Analysis of penalties taken in shoot-outs

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Analysis of penalties taken in shoot-outs.

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Abstract

Penalties are now a subject of myth, romance, excitement, dread, fear and pressure – depending upon whether you are watching or taking them. Many soccer managers and coaches have said that they are a lottery and many are of the opinion that practising them are a waste of time, because it is not possible to replicate the pressure. Little research has been completed on penalty shoot-outs, and most of this has been on the performance of goalkeepers. The aim of this work is to use notation to analyse the performances of the penalty takers and goalkeepers in penalty shoot-outs taken from the FIFA World Cup finals and also the finals of the European Champions League, and present these data so that a successful profile of optimal performance can be defined.

A notation system was designed to input data directly into Access, 129 penalties were notated with an intention to analyse the time in preparing the shot, the number of paces taken to approach the ball, their relative pace, the pace of the shot, its placement and the outcome.

It was found that:-

- One in five saved (20%; 3/15), one in fifteen missed (7%; 1/15) and three in four scored (73%; 11/15).

Table 1. Respective frequency of the different paces of striking the ball with the outcomes expressed as percentages.

Power of shot	Frequency	Goal	Missed	Saved
50%	12%	47%	0%	53%
75%	70%	81%	1%	18%
100%	18%	63 %	31%	7%

- 25% of shots a fast run are saved because the player then tried either 50% or 75% power.

- Best success ratios are from an even run up of 4, 5 and 6 paces.

- There is no laterality in the success ratios – left footed and right footed strikers have the same success when the frequencies are represented as percentages.

- No shots above waist height were saved, although 18% of those shots missed.

- In every case, the goalkeeper moved off the line before the ball was struck.

- There is only a small data set, but the goalkeepers who took a pace forward and stood up while the striker approached the ball, had the best save and miss ratios.

- The profile of Germany's penalty takers show a consistent pattern that is very different from the average, indicating analysis and training.

It was concluded that these data analyses demonstrate that there are optimal strategies in taking and saving penalties. These point to ways of enhancing the individual performance of the players in these closed skills. Coaches in this team sport will be helped by methods used in individual sports such as golf and racket sports, where the emphasis is on the attainment of expert technique.

Introduction

Penalties are now a subject of myth, romance, excitement, dread, fear and pressure – depending upon whether you are watching or taking them. They have helped careers of footballers and destroyed them. Many soccer managers and coaches have said that they are a lottery and many are of the opinion that practising them are a waste of time, because it is not possible to replicate the pressure. Yet little research has been completed on penalty shoot-outs, and most of this has been on the performance of goalkeepers.

Franks and Hanvey (1997) researched the cues that goalkeepers can use to anticipate the direction of the shot by the penalty taker, by initially analysing penalty shoot-outs from four FIFA World Cup competitions. Several cues were considered independently, but only three were found to reliably predict the position of the shot above an acceptable level of 80%. Placement of the non-kicking foot was chosen as the most appropriate response cue because it allows the goalkeeper time to make his move to the position of the ball. An experiment was then designed to test whether training with this cue could improve performance of the goalkeeper – using a lab-based simulation. Subjects significantly improved their response accuracy and reaction time. Franks and Hanvey went on to devise a training programme that enabled goalkeepers to successfully predict shot position and react within the allowable time constraints of the penalty kick situation.

Savelsbergh et al. (2002) solely used a lab-based approach in their attempt to research visual search, anticipation and expertise in soccer goalkeepers. Expert and novice goalkeepers used a joystick to respond to images shown them on film. Visual search behaviour was examined by means of an eye movement registration system. Expert goalkeepers used a more efficient search strategy and were more accurate in predicting the direction of the penalty kick, using the kicking leg, the non-kicking leg and the ball

areas as cues. They presented an informed overview of the area and discussed in depth the implications for improving anticipation skill at penalty kicks.

The aim of this work is to use notation to analyse the performances of the penalty takers and goalkeepers in penalty shoot-outs taken from the FIFA World Cup finals and also the finals of the European Champions League, and present these data so that a successful profile of optimal performance can be defined.

Method

A notation system was designed to input data directly into Access, 129 penalties were notated with an intention to analyse the time in preparing the shot, the number of paces taken to approach the ball, their relative pace, the pace of the shot, its placement and the outcome (see Table 1 for example data).

Table 1. Data entry system in Access for the actions of the penalty taker

Taker ID	Pen No	Approach Time Start	Placement Finish & Striking Start	Paces Back	Paces In	Striking Time Finish	Run In	Approach Direction	Placement non-striking foot	Strike Foot	Part of Foot	Pace of Strike	Shot Direction
De Kock	1	04:26:00	04:48:02	14	8	04:58:20	Slow	Left Curve	Left	Right	Instep	100	Left 2
Zidane	1	04:58:20	05:29:06	7	5	05:38:14	Medium	Left Curve	Right	Right	Side	75	Left 4
R. De Boar	2	05:38:14	05:57:00	7	4	06:04:15	Medium	Straight	Straight	Right	Side	75	Left 4

In addition the actions of the goalkeeper were notated – position, body shape, movements as the player approached, his first movements and the subsequent direction, the outcome (see Table 2 for example data).

Table 2. Data entry system in Access for the actions of the goalkeeper

GK	GK Position	Body Shape	Movement Made	Intitial Movement	Dive	Outcome	If Saved, How?
	Centre	Crouched	Still	Forward	No Dive	Goal	
Van der Sar	Centre	Arms & Legs Wide	Shuffle	Forward	Low Left	Goal	
	Centre	Crouched	Still	Forward	Low Right	Goal	

An intra-observer reliability test on 50 of the penalties resulted in percentage agreements ranging from 96% to 100%, depending upon the data analysed. Not all video recordings enabled all of these data to be notated, so in the subsequent analyses some of the totals are 128 and 127. Case studies were completed on 2 teams, England and Germany as an example of the power of this type of analysis.

Results and Discussion

The data in Table 3 show that generally penalties will result in one in five saved (3/15), one in fifteen missed (1/15) and three in four scored (11/15).

Decisions in taking a penalty

The player taking a penalty is faced with a series of simple decisions – how hard to hit the shot, whether to attempt to place the ball and, if so, where to place it. Then the player must decide on the pace of the run up, and the number of paces, to achieve the aims.

Table 3. Outcomes of penalties

Outcome	Frequency	%
Goal	94	73
Missed	9	7
Saved	26	20

Pace of strike

The largest percentage hit the ball at 75% of maximum power, placing the ball (70%, 87/128), this is the most efficient way of striking a penalty (see Table 2). Slow shots have only a 47% success rate, blasting the ball at 100% effort has only 63% success (31% miss the goal), whilst placing the ball has 81% success

Table 4. Respective frequency of the different paces of striking the ball with the outcomes expressed as percentages

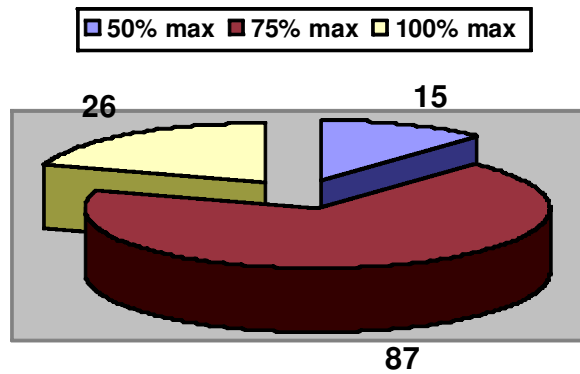| Pace of Strike (% of max)	Outcome	Frequency	%
50	Goal	7	47
50	Missed	0	0
50	Saved	8	53
75	Goal	71	81
75	Missed	1	1
75	Saved	15	18
100	Goal	16	63
100	Missed	8	31
100	Saved	2	7

Fig. 1. Respective frequency of the different paces of striking the ball
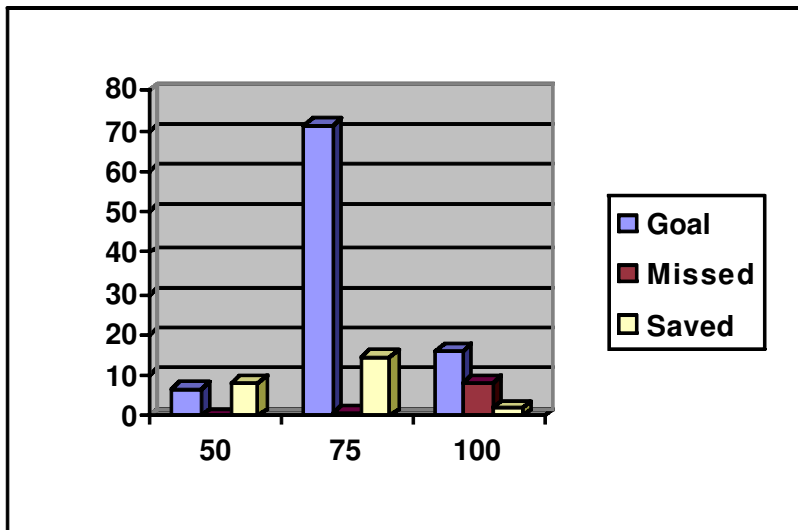

Fig. 2. Frequency of the different outcome at different pace of shot.

The frequencies of goals, misses and saved shots give an indication of the relative success of the different types of shots, but this is clouded by the different amounts of each types of shots (Fig. 2). By non-dimensionalising them, expressing each as a percentage of the total of each type of shot the picture becomes more clear. As the pace of the shot increases there are less saves, but more misses. The message is clear – if players can improve their accuracy at pace then they will score more goals..
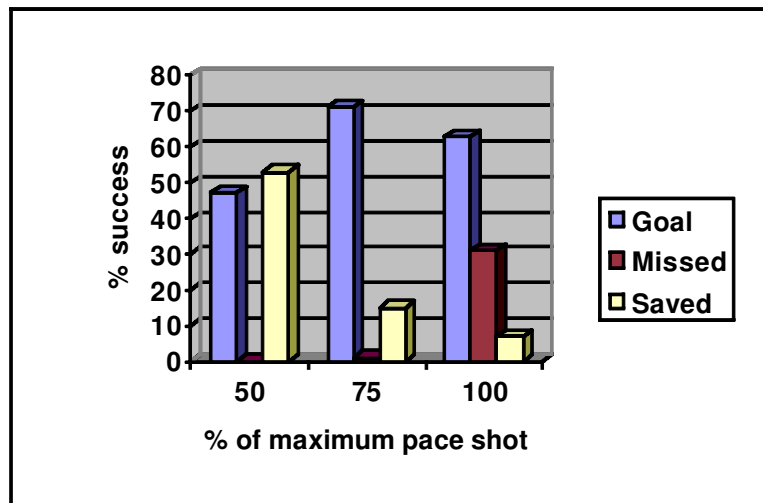
Fig. 3. Frequency of the different outcome at different pace of shot expressed as percentages of the total of each set..

Approach to Ball

Pace of Approach
Often players will try to deceive the goalkeeper with the run up, varying the pace and the direction. The 'check' was the term given to a slow run with a feint in it, the other speed terms are self-explanatory.
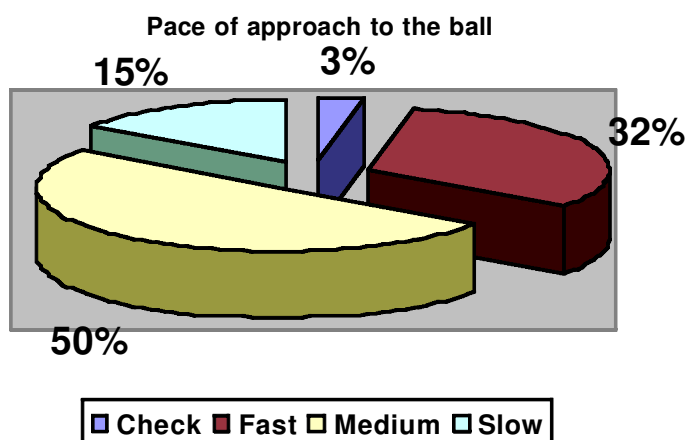

Fig. 4. Relative percentages of the different types of approach runs to the ball.

Most players place the ball at 75% of maximum pace so the distribution of the different types of run up reflect this, with the medium being the most common. Quite large numbers however, have a slow run up and still hit the ball at 75%, and also a 75% pace shot from a fast pace run-up – these types of data are further analysed later.

Table 5. Relative percentages of the different types of approach runs to the ball, with the different outcomes of the shots.

Run In	Outcome	Frequency	%
Other	Saved	1	20
Check Step	Goal	3	60
Check Step	Saved	1	20
Fast	Goal	30	68
Fast	Missed	3	7
Fast	Saved	11	25
Medium	Goal	47	83
Medium	Missed	5	8.5
Medium	Saved	5	8.5
Slow	Goal	14	61
Slow	Missed	1	4
Slow	Saved	8	35
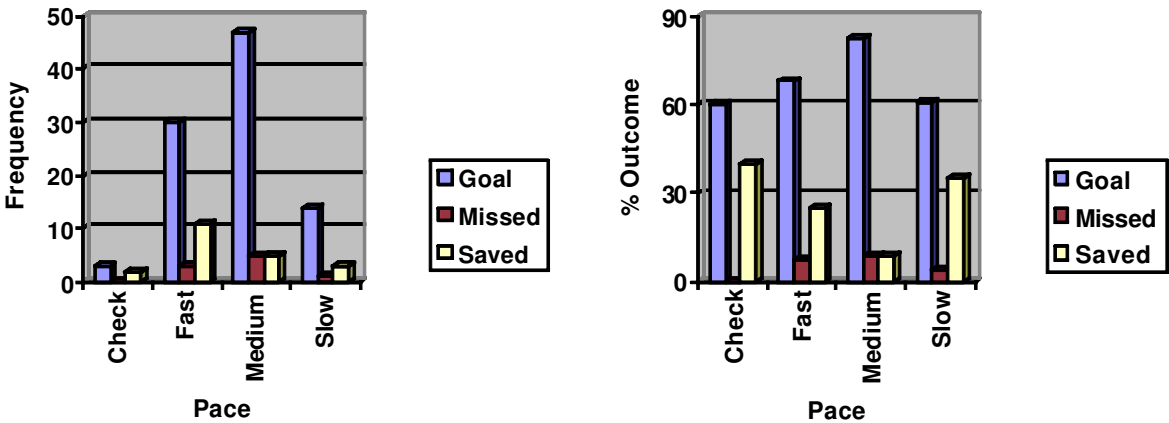
Figs. 5 and 6. The frequencies of the outcomes of each of the approaches, and these frequencies expressed as percentages of the totals of each approach.

Figures 5 and 6 show a similar message to the pace of the shot – a balanced even paced (medium) run will give low misses, low saves and high success. The slower the run, usually trying to disguise the shot (check and slow) results in high percentages of saves. High speed also has a high relatively high percentage of saves and misses. The interesting part of these data, and those data of the pace of shot, is that players have different success rates when they combine fast run-ups with 75% shots, and so on. Consequently the data were further analysed.

Table 6. Speed of run up and the pace of shot.

| Run In	Pace of Strike	Outcome	Frequency
Check Step	50	Saved	1
Check Step	75	Goal	3
Fast	50	Goal	1
Fast	50	Saved	2
Fast	75	Goal	19
Fast	75	Saved	8
Fast	100	Goal	10
Fast	100	Missed	3
Fast	100	Saved	1
Medium	50	Goal	4
Medium	75	Goal	39
Medium	75	Missed	1
Medium	75	Saved	4
Medium	100	Goal	4
Medium	100	Missed	4
Medium	100	Saved	1
Slow	50	Goal	2
Slow	50	Saved	5
Slow	75	Goal	10
Slow	75	Saved	3
Slow	100	Goal	2
Slow	100	Missed	1
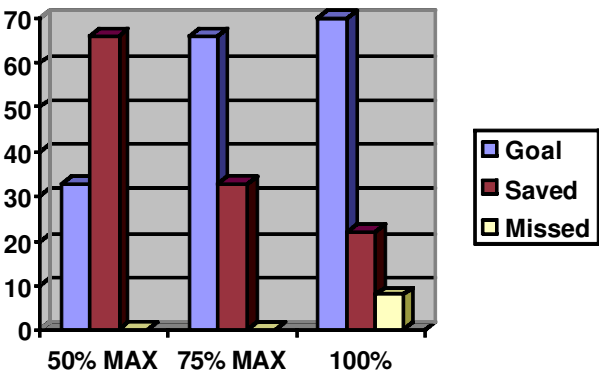
Fig. 7. Fast run up with different pace strikes and the respective outcomes.
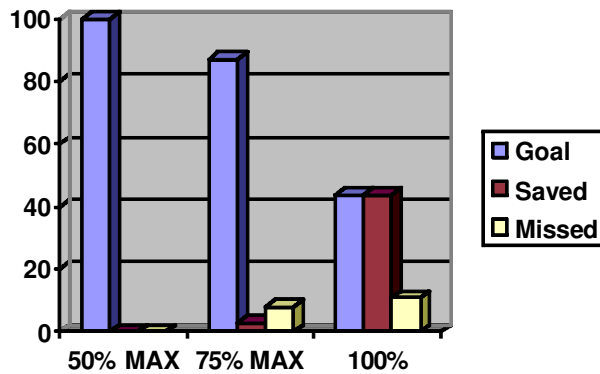
Fig. 8. Medium speed run up with different pace strikes and the respective outcomes.
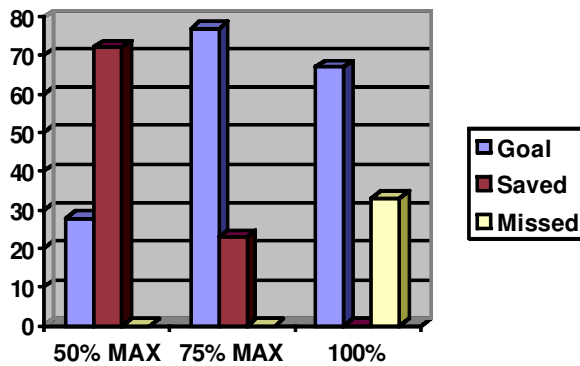

Fig. 9. Slow speed run up with different pace strikes and the respective outcomes.

Table 7. Frequency of penalty shots taken with the number paces of the approach run.

Paces In	Frequency
1	2
2	1
3	10
4	27
5	37
6	29
7	11
8	8
9	1
10	2

The figures 8 and 9 show how the players find it difficult to mix the speed of the run-up with the pace of the strike and sustain accuracy – compare these data with the overall performance of 73% goals, 7% missed and 20% saved. Only the medium paced run up gives better results, and then not with the 100% effort in the pace of the shot.

The number of paces in the run up

The data in Table 7 follows almost a normal distribution (Kurtosis = -0.73477; Skewness = 0.902751) about a maximum frequency of 5 paces, very much as expected, which of these show the best outcomes?

Table 8. Frequency and % of pena lty shots taken with the number paces of the approach.

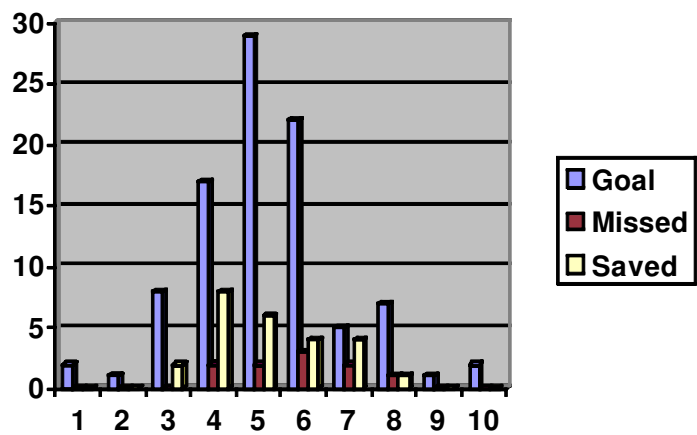| Paces In	Outcome	Frequency	%
1	Goal	2	100
2	Goal	1	100
3	Goal	8	80
3	Saved	2	20
4	Goal	17	63
4	Missed	2	7
4	Saved	8	30
5	Goal	29	79
5	Missed	2	5
5	Saved	6	16
6	Goal	22	75
6	Missed	3	10
6	Saved	4	15
7	Goal	5	46
7	Missed	2	18
7	Saved	4	36
8	Goal	7	87
8	Saved	1	13
9	Goal	1	100
10	Goal	2	100

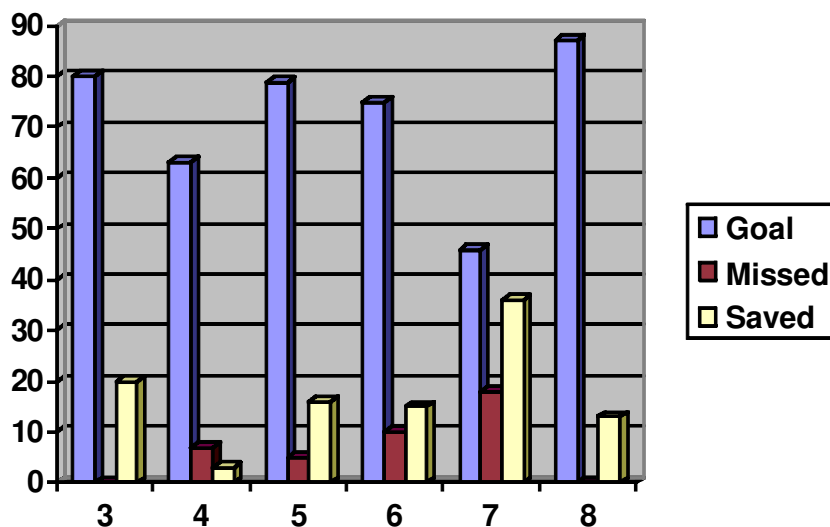Fig. 10. The frequency of outcomes associated with each of the different paced run ups.

Fig. 11. The frequency of outcomes associated with each of the different paced run ups expressed as percentages of the total number of shots at that number of paces. The very low and very high number of paces have been removed because of the small data samples.

The normalised data in Fig. 11 show that the balanced approach over 5 paces gives the player the chance to achieve a smooth approach, being marginally better than 4 or 6 in terms of percentage achievement. Although 8 and 3 paces appear to be better, these data samples are very small.

Strike Foot
The data show no significant differences in the performance of left and right footed strikers, once the data has been normalised to balance the respective overall frequencies.

Table 9. Laterality of striking foot and outcome

Strike Foot	Outcome	Frequency	%
Left	Goal	18	72
Left	Missed	2	8
Left	Saved	5	20
Right	Goal	76	75
Right	Missed	7	6
Right	Saved	20	19

Shot Direction
To analyse the position of the shot with respect to the goal, it was divided into 8 areas within the goal, and 4 areas outside the goals to define misses.
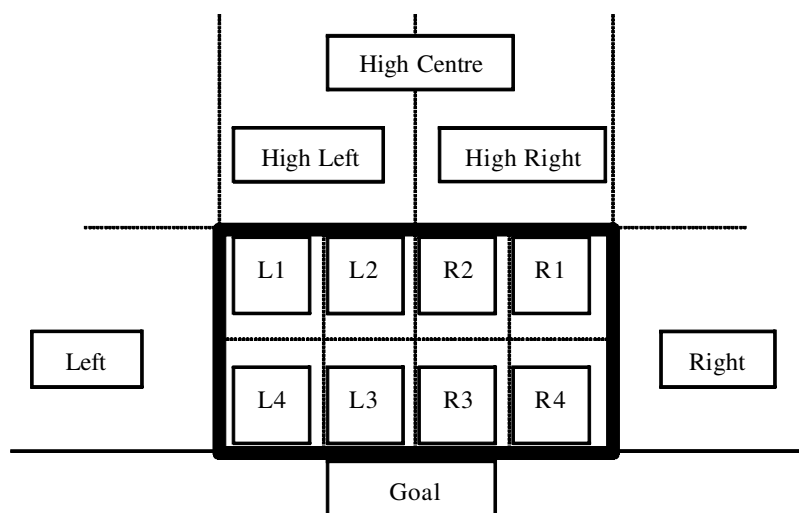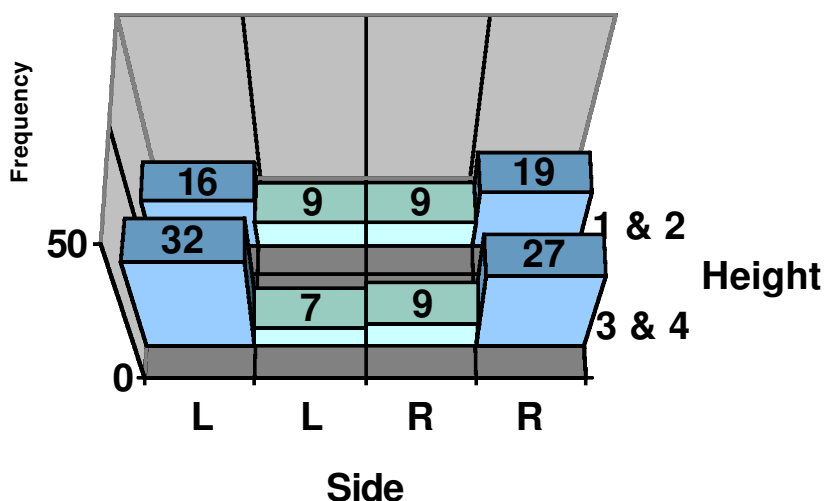
Fig. 12. The cell division of the goal and surround for direction of strike from the view of the striker.

The above divisions were linked with the outcomes of goal, saved and missed.

Fig. 13. The cell division of the goal and surround for direction of strikes (the misses are extrapolated into the top cells).
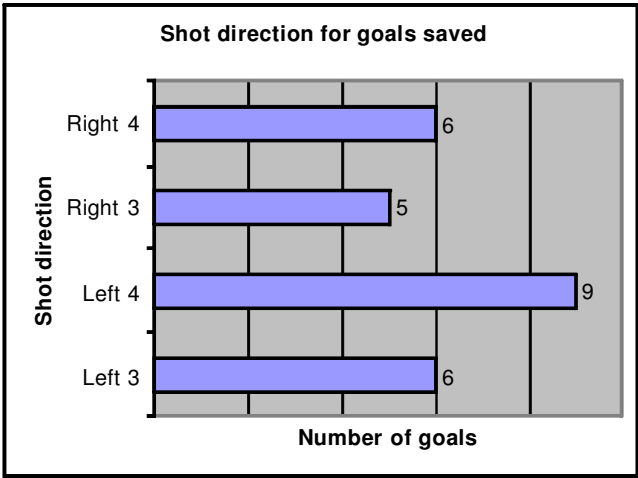
Fig. 14. The cell division of the goal and surround for direction of strike that are saved.

If the data from these figures are combined, the % efficacy of each of these cell divisions of the goal can be calculated. The conversion rates show a stark message in shooting on the floor, particularly close to the goalkeeper. Lifting the ball means that the shot will not be saved (none of the shots at the upper cells were saved – but there is the miss factor). It can be seen that goalkeepers have more success to their right – the strikers' less success to their left.
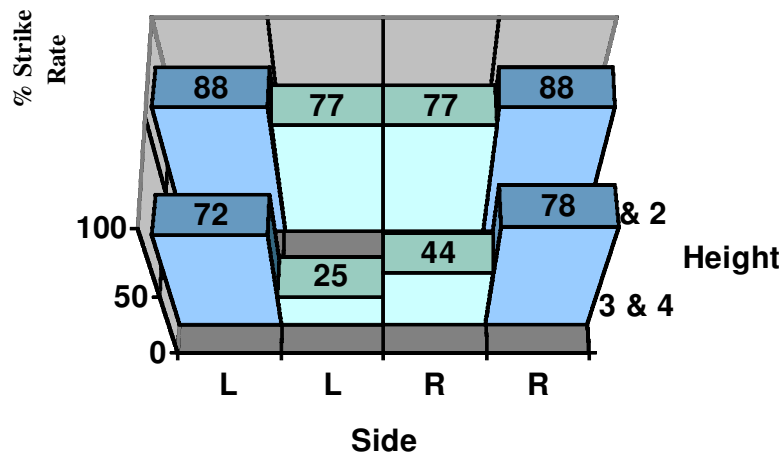

Fig. 15. The respective % conversion rates in different parts of the goal

Goal-keeper data

In spite of the clear rules about movement, the GK moves off the line, before the ball is struck, for 80% of the analysed penalties. The forward movement achieves the highest

number of saves, but if the data is examined as a percentage of its own total (Fig. 22), the standing still ploy then has the highest success rates
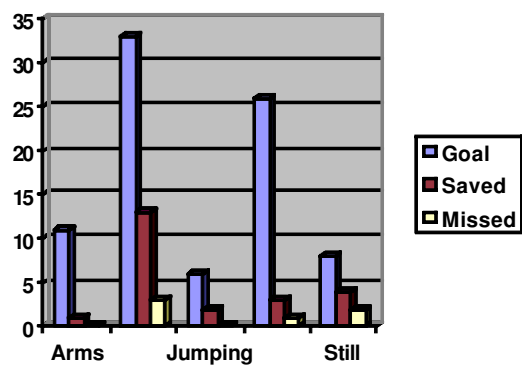

Fig. 16. Movement made by the GK and the outcome before the ball is struck

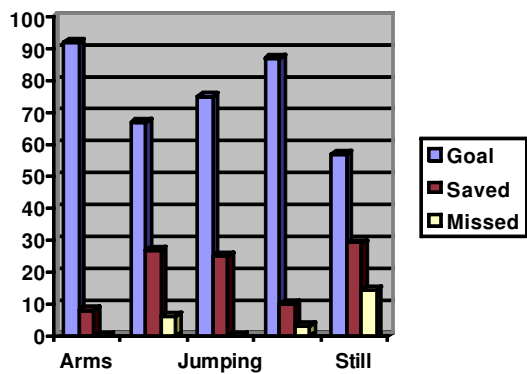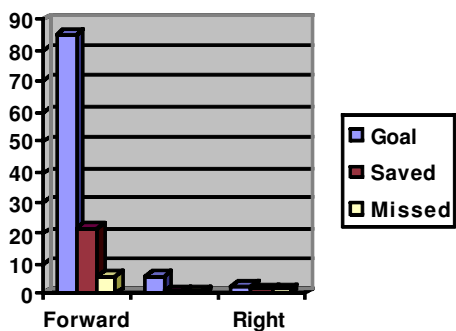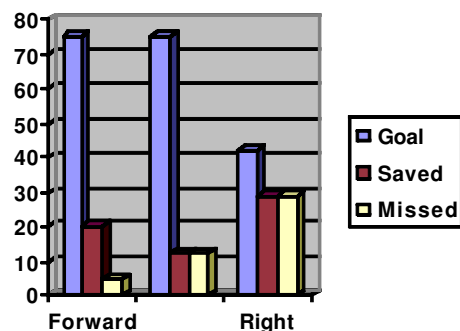Fig. 17. Percentage movement made by the GK and the outcome before the ball is struck

Figs. 18 and 19. Movement made by the GK and the outcome before the ball is struck, and expressed as a percentage (N.B. this right is the strikers' right – the GK's left).

It is not clear what the skewing of the percentage data means – other than the anticipation to the right side gives a high % return. This data set is so small it cannot be taken as meaningful, but it could be an area for further research with larger sets of data.

Performance Profiling

Although there was not a great amount of data available, profiles were analysed for England and Germany to investigate whether there were indications that the data would show distinct individual patterns. Summaries of these data are presented below. There are clear messages in these two data sets that fly in the face of common perceptions – that it is a lottery and that England are poor at taking penalties.

England's Performances
The data analysed for England comes from 4 tournaments:-

Germany	Lost 5-4
Germany	Lost 5-6
Argentina	Lost 5-4
Spain	Won 4-2

England took 20 penalties, scoring 15, missing 1 and had 4 saved.

- This means that their overall % performance was above average, despite the fact that they lost 3 of the 4 shoot-outs.

	Goals	Missed	Saved
Average	73%	7%	20%
England	**75%**	**5%**	**20%**

- The pace of the shots shows no slow shots taken, 3 saved at 75% pace and only 1 out of 3 scored at 100% power, 1 missed, 1 saved.

	Goals	Missed	Saved
Average (75% power)	81%	1%	18%
England (75% power)	82%	0%	18%
Average (100% power)	63%	31%	7%
England (100% power)	33%	33%	33%

- Four out of the 5 saves and misses were penalties delivered off a fast run up – even though 2 of these were then only at 75% power.

- Pacing – those at the extreme ends all scored, so nothing unusual.

- Accuracy, this is critical – 4 inaccurate shots. One accurate shot was saved, but the other 3 saves were all at L3, and of course a miss.

Germany's Performances
The data analysed for Germany comes from 5 tournaments:-

England	Won 5-4
England	Won 6-5
Czech	Lost 5-4
France	Won 5-4
Mexico	Won 4-1

Germany took 24 penalties, scoring 22, missing 1 and had 1 saved.

- This means that their overall % performance was well above average.

	Goals	Missed	Saved
Average	73%	7%	20%
Germany	**92%**	**4%**	**4%**

- The pace of the shots shows 3 slow shots taken (1 saved), 13 at 75% pace (all goals) and 7 out of 8 scored at 100% power, 1 missed.

	Goals	Missed	Saved
Average (75% power)	81%	1%	18%
Germany (75% power)	100%	0%	0%
Average (100% power)	63%	31%	7%
Germany (100% power)	88%	12%	0%

- Accuracy, this is critical – only 3 inaccurate shots, one of these scored. Surprisingly they were very accurate at 100% power – this was the real difference between Germany and England. The data suggest that this is probably the outcome of considerable analysis, training and practice – see the average at 100% power.

Summary and Conclusions

It was a pleasant surprise to find that very clear messages emerged from this data set. The 'competition within a competition' enables a far simpler analysis than the game of soccer itself.

The conclusions are summarised below.

- ❖ One in five saved (20%; 3/15), one in fifteen missed (7%; 1/15) and three in four scored (73%; 11/15).

Table 10. Respective frequency of the different paces of striking the ball with the outcomes expressed as percentages.

Power of shot	Frequency	Goal	Missed	Saved
50%	12%	47%	0%	53%
75%	70%	81%	1%	18%
100%	18%	63 %	31%	7%

Table 11. Relative percentages of the different types of approach runs to the ball, with the different outcomes of the shots.

Pace	Frequency		Goal	Missed	Saved
Check step	4	3%	60	0	40
Slow	23	15%	61	4	35
Medium	57	50%	83	8.5	8.5
Fast	44	32%	68	7	25

❖ 25% saved off a fast run because the player then tried either 50% or 75% power.

❖ Best success ratios are from an even run up of 4, 5 and 6 paces.

❖ There is no laterality in the success ratios – left footed and right footed strikers have the same success when the frequencies are represented as percentages.

Table 12. Schematic representation of the success ratios of shooting at the different areas of the goal.

% Success Rates	Goal			
Upper	88	77	77	88
Lower	72	25	44	78
	Left		Right	

❖ The figures in the upper half include the shots that went over the bar – No shots above waist height were saved.

❖ In every case, the goalkeeper moved off the line before the ball was struck.

❖ Although there is only a small data set, the goalkeepers who took a pace forward and stood up while the striker approached the ball, had the best save and miss ratios.

❖ Although there is only a small data set, the profile of Germany's penalty takers show a consistent pattern that is very different from the average, indicating analysis and training.

These data analyses demonstrate that there are optimal strategies in taking and saving penalties. These along with the goalkeeper research of Franks and Hanvey (1997) and Savelsbergh et al. (2002), point to ways of enhancing the individual performance of the players in these closed skills. Perhaps the coaches in this team sport will be helped by methods used in individual sports such as golf and racket sports, where the emphasis is on the attainment of expert technique.

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Savelsbergh, G.J.P., William, A. M., Van der Kamp, J. and Ward, P. (2002). Visual search, anticipation and expertise in soccer goalkeepers. *Journal of Sports Sciences*, **20** 279-287.