Training of Perceptual-Cognitive Skills in Offside Decision Making

Peter Catteeuw, Bart Gilis, Arne Jaspers, Johan Wagemans, and Werner Helsen
Katholieke Universiteit Leuven

This study investigates the effect of two off-field training formats to improve offside decision making. One group trained with video simulations and another with computer animations. Feedback after every offside situation allowed assistant referees to compensate for the consequences of the flash-lag effect and to improve their decision-making accuracy. First, response accuracy improved and flag errors decreased for both training groups implying that training interventions with feedback taught assistant referees to better deal with the flash-lag effect. Second, the results demonstrated no effect of format, although assistant referees rated video simulations higher for fidelity than computer animations. This implies that a cognitive correction to a perceptual effect can be learned also when the format does not correspond closely with the original perceptual situation. Off-field offside decision-making training should be considered as part of training because it is a considerable help to gain more experience and to improve overall decision-making performance.

Keywords: expertise, flash-lag effect, simulation, transfer, offside

In many sports, coaches try to translate scientific findings into training guidelines to facilitate the acquisition of expert performance. For example, physiological principles are taken into account when a physical training program is...
prepared. For perceptual and decision-making skills, however, the translation from laboratory findings to evidence-based practice on the training field has often been disregarded, although its importance is acknowledged (Abernethy, Parks, & Wann, 1998). From a theoretical point of view, the expert performance approach (Ericsson & Smith, 1991) is often used in research on perceptual and decision-making skills. This approach is characterized by three different stages. Earlier studies in offside decision making have already investigated the first step, i.e., the production of representative tasks that allow to capture the specific expertise of assistant referees (e.g., Gilis, Helsen, Catteeuw, & Wagemans, 2008). In the second step of the expert performance approach, mechanisms are identified that mediate expert performance on the one hand and may explain incorrect decisions in less experienced performers on the other. Recently, significant progress has been made with respect to the perceptual-cognitive mechanisms that explain incorrect offside decisions (e.g., Catteeuw, Gilis, Wagemans, & Helsen, 2010a). Finally, the current study contributes to the third step in which the learning processes and acquisition of expert performance is examined.

A review of the literature (Williams & Grant, 1999) has indicated that perceptual-cognitive skill training is more likely to be effective than visual skill training in improving decision making. Perceptual-cognitive expertise is induced by the acquisition of sport-specific knowledge structures underlying skilled perception, much more so than the training of general physical characteristics of the visual system. Researchers have identified several perceptual-cognitive discriminators for expertise such as pattern recognition and advance cue utilization (for an overview, see Helsen & Starkes, 1999a; Williams, 2000). In this regard, Williams and Ward (2003) suggested the use of video simulations coupled with appropriate instruction and feedback to improve the effective use of decision-making training.

In association football (known as soccer in North America), offside decision making is one of the major and most difficult duties of the assistant referee. The definition of an offside position states that “a player is in an offside position if he is nearer to his opponents’ goal line than both the ball and the second last opponent” (FIFA, 2009). “Nearer to his opponents’ goal line” means any part of the player’s head, body, or feet. In this definition, the arms and hands are not included. The difficulty for the assistant referee is to have a correct perception of an ongoing situation at the exact moment of the pass. The assistant referee has to assess the exact position of the attacker receiving the ball relative to the second-last defender at the precise moment the ball is passed.

In offside decision making, assistant referees can make two types of incorrect decisions, classified by Oudejans, Verheijen, Bakker, Gerrits, Steinbrückner, and Beek (2000) as the non-flag and flag error. The assistant referee makes a non-flag error when he does not signal for offside while the attacker is actually in an offside position. A flag error is made when the assistant referee signals for offside while the attacker is not in an offside position. A flag error is made when the assistant referee signals for offside while the attacker is not in an offside position. Two well-known hypotheses are considered in the literature to explain incorrect offside judgments: the optical error (Oudejans et al., 2000; Oudejans, Bakker, Verheijen, Gerrits, Steinbrückner, & Beek, 2005) and the flash-lag hypothesis (Baldo, Ranvaud, & Morya, 2002; Catteeuw et al., 2010a; Gilis et al., 2008; Gilis, Helsen, Catteeuw, Van Roie, & Wagemans, 2009; Helsen, Gilis, & Weston, 2006). Offside decision-making errors caused by the optical error are due to an incorrect positioning relative to the second-last defender,
that is, the offside line. A good physical fitness, agility, and coordination together with experience help the assistant referee to shadow the second-last defender and, consequently, to be always in line with the offside line (Oudejans et al., 2005). Flag errors caused by the flash-lag effect are due to limitations of the human visual information-processing system (Baldo et al., 2002). The flash-lag effect is defined as a moving object that is perceived as spatially leading its real position at an instant defined by a time marker (usually a briefly flashed stimulus) (Nijhawan, 1994).

Baldo et al. (2002) were the first to translate the flash-lag effect to offside situations in association football. The exact moment of the pass is the time marker (or flash) at which the assistant referee has to judge the position of the attacking player, which receives the ball, relative to the position of the defender. The attacker mostly runs forward at a high velocity. Due to the flash-lag effect, the ball-receiving player is perceived ahead of his actual position at the exact moment of the pass resulting in a bias toward flag errors (Baldo et al., 2002). Helsen et al. (2006) found a bias toward flag errors in the 2002 FIFA World Cup, whereas Gilis et al. (2008) found evidence for the flash-lag effect in offside situations presented as computer animations. In the 2006 FIFA World Cup and the English Premier League, the flash-lag effect was also demonstrated to explain the flag errors (Catteeuw et al., 2010a; Catteeuw, Gilis, García-Aranda, Tresaco, Wagemans, & Helsen, 2010).

Before the 2006 FIFA World Cup, FIFA took measures to decrease the number of incorrect decisions (e.g., training programs for referees and assistant referees) (Catteeuw, Gilis, García-Aranda, et al., 2010). In comparison with the 2002 FIFA World Cup, a decrease in incorrect offside decisions (from 26.1% to 10.0%) was observed in the 2006 FIFA World Cup, although there were more potential offside situations (Catteeuw, Gilis, García-Aranda, et al., 2010). Despite the significant decrease, there were still 10% incorrect decisions. The majority of the incorrect decisions were flag errors and could be explained by the flash-lag effect. In this study, the effect of perceptual-cognitive training on offside decision-making expertise was investigated. In particular, the perceptual-cognitive training was designed to decrease the number of flag errors as these were the major problem in the 2002 and 2006 FIFA World Cups. Extended feedback was provided to teach assistant referees to better deal with the flash-lag illusion resulting in a decrease of flag errors.

Several researchers (Catteeuw, Helsen, Gilis, & Wagemans, 2009; MacMahon, Helsen, Starkes, & Weston, 2007) described association football as a practice-poor environment for referees and assistant referees. Catteeuw et al. (2009) revealed that assistant referees sense a lack of decision-making training. Baker, Côté, and Abernethy (2003) found that experts reported spending time in video training, in contrary to nonexperts, who did not report to invest time in video training. Video training for referees and assistant referees is very limited and only a recent study (Catteeuw, Gilis, Wagemans, & Helsen, 2010b) investigated for the first time the effects of a video-based training program for offside decision-making. In other domains, such as aviation (Allerton, 2000), driving (Devos et al., 2009), law enforcement (Helsen & Starkes, 1999b), and medicine (Debes, Aggarwal, Balasundaram, & Jacobsen, 2010), where training possibilities are scarce, video training or simulators are used. For example, in medical schools, virtual training and video training are frequently used to train students. As surgeons have to operate in possible life-threatening conditions, video training can be helpful to practice without the overwhelming demands to save one’s life (e.g., Burkhart et al., 2010; Debes et al.,
In football refereeing, assistant referees, in particular, need to make important decisions, especially in offside decisions, with potentially big implications for the outcome of the match. As a consequence, video training for assistant referees should be considered as a form of additional training to improve decision-making skills in offside situations. Without additional offside decision-making training, assistant referees can only practice in the match. A recent study in the English Premier League calculated that assistant referees make on average 30 potential offside decisions per match of 90 min (Catteeuw et al., 2010a). The total number of offside decisions ranged from 8 to 60. In this perspective, video training can provide additional experience through a big amount of offside simulations in a short period of time outside the actual match. In addition, the difficulty of offside situations depends on the level of the competition and varies from match to match. For example, an assistant referee may have to judge only a few easy situations in a match. Therefore, the advantage of video training is that difficulty of the situations can easily be experimentally controlled.

The ultimate goal of video training is a positive effect on decision-making in real life matches. As it is very difficult to measure the improvement in judging offside in real matches, in comparison with a laboratory test setting, we tried to estimate the effect of the training intervention by a visual analog scale. It is a scale that can be used to measure a degree of change over time (Portney & Watkins, 2000). First, the purpose is to measure if the video training can increase the confidence of assistant referees in their offside decisions. If confidence in one’s own offside decision-making skills in video training increases over time, this might probably have a positive effect on judging offside in real matches (Lindsay, Read, & Sharma, 1998). Second, with accumulated training opportunities, the perception of difficulty for offside situations is predicted to decrease. Third, “fidelity” for the video- and computer-format was probed. Fidelity refers to the degree of similarity between the training task and the real task (Lintern, Sheppard, Parker, Yates, & Nolan, 1989; Williams & Grant, 1999). In this respect, a distinction is made between physical fidelity (how real the simulation looks), functional fidelity (how real the simulation feels), and psychological fidelity (how real the simulation is perceived).

Catteeuw et al. (2010b) found a positive effect of video training on an offside decision-making task. Response accuracy improved for the training group, while the control group did not make any progress. The training intervention consisted of four training sessions of 20 video simulations and 20 computer animations of offside situations with immediate feedback. First, the assistant referees judged an offside situation. Second, in a screenshot of five probe frames, they tried to detect the probe frame corresponding with the spatial positions of attacker and second-last defender at the moment of the pass. Subsequently, the correct probe frame was shown. Catteeuw et al. (2010b) could not account for potential positive effects of the video and computer format separately and test familiarity. In the pretest and posttest, assistant referees only performed an offside decision-making task with video simulations. Furthermore, testing and training procedures were very similar. Therefore, in the current study, we tested assistant referees for both formats and investigated the difference in effectiveness of two formats—video simulations and computer animations. Two formats were chosen to investigate the degree to which a format should replicate the real task to be effective as a training tool. Initially, scientists assumed that higher fidelity would automatically lead to better transfer.
However, studies with flight simulators suggest that fidelity should be matched to the level of the learner (Alessi, 1988; Allerton, 2000; Andrews, 1988). Boreham (1985) even indicates that decreasing physical fidelity can lead to greater transfer under certain circumstances.

Video simulations are realistic offside situations with a limited number of players videotaped from the touch line (i.e., the perspective of the assistant referee). The computer-animation format uses less realistic player figures shown from a top-view perspective. Interestingly, the computer format was found to be a good discriminator between different levels of assistant referees and correlated with on-field offside tests (Gulis et al., 2008, 2009). Still, it remains unclear whether either video or computer formats are effective to improve offside decision-making. In an attempt to test the efficiency of video and computer format, we uncoupled the training intervention in those two formats. Since the video format has a more realistic point of view, better results are predicted. Yet, if the results are similar or in favor of the computer format, this would offer new opportunities for the future development of more challenging offside decision-making training.

In addition, consistency between response accuracy on an offside decision-making task and accuracy of memory in an offside frame recognition task is also a measure of confidence. Catteeuw et al. (2010b) found that the consistency of the training group improved from pretest to posttest in contrast to the control group. The increase in consistency could point to improved offside decision making in general and a better potential transfer to real matches.

In summary, the first aim is to further examine efficiency of off-field offside decision-making training to reduce errors by providing feedback in form of freezing on the exact moment of the pass. More precisely, we predicted that the number of flag errors would drop for the training groups because the feedback in the training interventions may have taught them to better deal with the consequences of the flash-lag illusion. The second aim of the current study is to investigate the effect of different formats in off-field offside decision-making training. We predict a greater positive training effect for the video-format training group, because assistant referees usually indicate this format as most similar to the match.

Methods

Participants

The group of participants consisted of 40 Belgian assistant referees all active in the first division in Belgium (mean age: 38.8 ± 4.6 years). On average, they had 8.1 ± 4.2 years of experience as assistant referee. None of the assistant referees participated in earlier offside experiments. The test and training sessions took place after the monthly training sessions for assistant referees in Leuven, Belgium.

Eighteen assistant referees participated in the training group, and 22 assistant referees (control group) only performed the pretest and posttest. The assistant referees of the training group performed the pretest all together. Afterward they were assigned to one of two training groups, based on their personal results to create two equal training groups with normal distributed scores. The two training groups consisted of a video-format training group and a computer-format training group.
The study was designed and conducted in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and approved by the Committee for Ethical Considerations in Human Experimentation of the Faculty of Kinesiology and Rehabilitation Sciences from the Katholieke Universiteit Leuven.

**Experimental Design**

The experimental design can be described as the multigroup pretest–posttest design (Portney & Watkins, 2000). The pretest and posttest were conducted at the same time for both training and control groups, after a regular physical training session for assistant referees. The video-format training group participated in four training sessions of 30 offside video simulations each. The computer-format training group participated in four training sessions of 30 offside computer animations each. The control group received no intervention and continued in their regular training and match routines.

**Task and Apparatus**

*Pretest and Posttest.* All assistant referees judged 80 offside situations in the pre- and posttest. A laboratory offside assessment task, similar to earlier offside studies (Gilis et al., 2008, 2009; Catteeuw et al., 2010) was used: 40 offside situations in the video-simulation format and 40 offside situations in the computer-animation format. The offside decision-making task consisted of two different parts as an offside situation was shown followed by a screenshot of five potential probe frames of the moment of the pass (see Figures 1, 2, and 3). First, the assistant referees judged the offside situation and marked whether it was onside or offside. The second task was to remember the exact moment of the pass and indicate the frame corresponding with the spatial position of the attacker and second-last defender at the precise moment the ball was passed (Catteeuw et al., 2010b).

For the video simulations, the same laboratory assessment task was used as in Catteeuw et al. (2010b). Youth elite players of a Belgian second division team in Leuven simulated typical offside situations with two attackers and one defender. A digital high-definition video camera (Sony, XD CAM PDW-700 24p) placed at the touch line recorded these simulations from the perspective of the assistant referee. Forty high-quality offside situations were chosen out of 156 simulations based on the position of the defender relative to the camera position. To eliminate an incorrect angle of view, it was important that only those situations in front of the camera were selected. The offside situations were digitized and edited with the software program Final Cut Pro 6.0.6 (Apple, Inc., US). The pictures with the five probe frames were created with Adobe Photoshop CS2 9.0.2 (Adobe Systems, Inc., US). First, there were seven probe positions for each offside situation with a one-frame difference. Three probes were taken before the pass (–3, –2 or –1 frame[s] before the pass), one probe at the exact moment of the pass (0), and three after the pass (+1, +2 or +3 frame[s] after the pass). Then, the probe frames were reduced to a selection of five probes (–3 to +1, –2 to +2, or –1 to +3). One of the three selections was randomly shown after each situation for 10 s. In addition, these five probe frames were ordered randomly in every projection. On average, the offside situations had a duration of 6.4 ± 1.5 s (range 3.4–9.5). The moment of the pass was on average 2.7 ± 1.1 s (range 0.5–5.2) after the start of the situation.
Figure 1 — Example of the screenshot with five probe frames and a picture of the correct frame in the video-simulation format.
Figure 2 — Example of the screenshot with five probe frames and a picture of the correct frame in the computer-animation format.
For the computer animations, 40 offside situations were used that were developed with Macromedia Flash MX Professional 2004 version 7.2 (Macromedia, Inc., US) by Gilis et al. (2008). The computer animations showed from a top-view perspective three attackers playing against two defenders and one goalkeeper. The same procedures were followed for the editing and the creation of probe frames as for the video simulations of the offside situations. On average, the offside situations had a duration of 5.4 ± 0.5 s (range 3.9–5.7). The moment of the pass was on average 2.8 ± 0.5 s (range 0.8–3.1) after the start of the situation.

The two formats consisted of situations that were slightly different but equally valuable. First, the video simulations were situations with two attackers against one defender and a goalkeeper. The computer animations were situations with three attackers against two defenders and a goalkeeper. Second, the video simulations were simple offside situations where the passer played the ball forward to the attacker. The situations of the computer animations were all based on actual real-live game situations. A short pattern of play (i.e., two or three passes) preceded the final pass forward to the attacker.

In this study, visual analog scales were introduced to assess confidence of the assistant referee, difficulty of the offside situations and psychological fidelity of the video and computer format. Immediately after the pretest and posttest, assistant referees of both training groups were asked to answer six questions with a mark on a 10-cm line. The questions regarded three opinions about both video simulations and computer animations: (1) How much confidence do you have in your answers? (2) How do you perceive the level of difficulty of the test? (3) How do you perceive the grade of similarity between offside situations in video-/computer-format and offside situations in a real match?

Training Sessions. The training sessions had a similar procedure to the pre- and posttest. We followed the same procedure as Catteeuw et al. (2010b). Participants were first exposed to the offside situation, and then to the screenshot of five probe frames. Feedback was provided in the form of the correct probe frame. Following this frame, we extended feedback with a slow motion and freezing of the offside situation on the exact moment of the pass. The assistant referees judged a total of 120 offside situations over four training sessions.

The video simulations (four training sessions of 30 video simulations) were selected out of the same database used by Catteeuw et al. (2010b). Youth-elite players of a second division team in Spain played offside simulations with two attackers and one defender. The selection of the offside situations was based on the quality of the video simulations. We selected only offside situations in front of the camera to eliminate an incorrect viewing angle. The computer animations (four training sessions of 30 computer animations) were created in the same way as Gilis et al. (2008) with three attackers, two defenders and a goalkeeper. Again, the computer animations were all based on actual real-live game situations. The same procedures were followed for the editing and the creation of probe frames as for the pre- and posttest. We added the slow motion with freezing of the moment of the pass to the feedback.

Procedure

For the test and training sessions, the assistant referees were seated in front of a screen (2.60 × 3.60 m) within the edges of the screen to keep the viewing angle
small (12°–17°). The offside situations were projected on the screen with an LCD projector (EIKI Boardroom projector LCX 1100; EIKI International, Inc., US). First, all three groups conducted the pretest. In this test, five offside situations were given as example to familiarize with the test setting. Subsequently, both video- and computer-format training group had one video- or computer-training session after their monthly physical training session in Leuven. The control group received no intervention and continued in their regular training routines. Finally, all groups performed the posttest. Assistant referees were seated on the same place for the pretest as they were for the posttest.

The procedure of the test was in line with earlier studies (Catteeuw et al., 2010b; Gilis et al., 2008). For each offside situation, the assistant referees had to judge as accurately as possible, within a 5 s time window after the final pass, whether the attacker was in an offside position. They marked their answer on the test form. Subsequently, for the five probe frames, the assistant referees were asked to detect the probe frame matching the exact moment of the pass as accurately as possible. They marked the number of the probe frame on the test form. The probe frames were shown for 10 s.

The procedure of the training session was similar to the test. In addition to the test procedure, the correct probe frame was shown for 5 s and assistant referees had to mark whether their selected probe frame was the correct frame. They marked the correct probe frame. Finally, the slow motion with freezing on the exact moment of the pass was shown.

Data Analysis

First, response accuracy and type of error (i.e., flag errors or non-flag errors) were analyzed. To study the effect of training from pre- to posttest, repeated-measures ANOVAs were used with group (video, computer and control) as between-participants variable and test (pretest and posttest) as within-participants variable. For further analysis of the frame recognition, the weighted mean (cf. Thornton & Hayes, 2004) was calculated by multiplying the proportion of responses at a given probe position by that probe’s frame difference (–3, –2, –1, 0, +1, +2, or +3) from the correct probe (i.e., 0). These products are then added and divided by the total number of responses to yield a weighted mean (Catteeuw et al., 2010b). In addition, consistency between response accuracy on the clips and the frames was calculated. Consistent means that the assistant referee judged the situation as offside and chose at the same time a probe frame with an offside position or that the assistant referee judged the situation as onside and chose a probe frame with an onside position (Catteeuw et al., 2010b).

Second, for the visual analog scales, confidence and difficulty were analyzed with separate repeated-measures ANOVAs with group as between-participants variable and test as within-participants variable. Psychological fidelity between the video format and the computer format was compared with an independent t test. Effect sizes were calculated with Cohen’s (1988) $d$ to indicate the meaningfulness of any significant differences.

All statistical analyses were executed with STATISTICA version 9.0 (StatSoft, Inc., USA) and significance level was set at 0.05. Significant effects in the ANOVAs were examined using Fisher LSD post hoc procedures. Effect sizes were reported as partial eta squared ($\eta^2_{p}$).
Results

The repeated-measures ANOVA for response accuracy in the video simulations showed a Test × Group interaction effect, $F(2,37) = 4.16$, $p = .02$, $\eta^2_p = 0.20$, but only a marginally significant interaction effect in the computer animations, $F(2,37) = 1.44$, $p = .07$, $\eta^2_p = 0.29$. Figure 3 shows the response accuracy for both training

![Graph A](image)

A

![Graph B](image)

B

Figure 3 — Response accuracy for both training groups and the control group in pre- and posttest for the video simulations (A) and the computer animations (B). Significant differences ($p < .05$) between groups or tests are highlighted with an asterisk (*). Error bars indicate the standard error.
groups and the control group across pretest and posttest for the video simulations (Figure 3A; 40 offside situations) and computer animations (Figure 3B; 40 offside situations).

In contrast to the decrease in flag errors for both training groups, the flag errors remained at the same level for the control group in the video simulations and the computer animations (Table 1). The non-flag errors slightly increased for the three groups in the video simulations, but they remained at the same level in the computer animations (Table 1).

### Table 1  Flag Errors (n Out of 30) and Non-Flag Errors (n Out of 10) for the Video-Format and Computer-Format Training Groups and the Control Group in the Video Simulations and Computer Animations (Mean ± SD)

<table>
<thead>
<tr>
<th>Test and Group</th>
<th>Flag Errors</th>
<th>Non-Flag Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretest</td>
<td>Posttest</td>
</tr>
<tr>
<td><strong>Video Simulations</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Video</td>
<td>11.3 ± 4.0</td>
<td>8.3 ± 2.9</td>
</tr>
<tr>
<td>Computer</td>
<td>11.4 ± 4.9</td>
<td>7.5 ± 4.2</td>
</tr>
<tr>
<td>Control</td>
<td>10.5 ± 3.6</td>
<td>10.5 ± 3.2</td>
</tr>
<tr>
<td><strong>Computer Animations</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Video</td>
<td>9.0 ± 3.7</td>
<td>5.7 ± 5.0</td>
</tr>
<tr>
<td>Computer</td>
<td>6.9 ± 3.9</td>
<td>3.3 ± 1.8</td>
</tr>
<tr>
<td>Control</td>
<td>9.2 ± 3.7</td>
<td>8.1 ± 3.8</td>
</tr>
</tbody>
</table>

The Test × Group interaction for the response accuracy of the frames showed no differences for both training groups and the control group in the video simulations, $F(2,37) = 0.38, p = .69, \eta_p^2 = 0.02$, from pretest (video: 7.3 ± 3.2; computer: 8.4 ± 1.4; control: 8.2 ± 2.2) to posttest (video: 8.2 ± 1.9; computer: 8.0 ± 2.1; control: 8.7 ± 2.4) and in the computer animations, $F(2,37) = 0.19, p = .83, \eta_p^2 = 0.01$, from pretest (video: 14.4 ± 5.6; computer: 14.4 ± 3.7; control: 12.0 ± 4.5) to posttest (video: 15.9 ± 6.6; computer: 17.0 ± 7.0; control: 13.3 ± 3.5). In line with the response accuracy on the frames, the weighted mean showed no significant Test × Group interaction effect for the video simulations, $F(2,37) = 0.78, p = .47, \eta_p^2 = 0.04$, and the computer animations, $F(2,37) = 2.92, p = .07, \eta_p^2 = 0.14$. The weighted mean decreased for both training groups and the control group in the video simulations from pretest (video: –0.003 ± 0.19; computer: –0.07 ± 0.18; control: 0.14 ± 0.34) to posttest (video: –0.09 ± 0.17; computer: –0.21 ± 0.23; control: –0.09 ± 0.20) and in the computer animations from pretest (video: 0.47 ± 0.41; computer: 0.12 ± 0.26; control: 0.40 ± 0.26) to posttest (video: 0.07 ± 0.29; computer: –0.20 ± 0.38; control: 0.29 ± 0.31).
Consistency between response accuracy on the clips and frames improved for both training groups from pretest (video: 0.61 ± 0.08; computer: 0.63 ± 0.07) to posttest (video: 0.66 ± 0.06; computer: 0.71 ± 0.06), but not for the control group (pretest: 0.70 ± 0.12; posttest: 0.64 ± 0.07) in the video simulations, \( F(2,37) = 6.15, p = .005, \eta_p^2 = 0.25 \). In the computer animations, all three groups remained at a similar level from pretest (video: 0.92 ± 0.12; computer: 0.93 ± 0.05; control: 0.93 ± 0.09) to posttest (video: 0.96 ± 0.04; computer: 0.95 ± 0.03; control: 0.97 ± 0.03), \( F(2,37) = 0.23, p = .80, \eta_p^2 = 0.01 \).

For the visual analog scales, a significant effect of training format was found. The video-format training group became more confident from pretest (52.2 ± 21.7) to posttest (64.1 ± 15.2) for the video simulations in contrast to the computer-format training group (pretest: 63.5 ± 11.0; posttest: 47.8 ± 25.1), \( F(1,16) = 6.35, p = .02, \eta_p^2 = 0.28 \). The computer-format training group found the computer animations easier in the posttest (57.5 ± 13.9) than in the pretest (81.4 ± 10.7), whereas the video-format training group did not (pretest: 69.8 ± 14.0; posttest: 81.1 ± 10.7), \( F(1,16) = 30.77, p < .01, \eta_p^2 = 0.66 \). All assistant referees of both training groups assessed the psychological fidelity of the video simulations (66.4 ± 16.4) higher than the psychological fidelity of the computer animations (50.0 ± 23.4), \( t(34) = 2.43, p = .02, d = 0.83 \).

**Discussion**

Elite association football assistant referees participated in an offside decision-making training study, which investigated the impact of training and two different formats on decision-making accuracy, frame recognition, and consistency. One group trained with offside video simulations and another group trained with offside computer animations. Both training groups progressed in offside decision making for both formats. In line with earlier findings on off-field offside decision-making training (Catteeuw et al., 2010b), the progress in both formats indicated a training effect. A control group of elite assistant referees demonstrated no progress on both formats. The extensive feedback for every offside situation in the training session resulted in a decrease of flag errors.

In line with Catteeuw et al. (2010b), this study found support for the efficiency of these training programs for offside decision making and the application to teach assistant referees to better deal with the consequences of the flash-lag effect. First, in contrast to a control group, both training groups improved their response accuracy as well in the video simulations as in the computer animations. And second, in contrast to the control group, assistant referees of both training groups learned to deal with flag errors induced by the flash-lag illusion. Except for the video-format training group and the control group in the video simulations, no changes were apparent for the non-flag errors.

The results of the frame recognition were less obvious. On average, assistant referees recognized 20% of the probe frames correctly, which is a clear indication of the difficulty of the frame recognition. Again in line with Catteeuw et al. (2010b), no differences were found in accuracy of memory from pre- to posttest as well as between the three groups. Yet, a decrease of the weighted mean from pre- to posttest suggested a compensation for the flash-lag illusion, but the weighted mean could
not be differentiated between the three groups. Consistency between accuracy on the clips and frames, however, slightly improved for both training groups from pre- to posttest in the video simulations and computer animations. For the control group, consistency decreased in the video simulations and improved slightly in the computer animations.

The feedback of the training interventions in this study was extended to provide assistant referees with sufficient information on the training simulation. After the assistant referees judged the offside situation and recognized the potential correct frame, first the correct frame was shown, followed by a slow motion of the offside simulation with freezing at the exact moment of the pass. In this way, assistant referees could compare their perception of the moment of the pass with the real players’ positions at the moment of the pass. This should generate the possibility to adjust their perception. As predicted by the flash-lag illusion, assistant referees perceive the attacker ahead of his actual position at the moment of the pass, resulting in a bias toward flag errors. The results of the posttest suggested that assistant referees of the training groups picked up a compensation strategy to better deal with the perceptual illusion and to decrease the number of flag errors.

The second hypothesis that the video-format would generate a more pronounced training effect on offside decision making than the computer format, was not supported by our findings. Although assistant referees perceived the video format as more similar to the real match, the computer-format training resulted in an equal training effect for the video simulations and computer animations in the offside decision-making task. The only different changes over time for the two formats were the assistant referees’ perceptions on confidence and difficulty. The assistant referees of the video-format group became more confident in the offside assessment of the video simulations, whereas the assistant referees of the computer-format group perceived the computer animations as easier in the posttest than in the pretest. In general, it seems that, regardless of the format, assistant referees learned to cognitively correct their incorrect perception and successfully employed this strategy in video simulations as well as computer animations.

No differences were found between the video-training format and the computer-training format. This has some interesting implications for the development of future off-field offside decision-making training programs. The creation of video simulations is labor-intensive and time consuming. A large number of simulations is needed to select a few high-quality video simulations. The development of computer animations is more practical. Countless match situations can be simulated in the computer format. In addition, researchers and coaches can easily manipulate the difficulty of situations to offer elite assistant referees more challenging offside situations (e.g., increase the speed of the players and the ball).

In this study, the assistant referees of both training groups assessed their confidence, perception of difficulty and similarity with the real match for video simulations and computer animations with a visual analog scale. Interestingly, confidence for the video simulations improved for the video-format training group and difficulty of the computer animations decreased for the computer-format training group. The similarity with the real match or “fidelity” (Lintern et al., 1989; Williams & Grant, 1999) revealed a clear difference between video simulations and computer animations. The assistant referees regarded video simulations as more similar to the real match than computer animations. The most important reason
for this observation is probably the viewing perspective in both formats. The video simulations are filmed from the touch line in the “ego” perspective of the assistant referee. The assistant referee sees the simulation like he sees an offside situation in a real match. Unlike the video simulations, the computer animations are shown from a top-view perspective, which is an unfamiliar viewing perspective for assistant referees. In addition, players and ball move in a more natural way in video simulations than in computer animations. Although fidelity was regarded higher for video simulations, no benefit was obtained. Assistant referees of both training groups progressed also in the computer animations. Although increasing fidelity is assumed to increase transfer, several researchers (Boreham, 1985; Lintern et al., 1989) indicated already that physical fidelity is not a requirement for positive transfer. Williams and Grant (1999) regarded psychological and functional fidelity as more important for sport simulations. But, they questioned whether the training simulation needs to score highly on each component of fidelity. In this study, psychological fidelity was primarily probed, but it seemed no prerequisite for transfer to offside decision making.

Research in perceptual-cognitive skill training should further focus on transfer to the real match. Positive effects seem obvious, but need more support to convince scientists to further develop training programs and expert performers to use off-field decision-making training. While several decision-making studies (Christina, Barresi, & Shaffner, 1990; Devos et al., 2009; Helsen & Starkes, 1999b; Starkes & Lindley, 1994) demonstrated the effectiveness of video-based training, this study together with Catteeuw et al. (2010b) indicated positive effects of off-field decision-making training for assistant referees. Even relatively short bouts of training are effective in improving decision-making performance. Although this training experiment lacks a test of direct transfer, this can be a valuable tool to accumulate experience in a practice-poor environment as football refereeing.

In contrast with Catteeuw et al. (2010b), in the current study two training groups were used that were exposed to very different formats. In one format, the assistant referees observed video recordings of real offside situations with attackers and defenders from the point of view of the assistant referee in a real match (i.e., a point of view from the side line). The other group was exposed to computer animations of offside situations from a top-view perspective. Interestingly, training in one format also resulted in a performance improvement in the other format. As such, this finding allowed us to exclude that the positive training effect must be attributed to test familiarity as a result of repetitive execution of almost identical testing and training procedures (Abernethy & Wood, 2001). Instead, it appeared that the assistant referees of both training groups learned the concept of the flash-lag effect and how to deal with it irrespective of the training format. This increases the chance that the obtained training effects would also transfer to real offside decision making during actual games but the actual testing of such transfer effects awaits further research.

In summary, perceptual-cognitive skill training can have a positive effect on offside decision-making performance. It teaches assistant referees to better deal with the flash-lag illusion. Although the fidelity for the video-format was higher, both video as computer format had a positive effect on offside decision making and should be considered as part of practice routines of assistant referees to enhance offside decision-making performance.
References


*Manuscript received: February 22, 2010*

*Revision accepted: August 6, 2010*