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Anticipation and visual search behaviour in expert soccer goalkeepers

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A novel methodological approach is presented to examine the visual search behaviours employed by expert goalkeepers during simulated penalty kick situations in soccer. Expert soccer goalkeepers were classified as successful or unsuccessful based on their performance on a film-based test of anticipation skill, thereby allowing an intra-group comparison of visual search behaviour on the task. The anticipation test required participants to move a joystick in response to penalty kick situations presented on a large screen. The proportion of penalties saved was assessed as well as the frequency and time of initiation of joystick corrections. Visual search behaviour was examined using a portable eye movement registration system. The successful experts were more accurate in predicting the height and direction of the penalty kick, waited longer before initiating a response and appeared to spend longer periods of time fixating on the non-kicking leg compared with the non-successful experts.

Keywords: Ball flight; Eye movement; Fixation; Penalty kicks

1. Introduction

Successful performance in sport requires skill in perception as well as the efficient and accurate execution of movement patterns (see Williams *et al.* 1999, Savelsbergh *et al.* 2002). The awareness that skilled perception precedes appropriate action has led researchers to examine its role in sport performance. For example, researchers using the temporal occlusion paradigm have shown that experts are superior to novices in using predictive information ('advance cues') from an opponent's body movements to guide their anticipatory responses (see Abernethy 1987, Williams and Burwitz 1993, Abernethy *et al.* 2001). In this approach, participants are presented with filmed sequences that are

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representative of their customary view of the action. These film clips are selectively edited to provide a varying extent of predictive information from the opponent's body movements and the ball's flight path, with participants being required to predict the end result of the sequence observed. The expert performer's superiority over the novice has been demonstrated in a range of sports, including soccer (Keller *et al*. 1979, Neumaier *et al*. 1987, McMorris *et al*. 1993, Williams and Burwitz 1993, McMorris and Colenso 1996).

Although researchers have attempted to determine the important sources of information utilized by expert goalkeepers during the soccer penalty kick, findings are somewhat contradictory (for detailed reviews, see Williams 2000, Van der Kamp 2001). On the one hand, experimental evidence suggests that movement of the hips, kicking leg and trunk just before and during contact is important (Tyldesley *et al*. 1982, Williams and Burwitz 1993). On the other hand, others have argued, based on data from notational analysis, that the orientation of the non-kicking foot just before ball contact is more predictive (Franks and Hanvey 1997). However, researchers have typically relied on potentially less direct measures of information pick-up, such as verbal or written reports (Williams and Burwitz 1993) or event occlusion techniques, and there have been few attempts to record goalkeepers' visual behaviour using eye movement registration techniques.

Savelsbergh *et al*. (2002) used a novel methodological approach to examine skill-based differences in anticipation and visual search behaviour during the penalty kick in soccer. Expert goalkeepers who played semi-professional soccer (second division of the National League and highest amateur league) in the Netherlands and novice goalkeepers were required to move a joystick in response to penalty kick situations presented on film. The expert goalkeepers stopped more penalties and were generally more accurate in predicting the direction of the penalty kick, waited longer before initiating a response and made fewer corrective movements with the joystick. In addition, visual search behaviour was examined using an eye-movement registration system. The expert goalkeepers employed a more efficient search strategy involving fewer fixations of longer duration to less disparate areas of the display. The novices spent longer periods of time fixating on the trunk, arms and hips, whereas the experts spent more time fixating the head and found the kicking leg, non-kicking leg and ball areas to be more informative, particularly as the moment of foot–ball contact approached.

The majority of researchers interested in visual search behaviour in sport have attempted to identify differences in point-of-gaze as a function of skill, experience or sometimes age. The customary approach has been to compare different levels of expertise (i.e. experts vs. novices) in order to identify consistent skill-based differences in visual search strategies. Typically, researchers have neglected to examine whether successful performers employ different visual search patterns than unsuccessful performers within a group where the participants are presumed to have a similar level of *expertise*. In order to be able to make such a comparison, one has to create groups using a within-task criterion such as the number of penalties saved (Whiting 1986). The need to identify intra-group differences is particularly important if one acknowledges that not all expert goalkeepers are successful in stopping penalty kicks (Franks and Hanvey 1997, Van der Kamp 2001). For instance, an analysis of penalty kicks *within* a sample of expert goalkeepers (German Bundesliga) shows that the difference between successful and unsuccessful goalkeepers in stopping a penalty kick amounts to 30% (see figure 1; Van der Kamp 2001). A within-group comparison, therefore, may disclose subtle differences in visual search behaviour that may help to reveal the determinants of successful performance. These determinants may have remained obscure in studies that relied exclusively on expert–novice

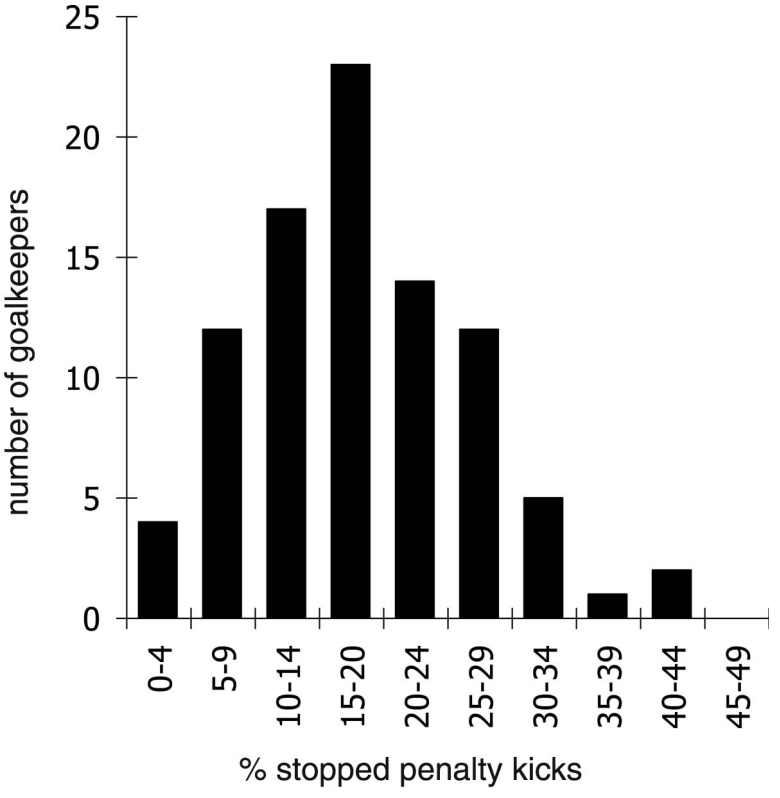

Figure 1. Frequency distribution of the percentage of penalty kicks stopped by goalkeepers in the German Bundesliga between 1963 and 1997. Only goalkeepers who faced 10 or more penalty kicks were selected. As a result the distribution represents 2615 out of the total of 3102 penalty kicks faced by 91 goalkeepers. Both skewness (i.e. 0.488, SE = 0.253) and kurtosis (i.e. 0.216, SE = 0.500) are smaller than twice the standard error, the frequency data therefore are normally distributed. Hence, an unsuccessful penalty saver can be defined as goalkeeper who stops 5% or fewer penalty kicks ($p_{0.05} = 4.8\%$), whereas a successful penalty saver stops 34% or more ($p_{0.95} = 34.1$) (adapted from Van der Kamp, 2001; raw data from Kropp and Trapp, 1999).

comparisons. The aim of this study was to examine whether there are differences in visual search behaviour within a group of expert-level goalkeepers. Goalkeepers were classified as successful or unsuccessful based on their performance on a film-based test of anticipation skill involving the soccer penalty kick. It was anticipated that this within-group comparison would help resolve the present debate regarding the key predictive source(s) of information used by goalkeepers when attempting to anticipate the direction of the penalty kick.

2. Method

2.1. *Participants*

Sixteen goalkeepers (mean age = 25.7, SD = 7.1 years) playing in one of the three highest leagues in The Netherlands (Premier, First division and semi-professional division)

provided informed consent prior to participating and were free to withdraw from testing at any stage. Data from seven of these players were reported previously by Savelsbergh *et al.* (2002). Participants were subsequently divided into two groups, successful (SE) and non-successful (NE) experts, based on their ability to predict direction correctly in a test of anticipation skill as detailed in the Results section.

2.2. *Test film*

The test film was produced in conjunction with PSV Eindhoven Football (soccer) Club. Ten youth players (mean age = 18.9, SD = 1.5 years) taking penalty kicks were filmed from the goalkeeper's perspective. The film clips were recorded using a digital video camera (Canon XM 1) positioned in the middle of the goal at a height of 1.77 m.

A 2.42 m × 1.50 m sailcloth was hung from a regulation cross-bar to indicate the area to which the players had to shoot. Six different target areas (0.81 m × 1.50 m) were painted on the sailcloth. The players were asked to try to disguise the intended target of the penalty kick, as they would in a normal competitive situation. Each film clip included the penalty taker's approach to the ball, their actions prior to and during ball contact and the first portion of ball flight. Two penalties were recorded in each target location for every player, providing a total of 120 trials. A microphone was attached to the sailcloth to indicate the moment at which the ball crossed the goal line, whilst a second microphone was positioned near the penalty spot to record the moment of ball–foot contact. These two temporal measures were employed to calculate the flight time and velocity for each penalty kick. The average ball flight time was 648 ms and the mean ball velocity was 16.84 m s^{-1}.

2.3. *Apparatus*

The film clips were back-projected (EIK CC-7000), using a reflective surface to increase image size, onto a large screen (2.29 m × 2.27 m) positioned 3.45 m from the participant. The experimental layout was the same as that reported by Savelsbergh *et al.* (2002). The image of the penalty taker subtended a visual angle of approximately 8° at foot–ball impact, thereby closely simulating the real image size and distance between the goalkeeper and the penalty spot.

The response movements performed by the participants were recorded using a hand-held joystick. The joystick (Dual Axis Farnell M11Q61P) was positioned at waist height just in front of the participant. The joystick signal in millivolts was amplified and stored on computer by means of LABVIEW (version 5.1) and could be moved through 360°. The film clip and the joystick were synchronized in milliseconds by means of a 5 V signal that marked the start and end of the film clip.

Visual search behaviours were recorded using an eye–head integration (EHI) system that included an Applied Science Laboratories (ASL) 4000SU eye-tracker and an Ascension Technologies magnetic head tracker (model: 6DFOB). The EHI is a video-based monocular system that measures eye line-of-gaze using head-mounted optics. The system works by collecting three pieces of information: displacement between the left pupil and corneal reflex (reflection of the light source from the surface of the cornea), position of the eye in the head and position and orientation of the head in space. The relative position of these features is used to compute visual point-of-gaze with respect to a pre-calibrated nine-point grid projected onto the scene plane. A simple eye calibration was performed to verify point-of-gaze before each participant was tested. The calibration was checked following each block of ten trials. The data were superimposed onto the

scene in the form of a positional cursor to highlight point-of-gaze. This image was then stored using a video recorder for further analysis. The data were subjected to a frame-by-frame analysis using a PAL standard video recorder (Panasonic AG7330) at 50 Hz. The accuracy of the system was $\pm 1^{\circ}$ visual angle. System precision (i.e. amount of instrument noise in the eye position measure when the eye is perfectly stationary) was better than 0.5° in both the horizontal and the vertical direction.

2.4. *Procedure*

After obtaining informed consent, the participants were positioned behind the joystick. They had to anticipate the direction of each penalty kick quickly and accurately by moving the joystick as if to intercept the ball. If the joystick was positioned in the correct location at the moment the ball crossed the goal line, the penalty was judged a successful save. Participants were allowed to use the joystick to make corrections to their initial decision as the penalty kick evolved. No feedback was given as to their performance on each trial. Before the penalties were presented, a test was undertaken to determine whether there were baseline differences between the two groups in simple reaction time. Instead of a penalty clip, a star was presented at one of six possible locations and the participant had to move the joystick as quickly as possible to the correct position. A star was randomly presented at each location four times, providing a total of 24 test trials. These trials helped the participants to familiarize themselves with the movements of the joystick.

After the reaction time test, five practice trials were carried out using the penalty clips to familiarize the participants with the experimental protocol. Thirty film clips were then presented to the participants, five penalties in each of six locations. These film clips were chosen from the original sample of 120 trials by a panel of three experienced soccer coaches as being representative of typical penalty kick scenarios. An equal mix of right- and left-footed penalty takers was included. The end location of the penalties was completely randomized, but kept in the same order for each participant.

2.5. *Dependent variables and analysis*

2.5.1. Reaction time. The reaction time was defined as the time period between the onset of the star stimulus and the initiation of the joystick movement (in ms). The start of the movement was defined as the moment at which the velocity of the joystick exceeded 5% of its peak velocity. This period was intended as a baseline measure of reaction time.

2.5.2. Anticipation test. The following measures were recorded from the anticipation test:

- *Penalties saved* – the percentage of trials for which the joystick was positioned in the correct location at the moment the ball crossed the goal line.
- *Correct side* – the percentage of trials for which the joystick was positioned on the correct side (i.e. right or left judgement) at the moment the ball crossed the goal line.
- *Correct height* – the percentage of trials for which the joystick was positioned at the correct height (i.e. high or low judgement) at the moment the ball crossed the goal line.
- *Proportion of corrections* – the percentage of trials where corrective movements (i.e. a joystick movement that was initially directed toward an incorrect location) of the joystick occurred before the ball passed the goal line. This dependent variable was interpreted as an indication of a change in the participant's decision.

- *Time of initiation of joystick movement* – the time when the participant began to move the joystick relative to foot – ball contact by the penalty taker (in ms). A minus sign indicates that the joystick was moved before foot – ball contact.

2.5.3. Visual search data

- *Percentage viewing time* – the amount of time participants spent fixating various areas of the display when attempting to anticipate ball direction. Eight fixation location categories were used, including at the head, hips, kicking leg and non-kicking leg. If the fixation was not in one of these areas, it was unclassified.
- *Search rate* – a fixation was defined as the period of time when the eye remained stationary within 1.5° of movement tolerance for a period equal to, or greater than, 120 ms (see Williams *et al.* 1999). From this measure, the following was calculated: the number of visual fixations, the number of areas fixated and the mean fixation duration per trial.

Each dependent measure was analysed separately using a one-way analysis of variance in which 'group' was the between-participants factor. With regard to percentage viewing time, we were interested only in a specific and limited number of contrasts based on earlier reported research (Savelsbergh *et al.* 2002), for instance, identifying whether group differences existed for time spent fixating each body segment only rather than contrasting, for instance, time spent fixating on the kicking leg for the SE group compared with time spent fixating on the trunk for the NE group. Partial η^2 was also calculated for each main effect as a measure of meaningfulness.

3. Results

In table 1 the percentage of penalties stopped is presented separately for each goalkeeper. On the basis of these performance scores, two groups of participants were created for further analyses. A cumulative method was used to determine the probability that a penalty could be stopped by randomly selecting from one of six possible locations. The method showed that only if a participant stopped nine or more penalties was the probability that a gambling strategy was invoked 5% or less (see table 2). Table 1 shows that participants 11 – 16 stopped less than nine penalty kicks (i.e. $< 30\%$). It can be reliably concluded that the strategy adopted by these participants was no better than one

Table 1. The expert goalkeepers ranked according to the percentage of penalties stopped. P refers to participants playing in the Premier League, F to goalkeepers of the First division and S to semi-professional goalkeepers [the latter group of participants was also included in the Savelsbergh *et al.* (2002) study].

Rank	Division	Score	Rank	Division	Score
1	F	63	9	S	33
2	S	57	10	F	30
3	F	50	11	S	26
4	S	43	12	P	23
5	F	37	13	F	23
6	S	37	14	S	20
7	S	33	15	F	17
8	F	33	16	P	17

Table 2. Probability table for randomly selecting one out of six locations. The number of locations is the number of locations correctly selected at random with 30 repetitions. The probability of occurrence is the probability that a particular number of locations is correctly selected at random (e.g. the probability that five locations are correctly selected at random is 19%). The cumulative probability is the probability that more than a particular number of locations are correctly selected at random [e.g. the probability that five or more locations are correctly selected at random (i.e. 0.575) is the total sum of the probabilities of occurrence of five and more locations that are correctly selected].

Number of correct locations	Probability of occurrence	Cumulative probability
0	0.004	1
1	0.025	0.995
2	0.073	0.970
3	0.136	0.897
4	0.184	0.760
5	0.192	0.575
6	0.160	0.383
7	0.109	0.223
8	0.063	0.113
9	0.030	0.050
10	0.012	0.019
11	0.004	0.006
12	0.001	0.002
13	0.000	0.000
14	0.000	0.000
15	2.1×10^{-5}	2.6×10^{-5}
16	4.0×10^{-6}	4.7×10^{-6}
17	6.6×10^{-7}	7.7×10^{-7}
18	9.5×10^{-8}	1.0×10^{-7}
19	1.2×10^{-8}	1.3×10^{-8}
20	1.3×10^{-9}	1.4×10^{-9}
21	1.2×10^{-10}	1.3×10^{-10}
22	1.0×10^{-11}	1.1×10^{-11}
23	7.1×10^{-13}	7.6×10^{-13}
24	4.2×10^{-14}	4.4×10^{-14}
25	2.0×10^{-15}	2.0×10^{-15}
26	7.7×10^{-17}	7.9×10^{-17}
27	2.3×10^{-18}	2.3×10^{-18}
28	4.9×10^{-20}	4.9×10^{-20}
29	6.7×10^{-22}	6.8×10^{-22}
30	4.5×10^{-24}	4.5×10^{-24}

where locations were randomly selected, and therefore, these expert goalkeepers comprised the NE group. The second group of experts comprised participants 1–6, who were much more successful in stopping penalties (37–63%). This group was labelled the SE group. In the remainder of this section, these two groups are compared on anticipation and visual search.

3.1. *Anticipation test*

The mean group performance variables are presented in table 3. Not surprisingly, given the within-task criterion, the SE group saved significantly more penalties [$F(1,10) = 31.64$, $p = 0.000$, $\eta_p^2 = 0.760$] and were more accurate in predicting the height

Table 3. The dependent measures recorded on the anticipation test across groups (mean ± SD). The novice data are from Savelsbergh *et al.* (2002).

	Experts		
	Successful	Non-successful	Novices
Penalties stopped (%)	47.8 ± 10.9	21.1 ± 4.0	25.9 ± 10.8
Correct height (%)	49.4 ± 9.3	30.6 ± 8.2	32.6 ± 8.2
Correct side (%)	93.3 ± 6.9	68.9 ± 16.3	71.4 ± 8.2
Proportion of corrections (%)	22.5 ± 9.4	21.1 ± 8.9	38.5 ± 15.3
Time of initiation of joystick Movement (ms)[a]	−230 ± 69.0	−359 ± 110	−479 ± 292
Reaction time (ms)	238 ± 33.2	262 ± 21.2	257 ± 46.4

[a]A minus sign indicates that the joystick is moved before foot–ball contact.

Table 4. Fixation duration, number of fixation locations and number of fixations (mean ± SD). The novice data are from Savelsbergh *et al.* (2002).

	Experts		
	Successful	Non-successful	Novices
Fixation duration (ms)	501 ± 129	529 ± 129	430 ± 76
Number of fixation locations	3.0 ± 0.4	2.9 ± 0.6	3.1 ± 0.5
Number of fixations	3.5 ± 0.6	3.3 ± 0.8	4.0 ± 0.5

[$F(1,10) = 13.827$, $p = 0.004$, $\eta_p^2 = 0.580$] and side of the penalty kicks [$F(1,10) = 11.41$, $p = 0.007$, $\eta_p^2 = 0.533$] than the NE group.

The SE group initiated the joystick movement nearer (−230 ms) to the foot–ball contact (i.e. later in the run-up) than the NE group (−359 ms) [$F(1,10) = 5.90$, $p = 0.035$, $\eta_p^2 = 0.371$]. These results were not attributable to differences in general reaction time between groups assessed on the star reaction test [$F(1,10) = 2.25$, NS]. Finally, no differences were revealed between the two groups for the percentage of corrective movements of the joystick [$F(1,10) = 0.75$, NS].

3.2. *Visual search data*

The visual search variables are presented in table 4. The measures of search rate were analysed separately using a one-way analysis of variance in which 'group' (UE, SE) was the between-participants factor. There were no significant differences between the SE group and the UE group for fixation duration [$F(1,10) = 0.14$], number of fixations [$F(1,10) = 0.38$] and the number of areas fixated per trial [$F(1,10) = 0.26$].

Percentage viewing time is presented graphically in figure 2. Pre-planned comparisons performed on the percentage viewing time data using separate one-way analyses of variance for each fixation location (head, hips, kicking leg and non-kicking leg) with 'group' (NE, SE) as between-participants factor showed that the SE group spent more time fixating the non-kicking leg [$F(1,10) = 5.50$, $p = 0.041$, $\eta_p^2 = 0.355$] than the NE group, whereas a trend for the NE group to look longer at the head was found [$F(1,10) = 3.64$, $p = 0.08$, $\eta_p^2 = 0.267$]. Moreover, in the case of the SE group the proportion of time

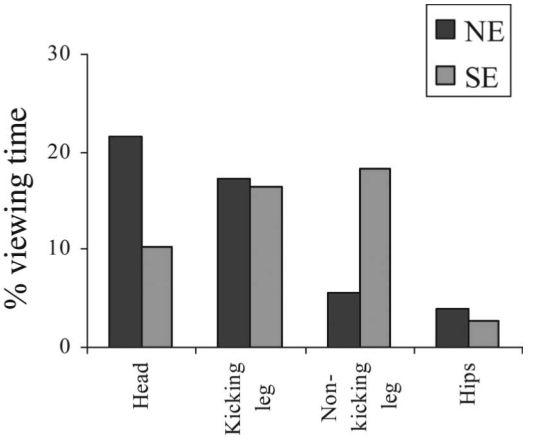

Figure 2. The percentage time spent viewing each fixation location for the successful and non-successful expert as a function of locations.

designated as 'unclassified' was larger than for the NE group [$F(1,10) = 5.16$, $p = 0.047$, $\eta_p^2 = 0.340$]. There were no significant differences between the groups with respect to the regions hips [$F(1,10) = 0.17$] and kicking leg [$F(1,10) = 0.01$].

4. Discussion

The aim of this study was to examine differences in anticipation and visual search behaviour between successful and non-successful expert goalkeepers in saving soccer penalty kicks. The successful experts were significantly more accurate in predicting the height and direction of the penalty kick, waited longer before initiating a response and spent longer periods of time fixating on the non-kicking leg in comparison to the unsuccessful experts. It appears that the difference between successful and less successful expert performers in stopping a penalty is determined by a combination of when to initiate a response and attention to the non-kicking leg.

In order to obtain a complete picture with respect to the role of visual search and anticipatory performance in saving penalty kicks, the data from the successful and less successful expert goalkeepers were compared with those collected from novice goalkeepers in a previous study by Savelsbergh *et al*. (2002). To facilitate the comparison process we have presented data from the novice group in tables 3 and 4. No significant differences between the NE group in the current study and the novice group used by Savelsbergh *et al*. (2002) were found, with the exception of percentage of joystick corrections [a one-way ANOVA comparing the NE-group of the current study with the novices of the Savelsbergh *et al*. (2002) study revealed a significant effect only for proportion of corrections; $F(1,11) = 5.98$, $p = 0.032$, $\eta_p^2 = 0.352$].

Although there were no differences in general visual search characteristics such as mean duration, number of fixations or number of fixation locations across the two expert groups in the present study, the experiment did reveal a difference between the groups with respect to the particular regions fixated. This difference is not in the amount of information, but in the *nature* of the information picked up by the goalkeepers. The non-successful experts showed a trend to fixate more on the head, whereas the successful experts fixated more on information from the non-kicking leg. The present findings

corroborate the ideas of Franks and Hanvey (1997), who argued that the orientation of the non-kicking leg is the optimal source of information available prior to foot–ball contact. According to Franks and Hanvey (1997), the non-kicking foot is oriented such that it points towards the ball's likely destination, and appears to be reliable in 80% of penalty kicks. The positioning of the non-kicking leg occurs at 200–250 ms prior to ball contact (Franks and Hanvey 1997), which makes it the most suitable source of information. Alternative sources of information (e.g. orientation of the kicking leg, foot–ball contact) may be more predictive but may not leave the goalkeeper sufficient time to make the initial anticipatory decision required to save the penalty. When experts fixate other areas, it is likely to act as a confirmatory source of information as well as to allow subtle on-line adaptations and modifications to take place within the scope of the available constraints (e.g. to make changes in hand position).

It is important to stress that the assumed importance of the non-kicking leg as a determinant of successful performance in stopping a penalty kick does not conflict with the *observations* from previous studies that have identified the head, kicking leg and/or foot–ball contact as the most important sources of information (Tyldesley *et al*. 1982, Williams and Burwitz 1993, Savelsbergh *et al*. 2002). The expert groups in these studies probably included expert goalkeepers using less successful strategies. For example, two of the seven expert goalkeepers in the Savelsbergh *et al*. (2002) study were designated to the NE group (see table 1). The NE group performed at a similar level and showed a similar search rate to the novice group (table 3). It is not unlikely therefore that the expert groups in previous studies may have been 'contaminated' with goalkeepers using a gambling strategy, which would have led to the identification of sources of information that were either less reliable or occurred very late during the run-up, leaving the goalkeeper insufficient time to stop the penalty. In contrast, the current study shows that the differences in anticipation skill between successful and less successful goalkeepers is probably due to subtle differences in visual search behaviour based around the extraction of information from the non-kicking leg. Manipulation of information sources is required, perhaps by spatial occlusion, to further assess whether it is the non-kicking leg *per se*, or whether it is an even more subtle source of information, for instance the relative motion between the kicking and non-kicking leg, that makes the difference between successful and less successful penalty stoppers.

The successful expert goalkeepers initiated their joystick movements later or nearer to foot–ball contact than the NE group and novices. The clear difference between successful and non-successful expert goalkeepers in the initiation of the movement would be expected, given that the potential sources of information become more specific (and hence more reliable) to the ball's destination with the unfolding of the run-up. In the film clips we used, the non-kicking leg is positioned around 350 ms before foot–ball contact. Considering the initiation of the joystick (230 ms before contact) and visual search data of the SE group, one can infer that the successful expert goalkeepers picked up this specific information prior to the initiation of the response. As a result of using such a highly specific and reliable source of information, the need to correct the response was minimized, as shown by the smaller proportion of corrected movements (at least when compared with novices). Similar strategies have been reported when attempting to intercept a ball in flight (see Oudejans *et al*. 1997, Rodrigues *et al*. 1999). Oudejans *et al*. (1997) showed that, when attempting to catch fly balls, expert catchers initiated their movements towards the ball later and made fewer corrective actions prior to interception. In the same vein, in a one-handed catching experiment, a straighter trajectory of the hand and an interception point later in time in order to 'buy extra time' was found for a

successful catch (Laurent *et al*. 1994). It can be concluded that the expert performer tries to extract information as long as possible – but not too long – before initiating the hit, catch or joystick movement. Because the detected information is more specific, the need to correct the movement is diminished.

In conclusion, the present study discerned two strategies among expert goalkeepers in their attempts to save a penalty kick. Like novices, the non-successful expert goalkeepers appeared to use a gambling strategy, in which they initiated their action relatively early. In contrast, the successful expert goalkeepers employed a distinct anticipation strategy and initiated their actions relatively late in the run-up of the kicker. The critical difference for success was the use of information related to the non-kicking leg to decide the ball's destination. Finally, we would like to stress that penalty saving is a multifaceted skill. While predicting the direction of the shot is a decisive factor for a successful save, it is only one out of several important factors in stopping a penalty kick.

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References

Abernethy, B., 1987, Anticipation in sport: a review. *Physical Education Review*, **10,** 5–16.

Abernethy, B., Gill, D.P., Parks, S.L. and Packer, S.T. 2001, Expertise and the perception of kinematic and situational probability information. *Perception*, **30,** 233–252.

Franks, I.M. and Hanvey, T., 1997, Cues for goalkeepers. High-tech methods used to measure penalty shot response. *Soccer Journal*, **42,** 30–33.

Keller, D., Hennemann, M.C. and Algria, J., 1979, Fussball; der Elfmeter. Analyse des spezifischen vorbereitenden Anpassungsverhaltens zur Durchfuhrung einer sportlichen Bewegung. *Leistungssport*, **9,** 394–398.

Kropp, M. and Trapp, A., 1999, *35 Jahre Bundesliga-Elfmeter* (Kassel: Agon Sportverlag).

Laurent, M., Montagne, G. and Savelsbergh, G.J.P., 1994, The control and coordination of one-handed catching: the effect of temporal constraints. *Experimental Brain Research*, **101,** 314–322.

McMorris, T. and Colenso, S., 1996, Anticipation of professional soccer goalkeepers when facing right- and left-footed penalty kicks. *Perceptual and Motor Skills*, **82,** 931–934.

McMorris, T., Copeman, R., Corcoran, D., Saunders, G. and Potters, S., 1993, Anticipation of soccer goalkeepers facing penalty kicks. In *Science and Football II*, T. Reilly, J. Clarys and A. Stibbe (Eds), 250–253 (London: E & FN Spon).

Neumaier, A., Poel, H. te and Standtke, V., 1987, Zur Antizipation des Elfmeterschusses aus der Sicht des Torwarts. *Leistungsport*, **17,** 23–32.

Oudejans, R.R.D., Michaels, C.F. and Bakker, F.C., 1997, The effects of baseball experience on movement initiation in catching fly balls. *Journal of Sports Sciences*, **15,** 587–595.

Rodrigues, S.T., Vickers, J.N. and Williams, A.M., 1999, Two visual systems and temporal pressure in table tennis. *Journal of Sport and Exercise Psychology*, **21,** p. S91.

Savelsbergh, G.J.P., Williams, 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.

Tyldesley, D.A., Bootsma, R.J. and Bomhoff, G., 1982, Skill level and eye movements patterns in a sport-oriented reaction time task. In *Motorik- und Bewegungsforschung*, H. Rieder, K. Bos, H. Mechling and K. Reische (Eds), 290–29 (Schorndorf: Hofmann).

Van der Kamp, J., 2001, De kunst van het stoppen van de strafschop. [The art of stopping a penalty kick.] *Sportpsychologie Bulletin*, **12,** 53–61.

Whiting, H.T.A., 1986, Isn't there a catch in it somewhere? *Journal of Motor Behavior*, **18,** 486–491.

WILLIAMS, A.M., 2000, Perceptual skill in soccer: implications for talent identification and development. *Journal of Sports Sciences*, **18,** 1–14.

WILLIAMS, A.M. and BURWITZ, L., 1993, Advance cue utilization in soccer. In *Science and Football II*, T. Reilly, J. Clarys and A. Stibbe (Eds), 239–243 (London: E & FN Spon).

WILLIAMS, A.M., DAVIDS, K. and WILLIAMS, J.G., 1999, *Visual Perception and Action in Sport* (London and New York: E & FN Spon).