Expertise and perceptual-cognitive performance in soccer: a review

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ABSTRACT
This review characterizes the importance of game intelligence between soccer players of different competition levels and according to a specific positional field status. However, research evidence on this topic is inconclusive and in some reports the importance of the perceptual-cognitive skills in the anticipation and decision-making performance remains unclear. Our intention is merely informative and indicative of the surrounding literature on the sport expertise, with the particular interest on the perceptual-cognitive performance, than depreciate some researches or taking part of some currents. Obviously that the variance in performance between soccer teams or players is depending of a several factors, like as anthropometric and physiological profiles, but one of the main factor that we want to include in the sport context is the perceptual-cognitive skills, such as visual search behaviour and the knowledge of situational probabilities.
The aims of the present article are: (i) to define and to contextualize the different terminology used in this specific domain; (ii) to typify the different perceptual-cognitive skills that seems to bring on soccer players' performance; and (iii) to provide some future research guidelines.

Key-words: expertise, perceptual-cognitive skills, soccer

RESUMO
Esta revisão caracteriza a importância da inteligência de jogo entre futebolistas de diferentes níveis competitivos e de acordo com as suas posições específicas em campo. No entanto, evidências científicas nesta área não são de todo conclusivas e em alguns estudos que atribuem importância às habilidades perceptivo-cognitivas no rendimento das acções de antecipação e de tomadas de decisão são algo díspares.
A nossa intenção é meramente informativa e indicativa da literatura em volta da excelência desportiva, com particular interesse para o rendimento perceptivo-cognitivo, do que depreciar algumas investigações ou tomar partido por alguma corrente investigacional. Obviamente que a variabilidade do rendimento desportivo tanto entre equipas de Futebol como entre futebolistas é dependente de inúmeros factores, como os perfis antropométricos e fisiológicos dos atletas, mas um dos mais importantes factores que intencionámos incluir no contexto desportivo são as habilidades perceptivo-cognitivas, tais como o comportamento da procura visual e o conhecimento das probabilidades situacionais.
Os objectivos do presente artigo são: (i) definir e contextualizar a diferente terminologia utilizada neste contexto específico; (ii) tipificar as diferentes habilidades perceptivo-cognitivas que parecem emergir no rendimento desportivo dos futebolistas; e (iii) fornecer algumas orientações para futuras investigações.

Palavras-chave: *excelência, habilidades perceptivo-cognitivas, futebol*

INTRODUCTION

There is empirical support to suggest that perceptual-cognitive skills, such as anticipation and decision-making, are crucial to high-level performance across a range of domains and within a specific-domain[e.g., see 18, 16, 13, 56, 55, 50]. Theoretically, sport expertise research is a fruitful domain to explore the validity of models developed in other fields, providing a rich source of empirical evidence on the true potential of human achievement[14, 15]. Sport expertise has been defined as the ability to consistently demonstrate superior athletic performance[39, 17, 27]. Although superior performance is readily apparent on observation, the perceptual-cognitive mechanisms that contribute to the expert advantage are less evident. At a practical level, knowledge of the factors underpinning the development of expert performers in sport can help highlight the important factors underlying effective practice and instruction and the important social support networks required to facilitate performance and learning in other domains[54].

In the situational or strategic sports, such as team sports, players have to make fast and accurate decisions in a complex and variable environment[33, 35]. Athletes' decisions are made upon information coming from different sources like the ball, teammates and opponents[58], and the decision-making process occurs under pressure with opponents trying to restrict the "time" and "space" available. In this context, the dynamics that govern the interactions between the athlete and sport environment are based on the presupposition of stimulus reception from which the player emits an answer (action-reaction). Thus, the athletes must focus their attention just on the most crucial and relevant information sources to carry out their performances efficiently and successfully.

The study of expertise in sport began in the early 1980s and perhaps owed as much to developments in the related field of skill acquisition as to corresponding developments in cognitive psychology. Allard and colleagues[6, 8] carried out the seminal work on perceptual-cognitive expertise in sport. By replicating the work of Chase and Simon[10, 11] and using groups of basketball players and untrained participants, they found that experts in sport have the same cognitive advantage over novices as experts in other domains. At the same time other researchers, such as Jones and Miles[28] became interested in anticipation skill in fast ball sports. They reported that experts were quicker and more accurate than novices at anticipating the direction of serve in tennis, using realistic film-based simulations of the return of serve scenario.

The first study in soccer using more and less skilled players was carried out by Helsen and Pauwels[19]. They proposed to examine the players performance across the full range of tasks designed to tap a variety of non-specific abilities related to the visual/central nervous system function and then increasingly soccer-specific skills. The authors have concluded that superior skill was attributable to a variety of processes. In combination with a more pertinent selection and accurate interpretation of environmental cues (i.e. perceptual component) and a more rapid selection of an appropriate response (i.e. decision component), the more skilled soccer players were able to execute a smooth and efficient movement (i.e. motor component) over the less skilled players. These findings confirmed, as McPherson and Thomas[31] and Allard and Starkes[7] noted, that a distinguishing feature of experts is their adeptness at both "Knowing" what to do and "doing it". While less skilled athletes may achieve a degree of success with one or the other of these capabilities, they were unable to "link" both.

EXPERT PERCEPTUAL-COGNITIVE SKILLS

The majority of the findings, which illustrated the skilled performers superiority over the less skilled and novices, have examined a number of perceptual-cognitive skills separately, with the premise of being essential for effective anticipation and decision making processes. These skills include advance visual cue utilization, pattern recall and recognition, visual search behaviour and the knowledge of situational probabilities. Stratton et al.[41] noted that, in lay terms, these skills are often referred to as "game intelligence".

Advance Visual Cue Utilization

Advance visual cue utilization refers to a player's ability to make accurate predictions based on information arising from an opponent's posture and bodi-

ly orientation previously to a key event, such as football contact[49]. This perceptual skill is essential to performance in fast ball sports because of the time constraints placed on the player[1]. The film-based "temporal occlusion paradigm" has been the most popular approach. For instance, Williams and Burwitz[51] required experienced and inexperienced players to observe near "life-size" filmed sequences of five different players taking penalty kicks during preparatory stance, approach run and kicking. The requirement was to indicate which of the four corners of the goal the ball was to be directed, prior to temporal occlusion. The results showed that experienced soccer players exhibited better performance only under the shortest durations (that is, pre-event or pre-contact occlusion conditions). These results are in agreement with those obtained in other studies[e.g., see 56, 40].

Only a few researchers have attempted to identify the underlying mechanisms or even the specific perceptual information that underpins the identification process that guides skillful action. This issue is usually addressed by combining the temporal occlusion approach with spatial occlusion, eye movement registration and verbal report techniques[e.g., see 2, 53]. In the event occlusion approach, the presumption is that if there is a decrement in performance on the trial when a particular cue is occluded compared to a full vision control condition, then the importance of the occluded source of information is highlighted. However, such systematic programs of research and attempts to cross-validate findings, and to extend knowledge by combining different measures, are rare in the literature. Although this argument could not be taken into account, researchers have recently argued that performers are more likely to extract global, motion-related information from an opponent's postural orientation than a specific information cue. The suggestion is that skilled performers use the relative motion between joints and/or limbs to guide successful performance rather than a specific cue(s)[29]. In the latter case, researchers have to convert video images of players in action into point-light displays. Point-light displays capture the motion of the major joint centers of the body, which are then displayed as points of light against a black background. The aim of using this technique is to remove background and contextual information and to present movement in its simplest terms[12]. Contemporary methods of creating point-light (or stick figure) images using optoelectronic motion capture systems rather than video provide significant advantages in this regard[for a detailed review, see 23, 54, 9, 24]. Several researchers have suggested that (i) both novice and skilled tennis players are prone to change the information they use when moving from normal to point-light conditions, however, the skilled players are much less affected than are their counterparts[47]; (ii) when executing a technical skill, such as controlling a ball in soccer, the best skilled players are able to use several potential sources of sensory information (e.g., vision, proprioception) in an interchangeable manner to facilitate effective performance[59]; (iii) it is possible that in certain situations skilled performers may decide not to use these cues during matches[26], because of the possible energetic cost associated with anticipation may result in performers adopting a 'wait-and-see' approach.

Pattern Recall and Recognition

Researchers have made extensive use of the recall paradigm to assess the degree to which the expert maintains a cognitive advantage over the lesser skilled performer. The recall paradigm comprises both static and dynamic images, portraying either a structured or unstructured task-specific display where the participant is required to recall the location of each player. Performance is then ascertained as the level of agreement between priori-identified features in the actual display (e.g., player positions) and the participant's recall of those features[52]. Another methodological approach that has been used to identify players' ability to recognize whether participants have previously viewed the action sequences in an earlier viewing phase is termed the recognition paradigm. The task for the participants is to indicate quickly and accurately those clips they have or have not seen before. Williams et al.[57] reported that experienced soccer players recognized previously viewed structured video clips more accurately and, consequently, were able to perceive an evolving pattern of play much earlier in its development than their less experienced counterparts. Once again, skilled players demonstrated superior recognition

skill when compared to less skilled players[52, 38, 3]. If players are able to encode soccer-specific information to a deeper and more conceptual level, they can anticipate their opponents' intentions and plan ahead as to the most appropriate course of action. Currently, researchers are attempting to identify the underlying mechanisms that differentiate skilled from less skilled participants. Using point-light displays, Williams et al.[60] showed that skilled soccer players maintain their superiority over less skilled players in pattern recognition performance even when players are presented as moving dots of light against a black background. This finding suggests that skilled soccer players are more attuned than their counterparts to the relative motions between players and/or the higher-order relational information conveyed by such motions. Another finding was that this information may be extracted from only a few key players, such as the main central attackers and strikers, using a film-based spatial occlusion approach.

Visual Search Behaviour

The definition of visual search strategy is the ability to pick up advance visual cues or to identify patterns of play[49, 22]. The eyes are used to search the display or scene in an attempt to extract the most pertinent information guiding the performers' action such that the appropriate allocation of visual attention precedes and determines effective motor behaviour. An eye movement registration system has been used to assess visual search behaviour by recording a performer's eye movements and interspersed fixations[see 56]. The duration of each fixation is presumed to represent the degree of cognitive processing, whereas the point-of-gaze is assumed to be representative of the most pertinent cues extracted from the environment, facilitating the decision-making process (this index is obtained by the number of visual fixations during a given period of time). However, it should be noted that corresponding movements of 5º or less are often considered noise and statistically removed from the calculation of fixation duration, which typically ranges from 150 ms up to 600 ms[25]. Researchers have recorded fixations as short as 100 ms and as long as 1,500 ms with corresponding movements of 1º or less[56]. Eye movements between successive fixations, known as saccades, are believed to suppress information processing. The majority of the research findings suggested that experts focus their gaze on more information areas of the display compared to novices, enabling them to more effectively anticipate action requirements[see 56, 49, 36, 50, 42].

One of the earliest studies to examine the importance of visual behaviour in soccer was carried out by Helsen and Pauwels[19, 20], who investigated the search patterns used by expert and novice players when presented with offensive simulations requiring tactical decision-making (e.g., microstate situations – 3 v 3, 4 v 4 – and "set-play" conditions – free-kicks). They concluded that (i) the expert players have significantly faster movement initiation times, ball-contact times and total response times, and are more accurate in their decisions; (ii) the expert players' better performance is attributed to an enhanced ability to recognize structure and redundancy within the display, resulting in more efficient use of available search time (this assumption was supported by eye-movement data that showed expert visual search patterns to be economical, with fewer fixations of longer duration on selected areas of the display); and (iii) the experts are more interested in the position of the "sweeper" and any potential areas of "free" space, whereas novice soccer players search information from less sophisticated sources such as other attackers, the goal and the ball. Some of these results were corroborated by Williams and colleagues[for a detailed review, see 56, 49].

Even when the athletes' visual behaviour is constrained by several factors, such as the nature of the task (for example number of players, playing area/size and role of peripheral vision), the performers' physical and emotional levels (such as cognition, emotion, fatigue, visual abilities) and environmental factors (for instance lighting, distractions, visual stimuli), the experts scan the display more effectively and efficiently than their counterparts[45, 49, 61, 44]. In strategic sports, such as soccer, skilled defenders employ different visual search strategies when compared to skilled attackers and different behaviors a rise when confronted with macro- to microstates of play, regardless of their own playing position[58, 53, 21].

Currently, there is one published study in the sports sciences focusing on how visual behaviour is influenced by physiological workload or fatigue. Vickers and Williams[44] tested the effects of fatigue on the quiet eye period and shooting performance using a group of Canadian biathletes. The individuals completed blocks of 10 shots towards a concentric circle target under varying levels of physiological stress ranging from an at rest condition to a 100% power output. They observed that the mean quiet eye period tended to decrease in linear fashion with the workload increase and that shooting performance tends to decrease nonlinearly as power output increases. However, more empirical work is needed to determine the mechanisms underpinning the changes observed at higher workloads, particularly during competition[61].

Vickers[43] suggested that maintaining gaze for an extended period of time (the so-called quiet eye period) may be the key factor in self-paced tasks where the accuracy of aiming is important. Specifically, the quiet eye period represents the elapsed time between the last visual fixation on a target and the initiation of the motor response. Singer[37] reported some advantages in using this visual measure in sport performance, but in dynamic situations some restrictions were pointed out. For instance, the requirement to maintain an extended quiet-eye period prior to response initiation, which is likely to interact with the need to monitor the positions and movements of teammates and opponents, and to execute the required action prior to being challenged by an opponent[30]. In this sense, there is evidence to suggest that sport performers often use peripheral and central vision in an integrated manner to extract relevant information from the display. Several researchers have noted that experts are more inclined to fixate gaze centrally in an attempt to pick up an opponent's relative motion profile using peripheral vision[34, 53, 56]. Moreover, in some sports experts are able to anticipate an opponent's intended shot direction by fixating on relatively deterministic and proximal postural cues (such as trunk/hip rotation) before using more distal cues (e.g., racket) to confirm their initial perceptions[60].

Knowledge of Situational Probabilities

This perceptual-cognitive skill has been defined as the ability of the expert performers to extract meaningful contextual information from the event outcomes. There is evidence to suggest that experts have more accurate expectations than novices of the events most likely to occur in any given scenario. In early research carried out by Alain and colleagues[4, 5], the importance of situational probabilities and their relationship with decision-making behaviour in squash, tennis, badminton and racquetball were examined. The results showed that players evaluated the probability of each possible event that could occur and then used this information to maximize the efficiency of subsequent behaviour. The players' initial anticipatory movements were guided by their expectations, with subsequent corrective or confirmatory movements being made on the basis of current information or contextual cues.

Ward and Williams[46] tried to assign the requirements of elite and sub-elite soccer players in predicting and ranking the "best passing options" available to a player in possession of the ball. The elite players were better than their sub-elite counterparts at identifying players who were in the best position to receive the ball and were more accurate in assigning an appropriate probability to players in threatening and non-threatening positions, as determined by a panel of expert soccer coaches. The skilled players were also better at hedging their bets, judiciously determining the importance of each potential option presented, effectively priming the search for new information, and ensuring that the most pertinent contextual information was extracted from each area of the display.

In an attempt to clarify the importance of the event probabilities in the sports domain, task specificity and participant skill level, Williams[49] distinguished general from specific event probabilities. The former refers to the likelihood that opponents will typically act in a certain way given the context in question, such as the typical options facing full-backs in possession of the ball in their own half, the typical runs made by centre forwards, or the proportion of crosses and corners played into the near post region. Specific probabilities relate to a player's knowledge of specific opponents' tendencies, for example, a par-

ticular player may always attack a full-back on the outside or a certain forward may always attack the near goal post area or place a penalty kick to the goalkeeper's right-hand side.
In conclusion, the aim of this review was to characterize the perceptual-cognitive skills that influence the anticipation and decision-making processes in or within a sports' domain, particularly in soccer. Although there is substantial work in the field of expertise (as we previously reported), it would be of interest in future research: (i) to clarify the mechanisms underlying perceptual-cognitive expertise; (ii) to identify the specific mechanisms mediating expert performance within the team, such as positional role (e.g., full-back, central defender, central midfield player, striker); (iii) to highlight the influence imposed by several constraints on the expert's performance in a realistic context; and (iv) to integrate simultaneously in the same research different measures of the perceptual-cognitive skills, constraints imposed by the task, the environment and the individual characteristics of the performer, and the collection of verbal reports. This last variable may provide the most informative approach given the need of performers to integrate knowledge and processes to effectively plan, act, monitor, evaluate, adapt, predict, and anticipate[48, 32].

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