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The Editors—June 10, 2010

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The Editors—June 10, 2010

*Perceptual and Motor Skills,* 2011, 112, 1, 1-11. 

# VISUAL SKILLS INVOLVED IN DECISION MAKING BY EXPERT REFEREES[1]

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*Summary.*—Previous studies have compared visual skills of expert and novice athletes; referees' performance has not been addressed. Visual skills of two groups of expert referees, successful and unsuccessful in decision making, were compared. Using video clips of soccer matches to assess decision-making success of 41 national and international referees from 31 to 42 years of age, 10 top referees were selected as the Successful group and 10 as the Unsuccessful group. Visual tests included visual memory, visual reaction time, peripheral vision, recognition speed, saccadic eye movement, and facility of accommodation. The Successful group had better visual skills than the Unsuccessful group. Such visual skills enhance soccer referees' performance and may be recommended for young referees.

Almost all sports are judged by one or more referees. It is clear that refereeing of a match is an integral facet of the sport itself, and in addition, errorless refereeing is ideal. Calling a penalty incorrectly can produce many problems on the field and among spectators (Plessner & Haar, 2006). In most professional team sports, referees must consider various information sources (such as markers on the field, player and ball positions, assistants' reports, etc.), make rapid decisions, and discuss calls with the person who analyzes and criticizes their decisions based on slow-motion replays from different angles (Mascarenhas, Collins, & Mortimer, 2003; Helsen, Gilis, & Watson, 2006). Under such conditions, referees require excellent visual skills to catch details of action on the field during matches. They also require the cognitive skills to predict actions, know which actions to watch, and to make rapid and appropriate decisions (Ghasemi, Momeni, Rezaee, & Gholami, 2010).

The focus of this study is the association of referees' decision making and visual skills. Compared with the number of publications on the performance of players, research on the performance of referees in association football (soccer) is limited and began only about a decade ago. Studies have tended to investigate primarily physical demands and physi-

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***Author: This does not match reference, lists Weston (2007). Please clarify.***

ological responses. While it is widely known that expert athletes have better perceptual cognitive skills than their less successful peers (Vaeyens, Lenoir, Williams, & Phillippartes, 2007; Nakamoto & Mori, 2008; Takeuchi & Inomata, 2009), it is not clear whether this may also be true of referees. Certain abilities have an essential role in expert players' task performance, including recognition and recall of patterns of play (e.g., Williams, Hodges, North, & Barton, 2006), high sensitivity to visual cues related to postural orientation (e.g., Ward, Nord; Williams, *et al*., 2006), accurate prediction of later occurrences (e.g., Ward & Williams, 2003), working memory capacity, speed of processing (Salthouse, 1991; Krampe & Ericsson, 1996), perceptual and peripheral motor speed (Krampe & Ericsson, 1996), and superior visual skills (e.g., Jafarzadehpur, Aazami, & Bolouri, 2007; Boden, Rosengren, Martin, & Boden, 2009). These skills should be investigated in referees as well, to assess whether they play a similar role in this related and complex task.

The main responsibility of the referee clearly involves perception and decision making, but errors by referees during a soccer match are frequent and there has been little effort to assess this variable. MacMahon, Helsen, Starkes, and Weston (2007) compared elite referees with players on a refereeing task; not surprisingly, referees performed with fewer errors. It has been shown that decision errors decrease with increasing expertise. Gilis and colleagues (Gilis, Helsen, Catteeuw, Van Roie, & Wagemans, 2009) showed that a computer-based task presenting a decision of "offside" was representative of the core skills of assistant referees and could differentiate expertise: international-standard assistant referees made fewer errors than Belgian national-standard assistant referees. Therefore, it is proposed that success in refereeing can be measured in terms of errors in decision making.

There is limited research on strategies used by referees while making decisions. Helsen and Pauwels (1993) compared tactical decision-making skill of expert and novice soccer players who viewed scenes of a defensive match and responded as rapidly and accurately as possible. Experienced players' visual accommodation was better than that of novices. Various types of superiority observed in expert players might result from more professional and task-specific practice (e.g., French & McPherson, 1999; Ward & Williams, 2003). There is good reason to expect that this would prove true in referees as well.

Although it is clear that visual skills of athletes are better than those of nonathletes, there are limited data on visual abilities involved in athletes' decision making, and in extension, in referees' decision making. Most researchers have examined visual search behaviors during decision making by athletes, but not visual proficiency. There is no information about either variable with respect to referees' performance. However, the abilities

***Author: Plese clarify, Ward, Nord not in reference list.***

underlying referees' performance may differ widely from those of expert athletes. Even closely related roles such as those of referees and assistant referees require specific decision-making skills. These skills and the underlying abilities that must be identified.

In the present study, previous methods of Vaeyens, Lenoir, Williams, and Phillippartes (2007) on visual abilities involved in decision making were applied to referees. Another component was added to the analysis, i.e., a measure of success in decision making. Comparing expert referees with equivalent experience, classified into successful and unsuccessful groups on the basis of their performance on a decision-making test, may help to identify visual abilities discriminating successful referees. This issue was not explicitly defined in previous work using traditional comparison strategies in an athlete population. Expert successful soccer referees were hypothesized to have better visual memory, peripheral vision, eye saccadic movements, accommodation facility, and recognition speed than their less successful peers.

## Method

### *Participants*

Participants were 41 Iranian top-standard referees (*M* age = 34.8 yr., *SD* = 3.6). Nine referees were on the FIFA list and had international refereeing degrees awarded by the Asian Football Confederation (AFC) and had 12.1 yr. (*SD* = 2.5) refereeing experience. Referees on this list are called upon to officiate international matches in the various AFC competitions (e.g., AFC Cup, AFC Champions League), AFC being one of the six FIFA Confederations. Nine of the referees were appointed to the FIFA list primarily based on their match reports and the associated performance reviews. Match reports are standardized protocols that are used for all international matches as well as for all the games in the national leagues.

Referees were recruited during a workshop at the Iran Football Federation training center. Informed consent was obtained prior to participation. Prior ethical approval was provided through the Iran Medical University Hospital.

### *Measure*

*Test film.*—Videotapes of the Iran soccer premier league in 2007 were used to prepare video clips. After selecting 100 scenes of errors which occurred inside and around the penalty areas, three FIFA referees—all of whom were game assessors in Iran soccer premier league and former FIFA elite referees—identified the type of errors and the respective cards that should be issued. They removed scenes which were considered not suitable for accurate decision making, for example, the camera angle did not display the scene clearly or the scene was well known to referees. Scenes

($N = 76$) were selected as appropriate for presentation to referees. All three referees agreed about the correct refereeing decision for each scene (MacMahon, *et al.*, 2007). Desired scenes were cut using Adobe Premiere 6 software and a clip number was recorded at the beginning of each. Also, a reverse counting technique was used at the beginning of each clip to catch the referees' attention.

Since the options identified in each clip could not be completely wrong (i.e., there is more than one way to score each decision), the scoring was not error/correct; instead, the viewing referees were asked to mention other decisions which might be made in each scene. Generally, assigned scores were 0: Completely wrong decision, 1: Almost wrong decision, without any change in ball possession or match outcome, 2: Correct decision, regardless of details such as showing a card or penalty awarding, and 3: Completely correct decision with regard to details.

Desired scenes were displayed via a video projector (Sony VT 302VGA) on a 5 m × 3.5 m screen. Clips were shown in a random order and at 6 m distance from referees. Referees were instructed to select the most correct option among four available written on an answer sheet (designed based on similar options with correct responses) after watching each scene. Following each clip, there was a 5-sec. interval for referees to record their choices.

The sum of scores for the 76 clips was the decision-making score for each referee. Scores were ranked for all 41 referees, and the 10 top referees ($M = 193$, $SD = 14.3$) were identified as the Successful group and bottom 10 ($M = 133$, $SD = 22.8$) as the Unsuccessful group. The remaining 21 referees were removed from the subjects.

*Procedure*

First, referees were asked to provide information including age, refereeing status, experience, the league in which they worked, plus international tournaments in which they had refereed. Basic visual and ocular examinations were given to all participants: static sharp sightedness, refraction, eye movement, and ophthalmoscopy. A specific code was assigned to each participant to discriminate the two groups for statistical analysis and avoid any bias of investigators. Good visual acuity and normal ocular condition were inclusion criteria. Five visual tests were performed. All tests were performed in an optometry clinic of the Iran University of Medical Science.

*Accommodation.*—Facility of ocular accommodation was evaluated with Rock Lens Test with ±2.00 diopter lenses. Improvements in facility of ocular accommodation refer to the flexibility of the visual system to see the objects at different distances clearly (Powers, Grisham, Wurm, & Wurm, 2009). Close distance tables were placed at a distance of 40 cm from the referee, who was asked to examine 20/25 Snalen Scale letters in a room with sufficient light (Griffin, 1988). Participants read aloud each letter as requested by the optometrist, who changed the lens and again asked the participant to read the letters. The number of lens change cycles per minute and vision clearance were recorded for each referee.

*Saccadic movements.*—Saccadic eye movement at 40 cm was measured by Merely Sequential Fixation (Griffin, 1988). Saccadic eye movement indicates how quickly the visual system can find objects and change its fixation from one point to another point. The optometrist held the saccadic board at a distance of 40 cm from the referee and asked him to change his gaze from one side to the other side of the board (and vice versa) as fast as he could in 1 min. The optometrist recorded the number of correct eye movement cycles.

*Recognition.*—Recognition speed was evaluated by Optosys software. Each referee sat before a computer monitor while different shapes (star, square, triangle, and pentagon) were displayed on the screen in a random order every 5 sec. The referee drew each shape with a marker on a transparent plastic sheet attached to the screen. Then the numbers of correctly drawn shapes were counted.

To evaluate visual memory, Landolt broken circles were used (Griffin, 1988). The optometrist showed 15 Landolt broken circles in a random order to each participant during 1 min. Then referees recalled the number and direction of the broken side of the Landolt circle on each card. The number of errors in recalling the number and direction of the opening in the circles (up, down, left, right) was recorded as the score on this test.

*Peripheral vision.*—The last test assessed was a peripheral vision test measured by a tangent screen (Griffin, 1988). The peripheral vision test measures the ability of the visual system to analyze information from the peripheral visual system. The tangent screen is a black screen with white and colored circular objects, used for visual field evaluation (West, 1988; Garber, 1994; Wong & Sharpe, 2000). On this test, the visual-motor response to peripheral vision in eight directions was evaluated. Each referee sat before the tangent screen, a circle which has eight equal sectors located at a 1-m distance. They were instructed to fixate on the central point of the circle. The optometrist moved the colored markers slowly from the outside toward the center of the screen. When the referee stated the color, its distance from the center of the screen was recorded. The mean distance for the eight presented colors from the eight sides of the screen was the overall score.

## Results and Discussion

In order to assess the differences in facility of accommodation, peripheral vision, recognition speed, visual memory, and saccadic eye move-

TABLE 1

Descriptive Statistics for Visual Tests by Successful and Unsuccessful Groups of Referees

| Measure | Successful | | Unsuccessful | | *p* | *t* | Hedges' *g* |
|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | | | |
| Accommodation facility, cycle $min.^{-1}$ | 11.95 | 2.9 | 7.59 | 5.3 | .002 | 3.60* | |
| Peripheral vision, cm | 78.26 | 11.1 | 51.47 | 9.33 | .001 | 4.22† | |
| Recognition speed, $min.^{-1}$ | 11.73 | 2.8 | 9.63 | 2.6 | .01 | 2.93* | |
| Saccadic eye movement, $min.^{-1}$ | 85.09 | 11.6 | 68.64 | 9.2 | .006 | 4.08* | |
| Visual memory, $min.^{-1}$ | 1.15 | 0.32 | 2.94 | 0.88 | .009 | 3.21* | |

*$p \le .01$. †$p \le .001$.

ment of Successful and Unsuccessful referees, these two groups were compared using independent *t* tests with alpha set at .01. Results showed the Successful referee group had better mean scores on all the visual tests than the Unsuccessful group (Table 1).

In contrast to previous work which classified athletes into expert, mid-expert, novice, and nonathlete groups based on the level of experience and age (Savelsbergh, Williams, Van der Kamp, & Ward, 2002), here the visual skills of referees were compared based on the number of errors (high or low) they made in the refereeing task. Following Vaeyens, Lenoir, Williams, and Phillippartes (2007), a within-task criterion was also used to classify referees into Successful and Unsuccessful groups. This criterion involved using a film-based decision-making test and was based on the actual decision-making performance by referees. This new method, not based on age differences or experience and dealing only with referees' actual performance, was chosen to obtain a more explicit view of visual abilities' involvement in decision-making success.

Based on these data, the Successful referee group had significantly better performance on all visual tests, consistent with findings by Jafarzadehpur, *et al*. (2007) and Montes-Mico, Bueno, Candel, and Pans (2000). Facility of accommodation may be associated with shortened time required by the visual system to develop a clear image. The ability to change fixation point on the ball and players as quickly as possible is regarded as a requisite skill. The speed of ball and players is very important in soccer. Referees who can focus on events occurring quickly could have more success in decision making because the information taken in by the visual system is more relevant and complete (Jafarzadehpur & Yarigholi, 2004). Facility of ocular accommodation can be modified by specific orthoptic or vision therapy procedures commonly used for different visual problems (Iwasaki, 1993; Junyent & Fortó, 1995; Vasudevan, Ciuffreda, & Ludlam, 2009). Testing and therapy may improve referees' performance when there are limitations in this ability.

Saccadic eye movements are useful in fixation on the ball and on players. This skill is accompanied by suppression of information (Ripoll &

Latiri, 1997), since only first and last fixation points are analyzed and the visual information from between these two points is suppressed. These first and last gaze points are very important for visual acuity (Jafarzadehpur, *et al*., 2007). A successful soccer referee's saccadic eye movements, as well as visual accommodation, should be as fast as possible. This combination of accommodation facility and saccadic eye-movement ability may aid in decision making. Fast fixation and refixation also can be improved with specific therapies (Dewhurst & Crundall, 2008; Bibi & Edelman, 2009; Guzman-Martinez, Leung, Franconeri, Grabowecky, & Suzuki, 2009; Kiyota & Fujiwara, 2010; Mannan, Pambakian, & Kennard, 2010).

These findings are consistent with studies related to visual search on decision making (Savelsbergh, Van der Kamp, Williams, & Ward, 2005). Vaeyens, Lenoir, Williams, Mazyn, and Phillippartes (2007) indicated expert soccer players use more goal-oriented visual search strategies, including more and shorter fixations on the player who possesses the ball and more changing of fixation than less successful players. These rapid fixation changes in successful players may be based on their superior skills in saccadic eye movement and facility of accommodation in addition to their greater experience in selectively changing these fixations on the ball and players. This appears also to be true for soccer referees.

Better peripheral visual ability was also characteristic of the Successful referee group. In stressful sport situations, it has been shown that the sympathetic nervous system is more dominant. Athletes' perceptual system mainly relies on peripheral stimuli and the pupils widen and vision accommodation is facilitated (Jafarzadehpur & Yarigholi, 2004). A main function of this peripheral system is recognition of movement (Ferreira, 2003). Referees must have wide peripheral vision to see elements in the field, including players, ball, assistants, etc., as well as monitoring their relative motion. Such conditions are usually accompanied by high mental stress and tension which may cause performance decrement. For example, in a corner scene, a referee should see all players for possible foul detection, the ball for movement toward the goal, and the assistant referee for calling off-side or goal faults. All this requires well-developed peripheral vision.

Visual perception in referees depends more on speed of recognition and reaction to a stimulus than to vision in the peripheral visual field (Takeuchi & Inomata, 2009). But some authors have observed that sports in which an athlete receives many stimuli simultaneously may require well-developed peripheral vision (Zwierko, 2007). For instance, Blundell (1985) examined peripheral vision of tennis players at differing levels of expertise and noted that the expert players had better peripheral vision for yellow and white colors.

Recognition speed in the Successful referee group was higher, in agreement with Beckerman and Hitzeman (2003) and Stine, Arterburn, and Stern (1982). Present results do not support results of Abernethy and Neal (1999), perhaps because they studied shooting, a static sport which does not require movement in the environment or peripheral vision. This disagreement suggests that visual demands of sports differ and that visual abilities of athletes may depend on their professional sport (Yuan, Fan, Chin, & So, 1995). A limiting factor in refereeing is time, so time management is essential in all refereeing situations; the referee must make decisions within a few seconds. Having high recognition speed can help a referee to make better and faster decisions in critical situations.

On the visual memory test, the Successful referee group had a higher mean. According to research on information retrieval of play pattern perceptions in a dynamic team sport, decision making is highly dependent on athletes' memory (Williams & Ericsson, 2005). Referees must recall a scene after seeing it in order to process information related to decisions effectively and to remember many different patterns of error occurrence. Better decisions are made when comparing current scenes with patterns held in functional memory. In addition, Hardiess, Gillner, and Mallot (2008) noted that having superior short-term visual memory improves visual search and, consequently, decision making.

Some visual abilities are critical components of visual search, so having superior abilities should improve the visual-search process in referees. Some researchers have also suggested that visual search is a *skill* which depends on the athletes' experience and having developed patterns of play in memory (Takeuchi & Inomata, 2009). Others have argued that visual search is somewhat related to perceptual ability and the superiority of experts derives from more effective visual fixation or greater peripheral vision (Savelsbergh, *et al.*, 2005).

Referees who have better visual ability and visual memory may be more successful. The less successful referees made more errors when applying soccer rules to real game scenarios and had poorer visual memory and visual abilities. This research potentially offers soccer referees a way to improve their decisions. Training of visual ability may improve decision making during a soccer match.

Ferreira (2003) classified visual skills into "software" and "hardware," the former including practiced skills dependent on experience, and the latter physiological or genetic. Visual memory and recognition speed would fall into the first category since they are largely dependent on experience, suggesting the necessity for visual practice in soccer refereeing. Facility of accommodation, eye saccadic movements, and peripheral vision could be classified as hardware and could be used for talent identification among referees; however, accommodation, saccadic eye movements, and other visual skills may be changed with specific therapy. Both physiological and environmental factors are important in visual function.

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# Visual skills Involved in Decision Making by Expert Referees[1]

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*Summary*.—Previous studies have compared visual skills of expert and novice athletes; referees’ performance has not been addressed. Visual skills of two groups of expert referees successful and unsuccessful in decision making were compared. Using video clips of soccer matches to assess decision-making success of 41 national and international referees from 31 to 42 years of age, 10 top referees were selected as a Successful group and 10 as the Unsuccessful group. Visual tests included visual memory, visual reaction time, peripheral vision, recognition speed, saccadic eye movement, and facility of accommodation. The Successful group had better visual skills than the Unsuccessful group. Such visual skills enhance soccer referees' performance and may be recommended for young referees.

Almost all sports are judged by one or more referees. It is clear that refereeing of a match is an integral facet of the sport itself, and in addition, errorless refereeing is ideal. Calling a penalty incorrectly can produce many problems on the field and among spectators (Plessner & Haar, 2006). In most professional team sports, referees must consider various information sources (such as markers on the field, player and ball positions, assistants’ reports, etc.), make rapid decisions, and discuss calls with the person who analyzes and criticizes their decisions based on slow motion replays from different angles (Mascarenhas, Collins, & Mortimer, 2003; Helsen, Gilis, & Watson, 2006). Under such conditions, referees require excellent visual skills to catch details of action on the field during matches. They also require the cognitive skills to predict actions, know which actions to watch, and to make rapid and appropriate decisions (Ghasemi, Momeni, Rezaee, & Gholami, 2010).

The focus of this study is the association of referees’ decision making and visual skills. Compared with the number of publications on the performance of players, research on the performance of referees in association football (soccer) is limited and began only about a decade ago. Studies have tended to investigate primarily physical demands and physiological responses. While it is widely known that expert athletes have better perceptual cognitive skills than their less successful peers (Nakamoto & Mori, 2008; Vaeyens, Lenoir, Williams, & Phillippartes, 2007; Takeuchi & Inomata, 2009), it is not clear whether this may also be true of referees. Certain abilities have an essential role in expert players' task performance, including recognition and recall of patterns of play (e.g., Williams, Hodges, North, & Barton, 2006), high sensitivity to visual cues related to postural orientation (e.g., Ward, Nord; Williams, *et al*., 2006), accurate prediction of later occurrences (e.g. Ward & Williams, 2003), working memory capacity, speed of processing (Krampe & Ericsson, 1996; Salthouse, 1991), perceptual and peripheral motor speed (Krampe & Ericsson, 1996) and superior visual skills (e.g., Jafarzadehpur, Aazami, & Bolouri, 2007; Boden, Rosengren, Martin, &Boden, 2009). These skills should be investigated in referees as well, to assess whether they play a similar role in this related and complex task.

The main responsibility of the referee clearly involves perception and decision making, but errors by referees during a soccer match are frequent and there has been little effort to assess this variable. MacMahon, Helsen, Starkes, and Weston (2007) compared elite referees with players on a refereeing task; not surprisingly, referees performed with fewer errors. It has been shown that decision errors decrease with increasing expertise. Gilis and colleagues (Gilis, Helsen, Catteeuw, Van Roie, &Wagemans, 2008) showed that a computer-based task presenting a decision of “offside” was representative of the core skills of assistant referees and could differentiate expertise: international-standard assistant referees made fewer errors than Belgian national-standard assistant referees. Therefore, it is proposed that success in refereeing can be measured in terms of errors in decision making.

There is limited research on strategies used by referees while making decisions. Helsen and Pauwels (1993) compared tactical decision-making skill of expert and novice soccer players who viewed scenes of a defensive match and responded as rapidly and accurately as possible. Experienced players' visual accommodation was better than that of novices. Various types of superiority observed in expert players might result from more professional and task-specific practice (e.g., French & McPherson, 1999; Ward and Williams, 2003). There is good reason to expect that this would prove true in referees as well.

Although it is clear that visual skills of athletes are better than those of non-athletes, there are limited data on visual abilities involved in athletes’ decision making, and in extension, in referees’ decision making. Most researchers have examined visual search behaviors during decision making by athletes, but not visual proficiency. There is no information about either variable with respect to referees’ performance. However, the abilities underlying referee’s performance may differ widely from those of expert athletes. Even closely related roles such as those of referees and assistant referees require specific decision-making skills. It is these skills and the underlying abilities that must be identified.

In present study, previous methods of Vaeyens, *et al*. (2007b) on visual abilities involved in decision making was applied to referees. Another component was added to the analysis, i.e., a measure of success in decision making. Comparing expert referees with equivalent experience, classified into successful and unsuccessful groups on the basis of their performance on a decision-making test, may help to identify visual abilities discriminating successful referees. This issue was not explicitly defined in previous work using traditional comparison strategies in an athlete population. Expert successful soccer referees were hypothesized to have better visual memory, peripheral vision, eye saccadic movements, accommodation facility, and recognition speed than their less successful peers.

## METHODS

### *Participants*

Participants were 41 Iranian top-standard referees (*M* age = 34.8 yr., *SD*= 3.6). Nine referees were on the FIFA list and had international refereeing degrees awarded by the Asian Football Confederation (AFC) and had 12.1 yr. (*SD* = 2.5) refereeing experience. Referees on this list are called upon to officiate international matches in the various AFC competitions (e.g., AFC Cup, AFC Champions League), AFC being one of the six FIFA Confederations. Nine of the referees were appointed to the FIFA list primarily based on their match reports and the associated performance reviews. Match reports are standardized protocols that are used for all international matches as well as for all the games in the national leagues.

Referees were recruited during a workshop at the Iran Football Federation training center. Informed consent was obtained prior to participation. Prior ethical approval was provided through the Iran Medical University Hospital.

### *Measure*

*Test film.*—Video tapes of the Iran soccer premier league in 2007 were used to prepare video clips. After selecting 100 scenes of errors which occurred inside and around the penalty areas, three FIFA referees—all of whom were game assessors in Iran soccer premier league and former FIFA elite referees—identified the type of errors and the respective cards that should be issued. They removed scenes which were considered not suitable for accurate decision making, for example, the camera angle did not display the scene clearly or the scene was well known to referees.  Scenes (*N*=76) were selected as appropriate for presentation to referees. All three referees agreed about the correct refereeing decision for each scene (MacMahon, *et al.*, 2007). Desired scenes were cut using Adobe Premiere 6 software and a clip number was recorded at the beginning of each. Also a reverse counting technique was used at the beginning of each clip to catch the referees' attention.

Since the options identified in each clip could not be completely wrong (i.e., there is more than one way to score each decision), the scoring was not error/correct; instead, the viewing referees were asked to mention other decisions which might be made in each scene. Generally, assigned scores were 0: Completely wrong decision, 1: Almost wrong decision, without any change in ball possession or match outcome, 2: Correct decision, regardless of details such as showing a card or penalty awarding, and 3: Completely correct decision with regard to details.

Desired scenes were displayed via a video projector (Sony VT 302VGA) on a 5m × 3.5 m screen. Clips were shown in a random order and at 6 meters distance from referees. Referees were instructed to select the most correct option among four available written on an answer sheet (designed based on similar options with correct responses) after watching each scene. Following each clip there was a 5-sec. interval for referees to record their choice.

The sum of scores for the 76 clips was the decision-making score for each referee. Scores were ranked for all 41 referees and the 10 top referees (*M*=193, *SD*= 14.3) were identified as the Successful group and bottom 10 (*M*=133, *SD*=22.8) as the Unsuccessful group. The remaining 21 referees were removed from the subjects.

*Procedure*

First, referees were asked to provide information including age, refereeing status, experience, the league in which they worked, plus international tournaments in which they had refereed. Basic visual and ocular examinations were given to all participants: static sharp sightedness, refraction, eye movement, and ophthalmoscopy. A specific code was assigned to each participant to discriminate the two groups for statistical analysis and avoid any bias of investigators. Good visual acuity and normal ocular condition were inclusion criteria. Five visual tests were performed. All tests were performed in optometry clinic of Iran University of Medical Science.

*Accommodation*.—Facility of ocular accommodation was evaluated with Rock Lens Test with ±2.00 diopter lenses. Improvements in facility of ocular accommodation refer to the flexibility of visual system to see the objects at different distances clearly (Powers, Grisham, Wurm, & Wurm, 2009). Close distance tables were placed at a distance of 40 cm from the referee, who was asked to examine 20/25 Snalen Scale letters in a room with sufficient light (Griffin, 1988). Participants read aloud each letter as requested by the optometrist, who changed the lens and again asked the participant to read the letters. The number of lens change cycles per minute and vision clearance were recorded for each referee.

*Saccadic movements*.—Saccadic eye movement at 40 cm was measured by Merely Sequential Fixation (Griffin, 1988). Saccadic eye movement indicates how quickly the visual system can find objects and change its fixation from point to another point. The optometrist held the saccadic board at a distance of 40 cm from the referee and asked him to change his gaze from one side to other side of the board (and vice versa) as fast as he could in 1 min. The optometrist recorded the number of correct eye movement cycles.

*Recognition*.—Recognition speed was evaluated by Optosys software. Each referee sat before a computer monitor while different shapes (star, square, triangle and pentagon) in a random order were displayed on the screen every 5 sec. The referee drew each shape with a marker on a transparent plastic sheet attached to the screen. Then the numbers of correctly drawn shapes were counted.

To evaluate visual memory, Landolt broken circles were used (Griffin, 1988). The optometrist showed 15 Landolt broken circles in a random order to each participant during 1 min.. Then referees recalled the number and direction of the broken side of the Landolt circle on each card. The number of errors in recalling the number and direction of the opening in the circles (up, down, left, right) were recorded as the score on this test.

*Peripheral vision*.—The last test assessed was a peripheral vision test measured by a tangent screen (Griffin, 1988). The peripheral vision test measures the ability of the visual system to analyze information from the peripheral visual system. The tangent screen is a black screen with white and colored circular objects, used for visual field evaluation (Wong & Sharpe, 2000; Garber, 1994; West, 1988). On this test, the visual-motor response to peripheral vision in eight directions was evaluated. Each referee sat before the tangent screen, a circle which has eight equal sectors located at a 1-m distance. They were instructed to fixate on the central point of the circle. The optometrist moved the colored markers slowly from the outside toward the center of the screen. When the referee stated the color, its distance from the center of screen was recorded. The mean distance for the eight presented colors from the eight sides of the screen was the overall score.

## RESULTS AND DISCUSSION

In order to assess the differences in facility of accommodation, peripheral vision, recognition speed, visual memory, and saccadic eye movement of Successful and Unsuccessful referees, these two groups were compared using independent *t* tests with alpha set at .01. Results showed the Successful referee group had better mean scores on all the visual tests than the Unsuccessful group (Table 1).

In contrast to previous work which classified athletes into expert, mid-expert, novice and non-athlete groups based on the level of experience and age (Savelsbergh, Williams, Van der Kamp, & Ward, 2002), here the visual skills of referees were compared based on the number of errors (high or low) they made in the refereeing task. Following Vaeyens, *et al.* (2007b) also a within-task criterion was used to classify referees into Successful and Unsuccessful groups. This criterion involved using a film-based decision-making test and was based on the actual decision-making performance by referees. This new method, not based on age differences or experience and dealing only with referees' actual performance, was chosen to obtain a more explicit view of visual abilities’ involvement in decision-making success.

Based on these data, the Successful referee group had significantly better performance on all visual tests, consistent with findings by Jafarzadehpur, *et al*. (2007), and Montes-Mico, Bueno, Candel, and Pans (2000). Facility of accommodation may be associated with shortened time required by the visual system to develop a clear image. The ability to changing fixation point on the ball and players as quickly as possible is regarded as a requisite skill. The speed of ball and players is very important in soccer. Referees who can focus on events occurring quickly could have more success in decision-making because the information taken in by the visual system is more relevant and complete (Jafarzadehpur & Yarigholi, 2004). Facility of ocular accommodation can be modified by specific orthoptic or vision therapy procedures commonly used for different visual problems (Iwasaki, 1993; Junyent & Fortó, 1995; Vasudevan, Ciuffreda, & Ludlam, 2009). Testing and therapy may improve referees’ performance when there are limitations in this ability.

Saccadic eye movements are useful in fixation on the ball and on players. This skill is accompanied by suppression of information (Ripoll & Latiri, 1997), since only first and last fixation points are analyzed and the visual information from between these two points is suppressed. These first and last gaze points are very important for visual acuity (Jafarzadehpur, *et al*., 2007). A successful soccer referee's saccadic eye movements, as well as visual accommodation, should be as fast as possible. This combination of accommodation facility and saccadic eye-movement ability may aid in decision making. Fast fixation and re-fixation also can be improved with specific therpaies (

Better peripheral visual ability was also characteristic of the Successful referee group. In stressful sport situations, it has been shown that the sympathetic nervous system is more dominant. Athletes' perceptual system mainly relies on peripheral stimuli and the pupils widen and vision accommodation is facilitated (Jafarzadehpur & Yarigholi, 2004). A main function of this peripheral system is recognition of movement (Ferreira, 2003).

Referees must have wide peripheral vision to see elements in the field, including players, ball, assistants, etc. as well as monitoring their relative motion. Such conditions are usually accompanied by high mental stress and tension which may cause performance decrement. For example, in a corner scene, a referee should see all players for possible foul detection, the ball for movement toward the goal, and the assistant referee for calling off-side or goal faults. All this requires well developed peripheral vision.

Visual perception in referees depends on speed of recognition and reaction to a stimulus than to vision in the peripheral visual field (Takeuchi & Inomata, 2009). But some authors have observed that sports in which an athlete receives many stimuli simultaneously may require well developed peripheral vision (Zwierko, 2007). For instance, Blundell (1985) examined peripheral vision of tennis players at differing levels of expertise and noted that the expert players had better peripheral vision for yellow and white colors.

Recognition speed in the Successful referee group was higher, in agreement with Beckerman and Hitzeman (2003) and Stine, Arterburn, and Stern, (1982). Present results do not support results of Abernethy and Neal (1999) perhaps because they studied shooting, a static sport, which does not require movement in the environment or peripheral vision. This disagreement suggests that visual demands of sports differ, and that visual abilities of athletes may depend on their professional sport (Yeh, Liu, Chui, & Soh, 1995). A limiting factor in refereeing is time, so that rapid judgment is essential in refereeing situations; the referee must make decisions within a few seconds. Having high recognition speed can help a referee to make better and faster decisions in critical situations.

On the visual memory test, the Successful referee group had a higher mean. According to research on information retrieval of play pattern perception in a dynamic team sport, decision making is highly dependent on athletes' memory (Williams & Ericsson, 2005). Referees must recall a scene after seeing it in order to process information related to decisions effectively, and to remember many different patterns of error occurrence. Better decisions are made when comparing current scenes with patterns held in functional memory. In addition, Hardiess, Gillner, and Mallot, (2008) noted that having superior short term visual memory improves visual search and consequently, decision-making.

Mann, [illegible] & Kerr, 2010; Kiyota & Fujiwara, 2010; Bibi & Edelman, 2009; Gorman, Martinez, Leung, [illegible], & [illegible], 2009; Dewhurst & [illegible], 2008).

These findings are consistent with studies related to visual search in decision making (Savelsbergh, Van der Kamp, Williams, & Ward 2005). Vaeyens, *et al.* (2007a) indicated expert soccer players use more goal-oriented visual search strategies, including more and shorter fixations on the players who possess the ball and more changing of fixation than less successful players. These rapid fixation changes suggest that players may be based on their superior skills in saccadic eye movement and facility of accommodation in addition to their large experience in selectively changing these fixations on the ball and players. This appears also to be true for soccer referees.

Some visual abilities are critical components of visual search, so having superior abilities should improve the visual-search process in referees. Some researchers have also suggested that visual search is a *skill* which depends on the athletes' experience and having developed patterns of play in memory (Takeuchi & Inomata, 2009). Others have argued that visual search is somewhat related to perceptual ability and the superiority of experts derives from more effective visual fixation or greater peripheral vision (Savelsbergh, *et al*., 2005).

Referees who have better visual ability and visual memory may be more successful. The less successful referees made more errors when applying soccer rules to real game scenarios and had poorer visual memory and visual abilities. This research potentially offers soccer referees a way to improve their decisions. Training of visual ability may improve decision making during soccer match.

Ferreira (2003) classified visual skills into “software” and “hardware”, the former including practiced skills dependent on experience, and the latter physiological or genetic. Visual memory and recognition speed would fall into the first category since they are largely dependent on experience, suggesting the necessity for visual practices in soccer refereeing. Facility of accommodation, eye saccadic movements, and peripheral vision could be classified as “hardware” and could be used for talent identification among referees; however, accommodation, saccadic eye movements and other visual skills may be changed with specific therapy. Both physiological and environmental factors are both important in visual function.

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Table 1

Descriptive Statistics for Visual Tests by Successful and Unsuccessful Groups of Referees

| Measures | Successful | | Unsuccessful | | *p* | *t* | *Hedge's g* |
|---|---|---|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* | | | |
| Accommodation facility, cycle $min^{-1}$ | 11.95 | 2.9 | 7.59 | 5.3 | .002 | 3.60† | |
| Peripheral vision , cm | 78.26 | 11.1 | 51.47 | 9.33 | .001 | 4.22‡ | |
| Recognition speed, $min^{-1}$ | 11.73 | 2.8 | 9.63 | 2.6 | .01 | 2.93† | |
| Saccadic eye movement, $min^{-1}$ | 85.09 | 11.6 | 68.64 | 9.2 | .006 | 4.08† | |
| Visual memory, $min^{-1}$ | 1.15 | 0.32 | 2.94 | 0.88 | .009 | 3.21† | |

†$p \leq .01$. ‡ $p \leq .001$.

**Comment [SAI1]:** Author was asked to calculate these; they must be included before publication.