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ORIGINAL ARTICLE

Does slow motion impact on the perception of foul play in football?

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Abstract
Objectives: Slow-motion replays of foul play situations are now used in the education and training of sports officials. We investigated the impact of video speed on the decision-making process of association football referees and how this interacted with expertise. *Methods:* Three different groups of referees, varying in level of expertise, assessed video clips from an in-game perspective. Video clips represented corner kick and open play situations in which a foul occurred or not. For these foul/no foul situations, the referees had to make a technical (no foul; indirect free kick; direct free kick; or penalty kick) and a disciplinary decision (no card; yellow card; or red card), under both slow-motion and real-time viewing conditions. Accuracy scores were determined by comparing participant's responses with the decisions of an expert panel. *Results:* Significant differences were observed across groups for foul/no foul situations, suggesting that the experts were able to process the available information more effectively than their less expert colleagues. The accuracy scores for the technical decision were higher in slow motion (67%) compared to a real-time viewing condition (56%), particularly for corner kick situations. No differences were found between real time and slow motion for the disciplinary decision. *Conclusions:* Slow-motion footage results in higher accuracy scores for complex technical decisions. These findings have implications for the use of slow-motion replays in the decision-making process of referees.

Keywords: *Team sport, Psychology, Performance, technology*

Highlights
- The impact of video speed on the decision-making processes of referees is examined.
- Slow motion results in higher accuracy scores for complex technical decisions.
- A novel and realistic decision-making task differentiates between expertise levels.

In association football (or soccer), referees are responsible for enforcing the Laws of the Game. Specific physical, perceptual and cognitive skills are required to fulfil this role accordingly and to make sure that the underlying decision-making process results in uniform and consistent decisions (Larkin, O'Brien, et al., 2014). According to Helsen and Bultynck (2004), a referee makes 137 'observable' decisions (i.e. when a referee intervenes with play) during a match. Approximately 45 of these decisions concern foul play situations and most of these foul play decisions (i.e. direct free kicks, penalty kicks) are made in open play. There are also 'non-observable' decisions (i.e. when a referee decides not to intervene with play) and this brings the total number of decisions to approximately 200. A correct implementation of the Laws of the Game is crucial to ensure there are no negative implications for the safety of the players and final outcome of a match.

Nevertheless, the judgments of referees are susceptible to human error. It is inevitable that referees make mistakes at some point, given the complex task environment and the various sources of information they have to deal with under emotional and time-constrained circumstances (Bar-Eli, Plessner,

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& Raab, 2011). Previously, researchers have shown that the average accuracy score of association football referees during a real game (i.e. agreement score with an expert panel) ranges from 64% to 77% (Gilis, Weston, Helsen, Junge, & Dvorak, 2006; Mascarenhas, Button, O'Hare, & Dicks, 2009). Therefore, several researchers have focused on the impact of external and contextual factors on the decision-making process of referees. Referees appear to adopt a strategy of game management, as discussed by Unkelbach and Memmert (2008), and this leads to different ways of evaluating a similar incident (e.g. tackle) in different situations and environments (Balmer et al., 2007; Mascarenhas, Collins, & Mortimer, 2002; Plessner & Betsch, 2001). As the importance of winning and losing, and the corresponding financial rewards for stakeholders increase over time, referees have to cope with these external influences and stressors. The referee needs to integrate and extract crucial information from every match incident in an appropriate way and this requires specific perceptual-cognitive skills (Broadbent, Causer, Williams, & Ford, 2015; MacMahon et al., 2015; Plessner, Schweizer, Brand, & O'Hare, 2009).

Training programs for referees mainly focus on developing the physical attributes that are considered important to allow them to deal with match demands. Only limited time is spent on decision-making training and improving perceptual-cognitive skills. Over the past few years, however, researchers have shown the importance of video-based decision-making training in referees (Schweizer, Plessner, Kahlert, & Brand, 2011), assistant referees (AR) (Catteeuw, Gilis, Jaspers, Wagemans, & Helsen, 2010; Put, Wagemans, Jaspers, & Helsen, 2013; Put, Wagemans, Spitz, Williams, & Helsen, 2016), and in many other environments in which decision-making is of utmost importance (e.g. drivers, fire fighters, police officers, surgeons; for a review, see Broadbent et al., 2015).

In addition to the implementation of specific training interventions, the use of technology has increased in a number of sports with the ultimate aim being to assist the referee's decision-making process. For example, goal-line technology has recently been introduced in association football to verify whether a goal has been scored (FIFA, 2014). In other sports such as basketball, cricket and field hockey, the use of video reviews may assist officials at the highest level to reconsider foul situations. In these sports, the referee has access to slow-motion replays of a particular incident from different viewing angles. Yet, it remains unclear how these slow-motion replays impact on the perception of foul play. The introduction of video technology can be a helpful tool, although it is still questionable whether all errors will be resolved by just using technology, particularly when these are doubtful and ambiguous situations (Collins, 2010; Royce, 2012).

A few researchers have investigated the impact of video speed and slow-motion footage on decision-making in sports. In Australian football, Lorains, Ball, and MacMahon (2013a) showed that the speed of video replays changes the entire way a body movement is viewed and judged. The decision accuracy of a group of elite Australian football players on a video task was significantly higher under fast speed (125–200% of real time) compared to slow speed exposure (75–100% of real time). These authors concluded that the faster speed and corresponding time pressure may allow elite athletes to perform more instinctively and with a faster processing efficacy. Sport athletes perform in time-pressured conditions, where timely and accurate decision-making is of utmost importance. They must quickly adapt to changes in the environment and decide upon an action (Lorains et al., 2013a; Lorains, Ball, & MacMahon, 2013b). Above real-time video decreases the time for information processing, thus forcing athletes to perform quickly as required in a real game situation.

When compared to elite sport athletes, referees have more time and can integrate all relevant information before a crucial decision is made (Plessner & Haar, 2006). For example, referees are often reminded to 'wait and see' in order to allow play to continue. Video technology and slow-motion replays provide more time for referees and reduce the probability that key information is missed. The decreased load imposed on the referees' perceptual and cognitive resources might therefore support decision-making in certain situations (De Koning, Tabbers, Rikers, & Paas, 2011). However, this question has never been investigated and it remains unclear whether slow-motion replays impact on the perception and assessment of dynamic events, such as foul play in referees.

In the current study, referees of different expertise levels watched real-time and slow-motion (0.2 of the real-time speed) video clips filmed from the in-game perspective of the additional assistant referee, positioned behind the goal line. The use of additional assistant referees (AAR) was introduced in professional association football in 2009 to support the main referee in his/her decision-making process with respect to goal/no goal situations and foul/no foul situations, particularly inside and around the penalty area.

Our main aim in the current paper was to investigate whether the speed of the video (slow motion versus real time) impacts on decision accuracy in foul/no foul situations (both open play and corner

kick situations). We hypothesized that the influence of video speed on the decision-making process, both for the technical (no foul; indirect free kick; direct free kick; or penalty kick) and disciplinary (no card; yellow card or red card) decision, would depend on the specific situation (open play; corner kick). We assumed that corner kick situations would present a more complex challenge due to the presence of a larger number of players in a smaller area of the field than in open play incidents and that consequently, the use of slow-motion footage would provide added benefit compared to real-time footage. In contrast, we predicted that slow-motion footage would probably not facilitate decision-making in relatively simple situations where there are many experiences stored in memory that can be retrieved instantly like, for instance, one-on-one tackle incidents in open play (Ericsson & Kintsch, 1995). Slow motion would only be better for more challenging situations where there are not so many stored experiences (because they are too complex and variable to lead to strong prototypes). In slow motion, there is enough time to extract and process all the relevant cues from the complex situation, such as, for instance, in corner kick situations with a dozen or more players in a small area running in all directions and blocking one another.

The second aim of this study was to examine whether the video-based decision-making task could elicit differences between referees of different skill levels. In line with previous research in sport (Williams & Ericsson, 2005), we predicted an expertise effect concerning foul/no foul situations. In particular, we expected that experienced AAR would outperform the (assistant) referees that did not have as much experience.

Methods

Participants

Three groups of referees that differed in terms of the nature and level of their expertise were selected to participate. The AAR ($n = 19$, mean age 36.0 years, $S_X- = 0.9$, range 30–42) were all experienced top-class referees in their own national leagues and acted as an additional assistant referee in European competitions. They had on average 3.6 years of experience as an additional assistant referee at international level and 8.5 years of experience as a referee at national level. Second, the group of less expert referees (REF) ($n = 18$, mean age 25.6 years, $S_X- = 0.6$, range 20–29) was on average 2.7 years active as a referee at national competition level in Belgium. The third group was composed of elite AR ($n = 24$, mean age 37.4 years, $S_X- = 1.4$, range 26–48), who had 9.7 years of experience as an assistant referee at national competition level in Belgium. The primary role of AR during a match is to award offside decisions. In terms of refereeing expertise and expertise in assessing foul situations, the groups can thus be classified as follows: AAR > REF > AR. Participants provided informed consent and approval was obtained from the local University ethics committee (G-2015 04 218).

Apparatus

Realistic and representative video clips of foul/no foul incidents, captured by a high-definition video camera (Sony, PMW-F55 4 K, digital cinema) from the perspective of the additional assistant referee (in-game perspective), were produced. The in-game perspective is important as researchers have shown that expertise-based differences become more evident as the task and experimental design are representative and closely aligned with the demands of the sport context (Dicks, Davids, & Button, 2009; Larkin, Mesagno, Berry, & Spittle, 2014). The situations were 'acted out' by a selection of competitive football players, aged between 19 and 21 years. Prior to the start of the filming session, a one-hour practice session was provided in which the players were instructed about the different types of situations and possible infringements: tackling; pushing; or holding an opponent. In order to have the situations acted out as naturally as possible, however, no specific instructions related to the type of infringement that should be executed were given to either the attacker or defender during the actual play.

Out of a total of 90 situations, 40 video clips of foul/no foul situations were selected. These included 20 video clips of corner kick situations, which started when a player kicked the ball from the corner arc. There were multiple potential fouls during the corner kick situations; six to seven attackers and seven to eight defenders (including a goalkeeper) were involved in front of the goal and two players from this group interacted for a possible infringement (Figure 1(a)). The 20 video clips of open play situations took place inside and around the penalty area, where 1 or 2 attackers played against 1 or 2 defenders. During these open play situations, a potential infringement occurred between two players (Figure 1(b)). Attackers and defenders were clearly distinguished in every situation; one team wore red and the other team wore white shirts/shorts/socks. Three independent and experienced ex-international referees, still involved as referee match observers for the Union des Associations Européennes de Football (UEFA), were involved in the final selection of the video clips, thereby helping to

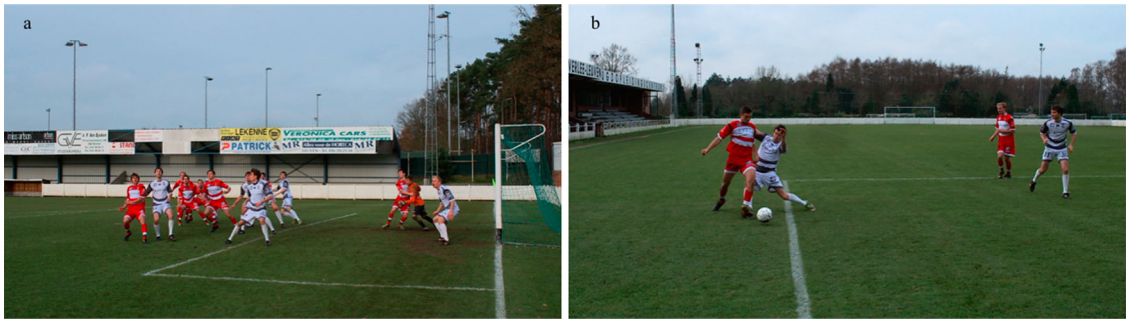

Figure 1. Example of a corner kick situation (a) and an open play situation (b). For these foul/no foul situations, the referee had to make a technical decision (no foul, indirect free kick, direct free kick or penalty kick) and a disciplinary decision (no card, yellow card or red card).

ensure that the selected situations were representative of the important decision-making aspects of referees. They determined independently the reference decisions based on the regulations regarding the application of Law 12 relating to Fouls and Misconduct (FIFA, 2014). This expert panel viewed the clips in real time and slow motion and then they came to a consensus decision (10 no foul; 10 no card; 11 yellow card and 9 red card situations).

The ratio of foul/no foul situations was similar to previous research on the decision-making processes of association football referees (Gilis et al., 2006; Spitz, Put, Wagemans, Williams, & Helsen, 2016). Each video clip was edited using the software program Final Cut Pro and was available in both real time and slow motion (0.2 of the real-time speed). Slow-motion clips at 0.2 of the real time speed are commonly used in association football broadcasts and in the education and training of association football referees. Long fragments at the beginning and the end of a situation (without any potential foul) were not present in slow motion.

Task and procedure

The video clips were presented to participants via a web-based application (www.perception4perfection.eu) that had been validated in previous research (Put et al., 2013; Put, Wagemans, Spitz, et al., 2016). Participants received an email with their individual login and password for this online platform. The study took place at two different test sessions, with five days in between. Prior to each session, standardized instructions and three demo clips were available upon familiarization with the procedures. The participants had only one opportunity to assess the different video clips.

In phase 1 (day 1–5), all referees were exposed to 40 foul/no foul situations, alternating between open play and corner kick situations. Immediately after each video clip, referees had to assess whether a foul occurred and to make a technical decision within a time window of 10 seconds. The technical decision refers to the way play should be restarted and could be one out of four options: no foul; indirect free kick; direct free kick; or penalty kick. Subsequently, referees were provided 10 seconds to make a disciplinary decision, which refers to the disciplinary sanction for the player who commits an offence: no card; yellow card; or red card. A break was provided after 20 video clips. Half of each group of referees, randomly selected, viewed the video clips first in slow motion, whereas the other half of the group viewed the video clips first in real time.

In phase 2 (day 11–15), all referees assessed the same 40 foul/no foul situations as in phase 1 (random order), but counterbalanced and in a different viewing condition: for those who were initially exposed to the video clips in real time, the same video clips were now displayed in slow motion and vice versa. All participants completed the two test phases within the indicated five-day test moment and no feedback was provided regarding the correctness of their responses.

Data analysis

Dependent variables. Accuracy scores for the technical and disciplinary decision were calculated separately as the total number of correct trials (in %), that is, decisions that were in correspondence with the reference decision.

Statistical analysis

Test–retest reliability. To assess the test–retest reliability, nine participants assessed the incidents a second time, three weeks after the first exposure. Intra-class correlation coefficients between the two separate viewings were calculated for this subsample of participants and indicated excellent levels of test–retest reliability (range 0.76–0.82).

Accuracy scores. Data on the aforementioned variables (technical decision and disciplinary decision) were examined initially for normality and homogeneity of variance by means of the Shapiro–Wilk test and the Levene test. Assumptions of normality and equality of variances were met ($P > .05$) and therefore, a parametric approach was employed.

For both the technical and disciplinary decision accuracy (foul/no foul situations), a mixed between-within participant ANOVA (3 × 2 × 2) with the factor group (AAR, REF, AR) as the between-participants factor and video speed (real time, slow motion) and situation (open play, corner kick) as within-participants factors was completed to investigate the impact of video speed on the decision-making accuracy. Significant main effects of group were further explored using Tukey's *post hoc* tests. Effect sizes were calculated as partial eta-squared values (η_p^2) and a P-value of <.05 was considered significant (Field, 2005).

Results

Foul/no foul accuracy

Technical decision. The analysis revealed a significant main effect of group ($F(2,58) = 17.268$, $P < .001$, $\eta_p^2 = 0.373$). *Post hoc* tests showed that the AR group ($M = 58.0\%$, $S_X- = 0.97$) and REF group ($M = 60.1\%$, $S_X- = 1.12$) scored significantly lower than the AAR group ($M = 66.4\%$, $S_X- = 1.09$) (Figure 2(a)). There were no differences between the AR and REF groups. Furthermore, a significant main effect of video speed was found ($F(1,58) = 62.313$, $P < .001$, $\eta_p^2 = 0.518$). Referees were more accurate in slow motion ($M = 66.5\%$, $S_X- = 0.83$) compared to a real-time viewing condition ($M = 56.4\%$, $S_X- = 0.94$). No main effect of situation was found ($F(1,58) = 2.451$, $P = .123$, $\eta_p^2 = 0.041$), indicating that the accuracy scores for the corner kick situations ($M = 60.5\%$, $S_X- = 0.95$) and open play situations ($M = 62.4\%$, $S_X- = 0.79$) were not significantly different. However, there was a significant interaction effect between group and

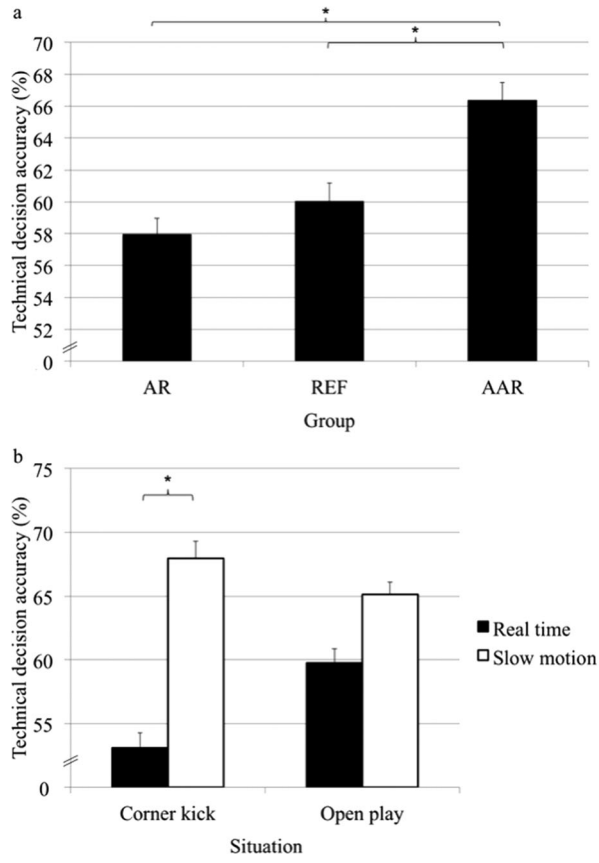

Figure 2. Mean accuracy scores for the technical decision of the foul/no foul situations, representing the main effect of group (a) and the interaction effect between video speed and situation (b). (AR, Belgian elite assistant referees; REF, Belgian less expert referees; AAR, international additional assistant referees). *$P < .01$.

Table I. Mean accuracy scores in percentage (and standard errors) for the foul/no foul situations for the different groups.

	Foul/no foul accuracy							
	Technical decision				Disciplinary decision			
	Real time		Slow motion		Real time		Slow motion	
	Corner	Open	Corner	Open	Corner	Open	Corner	Open
AR	45.6 (±2.0)	58.5 (±1.8)	63.5 (±2.3)	64.2 (±1.2)	65.2 (±1.6)	54.6 (±2.0)	66.9 (±2.4)	58.5 (±1.6)
REF	53.6 (±3.4)	58.6 (±2.7)	65.3 (±2.8)	62.8 (±2.0)	71.7 (±1.7)	60.8 (±2.2)	69.4 (±1.3)	60.0 (±1.6)
AAR	60.0 (±1.7)	62.1 (±2.2)	75.0 (±1.7)	68.4 (±1.9)	69.7 (±1.9)	61.3 (±2.4)	72.6 (±2.4)	60.0 (±2.4)

Notes: AR, Belgian elite assistant referees; REF, Belgian less expert referees; AAR, international additional assistant referees; Corner, corner kick situations; Open, open play situations.

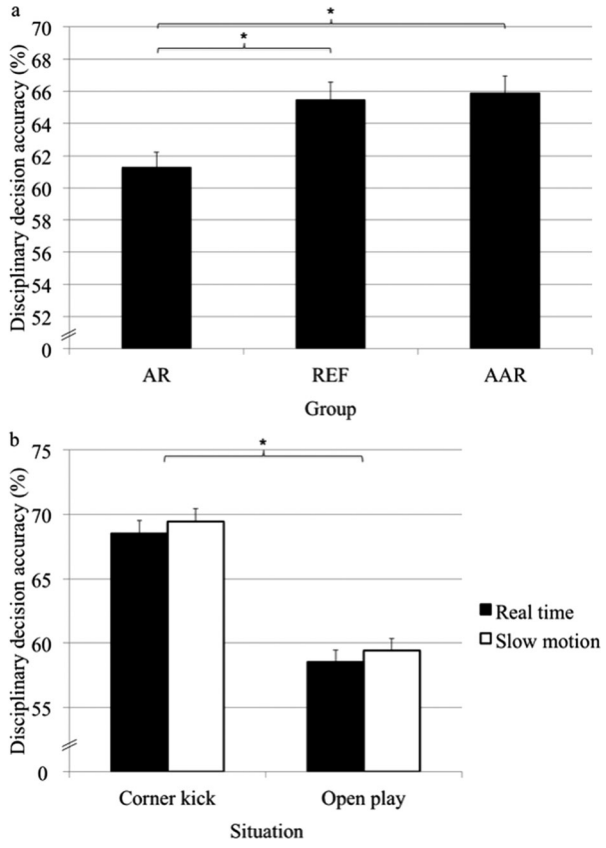

Figure 3. Mean accuracy scores for the disciplinary decision of the foul/no foul situations, representing the main effect of group (a) and the relation between video speed and situation (b). (AR, Belgian elite assistant referees; REF, Belgian less expert referees; AAR, international additional assistant referees). *$P < .01$.

situation ($F(3,58) = 4.889$, $P = .011$, $\eta_p^2 = 0.144$). Only the AR group differed significantly in its accuracy scores for corner kick situations ($M = 54.6\%$, $S_X- = 1.48$) when compared with open play situations ($M = 61.4\%$, $S_X- = 1.14$) (see Table I).

Further analysis revealed a significant interaction effect between video speed and situation ($F(1,58) = 13.733$, $P < .001$, $\eta_p^2 = 0.191$). For the corner kick situations, slow-motion video clips greatly facilitated decision accuracy ($M = 67.9\%$, $S_X- = 1.34$) compared to the real-time condition ($M = 53.1\%$, $S_X- = 1.40$). For the open play situations, on the other hand, this difference was not statistically significant (slow motion: $M = 65.1\%$, $S_X- = 0.97$; real time: $M = 59.8\%$, $S_X- = 1.28$) (Figure 2(b)). No significant interaction effects for group*speed ($F(3,58) = 0.794$, $P = .457$, $\eta_p^2 = 0.027$) and group*speed*situation ($F(3,58) = 0.340$, $P = .713$, $\eta_p^2 = 0.012$) were observed. The results are presented in Table I.

Disciplinary decision. The analysis revealed a significant main effect of group ($F(3,58) = 6.886$, $P = .002$, $\eta_p^2 = 0.192$). *Post hoc* tests showed that the AR group ($M = 61.3\%$, $S_X- = 0.93$) scored significantly lower than the REF ($M = 65.5\%$, $S_X- = 1.07$) and the AAR groups ($M = 65.9\%$, $S_X- = 1.04$) (Figure 3(a)). There were no differences between the REF and AAR groups. In contrast with the technical decision, no main effect of video speed was found ($F(1, 58) = 0.428$, $P = .516$, $\eta_p^2 = 0.007$), indicating that the accuracy scores in real time ($M = 63.9\%$, $S_X- = 0.77$) did not differ from those under slow-motion ($M = 64.6\%$, $S_X- = 0.81$) conditions (Figure 3(b)).

Furthermore, a main effect of situation was found ($F(1,58) = 58.370$, $P < .001$, $\eta_p^2 = 0.502$). The accuracy scores for the corner kick situations ($M = 69.3\%$, $S_X- = 0.93$) were higher compared to the open play situations ($M = 59.2\%$, $S_X- = 0.83$). No interaction effects of group*speed ($F(3, 58) = 1.446$, $P = .244$, $\eta_p^2 = 0.047$), group*situation ($F(3,58) = 0.058$, $P = .943$, $\eta_p^2 = 0.002$), speed*situation ($F(1,58) = 0.006$, $P = .938$, $\eta_p^2 = 0.000$) or group*speed*situation ($F(3,58) = 0.799$, $P = .455$, $\eta_p^2 = 0.027$) were found. The results are presented in Table I.

Discussion

A novel task was used to examine the decision-making process of referees in association football and the impact of slow motion on the perception of foul play. The decision-making task consisted of foul/no foul situations that were captured from the first-person perspective of an additional assistant referee.

The decision-making accuracy for foul/no foul situations does not always meet the high standards of professional association football. The rather low accuracy scores in this study are probably due to the difficulty of the situations and the fact that the Laws of the Game leave room for interpretation by the referee. Nevertheless, the performance of the elite referees was in line with previous research reporting the decision-making accuracy of elite association football referees. During crucial incidents in real games, the range of reported accuracy is between 64% and 77% (Gilis et al., 2006; Mascarenhas et al., 2009). In order to support the match referee, post-match disciplinary procedures based on video replays have been introduced in association football for fouls that are not observed and cautioned accordingly (Gilis et al., 2006). Retrospective punishments can be given, whereas other sports use instant video replays to assist the referee during play. Video replays, which are available in real time and slow motion, can be a helpful tool and we investigated for the first time whether the speed of the video

influences the way referees perceive game-play information. Our hypothesis was that the impact of the video speed on the decision-making process would depend on the specific situation, with slow motion being more useful in complex situations and real time being appropriate for relative simple situations.

The decision-making accuracy for the technical decision (no foul, indirect free kick, direct free kick or penalty kick) was higher in slow motion compared to a real-time viewing condition, particularly for the corner kick situations. Referees seem unable to process the important information in real time, thus preventing them from generating as many accurate decisions as in slow motion. According to Kahneman (2011), human thought and decision-making processes can be classified into two systems: system 1 for fast, subconscious and intuitive processing; and system 2 for slow, conscious and analytical processing. The role of these two systems depends on the characteristics of the tasks. The fast system is based upon experience and operates automatically and quickly in uncomplicated situations. The slow system, on the other hand, allows detailed and specific processing of information in more demanding, complex situations. Immediately prior to a corner kick, multiple players interact with numerous potential foul situations. In light of the lack of exposure to such situations (Helsen & Bultynck, 2004), it may be difficult to pick up all relevant information. In slow motion, there is increased opportunity to scan and process the information of these complex situations consciously, deliberately and in more detail (cf. system 2; Kahneman, 2011). This process allows referees to identify the offender and exact location of the foul.

During the second part of the decision-making process, the referee has to make a disciplinary decision (no card, yellow card or red card), which is related to the perceived seriousness of the offence. This disciplinary decision is generally more difficult for open play situations as reported in this study. In determining the seriousness of an offence, several factors have to be considered such as the element of intent, the speed of the player's action and the safety of the opponent (FIFA, 2014). Our findings show that the accuracy score for the disciplinary decision was not significantly different in slow motion compared to real time and there was no speed*situation interaction effect. Referees seem to be trained to make these judgments automatically and accurately under time-constrained circumstances (cf. system 1; Kahneman, 2011).

While slow-motion replays make it easier to see the actual contacts and sequence of actions (e.g. ball touched or not, ball touched before or after opponent's leg), they might make it more difficult to judge the proper impact and amount of risk for the opponent's safety involved. Scientists have shown that the contact and impact of a moving object is perceived differently under various speed conditions (Caruso, Burns, & Converse, 2016; Hubbard & Ruppel, 2002; Michotte, 1963). Furthermore, slowing down the video speed might distort the relative motion between important features in the visual display (Put, Wagemans, Pizzera, et al., 2016; Williams, North, & Hope, 2012). These factors make it difficult to make general claims about the possible benefits of slow motion for this type of decision. Additional research with a more refined classification of different impact situations, including real match incidents, would be useful to clarify this issue.

Previously, researchers have shown that elite athletes perform more accurately when they have less time to think and rely on automatic processing of information (Hepler & Feltz, 2012; Johnson & Raab, 2003; Lorains et al., 2013a). In refereeing, however, the influence of video speed seems to depend on the specific situation and the type of decision that has to be made. Slow motion is useful to detect the exact moment of contact and to make a technical decision, particularly in situations with a lot of interacting players (e.g. corner kick situations).

Slow-motion replays of complex situations should be considered during training sessions in order to give appropriate feedback and learn to allocate attention towards important details. It has been shown that this type of training (accurate feedback + slow-motion replays) results in better performances in AR because they are able to adjust their (incorrect) perception (Catteeuw et al., 2010; Put et al., 2013; Put, Wagemans, Spitz, et al., 2016). On the other hand, for the open play situations and disciplinary decisions, referees have to rely on their decisions in real time and replays in real time should be used to train referees in these situations. The effectiveness of video feedback within the domain of refereeing and team sports could be improved by using video clips of different speeds in specific situations. In future research, it would seem prudent to investigate the impact of above real-time video clips on referee's decision-making and the effectiveness of training sessions using different video speed manipulations.

The second aim of this study was to examine whether the video-based decision-making task could elicit differences between referees of different skill level. Significant differences in terms of refereeing expertise were reported for the technical and disciplinary decisions in foul/no foul situations. The AAR group was significantly more accurate than the REF group and AR group with respect to the technical decision in case of a foul/no foul situation. Furthermore, the AR group scored significantly lower

than the other groups for the accuracy of the disciplinary decision. Referees have developed specific expertise, depending on the role they fulfil on the field of play.

Catteeuw, Helsen, Gilis, and Wagemans (2009) examined refereeing expertise as a function of role specificity. These authors showed superior performance of elite referees in a tackle assessment task. Although one can assume that the availability of specific information is the same for the different skill groups, the expert groups are more competent in extracting the appropriate information and making the correct link between the informative items of a situation (e.g. a clear simulation) and the implications according to the Laws of the Game (e.g. indirect free kick + yellow card). Recently, researchers showed that elite referees spend significantly more time fixating the most informative areas (i.e. the contact zones) and less time fixating the body parts and players that were not involved in the infringement (Spitz et al., 2016). In our study, the perspective of the video clips was taken from that of the AAR. We cannot rule out the possibility that the smaller number of technical decision errors by the AAR group when compared to the other two groups can (at least partly) be based on their larger prior experience with this viewing perspective. Training programs can be designed to teach promising referees to look, think and act like elite referees by providing in-game, role-specific viewing perspectives, and directing attention to the crucial features via guided discovery (Savelsbergh, Van Gastel, & Van Kampen, 2010). As such, the probabilistic relationship between critical visual cues and the decision-making process can be highlighted. This interpretation is in line with previous literature regarding (social) information processing and possible biases in referees (Bless, Fiedler, & Strack, 2004; Plessner & Haar, 2006).

Conclusion

We present a novel study that explored the potential benefits of slow-motion video with respect to the decision-making process of referees. Referees are used to making decisions in dynamic and time-constrained environments. By decreasing the speed of the video-based task, referees were more accurate with respect to the technical decision for complex foul/no foul situations. However, the accuracy score for the disciplinary decision for the offending player did not differ when exposed to real-time footage and slow motion, respectively. Findings have implications for future research and for training perceptual-cognitive skills in referees in association football and potentially in other sports and domains.

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References

Balmer, N. J., Nevill, A. M., Lane, A. M., Ward, P., Williams, A. M., & Fairclough, S. H. (2007). Influence of crowd noise on soccer refereeing consistency in soccer. *Journal of Sport Behavior*, *30*, 130–145.

Bar-Eli, M., Plessner, H., & Raab, M. (2011). *Judgment, decision-making and success in sport*. Oxford: Wiley-Balckwell.

Bless, H., Fiedler, K., & Strack, F. (2004). *Social cognition: How individuals construct social reality*. New York, NY: Psychology Press.

Broadbent, D. P., Causer, J., Williams, A. M., & Ford, P. R. (2015). Perceptual-cognitive skill training and its transfer to expert performance in the field: Future research directions. *European Journal of Sport Science*, *15*, 322–331. doi:10.1080/17461391.2014.957727

Caruso, E. M., Burns, Z. C., & Converse, B. A. (2016). Slow motion increases perceived intent. *Proceedings of the National Academy of Sciences*, *113*, 9250–9255.

Catteeuw, P., Gilis, B., Jaspers, A., Wagemans, J., & Helsen, W. F. (2010). Training of perceptual-cognitive skills in offside decision making. *Journal of Sport & Exercise Psychology*, *32*, 845–861.

Catteeuw, P., Helsen, W. F., Gilis, B., & Wagemans, J. (2009). Decision-making skills, role specificity, and deliberate practice in association football refereeing. *Journal of Sports Sciences*, *27*, 1125–1136. doi:10.1080/02640410903079179

Collins, H. M. (2010). The philosophy of umpiring and the introduction of decision-aid technology. *Journal of the Philosophy of Sport*, *37*, 135–146. doi:10.1080/00948705.2010.9714772

De Koning, B. B., Tabbers, H. K., Rikers, R. M. J. P., & Paas, F. (2011). Attention cueing in an instructional animation: The role of presentation speed. *Computers in Human Behavior*, *27*, 41–45. doi:10.1016/j.chb.2010.05.010

Dicks, M., Davids, K., & Button, C. (2009). Representative task designs for the study of perception and action in sport. *International Journal of Sport Psychology*, *40*, 506–524.

Ericsson, K. A., & Kintsch, W. (1995). Long-term working memory. *Psychological Review*, *102*, 211–245.

Field, A. (2005). *Discovering statistics using SPSS*. London: Sage.

Fédération Internationale de Football Association. (2014). *Laws of the game*. Zürich: FIFA.

Gilis, B., Weston, M., Helsen, W. F., Junge, A., & Dvorak, J. (2006). Interpretation and application of the laws of the game in football incidents leading to player injuries. *International Journal of Sport Psychology*, *37*, 121–138.

Helsen, W. F., & Bultynck, J. B. (2004). Physical and perceptual-cognitive demands of top-class refereeing in association football. *Journal of Sports Sciences*, *22*, 179–189.

Hepler, T. J., & Feltz, D. L. (2012). Take the first heuristic, self-efficacy, and decision-making in sport. *Journal of Experimental Psychology: Applied*, *18*, 154–161. doi:10.1037/a0027807

Hubbard, T. L., & Ruppel, S. E. (2002). A possible role of naïve impetus in Michotte's "launching effect": Evidence from representational momentum. *Visual Cognition*, *9*, 153–176. doi:10.1080/13506280143000377

Johnson, J. G., & Raab, M. (2003). Take the first: Option-generation and resulting choices. *Organizational behavior and human decision processes*, *91*, 215–229. doi:10.1016/S0749-5978(03)00027-X

Kahneman, D. (2011). *Thinking, fast and slow*. New York, NY: Farrar, Straus and Giroux.

Larkin, P., Mesagno, C., Berry, J., & Spittle, M. (2014). Development of a valid and reliable video-based decision-making test for Australian football umpires. *Journal of Science and Medicine in Sport*, *17*, 552–555. doi:10.1016/j.jsams.2013.08.001

Larkin, P., O'Brien, B., Mesagno, C., Berry, J., Harvey, J., & Spittle, M. (2014). Assessment of decision-making performance and in-game physical exertion of Australian football umpires. *Journal of Sports Sciences*, *9*, 1–8. doi:10.1080/02640414.2014.896998

Lorains, M., Ball, K., & MacMahon, C. (2013a). Expertise differences in a video decision-making task: Speed influences on performance. *Psychology of Sport and Exercise*, *14*, 293–297. doi:10.1016/j.psychsport.2012.11.004

Lorains, M., Ball, K., & MacMahon, C. (2013b). An above real time training intervention for sport decision making. *Psychology of Sport and Exercise*, *14*, 670–674.

MacMahon, C., Mascarenhas, D., Plessner, H., Pizzera, A., Oudejans, R., & Raab, M. (2015). *Sports officials and officiating: Science and practice*. Abingdon: Routledge.

Mascarenhas, D. R. D., Button, C., O'Hare, D., & Dicks, M. (2009). Physical performance and decision making in association football referees: A naturalistic study. *The Open Sports Sciences Journal*, *2*, 1–9. doi:10.2174/1875399X00902010001

Mascarenhas, D. R. D., Collins, D., & Mortimer, P. (2002). The art of reason versus the exactness of science in elite refereeing: Comments on Plessner and Betsch (2001). *Journal of Sport & Exercise Psychology*, *24*, 328–333.

Michotte, A. (1963). *The perception of causality*. New York, NY: Basic Books.

Plessner, H., & Betsch, T. (2001). Sequential effects in important referee decisions: The case of penalties in soccer. *Journal of Sport and Exercise Psychology*, *23*, 254–259.

Plessner, H., & Haar, T. (2006). Sports performance judgments from a social cognitive perspective. *Psychology of Sport and Exercise*, *7*, 555–575. doi:10.1016/j.psychsport.2006.03.007

Plessner, H., Schweizer, G., Brand, R., & O'Hare, D. (2009). A multiple-cue learning approach as the basis for understanding and improving soccer referees' decision making. *Progress in Brain Research*, *174*, 151–8. doi:10.1016/S0079-6123(09)01313-2

Put, K., Wagemans, J., Jaspers, A., & Helsen, W. F. (2013). Web-based training improves on-field offside decision-making performance. *Psychology of Sport and Exercise*, *14*, 577–585. doi:10.1016/j.psychsport.2013.03.005

Put, K., Wagemans, J., Pizzera, A., Williams, A. M., Spitz, J., Savelsbergh, G. J. P., & Helsen, W. F. (2016). Faster, slower or real time? Perceptual-cognitive skills training with variable video speeds. *Psychology of Sport and Exercise*, *25*, 27–35. doi:10.1016/j.psychsport.2016.03.007

Put, K., Wagemans, J., Spitz, J., Williams, A. M., & Helsen, W. F. (2016). Using web-based training to enhance perceptual-cognitive skills in complex dynamic offside events. *Journal of Sports Sciences*, *34*, 181–189. doi:10.1080/02640414.2015.1045926

Royce, R. (2012). Refereeing and technology – reflections on Collins' proposals. *Journal of the Philosophy of Sport*, *39*, 53–64. doi:10.1080/00948705.2012.675066

Savelsbergh, G. J. P., Van Gastel, P. J., & Van Kampen, P. M. (2010). Anticipation of penalty kicking direction can be improved by directing attention through perceptual learning. *International Journal of Sport Psychology*, *41*, 24–41.

Schweizer, G., Plessner, H., Kahlert, D., & Brand, R. (2011). A video-Based training method for improving soccer referees' intuitive decision-making skills. *Journal of Applied Sport Psychology*, *23*, 429–442. doi:10.1080/10413200.2011.555346

Spitz, J., Put, K., Wagemans, J., Williams, A. M., & Helsen, W. F. (2016). Visual search behaviors of association football referees during assessment of foul play situations. *Cognitive Research: Principles and Implications*, *1*, 1–12. doi:10.1186/s41235-016-0013-8

Unkelbach, C., & Memmert, D. (2008). Game management, context effects, and calibration: The case of yellow cards in soccer. *Journal of Sport & Exercise Psychology*, *30*, 95–109.

Williams, A. M., & Ericsson, K. A. (2005). Perceptual-cognitive expertise in sport: Some considerations when applying the expert performance approach. *Human Movement Science*, *24*, 283–307. doi:10.1016/j.humov.2005.06.002

Williams, A. M., North, J. S., & Hope, E. R. (2012). Identifying the mechanisms underpinning recognition of structured sequences of action. *The Quarterly Journal of Experimental Psychology*, *65*, 1975–1992. doi:10.1080/17470218.2012.678870