and female athletes and evaluate the Computerised Analysis (CCAS), developed by Franks et al (1988), as a tool for behavioural observation.

Three female Lawn Tennis Association, grade three, coaches ($\bar{x}$ age = 27 years $\bar{x}$ teaching experience = 7 years) were videoed coaching a total of twenty one drills to a mixed group of intermediate players ($\bar{x}$ age = 11 years). Each drill was subsequently analysed using the Coach Analysis Instrument of the CCAS.

Chi-squared (χ^2) analysis of the data indicates that significantly more comments were presented verbally to the athletes than via demonstration or reconstruction (χ^2 = 15.1, $p<0.05$). A statistically similar number of skill and non-skill related comments were given to the athletes (χ^2 = 1.477, $p>0.05$). A significantly higher frequency of appropriate than inappropriate comments were issued by each coach (χ^2 = 0.530, $p> 0.05$). The coaches also made significantly more positive than negative comments (χ^2 = 6.73, $p<0.05$).

The findings of the study suggest that the coaching behaviour of the female LTA grade three tennis coaches are both similar and consistent.

Statistical analysis reveals no significant difference ($p>0.05$) in the verbal behaviour exhibited by each coach towards the male and female tennis players. The coaches adopt an 'asexual' approach.

The study produces a favourable evaluation of the CCAS, as an objective and quantitative system for behaviour analysis.

THE USE OF A COMPUTER-ASSISTED STOCHASTIC SIMULATION SYSTEM FOR THE PREDICTION OF SQUASH MATCH PLAY

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Sport analysis provides quantitative feedback to the coach and/or athlete. Its utility is to inform the coaching process and so direct future practice to optimal sport behaviour. A limitation, however, is that sport analysis tends to be directed towards description and explanation of past occurrence (hindsight) rather than future prediction (foresight).

The problem is that past sport data are not readily used for inference to the near future. This is unfortunate since it is invariably the next contest, often against a different opponent, which the coach and athlete must prepare for. A stochastic analysis, however, lends itself to the prediction of future events from past match data and in identifying optimal tactical strategy.

A stochastic model of squash match play is reported which predicts future events from previous sport behaviour. Pilot analysis reveals a first order Markov model (where shot behaviour is determined from the preceding shot) to approximate observed match behaviour well. The hypothesis that future contest outcomes can be accurately predicted from past match performances is supported.

A limitation of the described model arises in its reliance on the obligatory winning or losing profile assigned to a player in determining subsequent contest outcomes. The dilemma is clearly understood if one contests a winning profile of a low ranked player to a losing profile of a high ranked player. A subsequent refinement of the model is to somehow quantify a player's performance, perhaps through the inclusion of positional data (where the shot fell) in an attempt to grade shot quality. This paper addresses various approaches to classifying a player's performance for future study.

A stochastic simulation is a powerful tool to assist the coach and athlete in achieving optimum sport performance. Its advantage over traditional sport analysis to date is its valuable informational use preceding competition.

POSTER PRESENTATIONS

SMACK IT AND SEE!

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AN ANALYSIS OF DIRECT FREE KICKS

Between July 1989 and January 1992, 300 entire football matches were watched most live, some on T.V. A record was kept of the direct free kicks awarded ie. how they were played and their outcome.

Matches:	World Cup (1990)	34
	European Competitions	12
	English League (37 1st Div.)	141
	F.A. Cup	14
	Other Cups	25
	Non League	18
	Reserve/Pontins	43
	Other (Youth Cup)	2
	Friendlies	11
		300

Only those direct free kicks which gave a good goal scoring opportunity ie. the defending side responded by making a wall of three or more players, were included.

The stategy of the attaching side was divided into three categories:

1. Attempted direct shot
2. Lay off for direct shot from another player.
3. Attempt at set piece or other play.

The resulting outcome was also divided into three categories:

A. Goal scored.

B. Goal scored from a rebound.

C. Ball misses target, goalkeeper saves or defence clears the ball.

Results

	Direct	Lay off	Set piece
Goal scored	26	3	4
Score from rebound	2	0	0
Miss/saved/cleared	249	77	106
	277	80	110

Analysis

During the 300 games, 467 direct free kick goal opportunities arose, which is equivalent to 1.55 per game.

The attacking team attempted:

1.	Direct shot	277	(59%)
2.	Lay off for shot	80	(17%)
3.	Set piece or other play	110	(24%)

The outcome comprised:

A.	Goal scored	33	(7%)
B.	Goal scored from rebound	2	(0%)
C.	Missed, saved or cleared	432	(93%)

Overall, 35 goals were therefore scored from 467 opportunities ie. a 7% success rate. These can be divided into:

28 goals resulted from a direct shot
3 goals resulted from a lay off for a shot
4 goals resulted from a set piece or other play

In conclusion the success rate/goals scored depending on method employed by attacking side is as follows:

1. Direct shot — 28 goals scored from 277 opportunities ie. a 10% success rate
2. Lay off for shot — 3 goals scored from 80 opportunities ie. a 4% success rate
3. Set piece/other — 4 goals scored from 110 opportunities ie. a 4% success rate.

Several trends can be read into these results and there are of course numerous variables, but it is evident that when it comes to direct free kicks with a scoring opportunity, a single direct shot at goal would seem to create the most likely chance of scoring.

HOW GOALS WERE SCORED IN THE 1990 WORLD CUP FINALS - OR 80% OF WHAT?

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The influence of the work of Reep and Benjamin (1973) and Hughes (1979) has had a profound influence on the development of the long ball tactic in association football in Britain. The presentation of the statistic that 80% of goals are scored by 4 pass moves and less has been taken to heart by British football management resulting in a unique ethnic style (Yamanaka, Hughes and Lott, 1992). The aim of this work was to re-examine this statistic and present the data in a more realistic manner. The 1990 finals of the World Cup for association football were analysed using a computerised notation system. All 52 matches were recorded post-event from video in IBM compatible computers using concept keyboards as a means of making the data input easier.

Table 1. Analysis of goals scored in the 1990 World Cup for Soccer

Pass/Poss	0	1	2	3	4	5	6	7	8	> 8
No. goals	28	23	20	16	10	4	5	4	2	3
%	24.3	20	17.4	14	6.5	3.5	4.3	3.5	1.7	2.6

Table 2. Normalising the frequency of goals by the frequency of the pass/poss.

Pass/Poss	0	1	2	3	4	5	6	7	8	> 8
Frequency	7334	3641	2338	1545	1158	783	557	331	277	582
Goals/ 1000 poss	3.81	6.30	8.54	10.3	8.62	5.1	8.93	11.8	7.14	5.15
4 pass moves and less: Total=37.52					5 pass moves and more: Total=38.84					

Table 3. Normalising the frequency of shots with the frequency of the pass/poss.

Pass/Poss	0	1	2	3	4	5	6	7	8	> 8
Shots/ 1000 poss	43.7	79.5	71.4	73.7	55.6	101	83.1	106	100	62
4 pass moves and less: Total=323.87					5 pass moves and more:Total=450.93					

To analyse these data with statistical processes based upon the assumption that actions have equal probabilities does not seem acceptable for the actions in soccer, with such a large playing area. It was concluded that the simplistic method of presenting the classic statistic of 80% of goals being scored from 4 pass moves and less does not present a complete picture of goal scoring. Possessions with larger numbers of passes per possession have slightly higher numbers of the goals scored, but they do have a markedly higher number of shots per 1000 possessions. The conversion rate of these shots are significantly lower than the shots/goals ratio of 4 pass moves and less.

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