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How position and motion of expert assistant referees in soccer relate to the quality of their offside judgements during actual match play

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In the present study, we investigated the relationship between the position and velocity of professional assistant referees and the quality of their offside judgements during actual match play. To this aim, we identified potential offside situations in four top-league football matches and examined the position and velocity of the assistant referee at the moment of passing in relation to whether there was a violation of the offside rule and whether the assistant referee flagged or not. The assistant referees were frequently positioned away from the offside line when judging offside, which they did correctly in 94% of the selected situations. The type of error made in the remaining 6% of the selected situations depended on whether assistant referees were leading or trailing the offside line. It further appeared that assistant referees were almost always in motion when they judged offside, with speeds varying from walking to sprinting. More errors were made when assistant referees were running than when they were standing still, walking or jogging, indicating that, in addition to positioning, speed of locomotion also affected the quality of offside judgements.

KEY WORDS: Decision making, Football, Information detection, Perceptual expertise.

Despite the importance of the decisions of referees in association football (soccer), very little is known about the factors that influence the quality of their decision making. In the present study, we seek to gain more insight into these factors by investigating whether and how the manner in which assistant referees (ARs) position themselves relative to the offside line affects their offside judgements.

In association football, the offside rule is violated when a player "is nearer to the opponents' goal line than both the ball and the second last opponent"

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(FIFA, 2004, p. 34) (i.e., on the opponents half of the field) at the moment that the ball is played in his or her direction, and he or she is actively involved in the play. It is (primarily) the duty of the ARs to determine whether the offside rule is violated. They must follow the fast evolving play, specifically the second last defender. Then they must determine (a) when the pass is made forward, (b) where attackers are relative to the second last defender at the moment of passing, and, when offside, (c) whether attackers are involved in active play. All of this has to be accomplished in a split second and from a position on the sideline, often far away from the to be judged situation. Therefore, it is no surprise that ARs sometimes make errors in judging offside.

One explanation for erroneous judgements is that ARs cannot see the passer and receiver simultaneously (Belda Maruenda, 2004; Sanabria, Cenjor, Márquez, Gutierrez, Martinez, & Prados-García, 1998), for instance, when a long pass is given from the defensive third to the attacking third, implying that the AR has to shift his gaze over an area of well over 50 meters. As it takes time to shift gaze from passer to receiver, ARs judge a situation a split second later than the moment of passing, a sufficiently long time, for instance, for the receiver to have gone past the second last defender and to appear offside. Thus, at the moment the AR sees the situation he or she may come to the wrong conclusion due to the time delay involved with the gaze shift from passer to receiver (Belda Maruenda, 2004; Sanabria et al., 1998).

However, Oudejans, Verheijen, Bakker, Gerrits, Steinbrückner, and Beek (2000) found no support for this hypothesis. In their field experiment, expert ARs, judged 200 played offside situations, while carrying a miniature video camera on their head. The idea by Sanabria et al. (1998) could not account for the 40 errors that were made as the ARs did not shift their field of view from passer to second last defender after the pass was made. Instead, ARs appeared to make a gaze shift just prior to the pass so that they were already looking at the defender at the moment the pass was made. These data suggested that ARs determined the moment of passing by anticipating the pass in combination with peripheral vision and perhaps the sound of foot-ball contact.

Oudejans et al. (2000) further showed that the errors that were made in judging offside were consistent with the use of information that does not always veridically specify[1] who is closer to the goal (attacker or defender), namely, the optical angle between second last defender and receiving attacker (see Figure 1). This information only specifies who is closer to the defender's goal line if the AR is positioned on the offside line. In their field experiment, however, Oudejans et al. (2000) showed that the ARs were frequently positioned away from that line when they judged offside[2], occupying a point of observation from which errors are optically inevitable (Figure 1). Thus, Oudejans et al. (2000) concluded that the observation point of ARs relative to the offside line is an important determinant of many incorrect decisions in judging offside.

Krustrup, Mohr, and Bangsbo (2002) confirmed that, irrespective of whether or not offside had to be judged, throughout real matches top-class ARs are frequently positioned away from the offside line. The average distance from this line during a match varied from 1 to 3 m among ARs. However, it has never been investigated where exactly ARs are positioned in real matches at the moment they are judging potential offside situations, nor how this positioning of ARs relates to the quality of their decisions regarding offside. Likewise, it has never been investigated whether ARs are standing still, walking or running when they are judging offside in real matches and whether speed of locomotion bears any relation to the quality of offside judgements. Krustrup et al., (2002) and Helsen and Bultynck (2004) reported locomotor activities of ARs in real matches but again irrespective of the quality of their offside judgements. Krustrup et al. (2002) showed that expert ARs "on average perform more than 110 high-intensity running activities and 100 bouts of sideways running, and ... more than 225 direction changes and a total of 1000 activity changes" (p. 869). Therefore, one would expect ARs to be more often in motion than standing still when judging offside. For reasons to be discussed below, it is quite plausible that the position and velocity of ARs at the moment of judging offside influence the quality of their judgements. Uncovering this relationship is of both theoretical and practical relevance.

The most ecologically valid way to gain insight into the relationship between ARs' positioning and velocity of locomotion and the quality of their offside judgements is to examine it in real-life football situations. Therefore,

[1]Specifying information is information that is specific to (to-be-perceived) properties of the environment. Detecting information that specifies a property of the environment allows the observer to make reliable judgments about this property (Beek et al. 2003). Non-specifying information might be related to a to-be-perceived property, but it is not specific to it in that its value does not under all circumstances reliably predict the value of the to-be-perceived property (ibid.).

[2]It is interesting to note that the ARs indicated, in informal interviews afterwards, that they were unaware of their mispositioning, and that they tried to stay in line with the second last defender. Although there is no formal instruction material available stating so explicitly, it is common practice that ARs are instructed and trained to be in line with the second last defender (personal communication with Jaap Uilenberg, head of refereeing, Royal Dutch Football Association).

we examined this relationship under natural conditions rather than in a laboratory or experimental setting. For four matches played in the highest Dutch professional football competition we identified potential offside situations, that is, situations in which the ARs had to judge offside. For these situations we determined: (a) where the ARs were positioned relative to the second last defender, (b) what the direction and speed of their locomotion was at those moments, and (c) whether the offside decisions of the ARs were correct or not. Subsequently, we tested how position and velocity of locomotion were related to the quality of their offside judgements. To obtain an overall impression (i.e., not just one restricted to the errors), and to determine how often ARs err relative to the total number of offside decisions they make, we were specifically interested in analysing *all* potential offside situations (e.g., it is only possible to report error percentages if the entire population of possible offside situations is known).

For positioning the most important prediction ensuing from the explanation by Oudejans et al. (2000) is that type of error depends on whether the AR is leading or trailing the offside line. ARs can make two types of error: flag errors (FEs) are made when the AR flags while the receiving attacker is not offside; not-flag errors (NFEs) are made when the AR does not flag while the receiving attacker is offside (Figure 1). In general, it is more likely that one or more defenders are positioned between the receiving attacker and the AR (Figure 1: Situation 1) than that no defender is positioned between the attacker and the AR (Figure 1: Situation 2: Situation 1 will occur more frequently than Situation 2). Only when the attacker is near the AR, the latter situation might be more probable. Therefore, and following Oudejans et al. (2000), we hypothesize that, when judging offside, ARs make more FEs than NFEs when they are leading the offside line (Figure 1a), and, conversely, that they make more NFEs than FEs when they are trailing the offside line (Figure 1b).

How direction and speed of locomotion are related to the quality of offside judgements is an empirical question. Based on the study of Oudejans et al. (2000), we expect that type of error (i.e., flag error versus not-flag error) is primarily dependent on whether the AR is leading or trailing the offside line. In contrast, we have no a priori theoretical reason to believe that type of error would be related to either direction of locomotion (to the goal line or halfway line) or speed of locomotion. Nevertheless, the possibility exists that more errors will be made when the AR is running as opposed to when he is standing still or walking. Research has shown that moving too fast may affect retinal image stabilization (cf. Crane & Demer, 1997) or lead to divided attention (e.g., between judging offside and quality of self-motion). This could lead to more errors when ARs are moving at higher speeds.

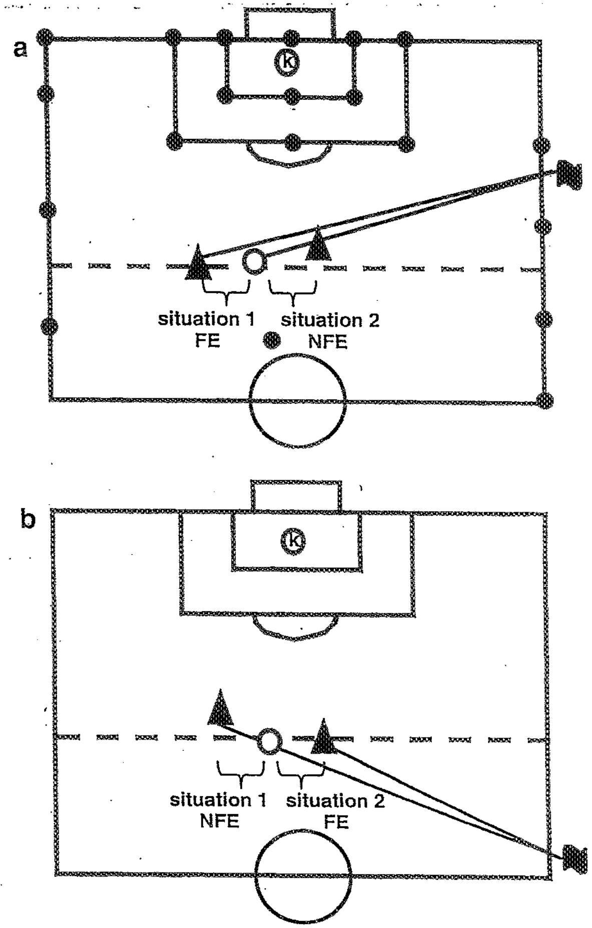

Fig. 1. - Schematic top view representation of offside situations showing the optical angle between the attacker (black triangles), the AR (black symbol) and the defender (open circles) when the AR is leading (a) or trailing (b) the offside line. FE (flag error) and NFE (not-flag error) represent the types of error that are expected to prevail in each situation. In Situation 1 there is a defender between the attacker and the AR, whereas in Situation 2 there is not. The open circle with the K represents the keeper. The black circles in panel (a) indicate the positions of the markers of the calibration frame as used for the purpose of the video analysis (see Method section).

Method

Participants

Video recordings were made of four complete home competition matches of one team in the highest Dutch football league, each time against a different opponent. The team managers had given permission to make the recordings. The behaviour of four male ARs was analysed, one for each match (mean age = 42.2 years, range 38-46). Each AR had more than five years of experience in the highest Dutch football league. They were informed afterwards that video recordings had been made. They gave informed consent for using the data for scientific purposes. The study reported was approved by the local ethics committee.

Experimental set-up

The four matches were videotaped at 50 Hz using two S-VHS camcorders (Panasonic ag-DP 200). The cameras were positioned in the stadium of the home team, at the television platform located high in the stands and horizontally near the halfway line. The left camera captured almost the entire left half of the pitch, apart from the near left corner, and the right camera captured almost the entire right half of the pitch, apart from the near right corner. The right edge of the right video image cut the touchline approximately at the height of the half of the penalty area furthest from the goal line, thus approximately missing the final 8 m of the touchline closest to the goal line. The AR covering the left half of the field was too far away from the cameras to accurately digitise his exact position and speed of locomotion. By combining the images of both camcorders almost all potential offside situations on the right half of the field could be fully analysed. As the video recordings did not capture the near right corner of the field, several situations for which the AR moved close to the goal line, were excluded because the AR was not visible on video (maximally 10-15 potential offside situations in total were missed in this way).

Data reduction

Selection of relevant situations. Through repeated joint observation two observers selected all potential offside situations that were visible on the video footage at the right half of the pitch during the four matches. A potential offside situation was defined as a situation in which the ball was passed forward towards the right goal and in the direction of a receiving attacker who was positioned within a few meters of the offside line. Discarded as potential offside situations were situations in which, according to the rules, there was no offside offence, that is, if the ball was received from a goal kick, a throw-in or a corner kick. A third independent observer checked the video recordings of one of the four matches to verify the selection of potential offside situations and to determine inter-observer agreement. This additional observer selected all 45 situations that were selected by the original observers. In addition, he selected four situations that were not selected by the first two observers, leading to an agreement of 92%. The selection by the original observers, which was available for all four matches, was considered sufficiently reliable to be used for further analyses.

For each potential offside situation, the following variables were determined from video: the moment of passing (defined as the time of the last video field before the ball started moving in the direction of the receiving attacker; accuracy ± 20 ms), the positions of the AR, the second last defender and the receiving attacker, and whether the AR flagged or not (and consequently whether the offside decision was correct or not). We also determined the velocity of locomotion of the AR (see below).

Digitisation of positions. Positions were determined using a digitisation procedure of the video images. Before each match a calibration frame was recorded on video by repeated positioning (at thorax height) of a white Styrofoam ball at 20 different positions at the right half of the pitch (see Figure 1a). The calibration frame was used to compute the positions of players relevant for the offside rule and the AR on the basis of digitised pixel coordinates. Players and AR were digitised at thorax height, that is, the height at which the markers of the calibration frame were positioned. The pixel coordinates were converted into real-world coordinates using the Direct Linear Transformation method (see Miller, Shapiro & McLaughlin, 1980). A separate accuracy test consisting of repeated digitisation of horizontally adjacent pixels revealed that at the touchline along which the AR was moving (i.e., at the side of the pitch near the camera) one pixel corresponded to 0.07 m in real-world coordinates in x-direction (corresponding to the line of motion of the AR). At the touchline across the pitch (i.e., at the side of the pitch far from the camera) one pixel corresponded to 0.13 m (x-direction).

The x-coordinates of the AR, defender and attacker were used to determine for each situation whether there was an offside violation, whether the AR was in line with the defender, and how far from the offside line the AR was positioned. The AR was considered to be in line with the defender when the difference between their x-coordinates was 0.20 m or less. We took 0.20 m because it is larger but still close to 0.13 m, the accuracy of a pixel at the far side of the pitch.

Determining velocity of locomotion. To calculate the velocity and direction of locomotion of the AR, we also digitised his position at the video field before and the video field after the moment of passing. From these three positions (before, at and after the moment of passing) we determined the velocity of the AR, as well as whether he was moving towards the goal line or towards the halfway line.

Errors. For the erroneous decisions it was determined what type of error was made, a flag error or a not-flag error. To increase the sample size of the errors (n = 12, see Results section), we decided to also score the errors made on the left half of the pitch. Although the video recordings of the left half of the pitch were not suited for digitisation of player or AR positions (in the absence of a calibration frame), they were made from high up in the stands with a clear view of the field and the mowing lanes parallel to the halfway line and the goal lines. As such, they were of sufficient quality to determine relative player positions on the field, especially by replaying and freezing of images. Therefore, the recordings could very well be used to code the following variables: number and type of error, and whether ARs were trailing or leading the offside line when they made those errors. The independent (third) observer who verified the selection of potential situations for the right half of the field selected the errors on the left half of the pitch from the video footage. Another observer (an experienced football player and amateur AR) independently coded the errors as well, yielding an inter-observer agreement of 100%.

Difficult cases. It is not unlikely that many potential offside situations were easy to judge because the distance between the receiving attacker and last defender was relatively large at the moment of passing. As we suspected that most errors would be made in situations that would be difficult to judge, we analysed the more difficult cases separately. We operationalised 'difficult' cases as those situations in which the difference between the x-coordinates (i.e., across the length of the pitch) of the relevant attacker and the second last defender was less than 1 m. In principle, the cut-off point of 1 m is arbitrary, but given the human proportions (shoulder widths of around 40-50 cm), 1 m would provide an adequate division between more difficult and easier to judge situations.

Statistical analyses. Distance to the offside line when trailing and leading as well as speed of locomotion towards the goal line and halfway line were tested using two-tailed, unpaired t-tests. Differences in frequency (e.g., in errors or positioning) were tested using χ^2-analyses. Where necessary we used Fisher's exact test, which is specifically designed for small sample sizes (Siegel, 1956).

Results

Before analysing the relationship between ARs' positioning and velocity of locomotion and the quality of their offside judgements, we sum up the most relevant game statistics that served as a basis for the analyses.

GAME STATISTICS

The observers selected 215 potential offside situations in the four matches (match 1, $n = 48$; match 2, $n = 81$; match 3, $n = 45$; match 4, $n = 41$). Note that these 215 situations represent about half of the total number of potential offside situations that occurred in the matches, as those that occurred at the left half of the field were not analysed. Of the 215 potential offsides that we identified, we found that the number of actual offsides was 19. However, the ARs flagged 21 times. Fourteen of these decisions were correct, while on 7 occasions the ARs flagged when the player was actually onside. Therefore, the ARs did not flag on 5 occasions when the player was actually offside. Thus, in the 215 selected potential offside situations, the ARs judged the situation incorrectly on 12 occasions (5.6%).

Errors. Table I summarises the relevant characteristics of the 12 situations in which a judgement error was made. In 4 situations the AR was leading the second last defender. In one he was on the offside line, and in the remaining 7 he was trailing. Seven flag errors (FE) and 5 not-flag errors (NFE) were made. The extra analysis of errors made on the left half of the pitch nearly doubled the sample size of errors as it yielded 11 additional errors, 8 FE and 3 NFE. In all cases the ARs were leading the offside line. Thus, the total number of errors (right [n =12] and left [n = 11] half of the pitch combined) was 23 (15 FE and 8 NFE).

Difficult cases. There were 45 difficult and 170 easy cases. The number of errors made confirms that this distinction was relevant. More errors were made in the difficult cases (9 out of 45 = 20%) than in easy cases (3 out of 170 = 1.8%; $\chi^2(1, N = 215) = 22.45, p < .0001$).

TABLE I
Speed of the AR (km·h⁻¹), Relative Distances (m), Type of Error and Who Was Closer to the AR, the Receiving Attacker (RA) or the Second Last Defender (LD), for the Twelve Error Situations.

Error	speed AR[a]	distance RA-LD[b]	distance AR-LD[c]	type of error	closer to AR
1	13.9	-0.45	0.72	FE	LD
2	10.1	0.19	-0.46	NFE	LD
3	-3.0	0.61	-0.89	NFE	LD
4	5.3	-0.17	1.21	FE	LD
5	6.7	-0.12	4.33	FE	LD
6	14.0	-1.69	1.77	FE	LD
7	11.4	-1.15	-0.69	FE	LD
8	-2.3	0.15	-0.69	NFE	RA
9	8.1	-0.01	-0.31	FE	RA
10	-5.9	1.05	-0.74	NFE	RA
11	11.6	-0.23	0.10	FE	LD
12	-8.8	0.68	-1.66	NFE	RA

FE = Flag Error; NFE = Not-Flag Error
[a]positive and negative values indicate locomotion in the direction of the goal line and halfway line, respectively.
[b]positive values indicate that the receiving attacker was in an offside position.
[c]positive and negative values indicate that the AR was leading or trailing, respectively.

TABLE II
Positioning of ARs Relative to the Second Last Defender and Their Direction and Speed of Locomotion at the Moment of Passing in All 215 Potential Offside Situations and in the Selection of 45 Difficult Situations (see text for details).

Positioning	in line		leading		trailing	
n all (215)	29		70		116	
n difficult (45)	4		20		21	
distance all (m)	0.002 ± 0.12		0.99 ± 0.60		0.88 ± 0.47	
distance difficult (m)	0.040 ± 0.10		1.20 ± 0.62		0.86 ± 0.37	
Direction of locomotion	goal line	halfway line	goal line	halfway line	goal line	halfway line
n all (213)*	25	4	62	8	86	28
n difficult (45)	3	1	18	2	15	6
speed all (km·h⁻¹)	7.87 ± 5.09	2.71 ± 1.59	7.02 ± 4.72	4.99 ± 4.17	7.23 ± 4.60	2.74 ± 1.93
speed difficult (km·h⁻¹)	8.01 ± 3.26	1.70 ± —	6.39 ± 4.36	4.42 ± 4.03	7.07 ± 5.32	3.62 ± 2.65

*Note that in two situations the AR was standing still.

Position and distance relative to the offside line

All cases. The frequencies and averages concerning the ARs' positioning and locomotion are summarized in Table 2. ARs were more often off (n = 186) than on (n = 29) the offside line, $\chi^2(1, N = 215) = 114.65, p < .0001$. In addition, ARs appeared to trail the offside line more often (n = 116) than they led it (n = 70), $\chi^2(1, N = 186) = 11.38, p < .001$. Average distances with which ARs trailed (0.88 m, SD = 0.47) or led (0.99 m, SD = 0.60) the offside line did not differ, $t_{184} = 1.37, p > .10$. From the distribution presented in Figure 2 it can be inferred that ARs tried hard to be at the offside line as often as possible, but inevitably trailed or led a little, with the average distances just reported.

Difficult cases. In difficult cases ARs were also more often off (n = 41) than on (n = 4) the offside line, $\chi^2(1, N = 45) = 30.42, p < .0001$ (Table II). Furthermore, ARs did not trail the offside line more often (n = 21) than they led it (n = 20), $\chi^2(1, N = 41) = 0.02, p > .10$, which was the case when all situations were considered. The average distance to the offside line with which ARs led (1.20 m, SD = 0.62) was significantly larger than the average trailing distance (0.86 m, SD = 0.37), $t_{39} = 2.15, p < .05$. The distribution of distances in difficult cases is also presented in Figure 2. Given the two peaks in this distribution at distance categories –2 (trailing 0.6 to 1 m) and 3 (leading 1 to 1.4 m) it seems as if ARs had more difficulty staying in line with the second last defender in the difficult cases.

Locomotion (frequency, speed and direction) relative to the offside line

All cases. ARs were more often in motion (n = 213) than standing still (n = 2), $\chi^2(1, N = 215) = 207, p < .0001$, and they moved more often to the goal line (n = 173) than the halfway line (n = 40), $\chi^2(1, N = 213) = 83.04, p < .0001$ (see Table II). Since offside is characterized by movement of the ball (and several players) in the direction of the goal line, the latter is not surprising. When the ARs moved in the direction of the goal line, their speed of locomotion was, on average, higher ($M = 7.16$ km·h^{-1}, $SD = 4.72$) than when they moved in the direction of the halfway line ($M = 3.20$ km·h^{-1}, $SD = 2.59$), $t_{213} = 6.4, p < .001$.

Difficult cases. For the difficult cases the same pattern of results was found. ARs were always (n = 45) in motion, moving more often towards the goal line (n = 36) than the halfway line (n = 9); $\chi^2(1, N = 45) = 16.20, p < .0001$ (Table II), and at higher speeds (to the goal line: $M = 6.80$ km·h^{-1}, $SD = 4.61$; to the halfway line: $M = 3.60$ km·h^{-1}, $SD = 2.66$), $t_{43} = 2.0, p < .05$.

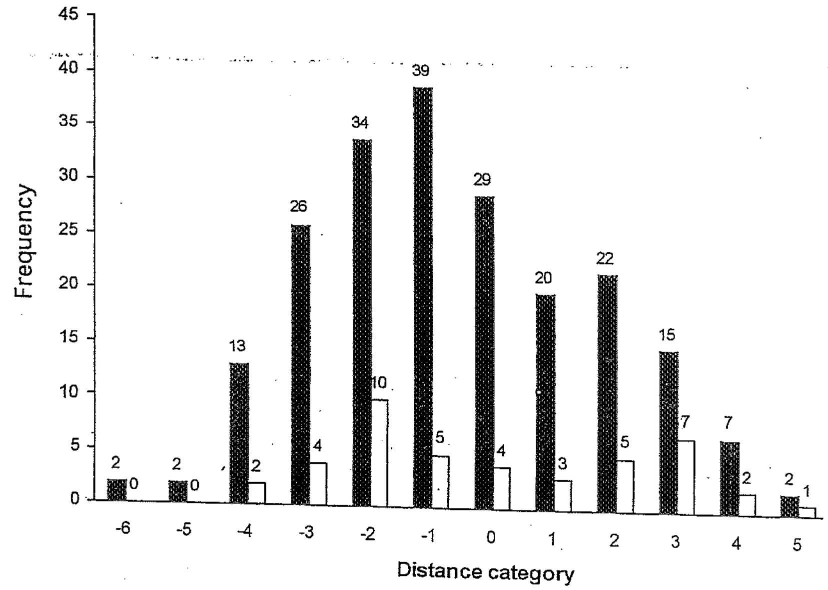

Fig. 2. - Distribution of ARs' distances from the offside line for all cases and for difficult cases. The distance categories consist of 0.40 m bins: 0. from –0.20-0.20 m; 1. from 0.20-0.60 m; 2 from 0.60-1.00 m; 3. from 1.00-1.40 m; 4. from 1.40-1.80 m; 5. from 1.80-2.20 m; 6 larger than 2.20 m. Positive and negative values indicate that the AR was leading and trailing the offside line, respectively.

Positioning and quality of offside judgements

For the right half of the field we determined how many errors and correct decisions were made when the AR trailed and when he led the offside line. Relative number of errors made were not statistically different when ARs trailed (7 out of 116) or led (4 out of 70), $\chi^2(1, N = 186) = 0.01, p > .10$, neither in all situations nor in difficult cases with 5 errors out of 21 when trailing and 3 out of 20 when leading, Fisher's $p > .10$.

However, more important and in line with the predictions, when ARs led the offside line they made relatively more FEs (12) than NFEs (3), whereas the reverse was true when they trailed the offside line (2 FEs vs 5 NFEs), $\chi^2(1, N = 22) = 5.46, p < .05$ (Fisher's $p < .05$; the analysis of errors on the right half of the pitch yielded the same results). This is in line with the explanation by Oudejans et al. (2000) for situations in which the defender is closer to the AR than the attacker in the width direction of the field (see Fig-

2

ure 1). This was the case for most of the error situations on the right half of the pitch (see last column of Table I) as well as for the additional errors made on the left half of the pitch (for 7 out of the 8 FE, and 2 of the 3 NFE the last defender was closer to the AR than the receiving attacker).

Locomotion and quality of offside judgements

As the average speeds tested above obscure how often ARs were standing still, walking or running when judging offside, we categorized the selected situations according to the locomotor categories developed by Krustrup et al. (2002) and Mohr, Krustrup, and Bangsbo (2003) for studying the running profiles of professional football players: standing still (0 $km \cdot h^{-1}$), walking (speeds < 6 $km \cdot h^{-1}$), jogging (6-8 $km \cdot h^{-1}$), low-speed running (8-12 $km \cdot h^{-1}$), moderate-speed running (12-15 $km \cdot h^{-1}$), high-speed running (15-18 $km \cdot h^{-1}$), sprinting (speeds higher than 18 $km \cdot h^{-1}$). Figure 3 shows the percentages of all situations and of the errors that the AR's speed fell in those categories.

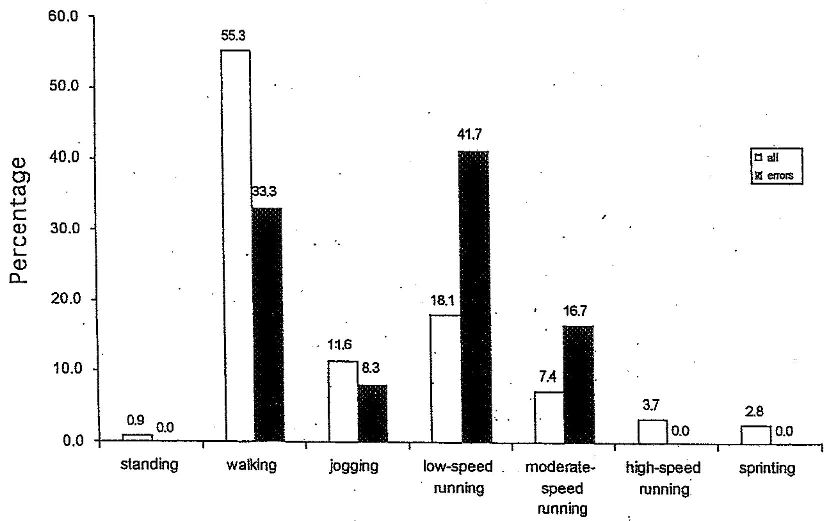

Fig. 3. - Percentages of situations and errors as a function of locomotor speed category. Note that the error percentages are based on only a few observations (e.g., 8.3% is based on a single observation).

To test whether more errors were made at the higher than at the lower locomotion speeds we pooled the situations in which the ARs were running or sprinting, and those in which they were standing, walking and jogging. It appeared that, as expected, the ARs made more errors when they were running or sprinting (7 out of 69) compared to when they moved at jogging speeds or slower (5 out of 146), $\chi^2(1, N = 215) = 4.02, p < .05$. This was also the case for the difficult situations, where 5 errors were made in 13 situations in which ARs were running versus 'only' 4 errors in 32 situations in which ARs were walking or jogging, $\chi^2(1, N = 45) = 3.84, p < .05$. Furthermore, in the difficult situations, errors were significantly more often accompanied by speeds higher than normal walking speeds (5 out of 9, i.e., 55.6%) than non-errors (8 out of 36, i.e., 22.2%), $\chi^2(4, N = 45) = 3.89, p < .05$. Closer examination of the running speeds in the error situations (Table I) revealed that in 8 (66.7%) of the 12 error situations the AR was moving in the direction of the goal line at an average speed of 10.1 $km \cdot h^{-1}$, almost twice the speed of normal walking. In the other four situations he moved in the direction of the halfway line at an average speed of 5.0 $km \cdot h^{-1}$.

Finally, the number of errors were not significantly different when ARs were moving towards the goal line (8 out of 173) rather than the halfway line (4 out of 40), $\chi^2(1, N = 213) = 1.77, p > .10$. This was also true for difficult cases: 6 out of 36 errors versus 3 out of 9 for moving towards the goal line and halfway line, respectively, $\chi^2(1, N = 45) = 1.25, p > .10$.

Discussion

In the present study, we established that in the majority of cases ARs were not positioned on the offside line when judging offside. Instead, ARs led or trailed the second last defender by about a meter on average. In addition, of the more difficult situations 20% was judged erroneously a percentage that is not marginal, and, incidentally, the same as the error percentage that was found in the field experiment of Oudejans et al. (2000), in which 40 errors were made in 200 difficult cases. Most important, the type of errors that were made by the ARs, that is, flag errors or not-flag errors, depended on whether they were trailing or leading the offside line, a finding that is consistent with the explanation for erroneous offside judgements provided by Oudejans et al. (2000).

Although, admittedly, other factors, such as AR's gaze behaviour (Sanabria, et al., 1998), fatigue (Krustrup et al., 2002) and the so-called flash-lag effect (Baldo, Ranvaud, & Moyra, 2002), may have affected the quality of decision making, the explanation by Oudejans et al. (2000) seems to account for the majority of the errors that were made. In total, 14 of the 23 error situations (61%; e.g., Errors 1-6 and Error 9, see Table I) were consistent with the explanation provided by Oudejans et al. (2000) that expert ARs use a variable for judging offside that does not always specify actual relative player positions, namely, the optical angle between the second last defender and receiving attacker (see Figure 1). In these 14 error situations the AR, receiving attacker and second last defender were positioned in such a way that the AR could have easily misperceived the actual relative player positions on the basis of this angle. This angle only veridically specifies who is closer to the defender's goal line (attacker or defender) when the AR is positioned on the offside line. When this is the case, a negative (attacker positioned further towards the halfway line than the defender from the assistant's perspective) or zero angle between defender and attacker specifies that the attacker has not gone past the defender. A positive angle (attacker more to the goal line than the defender) specifies that the attacker has gone past the defender and is thus offside. When the AR is not on the offside line, this angle no longer correctly specifies whether or not the attacker is in an offside position, as is shown in Figure 1, leading to a predictable pattern of errors depending on the position of the AR and the relevant players (defender and attacker). Thus, in most cases being positioned offline, and consequently viewing relevant players and the offside line at an oblique angle, provided a plausible explanation for the type of errors made in judging offside.

Furthermore, we found several indications that speed of locomotion of ARs at the moment of judging offside may also have affected their decision making. First, ARs were almost never standing still when judging offside. This is in line with the expectations on the basis of the results of Krustrup et al. (2002) and Helsen and Bultynck (2004) who studied the physical load and activity profiles of top-class ARs. Because most potential offside situations were judged correctly, being in motion per se apparently did not harm the offside decisions of the ARs. However, it did appear that more errors were made when ARs were running or sprinting compared to when they were standing still, walking or jogging. When running, attention may have shifted away from the pick-up of information about the play to the aspect of self-transport itself and the perceptual control of the direction of heading. In addition, it is possible that at running speeds retinal motion is also higher, leading, beyond a certain point, to a decrease of visual acuity (cf. Crane & Demer, 1997) and subsequently to poorer decisions. Furthermore, it has been suggested that at higher exercise intensities, which may occur at higher locomotion speeds, complex psychomotor functions, including decision making, may be harmed (Krustrup et al., 2002; Reilly & Smith, 1986). Further investigation of the relation between speed of locomotion and decision making by ARs is clearly required.

There is one important issue we have not addressed so far but that might play a role in the decision making of ARs. Krustrup et al. (2002) found that irrespective of offside ARs moved as much sideways (body oriented to the play) as forward (body oriented to the goal line). When the body is oriented forward (to the goal line) when offside is judged the AR has to look over his left shoulder to perceive the play. This might affect the quality of decision making. Therefore, we checked body orientation (trunk and face) of the ARs at the moment of passing for two matches as well as for the errors at right half of the field. We found that ARs were almost always oriented towards the field and thus the developing play (88%) at the moment of passing (inter-observer agreement of 98% for one match). In the error situations the ARs were oriented towards the play in all cases, even when they were running (inter-observer agreement 100%). This does not imply that they were never oriented forward as was found by Krustrup et al. (2002) because on many occasions they were, but not at the moment of passing when they had to judge offside. Thus, differences in body orientation do not seem to play a major role in judging offside.

Coming back to our main findings concerning the positioning of the ARs, it was already noted that these findings support the hypothesis of Oudejans et al. (2000) that expert ARs use a variable for judging offside that does not always specify actual relative player positions. This may seem odd, as in sports in general, experts have most often learned to attend to the most useful information sources for their actions, while leaving unattended those sources that are irrelevant or less useful (e.g., Williams & Grant, 1999). In the ecological approach to perception the learning process to perceptual expertise is called "the education of attention" (Gibson, 1966; Jacobs, 2001; Jacobs & Michaels, 2002; Michaels & Carello, 1981). The education of attention is the process by which one learns which variables to attend to in which situation, that is, the process by which one learns to control the detection of information. One may wonder why expert ARs have not converged onto using a more useful or specifying variable for judging offside.

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[3]Baldo et al. (2002) argued that even when ARs are in line with the last defender, the so-called 'flash-lag effect' may lead to the perception of attackers being positioned further ahead than they really are. In the flash-lag effect (see e.g., Baldo and Klein, 1995; Nijhawan, 2001) "a moving object is perceived as spatially leading its real position at an instant defined by a time marker (usually a briefly flashed stimulus)" (Baldo et al., 2002, p. 1205).

One possible reason is that given the circumstances it is difficult for ARs to detect differences in depth between players. Cutting and Vishton (1995) showed that from about 10 m onward the utility of information sources for perceiving (differences in) depth (e.g., convergence and accommodation, binocular disparity, occlusion, relative size and density, motion perspective, aerial perspective, and height in the visual field) quickly declines (see also Gibson, 1950; Oudejans, in press). Therefore, combined with the fact that ARs are often unaware of their mispositioning (see Footnote 2), it is questionable in many potential offside situations, especially the more difficult ones, whether specifying information sources will be available for ARs to correctly judge offside. Beyond about 10 m the perception of differences in depth by ARs is expected to be poor on the basis of the information sources available (Cutting & Vishton, 1995; Gibson, 1950; Oudejans, in press). One implication would be that more errors are made when the relevant players are far from the AR compared to when they are near him or her. This is confirmed by the findings of Oudejans et al. (2000) who found that 266 errors were made when the players were far from the AR which is significantly more than the 153 errors that were made when they were near him (see their Table 1), $\chi^2(1, N = 419) = 30.48, p < 0.001$[4].

Given the apparent lack of useful information sources for perceiving (differences in) depth, it remains to be seen whether it is possible to educate the attention of ARs, that is, to perceptually educate ARs, to use more useful variables in judging offside in their natural surroundings of a 64-75 m wide football pitch (cf. Beek, Jacobs, Daffertshofer, & Huys, 2003; Oudejans, in press). Maybe ARs can be taught to take advantage of (one of) these sources, off the field, for example, using video training (Farrow & Abernethy, 2002; Helsen & Starkes, 1999; see also Helsen & Bultynck, 2004), or perceptual training in a virtual environment in which one can manipulate variables and what they specify. In a CAVE (Computer Aided Virtual Environment), for instance, it should be possible to create appropriate practice conditions and provide proper feedback that will help ARs to converge onto useful variables for judging offside in this environment (cf. Beek et al., 2003; Oudejans, in press).

Another option to improve offside judgements would be to add variables to the scene that might help ARs in judging offside (see Oudejans, in press). As an example, additional information might be made available by adding texture to the grass either by mowing it in a certain pattern as is often seen or by adding more lines to the field as is also done in, for instance, American football. Informal interviews with the participating ARs in the study by Oudejans et al. (2000) made clear that when different mowing lanes are available ARs sometimes use the information it provides to judge offside. Future research into the possible effects of differently textured fields is clearly required.

One could, of course, also resort to alternative ways of judging offside involving at least some degree of interference with the game of football as it is currently played. The alternatives are often discussed and they vary from additional referees in the stands (where the height provides a better perspective to judge offside), video-replay, and monitoring positions of players and ball using modern technology involving senders and receivers.

In the end, improving offside judgements will benefit the game of football directly (less errors) as well as indirectly, for instance, by virtue of the possible reduction of the stress of ARs (Schuurman-van der Linden & Van Rossum, 2001) as well as aggression that may result from dubious offside judgements (Bakker, Whiting, & Van der Brug, 1990; cf. Schuurman-van der Linden & Van Rossum, 2001; Nevill, Balmer, & Williams, 2002). Schuurman-van der Linden and Van Rossum (2001) found that offside situations were perceived as the number one stressor by ARs. In addition, offside situations were perceived to cause most of the conflicts with players, dug-out and spectators. Thus, being relieved of the sole responsibility for offside judgements might alleviate the task of ARs considerably.

As a final remark, we wish to emphasize that judging offside follows from a combination of whole-body positioning, gaze behaviour, and anticipation (of foot-ball contact and player positions), involving a snapshot decision in a highly dynamic situation in which the relation between positioning, speed of locomotion, and decision-making appears to be crucial, yet the information available is limited (Oudejans et al., 2000; Oudejans, in press). Given those circumstances and with over 90% correct decisions (94% in the present study) we can only conclude that ARs do an excellent job.

[4]For the current study we also made a rough estimation of how far away the second last defender and receiving attacker were positioned from the AR when he made an error at the right half of the pitch. We divided the field in the following four zones receding from the AR: from the touchline where the AR was moving to the 16-m box (0-15 m), from the 16-m box to the middle of the field (15-35 m), from the middle to the other end of the 16-m box (35-55 m), and from the 16-m box to the touchline across the field (55-70 m). For all twelve errors the defender and attacker were more than 10 m away from the AR. Only for one of the twelve errors the defender was approximately 15 away from the AR. Other than that the defender and attacker were always positioned further than 15 m away from the AR when he made an error. For eight errors they were even further away than 35 m.

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