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The role of domain-generic and domain-specific perceptual-cognitive skills in association football referees

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ABSTRACT

Objectives: We examined the importance of perceptual-cognitive skills in association football referees.
Design and method: Using a novel approach, elite (n = 22) and sub-elite referees (n = 21) completed an extended test battery of perceptual-cognitive measures. Participants were assessed using both domain-generic (e.g., sustained attention; working memory) and domain-specific (e.g., pattern recognition) perceptual-cognitive measures within the domain of refereeing.
Results: A multivariate analysis of variance revealed significant differences between groups on the following domain-specific perceptual-cognitive skill measures, with elite referees performing significantly better than their sub-elite counterparts: overall decision-making performance; anticipation; and recall capacity. No significant differences were reported between the elite and sub-elite referees on domain-generic perceptual-cognitive skill measures. A stepwise discriminant analysis highlighted that a combination of five predictor variables, including four domain-specific and one domain-generic perceptual-cognitive skill measure, significantly discriminated elite and sub-elite referees, with 90.7% of referees being classified correctly.
Conclusions: Our findings shed light on the skills underpinning perceptual-cognitive expertise in referees and are consistent with the existing findings on expert outfield players. Implications are discussed with regard to testing and training programs for referees and across other professional domains.

Expertise has been defined as a unique knowledge and mastery of performance in a particular area. It has been investigated in different domains, including law enforcement, medicine, military, and sports (Ward, Suss, & Basevitch, 2009). A complex recipe of hereditary, environmental, and training factors is needed before the highest level of expertise is attained. Expert athletes may embody the most visible characteristics of all expert performers, showing exceptional physical, technical, emotional, and perceptual-cognitive skills (Ericsson, 2014a). Researchers have been challenged to unravel the mechanisms underlying expert performance and sport scientists have argued that perceptual-cognitive skills play a crucial role in sports performance, particularly at the highest levels (Williams & Ericsson, 2005; Williams, Ford, Eccles, & Ward, 2011). Perceptual-cognitive expertise refers to the ability of performers to identify and process (environmental) information for integration with existing knowledge to facilitate the selection of appropriate responses under time pressure (Marteniuk, 1976). Perceptual-cognitive superiority in the sports domain can be assessed either in a sport-specific context representing the requirements of a competitive and realistic setting (domain-specific skills) or by use of more generic tests with no direct link to the performance setting (domain-generic skills).

A number of domain-specific perceptual-cognitive skills have been identified, which are related to a superior performance. It is well reported that anticipation is an important domain-specific attribute of expertise and it relates to the performer's ability to use situational probabilities and advance cues emanating from the postural movements of players (Mann, Williams, Ward, & Janelle, 2007; Williams, Huys, Cañal-Bruland, & Hagemann, 2009). Athletes have an idea of what is likely to happen, creating more time to execute an appropriate response. Previously, researchers have

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shown that anticipation is strongly associated with expertise in various sports, including badminton (Wright, Bishop, Jackson, & Abernethy, 2011), tennis (Tenenbaum, Sar-El, & Bar-Eli, 2000), and soccer (Van der Kamp, 2011; Williams, 2000). It is often concluded that experts can recognize patterns, or chunks of information, within the game structure to a deeper level than novices, allowing them to subsequently recall the position of players more accurately or to better distinguish previously seen from novel action sequences of play. This ability to recall and recognize sport-specific patterns of play has been shown to be important in different sports where there is considerable time pressure, requiring individuals to selectively attend to the most relevant sources of information (North, Ward, Ericsson, & Williams, 2011). Scientists have also shown clear expertise effects in referee-specific decision-making tasks across various team sports, such as rugby (Mascarenhas, Collins, Mortimer, & Morris, 2005), association football (Catteeuw, Helsen, Gilis, Van Roie, & Wagemans, 2009; Gilis, Helsen, Catteeuw, & Wagemans, 2008; Put et al., 2014), Australian football (Larkin, Berry, Dawson, & Lay, 2011), and ice hockey (Hancock & Ste-Marie, 2013). Moreover, Gilis et al. (2008) showed that international assistant referees were significantly more accurate in recalling the spatial positions of football players in complex offside situations than national assistant referees. Ste-Marie (1999) showed that expert judges in gymnastics were significantly better at anticipating upcoming gymnastic elements from advance information. It is suggested that experts only differ in processing skills directly related to their field of expertise and that those skills do not translate to other domains (Ericsson, Charness, Feltovich, & Hoffman, 2006; Feltovich, Prietula, & Ericsson, 2006). However, there can be transfer of processing skill during role transitions, for example when a player becomes a referee (MacMahon, Starkes, & Deaking, 2009).

A second approach towards expertise acquisition is the cognitive component skills or domain-general approach, which examines the relationship between sport expertise and domain-generic perceptual-cognitive skills (Furley & Memmert, 2010; Hill & Schneider, 2006; Nougier, Stein, & Bonnel, 1991). Domain-generic perceptual-cognitive skills, such as working memory capacity, processing speed, motor inhibition, and attentional abilities, are determined largely by the processing efficiency of the central nervous system and are tested outside the sport-specific domain. Research on the cognitive component skills approach has yielded contrasting findings regarding the relationship between levels of performance on domain-generic perceptual-cognitive skills and expertise in sport or other domains, where perceptual-cognitive skills are of utmost importance (Voss, Kramer, Basak, Prakash, & Roberts, 2010).

In a meta-analysis of 20 studies, Voss et al. (2010) showed that expert athletes perform better compared to novices on measures of processing speed and several attentional paradigms. Moreover, elite and sub-elite team sport players' scores on tasks measuring creativity, inhibition, cognitive flexibility, and executive control have been compared (Alves et al., 2013; Verburgh, Scherder, van Lange, & Oosterlaan, 2014; Vestberg, Gustafson, Maurex, Ingvar, & Petrovic, 2012). These authors found significant variation between the two levels of athletes, with better scores for the elite players. Additionally, Vestberg et al. (2012) observed a significant relationship between the performances on domain-generic perceptual-cognitive skill measures and the number of goals and assists association football players had scored two seasons later. Similarly, Ghasemi, Momeni, Jafarzadehpur, Rezaee, and Taheri (2011) reported differences between successful and unsuccessful Iranian referees on several general visual skills such as facility of accommodation, peripheral vision, recognition speed, visual memory, and saccadic eye movements. The link between expertise and generic skill performance has also been demonstrated in medicine and other domains. For example, Harenberg et al. (2016) showed that the multiple objects tracking score predicted laparoscopic surgical skill in medical students.

In contrast, other researchers have reported no improved performances on cognitive measures in favor of (elite) athletes and no consistent relations between domain-generic perceptual-cognitive skills and domain-specific skills (for a review, see Ericsson, 2014b). For instance, no differences were observed between experts in team handball, expert track athletes and novices on a visual attention test battery (Memmert, Simons, & Grimme, 2009). Furley and Memmert (2010) reported that basketball players and non-athlete college students did not differ in spatial working memory as measured with the 'Corsi Block-tapping task'. Similarly, generic measures of cognition are not considered predictors of skill level in outfield players in association football (Belling, Suss, & Ward, 2015). In sum, these latter studies claim that experts only differ in processing abilities directly tied to their domain of expertise, in contrast with studies supporting the cognitive component skills approach.

Only a few researchers have examined both domain-generic and domain-specific perceptual-cognitive skill measures to evaluate their relative contribution to expert performance. Helsen and Starkes (1999) adopted a multidimensional approach to predict performance between expert, intermediate, and novice association football players and found that 84% of variance was accounted for by sport-specific skills. The only generic visual component that contributed a small amount (3%) was peripheral horizontal visual range. Very similar results were reported by Ward and Williams (2003), examining the relative contribution of visual, perceptual, and cognitive skills to the development of expert performance in association football players throughout their development. Elite and sub-elite association football players were not discriminated based on their visual function throughout late childhood, adolescence or early adulthood. In contrast, elite players developed superior sport-specific perceptual-cognitive skills allowing them to perform more successfully in each of the respective age groups. These studies mainly used generic visual and optometric parameters, such as static visual acuity and stereoscopic depth sensitivity. These visual 'hardware' variables should not be confused with generic measures of enhanced cognitive processing as proposed within the cognitive component skills approach.

In the current study, we extend understanding of the role of domain-generic and domain-specific perceptual-cognitive skills in expert decision making. We examine which components account for the largest proportion of the variance in performance levels using a battery of domain-generic and domain-specific tests. The focus in the current study is on referees in association football, an under-researched target group for whom perceptual-cognitive skills are of utmost importance. In similar vein to the demands on outfield players, referees need to be attentive and to quickly and efficiently make appropriate decisions in dynamic, ever-changing situations. This decision-making process requires an efficient information processing system (MacMahon et al., 2015). Therefore, we included a test battery of four domain-specific and six domain-generic perceptual-cognitive skill measures.

The selected domain-specific skills (decision-making performance; anticipation; recognition/recall capacity) are generally accepted as key performance indicators within sports literature and were adapted for the domain of refereeing (North et al., 2011; Williams et al., 2009). With respect to these domain-specific perceptual-cognitive skills, we hypothesized that elite referees would outperform sub-elite referees because they have acquired specific and more elaborate knowledge from their respective performance environment. Previously, researchers have shown clear