

## Cognition in Football

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### Abstract

Football players are required to make instantaneous and continuous decisions throughout the match, without have pre-determined playing sequences at their disposal. The football field is an unpredictable area, with players required to access cues from team-mates, opponents, the ball, playing surface, environment, coaches and referees. A high level of cognitive skill is required to enable players to fulfill their physical and technical potential. Skills such as game intelligence, spatial perception, anticipation, reaction time, attention shifting, and pattern recognition is relevant cognitive skills. These skills can be enhanced by ensuring training sessions train not just the physical components but also challenge and train the neural pathways. This review looks at some of the important cognition elements that are relevant in football performance.

**Keywords:** Physical components; Cognitive skills; Physical training

### Introduction

Every football action includes a cognitive element. Players make decisions with the brain playing a role in analysing all the stimuli a player is exposed to and enabling players to make correct decisions. Football decisions are naturalistic and dynamic with players required to make correct decisions while under pressure, with limited time, during various intensities of exercise and sometimes with limited resources and information [1-5]. The sequences of these actions are not replicated throughout the match nor can they be precisely predicted. The decision-making process in football is a very complex one, requiring a high level of skill. Each player will approach a situation in their own individual ways and rely on a combination of intuition, experience and the laws of the game [6-9]. The domain specific cognitive mechanisms that experts acquire enable them to anticipate future retrieval demands, correctly predict the outcome of a situation and adapt in a dynamic environment [10,11].

Footballers are physically fit individuals and their physical training may help them with increased cognition. Physical and mental training modify the creation and functioning of neurons. Physical training increases the number of new neurons while mental training increases the survival of neurons. When combined mental and physical training and stimulation will increase cognitive functioning [12].

### Intelligence

Intelligence is a complex cognitive function that has been discussed relative to sport intelligence and with reference to intellectual properties that affect sport performance such as information processing, knowledge, experience, decision making, reaction time, timing, memory and recall, vision, sensorimotor processing, attention, anticipation, cognitive styles, and time and space perception. Intellectual properties that affect sport performance such as information processing, knowledge, experience, decision making,

reaction time, timing, memory and recall, vision, sensorimotor processing, attention, anticipation, cognitive styles, and time and space perception. These skills can be referred to game intelligence [13,14].

Intelligence is contextual and within the sports context elite players have better tactical or game intelligence, enabling them to understand match situations better and find better solutions. Tactical creativity is the ability to find innovative and unexpected solutions in match situations. Players with higher cognitive ability show greater tactical creativity [15].

### Perception

High level of perceptual skill and ability is a pre-requisite for successful sport performance [16]. The common elements of all the decision-making models are the input of stimuli and the output of a behavioral response. Perception is the process that provides information of the surround areas [17]. Perceptual decision making is vital in football actions such as blocking shots on goal [18].

Perceptual speed is defined as the ability to utilize the visual and auditory senses to decipher and process elements of the game as they take place. Players are exposed to several types of visual and auditory stimuli throughout a match (e.g. position of opponents, calls from teammates). These may be present both on and off the field of play and must be processed and converted into decisions. Sometimes there may be conflicting stimuli. Deliberate visual search strategies assist in players sifting relevant information and together with other specific perceptual training and experience can enhance perceptual speed [16,19]. Perceptual skill is partially dependent on visual search strategy used [20].

### Spatial Ability

Spatial ability is the ability to generate, retain and transform abstract visual information. Visio-spatial perceptual speed, spatial visualisation and mental rotation abilities are relevant to defining spatial mental representations [21]. Players perceive environmental properties in

relation to their own bodies, action capabilities and relative location to important objects and surfaces in the environment [22]. Spatial and temporal characteristics of visual behaviour provide information on decision making [23].

Footballers have severe spatial and temporal constraints imposed on them by regulations and the opponents. Under these constraints players must be able to quickly and accurately perceive relevant information that facilitates decision making allowing more time for preparation and organization of motor behavior [24]. Temporal-spatial patterning can be regarded as a reflection of the perceptual strategy being used to extract relevant information from all the exposed stimuli [16].

## Judgement

Judgement can be defined as “a set of evaluative and inferential processes that people have at their disposal and can draw on in the process of making decisions” [25]. Sometimes these judgements are intuitive and enter the consciousness quickly for a brief time, relies on no deep knowledge, cannot always be explained, and are highly sensitive to specific domains but results in a ‘feeling’ strong enough to act on. Athletes have reported that their motor reactions are as a result of decision making without any conscious thought processes [26,27].

Stimuli produce specific mental operations that are based on the individual’s retrieval of stored memory information before initiating a response. The accuracy and speed of the response is dependent on the previously stored information specific to that situation [28]. There are three dimensions to judgement. The first is evaluative judgements and is based on a scale of good and bad. A judgment of identification is the second. This involves taking a decision of whether the ‘when’ condition is present for a decision. The third judgement is of cause which involves judging the contribution of factors that lead to a specific outcome [29].

## Working Memory

When making a decision the factual live information obtained is retrieved along with episodic memory in order to identify errors or infractions. Working memory is also vital in the decision making process [30]. Sometimes there is not enough information to make a decision and in these cases players may draw on prior knowledge to assist in the interpretation of a situation and in the decision-making process [31]. The use of prior knowledge categorized in mental structures is called schemata. With practice and repetition skill memories become incorporated at the subconscious level. This is a valuable tool in enabling individuals to process information quickly. Schemata can be acquired from personal experience or communication from others [32,33].

When a stimulus is encountered for the first time it is encoded. The quality of encoding is determined by the quality of perception. Thus footballers will encode football related memories better than memories related to an unlearned skill [33]. Skill memories involve integrated and complex motor patterns in the cerebral nuclei, cerebral cortex and cerebellum. The amygdaloid body and the hippocampus are two components of the limbic system which are important to consolidate memory. The hippocampus helps convert short-term memories to long term memories. The nucleus basis plays a role in memory storage and retrieval. The amygdaloid body determines what memories are stored and where in the brain each memory is stored. Most long term memories are stored in the cerebral cortex. Conscious motor and

sensory memories are stored in the appropriate association areas. Visual memories are stored in the visual association areas; voluntary motor activities are stored in the premotor cortex [32].

Working memory is a neural mnemonic system that processes and temporarily stores information required for complex cognitive activities and thus is a vital component of decision making and is thought to be one of the limiting factors of cognitive functioning under overloaded conditions [9,21,34]. Working memory is used for short term active maintenance of information as well as processing maintained information [34,35].

Working memory plays a significant role in higher cognitive functioning such as thinking, planning, reasoning and decision making. Thus the neuronal mechanisms that are utilized in working memory provide relevant information on cognitive functioning [35]. There are two models that have been identified to explain expert performance in memorization tasks and decision-making tests. The knowledge base theory stipulates that through practice domain-specific knowledge is not just stored but structured and organized within the long term memory. The skilled memory theory describes how practice improves efficiency of data encoding, storage and retrieval of the various memory systems [9]. Thus experts use long-term memory to complement their working memory which enhances their decision making capabilities. Making use of this memorized information is an automatic process that does not utilize conscious recall of previous events [9].

When working memory capacity available for skill execution is reduced, it results in decreased performance. This was highlighted in a study of experienced football players where reaction time increased when faced with dual task conditions and asked to make a decision [9]. The dorsolateral prefrontal cortex plays an important role in working memory [35].

## Pattern Recognition

Sport specific assessment also plays a role in assessing cognitive skills [36]. Football specific memory tests relate to football performance, with players able to identify certain cues and patterns such as positions of the ball and attacking and defending players as well as actions such as movement patterns, passes and runs highlighting pattern recognition as an important tool for enhancing football specific memory.

Players need to study the shift from one configuration of play to another and to learn to recognize patterns in order to understand the evolution of the play [30,37]. The ability to recognize the opposition’s patterns of play is an important aspect of football as it provides additional cues that the player can react to or adjust his own play accordingly in order to gain an advantage [38]. Early identification of pattern of play can result in better prediction of how the sequence of play ends [39].

Pattern recognition is based on relational similarity (relative position, relative motion, and interplay between players), surface features (shirt colour, player location) and pragmatic elements [38]. Training sessions are specific training sessions that train players for better recognition of their team-mates, so that passing in matches can be more effective [39]. Differences have been found when comparing the recalling and recognition of structured scenes and patterns of play ability in novice and expert players [24]. Expert players can recall and recognize patterns of play better than non-expert players [14].

## Reflexes

Not all decisions involve conscious thought or processing of information before an action is executed. Reflexes are automatic responses to a stimulus. Reflexes are classified by development, response, processing site and complexity of the circuit. Innate reflexes are genetically determined and result from connections that form between neurons during development. Acquired reflexes are learned motor patterns which are rapid and automatic. The more a specific reflex is practiced and repeated, the better the ability to execute the required action. When information is processed in the spinal cord the reflex is known as a spinal reflex. Cranial reflexes refer to information processing that takes place in the brain. Somatic reflexes provide a mechanism for the involuntary control of the muscular system. Stimuli at the skin or mucous membrane trigger superficial reflexes. Sudden elongation of the tendons trigger stretch reflexes. Somatic reflexes are immediate and may lack precision. However, these immediate involuntary actions may be corrected by voluntary motor commands [32].

## Reaction Time

Reaction speed is the ability to react to the actions of the teams or movements of the ball. Reaction time is the minimum time from the presentation of a stimulus to the onset of a response and includes the time taken to identify relevant cues and process the information, as well as go through all the possible reactions before acting [28].

Reaction time is a sensitive measure of reaction speed, with simple reaction time tests measuring overall speed of perceptual and motor systems but these do not correlate to sport performance. Simple reaction time depends on the type of stimulus, arousal and state of attention, muscular tension, gender, fatigue, effect of distraction, exercise, anxiety levels and personality type [26,40]. The accuracy of the responses may be affected by task specificity. Tasks with greater meaning provide a better basis for attentional arousal and focus as opposed to general information. Players participate in rapidly changing environments in which they are exposed to a lot of information, with only some of the information relevant [16]. Two key elements linked with decision-making are the speed and accuracy of the decision and the time taken to implement the decision. Decision-making speed is the ability to execute quick decisions when faced with a variety of options in the shortest possible time [19].

## Experience

Playing experience and development also can play a role in performance in elite footballers. During adolescence a better, smarter and faster brain is developed. While age provides some guidelines in the development of cognitive ability and vision, it is experience that highlights how well these tasks are implemented and plays a role in the outcome. However, the environment and learning experience plays a big role in the rate of development. Brain connections that are stimulated and used repeatedly grow stronger and unused connections wither away. The amount of experience coupled with the type of experience and the development experience are important factors in ensuring that the general cognitive and visual abilities are enhanced in the sporting context and that players excel on the field. However, the quality of the player's problem-solving capacity will be linked to their knowledge base and quality of their motor-skill development [41,42].

It has been suggested that a minimum of ten years is required for a person to become an expert in any field. These ten years though must include deliberate practice relevant to the skills required for performance. Deliberate practice refers to activities done with specific goals of improving performance, which are performed in a daily-work like manner, with participants putting in the required effort and attention despite not getting short term social or financial rewards [43]. Skill memories are learned motor behavior's [32]. This deliberate practice is domain specific and leads to acquisition of specific representations and mechanisms to excel within that specific domain and rarely is transferred to other domains [11,15].

Deliberate practice leads to familiarity of situations which ensure that decisions are fast and not costly when faced with such situations [9]. Through domain specific practice, players would learn how to select the relevant cues when faced with a wealth of information [44]. Deliberate practice combined with experience creates a more elaborate task specific knowledge base [43]. This enhances the visual search strategies of experts directing them to more pertinent areas of the display based on their expectations and allow for more effective processing of contextual information leading to pattern recognition and advanced cue utilization [45].

Superior athletes in football, snooker, basketball, tennis and golf have superior recognition and recall of structured information, better anticipation skills through the use of advanced information, more effective visual search strategies, use fewer fixations, fixated on additional sources of contextually relevant information, and superior knowledge of interrelationships among relevant context variables [16,46,47]. Knowledge about where important cues are derived, understanding the basic nature of a players tasks, understanding the ability to filter relevant cues from irrelevant information help in ultimately understanding the decision-making process [13].

Experience and expertise enhances visual discrimination and visual cue utilization involves making correct predictions and being able to anticipate the movements of teammates and opponents based on visual cues such as posture and body orientation [6,14,30,39]. Goalkeeping experts have often spoken about the visual cues goalkeepers use to guess which direction to dive for penalties, and research has shown that moving goalkeepers distract penalty takers. For outfield players, cues like players looking to the goalposts can be indicative of a player being about to shoot for the goal rather than pass the ball [48,49]. The importance of visual cues and stimuli makes the eyes the first source in most decisions made by football players. Professional football players in the initial stages of development who are starting to learn basic skills should be advised on where the area of focus should be for learning a skill and also for interpreting an opponent's action [50].

## Anticipation

Anticipation is the ability to recognise the pattern of play and use situational probability to predict an event shortly before it occurs, which can reduce reaction time. Anticipation depends on prior knowledge (of a situation) or experience of specific stimuli and specific situations [17].

Players must also anticipate the moves of the opposition: they must be able to extract information from cues like the speed and direction a player is moving, where he or she is relative to the ball and the goalposts, what the movements of his teammates are what the score of the game is and how much time is left [51]. The domain-specific cognitive mechanisms that experts acquire enable them to anticipate

future retrieval demands, correctly predict the outcome of a situation and adapt in a dynamic environment [11].

The efficiency of how the brain and nervous system process information and control performance is regulated by changes in perceptual cognitive skills, knowledge and mechanisms. Positive change can enhance anticipation and decision-making skills [52,53]. Elite players have the ability to better anticipate play [14,54]. The ability to identify different cues, such as the kinematics of an opponent's kicking leg and hip, can enhance a player's ability to anticipate the trajectory of a pass, and thus they could react more quickly than someone who has not identified these cues [55]. Elite goalkeepers can accurately predict the flight path of penalty kicks. Lateral movement can be predicted from the biomechanics of a kick and from ball-foot contact. Height can be predicted by observing the initial portion of ball flight [39]. Previously, differences have been found when comparing the ability of novice players to expert players in their ability to anticipate the flight and direction of the ball, and the actions of opponents [24].

## Attention

Attention is another key element in the identification of stimuli. As physiological requirements of a task increases to the maximal capacity, the ability to maintain optimal attentional focus on a cognitive activity being performed simultaneously decreases [53]. The ability to coordinate all the necessary factors required for maximal performance is compromised when the athlete attention is not fully on the task at hand or outside thoughts distract him [56].

Attention switching and orientation enhances anticipation [39]. Participants in open skill sports exhibit higher attentional flexibility and can modulate specific attention resources according to task demands. Expert performers are able to select the source and type of information relevant to a specific decision and focus only on that while blocking out other information [8,57].

## Conclusion

Conscious perception requires attentional processes. Inattentive blindness could lead to a person not noticing something right in front of them because their attention has been diverted elsewhere. This results in failure of awareness [7]. Selective attention and attention orienting are important aspects of decision-making. Players need to be able to switch their attention and direct it towards the information-rich aspects of the match [37,58].

In order to be successful players are required to make and execute good football decisions. Cognitive ability is a vital skill in enhancing players perceptions and information processing ability and improving their speed of play. Skills such as reaction time, spatial awareness, pattern recognition, long and short term memory, attention shifting, ability to minimize Inattentive blindness, sorting through available information etc. are all vital cognitive skills that maximize player performance. A player may have high cognitive ability but execution of cognitive skills may be situation-specific with things such as fatigue, lack of concentration, fear and anxiety, self-doubt, arousal level, match situation, history with opponents, muscle tension, injury etc. all impacting level of cognitive functioning. Thus actively training cognitive skills within a football context under different conditions is an important consideration in the training and development of players.

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