From Notation to Training: Analysis of the Penalty Kick

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The analysis of football by notation has been common for many years. Coaches accrue information about team or individual performance using many different memory aids ranging from simple pencil and paper to sophisticated video/computer technology.

This is necessary because the human memory system is fallible. Indeed, there has been an exponential growth in the research and development surrounding the acquisition, storage, tabulation and presentation of meaningful team and individual events. In fact, several top ranked international teams now use information gained from interactive computer-video technology to make informed decisions about technique, strategy and tactics.

Over the past 20 years researchers have been concerned with the development of fast, efficient recording and display systems. This process of system development would likely involve the coach and researcher answering such questions as: what information should be collected; can it be collected during the game; how should the information be tabulated and displayed; what types of data base should be constructed and who will access the information7 Once agreement has been reached on these and other issues (eg reliability and objectivity of the data collection process) informative feedback can be provided to players. However, using this information to augment and correct first hand impressions gained from game performance is only a small part of the potential benefits notation can provide.

Notation can be more than a simple recording method. As we have noted in previous research papers, data collected from sport can be used to identify important playing behaviours. One of the earliest examples of this type of research was reported by Reep and Benjamin (1968), who found among other things a stable correspondence between shots on goal and goals scored (10:1). Without the aid of modern day computers, these researchers used data from passes leading to 9,175 goals scored in 3,213 matches between 1953 and 1968. Unfortunately, the importance of this study's attempt at using such a large data base to model team performance was overshadowed by controversy surrounding the interpretation and application of their findings by many coaches and researchers. Clearly, there is a problem m attempting to predict future events from past data. In this particular case the problem is exacerbated by the large number of variables that present themselves in a football game The rules constrain the actions of 22 players and the ball over an area of approximately 8,000 square metres Despite the fact that coaches attempt to impose a further constraint of strategy and tactics on the players, there is still a formidable array of variables to control. However, with the advent of powerful computers researchers are continuing their quest to produce global descriptors of team performance in new and exciting ways.

An alternative approach that we have used in the past is to isolate certain aspects (key factors) of the game and analyse these elements of performance in detail. This has the advantage of reducing the number of variables that would create error in future prediction and interpretation. For example, in 1986 our laboratory undertook an extensive analysis of crosses from the 1986 World Cup finals (Partridge and Franks. 1989) We reasoned that since 33 per cent of goals were scored from crosses, a fruitful line of inquiry would be to define a "successful" cross (using such information as type of cross, area it was delivered from/to, runs made by attackers/defenders, and how shots and goals resulted from these crosses) and then use this information (40 pieces of information on each of 1427 crosses) to help design practices that would stress the important elements of a "successful" cross (a cross that resulted in a shot on goal). Two tests of the research are immediately apparent. First, test the efficacy of the definition of "successful cross" in future competitions Second, and more relevant for coaches, notate the pertinent information about "crosses" during a game both before and after practice. Whereas, the first test is straightforward and the definition of success has been validated on many occasions, coaching players to produce a successful cross presents other problems However, the first step is to identify successful performance and then establish a training regime that allows players to recognise deviations from this criterion and ultimately improve their own performance.

In a similar vein we (Franks and Hanvey, 1997) have recently isolated and notated the penalty kick as a critical element in deciding the outcome of a game. Its importance has been obvious in England, extending from World Cup '90 to last summer's World Cup '98. There can be little doubt that the penalty kick has been an important determining factor in deciding recent major football competitions. Therefore, such research is both timely and relevant. There are two branches to this research. First, is the examination of the penalty kick from the goalkeeper's perspective. Can we provide the goalkeeper with information that will enable him (or her) to predict the placement of the kick? Furthermore, can we train the goalkeeper to use the appropriate response cues provided by the kicker7 Second, is the examination of the penalty shoot-out. Is there an optimal ordering of the selected group of penalty takers9 We will briefly discuss each branch of this research and provide the reader with our most recent findings.

Response Cues For Goalkeepers Notation

It has been suggested by Williams and Burwitz (1993) that you can distinguish between novice and expert goalkeepers on the basis of the anticipatory cues they use during the penalty kick. However, it was evident in our initial notational analysis of 138 penalty kicks taken of the World Cup finals between 1982 and 1994 that expert goalkeepers were not successful at predicting

the direction of the penalty kick. This analysis revealed that goalkeepers correctly predicted shot direction on only 41 per cent of all shots (no better than chance) Furthermore, only 14.5 per cent of the shots were saved by the goalkeeper. Clearly, expert (international) goalkeepers were not using effective strategies in trying to predict the direction of the shot and eventually save the penalty. Therefore, our first step was to identify reliable response cues that could be used effectively by goalkeepers. The limitation of the notational analysis was that our raw data were derived from television video. Despite the fact that the frame rate was 33 frames per second (giving a measuring error of 30 ms) it was possible to gain relevant and useful information.

Information related to ball speed and the movement of the goalkeeper are understandably variable. The shot can vary in speed and direction as can the goalkeeper's movement Also, on several occasions the goalkeeper did move before the kick was taken even though the rule at that time prohibited movement before the kick. Nevertheless average values of ball time (time from the kick to when it crosses the goal line) and goalkeeper movement time (time from the goalkeeper's first observable movement to when his body intersects the plane of the ball flight) are quite robust and have been validated now in three separate studies. The average ball time is approximately 500 ms (half a second) while the average goalkeeper movement time is about 600 ms If we can assume that goalkeepers do attempt to detect an appropriate stimulus to move and then decide on movement direction, we must then factor in reaction time (time from the stimulus onset to first observable movement). In laboratory based studies, reaction time for correctly anticipated events is approximately 100ms The recent rule change allowing goalkeepers to move before the kick would then, at first glance, appear to be a reasonable attempt at improving the goalkeepers chance of saving the shot. However, results from this analysis lead us to believe that the strategy of moving too early does not help the goalkeeper.

Clearly goalkeepers should make the decision to move before ball contact: otherwise they will be too late, unless of course the ball hits them. On the other hand if goalkeepers move too early they will not benefit from late anticipatory response cues provided by the penalty taker and also provide the kicker with additional information prior to the kick. The problem then is to find response cues that are reliable and presented early enough to allow the goalkeeper the opportunity to move in time to stop the shot. We identified the following possible response cues in chronological order. The penalty taker's starting position; angle of approach to the ball; forward or backward lean of the trunk; placement of the non-kicking foot just prior to contact; and finally point of contact on the ball of the kicking foot. Response cues were considered independent We reasoned that on the occasions when prediction from an early cue was mcongruent with a later one, the time taken to disconfirm the first cue would inflate the reaction time causing the goalkeeper to move too late.

The only response cue that was both reliable and time efficient was the placement of the non-kicking foot This allowed the goalkeeper between 150 and 200 ms to react after detection The position of this foot placement dictates the direction of the shot on over 80 per cent of penalty kicks we analysed. If the non-kicking foot points to the left the ball will be placed to the left, if placed to the right the shot will go to the right. A further test of the response cue's reliability was completed on the penalties of Euro '96 and the accuracy of predicting shot direction using this cue was in excess of 85 per cent.

Given the fact that we had found a potentially effective response cue through notation, the next task was to test the utility of the cue with knowledgeable football players and coaches. Experienced goalkeepers were not used at this stage of the research because they would bring previous experience and learned habits to the penalty kick situation We felt it would be difficult to abandon cues they were already using to predict shot direction. If the cue was found to be useful then a training program would be designed for goalkeepers.

Simulation Experiment

The experiment used a simulated penalty kick in which participants viewed a life size video image of the penalty taker moving towards them and taking the kick at them. Participants stood at the appropriate distance from the image of the ball and responded to the kick by lifting their index finger from a home key and moving to press a response key positioned either at the right or the left of them. The image on the screen was occluded at the point of the kick and participants had to indicate as quickly as possible in which direction the shot would go. Two groups of players and coaches were used in this pre- (100 trials) and post-000 trials) test design. During the period between pre- and post-test the experimental group was given a brief training period using ten penalty kicks from the World Cup data This training emphasised the importance of viewing the non-kicking foot for directional cues prior to ball contact. The control group was shown the same ten penalties but these participants were not told of the response cue.

Reaction time (time from image occlusion to finger lift from home key), movement time (time from finger lift to response key depression) and correct response (pressing the correct right or left key) were the measures of importance when comparing performance pre- and post-test. It was clear that knowledgeable coaches and players can effectively use the response cue, non-kicking foot direction, to predict the direction of the penalty kick. The experimental group showed a significant improvement in correct responses from pre- to post-test but there was no difference in the control group's performance at prediction. As expected, movement time for both groups was significantly reduced due to learning the laboratory based task However, the most interesting result came from the reaction time data. After the intervention (period between pre- and post-test) reaction time decreased for the control group but increased for the experimental group. Given the nature of the laboratory based task participants would be expected to decrease their reaction time over 200 trials (100 pre- and 100 post-test), as was observed for the control group. However, providing the experimental group with a valid response cue that occurs close in time to the stimulus signal (image occlusion) slowed their reaction time. These participants were involved in extra cognitive processing as a consequence of searching for, and using, the relevant response cue Whereas the results of this experiment were encouraging, it was clear that a training programme had to be developed and tested before goalkeepers could use this response cue to improve shot prediction under time constraints.

Training

We have recently completed the first stage in the development and testing of a training programme for goalkeepers. Eight nationally ranked (Canadian youth, under 20, and under 23) goalkeepers were used in this study. In order to test the effectiveness of this programme a pre-test, training intervention and post-test design was used

The pre- and post-test involved each goalkeeper facing 40 penalty shots from 4 different penalty takers (each taking 10 shots). Information collected from these tests included goalkeepers' movement (movement time, incorrect/correct prediction of ball placement, and save percentage), penalty takers' non-kicking foot placement, ball time and final ball position. After the pre-test, the goalkeepers were asked what strategies they used m regard to predicting the shot direction.

The intervention involved three components First, the goalkeepers were shown how the response cue "placement of the non-kicking foot" was reliable for detecting shot direction. This took the form of a video presentation in which a compiled set of penalty kicks from previous World Cups was shown to the goalkeepers. It was made clear to the goalkeepers after this presentation, and subsequent discussion, that the problem with using this cue was that stimulus (response cue) identification and response (goalkeeper

movement) initiation time should be kept to an absolute minimum. Second, the goalkeepers were brought into the laboratory and given a similar test to the simulation experiment described above. After this test, they continued viewing the simulated penalty kick situation with the addition of using an eye movement recorder. This recorder was mounted on their heads and provided the goalkeepers with feedback about their gaze control That is, where they were looking at (fixations) during the penalty kick Visual scan paths within and between goalkeepers were variable, unreliable and inaccurate (with respect to the penalty taker's non-kicking foot). It was important for the goalkeepers to fixate on the non-kicking foot prior to the shot in order to maximise the benefits of using the advanced response cue. With the aid of the eye movement recorder, we were able to provide feedback after each shot as to where the goalkeepers were looking.

In the third stage of the intervention a more realistic set-up was used. Goalkeepers still wore the eye movement recorder and faced a real penalty. Unfortunately, due to the fragility and expense of the equipment in addition to the possibility of injury, it was not possible to allow the goalkeeper to dive for the shot. From a "ready stance', goalkeepers were instructed to move their hands to the right or the left as soon as they detected shot direction. Movement time and shot direction were measures used in this stage of the study Also, visual fixations were recorded as a function of learning, In total the goalkeeper faced 60 simulated and 120 real penalty shots in the entire study

At this time only preliminary results are available It appears that before intervention the goalkeepers' ability to predict correct direction of the penalty kick is about 46 per cent (similar to the notation study of the World Cup penalty shots) and after training this figure improves significantly to 75 per cent. The time it takes the ball to move from the penalty spot to the goal line, for this group of penalty takers, was again 500 ms both in pre- and post-test trials providing a realistic and consistent test situation. During the pre-test it took goalkeepers 551 ms to move to the point of ball plane intersection but they increased this time to 567 ms after training. As yet, we cannot be sure that this is a real difference. However, it is possible that the extra movement time is due to either a lack of conviction on the part of the goalkeeper that the movement is indeed going to be in the correct direction (therefore not made as forcefully as usual), or the goalkeeper is engaged in continued processing of information during the movement itself Further detailed analysis should help clarify our position on this matter. Even so, further training on this task would be expected to reduce both reaction time and movement time. It is clear that a programme of training for goalkeepers in the use of advanced cues should exceed the 120 trials that were given in this study. We are following the performance of the 8 goalkeepers involved in this study while they pfay with their respective clubs and our initial observations from this group appears to be extremely promising They are using the response cues and are nearly always predicting correctly. This should improve their chances of saving the penalty kick.

Optimal Order of the Penalty Shoot-out

Penalties can occur in either regular game time or in a penalty shoot-out, if it should be necessary to break game ties after extra time. Given its importance in deciding game outcomes since its introduction in World Cup '82 through World Cup '98, including Euro '96, we present some ways in which the outcome of a penalty shoot-out might be optimised.

One result from our analysis was the indication of a marginal disadvantage for the team to strike first. This finding stands against the standard practice of first strike which is usually advanced on the reasoning that it is important to get off to a good start and, in so doing, pressurise the opponent. It is important to bear in mind that the result reported here is dependent on the following assumption. Specifically, we considered that the likelihood of a player scoring on a penalty kick would be reduced if, (a) the first team had to score in order to get ahead, and (b) the second team had to score in order not to get behind. This assumption favours the second team on the basis that the first team to strike has the first chance to miss. Notwithstanding, it is interesting to note from the data (1982 through 1998) that the first team to strike has won the penalty shoot-out seven times while the second team to strike has won the penalty shoot-out 11 times In short, there is no evidence to support the accepted convention that the first team to strike ts advantaged.

Importantly, the training of penalties should be undertaken by each individual player in order to improve on the probability of scoring on a penalty kick. Likewise, the training of goalkeepers along the lines advanced earlier in this paper should also be undertaken in order to improve on the probability of stopping a penalty kick by the opponent. In addition to training, the coaching staff should identify beforehand an estimate of the probability of scoring from a penalty kick for each individual player (this would have been gained during many test situations during practice). The available players left on the field of play at the end of regular time can then be assigned 'on-the-fly' according to their known probabilities in the following order: if the team strikes first then assign the last three slots to the best three penalty takers; if the team strikes second then assign the second, third and fourth slots to the best three penalty takers, and if the order is to be assigned beforehand then either option would suffice These results are preliminary and further analyses are required so that an optimal general order can be identified that covers a variety of initial conditions.

Lastly, the use of substitutes for the express purpose of taking a penalty in a shoot-out should be promoted. This intelligent usage was evidenced in the case of West Germany against Mexico in World Cup '86 Littbarskt, came on to the field as a substitute in the 115th minute, and shortly thereafter struck the fourth penalty in the shoot-out in emphatic style to win the game 4-1. Interestingly, Littbarski had also taken the fourth penalty in a shoot-out against France in World Cup '82 West Germany won that penalty shoot-out 4-5.

Further Reading

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