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Editorial

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Dear readers:

Welcome to the first issue of the **International Journal of Computer Science in Sport** (**IJCSS**) in 2005.

Three months have passed since the **5th International Symposium on Computer Science in Sport** in Hvar, Croatia (25th-28th May). Delegates from 18 nations participated in this successful and perfectly organized event.

In the name of IACSS I again thank **Leo Pavičić** (Univerity of Zagreb), chairman of the organizing committee, for a stimulating scientific and an impressive social program. 11 invited keynote and plenary lectures were presented, 33 oral presentations were given and 10 posters were displayed. **Keynote speakers** were Professor Larry Katz (University of Calgary), Prof. Tom Reilly (Liverpool John Moores University), Boris Sakac (Head of the Olympic Results and Information System), Prof. Wolfgang Schöllhorn (University of Münster) and Prof. Otto Spaniol (RWTH Aachen University).

During the General Assembly of IACSS in Hvar it was decided that the 6th International Symposium in 2007 will be organized by Prof. Larry Katz in Calgary.

Four original papers have been included within this issue.

Michael T. Hughes and **Mike Hughes** describe the evolution of computerised notational analysis through the example of squash. The paper gives a broad overview on notational analysis research done in this kind of sport. It refers to several application areas and informs about the historical development as well as current topics of research.

In the paper by **Dario G. Liebermann**, **Larry Katz** and **Ruth Morey Sorrentino** a very important question for Computer Science in Sport is examined, the attitudes of coaches towards science and technology. If somebody wants to have an impact in sports practice this will only be possible with agreement and active support of coaches. Their consent is in many sports more important than the athlete's one.

The aim of the research project presented by **Memmert** and **Perl** is to demonstrate that the combination of net-based qualitative analyses and stochastic quantitative analysis can be utilized to evaluate performance data from games. The stochastic approach reduces the total of recorded data to only a few statistical quantities and checks their significance by means of variance analysis. In contrast, neural networks can be used to extract specific striking features and qualitative trends on all original data.

Ruth Morey Sorrentino, **Richard Levy**, **Larry Katz** and **Xiufeng Peng** report on the use of a virtual environment of the Salt Lake City Olympic Oval as a tool to support visualization to help athletes prepare for the 2002 Winter Olympic Games. The results of their study promote the use of virtual environments for enhancing athlete visualization.

If you have any questions, comments, suggestions and points of criticism, please send them to me.

Good reading!

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The Evolution of Computerised Notational Analysis through the Example of Squash

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Abstract

By analysing past and current work in squash, it was found that notational analysis of sport could be systematically analysed by using these delimitations.

The development of analysis and technology in the analysis of squash
The technological developments in notational analysis have inevitably lagged those in the applied computing technology environment.

Application of feedback in squash
The main applied areas of objective feedback were found to be:-

- Tactical evaluation
- Technical evaluation
- Movement analysis
- Databases and modelling

Performance profiling and reliability

Performance profiling
The definition of profiles is much less a matter of guesswork because of methodological advances.

Reliability
The methods of measuring and calculating the reliability of non-parametric data has grown with research over the last few years.

Areas of Research and Support
More research in modelling in performance analysis is vital as we extend our knowledge and databases into those exciting areas of prediction.

It is clear from these analyses of the on-going research and development work in squash, that the working notational analyst must have a broad set of skills and be prepared to maintain and extend those skills just as the research in this area develops the knowledge base.

KEY WORDS: COMPUTERISED NOTATIONAL ANALYSIS, SQUASH, SPORT.

Introduction

Squash and soccer were the first sports to be analysed in Britain by way of computerised analysis systems, and squash in particular has been a precursor to the analyses of all those other sports in terms of the development and involvement of computerised notational analysis. This is due to many of the first programmers of analysis software choosing squash as the sport to analyse, squash was seen as a simple game and one that could easily be recorded .

The first hand notational analysis system published in Britain was in fact for tennis (Downey, 1973). This system was never actually used to gather data however due to its complexity. Not only did this system enable the user to record such variables as shots used, position on the court, and the result of the shot, but also the type of spin used in a particular shot. This system was significant as it provided other researchers with a wealth of ideas (Hughes, 1998).

Reilly and Thomas (1976) were very interested in Downey's (1973) concept of recording sporting actions and they recorded and analysed the intensity and extent of discrete activities during match play in soccer. Sanderson and Way (1977) reported devising a system for squash, it seems to be based on the work by Downey (1973). Their hand notation system was created to analyse successful and unsuccessful patterns of play in squash and was further developed by Sanderson (1983) to include symbols to represent shots that were placed upon a diagram of a court. Results obtained from matches were presented using longitudinal and lateral summations next to the different areas of the court. However it took 5 – 8 hours to learn how to use this system, and a further 40-50 hours to analyse the data from one match. Because of these problems inherent in using more sophisticated hand notation systems, computers were used to minimise learning time and process the data gathered. Hughes (1985) began this progression by computerising the processing of the data gathered by hand with the system of Sanderson and Way.

It is the aim of this paper to trace the development of computerised performance analysis through the examination, as a case study, of the maturation of the process in squash, which not only has one of the most advanced performance analysis support systems, but also has been clearly chronicled in research papers.

The development of analysis and technology in squash

The advent of computerised technology enabled these first hand notation systems to be further developed. A computerised version of Sanderson and Way's (1977) data gathering system was produced by Hughes (1985). It was not an exact transfer of the hand notation system onto computer, as compromises had to be made because of the limited memory of the microcomputer available at the time In addition, the ergonomics of the layout of the keyboard, and concerns over the accuracy of defining player position in the old hand system, led to different design specifications, particularly of the player position (Hughes, 1998). As computer technology evolved it was eventually possible to record the data courtside using a microcomputer. But because of difficulties with the speed of the game and the storage capacity, only one player was notated at a time (Hughes, 1994).

Difficulties with data entry and system learning time were reduced with the development of the digitisation pad. Digitisation pads are programmable, touch sensitive, pads, over which one places an overlay with a graphic representation of the playing surface and aptly labelled keypad areas for the actions and the players (Hughes, 1994). A number of studies both in Britain (Hughes and Feery, 1986; Sharp, 1986; Treadwell, 1988) and in the Notational Analysis Centre at UBC, Vancouver (Franks et al., 1986) have used 'Concept keyboards' and Power Pads' respectively.

Making the use of the analysis systems easier for non computer-literate operators was the development of a voice interaction system by Taylor and Hughes (1988). They were able to demonstrate that a computer 'non-expert' was capable of using the system despite their study being limited by cost, and therefore the sophistication of the technology they were able to use. Intuitively this seems like the most 'user friendly' system, but despite this there has been little advances in this area since.
Concurrent with developments in how the data were entered into the computer, there were also advances in how the data were displayed post processing. Because there were no graphical software packages at the time, frequency distributions were represented on a two-dimensional representation of the court, very much in the same way pioneered by Sanderson (1983). These were not always so easy to understand, particularly for most coaches and players. Hughes and McGarry (1989) designed a program that presented the data in coloured three-dimensional histograms that could be rotated and viewed from different angles. This made the results of the computer processing easier to understand.
Another step forward in terms of data entry was when the computer programming language visual basic was utilised by Brown and Hughes (1994) to write a program that created a graphical user interface. This interface allowed the user to enter data by moving the mouse around the screen and clicking on icons representing the actions that they want to enter. Also recent systems that are programmed using visual basic, and utilise the Windows environment, are interactive with a number of graphics packages making representation far clearer and easier to understand (Hughes, 1994).
Hughes developed a computerised analysis system, based on a hand notation system developed by Hughes and Robertson (1995), that could be inputted live by the user. Information regarding number shots in the rally, court position, how the rally ended and with what type of shot is typed in after every rally. The advantage of this system was that 3-D histograms were produced immediately by the computer and could be used to offer the players feedback between games. Once a number of matches involving a particular player were processed the data on that player could be collected together and viewed graphically to display a fingerprint of where and with what shots a certain player hits winners and errors. This Simple Winner Error Analysis Technique is known as SWEAT analysis (Murray et al., 1998). The in-event analysis SWEAT systems, and the post-event full match analysis systems, were used effectively for a number of years. The next development in the systems since 1995 was brought about by doubles squash being made a Commonwealth sport in 1998. It however took until Wells et al. (2004) for an analysis system to be designed to incorporate the larger squash court and the greater number of players.
The main purpose of designing these analysis systems has been to provide objective, quantitative feedback for athletes and coaches alike. Extensive research carried out by Schmidt (1975) found that feedback, if presented at the correct time and in the correct quantity, played a great part in the learning of new skills and the enhancement of performance (Murray, Maylor & Hughes, 1998). However, research has shown that the more quantitative and objective the feedback the greater effect it has on performance (Franks, Goodman & Miller, 1983; Franks, 1997). This research shows that objective feedback presented at the correct time can be of great benefit to an athlete or team. As such the feedback offered by the squash analysis systems is in exactly the right form to present to squash players and coaches to enhance performance. Due to the multitude of factors that contribute to a squash player's performance, it has been hard to quantify the specific effect that feedback has. Murray, Maylor and Hughes (1998), however, did find that quantitative feedback did induce a significant temporal transition in performance levels for elite and sub-

elite players. As complete control conditions were not in place however it makes it hard to gauge the exact effect of the feedback.

Application of feedback in squash

Hughes (1994) outlined four major areas within which feedback gathered via computerised notational analysis can be applied to racket sports as tactical evaluation, technical evaluation, movement analysis, and creating databases and modelling .

Tactical evaluation

The first analysis of the tactics of players of varying ability was performed by Hughes (1985; 1986) who compared shot distributions of recreational, county standard and nationally ranked players using the notational analysis systems he had developed. The data for the distribution of shots played by recreational players showed that they were not skilful enough to play to a 'game-plan' and that they were particularly inaccurate with their straight and cross-court drives. Their frequency of short shots was also a lot higher than that of county or nationally ranked players, and although they hit more winners they hit more errors as well. County players were able to perform tactics involving keeping the ball deep and primarily on the backhand. County players hit significantly more straight drive winners than recreational players and although their short game was significantly more accurate than that of the recreational players it was significantly less consistent than the nationally ranked players. Nationally ranked players used far more complex tactics in their matches employing more of an 'all-court' game. This was facilitated by their superior fitness and technical ability when compared to the other standards of players. Hughes & Robertson (1998) used computerised notational analysis to re-examine the patterns of play at the elite level and create a 'structural archetype' of elite squash. This in turn enabled the creation of a tactical model of the game at the elite level for men, it enumerated the structures of the rallies and games, shot distribution frequencies, or ratios, across the court, and the percentages of shots played in the 4 corners of the court, enabling individuals to compare their own patterns.

It took a further 15 years for a similar study to be performed upon female players of differing standards (Hughes, Wells & Matthews, 2000). The majority of the research conducted in squash has been in the men's game and it has taken a number of years for equivalent studies to take place in the women's game.

Technical evaluation

Highlighting technical deficiencies or strengths in players can be of vital importance to coaches in their quest to improve the athletes. The analysis systems used over the years (Hughes, 1985; Brown & Hughes, 1994) have been used to show the areas on the court where players hit their winners and errors (the 'N th' shot of a rally) from and with what shots. To add greater depth to the analysis, and hence the feedback, data upon the N-1 and N-2 shots to errors and winners could also be provided, shots that might not normally be remembered by the coach. If these data are collected from a number of matches, against players of an appropriate standard, then they can give indications of those types of shots that are the strengths and weaknesses of the respective player. Armed with this information the coach can then analyse any technical deficiencies of their players when playing in these particular areas of the court or when playing a certain shot. This in turn will inform the player of tactical considerations of shot sequences. This can be done live in training, or with use of video feedback. Seeing technical faults in the past has been quite difficult on video due to the frame rates. However with introduction of high-speed cameras for feedback purposes, technical analyses of the racket swings and individual player movement can now be scrutinised to the minutest detail.

Movement analysis

Based upon the work conducted by Reilly and Thomas (1976), on movement duration and intensity in soccer, Hughes, Franks and Nagelkerke (1989) designed a tracking system for squash. The tracking system was designed to be used post-match from video at match speed. A 'Power Pad' was used to gather the positional data along with the time base (Hughes, 1998). Accurate tracking was enabled by training a video camera on the 'Power Pad' and mixing the image from the camera with the footage of the match and transferring it to a single VDU screen. The image of the representation of the playing area on the 'Power Pad' was aligned to exactly meet the dimensions of the court on screen. This allowed the operator to be able to focus upon where they were tracking and where the player was moving at the same time. This was shown to be an accurate and reliable method of gathering information regarding player velocities and accelerations.

This system was utilised by Hughes and Franks (1994) in a study comparing the motions of squash players of differing standards. They recorded the distances moved, the average velocities and the accelerations during rallies of four different standards of players ranging from club level to elite internationals. The mean distance travelled by recreational and regular club players was only 12m, which raised some questions about the type and specificity of the training that these players were performing. The study also showed that the then number 1 player in the world, Jahangir Khan, had a physiological advantage over the other top players in the world. It was found that when the data for Jahangir Khan were compared to that of the top six players, including his own data, his acceleration during a rally was 50% greater than that of his opponents.

Wells and Hughes (2001) developed a very different system from that conducted by Hughes & Franks (1994), analysing specific types of movement, many particular to squash, analysing the sequences that preceded winners and errors in different parts of the court. Their analyses were carried out on elite female players. A reliable system of notating movement was devised using a hand notation system transposed into Microsoft Access, enabling quicker analysis of the gathered data. A profile of how elite female squash players could move successfully around the court was then created from the data gathered. This model could then be used by coaches to devise future training sessions to ensure improved and economical movement.

Movement analysis in squash has enabled a better understanding of the physical demands of the sport and, as a result, the creation of specific training drills to better prepare the players for matchplay. This information can also be used to help strengthen junior players who are currently finding the transition from junior to senior squash difficult due to the greater physicality of the senior game (Pearson, 1999).

Databases and modeling

Once sufficiently large amounts of data have been collected using notational analysis systems, models of the 'norms' of behaviour of players can be formed. Modelling can be invaluable when predicting how an opponent will play the game.

Mathematical modelling can be used to describe sport and can be applied to squash to expose strategic patterns of play. Using the mathematical theory of probability, Alexander et al. (1988) analysed and modelled the game of squash. They first suggested that the actions in squash a series of discrete events with each event having an associated probability function. However this model cannot take into account the human factor of the game such as form and tiredness. They then took these factors into account and were then able to make recommendations for players on how to ‘set’ the game at 8-8 depending on fatigue and technical ability.

McGarry and Franks (1994) created a stochastic model of championship squash match-play which inferred prospective results from previous performance through forecasting shot response and associated outcome from the preceding shot. Their results were limited however by the fact that players used the same playing patterns against the same opponents but different playing patterns against different opponents. This was in contrast to the work of Sanderson (1983) who found that squash players did not alter their patterns of play against different opponents whether they were winning or losing. These discrepancies could be the result of differing levels of detail in terms of measuring the responses of the players, McGarry and Franks used a very detailed analysis structure, but they do remain a contradiction to the more generally accepted view of the stabilisation of playing patterns.

To try to promote a more attacking style of play in squash, ‘point-per-rally’ scoring was introduced to all PSA tournaments in 1990 along with the tin being lowered from 19 inches to 17 inches. It was thought that with points on offer when receiving serve as well as being able to play shots lower on the front wall, players would hit more offensive shots, rallies would become shorter and squash would become more spectator friendly. To analyse the differences in the game when using point-per-rally scoring compared to the traditional English scoring method, Hughes and Knight (1995) designed a computerised notational analysis system that utilised a graphical user interface. Surprisingly rallies were found to be marginally, but not significantly longer, when playing using the point-per-rally scoring. There was an increase in winners but no increase in errors, which was attributed to the lower tin.

Further analysis of the scoring systems in squash was conducted by Hughes (1995), when he investigated the scoring structures in tennis and squash. Key terms ‘activity cycles’ and ‘critical points’ were described by Hughes as the crucial events that lead up to exciting points in the games. In tennis the activity cycles leading up to a ‘game point’ were about 3 mins in duration, whereas in squash (and in badminton at that time) it took 15-20 mins to reach a critical point,i.e. game-ball. Hughes realised that in order to make the game more attractive the activity cycles preceding critical points in the games needed to be shortened to make the game more appealing, more exciting. So Hughes recommended playing more, shorter games in squash thereby increasing the number of critical points and hopefully crowd excitement. The new recommended scoring system (‘Welsh scoring’, based on tennis scoring) meant that games were now first to four points and if the scores were tied at three all then it would be the receiver to decide whether they play to two clear points, or to just one (’sudden death’). Also players would serve for a whole game with the serve alternating between players after each game. This meant that both players would receive the same amount of serves which Hughes (1995) stated would correct the imbalance of previous scoring systems, that dictated that the winner of the previous rally serve the next. The old systems put the receiver at a disadvantage and as such the lesser player was being penalised for not winning enough rallies. This was particularly evident in English scoring when players could only win points when serving. In the new scoring system sets were the first to five games and the match was the best of three sets. A similar scoring system was used at the Grasshopper Cup, a large PSA tournament in 1995, with some positive feedback from the players. Analysis of the effects of rule changes in sport is commonplace with notational analysis being used to create statistical norms or models of performance pre and post rule change. This work is quite unique in that the research was proactive in the need to examine the rules in squash and not vice versa.

Performance profiling and reliability

Performance profiling

The early work of Sanderson and Way (1977) and Hughes (1986) highlighted that the formation of a database of matches could provide information regarding patterns of play that could be considered representative of the subjects used to form the database. The formation of 'profiles' of different groups of players could be a very powerful tool in attempts to understand the sport better and to formulate a successful game-plan prior to matches. As such, a number of studies over the years have attempted to profile different player groups and aspects of the game.

Hughes and Franks' (1994) movement analysis study provided profiles of the movement patterns of male squash players at four different ability levels. These profiles provided a great insight into the physiological demands of the game and as such had a great practical application in the creation of squash specific training drills.

Using the Hughes and Knight (1995) system, Hughes and Robertson (1998) created a 'structural archetype' of elite squash for men and extended it to produce a tactical model of the game. The model was formed using the data gathered from 5 elite level matches. To accompany the model several simple hand notation systems for specific areas of the court were developed and these have been implemented over the years by a number of squads. After the Hughes and Robertson (1998) study questions started to be asked about the validity of profiling studies, and how many matches needed to be analysed to form a reliable profile. Hughes, Wells and Matthews (2000) sought to answer this question as part of their study. They also replicated the study of Hughes (1986) but used female players of 3 different standards as their subjects. During the study they compared the profiles obtained from databases containing 8, 9 or 10 matches to investigate when the profiles had become 'normative', that is stable. Analysis of variance and chi-squared analysis were used to test for differences in the overall match totals and distributions of shots. They found that recreational players did not establish a normative playing pattern but county and elite players did ascertain a pattern that could be considered normative. There was a difference however in the number of matches it took for the county and elite players profiles to become normative. For county players it took 8/9 matches and for elite players it took 6 matches. More data are produced during an elite match due to their greater duration and this could be one reason as to why their profiles stabilise quicker. Also as players improve in standard they are able to sustain set patterns of play due to their greater skill level. The opposite is true of recreational players, who are not skilful enough to play to fixed tactical patterns and so their profiles do not stabilise. This study showed that creating normative profiles is highly dependant on the nature of the data being collected and the ability of the performers.

Intuitively one would assume that the greater the number of matches in the database the more reliable the profile produced would be (Potter & Hughes, 2000). However later work suggested that as a database grows larger it becomes less sensitive to changes in playing patterns and so becomes less accurate (Hughes, Evans & Wells, 2001). Therefore the number of games analysed in the database is of great importance to the reliability of the profile produced.

Hughes, Evans and Wells (2001) highlighted this point when they reviewed Hughes, Wells and Matthews (2000) in their own research. They stated that all future performance profiling studies should provide supportive evidence that the variable means in their profiles are stabilising. They stated that assuming a profile was stable just because n number of matches had been analysed in the database was subject to possible flaws. They suggested that using a percentage error plot that displayed the mean variation as each match is analysed is one technique of testing as to whether the profile data is stabilising and can be regarded as normative of that player group.

The movement patterns of 10 elite female squash players was analysed by Wells and Wells (2001). Although similar in terms of aims to Hughes and Franks (1994), a new and reliable system of notating movement using Microsoft Access was devised for this study. Microsoft Access is perfect for creating large databases and for processing the data collected quickly. A model of how elite female players move successfully was produced from the study that can be used to design specialised training sessions to encourage these movement patterns. Recent studies have built upon the work by Hughes, Evans and Wells (2001) and extended reliable performance profiling to other groups of players (Lynch, Hughes and Wells, 2001; Allen, Wells and Hughes, 2001).

James et al. (2004) suggested an alternative approach whereby the specific estimates of population means are calculated from the sample data through confidence limits (CL's). CL's represent upper and lower values between which the true (population) mean is likely to fall based on the observed values collected. Calculated CL's naturally change as more data is collected, typically resulting in the confidence interval (upper CL minus lower CL) decreasing. Confidence intervals (CI's) were therefore suggested to be more appropriate as performance guides compared to using mean values. Using a fixed value appears to be too constrained due to potential confounding variables that typically affect performance, making prescriptive targets untenable. From a theoretical perspective, James et al. argued that the use of CI's can also add significance to the judgement of the predictive potential of a data set, i.e. whether enough data has been collected to allow a reasonable estimation. For their investigation a criterion was formulated to test the rate of change of the CI for stability. Initially 95% CI's were calculated for each performance indicator as soon as enough match data had been collected (N = 2) and each time more data was added the new CI was calculated. This meant that CI's could be constructed for each performance indicator after 2, 3 and…. N matches respectively. Behavioural frequencies fell outside the 95% CI more often for small data sets and less often as the data set increased. However, this was inevitable as any measure related to the mean of a data set becomes progressively more resistant to change as the data set increases.

Recent research (Hughes et al., 2003), now suggests that, contrary to previous ideas that if an action had a high frequency of occurrences within performances, then relatively fewer matches would be required to obtain a normative profile of this action. For example sides in a typical soccer match will often make 450 passes in a match, whereas they will make about 30 shots on average. Intuitively, one could be forgiven for thinking that an analyst analysing shooting will require more matches to acquire a stable profile than when analysing passing. This is not the case, Hughes et al. demonstrated that shooting stabilises after 4 matches whilst passing was still not stable after 16 matches. They suggest that it is the variance from match to match, not the size of the mean, of these performance indicator data that will determine how many matches are required to reach stability. Further research in performance analysis needs to address the problems specific to these particular types of non-parametric data, utilising more advanced techniques such as time series, where appropriate, and perhaps could investigate statistical methods based on the respective variances to predict the number of matches required, thus replacing these empirical techniques.

Reliability

It is vital that any data gathering system used within research has been proven to be reliable and in a manner that is compatible with the intended analyses of the data. The data gathered must be tested in the same way and to the same depth in which it will be processed in the subsequent analyses (Hughes, Cooper & Nevill, 2002). The most popular statistical method used over the years to confirm reliability has been correlation. However Bland and Altman (1986) highlighted the need to perform other statistical tests in conjunction with correlation to prove reliability. In a review of 72 notational analysis papers, Atkinson and Nevill (1998) found that 70% of the studies failed to report any sort of reliability study and of the remaining 30% their methodology was dubious.

Hughes, Cooper and Nevill (2002) researched into analysis procedures for non-parametric data gathered from notational analysis. Two trained notational analysts notated one game and the differences between the two sets of data were compared. In light of the results, they suggested the following conditions should apply to researchers considering reliability studies:

- The reliability test should be examined to the same depth of analysis as the subsequent data processing, rather than being performed on just some of the summary data.
- Careful definition of the variables involved in the percentage calculation is necessary to avoid confusion in the mind of the reader, and also to prevent any compromise of the reliability study.

It is recommended that a calculation based upon

$$\left(\sum \frac{\mathrm{mod}(V_1 - V_2)}{V_{mean}}\right) \times 100\% \qquad [1]$$

(where V_1 and V_2 are variables, V their mean, mod is short for modulus and Σ means sum of)

is used to calculate percentage error for each variable involved in the observation system, and these are plotted against each variable, and each operator. This will give a powerful and immediate visual image of the reliability tests (Hughes, Cooper and Nevill 2002, p. 19).

Current Areas of Research and Support

Most of the support that is currently being offered to England Squash is based upon the work of Murray and Hughes (2001). During their research they offered England Squash various types of feedback from information gathered using the SWEAT and the full analyses systems. Analyses ranging from simple winner and error ratios to complex rally ending patterns were produced from the computerised systems. Using the full analysis system (Brown & Hughes, 1995) they analysed five matches of a particular player and pooled the data from these five matches into a single database. From these data the system is able to produce up to 300 different distribution graphs from the different combinations of shots and positions. This is of course far too much information for coaches and players to use. So Murray and Hughes (2001), using feedback from coaches and players and their years of experience, condensed the information into bullet points that were used as a storyboard to accompany an edited video of the player. After further feedback the information was normalised, converted into percentages and condensed further onto a representation of the court. The representation of the court was divided into 16 sections (in the same manner as the SWEAT system, Hughes & Robertson, 1995) with the areas of the court containing unusual data analysed with respect to shot type. These profiles could be created for winners, errors, and N-1 and N-2 for winners and errors. The profiles were presented at a national squad and the players were very receptive of the style and content of the feedback.

The paper by Murray and Hughes (2001) was also the first to introduce the concept of momentum analysis. From the SWEAT analysis they already had all of the information concerning winners and errors during a particular match. By writing a new program they were able to give players a running score (momentum) during a match depending on the rally ending shots. A winning shot by a player was given a '+1' score, an error a '-1' score, and if the opponent hit the rally end shot, or it was a let, the score stayed the same. From this information line graphs could be drawn to visually show any swings in momentum during a match. These lines graphs can also be coupled with data regarding rally length to highlight whether any swings in momentum are perhaps fitness related. This work was born from conversations with the SRA psychologist who was interested to see whether extremes of body language had any effect on the outcome of the next 3 or 4 rallies. By matching up positive or negative forms of body language on tape with points on the graph the psychologist was then able to see how these physical outbursts affected the momentum of the players.
The research into momentum analysis was furthered by Fenwick et al. (2003) who analysed matches of elite squash players (N=8 per player; 6 male and 6 female, all in top 40 in the world) to examine the length of the 'peaks' and 'troughs' of momentum in a match. Inevitably large variations were found within each player's set of data, but all of these characteristics of the profiles stabilised to within 10% of their respective means within 6 of the 8 matches, for all the players. The data from each match were summated and the average positive and negative increases in momentum were calculated. A Xi^2 analysis was used to test for inter-player differences and it was found that there were significant differences between patterns of peaks, peak lengths, troughs and trough lengths ($P < 0.05$). Also both the male and female, world #1 players had positive averages much higher than their peers.
Currently, the practical applications of these researches are being used with England Squash. Prior to the World Team Championships in November 2003 the England team were provided with player profiles of all possible future opposition, based on Hughes and Murray (2001). The only difference being that the profiles were created using the SWEAT analysis systems, rather than the full analysis system, due to time constraints and the large number of profiles that needed to be created. Compact discs containing edited video material of the unusual aspects of the relevant player profiles were provided to the players. They were created using the sports analysis package 'Focus'. Also English players competing in the World Individual Championships in December 2003 were provided with SWEAT analyses of their previous encounters with likely opponents and the respective momentum analyses of these matches. This process was performed relatively quickly due to the large database of matches at the English Institute of Sport.

Future Research

Momentum analysis is a new way of extending performance analysis and the significance of it is not yet fully understood. It does seem apparent however that the results of the analysis combined with the work of sport psychologists can be of great benefit to players in their attempts to maintain focus during matchplay. Further research needs to be carried out as to why the peaks of the top players in the world are longer and steeper than those of the lesser players.
The research being conducted by Perl (2001) into neural networking and fuzzy logic has huge potential for modelling purposes. If models for elite squash players can be created, using the theories that he is applying to other aspects of sports science, this could have huge potential for analysts and coaches. The ideal would be to have models created via neural networking that could be used to predict future performance of players taking into account factors such as

fatigue, temperature, crowd support etc… These types of applications of fuzzy logic, together with artificial intelligence shells should make ideal models for analysing the coaching process – a 'nettle' few coaching science experts have grasped so far.

To further squash analysis perhaps there is something that can be learned from the analyses taking place in soccer and rugby union. Currently there is software being used in these sports called ProZone, with which the movement of the ball and all the players on the pitch is recorded using a number of cameras placed around the grounds. Many elite soccer and rugby professional teams are beginning to make use of these complex systems. Perhaps there is some scope for using this software in squash for monitoring movement patterns, distances travelled, velocities and movement with respect to the ball. Vukovic (2003) is currently conducting some research into monitoring movement in squash using an overhead camera. From this video material, velocities and accelerations of players can be calculated.

This work with overhead cameras also has some applications with regard to the research of perturbations in squash. It may well create a methodology that can enable accurate identification of perturbations in a squash rally. Perturbations in sport are events in the game that break up the cyclical nature or rhythm of the match. These perturbations themselves can be critical incidents or they can lead to critical incidents in the game.

McGarry and Franks (1994) have shown that perturbations, the changes in phases in dynamical systems, can be identified successfully in a game of squash. They were recognised by interviewing top coaches and questioning them as to what constituted an arythmical motion in the game. As such McGarry and Franks' (1994) definition of a perturbation was defined via qualitative means. McGarry, Khan & Franks (1999) began to analyze squash contests as a dynamical system, first by investigating whether the system can be detected as switching between periods of stability and instability from visual inspections (Independent observers were able to identify those behavioural transitions, or perturbations, that were held as switching the system from and to regions of stability and instability). The identification of perturbations from visual inspections of soccer behaviours were likewise reported by Hughes, et al. (1998). Further considerations on this new line of inquiry for sports contests as dynamical systems are detailed in McGarry, Anderson, Wallace, Hughes and Franks (2002). However attempts have been made to identify perturbations quantitatively via measurement of velocities. It has been shown that sudden increases in velocity i.e. large accelerations by the reliably denotes a perturbation. Measuring velocities from the traditional view from behind the court can prove quite time consuming due to the angle of the view. Vukovic (2003) however has designed a program that can automatically calculate all velocities of the players as long as the footage is taken from overhead. Such a system would make identification of perturbations far less ambiguous. This could then lead to the detection of how certain players create perturbations in the game and the tactics they use to induce a rally ending shot. Identification of critical incidents is not just about analysing these most important sets of data, by analysing these perturbations the size of the task of interpreting a performance is reduced by an order of magnitude, i.e. instead of examining 1000's of bits of data it is reduced to 100's of bits. This makes the analyst's task easier.

Applying McGarry and Franks' (1995a, b and c) work on perturbations in squash, Hughes et al. (1997) attempted to confirm and define the existence of perturbations in soccer. Using twenty English league matches, the study found that perturbations could be consistently classified and identified, but also that it was possible to generate specific profiles of variables that identify winning and losing traits. After further analyses of the 1996 European Championship matches (N=31), Hughes et al. attempted to create a profile for nations that had played more than five matches. Although supporting English League traits for successful and unsuccessful teams, there was insufficient data for the development of a comprehensive normative profile. Consequently, although failing to accurately predict performance it introduced the method of using perturbations to construct a prediction model. By identifying 12 common attacking and defending perturbations that exist in English football leading to scoring opportunities, Hughes, Dawkins and Langridge (2000) had obtained variables that could underpin many studies involving perturbations. These twelve causes were shown to occur consistently, covering all possible eventualities and had a high reliability. Although Hughes et al. (1997) had classified perturbations; the method prevented the generation of a stable and accurate performance profile. In match play, teams may alter tactics and style according to the game state; for instance a team falling behind may revert to a certain style of play to create goal-scoring chances and therefore skew any data away from an overall profile. Conclusions therefore focussed on improvements in technical skill of players, however with patterns varying from team to team, combining data provides little benefit for coaches and highlights the need for analysing an individual teams 'signature'.

Squash is potentially an ideal sport for analysing perturbations, and as such has received considerable attention from researchers. It is of a very intense nature and is confined to a small space. The rhythms of the game are easy to see, and the rallies are of a length (mean number of shots at elite level = 14 (Hughes and Robertson, 1997)) that enables these rhythms and their disruption i.e. perturbations and critical incidents, to be more easily identified than other sports. The work of McGarry and Franks (1995a, b and c), in their use of phase relationships, points to a very interesting, and potentially very rewarding, area of research into the interaction of players in this game.

The amount of research that has been performed in squash means that it is one of the leading sports in terms of the level of application of performance and notational analysis. Perhaps rugby can match squash in terms of development of its technology but the work being conducted with the England rugby team is not in the public domain. With regards to published work no other sport has the same depth and width of profiling that squash boasts. The insight offered by this profiling is quite unique to squash. The current male and female England squash teams receive very complex and thorough performance analysis support including, player profiles on themselves and future opponents, the SWEAT in-event analyses, and full match (every action) post-event analysis on previous matches, edited CD's of technical strengths or faults, motivational DVD's, and very advanced technical analyses using high-speed camera feedback. This symbiotic relationship between England squash and performance analysis has only come about however because of the receptiveness and the open minded approach of the coaches and the players.

This excellent relationship can still be built upon and improved. There are still many areas regarding momentum theory and perturbations that need to be explored and explained. Also the work concerning neural networking has enormous potential in terms of modelling the game of squash and predicting future results. These are the areas of performance analysis in squash that need to be researched in order to take the support offered to the next level.

Conclusions

By analysing past and current work in squash, it was concluded that notational analysis of sport could be systematically analysed by using the following delimitations, with the ensuing deductions made on the recent research.

The development of analysis and technology in the analysis of squash

The technological developments in notational analysis have inevitably lagged those in the applied computing technology environment. But this gap has decreased over the years as commercial software has become available and video specific computers also came on the market. Current instant communications, via the internet, sophisticated generic analysis systems and video editing software, have enabled teams performing on the other side of the world to be analysed immediately back at home, and receive those analyses and edited videos within hours of finishing their competition.

Application of feedback in squash

Because of several decades of experience, the application of feedback in squash can be used as a template that other sports can aspire. The main applied areas of objective feedback were found to be:

- Tactical evaluation
- Technical evaluation
- Movement analysis
- Databases and modelling

By applying any combination of these techniques, it has been shown that these types of enhanced and objective feedback improve performance and increase our understanding of performance. England Rugby has also employed many of these techniques and demonstrated the benefits in winning the Rugby World Cup , 2003.

Performance profiling and reliability

Performance profiling

Recent applied research has made the definition of profiles much less a matter of guesswork in terms of how accurately a particular profile really represented the way a player or a team performed in general. The use of performance profiling techniques (Hughes, Evans and Wells, 2001); has created a sound empirical method of ensuring the stability of the data profiles. Further, the work of James et al., (2004) have introduced the ideas of using confidence intervals, that enable the use of any number of matches for a profile with some quantitative statement about the quality of the data.

Reliability

Considerable amounts of recent research have increased knowledge and understanding of the methods of measuring and calculating the reliability of non-parametric data, which are usually the type of data that are gathered and analysed in notational analysis. The statistical methods that we use are improving, but more work needs to be done on making the more sophisticated systems more transparent, in terms of how they relate to the experimental aims of the comparisons, and also the basic practical demand of them being easier to apply.
The sensitivity of the tests needs to be examined – how can we determine the significant differences in performance when the increments of comparison are very small?

Areas of Research and Support

As the field of notational analysis is becoming more accepted, then we can confidently predict that there will be ongoing research in all these areas defined here. More research in modelling in performance analysis is vital as we extend our knowledge and databases into those exciting areas of prediction. There are also some exciting developments, such as perturbations and momentum, used with current computer developments such as neural networks, that promise exciting possibilities of profiling and even prediction in the near future. Using databases to enable prediction in sport is very difficult, almost impossible, because of the inherent nature of sport. Nevertheless, working towards the extended aims of modelling, and therefore forecasting, must be the most exciting of the ways to further develop performance analysis.

It is clear from these analyses of the on-going research and development work in squash, that the working notational analyst must have a broad set of skills and be prepared to maintain and extend those skills just as the research in this area develops the knowledge base.

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Experienced Coaches' Attitudes Towards Science and Technology

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Abstract

In this study, the attitude of experienced coaches towards technologies and sport sciences was assessed. A questionnaire was used to evaluate three areas: (1) Attitudes towards technology and sport science in coaching, (2) Technology and scientific knowledge in practice, and (3) Perceived importance of technology and science in enhancing sport results. A group of 27 highly experienced coaches completed the questionnaire. The questionnaire consisted of three parts, starting with demographic information, followed by a series of 27 questions with answers on a Likert scale ranging from strongly agree to strongly disagree, and finally, coaches were requested to rank 14 well-defined 'coaching goals' from 1 (most important) to 14 (least important). Results showed that top-level coaches rated having a good relationship with the athletes' as a major goal. Overall, members of this group of experienced coaches seem to recognize the general importance of sport sciences, and appear to be positive about the use of sport technologies, but do not necessarily translate these positive attitudes into actual practice within their competitive sport environments, even when they all use information technology for other activities. According to these results, sport science researchers and technology developers need to adapt their strategies. Coaching education should encourage coaches to incorporate technologies as part of their coaching routines. Developing innovative resources and incorporating them in coaching education, as is done in some countries, may be a starting point. However, placing the emphasis on educating successful coaches on the practical use of technology and scientific knowledge is suggested as a short-term goal. This may allow for a more immediate effect on the attitude and practice of less senior coaches that tend to adopt methods and training routines through following the personal example provided by top-level coaches.

KEYWORDS: COACHING, TECHNOLOGY, ATTITUDES, COMPUTERS, COACHING PRACTICE

Introduction

The use of technology to enhance coaching and performance has been recognized as an important and effective undertaking (Katz, 2001). Moreover, coaches must prepare themselves in order to be successful in an ever more complex and constantly changing world which includes evolving sport technologies (Liebermann, Katz, Hughes, Bartlett, McClements, & Franks, 2002). In order to keep up with such change, it is necessary for coaches to review and update their knowledge and skills more frequently than in the past. Technology can play a role in providing coaches with quality information in a timely fashion and with potentially valuable tools for improving athlete performances. However, coaches are not adopting technology or accessing scientific data and resources in meaningful numbers (Raz-Liebermann, 2000). In the formal education of coaches, there is evidence of a positive attitude towards the use of computer-aided multimedia instruction, but most young coaches still maintain the traditional approach of learning coaching contents from lecture notes rather than from sport related computer programs (Wiksten, Spanjer, & LaMaster, 2002). An individual's prior experience, and the perceived characteristics of the innovation, have been shown to influence a person's decision to adopt a relevant technology (Norman, 1998). Kocak (2003) studied computer usage amongst physical education teachers, sport managers, and students in Turkey. His results suggest that all users had positive attitudes towards computers but competencies varied and were not correlated with attitude. He concluded that effective technology integration is needed for present and future development of sport in Turkey.

According to the Australian Coaching Council (2000), the main goal of the sports coach is to assist athletes in developing to their full potential. In the area of sport as a whole, there has been a shift towards increased use of technological and scientific innovation for both instructional and administrative purposes. Although many coaches are beginning to use technology in the gymnasium as well as in the field, little research has been carried out on coaches' attitudes towards technology and sport science. Similarly, there does not appear to be any reports that focus on the particular areas of coaching that benefit most from the integration of technology and sport science.

Akaba and Krubacak (1998) examined the attitudes of teachers towards technology. These authors were motivated by the observations of Huan, Compley, Williams, and Waxman (1992) and Padron (1993) who found that teachers did not always have positive attitudes towards technology. However, teachers indicated that technology could be an effective instructional method for teaching parts of a course. Based on the need to objectively assess the teachers' attitudes towards technology, Knezek and Christensen (1998) developed the Teachers' Attitudes Toward Information Technology questionnaire.

Technologies comparable to those developed for educational purposes have also been developed for coaches in sports. The use of computers in sports dates back to the 1970s, when computers were being used by sport scientists and coaches to analyze the movement of elite athletes and to aid scoring (Lees, 1985). Fraser and Danielson (1980) even predicted that the computer would be the coaching tool of the 1980s. In fact, much research and development of technologies has been carried out to enhance achievements in competition (Liebermann & Franks, 2004). It is widely recognized today in sport coaching that computer hardware and software, among other technological advances, are not only are available to most coaches, but can be used to directly enhance performance (e.g., Fowler, 1995; Jalilov, 1996; Smith, Galloway, Patton, & Spinks, 1994). This can be done by recording movements and analyzing technique, evaluating fitness progress, planning future strategies, or by simply facilitating management (e.g., scheduling tournaments, planning trips, and monitoring seasonal training). Coaches can benefit from these products. What is not known is why coaches use available technologies or, conversely, why they are reluctant to do so. Coaches' priorities and their general opinions regarding the integration of technologies during the training season are currently un-documented.

This study was undertaken in order to survey the attitudes and opinions of coaches regarding technology and its uses in sports coaching. A secondary aspect of the survey was to determine the attitude of coaches towards scientific knowledge, and their attitude towards implementing scientific knowledge to enhance competition results.

Method

Participants

The participants included 22 male and 5 female coaches (mean age =36.2 ±9.53 years, range 24-63 years). All but one of the coaches were certified by the Canadian Coaching Association, at different levels, and all had an extensive range of experience in their specific sport (mean =12.6 ±8.2 years). Although all the participants were actively involved in coaching at the time of the survey, coaching was not the main occupation for some of the coaches surveyed. The participants coached a variety of sports, including individual and team sports (judo, badminton, cross-country skiing, hockey, canoeing, volleyball, swimming, and speed skating). All but one of the participating coaches had a level 2 certification or higher in the Canadian National Coaching Certification Program (NCCP). A majority of the individuals (14 out of 27) were level 3, 4, or 5 (level 5 being the highest obtainable coaching certification in Canada). Thirteen out of 27 participants were coaching at the national or international level of competition. The personal information suggested that most of the coaches were well-trained professionals.

Design and Procedure

Following approval of the research protocol by the institutional review board, an open invitation to participate in the study was sent to all coaches associated with various programs situated at the University of Calgary, including the Olympic Oval training Centre, university team coaches, and the National Sport Centre (a one year training program for elite coaches). Participants completed a questionnaire composed of three sub-sections. In the first part, participants were asked personal information (their age, gender, years of coaching experience, level of education, and ages and sports coached). This was followed by a series of questions in which participants were asked to rate their answer on a five-point Likert scale ranging from strongly agree to strongly disagree. In the last section of the questionnaire, they were asked to rank a series of coaching goals from the ‘most important’ to the ‘least important’ (rank order 1-14, respectively). Finally, coaches described the different technologies that they use for training purposes. The coaches were given the survey to take away and complete in their own time. Coaches were not provided with any operational definitions of the terminology used within the survey.

Data Analysis

Evaluation of the data was based on descriptive results. It was expected that these would show the general attitudes of top-level coaches towards the use of conceptual scientific knowledge and their preferences for using technologies during coaching practice (such as video, computers, and software). In addition, it was of interest to understand how these coaches perceived the relevance of science and technology, particularly in relation to their athletes' successes in competition.

Results

It was expected that the results from the survey would shed light on three main areas of interest: attitudes towards technology and sport science in coaching; technology and scientific knowledge information in practice; and, perceived importance of technology and science in enhancing sport results. Each area of interest was divided into four specific questions. Table 1 highlights the results found for each of these questions.

Table 1. Results from Questionnaire According to Selected Areas of Concern

Questions	**Scores***			
Categories	**Mean**	**S.D.**	**Median**	**Mode**
Attitudes towards computers and technology in general				
A) There is a role for technology in coaching	4.54	0.51	5	5
B) The use of computers and other technologies for motion analysis are relevant to coaching	4.42	0.50	4	4
C) I feel comfortable using computer technology in sports	4.33	0.55	4	4
D) The computer is a timesaving device for planning and coaching	4.04	0.94	4	4
Scientific & technological knowledge in coaching practice				
A) It is important to understand the how the motor system functions at all levels to be an effective coach	3.93	0.87	4	4
B) A coach's knowledge of physiological responses is important	3.73	0.78	4	4
C) Coaches should collect biomechanical data and apply it immediately	3.67	0.78	4	4
D) The use of computer technology is relevant for analyzing sport performances	4.31	0.62	4	4
Perception of science and technology in sport				
A) Sport Science and research are important to improve athletic performance	4.48	0.51	4	4
B) Science & Technology help in measuring, but results are distanced from my understanding of coaching	2.56	1.09	2	2
C) Technologies and devices are useful in enhancing motor skill	3.93	0.87	4	4
D) Knowledge of biomechanics and other applied sciences in sports are important to enhance performance	4.54	0.51	5	5

*Scale: 1 = strongly disagree, 2 = disagree, 3 =unsure, 4 =agree, and 5 =strongly agree

All of the coaches agreed that there was a role for technology in coaching and most felt that they were comfortable using technology (22 out of 27). Most coaches reported that using technology is helpful and saves time during planning (26 out of 27). They also recognized that technology is relevant for analyzing their athletes' performances (26 out of 27); and has practical usefulness to aid the coach in enhancing their athletes' motor skills (18 out of 27 with 8 unsure).

In terms of the usefulness of scientific knowledge, the coaches believed that results from scientific research is important in improving athletic performance (27 out of 27) and that their personal knowledge should include biomechanics and other applied sport sciences (27 out of

27). The coaches felt that knowledge of athletes' physiological responses was very important (27 out of 27).

While most coaches reported using technology for administrative purposes (26 out of 27), just over half (16 out 27) reported regularly using technology in coaching.

When the participants were asked to prioritize coaching goals, the results suggest that emotional aspects such as "having a good relationship with your athletes" or "observing relative improvement in performance" were the most important goals (see Table 2).

Table 2. Rank order (1-14) of goals according to the present sample of coaches in different sports

Goals	Scores			
	Mean	**S.D.**	**Median**	**Mode**
Having a good relationship with your athletes	2.74	3.18	2	1
Observing relative improvement in performance	3.89	2.94	3	1
Understanding how the body functions during exertion	4.84	2.52	5	7
Using scientific knowledge to become a better coach	5.26	3.28	4	3
Understanding the theoretical basis of performance	5.53	2.74	5	4
Using the services of science and medicine to prevent overuse injuries	6.32	3.28	6	6
Using technology to improve performance	6.47	3.15	6	4
Monitoring seasonal changes in performance using objective devices	7.32	2.96	7	10
Measuring performance very precisely and applying the results	8.26	2.73	8	8
Winning medals and championships	9.42	3.53	9	9
Sharing your achievements as a coach with a scientific team	10.26	3.38	11	14
Receiving positive public coverage of your athletes	10.63	2.19	10	10
Letting sport scientists deal with the problems and questions you pose	11.84	2.19	13	13
Mastering a computerized instruction program for coaching	12.21	1.72	12	12
Winning medals and championships	9.42	3.53	9	9
Using the services of science and medicine to prevent overuse injuries	6.32	3.28	6	6
Using technology to improve performance	6.47	3.15	6	4
Using scientific knowledge to become a better coach	5.26	3.28	4	3
Understanding the theoretical basis of performance	5.53	2.74	5	4
Understanding how the body functions during exertion	4.84	2.52	5	7
Sharing your achievements as a coach with a scientific team	10.26	3.38	11	14
Receiving positive public coverage of your athletes	10.63	2.19	10	10
Observing relative improvement in performance	3.89	2.94	3	1
Monitoring seasonal changes in performance using objective devices	7.32	2.96	7	10
Measuring performance very precisely and applying the results	8.26	2.73	8	8
Mastering a computerized instruction program for coaching	12.21	1.72	12	12
Letting sport scientists deal with the problems and questions you pose	11.84	2.19	13	13
Having a good relationship with your athletes	2.74	3.18	2	1

"Mastering a computerized instruction program for coaching" and "letting sport scientists deal with the questions and problems you pose" were rated as the two least important priorities.

Discussion

Attempts have been made to use computer-aided instruction for physical education and sports, but only in the last fifteen years has it become more popular with the development of easy-to-use computer applications and the wide-spread availability of personal computers

(Colman & Persyn, 1992; Raz Liebermann & Liebermann, 1992). These researchers observed that sport coaches tended to be conservative about using computerized modeling and simulation as tools for improving performance in competition (Dobrov & Liebermann, 1992).

Most of the coaches in the current study were considered to be at the elite level, and had access to university facilities and professional resources. While they indicated comfort with the application of computers for personal use, most of them rated 'mastering a computerized coaching instruction program' very low in the prioritized goals, and only 60% of them were using computers significantly in the training of their athletes. These findings are surprising in light of the expressed positive attitudes towards computer programs and acknowledgement that computer technology and software applications contribute to better coaching and better results in competitions. One possible explanation is that previous coaching education did not include the use of computerized coaching instruction and sport technology tools. While coaches indicated much interest in integrating sport science and technology, formal education may not have provided them with the elements necessary to use scientific and technological knowledge in an independent manner, that is, without the intervention of scientific experts and technicians. As a consequence, they have developed alternate strategies for success (in the sense that they are based on a social and psychological folk knowledge) rather than strategies based on objective data collection, analysis, and scientific knowledge combined with the other aspects that are no less important.

Some effort has been made in the last few years to improve information technologies and notational analyses tools, and to encourage coaches not only to use them, but to develop the technologies in accordance with their knowledge of competitive sport performance (Hughes & Franks, 2004). Since having a good relationship with their athletes was chosen as one of the most important goals, it is not surprising that coaches generally placed greater emphasis on psychosocial factors than on other physiological or biomechanical factors. The psychosocial factors are inherent in the relationship between coaches and athletes during training and competition, and are often important for maintaining the coach's personal status. It is the status of coaches that succeed in competition that helps shapes the attitudes and strategies of other coaches, particularly those with less senior status. In this study, the responses of a group of successful and highly qualified individuals have suggested that technology and science are not used as much as one would expect, despite their:

- availability;
- use for other purposes; and,
- the expressed positive attitudes of coaches.

Given the influence of senior coaches on younger ones, it is important to increase efforts to influence the actions of these senior coaches. Therefore, in order to change the attitudes and behavours of young coaches, it is first necessary to change the practices of senior coaches as they relate to science and technology.

The findings in this study are based on a relatively small sample of successful and experienced sport coaches and, therefore, results and suggestions should be interpreted with this in mind. Individuals in this group were generally experienced and highly educated (mean coaching certification level was 3) and most were very active coaches in Canada. Some of the participants coached Olympic athletes and world-record holders at the national level that would allow them to exert a great influence on less experienced coaches. Even though these high-level coaches have achieved success, they should be targeted to receive education that would close the gap between technology and its implementation in sports simply because this population is the best marketing agent available for convincing younger and less experienced coaches that the objectivity of sports science and IT, are the future of efficient competitive sports.

Conclusions

The authors' data indicates that highly experienced and successful coaches perceive both technology and sport science as playing an important role in coaching and achieving excellence in their athletes' performances. However, the variance in responses to items related to the role of technology and science in sports indicates that this opinion is not uniform. The use of science and technology in sports may depend on a variety of factors including a coach's prior education level, source of income (i.e., coaching as a professional versus as a volunteer), access to technology and science consultants, and previous experience with technology. Based on follow-up interviews, it seems many coaches are unaware of the vast technologies available or even how to use them, despite the evidence that appropriately applied technologies are invaluable resources for coaches and athletes (Katz, 2001).

In competitive sports, it is often not what is said that is important, but rather, who is saying it. Top, successful, national and international coaches are "raw professional models". Frequently, they are also involved in the education of younger or less qualified coaches in many countries. The attitudes of highly qualified coaches do spread in a top-down direction within the coaching hierarchy. Thus, their attitudes towards information technology and sport science would strongly shape trends among less qualified coaches.

While attitudes towards technology seem to be very positive, it is necessary to find strategies that will encourage coaches to use scientific knowledge and technologies in their practical work. Coaches can also influence their athletes to use technology. Sport scientists are frustrated that their knowledge, research, and development efforts are not being recognized and used. Any strategy requires a focus on the needs of coaches, athletes and sport scientists. Moreover, the cost, time, and practical issues associated with "keeping up" with evolving trends and technologies need to be factored into the equation.

The findings in this study suggest that an essential part of any coaching education protocol should include an emphasis on the use and impact of technology and science in sports as well as the role of sport scientists. In addition, for a more immediate impact, it is suggested that practical education on science and technology should be given first to successful and highly experienced coaches because they are the carriers of a message that can perfuse by example and imitation to less senior individuals. Perhaps technologies that enhance the relationship between coach and athlete would be a good starting point.

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Game Intelligence Analysis by Means of a Combination of Variance-Analysis and Neural Networks

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Abstract

In order to evaluate performance data from games, normally qualitative and quantitative methods are used separately. The aim of this contribution is to demonstrate that the combination of net-based qualitative analyses and stochastic quantitative analyses can improve the information output significantly. The stochastic approach reduces the total of recorded data to only a few statistical quantities, which are not necessarily data-specific. In contrast, neuronal networks – considering data to be high-dimensional points that correspond to neurones – can (e.g.) be used to extract specific striking features on the original data (see Schöllhorn & Perl, 2002).
This approach will exemplarily be demonstrated using data from a BISp-sponsored project that was run by Roth and Memmert (2003). In this field-study, sport-specific training concepts were compared with non-specific ones, dealing (e.g.) with the game intelligence of about 150 children from two measuring points (MZP). The convergent reference numbers were determined by means of concept-oriented expert ratings (3 evaluators) using three game-test-situations with two rotations each (see Memmert & Roth, 2003).
Using dynamical adaptive neural networks ("DyCoN"; Perl, 2000) allows for simultaneous processing of 12-dimensional attribute vectors (2 MZP x 3 evaluator x 2 rotations) instead of 2-dimensional aggregated vectors – avoiding reduction of semantic structures and information.

This way, by means of

- visual evaluation of data distribution projected to the net structure
- analysis of inter- and intra-individual correspondences

useful information become available which can hardly or not be obtained from variance-analyses.

The existing evaluations suggest that DyCoN, similar to the case of convergent performance attributes, will also be successful in the divergent case.

KEYWORDS: GAME ANALYSIS, STOCHASTIC QUANTITATIVE ANALYSES, NEURAL NETWORK, GAME INTELLIGENCE, CREATIVITY

Introduction: knowledge transfer in game analysis

Over the past years there has been an increasing demand for installing interdisciplinary projects which bring institutes from different fields of research into collaboration. This tendency is based on the expectation that new results, even in individual disciplines, depend more and more on a fruitful transfer of knowledge.

"Vielmehr ist die dauerhafte Institutionalisierung solchermaßen integrativer und technologisch ausgerichteter wissenschaftlicher Arbeitszusammenhänge ebenso erforderlich wie die Institutionalisierung eines solchen Wissenstransfers, der Evaluation und der Implementation von wissenschaftlichen Befunden in die Trainingswirklichkeit."(Daugs, Mechling, Blischke & Oliver, 1991, S. 27)

It is to be expected that in the case of well-structured and successfully run research paradigms in especially, additional potential is available from interdisciplinary collaboration – particularly by a creative exchange of methods.

Team game research and game analysis have played an important role in the field of sport science for a long time (for a review see Hohmann, 2004; Hohmann & Lames, 2004; Hossner, 2004; Memmert & Roth, 2003; Schöllhorn & Perl, 2002). They could be described as well-structured research paradigms. In order to evaluate performance data from games, qualitative and quantitative methods are normally used separately. The aim of this research project is to demonstrate that the combination of net-based qualitative analyses and stochastic quantitative analysis can improve the information output significantly. The stochastic approach reduces the total of recorded data to only a few statistical quantities and checks their significance by means of variance analysis. In contrast, neural networks – considering all available data to be high-dimensional points that correspond to neurons – can be used to extract specific striking features and qualitative trends on all original data.

At the University of Heidelberg, on the one hand, the focus is on the education of beginners and talent development in the area of games, with non-specific creativity and game intelligence as main points. A BISp-sponsored field experiment generated longitudinally structured data with five different kinds of treatment and convergent and divergent tactical game performance as dependent variables (see Section *Data Material*). Appropriate methods for additional differentiated analyses are currently not available.

At the University of Mainz, on the other hand, a type of Dynamically Controlled Network ("DyCoN") has been developed, which can be used for the analysis of adaptive processes, among other things. Normally, a Neural Network responds primarily to frequent data and ignores infrequent data. In a next step the DyCoN-concept will be completed by the ability to also react to infrequent but relevant data, such as creative behavioural patterns of players in a game (see Section *Method of Solution*). To this end, a large amount of sufficiently reliable data with a large statistical spread is necessary for validation and calibration.

This research project will make plain that there are a number of synergy effects that can be expected from a combination of both approaches (see Section *Research Strategy*). The initial results are presented, which demonstrate that convergent results obtained using the stochastic approach can be replicated using neural networks. Furthermore, we were able to detect additional interesting aspects that were not open to the stochastic approach (see Section *Exemplary Implementation*). It will be shown that the results of such an interdisciplinary collaboration are not limited to convergent performance attributes, but that they also can be most useful in the intended validation of the creative learning model of DyCoN (see Section *Further Research*).

Data material: A field study based on game intelligence and creativity

This approach will be demonstrated exemplarily using data from a BISp-sponsored project (VF 0407/06/12/2001-2002) that was run by Roth and Memmert (2003). In this field experiment, sport-specific training concepts were compared with non-specific ones. In addition to the general non-specific basic training (N = 54), a handball-specific (N = 13) and soccer-specific training concept (N = 20) and a mixed training model (N = 16) in the area of mini-hockey – 50 % non-specific and 50 % hockey-specific content – were included. The control group consisted of first-year primary school pupils (N = 17). The starting age selected was relatively consistent at an average of 7.2 years (SD: 0.9).

The dependent variables are non-specific creativity and game intelligence. They are measured at two points over six months. Furthermore, divergent and convergent characteristics are ascertained in the game situations Using gaps and Supporting and orienting using concept-oriented expert ratings. Game test situations are tasks in which particular tactical behaviour is provoked reliably and regularly by presenting the game idea, the number of players and rules and environmental conditions (see Memmert & Roth, 2003). It is essential that distribution of the positions be changed systematically by rotating the positions twice for each subject. As such, hand, foot and hockey stick are used one after the other in a random sequence. The performance of the children in the game test situations was recorded on video tape and evaluated using a subsequent concept-oriented expert rating. This means that (i) fixed characteristic definitions and scalings were given for the experts, (ii) they were trained with special video tapes and (iii) they had to make a final video-based test to check their expert coding qualities. Only those experts with a high reliability as measured against a golden standard of experts in ball games were chosen. The children in the game test situations were each judged by three experts in ball games. These values were later averaged. Extensive preliminary studies validated this diagnosis inventory with regard to the classic quality criteria (see Memmert, 2004).

Only the pattern of results for game intelligence shall be discussed below (see Figure 1, left). In the study, more than 90 % of the objectivity coefficients (intra-class correlations) for the game test situations are above the value of 0.80. The development of the convergent increases in learning determined via the two dependent variables and the three forms of performing motor functions is shown in Figure 1 (left). A general training effect is evident here ($F(1,219) = 10.15$; $p < 0.01$, $h2 = .04$). The various types of treatment caused differing increases or decreases in performance ($F(4,219) = 3.78$; $p < 0.01$, $h2 = .07$). Furthermore, average differences in performance were found between the groups which could not be attributed to coincidence alone ($F(4,219) = 10.46$; $p < 0.001$, $h2 =.16$). However, only the mixed ($p < .0001$) and soccer-trained ($p < .01$) groups made a significantly greater improvement compared with the control group. It must be mentioned here that the performance of the children at the pre-test varies ($F(4,220) = 12.18$; $p < 0.001$, $h2 =.16$). As is only to be expected in a training experiment under field conditions, the varying levels of previous experience complicate interpretation. However, no changes in the results can be identified when the results of the pre-test act as a covariable.

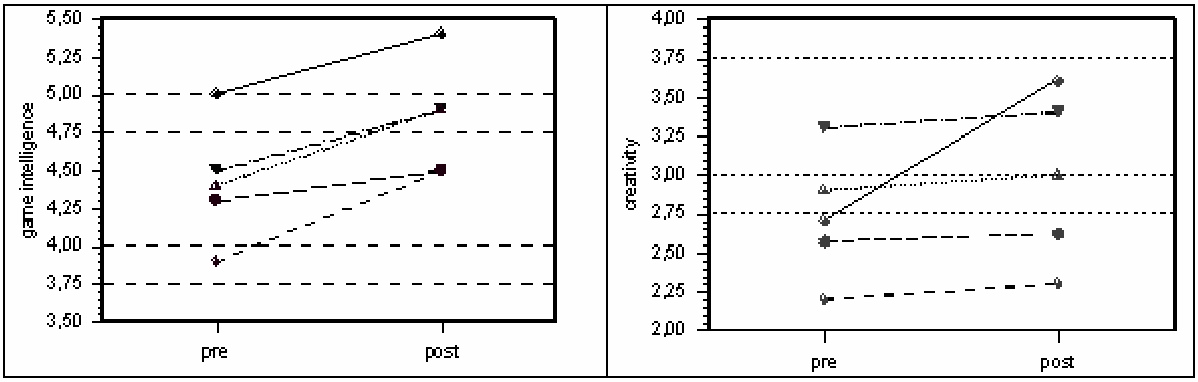


Figure 1. Convergent (left) and divergent (right) non-specific increases in learning between the first and second measuring points (non-specific = – – –; specific handball = ××××××××××; specific soccer = – × – × –; mixed = ———; control group = – – – –)

Method of solution: qualitative analyses with DyCoN

The above mentioned DyCoN is a type of Kohonen Feature Map (KFM), the training of which is normally controlled by external functions which guarantee that a final state is achieved (cf. Mc Garry &Perl, 2004). This approach is helpful when training a network statically to be used as a tool. It is not helpful if the aims are to learn dynamically, adapt to changing situations and analyse learning processes. Therefore each DyCoN neuron contains an individual learning self-control, which was originally developed as an autonomous model for physiological adaptation (cf. Perl, 2003). In this way, the network is always in a well-defined non-terminal state. The consequences and advantages of this concept are as follows (see also Perl, 2002; Schöllhorn & Perl, 2002):

- Training steps and test steps do not have to be separated into different phases but can be combined arbitrarily. Temporary states of the network can therefore be watched during the training process - and can be influenced by appropriate training data if necessary.
- A training process can be interrupted and continued arbitrarily. Data on time-dependent patterns can be trained repeatedly to increase the quality of pattern recognition adaptively.
- In the case of small amounts of data, which are not normally sufficient for network training, the network can be pre-trained with an unlimited amount of Monte Carlo-generated data, the structure or distribution of which follow that of the original data (Perl, 2002). The training is then completed by a second phase, in which the network is specifically moulded using the original data. This method has been used successfully in several projects when the structure of the data was well-known, but the amount of original data was too small (cf. Lippold, Schöllhorn, Perl, Bohn, Schaper, & Hillebrand, 2004; Perl & Weber, 2004).

In order to study interactive learning processes and develop training strategies (e.g. completing learning vs. replacing learning), different patterns can be trained to the same net in different phases. Moreover, there are four reasons that make clear why neural networks should be used and developed in order to analyse particular aspects of divergent performance.

- Neural networks of the KFM-type are of importance if data have to be classified without any a priori information on the given cluster structure – as is typically the case with data from convergent or divergent tactical game performance.
- As has been pointed out by projects, neural networks of the DyCoN-type are of specific importance if the amount of data is small and data profiles and/or cluster structures change dynamically in time – as is the case with the available project data, which is recorded from only a medium number of subjects over a time interval of six months.
- In addition to the advantages mentioned above, neural networks – unlike stochastic methods – allow for qualitative evaluations, which can be deduced from spatial (topological cluster representation) or temporal (trajectories) structures of the network.
- In particular, the intended completion of DyCoN with regard to associative clusters, bridging neurons and semantic relevance (see Section *Further Research*) enables us, in addition to quantitative stochastic methods to analyse qualitative phenomena, such as creative performance.

Research strategy: "win-win-situation"

In addition to a replication of the results of the BISp-project, the application of neural networks to the BISp-data from Section *Data Material* allows for a deeper understanding and yields new intuitions. As will be made clear below, there are advantages in both directions: On the one hand, the BISp-data builds a valuable basis for the development of the adaptive network concept. On the other hand, networks can to provide a more differentiated interpretation of the BISp-data. Moreover, they can produce additional information, which can help to structure new experiments. Firstly, the reasons as to why the BISp-data serves as a good basis for developing neural networks are listed below:

- One central point is the fact that specific research into divergent learning behaviour yields data, which is excellently suited to the particular purpose of validating the intended creative learning model of DyCoN (see Section *Further Research*). As far as we know, a sufficient amount of such data is only available from our project. In this paper, however, the data initially serves only to replicate the convergent results of the BISp data (see Section *Exemplary Implementation*).
- Moreover it should be mentioned that the necessary conditions for the applicability of those networks – namely that the characteristic attributes are scaled relative to a not too large scale – in the case of the BISp-data are given in an excellent way.
- As is shown in Section *Data Material*, there are 6 pieces of data available for each tactical performance and child (i.e. 3 experts ´ 2 player rotations per tactical behavior and child), which means a 12-dimensional attribute vector for both measuring points in time. These vectors form the patterns that have to be learned and, later on, recognized by the network. The vector dimension "12" on the one hand is large enough to spread a sufficiently differentiated pattern space during the network training. On the other hand, the dimension is small enough to guarantee a sufficient representation of the original patterns by the network. Therefore the data configuration fits the demands of a successful network analysis perfectly.
- A further advantage regarding the application of DyCoN is the statistical spread of the BISp-data. This spread enables – particularly when only a small amount of

original data is available – the DyCoN method of pre-training with stochastically generated data, followed by a specific moulding with the original data (see Section *Method of Solution*). Due to the study design described in Section *Data Material*, a sufficiently large variance regarding the dependent variables (four tactical performances) and independent variables (five different kinds of treatment) is given.

Furthermore, networks present possibilities for qualitative evaluation of the data material, which conventional variance analyses offer only restricted form, if at all:

- Simultaneous processing of 12-dimensional attribute vectors (2 measuring points ´ 3 experts ´ 2 rotations) – instead of the 2-dimensional vectors of the aggregated values – creates a data situation which permits more information on the divergent and convergent tactical development of the children. Aggregate indicators are no longer actually included in the calculations, but rather three experts' evaluations for each of the two measuring points at both rotations (see Section *Exemplary Implementation* for more detailed information). Increasing the dimensions from 2 to 12 enables a more complex interpretation of the pattern of results (see Section *Exemplary Implementation*).
- In short, this allows for qualitative interpretation that completes quantitative evaluations. This means that an additional gain in knowledge is not limited to the recognition of basic principles, but moreover and in particular that it can be most useful for practical applications.
- For example, the graphical representation makes it apparent that the spectrum between very good and less good performances can be represented almost in its entirety (see Section *Exemplary Implementation*). In this way the neural networks can illustrate mean variations in the behavior data.
- It is possible that neural networks could be used to visualize the time-dynamic development of learning processes and – not least through the aforementioned reduction to 2-dimensional trajectories (see Section *Exemplary Implementation*) – make these processes accessible for further analyses investigating inter- and intra-individual correspondences.

To sum up, by means of visual evaluation of data distribution projected onto the network structure and analysis of inter- and intra-individual correspondences, useful information made available, which can rarely be obtained from variance-analyses, if at all. First of all, the use of neural networks for the replication of convergent tactical performances is considered. Checks are made to ascertain whether further information on the data material can be gleaned using this method (see Section *Exemplary Implementation*). Not until a second stage are networks conceived that can evaluate divergent performances (see Section *Further Research*).

Exemplary implementation: game intelligence with DyCoN

Initial tests and plausibility approaches suggest analyzing the convergent tactical behavior separately with regard to the types of execution. Figure 2 below shows the advantages of combining the network approach and the variance-analysis approach. The top left section of Figure 2 shows a set of typical original data. Three experts, two player rotations and two measuring points in time give a 12-dimensional attribute vector.

Firstly, the dependent variable Supporting and Orienting (convergent tactical behavior; motor performing "hockey stick") shows a result pattern similar to that obtained using conventional methods. As can be seen from the increased frequencies in the green areas, the network approach indicates an improved formation of game intelligence in the case of the non-specific trained model (see Figure 2, top right). This result corresponds to the significant (percentage) increase of convergent tactical performance, which is maximal in the "mixed" training group ($F(1,53) = 9.732$; $p < 0.01$, $h2 = .16$; see Figure 2, top right and below). In contrast, the control group – for both methods – shows a small decrease in the convergent tactical performance ($F(1,16) = 4.548$; $p < 0.05$, $h2 = .22$; see Figure 2, middle and below). A decreased performance is represented by high frequencies in the red areas.

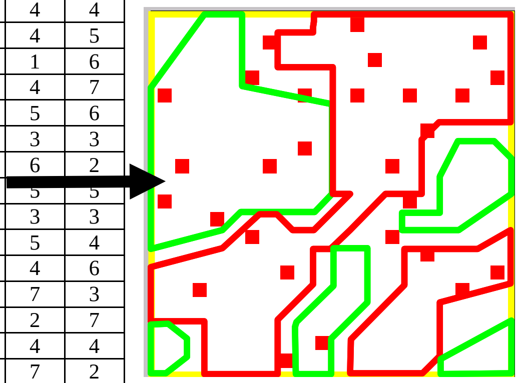
Secondly, the graphical representation of the neural networks for the non-specifically trained group illustrate that larger mean variations in the twelve behavior data are present here (see Figure 2, top right). This can be seen from the distribution of "hits", which build a large number of small centres of low frequencies spread over the whole network, apparently representing the spectrum between very good and less good performances almost in its entirety. Interestingly, however, the tactical development of the non-specific trained children proves to be much more heterogeneous than that of the mixed trained children – although the percentage of improvement is almost equal (see Figure 2, middle left). So size and distribution of the neurones together with their correspondences to the clusters give an idea of the quality of the training results and help to detect striking features, such as specific similarities or differences.

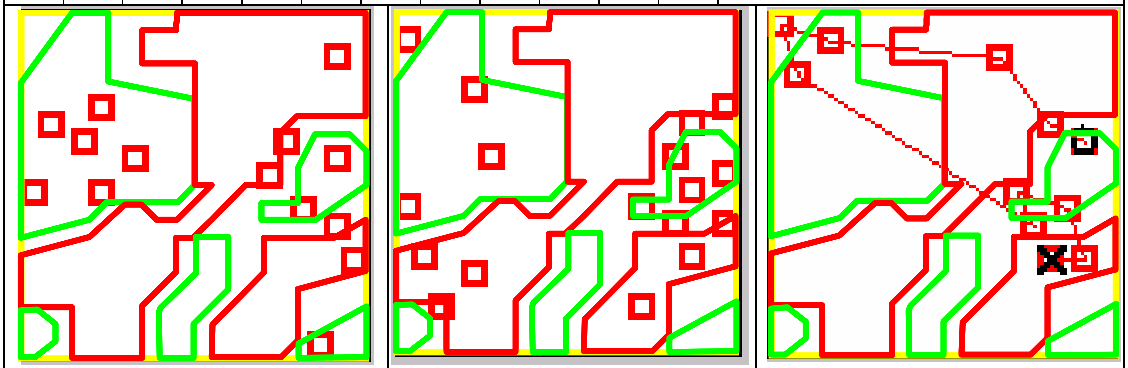
Thirdly, Figure 2 shows a trajectory that represents a training process (middle right). Starting with "o", the time-steps of the training process move through the areas of the network, indicating successful (green areas), unsuccessful (red areas), or indifferent (yellow areas) phases of the training. In the example given, the subjects' performance decreases at first (which could be interpreted as a super-compensation effect), then improves (green areas, above left and middle right), but in the end at step "´" is worse than at the beginning. Such a process-oriented presentation of the result might help to detect problems and find reasons. In this particular example, this could be due to the fact that that the whole training process was not optimal, only temporarily resulting in improved performance. This way, clusters together with trajectories can help to recognize qualitative features and analyse process dynamics.

To sum up, the neural network was able to replicate the BISp-results mentioned above and demonstrate the advantages of network-based qualitative analysis in addition to quantitative stochastic analysis. The stochastic approach reduces the totality of recorded data to a very small number of statistical parameters, which moreover are not necessarily data-specific. Variance analysis can, however, be used to check the significance of changes in the data. In contrast, it should be pointed out that network-based analysis allows for mapping the 12-dimensional time-dependent process structure to 2-dimensional trajectories without destroying topological and qualitative structures such as similarity and connectivity. This enables interpretable representations of time-dependent learning processes as well as improved visual judgement of distributions. The mapping of the complete data set to the type structure of the network allows for recognition of specific data structures and striking features, which can also be helpful in developing new ideas and theories.

Further studies have to prove whether the individual convergent results of the subjects produced by the neural network agree with the ANOVA results. For example, you could use

6	2	2	2	3	3	4	5	5	5	1	4
7	3	3	7	3	3	1	2	5	3	7	3
1	2	6	2	1	1	4	4	4	4	4	4
1	3	3	1	3	3	3	6	6	5	4	5
1	1	3	3	3	3	4	1	3	3	1	6
1	1	1	2	2	2	1	3	6	3	4	7
2	2	6	2	2	2	4	4	4	6	5	6
6	3	3	3	1	1	2	5	7	5	3	3
1	2	3	3	3	3	7	2	3	3	6	2
2	6	6	3	5	5	5	5	5	5	5	5
3	3	2	7	5	5	5	3	3	6	3	3
3	3	3	3	4	2	6	4	4	5	5	4
6	2	6	6	4	5	4	6	6	6	4	6
5	7	7	7	3	7	5	3	7	7	7	3
3	2	6	3	5	6	7	3	3	7	2	7
2	2	6	6	4	2	6	4	5	2	4	4
4	6	6	2	5	7	1	2	2	1	7	2
7	3	1	7	7	7	7	3	1	4	5	7





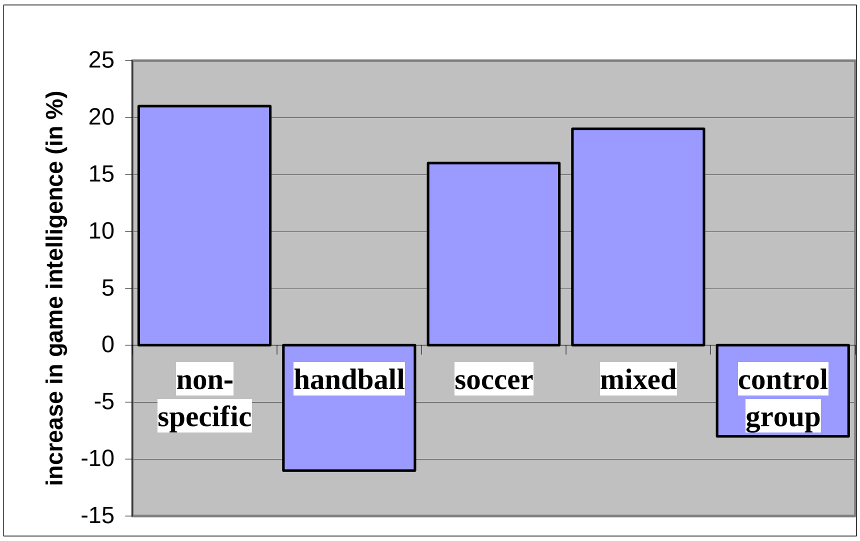


Figure 2. Data matrix of the learning behavior and its mappings to the network: "non-specific" (top right), "mixed" (middle left), "control group" (middle) a representation of a trajectory (middle right). Below: Percentage increases of the convergent tactical behavior SUPPORTING AND ORIENTING with the motor performing "hockey stick". The sizes of the neurons in the network representation map the frequencies with which the corresponding constellations appear in the test data.

kappa coefficients to compare declining, unchanged and improving subjects according to the network-based qualitative and quantitative stochastic analysis. Another way to analyse the correctness of individual improvement of subjects is to generate quantitative network-based data and compare them to the ANOVA results. You could use 95% limits of agreement on the two sets of data to assess systematic bias and random errors.[1]

The results obtained in this project suggest that, like the case of convergent performance attributes, properly adapted versions of DyCoN may also be successful in divergent cases (see Section *Further Research*).

Further Research: DyCoN next steps – creativity

Based on the activities presented so far, a new approach will be developed, which – besides the quantitative relevance of situations and actions (e. g. frequencies) – also takes the qualitative relevance into consideration, which can help to make "creativity" an object of analyses and learning strategies. Two main aspects of opening the network approach to "creativity" are those of "association" and "relevance" (Perl & Uthmann, 2002).

The first aspect deals with association. Let us assume a behavioural process to be a sequence of situations that have to be recognized and corresponding activities that have to be selected. In a net-based simulation, KFM or DyCoN type networks are responsible for the recognition of situations, which are encoded and presented by the clusters. Network learning is normally described and handled by means of "if then" rules – i.e. if the recorded data belong to a certain cluster then the corresponding situation is unambiguously determined, and so is the activity that corresponds to that situation (see Figure 3, above graphic). Using this concept there is no room for associations like "The data belong to cluster A but have a strong affinity to cluster B. Therefore let us try the activity corresponding to B instead of that corresponding to A". In turn, a concept that takes into account aspects of association has to connect clusters by associative bridges instead of strictly separating them (see Figure 3, below graphic).
A second aspect that is normally used in network training is that of frequency-based relevance – i.e. data are more relevant and the corresponding clusters are bigger the more frequently they appear in the set of training data. This concept contrasts with that of information theory where the information of an event decreases with the number of its appearances – i. e. a frequent event is not surprising. Transferred to behavioural processes, the consequence is that even seldom situations can be of high semantic relevance because they can trigger spontaneous and/or unexpected activities.

The question is how "association" and "relevance" as aspects of creativity can be transferred to an appropriate network model. This approach is not currently in use but is only projected. The main ideas of how it should work are sketched in Figure 3. In the top graphic, the usual method is shown as described above – i.e. in a first step the situation is recognized by its characteristic data corresponding to a specific cluster, which it is connected with by a horizontal edge. In a second step, the recognized cluster can trigger the corresponding activity, which it is connected with by a vertical edge.

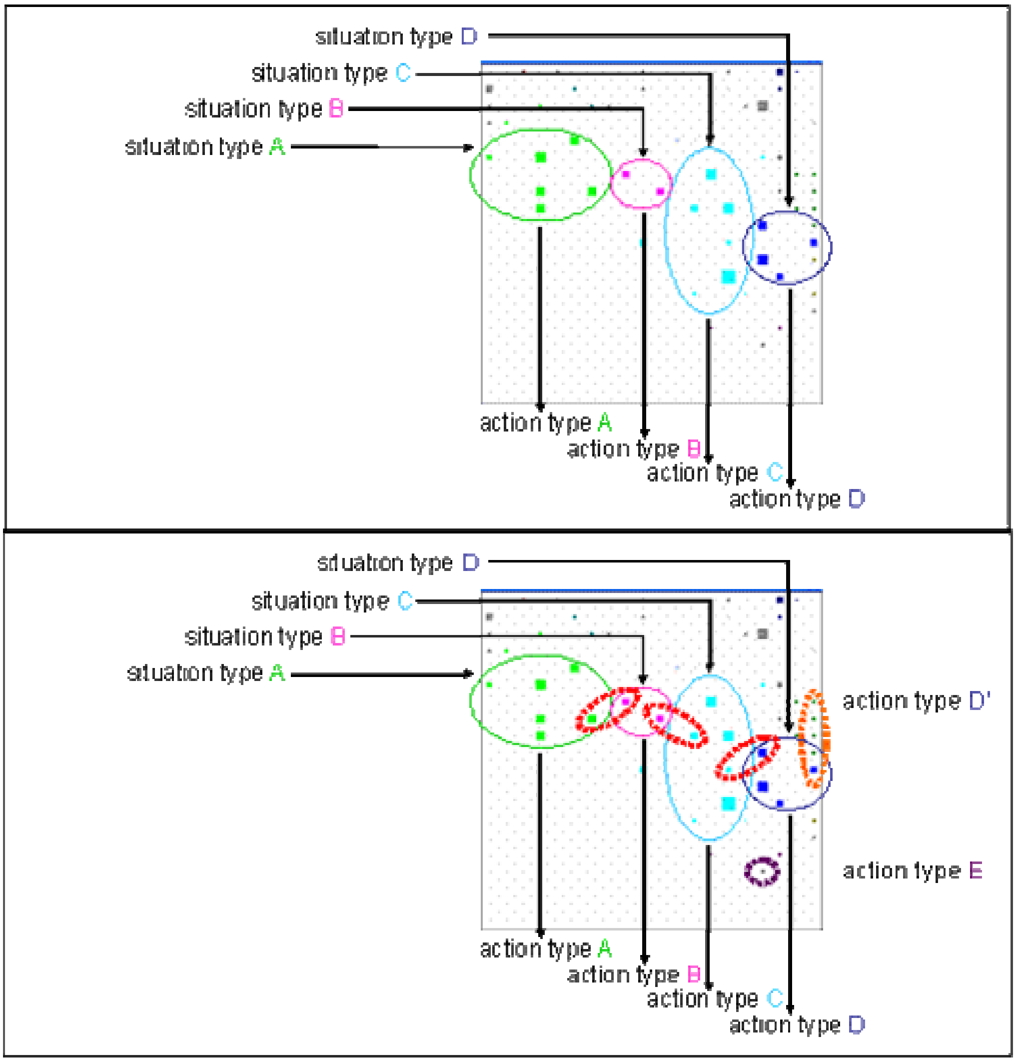


Figure 3. Normal convergent behaviour (top graphic) compared to divergent creative behaviour (bottom graphic): Associative bridges (dotted ellipses) allow moving between clusters, causing unexpected activities. In particular, small but semantically relevant clusters can become important. (The horizontal and vertical edges symbolize the correspondences between situations, clusters, and actions; see explanations in the text below).

In the bottom graphic, different ways of making "creative" decisions are shown. The first is that of associative bridges (dotted red ellipses), which connect clusters with each other and so allow for moving between clusters and changing decisions regarding the appropriate activity (see action types A', B', C', D'). The second is that of associations from frequency-relevant clusters to semantically-relevant ones (dotted orange ellipse), causing unexpected activities (see action type D'). The third method is that of spontaneously jumping to a semantically-relevant cluster or neurone without having any associative bridge (dotted violet ellipse), causing unexpected and surprising activities (see action type E). This could finally help in deeper analyses of divergent tactical behaviour in the BISp data similar to that dealt with the results in Section *Data Material* (see Figure 1, right).

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[1] Thanks to an anonymous reviewer for pointing out this further analysis method.

Virtual Visualization: Preparation for the Olympic Games Long-Track Speed Skating

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Abstract

Visualization is a known preparation tool for athletic competition. This study used a virtual environment of the Salt Lake City Olympic Oval as a tool to support visualization to help athletes prepare for the 2002 Winter Olympic Games. Five long-track speed skaters from the Canadian Olympic Team used the virtual environment with their sport psychology consultant to prepare for the Olympics prior to leaving for Salt Lake City. All five skaters had previously visited the competition venue and found the virtual environment to be very realistic. In addition, skaters commented that they had struggled with visualization and, consequently, they thought that having the virtual venue provided for them was very useful. After using the environment, athletes indicated that they felt less anxious about going to the Olympics. Experiencing the virtual environment allowed them to focus on their race, how they would prepare for the race, their race plan, and what they would think about while competing in the race. The results of this study promote the use of virtual environments for enhancing athlete visualization. Moreover, the study identifies four ways in which virtual environments can be used by athletes in preparation for competition, as well as part of their regular training program.

KEY WORDS: VIRTUAL ENVIRONMENTS, ATHLETE, TECHNOLOGY, ATTITUDES, VISUALIZATION

Introduction

“Visualization, can…help athletes conquer fears, build confidence and expand their limits” (Telch, 1990, p.71). Visualization (also referred to as mental imagery) is conducted by imagining the performance environment, creating a mental picture of it, and imagining what it is like to perform in that environment (Hall, 1998; Martin, Moritz & Hall, 1999; Sugarman, 1999; Wann, 1997). While a sport psychologist or sport psychology consultant often aids the athlete in visualizing their performance, many accomplished and experienced athletes are able to visualize successfully on their own. Research has found that athletes tend to visualize more in preparation for competition than for training (Barr & Hall, 1992; Hall, Rodgers & Barr, 1990; Salmon, Hall & Haslam, 1994). When preparing for a specific competition, the athlete will attempt to visualize the unique factors that he or she will face during a successful performance in the competition venue. Some of those unique elements within the speed skating competition environment such as, the colour of the bumpers, the position of the timing clock, the crowd placement, and the acoustics, are difficult to visualize successfully even if the athlete has performed in the venue on many occasions. Practicing in a virtual environment of the competition venue enables the athletes to familiarize themselves with those unique aspects. Much anecdotal evidence supports the theory that previously having viewed and performed in a venue reduces anxiety when competing in that same venue (Martin et al., 1999; Sugarman, 1999). Sugarman describes how the Russian coaches used photographs of the venues at the 1976 Montreal Olympics to acclimatize their athletes prior to the Olympics. The athletes felt more comfortable, and were able to focus solely on their performance, because they knew what to expect.

Research has found that visualization techniques enhance performance in a number of different sports, from team sports such as, basketball and soccer, to individual sports such as, track and field and figure skating (Rogers, Hall & Buckolz, 1991; Salmon et al., 1994; Templin & Vernacchia, 1995; Ungerleider & Golding, 1991). Although speed skaters have reported finding visualization useful, there is no empirical evidence to support this. Some studies have found that although visualization focuses on the mental aspects of performance, there is also a physical training component (Jacobsen, 1930; Vealy & Walter, 1993). Vividly imagined events have been shown to produce innervations in muscles similar to those produced during the actual physical activity (Jacobsen, 1930) that can, in turn, strengthen muscle memory (Vealy & Walter).

To maximize the effects of visualization, Templin and Vernacchia (1995) recommend combining self-modeling with visualization, where the athlete uses video of a performance to aid in creating a positive mental image of a successful performance. In other activities where there are physical dangers in learning to perform a skill such as, landing an airplane, driving a car, or operating an army tank, computer simulations and virtual environments have been used to help train the individual to cope with the performance environment (Phillips Mahoney, 1995). Computer simulations are often referred to as virtual reality (VR); an alternate world filled with computer-generated images that respond to human movements (Broida & Clark, 1999).

The purpose of this study was to examine the use of a virtual environment as a tool to help prepare athletes for long-track speed skating at the Salt Lake City Winter Olympic competitions. Specific research questions included:

1. How is the environment used?
2. How does the environment aid preparation? and
3. How would athletes envision using the environment for future training and competition preparation based on their experience in the environment?

A computer generated virtual speed skating oval was created by the researchers using Sense8 WorldUp R5 software (http://sense8.sierraweb.net/) based on photos and a structural drawing from the Salt Lake City Olympic Oval project. This virtual environment was then made available to athletes through their sport psychology consultant as an optional part of their visualization training in preparation for the 2002 Winter Olympics. This research highlights ways in which athletes can use such a tool and how it can be beneficial in mentally preparing athletes in conjunction with a sport psychologist.

Real Environment Virtual Environment

Figure 1. Figure to show the real environment compared to the virtual environment of the Salt Lake City Olympic Oval

Methods

All athletes on the Canadian National Long-Track Speed Skating Team (like most elite athletes) have access to a sport psychology consultant. As part of the research, the sport psychology consultant offered the athletes the option of using the virtual environment of the Salt Lake City Olympic Oval in conjunction with their visualization training. There were no preconditions for participation, and choosing not to participate had no impact on an athlete's access to the sport psychologist.

Five athletes chose to view the virtual environment and each met with the sport psychologist in the Virtual Reality Lab. In order to maintain the integrity and confidentiality of the session, only the athlete and the sport psychology consultant were present for the appointment. During the session, no restrictions were placed on the athlete in the VR environment. The athletes were free to decide if they wished to view or enter the virtual environment, what they did within the environment, and how long they spent in there. In addition, they could choose to stop participation at any time.

During the session, the consultant, a trained researcher in qualitative methodology, made detailed written observations (standard practice during a sport psychology appointment). The observations were focused on five specific elements of the session.

These included:

1. How the athlete felt at the beginning of the session.
2. How the athlete chose to use the virtual environment.
3. How the athlete reacted to the environment.
4. How the athlete felt during their time in the virtual environment.
5. How the athlete felt at the end of the session.

On return from the Olympics, those athletes who had used the virtual environment were asked if they would attend a debriefing session. The debriefing session was conducted by the sport psychology consultant who asked specific questions about how the athlete now felt about being able to prepare in the virtual environment, how this opportunity had impacted their performance at the competition, what improvements could be made to the environment, and other ways in which, in retrospect, they felt the virtual environment could be used.

Results

In total, five athletes (male=3, female=2, mean age= 25) chose to view the virtual environment as part of their psychological preparation for the Salt Lake City Olympic Games. Unfortunately, due to competition schedules, some athletes were only able to view the environment once, whereas other athletes viewed the environment up to three times prior to leaving for the Olympics. All five athletes participated in the debriefing after the Olympics.

Overall Impression

All of the athletes felt that the virtual oval was a very realistic representation of the competition venue. All the skaters had been to the venue at least once for a training camp and, therefore, they had some experience skating on the oval in Salt Lake City. Many of the skaters also commented on the difficulty that they have with visualizing themselves competing in the venue. One skater commented that using the virtual oval was like visualizing with his eyes open. A number of the skaters found the virtual oval helped them with their visualization as they no longer had to rely on their ability to create the images in their head. Consequently, they were less distracted and better able to focus on visualizing the race.

Utilization Pre-Olympics

Four out of five of the skaters asked the sport psychology consultant to control the mouse and their movement through the environment. This enabled the athlete to focus on the image on the screen and the race, rather than on navigating through the environment. The one skater who controlled the environment himself commented that it was difficult to use as a preparation tool because much of his attention was taken simply by navigating, which reduced his ability to focus on preparing for the race.

Perceived Impact

Three of the athletes stated that they felt less anxious about the Olympics after being in the virtual environment. The environment allowed them to concentrate on their race plan, how they would prepare for the race, and what they would focus on while competing in the race.

At the Olympics

Only one of the skaters commented that her impression of the virtual oval changed once she got to the Olympics. She found that the venue looked very different during the Olympics because of a number of coloured banners that had been erected and the increased number of stands that had been placed around the track. She noted that when she first walked into the oval, she did not recognize the place even though she had been in the building before. However, all of the other skaters still agreed that the virtual oval was a very realistic representation of the venue. One athlete, a first time Olympian, added that the virtual reality gave him a realistic idea of what the atmosphere would be like at the Olympics. He also felt that having used the virtual oval, he and the other Canadian athletes had somewhat of an advantage over the athletes who had not used it.

Improvements

All the skaters commented on the static pictures of skaters in the warm-up lane and noted that these images were distracting because they did not move and, from some angles, appeared to be facing the wrong direction (which is unrealistic). Some of the skaters commented that it would be helpful and it would add to the reality of the environment, to hear comments from their coach, and to hear the commentator call out lap times, as they skated round. These events occur during a real race and athletes sometimes use them to modify their performance, especially in longer distance races.

A number of the skaters also commented that they would find the virtual environment more useful if it was automatic, so that navigating through the space once the race started was unnecessary. This would allow the skaters to concentrate fully on the race. However, for performing their pre-race routine, they liked the fact that they had full control over the environment. Two of the skaters also commented that it was useful to be able to stop while in the middle of the race to discuss focusing with their sport psychology consultant and strategy and technique with their coach.

Other Potential Uses

Visualization and venue familiarization were the two main uses of the program. In addition, three of the athletes commented that they felt that they were not very good at visualizing their races, and that using this tool enabled them to visualize more successfully. Although not all of the athletes found the virtual environment useful for familiarization with the competition venue, they did comment that this would be especially useful for athletes performing in a particular venue for the first time.

Other potential uses were noted by a couple of the athletes. One was that they could use this tool in collaboration with their coach to provide simulations of their race when making a race plan, or when discussing race strategy such as, at what point on the track they should start building for the turns. Another athlete commented that it would be a useful tool for enhancing ones ability to visualize alone. This athlete thought that after using the virtual reality on a regular basis for visualization, it would enable him to visualize alone more successfully without distracting images appearing in his mind.

Conclusions

This preliminary case study provides support for the use of virtual environments as a potential visualization tool in training and preparing athletes for competition. Given the small sample size and anecdotal, observational nature of the data, it is not possible to make definitive statements. Clearly, more research into the effectiveness of these environments is required. The athletes interviewed for this study used the virtual environment in two main ways: firstly, to familiarize themselves with the competition venue; and, secondly, to rehearse and mentally prepare for their race (with their sport psychology consultant). Both uses were reported to be advantageous by all of the athletes to varying degrees.

This study has also highlighted two other areas that warrant further investigation:

1. The potential use of virtual reality to train athletes in effective visualization techniques so that ultimately, the athlete would have the ability to independently visualize without an artificial environment and without being prone to distracting images.
2. Using virtual reality as a regular training tool where athletes working with their coach to discuss race strategy and specific technical elements of the race such as, when to "change up" the pace of the race, or what position to take within the lane to maximize performance.

Designing effective virtual environments requires resources and research. Moreover, performance can be impacted by factors such as, athlete experience, preparation style, imagination, proneness to motion sickness, and comfort with technology. It would appear that virtual environments have great potential for enhancing athlete performance, but this area of research is relatively untapped.

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