UNIVERSIDADE DO PORTO
FACULDADE DE DESPORTO

CENTRO DE INVESTIGAÇÃO FORMAÇÃO INOVAÇÃO E INTERVENÇÃO EM DESPORTO
CIFI2D

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Filipe Luis Martins Casanova

Perceptual-Cognitive Behavior in Soccer Players:

Response to Prolonged Intermittent Exercise.

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Dissertação apresentada às provas para obtenção do grau de Doutor em Ciências do Desporto, nos termos do Decreto – Lei n.º 74/2006 de 24 de Março, orientada pelo Professor Doutor Júlio Manuel Garganta Silva e co-orientada pelos Professor Doutor José Manuel Fernandes de Oliveira e Professor Doutor Andrew Mark Williams.

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KEY WORDS: VISUAL SEARCH BEHAVIOR, THOUGHT PROCESS, REPRESENTATIVE TASK SIMULATION, EXERCISE, SOCCER.

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Table of Contents

List of Figures

List of Tables

Chapter V – Study IV

List of Appendix

Resumo

Objetivo: Esta dissertação teve como objetivos: (i) analisar as habilidades perceptivo-cognitivas que parecem emergir no rendimento de excelência no Futebol; (ii) desenvolver cenários de jogo ofensivos que sejam representativos do jogo e que possam ser utilizados no estudo das habilidades perceptivo-cognitivas do futebolista; (iii) analisar o efeito do exercício intermitente prolongado nos processos percetivos e cognitivos subjacentes à capacidade de antecipação em futebolistas de diferentes níveis competitivos; e (iv) analisar a contribuição dos processos percetivos e cognitivos na performance antecipatória dos futebolistas, em exercícios de baixa e de alta intensidade. **Métodos:** Esta dissertação contem um estudo de revisão e três experimentos originais. No estudo II, quatro treinadores de elite do Futebol português visionaram diferentes sequências estruturadas de jogo ofensivas para determinar a sua representatividade do jogo de Futebol. Nos estudos III e IV, dezasseis futebolistas, divididos em dois grupos (elite e não-elite) foram submetidos a um protocolo de exercício intermitente simulando as exigências físicas de um jogo de futebol, em blocos de baixa e de alta intensidade. Simultaneamente à realização do exercício, os futebolistas observavam diferentes cenários de jogo, com avaliação (em quatro momentos) do desempenho antecipatório, dos comportamentos da procura visual e dos relatos verbais retrospetivos. **Resultados:** No estudo II, a concordância dos observadores quanto à representatividade dos diferentes cenários de jogo foi significativa (W = 1, $p < 0.05$). A fiabilidade inter-observadores foi estatisticamente significativa ($\alpha = 0.889$) e a reprodutibilidade entre observações foi muito elevada (Z = 0; p = 1). No estudo III, os futebolistas de ambos os grupos registaram uma diminuição similar da resposta antecipatória no decurso do exercício intermitente prolongado, apesar de o grupo de elite registar sempre valores de acerto significativamente mais elevados. Os resultados da procura visual evidenciaram uma interação significativa grupo*sessão avaliativa ($p < .0001$) e uma interação sem significado estatístico entre grupo*local de fixação*sessão avaliativa ($p = .204$). Comparativamente com os futebolistas não-elite, no início de cada uma das duas partes que compõe o protocolo de exercício, os futebolistas de elite utilizaram um maior número de fixações de curta duração, em diferentes locais do campo visual, enquanto no final um menor número de fixações de longa duração e em menor número de locais. Relativamente aos resultados dos relatos verbais, observou-se uma interação significativa grupo*tipo de relato verbal*sessão avaliativa ($p = .001$); os futebolistas de elite verbalizaram um maior número de relatos do tipo avaliativo, preditivo (no início da segunda metade do protocolo) e do tipo planificativo (durante a primeira e a quarta sessão), contrastando com os futebolistas não-elite que verbalizaram em maior proporção relatos do tipo cognitivo em ambas as metades do protocolo de exercício. No estudo IV, os futebolistas de elite demonstraram acerto mais elevado na antecipação da decisão do portador da bola após exercícios de baixa e alta intensidade, sustentado por comportamentos visuais mais apropriados e por um conhecimento mais específico, quando comparados com o grupo não-elite. Em exercícios de baixa intensidade, os comportamentos visuais foram associados ao desempenho antecipatório dos futebolistas de elite ($R^2 = .23$, $p = .001$), enquanto os relatos cognitivos e avaliativos foram relacionados significativamente à performance dos futebolistas não-elite ($R^2 = .24$, $p = .016$); em exercícios de alta intensidade, as verbalizações do tipo avaliativo e planificativo foram associadas significativamente ao desempenho antecipatório dos futebolistas de elite ($R^2 = .27$, $p = .009$), enquanto os relatos do tipo cognitivo obtiveram um grau de associação estatisticamente significativo com a performance dos futebolistas não-elite ($R^2 = .09$, $p = .043$). **Conclusões:** Os cenários do jogo de Futebol desenvolvidos são um instrumento útil para avaliar as habilidades perceptivo-cognitivas; durante a realização do protocolo de exercício intermitente prolongado e em exercícios de baixa e alta intensidade, os futebolistas de elite evidenciaram um desempenho antecipatório superior ao dos futebolistas não-elite; ao longo do protocolo de exercício intermitente, alterações adaptativas dos processos perceptivos e cognitivos dos futebolistas de elite resultaram num decréscimo menor do desempenho antecipatório em relação aos futebolistas não-elite; de acordo com as exigências da intensidade dos exercícios, a o desempenho antecipatório dos futebolistas de elite foi sustentada na alternância e na adaptabilidade dos processos percetivos e cognitivos, enquanto a performance antecipatória dos futebolistas não-elite foi associada com o processamento de eventos em curso.

PALAVRAS-CHAVE: COMPORTAMENTO DA PROCURA VISUAL, PROCESSO COGNITIVO, SIMULAÇÃO REPRESENTATIVA DA TAREFA, EXERCÍCIO, FUTEBOL.

Abstract

Purposes: This thesis aimed to: (i) review the perceptual-cognitive skills important to superior performance in soccer; (ii) develop simulated representative attacking sequences for research on perceptual-cognitive skill in soccer; (iii) examine the effects of prolonged intermittent exercise on the perceptual and cognitive processes underpinning anticipation in soccer players with different competitive levels; and (iv) study the contribution of perceptual and cognitive processes in anticipation performance of soccer players under low- and high-intensity exercise demands. **Methods:** This thesis contained one review study and three original experimental papers. In Study II, four elite Portuguese soccer coaches were presented with separate test film sequences encompassing structured attacking soccer action to determine the representativeness of the scenarios. In Study III and Study IV, eight elite and eight non-elite soccer players completed a prolonged intermittent exercise protocol, and performed low- and high-intensity soccer-specific exercise, respectively, while simultaneously viewing realistic filmed simulations of match play, and anticipation performance, visual search behaviours and immediate retrospective verbal reports were collected. **Results:** In Study II, the representativeness of all attacking soccer scenarios was significantly concordant among the observers (W = 1, $p < 0.05$), the reliability between observers was statistically consistent ($\alpha = 0.889$), and the reproducibility of the results between both moments of evaluation was very high (Z = 0; p = 1). In Study III, elite players demonstrated superior anticipation performance during prolonged intermittent exercise, and a decrement in performance was observed across test sessions for both groups. Visual search data revealed a significant group*test session interaction ($p < .0001$), and no significant group*fixation location*test session interaction ($p = .204$) for percentage viewing time. When compared with non-elite participants, elite players employed more fixations of shorter duration on significantly more locations in the visual display in the beginning of each half, whereas at the end of the exercise protocol they employed significantly fewer fixations of longer duration to a lower number of locations. For the verbal report data, there was a significant group*type of statement*test session interaction ($p = .001$); elite participants generated a great number of evaluation, prediction (in the beginning of the second half), and deep planning statements (during the first and the fourth test sessions), in contrast, non-elite players had a higher proportion of lower-level cognition statements than elite individuals in both halves. In Study IV, elite players were more accurate in anticipating the decision of the player in possession of the ball than their non-elite counterparts, under both low- and high-intensities, sustained by a more appropriate gaze behavior and specific-knowledge process. Under low-intensity exercise, gaze behaviours exhibited by elite players accounted for a significant association in anticipation performance ($R^2 = .23$, $p = .001$), whereas non-elite performance was significant related with cognition and evaluation statements ($R^2 = .24$, $p = .016$); under high-intensity exercise, evaluation and deep planning verbalizations had a significant influence on elite group performance ($R^2 = .27$, $p = .009$); in contrast, verbal statements coded as cognition was the only process-tracing measure that had a significant influence on non-elite group performance ($R^2 = .09$, $p = .043$). **Conclusions:** The created scenarios representing soccer match patterns are a useful tool to evaluate perceptual-cognitive skills; elite soccer players exhibit a superior anticipation performance, compared to their non-elite counterparts, during prolonged intermittent exercise protocol under both low- and high-intensity exercise demands; adaptive changes in gaze behavior and cognitive processing in elite players resulted in less marked decrements in performance across the intermittent exercise protocol when compared with their non-elite counterparts; the perceptual-cognitive ability of elite players is sustained in alternating and adapting the perceptual and cognitive resources according to exercise intensities demands, whereas, in contrast, the anticipation performance of non-elite group was associated with processing current ongoing events.

KEY WORDS: VISUAL SEARCH BEHAVIOR, THOUGHT PROCESS, REPRESENTATIVE TASK SIMULATION, EXERCISE, SOCCER.

List of Abbreviations

ACT – Attentional Control Theory

ANOVA – Analysis of variance

ASL - Applied Science Laboratories

bpm – Beats per minute

cf. - Confer

e.g. – For example

et al. – And colleagues

FCT – Fundação para a Ciência e a Tecnologia

FD - Fixation duration

HR – Heart rate

i.e. – That is

$km.h^{-1}$ – Kilometers per hour

La - Lactate

LTWM – Long-term working memory

m - Meters

min - Minutes

mmol/l – Millimole per liter

ms – Milliseconds

N - Number

NF - Number of fixations

NFL - Number of fixation locations

η^2_p - Partial eta squared

PET – Processing Efficiency Theory

RA – Response accuracy

RA% - Response accuracy percentage

s - Seconds

SD – Standard deviation

SPSS - Statistical Package for the Social Sciences

TTF - Take The First

v / vs. - Versus

W - Kendall's coefficient of concordance

Z - Wilcoxon Signed Rank Test

α - Cronbach's Alpha

% - Percentage

% VT – Percentage viewing time

® - Registration mark

CHAPTER I

INTRODUCTION

INTRODUCTION

Soccer is one of the most extensively researched team sports (Ali, 2011), which directly benefits other scientific areas, for example, the natural and physical sciences, medicine and social sciences (Reilly, 1996a). Within the domain of exercise science, soccer research includes match analysis, evaluating the physiological demands on players during training and match-play, identification of talent, strategies for acquisition of skill and interventions to maintain skill performance during or following match play (Ali, 2011).

During soccer match-play, the player has to have the ability to read the opponents' intentions and perform the correct technique to achieve the main purposes of the game, which is to overcome opponents, score goals and, lastly, win the match. Research on superior performance indicates that many elements of the perceptual-cognitive skills, decision-making and motor skill execution strongly influence sport performance (e.g., Abernethy et al., 1999; Williams & Davids, 1998), especially in sport tasks in which individuals are required to perform under strict temporal and spatial constraints (e.g., Williams et al., 2006; Williams & Ford, 2008).

Perceptual-cognitive skill refers to the ability to identify and acquire environmental information for integration with existing knowledge such that appropriate responses can be selected and executed (Marteniuk, 1976). These skills could discriminate performers as they progress through the ranks (Williams & Reilly, 2000). The superior athletic performance between elite and non-elite players are typically apparent through observation, but the underlying perceptual and cognitive mechanisms that contribute to an advantage in anticipatory behavior are less evident. Therefore, the process of selective attention and the need to invoke a detailed role for knowledge structures stored in memory are deemed essential to help guide the search for, and effective processing of, task specific information. Williams and Ward (2007) illustrated a simple information-processing model involving the main components in anticipation and decision-making, which helps to contextualize the purpose of perceptual-cognitive research (see Figure 1).

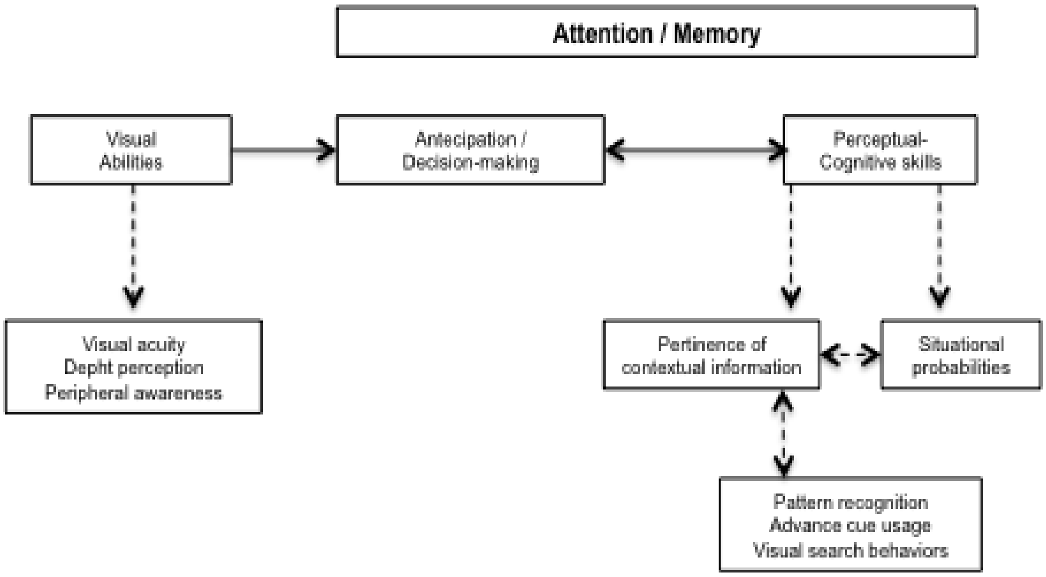

Figure 1- A simple information-processing based model of anticipation and decision-making skill in sport (adapted from Williams & Ward, 2007).

Knowledge of the factors underpinning the development of elite 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. The 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) provides elite soccer players the ability to execute a smooth and efficient movement (i.e. motor component) over the non-elite players. Additionally, Williams (2009) and Williams and colleagues (2010) reported that those who are skilled at decision-making have been shown to rely on elaborate perceptual and cognitive processes in order to effectively interpret complex information and formulate an appropriate plan of action.

Scientists have employed eye-movement recording methods to identify the perceptual processes that under skilled anticipation in elite and non-elite players (Vickers, 2007; Williams et al., 2004). For example, during open-play situations in soccer, elite players show search strategies in which they fixate for shorter durations on more informative cues and locations in the visual display, such as the movements and positions of other players, in comparison with non-elite peers (e.g., Williams et al., 1994). Elite players also shift their gaze away from the "player in possession" more frequently compared with non-elite players (e.g., Vaeyens et al., 2007). These differences in visual search strategies are thought to underpin the superior anticipation and decision-making skills of elite when compared with non-elite players.

To overcome some limitations associated with the recording of gaze behaviors, researchers have collected verbal reports to better understand how elite performers use the information extracted from the display when making strategic and tactical decisions (e.g., McPherson, 2000, 2008; North et al., 2011; Roca et al., 2011). This method has been used to assess the thought processes engaged when performing a motor task (Ericsson & Simon, 1993), which is supported by the Long-Term Working Memory theory (LTWM; for a review, see Ericsson & Kintsch, 1995). This theory holds that elite performers develop domain-specific memory structures stored in long-term memory as an abstract and complex knowledge representation through extended deliberate practice. This stored information remains accessible via the use of retrieval cues in short-term memory. Originally, verbal reports were categorically coded based on a structure adapted from Ericsson and Simon (1993), and further developed by Ward (2003). The author conceptualized cognitions as all statements representing current actions or descriptions of current events, evaluations as some form of positive, neutral or negative comparisons or assessment statements of events that are relevant, predictions reflected statements about what occurs next, and deep planning statements concerned information about searching possible alternatives beyond the next move. The findings employing dynamic, externally paced tasks have suggested that elite performers' superior anticipation skill have been characterized by processing the information at a deeper level in order to plan an appropriate response strategy, providing significantly more planning and prediction statements when making constrained judgments than their non-elite counterparts (McRobert et al., 2009).

Although several researchers have examined the influence of perceptual-cognitive skills on sports performance (for review, see Williams, 2009), few have identified the mediating processes underpinning perceptual-cognitive expertise under different constraints, particularly in which the participants are exposed to constraints such as physical and physiological workload. Vickers and colleagues (1999) tested the effects of fatigue on the quiet eye period and shooting performance using a group of elite Canadian biathletes. The mean quiet eye period tended to decrease in line with the increase in workload with these changes, as well as the decline in shooting performance, being most pronounced at the 85% and 100% power output workloads.

Researchers using time-motion and performance analysis in soccer have suggested that reduced physical performance and changes in physiological responses seems to occur after short-term intense periods in both halves, in the initial phase of the second half, and towards the end of the game (Mohr et al., 2005). Other researchers reported that technical performance decreased significantly among soccer players of different competitive levels or ranking positions during match-play (Rampinini et al., 2009), and that most goals are scored towards the end of a game (Jinshen et al., 1991), probably due to physical and/or mental fatigue, as well as potentially changes in decision-making and tactics (Reilly, 1996b). Moreover, the amount of high-intensity running in the 5 min period immediately after the most intense 5 min interval recorded during the game was observed to be less than the average of the entire game (Mohr et al., 2003).

However, studies examining the effect of specific demands, close to soccer match-play (such as duration and exercise intensities) on perceptual and cognitive processes underpinning the anticipation performance are still lacking.

The difficulties in undertaking research on this issue are mainly based on the manipulation of performance-specific demands using a representative task.

Based on the research described above, this thesis set out to achieve the following aims:

1. To review the perceptual-cognitive skills that contribute to superior performance in soccer players;
2. To design and validate a simulated, film-based test of anticipation skill in soccer;
3. To examine the effects of a prolonged intermittent exercise protocol that simulates the specific workload experienced during a soccer match on perceptual and cognitive processes underpinning anticipation, using a dynamic video-based representative task;
4. To identify the perceptual-cognitive skills that could explain the variance in anticipation performance under low- and high-intensity soccer-specific demands.

In order to achieve these aims, the thesis was divided into nine chapters. Chapter I contains a brief introduction of the theme and highlights the relevance of this area of study and the rational for the work as well as the main objectives of the thesis. The following four chapters (II, III, IV and V) present four original studies, presented according to scientific journal guidelines; all of these chapters have been submitted, accepted or published in peer-reviewed scientific journals. Chapters VI and VII report the general discussion and the main conclusions of the thesis, respectively. Chapter VIII includes the references and the final chapter (IX) contains the appendix.

Table 2 – The titles, authors names, specific purposes, and status of each study included in the thesis.

Chapter II **Study I**	**Title:** Expertise and perceptual-cognitive performance in soccer: a review. **Authors:** Filipe Casanova, José Oliveira, Andrew Mark Williams, & Júlio Garganta. **Purpose:** To define and to contextualize the different terminology used in this specific domain; to typify the different perceptual-cognitive skills that seems to bring on soccer players' performance; and to provide some future research guidelines. **Status:** Published in Revista *Portuguesa de Ciências do Desporto* (2009), 9 (1), 115-122.
Chapter III **Study II**	**Title:** Representativeness of offensive scenarios to evaluate perceptual-cognitive expertise of soccer players. **Authors:** Filipe Casanova, Júlio Garganta, & José Oliveira. **Purpose:** To set representative attacking sequences trials for further use in the research of perceptual-cognitive skills for playing soccer. **Status:** *Open Sports Sciences Journal* (Special Issue - in press).
Chapter IV **Study III**	**Title:** The effects of prolonged intermittent exercise on perceptual-cognitive processes. **Authors:** Filipe Casanova, Júlio Garganta, Gustavo Silva, Alberto Alves, José Oliveira, & Andrew Mark Williams. **Purpose:** To study the effects of prolonged intermittent exercise on the perceptual and cognitive processes underpinning anticipation in soccer players with different competitive levels. **Status:** Submitted to Peer-reviewed Scientific Journal.

Chapter V **Study IV**	**Title:** Dynamical decision-making task of soccer players, under low- and high-intensity exercise. **Authors:** Filipe Casanova, Júlio Garganta, Gustavo Silva, & José Oliveira. **Purpose:** To study the variance, and contribution of the perceptual and cognitive processes in the decision-making performance in soccer players, under low- and high-intensity exercise demands. **Status:** Submitted to Peer-reviewed Scientific Journal.

CHAPTER II

STUDY I

Filipe Casanova, José Oliveira, Andrew Mark Williams, & Júlio Garganta (2009). **Expertise and Perceptual-Cognitive Performance in Soccer: A Review. *Revista Portuguesa de Ciências do Desporto*, 9 (1), 115-122.**

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 behavior 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 carateriza 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 percetivo-cognitivas no rendimento das ações 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 percetivo-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 fatores, como os perfis antropométricos e fisiológicos dos atletas, mas um dos mais importantes fatores que intencionámos incluir no contexto desportivo são as habilidades percetivo-cognitivas, tais como o comportamento da procura visual e o conhecimento das probabilidades situacionais.

Os objetivos do presente artigo são: (i) definir e contextualizar a diferente terminologia utilizada neste contexto específico; (ii) tipificar as diferentes habilidades percetivo-cognitivas que parecem emergir no rendimento desportivo dos futebolistas; e (iii) fornecer algumas orientações para futuras investigações.

PALAVRAS-CHAVE: Excelência, Habilidades Perceptivo-Cognitivas, Futebol.

1- 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 (8, 6) 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 skilled 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.

2- 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 behavior and the knowledge of situational probabilities. Stratton et al. (41) noted that, in lay terms, these skills are often referred to as “game intelligence”.

2.1- 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 bodily 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 provides 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.

2.2- 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 with 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 might be extracted from only a few key players, such as the main central attackers and strikers, using a film-based spatial occlusion approach.

2.3- Visual Search Behavior

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 behavior.

An eye movement registration system has been used to assess visual search behavior 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 behavior 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 behavior 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 behavior 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) might 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).

2.4- 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 behavior 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 behavior. 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 center 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 particular 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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CHAPTER III

STUDY II

Filipe Casanova, Júlio Garganta, & José Oliveira. **Representativeness of offensive scenarios to evaluate perceptual-cognitive expertise of soccer players. *Open Sports Sciences Journal* (Special Issue - in press).**

Abstract

In soccer, players have to carry out fast and accurate decisions in a complex and variable environment. The purpose of the present study was to set representative attacking sequences trials for further use in the research of perceptual-cognitive skills for playing soccer. Elite Portuguese soccer coaches (n = 4, UEFA-A) were presented with separate test film sequences encompassing structured attacking soccer actions to determine the representativeness of the scenarios. In the experiment the coaches viewed 41 offensive clips. Each clip has approximately 5 s long with an inter-trial interval of 5 s. To help the participants to the viewing process, just before the start of each clip a small circle surrounding the ball it is shown on screen to indicate the area of its first appearance. The order of presentation of video clips was counterbalanced and randomly determined, during both moments of evaluation. In all testing film sequences watched the representativeness of an attacking soccer phase was significantly concordant among the observers ($W = 1$, $p < 0.05$). The reliability between observers was statistically consistent ($\alpha = 0.889$). And the reproducibility of the results between both moments of evaluation was very high ($Z = 0$; $p = 1$). The entire footage could be used in research that required knowing the tactical awareness of soccer players.

Key words: Attacking Game Patterns, Reliability, Soccer.

INTRODUCTION

The fastest and the most accurate decisions of a soccer player elapses from information coming from several sources (i.e., the ball, the other players) and the decision-making process takes place under pressure with opponents trying to restrict the “time” and “space” available. Considering the specific constraints of training and competition demands, the performer has to carry out several tasks, such as: (i) to extract from a scene the essential information needed to predict future response requirements [1, 2]; (ii) to recall and recognize patterns of play properly [3, 4]; and (iii) to anticipate successfully the opponent’s actions, based on advanced visual cues [5, 6]. It has been hypothesized that superior performance in sport is based on perceptual and cognitive skill as well as the efficient and effective execution of movement patterns. To differentiate the perceptual-cognitive skills between participants, the researchers have used a range of perceptual and cognitive measures that could be demonstrative of the high-ability during a dynamical sport task, such as soccer [7].

Ericsson and Smith [8] proposed a descriptive and inductive framework for the study of expertise, which they referred to as the expert performance approach. Using this approach they identified three researching stages. The first necessitates that superior performance must be observed *in situ* and to design representative tasks such that reliable individual differences in performance can be objectively measured under laboratorial conditions. In the second stage the aim is to determine the mechanisms underlying performance using process-tracing measures such as eye-movement recordings, verbal protocol analysis and/or representative task manipulations. The final stage involves efforts to detail the adaptive learning and explicit acquisition processes relevant to the development of expertise, with potential implications for practice and instruction [9].

Williams *et al.* [7] have argued that perception and action are mutually interdependent, cyclical processes that directly constrain and influence one another. Although it has been well documented that the effective use of relevant advance visual cues facilitates sport performance by means of anticipating the intentions of the opponents [4, 7], the development of research protocols that provide relevant perception and action are warranted, as well as the several paradigms used to provide valuable insight into the effects that the decoupling of perception and action may have on performance [7, 9, 10].

Instead of using field-based conditions, some researchers have reported some limitations in using the video-based paradigms to capture the appropriate essence of superior performance [11]. However, when field-based approaches are not possible, presentation of video images are appropriate stimuli when compared to static slides. For example, Williams and Grant [12] have suggested a combination of subjective measures based on coach opinion and objective data based on qualitative and quantitative video analysis. They argued that in dynamic “open sports” the coaches’ opinions could be gleaned pre- and post training using behavioral assessment scales [13, 14], while their validity could be substantiated using video analysis techniques [15]. Video analysis has already been used to measure anticipation skill in laboratory [16, 17] providing advantageously natural perception of the scene when compared with static slides [10].

Therefore, in the present study we aimed to create some game setting scenarios that could be representative of a real offensive soccer pattern. These situations were submitted to a panel of elite soccer coaches.

METHODS

Participants

The representativeness of the scenarios was determined through a panel of four elite Portuguese soccer coaches, with UEFA-A license and not less than 10 years experience of effective training. Participants were recruited and selected from the National Association of Portuguese Soccer Coaches’ database. The study was carried out under the ethical guidelines of Faculty of

Sport, University of Porto, and participants provided consent before taking part in the experiment.

Match scenarios

Coaches were presented with separate video clips showing match sequences representing different game phases, i.e., attack, defense and transition play. The entire footage ends with an offensive skill that could unbalance the defensive organization. To guarantee that the scenario was truly realistic we conducted three practical sessions before the video recording. The first and the second experiment sessions were based on observing, memorizing and performing the theoretical schemes designed (for an example, see Figure **1**). The third session could be defined as a brief summary of the last two sessions. All the structured sequences were created by the Soccer Unit of Faculty of Sport, University of Porto. Portuguese Soccer players competing at the Second National League (n = 22) participated in the scenarios build-up and permission was obtained from each one of them for public use of the recorded video images.

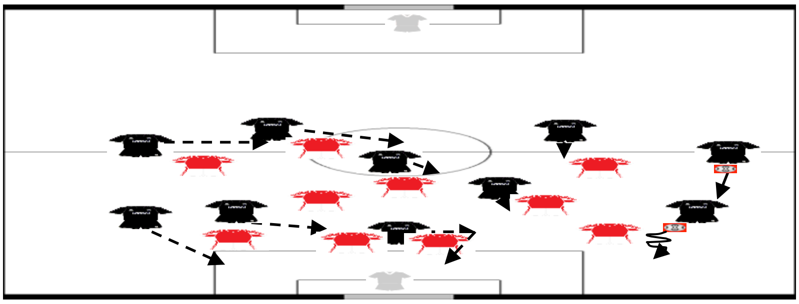

Figure 1- Theoretical-scheme from the structured trial.

Each trial was filmed from the position behind (15m) and slightly above (5m) the goal with a 16 by 9 video camera (Sony DSR 570 DVCAM), such that the entire width of the playing field could be viewed and ensuring that potentially important information from wide positions was not eliminated. The elevated filming position helped give participants some element of depth. A single frame from a typical structured action sequence is depicted in Figure **2**.

Figure 2- Frame from the structured trial presented in video.

To edit the video into 41 different clips[1] Pinnacle Software package software, Avid Liquid edition 7, was used. Each clip last approximately 5 s long with an inter-trial interval of 5 s. The test consists in a clip-by-clip analysis, and just before the start of each clip, a small circle surrounding the ball appeared on screen to indicate the area of its first appearance. The clip stopped for 120 ms before the player in possession of the ball was about to make a pass or take a shot to goal or maintain the possession of the ball, and then the clip projection continued until the final event was finished, this last moment was identified when the screen turned to black. These three potential events were classed as offensive events: the *Pass*, i.e., a situation when the player has ball possession and attempts to play it to his team-mate with any part of the body except the head; the *shot at goal, i.e.,* when the player is in ball possession and makes an attempt to score a goal for his team with any part of the body; the *retain possession, i.e.,* when the player has ball possession and attempts to move with the ball, without losing it. All of the playing sequences finished when an attack to the goal is performed at the bottom of the screen.

Procedures

The video clips were presented in a dark room, in which the coaches were seated 2m away from a Sony Television (model LCD KDL40P3600E). To

[1] To have full access to the clips please send an email to fcasanova@fade.up.pt and/or jgargant@fade.up.pt

ensure that the action was wholly perceived, the experts viewed the clips as many times as they wanted. Coaches answer using pencil and specific questionnaire. The panel of experts carried out another evaluation within 2 months of the first test.

The criterion was based on a 5-point Likert-type scale, where 5 means total agreement with the correct representativeness of the action, whereas 1 indicates total disagreement (see Table **1**). Questionnaires based on Likert scales are often used in psychometrics, social studies and panels, in marketing research [18, 19], or in perceptual-cognitive performance research [20]. The order of presentation of video clips was counterbalanced and randomly determined, during both moments of evaluation. Four additional trials were presented to participants prior to testing so that they could familiarize themselves with the video test and protocol.

Table 1- Likert-type Scale (5 point).

	Likert-type Scale
1	Totally Disagree
2	Disagree
3	Neither Disagree nor Agree
4	Agree
5	Totally Agree

Statistical Analysis

Descriptive statistical analysis was used to examine the valid values of the chosen Likert-point scale. To test the agreement between observers we used the Kendall’s coefficient of concordance (W). Internal consistence reliability between observers was tested by using the Cronbach’s Alpha (α). To test the construct validity (re-test) of the scenarios we used the nonparametric Wilcoxon Signed Rank Test (Z). Statistical significance was set at $p < 0.05$ for all tests. The statistical software used was the SPSS Version 18.0 (SPSS Inc., Chicago, Il).

RESULTS

The final offensive event of each clip is highlighted in Table **2**.

Table 2- Offensive event in each clip.

Clip	Event		
	Pass (To which player)	**Shot at Goal**	**Retain Possession**
1	X (Right Winger)		
2	X (Left Winger)		
3	X (Center Midfielder)		
4			X
5	X (Center Midfielder)		
6			X
7			X
8	X (Left Winger)		
9	X (Striker)		
10			X
11	X (Striker)		
12			X
13		X	
14	X (Left Midfielder)		
15	X (Striker)		
16	X (Left Midfielder)		

17		X	
18			X
19		X	
20			X
21	X (Left Winger)		
22	X (Right Midfielder)		
23		X	
24	X (Left Midfielder)		
25		X	
26	X (Left Midfielder)		
27			X
28			X
29	X (Center Midfielder)		
30			X
31	X (Right Winger)		
32	X (Striker)		
33	X (Center Midfielder)		
34			X
35	X (Left Winger)		
36	X (Left Winger)		
37	X (Right Midfielder)		
38	X (Striker)		

39	X (Left Winger)		
40	X (Right Winger)		
41	X (Left Back)		

The valid values of the chosen Likert-point scale shows that the entire sequence of the 41 clips projected was representative of a soccer game pattern, ending with an offensive event (see Table **3**). As an exception, the clip 41 was rated at level 4 in the Likert-point Scale, since in the opinion of three expert coaches (A, C and D) this clip could be ended with a pass to another player.

Table 3- Mean valid values of the Likert-point scale (± SD) pointed out by the coaches, in both moments of evaluation.

Coach	Test	re-Test
A	4.98 ± 0.16	4.98 ± 0.16
B	5 ± 0	5 ± 0
C	4.98 ± 0.16	4.98 ± 0.16
D	4.98 ± 0.16	4.98 ± 0.16

In all test film sequences the representativeness of the game scenarios observed was significantly concordant among the observers ($W = 1$; $p < 0.05$). Moreover, the internal consistency reliability between observers showed that the responses scored were statistically consistent ($\alpha = 0.889$; $p < 0.05$).

Concerning the construct validity of the clips, the results obtained illustrated that when the experts watched again the projection of the 41 clips the values of the Likert-point scale were strongly reproduced ($Z = 0$; $p = 1$).

DISCUSSION

The aim of the present study was to set representative attacking sequences trials for further use in the research of perceptual-cognitive skills for playing soccer. According to the results of the present study the panel of expert coaches agreed that the entire footage was representative of a real soccer situation, which ends with a correct offensive event. Therefore, it seems useful tool to be used in perceptual-cognitive research, namely under controlled laboratory tasks. The design of the different game patterns used in this study was developed according to the three main categories of problems brought by team sports, which are: (i) space and time, (ii) information, and (iii) organization [21]. So, we have been constantly concerned with a tactical / strategic purpose, during the prescription of the game patterns and the practicing situations, as well.

Even the final event of the player in possession of the ball was sustained in Hughes *et al.* [22] reports. They defined a perturbation in soccer as an incident that changes the rhythmic flow of attacking and defending, leading to a shooting opportunity. For example, a perturbation could be identified from a penetrating pass, a dribble, a change of pace or any skill that creates a disruption in the defense and allows an attacker a shooting opportunity. In some cases, a perturbation of the defense may not result in a shot, owing to defensive skills or a lack of skill in attack. The clip stopped before the player in ball possession was either doing pass, shot at goal or retain possession. Both, pass and shot at goal have been associated with teams that has a higher percentage of success [23, 24] and the retain possession is being classified as the main goal to reach the truly purpose of the game, to score a goal. Bell-Walker *et al.* [24] reported that the successful teams at World Cup 2006, who were better able to hold ball possession, created more attempts at goal from open play and they also suggested that these teams had more positive attacking attitude.

Regarding to the duration of a video clip, McRobert *et al.* [25] noted that the perceptual and cognitive skills are inferred from the quality, speed and accuracy of an individual's performance, with minimal attempt to explain the cognitive processes involved during anticipation. Another scientific finding was reported by Ericsson and Simon [26] as they pointed out that subjects were able to recall accurately and completely the sequence of thoughts, cognitive information, after a 0.5 – 10s task performance.

Although the video presentations reduce a three-dimensional setting to a reality of two-dimensional scenarios, we tried to give to the subjects enough references of depth and width by elevating the film recording position and by using a 16 by 9 video camera, respectively. Another advantage of film projection is that it enables sequences of action to be reproduced in a consistent manner from trial to trial [27].

The results of the valid values of the Likert-point scale demonstrated that the panel of experts agreed with the representativeness of the clips. Three coaches, in the clip number 41, reported an exception of last decision of the player in possession of the ball, when the player did not pass the ball to a team mate in a better position/space to receive it (see Table 2). Although being the game scenario included in clip 41 a common situation in soccer matches, the lower degree of total agreement between experts regarding the appropriate decision of the player in possession of the ball might preclude it's utilization as a scenario for assessment perceptual-cognitive skill, since it could influence components such as advanced visual cue utilization, pattern recall and recognition, visual search behaviour and the knowledge of situational probabilities. In addition, previous published investigations support the use of this type of instrument to assess perceptual-cognitive performance [7, 10, 28, 29, 30, 31].

Also, when presenting images with standard video, digital editing techniques can be used to add, remove, or distort normally invariant relations between different information sources. But to have not a detrimental effect on the perceptual information, we have to make sure that the manipulation or removal of perceptual information is only incremented in nonessential information. Ericsson [32] has argued that this type of method is particular relevant in sport where sequences of events are rarely if ever repeated in an exact form. Additionally, Ali [33] reported that using such instruments can enable scientists to carefully examine the core aspects of perceptual skill performance in soccer players.

CONCLUSION

Our findings indicated that the created scenarios representing soccer match patterns are an useful tool to evaluate perceptual-cognitive expertise, namely under controlled laboratory tasks. Moreover, more research is needed to understand the congruence between the results obtained in laboratory environment and performance of players in real game.

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CHAPTER IV

STUDY III

Filipe Casanova, Júlio Garganta, Gustavo Silva, Alberto Alves, José Oliveira, & Andrew Mark Williams**. The Effects of Prolonged Intermittent Exercise on Perceptual-Cognitive Processes.** ***Submitted to Peer-reviewed Scientific Journal*****.**

ABSTRACT

Purpose: We examined the effects of prolonged intermittent exercise on the perceptual and cognitive processes underpinning anticipation in soccer players with different competitive levels. **Methods:** Eight elite and eight non-elite soccer players completed an exercise protocol that simulated a soccer match, while simultaneously viewing dynamic and realistic filmed simulations of match-play. During exercise, heart rate, blood lactate concentrations, anticipation performance, visual search behaviours, and immediate retrospective verbal reports were assessed. **Results:** Mean heart rate and blood lactate values increased significantly from the beginning to end of each half of the protocol. Visual search data revealed a significant group*test session interaction ($P < .0001$), and no significant group*fixation location*test session interaction ($P = .204$) for percentage viewing time. When compared with non-elite participants, elite players employed more fixations of shorter duration on significantly more locations in the visual display in the beginning of each half, whereas at the end of the exercise protocol they employed significantly fewer fixations of longer duration to a lower number of locations. For the verbal report data, there was a significant group*type of statement*test session interaction ($P = .001$); elite participants generated a great number of evaluation, prediction (in the beginning of the second half), and deep planning statements (during the first and the fourth test sessions). In contrast, non-elite players had a higher proportion of lower-level cognition statements than elite individuals in both halves. **Conclusion:** The intermittent exercise protocol induced changes in the underlying perceptual-cognitive processes used during task performance in elite and non-elite players. However, the elite players exhibited superior anticipation performance, supported by more effective search behaviours and more elaborate thought processes across the intermittent exercise protocol.

Key Words: Anticipation; Visual search behavior; Thought processes; Soccer-specific exercise.

INTRODUCTION

Soccer is played in a complex and rapidly changing environment and consequently, in order to be successful players need to anticipate the actions of opponents and make appropriate decisions under stress. The ability to anticipate and make decisions is critical to performance and both are reliant on the interaction between a number of different perceptual and cognitive processes (33). Several researchers have examined how elite and non-elite soccer players may be discriminated based on their perceptual and cognitive skills (cf., 1). Although there are concerns over the validity of the typical test protocols employed, the perceptual-cognitive processes underpinning anticipation and decision-making have been shown to differ across skill groups, tasks and situational constraints (1).

In order to understand the mechanisms underpinning superior anticipation and decision-making, researchers have collected process-tracing measures such as gaze behavior and verbal reports of thought processes simultaneously during performance on a task (22, 27, 37). Skill-based differences in gaze behaviors have been reported (27, 36). For instance, during open-play situations in soccer, skilled players typically show search strategies in which they employ shorter fixation durations, implying the more efficient extraction of information from more pertinent locations in the display when compared with less skilled counterparts (e.g., 31). Also, skilled players vary significantly gaze behaviors according to their specific functional role, for instance, when in offensive and defensive situations (e.g., 23, 24).

A number of researchers have used think-aloud and retrospective verbal reports to better understand how experts use information arising from the display when making strategic and tactical decisions (16, 19, 22, 28). The consensus is that skilled athletes provide more detailed verbal reports of thinking when compared to less skilled individuals (e.g., 17, 19, 28). Kintsch (14) and Ward et al. (28) reported that skilled participants anticipate future events and search possible alternatives beyond the next move by using anticipatory encodings and building dynamic situational representations or cognitive models “on the fly” more effectively than less skilled players. In contrast, less skilled participants have impoverished retrieval structures, and while they may verbalize thoughts related to the information immediately available, are less able to anticipate future retrieval demands and evaluate alternative courses of action (19).

Time-motion analyses and physiological measurements show that soccer players cover large distances during a game (9-12Km), with a change in intensity and activity pattern every 4-6s. Such activities engage various metabolic pathways (2, 18, 20, 21) and can impact negatively on physical and technical performance (13, 15, 18). As reported by Jinshen et al. (13), during soccer matches, most goals are scored towards the end of a game. The high proportion of goals scored late in the game may be due to physical and/or mental fatigue, as well as potentially changes in strategy and tactics (20). However, there remains a paucity of studies examining how the physiological demands of soccer match-play could influence the perceptual and cognitive processes underpinning components of performance such as anticipation and decision-making.

Eysenck and Calvo (11) proposed processing efficiency theory (PET) to explain the effects of stress on performance. The PET distinguishes between performance effectiveness and efficiency. Effectiveness refers to the quality of task performance indexed by standard behavioral measures (such as response accuracy). In contrast, efficiency refers to the relationship between the effectiveness of performance and the effort or resources invested on task performance (as determined by changes in indirect measures such as gaze, probe reaction times, verbal reports and ratings of mental effort). Stress is generally associated with poor processing efficiency under test conditions, as high-stress individuals use more processing resources than low-stress individuals. The effect of stress on performance effectiveness depends on the availability and utilization of additional resources, as well as the demands of the task on working memory (11).

Vickers and Williams (26) provided support for PET and illustrated how factors related to stress influence the gaze behaviors employed during performance in biathlon shooting. These authors tested the effects of physical workload on gaze behaviors and shooting performance using a group of ten elite biathlon shooters. The mean duration of final fixation on the target decreased as workload increased suggesting a decline in processing efficiency, whereas there was a corresponding decrement in performance effectiveness, as indicated by a drop in shooting accuracy. The negative changes in performance efficiency and effectiveness were more marked in low-performing compared with high-performing elite shooters. A suggestion is that the high-performing shooters had more spare processing capacity that their low-performing counterparts and consequently, they were able to maintain performance by investing more resources in the shooting task at the higher stress levels.

Drust et al. (5) developed a soccer-specific, intermittent exercise protocol on a motorized treadmill, based on the motion-analysis data reported by Reilly and Thomas (21). The intermittent exercise protocol simulates different exercise activities with varying intensities (e.g., walking, jogging, running, cruising, sprinting), as observed during soccer match-play, and it has been adapted to simulate the physical demands of full 90-minute soccer game (4, 12). Some displacements (backwards and sideways) were not included as a result of the technical limitations of the ergometer and the health and safety risks of changing orientation on the treadmill. Additionally, to increase the ecological validity of the simulation, treadmill speeds assigned to each activity category are based on the data of Van Gool et al. (25).

In the present study, we examine the effects of prolonged intermittent exercise on the visual search behaviors and cognitive processes that underpin anticipation in elite and non-elite soccer players under controlled and reproducible laboratory conditions. The exertion levels of participants in response to the soccer-specific exercise protocol (5) were assessed using measures of heart rate and blood lactate concentrations. We hypothesized that the exertion levels would increase across the prolonged intermittent exercise for both groups of participants. We present participants with a film-based test of anticipation in soccer and record process-tracing measures to evaluate the perceptual-cognitive processes employed by elite and non-elite players when making such judgments, as well as how these processes may alter as a result of engaging in prolonged intermittent exercise. The literature states that elite participants demonstrate superior anticipation underpinned by more appropriate visual behaviors and more advanced, higher-level thought processes when compared with their non-elite counterparts (17, 19, 22, 36). However, there have been no previous attempts to examine how anticipation and the underlying perceptual and cognitive processes are altered during engagement in prolonged intermittent exercise. We expected that elite players would demonstrate superior anticipation performance across the intermittent protocol when compared with non-elite players. Moreover, according to the predictions of PET, we expected the differences in performance across skill groups to increase as the intermittent exercise protocol progressed with varying differences in processing efficiency and effectiveness. The elite players were expected to maintain performance at a higher level potentially by investing more available resources (as indicated by gaze and think-aloud data) to the task, whereas, in contrast, the non-elite players were expected to show decrements in performance efficiency and effectiveness across the intermittent exercise protocol.

METHODS

Participants

Sixteen players were recruited according to their previous competitive level in soccer (elite and non-elite). The elite (N = 8) participants (mean age = 24.63 years, SD = 3.9) had played at a semi-professional or professional level an average of 5.1 years (SD = 2.4). All participants had been involved with a professional club’s training academy for an average of 3.5 years (SD = 2.7).

The non-elite (N = 8) group (mean age = 26.25 years, SD = 2.9) had played soccer only at an amateur level (mean age = 2.1 years, SD = 2.4). The participants reported normal or corrected to normal levels of visual function. Participants provided written informed consent. The study was carried out with the ethical approval of the lead institution, which conforms to the Helsinki Declaration.

Test Film

The test film consisted of 40 video clips showing offensive sequences of play in soccer. Professional players from the Second National League in Portugal (N = 22) were requested to act out a number of realistic match scenarios that were representative of actual situations that would occur in a match. A panel of four elite Portuguese soccer coaches, who all held the UEFA-A license, and had at least 10 years experience, validated the footage. The level of agreement between observers in regards to suitability of the clips was high ($\alpha = 0.889$). The action sequences were filmed from a position behind (15m) and slightly above (5m) the goal with a 16:9 ratio camera (Sony DSR 570 DVCAM), such that the entire width of the playing field could be viewed and ensuring that potentially important information from wide positions was not eliminated. The elevated filming position helped give participants some element of depth. Altogether, four different test films were created each comprising of ten different offensive sequences. The clips each lasted approximately 5 s with an inter-trial interval of 5 s. Moreover, just before the start of each clip, a small circle surrounding the ball appeared on screen to indicate the area of its first appearance. The clips were all occluded 120 ms before the player in possession of the ball was about to make a pass or take a shot at goal or maintain the possession of the ball.

Apparatus

Film clips were projected onto a large screen (2.5-m x 2-m). The screen was placed 1.5 m directly in front of participants to ensure the image was representative of real match-play.

The visual search behaviors were recorded using an Applied Science Laboratories (ASL®) 3000 eye-movement registration system. This is a video-based, monocular corneal reflection system that records eye point-of-gaze with regard to a helmet-mounted scene camera. The system measures the relative position of the pupil and corneal reflection. These features are used to compute point-of-gaze by superimposing a crosshair onto the scene image captured by the head-mounted camera optics. The image was analyzed frame-by-frame using Pinnacle Software, Avid Liquid edition 7. System accuracy was ± 1º visual angle, with a precision of 1º in both the horizontal and vertical directions.

A lapel microphone, telemetry radio transmitter (EW3; Sennheiser, High Wycombe, UK), and telemetry radio receiver (EK 100 G2; Sennheiser) were employed to collect verbal reports. Verbal reports were recorded onto miniDV tape using a digital video camera, converted into computer audio .wav files and then transcribed prior to analysis.

Procedure

Prior to commencing the experimental task, the test procedure was explained and the eye-movement system fitted onto the participant's head. The ASL® eye-movement system was calibrated using a 9-point reference grid so that the fixation mark corresponded precisely to the participant's point-of-gaze. A simple eye calibration was performed for each participant to verify point-of-gaze and four periodic calibration checks were conducted during the test (cf., 32). After calibration, participants were presented with six practice trials in the laboratory task environment to ensure that they were familiar with the test procedure.

Before starting the experiment, participants practiced giving verbal reports on how to think aloud and provide retrospective verbal reports by solving generic and sport-specific tasks for approximately 30 minutes (8). The transcriptions of retrospective verbal reports were segmented using natural speech and other syntactical markers. Participants were presented with six practice trials to ensure familiarization with the experimental setting. We collected retrospective verbal reports directly at the end of each sequence. Participants were asked to anticipate which of three possible actions was about to be performed by the player in possession of the ball: *Pass (*i.e., a situation when the player attempted to play the ball to a team-mate); S*hot at goal (i.e.,* when the player makes an attempt to score a goal); R*etain possession (i.e.,* when the player has ball possession and attempts to move with the ball).

Participants completed an intermittent exercise protocol (5), simulating the physical demands of a soccer match-play by the inclusion of specific categories of intensity (e.g., walking, jogging, running, cruising, sprinting). The exercise protocol lasted 119 min, and was divided into two halves with the same duration (52 min), interspersed by a 15 min interval for rest. A static recovery period was included, in which the participant remained stationary on the treadmill (H/P cosmos, Pulsar, Germany).

The treadmill speeds used for each activity pattern were as follows: walking 6 $km.h^{-1}$; jogging 12 $km.h^{-1}$; running 15 $km.h^{-1}$; cruising 18 $km.h^{-1}$; sprinting 23 $km.h^{-1}$. The protocol included two identical periods of seven running blocks (five low-intensity blocks and two high-intensity blocks), separated by a recovery period of 15 minutes (Figure 1). The low-intensity phase consisted of five blocks of activity, with the same pattern: walking; stopping; jogging; walking; jogging; and running. The total duration of each low-intensity block was six minutes and twenty four seconds, with this period including 18 seconds of walking, 18 seconds of stopping, 16 seconds of jogging, 18 seconds of walking, 14 seconds of jogging and 12 seconds of running, each cycle being repeated four times. The high-intensity phase consisted of two blocks of activity, with the same pattern of walking, sprinting, stopping, and cruising. The duration of each high-intensity block was seven minutes, involving 13 seconds of walking, 10 seconds of sprinting, 15 seconds of walking, 10 seconds being stationary, and 12 seconds of cruising. This pattern was repeated seven times. The duration of each period of seven blocks (first half) was 52 minutes. So, the soccer-specific protocol was 119 minutes (first half: 52 minutes + recovery: 15 minutes + second half: 52 minutes).

The data were collected in four test periods and in each test the participants viewed 10 clips presented in a counterbalanced order. During the exercise protocol, four test sessions were made, two in each half. The total duration of the experimental protocol, including the period of familiarization with the procedures, lasted approximately 210 minutes. The experimental design is depicted in Figure 1.

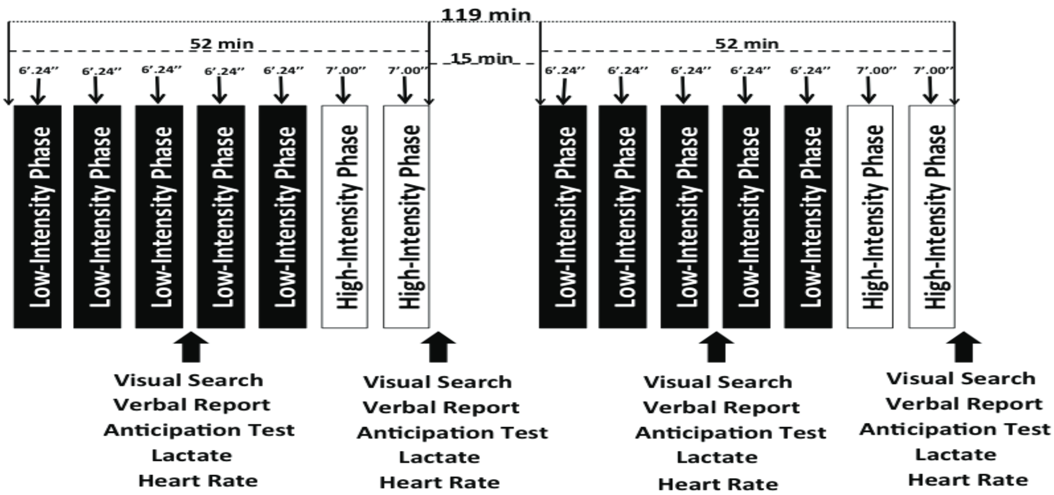

FIGURE 1- The representation of the Drust protocol and the four test sessions of data collection.

Analysis methods

Exertion levels

Heart rate (HR) was monitored continuously at 5-s intervals to provide an indication of the circulatory strain (Polar S610i, Finland). We calculated the mean value for each block of the intermittent exercise protocol. A lactate analyzer (Lactate-Pro, Japan) was used to collect the blood lactate (La) concentration samples. These measures were obtained from the third, seventh, tenth, and fourteenth blocks of the intermittent exercise protocol.

We used separate two-way factorial ANOVAs with group (elite/non-elite) as the between-participants factor and test session as the within-participants factor to analyze differences in heart rate (bpm) and lactate concentration (mmol/l) across the intermittent exercise protocol. Partial eta squared (η^2_p) values were provided as a measure of effect size for all main effects and interactions. Bonferroni post hoc tests were used to analyze pairwise comparisons between test sessions when appropriate.

Anticipation

The response accuracy (RA) scores were calculated based on the participant's responses after viewing each clip. A correct response was recorded if the participant correctly anticipated the decision of the player in possession of the ball, compared to what actually happened in the match situation. Response accuracy was reported as a percentage (%).

The response accuracy data were analyzed using a factorial two-way ANOVA with group (elite/non-elite) as the between-participants factor and test session as the within-participants factor. Partial eta squared (η^2_p) values were provided as a measure of effect size for all main effects and interactions. Bonferroni post hoc tests were used to analyze pairwise comparisons between test sessions when appropriate.

Visual search behavior

In each test session, the three most discriminating trials between elite and non-elite participants based on group mean scores from the measures of response accuracy percentage were chosen for visual search analysis.

Visual behaviors were analyzed to obtain search rate and percentage viewing time (% VT) data. The measures of search rate comprised the mean number of visual fixations, the mean fixation duration, and the total number of fixation locations per trial. Mean fixation duration was the average of all fixations that occurred during the trial. A fixation was defined as the period of time (120 ms) when the eye remained stationary within 1.5º of movement tolerance (cf., 32). The search rate data were analyzed using separate two-way factorial

ANOVAs with group (elite/non-elite) as the between-participants factor and test session as the within-participants factor. Partial eta squared (η^2_p) values were provided as a measure of effect size for all main effects and interactions. Any significant main and interaction effects were followed up using Bonferroni post hoc pairwise comparisons.

Percentage viewing time was defined as the proportion of time spent fixating on each area of the display. The display was divided into five fixation locations: ball; team mate; opposition; player in possession of the ball; and undefined. The undefined category was excluded because the percentage viewing time in this location was less than 1%. Percentage viewing time data were analyzed using a factorial three-way ANOVA with group (elite/non-elite) as the between-participants factor and fixation location and test session as the within-participants factors. Partial eta squared (η^2_p) values were provided as a measure of effect size for all main effects and interactions. Bonferroni post hoc pairwise comparisons were employed as follow-ups where appropriate.

An inter-observer agreement formula was used to determine the percentage of agreement for percentage viewing time and search rate data. For both variables, the data reached an inter-observer agreement of 99%. To provide this figure, 25% of the data was re-analyzed.

Verbal reports

Verbal reports were categorically coded based on a structure originally adapted from Ericsson and Simon (10) and further developed by Ward (30) to identify statements made about cognitions, evaluations, and planning (including predictions and deep planning). Ward (30) conceptualized cognitions as all statements representing current actions or recalled statements about current events and evaluations as some form of positive, neutral or negative assessment of a prior statement. Planning statements were divided into predictions and deep planning. Predictions reflected statements about what occurs next and deep planning statements concerned information about searching possible alternatives beyond the next move.

Retrospective verbal reports were collected after every trial and in each test session we used the three most discriminating trials between groups based on mean scores from the anticipation test. Consequently, the trials identified were the 3, 7, 10, 11, 16, 19, 22, 25, 27, 31, 36, and 40. Statistical analysis was conducted using a factorial three-way ANOVA with group (elite/non-elite) as the between-participant factor and type of statements and test session as the within-participant factors. Partial eta squared (η^2_p) values were provided as a measure of effect size for all main effects and interactions. Bonferroni post pairwise comparisons between test sessions were used when appropriate. An independent investigator re-analyzed all of the data in order to check for reliability; the inter-observer agreement was 98%.

The alpha level of significance for all tests was set at $P < .05$.

RESULTS

The mean values for heart rate (HR) and blood lactate (La) concentrations, and mean scores for response accuracy are presented in Table 1.

TABLE 1- Mean heart rate (HR), blood lactate (LA) concentrations, and response accuracy percentage (RA %) per group across the intermittent exercise protocol (± SD).

	Group	1st	2nd	3rd	4th
HR	**Elite**	116.8 ± 9.3 a)	155.9 ± 12.1	126.3 ± 19.7	163.1 ± 10.2
	Non-elite	123.6 ± 12.4 a)	158.4 ± 12.7	132.1 ± 13.7	164.3 ± 8.6
La	**Elite**	1.4 ± .3 *b)*	3.9 ± 1.3	1.5 ± .5	5.9 ± 1.1
	Non-elite	1.8 ± .7 b)	3.8 ± 1.8	1.8 ± .7	4.7 ± 1.8
RA %	**Elite**	56.3 ± 9.2 *a) c)*	51.3 ± 9.9 *c)*	50.0 ± .0 *c)*	41.3 ± 13.6 *c)*
	Non-elite	40.0 ± 14.1 *a)*	37.5 ± 10.4	36.3 ± 7.4	23.7 ± 5.2

a) significant difference for both groups from 1st to 2nd, 3rd, and 4th test session (*P* < .05).
b) significant difference for both groups from 1st to 3rd, and 4th test session (*P* < .05).
c) significant difference between elite and non-elite groups (*P* < .05).

Exertion levels

There was a significant main effect for test session for HR ($F_{2.06,\ 28.86}$ = 187.66, *P* < .0001, η^2_p = .93). Heart rate was significantly higher during the second test session compared to the first test session in each half (*P* < .05). Moreover, HR was significantly lower in the first test session compared to the third (*P* < .05). There was no significant main effect for group ($F_{1,\ 14}$ = .50, *P* = .49, η^2_p = .04) and there was no significant group * test session interaction ($F_{2.06,\ 28.86}$ = .78, *P* = .47, η^2_p = .05).

The results of blood La concentrations revealed that there was a significant main effect for test session ($F_{1.02,\ 14.33}$ = 3.33, *P* = .03, η^2_p = .19). Blood La concentration was significantly higher (*P* < .05) in test session four compared to the first and third test sessions. There was no significant main effect for group ($F_{1,\ 14}$ = .29, *P* = .59, η^2_p = .02) and no group * test session interaction ($F_{1.02,\ 14.33}$ = 1.01, *P* = .39, η^2_p = .07).

Anticipation

There were significant main effects for group ($F_{1, 14}$ = 18.69, P = .001, η^2_p = .57) and test session ($F_{3, 42}$ = 12.17, P < .0001, η^2_p = .47). The elite group reported higher accuracy scores across all four test sessions (P < .05). The main effect for test session indicated that players were significantly less accurate in making anticipation judgments in test session four when compared to the first three test sessions (P < .05). There was no significant group * test session interaction ($F_{3, 42}$ = .24, P = .80, η^2_p = .02).

Visual search behavior

Descriptive data of visual search rate variables are presented in Table 2.

TABLE 2- Mean Fixation Duration (FD) and Number of Fixations (NF) and Number of Fixation Locations (NFL) per group across the intermittent exercise protocol (± SD).

	Group	1st	2nd	3rd	4th
FD (ms**)**	**Elite**	267.9 ± 66.5 [a)]	289.8 ± 78.2	285.0 ± 81.5 [a)]	334.4 ± 98.2
	Non-elite	362.9 ± 98.4	309.8 ± 74.6 [b)]	387.8 ± 92.5	312.9 ± 83.8
NF	**Elite**	16.4 ± 2.2 [c)]	14.3 ± 1.8	15.1 ± 2.2 [c)]	14.1 ± 2.8
	Non-elite	12.9 ± 2.7 [d)]	14.8 ± 3.3	12.1 ± 1.6 [d)]	14.6 ± 2.7
NFL	**Elite**	3.3 ± 0.4 [e)]	2.9 ± 0.4	3.0 ± 0.4	2.8 ± 0.5
	Non-elite	2.6 ± 0.5 [f)]	2.9 ± 0.6	2.4 ± 0.3 [f)]	2.9 ± 0.5

[a)] significant difference between elite and non-elite group (P < .05).
[b)] significant difference within non-elite from 2nd vs 3rd test session (P < .05).
[c)] significant difference within elite group from 1st to 2nd and 3rd to 4th test session (P < .05).
[d)] significant difference between non-elite and elite group (P < .05).
[e)] significant difference within elite group for 1st to 2nd and 4th test session (P < .05).
[f)] significant difference within non-elite group for 1st to 2nd and 3rd to 4th test session (P < .05).

There were no significant main effects for group ($F_{1, 14}$ = 1.81, *P* = .2, η^2_p = .11) or test session ($F_{3, 42}$ = 1.46, *P* = .24, η^2_p = .09) on the FD variable. However, there was a significant group * test session interaction ($F_{3, 42}$ = 5.58, *P* = .003, η^2_p = .29). Non-elite participants demonstrated significantly (*P* < .05) longer fixations at the beginning of each half (first and third test sessions) compared with elite participants. Moreover, the non-elite participants increased their FDs between the second and third test session, whereas the elite group did not.

There were no significant main effects for group ($F_{1, 14}$ = 1.69, *P* = .21, η^2_p = .11) or test session on the number of fixations per trial ($F_{3, 42}$ = 1.44, *P* = .24, η^2_p = .09). However, there was a significant group * test session interaction ($F_{3, 42}$ = 8.45, *P* < .0001, η^2_p = .38). The non-elite participants increased the number of fixations from the first to second test session in each half, whereas the elite participants decreased the number of fixations from the first to the second test session in each half. The elite participants employed a significantly higher (*P* < .05) number of fixations in the first and in the third test sessions compared to their counterparts.

There were no significant main effects for group ($F_{1, 14}$ = 1.69, *P* = .21, η^2_p = .11) or test session ($F_{3, 42}$ = 1.44, *P* = .24, η^2_p = .09) in regards to the number of different fixation locations used per trial. The group * test session interaction was significant ($F_{3, 42}$ = 8.45, *P* < .0001, η^2_p = .38). The elite participants fixated on more locations in the first test session compared to the second and fourth test sessions. In contrast, the non-elite participants fixated on more locations during the last test session compared to the first session in each half.

The mean data for percentage viewing time are presented in Table 3. There was no significant main effect for group ($F_{1, 14}$ = 2.40, *P* = .144, η^2_p = .146) or test session ($F_{3, 42}$ = .88, *P* = .459, η^2_p = .059). However, there was a significant main effect for fixation location ($F_{3, 42}$ = 122.59, *P* < .0001, η^2_p = .898). Pairwise comparisons demonstrated that participants spent significantly

(P < .05) more time fixating the location of the player in possession of the ball compared to other locations. In addition, participants spent significantly (P < .05) less time fixating the ball compared to all other locations coded.

TABLE 3- Mean Percentage Viewing Time (% VT) per location by group across the intermittent exercise protocol (± SD).

% VT	Group	1st	2nd	3rd	4th
Ball	**Elite**	.9 ± 1.7 [a)]	3.6 ± 5.1	1.4 ± 2.7	1.6 ± 2.5
	Non-elite	3.8 ± 4.5 [a)]	5.5 ± 6.1	3.9 ± 7.9	4.5 ± 3.3
Team mate	**Elite**	19.8 ± 11.2	19.8 ± 7.1	18.9 ± 8.8	18.2 ± 10.4
	Non-elite	19.4 ± 10.2	18.6 ± 11.3	12.5 ± 5.2	18.7 ± 9.4
Opposition	**Elite**	38.9 ± 7.9 [c)]	30.9 ± 8.8	34.3 ± 8.9	28.6 ± 10.8
	Non-elite	33.2 ± 13.6 [c)]	27.8 ± 9.5	21.3 ± 10.3	29.1 ± 8.9
Player in Possession of the ball	**Elite**	39.7 ± 11.9 [b) d)]	45.5 ± 13.5	42.9 ± 12.3	50.7 ± 11.8
	Non-elite	43.6 ± 14.7 [b) d)]	47.6 ± 13.5	62.1 ± 12.3	47.7 ± 11.8

[a)] significant difference between the ball and the other locations in both groups (P < .05).
[b)] significant difference between the player in possession of the ball and the other locations in both groups (P < .05).
[c)] significant difference on the opposition from 1st to 4th test session in both groups (P < .05).
[d)] significant difference on the player in possession of the ball from 1st to 3rd test session in both groups (P < .05).

There was a significant test session * fixation location interaction ($F_{9, 126}$ = 1.98, P = .046, η^2_p = .124). There was a significant difference between the first and third session in the time spent fixating the player in possession of the ball (P < .05). Although it narrowly failed to reach conventional levels of significance (P = .073), participants tended to decrease the time spent fixating the opposition between the first and the last test session.

There were no significant group * test session interaction ($F_{3, 42}$ = 1.59, P = .204, η^2_p = .102), no significant group * fixation location interaction ($F_{3, 42}$ =

2.01, P = .128, η^2_p = .125), and no group * fixation location * test session interaction ($F_{9, 126}$ = 1.59, P = .204, η^2_p = .102) for the percentage viewing time variable.

Verbal reports

The verbal report data are presented in Table 4.

TABLE 4- Mean verbal statements percentage (± SD) per group after each test session across the intermittent exercise protocol.

	Group	1st	2nd	3rd	4th
Cognition	**Elite**	43.2 ± 13.4 [a) d)]	44.1 ± 17.3	39.5 ± 16.3 [d)]	46.7 ± 16.7 [d)]
	Non-elite	66.7 ± 14.7 [a) c) h)]	54.9 ± 15.1 [c)]	75.6 ± 21.8 [c) h)]	70.9 ± 21.2 [c)]
Evaluation	**Elite**	30.6 ± 10.0 [b)]	32.9 ± 16.5	42.3 ± 11.3 [e)]	31.1 ± 10.3
	Non-elite	24.3 ± 15.8 [b)]	30.6 ± 15.3 [i)]	13.6 ± 10.5	24.9 ± 16.5
Prediction	**Elite**	11.4 ± 15.5	16.9 ± 22.4	11.6 ± 17.9 [e)]	15.9 ± 12.7
	Non-elite	9.0 ± 15.7	12.6 ± 14.9	7.9 ± 10.7	4.2 ± 7.9
Deep Planning	**Elite**	14.8 ± 12.3 [c) f) g)]	6.1 ± 8.1 [c)]	6.7 ± 10.2 [c)]	6.2 ± 7.9 [c)]
	Non-elite	.0 ± .0 [f)]	1.9 ± 5.3	2.9 ± 8.4	.0 ± .0 [f)]

[a)] significant difference between cognition and the other types of statements in both groups and across test sessions (P < .05).
[b)] significant difference in both groups between evaluation and prediction, and evaluation and deep planning across test sessions (P < .05).
[c)] significant difference between non-elite and elite groups across test sessions (P < .05).
[d)] significant difference between elite and non-elite groups (P < .05).
[e)] significant difference between elite and non-elite groups on evaluation and prediction (P < .05).
[f)] significant difference between non-elite and elite groups on deep planning (P < .05).
[g)] significant difference within elite from 1st to 2nd and 4th test session (P < .05).
[h)] significant difference within non-elite from 1st to 2nd and 3rd to 4th test session (P < .05).
[i)] significant difference within non-elite from 2nd to 3rd test session (P < .05).

There was a significant main effect for type of verbal statement ($F_{2.19, 30.62}$ = 41.56, *P* < .0001, η^2_p = .748). Participants made significantly more verbal statements coded as cognitions than evaluations, predictions, and deep planning (*P* < .05). Moreover, significantly more evaluation statements were verbalized compared with those coded as prediction and deep planning (*P* < .05).

There was a significant group * type of statement interaction ($F_{2.19, 30.62}$ = 5.17, *P* = .01, η^2_p = .269). The non-elite participants made significantly more statements coded as cognition compared to the elite participants, whereas the elite participants provide more deep planning statements compared with their non-elite counterparts (*P* < .05).

The type of statement * test session interaction ($F_{9, 126}$ = 1.95, *P* = .05, η^2_p = .122) was sufficiently close to the levels of significance to warrant discussion (Table 4). Post hoc analysis showed that the deep planning statements decreased significantly between the first and the last test sessions (*P* < .05).

There was a significant group * type of statement * test session interaction ($F_{4.96, 69.39}$ = 4.88, *P* = .001, η^2_p = .259). The non-elite participants verbalized significantly more cognition statements during the first, third and fourth test sessions compared to elite participants (*P* < .05). When compared to their non-elite counterparts, the elite participants provided significantly more statements coded as evaluation and prediction in the beginning of the second half (third test session), and deep planning statements during the first and the fourth test sessions (*P* < .05). Moreover, the elite group made significantly less deep planning statements in the second and fourth test sessions compared to the first (*P* < .05). In contrast, the non-elite participants decreased significantly their verbalizations coded as cognition at the end of each half as well as evaluation statements between the second and the third test session (*P* < .05) (see Figure 2).

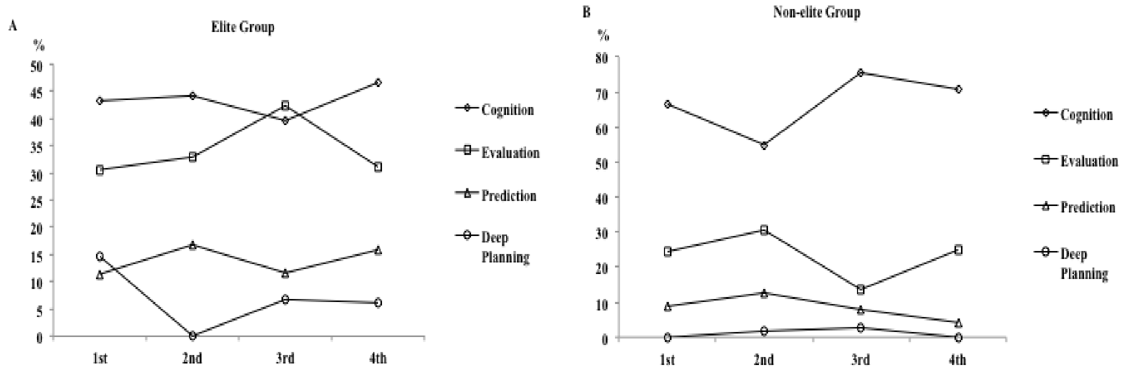

Figure 2. Mean type of statements values (%) for elite (A) and non-elite (B) groups across the intermittent exercise protocol.

DISCUSSION

We examined the effects of prolonged intermittent exercise on the perceptual and cognitive processes that underpin anticipation in elite and non-elite soccer players. We used a realistic, film-based test of anticipation coupled with an innovative, soccer-specific, intermittent exercise protocol. We hypothesized that the exertion levels would increase across the prolonged intermittent exercise protocol, independently of group. Additionally, measures of gaze behavior and think-aloud protocols were gathered during performance on the task in order to identify the perceptual-cognitive processes mediating performance and how these were affected by intermittent exercise. We predicted that elite players would demonstrate superior anticipation supported by more appropriate visual search strategies and more advanced specific-knowledge representations. Moreover, we hypothesized that the differences in performance across groups would increase as the level of stress increased across the intermittent protocol. The elite participants were expected to cope with the increased demands by investing more resources to the task, whereas, in contrast, the non-elite players were expected to show decreases in performance efficiency (i.e., greater effort investment) and effectiveness (i.e., accuracy) across the intermittent test protocol.

The elite players demonstrated superior anticipation performance when compared with non-elite players across the prolonged intermittent exercise. Our findings highlight the superior ability of elite participants to anticipate the actions of opponents when compared with non-elite counterparts (19, 22, 29, 32). Moreover, distinct differences were observed in both the gaze behaviors and thought processes employed during performance between groups and across test sessions. As expected, the exertion levels achieved during the intermittent exercise protocol, assessed by the heart rate and blood lactate concentrations, were comparable to those observed in other laboratory-based studies (4, 12) and during real soccer matches (2, 15). Both elite and non-elite soccer players were exposed to an increased circulatory strain, especially in the last test session of each half (4, 18). The involvement of anaerobic glycolysis, assessed by the blood La concentrations, increased significantly at the end of each half. In the present study, the mean blood La concentrations were in the range observed by Bangsbo (2) and Krustrup et al. (15) during soccer games (3-6 mmol/l). Although not measured in the present study, others have reported a pronounced increase in the rate of perceived exertion, and a reduction in performance, in the last 15 min of soccer match and occasionally, after a period of intense exercise, independently of playing position, level of competition, and gender (4, 18).

In the present study, the elite participants used a more appropriate visual search strategy (fixation duration, number of fixations, number of fixations per locations, and amount of time fixating in specific locations) compared to their non-elite counterparts, and the nature of these differences varied across the intermittent exercise protocol. The elite participants employed more fixations of shorter duration compared with non-elite participants, and on significantly more locations in the visual display at the beginning of each half. Our findings agree with other studies that reported differences in visual search behaviors between groups with different competitive levels (22, 23, 24, 31). Williams and Davids (32) reported that a search behavior involving more fixations of shorter duration is considered to be an advantage for elite players, particularly during dynamic open-play situations, since it enhances the player's awareness of more pertinent or relevant information (e.g., position and movements of team mates and opponents, areas of free space that may be exploited or exposed). Additionally, to pick up the most pertinent information elite participants used a lower search rate, probably increasing the role of peripheral vision (32, 36). At the end of each half, where the physical demands increased considerably, elite participants employed significantly less fixations of longer duration to fewer locations compared to their non-elite counterparts. Moreover, across the intermittent exercise protocol, the elite players maintained their time fixating on a greater number of locations compared with non-elite players.

Previous investigations have reported that stress has an impact on visual search behaviour in a manner that is task-specific. For example, in karate, anxiety increased the number of fixations to peripheral display areas (34), whereas in table tennis anxiety increased the amount of time spent fixating the ball (37). In biathlon, the effect of progressive increases in workload varied across individuals with in most instances stress leading to a reduction in quiet eye period, whereas the two most skilled shooters increased their quiet eye period (26). According to our findings, elite soccer players tend to be more selective in picking up the most pertinent visual cues as accumulated work increased. In contrast, in the same conditions, non-elite soccer players exhibited a higher search pattern, and potentially reduced efficiency, in an effort to capture the cues arising from the visual display.

When compared with non-elite participants, elite participants showed differences in the manner in which information was processed during the intermittent exercise protocol. The elite participants generated a great number of verbal statements coded as evaluation and prediction (at the beginning of the second half) and deep planning statements (during the first and the fourth test sessions). In contrast, non-elite players made a greater proportion of statements recalling current actions or descriptions of current events during the intermittent exercise protocol. These data suggest that elite participants activate more elaborate domain-specific memory representations when compared with non-elite players, leading to engagement of higher-level thought processes that enable events and potential outcomes to be considered, assessed and predicted, rather than merely monitored in their present state (16, 22, 28).

Our findings support the predictions of long-term working memory theory (LTWM; 6, 7). Skilled participants' complex retrieval structures permit anticipatory encodings, thereby allowing skilled players to dynamically update their cognitive representations and verbalize these forward planning thoughts. These complex memory representations allow elite individuals to perceive, encode, and store information when engaging in anticipation tasks that are representative of real-world demands (3, 9, 19, 35). Although elite players provided fewer deep planning statements at the end of each half, when compared to the first test session, they continued to show superior anticipatory performance than their non-elite counterparts.

In keeping with the predictions of PET (11), there were significant interactions for group * test session and group * type of statement * test session (P = .001) for search rate suggesting that the efficiency of performance changed differently for the two skill groups across tests sessions. The observed decrement in performance was less marked for the elite players who maintained performance effectiveness to a degree at the expense of a decline in performance efficiency. However, for non-elite players the demands of the primary task are already high such that there are no additional or spare resources available to devote to the secondary task leading to a decrement in both processing efficiency and effectiveness. These changes in the non-elite group are particularly evident in the fourth test session as illustrated by the negative impact on gaze behavior and thought processes and the decline in performance accuracy to levels significantly below chance.

In conclusion, we used a novel method that involved a realistic test of anticipation and a soccer-specific exercise protocol to examine how prolonged intermittent exercise influences the perceptual and cognitive processes underpinning performance. The affects induced by prolonged intermittent exercise produced adaptive changes in gaze behavior and cognitive processing (i.e., compensatory resource strategies) in elite players resulting in less marked decrements in performance across the intermittent exercise protocol when compared with their non-elite counterparts. In contrast, the non-elite players were more negatively affected by the intermittent exercise conditions, particularly in the fourth test session, resulting in lower performance effectiveness (as demonstrated by accuracy scores below chance) and efficiency (as illustrated by negative changes to gaze behaviors and thought processes).

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CHAPTER V

STUDY IV

Filipe Casanova, Júlio Garganta, Gustavo Silva, & José Oliveira**. Dynamical Decision-Making Task of Soccer Players, under Low- and High-Intensity Exercise.** ***Submitted to Peer-reviewed Scientific Journal*****.**

Abstract

The purpose of the present study is to examine the contribution of perceptual and cognitive processes in anticipation performance of soccer players under low- and high-intensity exercise demands. Eight elite and eight non-elite players completed a soccer-specific protocol, while simultaneously viewing dynamic and realistic filmed simulations of a soccer game. Anticipation, gaze behaviours, and retrospective reports were assessed. Results indicated that elite players were more accurate in anticipation performance. Under low-intensity, gaze behaviours exhibited by elite players accounted for a significant association in performance, whereas non-elite performance was significant related with cognition and evaluation statements. Under high-intensity, evaluation and deep planning verbalizations had a significant influence on elite group performance; in contrast, cognition statements was the only process-tracing measure that contributed significantly with non-elite performance. These findings indicated that the superior performance of elite players was associated with their ability to adapt perceptual and cognitive resources according to exercise intensities.

Key words: Perceptual-cognitive processes; Intensity demands; Response accuracy; Soccer.

INTRODUCTION

In high-performance sport, the ability to “read” opponents’ actions, often while simultaneously disguising one’s own intentions is crucial to performance (Reilly, Williams, Nevill, & Franks, 2000). Moreover, these requirements to anticipate what others will do and to select and execute the appropriate response are influenced by several task-specific constraints. Knowing where and when to look, and select the appropriate decision is crucial for successful sport performance, yet the visual display is vast and often saturated with information both relevant and irrelevant to the task that could be shaped by the constraints imposed by the organism, the task itself and the environment (Mann, Williams, Ward, & Janelle, 2007; Newell, 1986).

Usually, perceptual and cognitive skills are inferred from the quality, speed and accuracy of an individual‘s performance, with minimal effort to explain how perceptual and cognitive processes are associated with anticipation performance of soccer players, under different exercise-specific intensities. Researchers have employed eye movement recording methods to identify the perceptual processes that discriminate skilled and less-skilled performers (North, Williams, Hodges, Ward, & Ericsson, 2009; Roca, Ford, McRobert, & Williams, 2011; Williams & Davids, 1998; Williams, Ward, Knowles, & Smeeton, 2002; Williams, Janelle, & Davids, 2004). In general, the results reveal that skilled performers use different search strategies and fixate on more informative cues compared to their less-skilled counterparts. Although elite performers can identify relevant information early, they have the ability to make use of domain-specific knowledge that facilitates superior anticipation performance, when compared with non-elite (Ward, Williams, & Ericsson, 2003; Williams, Eccles, Ford, & Ward, 2010).

Therefore, researchers have used think-aloud protocols to gather information about the underlying knowledge structures and in-event thought processes, suggesting that skilled players employed more complex domain-specific memory representations to solve the task (Ericsson & Simon, 1993; North, Williams, Ward, & Ericsson, 2011; Roca et al., 2011). This assumption is sustained by the long-term working memory theory (LTWM) developed by Ericsson and Kintsch (1995), in which experts are able to acquire the necessary skills to index and encode information into an elaborate representation stored in long-term memory. This information remains accessible via the use of retrieval cues in short-term memory. Ward et al. (2003) proposed that these skills and underlying representations provide a dual function: (i) they provide memory support for performance, in the form of planning, monitoring and evaluations; (ii) while simultaneously enabling retrieval structures to be built and update "on the fly" that promote direct access to task pertinent options. This process allows experts to predict the occurrence and consequences of future events, and anticipate the retrieval demands likely to be placed on the system (McRobert, Williams, Ward, & Eccles, 2009). Alternative models, like the *Take The First* (TTF) heuristic of decision making proposed by Johnson and Raab (2003) and Raab and Johnson (2007), argues that decision-making quality is enhanced if performers select the first decision option that comes to mind, with an inverse relationship being reported between skill level and number of decision options generated. Regarding the TTF heuristic, expert performers should generate only one decision option (Yates, 2001), implying minimal forward planning and evaluation.

In recent years, researchers have developed representative methods to evaluate the superior anticipation performance of elite individuals. The available methods range from film-based simulations of the performance context to data captured in the field setting using liquid crystal occlusion glasses, high-speed film analysis, and the collection of performance data using match analysis procedures (Carling, Reilly, & Williams, 2009). Rampinini, Impellizzeri, Castagna, Coutts, and Wisløff (2009) reported that both physical, and technical performance decreased significantly among soccer players of different competitive levels or ranking positions during match-play. Other researchers using time-motion and performance analysis in soccer have suggested that reduced physical and physiological performance seems to occur at three different stages in the game: (i) after short-term intense periods in both halves; (ii) in the initial phase of the second half; and (iii) towards the end of the game (Mohr, Krustrup, & Bangsbo, 2005). Moreover, evidence from time-motion analysis shows that the amount of high-intensity running in the 5 min period immediately after the most intense 5 min interval recorded during the game was observed to be less than the average of the entire game (Mohr, Krustrup, & Bangsbo, 2003).

Generally, the influence of exercise intensity in decision-making performance was classically supported by Easterbrook's (1959) cue utilization theory. This theory states that a moderate-intensity exercise could improve performance, whereas high-intensity exercise would lead to a decrease in cognitive performance. The author provided evidence to suggest that, as one experiences higher emotion, the attentional field narrows. As a result, performance on primary tasks will be facilitated at the expense of performance on secondary tasks at moderate levels of emotion, and eventually a deterioration of primary task performance will occur when individuals become highly emotional. More recently, Eysenck, Derakshan, Santos, and Calvo (2007) proposed the Attentional Control Theory (ACT), in an effort to examine how stressors influences performance. The authors have defined effectiveness as the quality of task performance indexed by standard behavioural measures (generally, response accuracy), and efficiency as the relationship between the effectiveness of performance and the effort or resources spent in task performance (collected indirectly by process-tracing measures like as gaze and verbal reports). The ACT approach assumes that stress decreases the influence of the goal-directed attentional system (which is influenced by expectation, knowledge, and current goals) and increases the influence of the stimulus-driven system (which responds maximally to salient or conspicuous stimuli), resulting in a reduced attentional control and impairment of the inhibition and shifting functions. This theory predicts that stress decreases the influence of the goal-directed attentional system and increases the influence of the stimulus-driven system. Therefore, stress might not impair performance effectiveness when it leads to the use of compensatory strategies such as enhanced effort or increased use of processing resources. In this vein, Easterbrook's hypothesis and ACT indicates different predictions when the secondary or peripheral stimuli are at least as salient as those of the primary task. However, there have been no previous attempts to associate the underlying perceptual and cognitive processes in soccer anticipation performance, under low- and high-intensity demands.

The present study includes video-based offensive scenarios, involving a near-life-size video simulation, and a prolonged intermittent exercise protocol, simulating soccer match specific workloads, under controlled and reproducible laboratory conditions (Drust, Reilly, & Cable, 2000). The soccer-specific intermittent exercise protocol is performed on a motorized treadmill, and includes different exercise activities with varying intensities (e.g., walking, jogging, running, cruising, sprinting), as observed during a soccer game (Gregson, Drust, Batterham, & Cable, 2005). To increase the ecological validity of the simulation, treadmill speeds assigned to each activity category are based on the data of Van Gool, Van Gervan, and Boutmans (1988).

To summarize, we examined the variance of decision-making performance between elite and non-elite soccer players under low- and high-intensity exercise demands. The literature states that the superior performance of elite participants is mediated by more appropriate visual search pattern (Williams & Davids, 1998; Williams et al., 2002), extensive task-specific retrieval structures (Ward et al., 2003; Williams et al., 2010), and strategically allocated compensatory resources at high-intensity exercise (Eysenck et al., 2007). We hypothesized that elite players will exhibit superior anticipation performance mediated by using a better compensatory resources strategy (as designated by gaze and think aloud data), under both low- and high-intensity workloads, when compared to non-elite players.

Additionally, we examined the contribution of gaze behaviours and thought-processes in response to low- and high-intensity exercise for elite and non-elite players. Under low-intensity exercise demands, we predicted that elite players performance would be associated with the gaze behaviours employed around the visual display, whereas non-elite performance would be related to the contribution of verbalizing current actions or recalled statements about current events, expressed by verbal statements coded as cognition; whereas under high-intensity exercise demands, we expected that elite players anticipation performance would be based in a engagement of thought processing, verbalizing more evaluative and deep planning statements, and non-elite performance would still be related to their verbalizations on current events. Both assumptions were sustained by LTWM (Ericsson & Kintsch, 1995) and ACT theories (Eysenck et al., 2007).

METHODS

Participants

A total of eight elite and eight non-elite soccer players participated. Players in the elite group (mean age = 24.63 years, SD = 3.9) had played at a semi-professional or professional level (mean = 5.1 years, SD = 2.4) and had been involved in a professional club's training academy (mean = 3.5 years, SD = 2.7). The non-elite group (mean age = 26.25 years, SD = 2.9) had played soccer only at an amateur level (mean = 2.1 years, SD = 2.4). The participants reported normal or corrected to normal levels of visual function. Participants provided written informed consent. The study was carried out with the ethical approval of the lead institution, which conforms to the Helsinki Declaration.

Test Film

The film consisted of 40 video clips showing offensive sequences of play in soccer. Professional players from the Second National League in Portugal (N

= 22) were requested to act out a number of realistic match scenarios that were representative of actual situations that would occur in a match. A panel of four elite Portuguese soccer coaches, who all held the UEFA-A license, and had at least 10 years experience, validated the footage. The level of agreement between observers in regards to the suitability of the clips was high ($\alpha = 0.889$). The action sequences were filmed from a position behind (15m) and slightly above (5m) the goal with a 16:9 ratio camera (Sony DSR 570 DVCAM), such that the entire width of the playing field could be viewed and ensuring that potentially important information from wide positions was not eliminated. The elevated filming position helped give participants some element of depth. Altogether, four test films were created each comprising of ten different offensive sequences. The clips each lasted approximately 5 s with an inter-trial interval of 5 s. Moreover, just before the start of each clip, a small circle surrounding the ball appeared on screen to indicate the area of its first appearance. The clips were all occluded 120 ms before the player in possession of the ball was about to make a pass or take a shot to goal or maintain possession of the ball.

Apparatus

The film clips were projected onto a large screen (2.5-m x 2-m). The screen was placed 1.5 m directly in front of the participants to ensure the image was representative of real match-play.

An Applied Science Laboratories (ASL®) 3000 eye-movement registration system was used to record the visual search behaviours. This is a video-based, monocular corneal reflection system that records eye point-of-gaze with regard to a helmet-mounted scene camera. The system measures relative position of the pupil and corneal reflection. These features are used to compute point-of-gaze by superimposing a crosshair onto the scene image captured by the head-mounted camera optics. The image analyzed frame-by-frame using Pinnacle Software, Avid Liquid edition 7. System accuracy was ± 1º visual angle, with a precision of 1º in both the horizontal and vertical directions.

To collect verbal reports a lapel microphone, telemetry radio transmitter (EW3; Sennheiser, High Wycombe, UK), and telemetry radio receiver (EK 100 G2; Sennheiser) were used. Verbal reports were recorded onto miniDV tape using a digital video camera, converted into computer audio .wav files and then transcribed prior to analysis.

Procedure

The test procedure was explained and the eye-movement system fitted onto the participant's head before starting the experimental task. The ASL® eye-movement system was calibrated using a 9-point reference grid, so that the fixation mark corresponded precisely to the participant's point-of-gaze. A simple eye calibration was performed for each participant to verify point-of-gaze and four periodic calibration checks were conducted during the test (cf., Williams & Davids, 1998). After calibration, participants were presented with six practice trials in the laboratory task environment to ensure that they were familiar with the test procedure.

Prior to completing the experimental task, participants were instructed on how to provide retrospective verbal reports by solving generic and sport-specific tasks for approximately 30 minutes (Ericsson & Kirk, 2001). The transcriptions of retrospective verbal reports were segmented using natural speech and other syntactical markers. Participants were presented with six practice trials to ensure familiarization with the experimental setting. We collected retrospective verbal reports directly at the end of each sequence. Participants were asked to anticipate which of three possible actions was about to be performed by the player in possession of the ball: *Pass (*i.e., a situation when the player attempted to play the ball to a team-mate); S*hot at goal (i.e.,* when the player makes an attempt to score a goal); R*etain possession (i.e.,* when the player has ball possession and attempts to move with the ball).

Participants completed an intermittent exercise protocol (Drust et al., 2000), simulating the soccer-specific categories of intensity demands (e.g., walking, jogging, running, cruising, sprinting). The exercise protocol lasted 119 min, and was divided into two halves with the same duration (52 min), interspersed by a 15 min interval for rest. A static recovery period was included, in which the participant remained stationary on the treadmill (H/P cosmos, Pulsar, Germany).

The treadmill speeds used for each activity pattern were as follows: walking 6 $km.h^{-1}$; jogging 12 $km.h^{-1}$; running 15 $km.h^{-1}$; cruising 18 $km.h^{-1}$; sprinting 23 $km.h^{-1}$. The protocol included two identical periods of seven running blocks (five low-intensity blocks and two high-intensity blocks), separated by a recovery period of 15 minutes (see Figure 1). The low-intensity phase consisted of five blocks of activity, with the same pattern: walking; stopping; jogging; walking; jogging and running. The total duration of each low-intensity block was six minutes and twenty four seconds, with this period including 18 seconds of walking, 18 seconds of stopping, 16 seconds of jogging, 18 seconds of walking, 14 seconds of jogging and 12 seconds of running, each cycle being repeated four times. The high-intensity phase consisted of two blocks of activity, with the same pattern of walking, sprinting, stopping and cruising. The duration of each high-intensity block was seven minutes, involving 13 seconds of walking, 10 seconds of sprinting, 15 seconds of walking, 10 seconds being stationary and 12 seconds of cruising. This pattern was repeated seven times. The duration of each period of seven blocks (first half) was 52 minutes. So, the soccer-specific protocol was 119 minutes (first half: 52 minutes + recovery: 15 minutes + second half: 52 minutes).

The data were collected after the third, seventh, tenth and fourteenth blocks, and then collapsed according to their intensity phase: low-intensity - third and tenth blocks; high-intensity - seventh and fourteenth blocks. In each assessment, the participants viewed 10 clips presented in a counterbalanced order. The total duration of the experimental protocol, including the period of familiarization with the procedures, lasted approximately 210 minutes. The study design is illustrated in Figure 1.

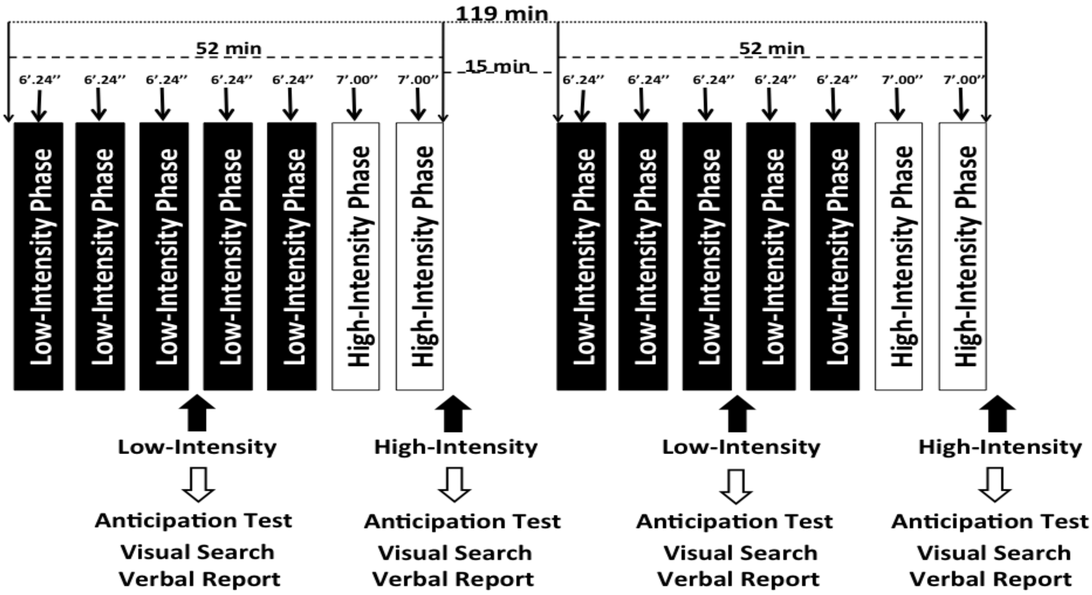

FIGURE 1- The representation of the Drust protocol and the four evaluations of data collection, collapsed according to low- and high-intensity exercise demands.

Dependent Measure

Anticipation

Anticipation performance was obtained by response accuracy (RA) scores, calculated based on the participants responses after viewing each clip. A correct response was recorded if the participant correctly anticipated the decision of the player in possession of the ball, compared to what actually happened in the match situation. Response accuracy was reported as a percentage (%).

Independent Measures

Perceptual and cognitive processes

The three most discriminating trials between elite and non-elite players based on group mean scores from the measures of response accuracy percentage were chosen for visual search analysis. Visual behaviours were analyzed to obtain search rate. Search rate comprised the mean number of visual fixations, the mean fixation duration, and the total number of fixation locations per trial. Mean fixation duration was the average of all fixations that occurred during the trial. A fixation was defined as the period of time (120 ms) when the eye remained stationary within 1.5º of movement tolerance (cf., Williams & Davids, 1998). The display was divided into five fixation locations: ball; team mate; opposition; player in possession of the ball; and undefined. An inter observer agreement formula was used to determine the percentage of agreement for search rate data. The data reached an inter observer agreement of 99%. To provide this figure, 25% of the data was re-analyzed.

The cognitive processes were recorded using verbal report protocols. The verbal statements were categorically coded based on a structure originally adapted from Ericsson Simon (1993) and further developed by Ward (2003) to identify statements made about cognitions, evaluations, and planning (including predictions and deep planning). Ward (2003) conceptualized cognitions as all statements representing current actions or recalled statements about current events and evaluations as some form of positive, neutral or negative assessment of a prior statement. Planning statements were divided into predictions and deep planning. Predictions reflected statements about what would and could arise next and deep planning statements concerned information about searching possible alternatives beyond the next move.

We collected retrospective verbal reports after every trial, and in each evaluation we used the three most discriminating trials between elite and non-elite players based on group mean scores from the anticipation task, converted into frequency data. Consequently, the trials identified were the 3, 7, 10, 22, 25, 27 (low-intensity demand), and 11, 16, 19, 31, 36 and 40 (high-intensity demand). An independent investigator established the figure reliability re-analyzing 100% of the data. For these variables the data reached an inter observer agreement of 98%.

Statistical Procedures

Response accuracy, perceptual, and cognitive measures were analyzed using separate factorial two-way ANOVA with group (elite/non-elite) as the between-participants factor and intensity exercise demand as the within-participants factor. Partial eta squared (η^2_p) values were provided as a measure of effect size for all main effects and interactions. To identify which perceptual and cognitive measures explained the variance in the response accuracy performance on elite and non-elite players, we conduced multiple linear regression analyses, separated for each group and for each exercise demand (low- and high-intensity). For each group and intensity exercise analysis, the response accuracy percentage was set as the dependent variable and perceptual and cognitive measures were considered the independent variables. Stepwise method with forward selection was employed retaining the independent variables, with *p* value greater than 0.05 in the final model. The statistical software used was the SPSS Version 18.0 (SPSS Inc., Chicago, II).

RESULTS

Anticipation

The response accuracy at low- and high-intensities is presented in Table 1.

TABLE 1- Mean Response Accuracy Percentage (RA %) from elite and non-elite players, under low- and high-intensity exercise demands (± SD).

	Group	Exercise Demands	
		Low-intensity	**High-intensity**
RA %	Elite	53.1 ± 6.9[a] [b]	46.3 ± 12.3 [a]
	Non-elite	38.1 ± 10.8[b]	30.6 ± 10.4

[a] significant difference between elite and non-elite ($p < .05$).
[b] significant difference between low- and high-intensity exercise ($p < .05$).

There were significant main effects for group ($F_{1, 60} = 33.82$, $p < .0001$, $\eta^2_p = .36$) and intensity ($F_{2, 60} = 7.45$, $p < .0001$, $\eta^2_p = .11$). Elite players were more accurate in anticipating the decision of the player in possession of the ball than their non-elite counterparts. Moreover, for both groups (elite/non-elite) accuracy in anticipating the judgment of the player in possession of the ball decreased significantly under high- compared to low-intensity demands ($p < .05$). There was no significant group * intensity interaction ($F_{2, 60} = .014$, $p = .91$, $\eta^2_p = .00$).

Perceptual and Cognitive Processes

The descriptive data from gaze behaviours (number of fixations, number of fixation locations, and mean fixation duration), and type of verbal statements (cognition, evaluation, prediction and deep planning) under low- and high-intensity exercise demands are presented in Table 2.

TABLE 2- Mean Fixation Duration (FD), Number of Fixations (NF), Number of Fixation Locations (NFL) and Verbal Statements – cognition, evaluation, prediction and deep planning – between elite and non-elite players, under low- and high-intensity exercise demands (± SD).

Variables	Group	Exercise Demands	
		Low-intensity	**High-intensity**
FD	Elite	276.4 ± 70.9 [a) b)]	312.1 ± 86.9
	Non-elite	375.4 ± 92.4 [b)]	311.3 ± 75.0
NF	Elite	15.8 ± 2.2 [a) b)]	14.2 ± 2.2
	Non-elite	12.5 ± 2.2 [b)]	14.7 ± 2.8
NFL	Elite	3.2 ± 0.4 [a) b)]	2.8 ± 0.4
	Non-elite	2.5 ± 0.4 [b)]	2.9 ± 0.6
Cognition	Elite	2.6 ± 1.3	2.9 ± 1.6
	Non-elite	2.7 ± 1.2	2.9 ± 1.4
Evaluation	Elite	2.4 ± 1.5 [a)]	2.3 ± 1.4 [a)]
	Non-elite	0.8 ± 0.8	1.4 ± 1.2
Prediction	Elite	0.7 ± 1.1 [a)]	1.1 ± 1.3 [a)]
	Non-elite	0.3 ± 0.7	0.4 ± 0.7
Deep Planning	Elite	0.7 ± 0.9 [a)]	0.5 ± 0.7 [a)]
	Non-elite	0.1 ± 0.3	0.04 ± 0.2

[a)] significant difference between elite and non-elite ($p < .05$).
[b)] significant difference between low- and high-intensity exercise ($p < .05$).

Fixation duration

There was a significant main effect for group ($F_{1, 188} = 17.32$, $p < .0001$, $\eta^2_p = .08$). Elite players demonstrated significantly shorter fixations compared with non-elite participants, under low-intensity exercise. There was a significant group * intensity interaction ($F_{2, 188} = 17.87$, $p < .0001$, $\eta^2_p = .09$). Elite players employed significantly shorter fixations under low-intensity exercise, and significantly longer fixations when the exercise was performed in a high-intensity demand ($p < .05$). In contrast, non-elite group employed longer fixations under low-intensity exercise, and decreased significantly their fixation time when performed under high-intensity exercise. There was no significant main effect for intensity ($F_{2, 188} = 1.45$, $p = .23$, $\eta^2_p = .008$).

Number of fixations

There was a significant main effect for group ($F_{1, 188} = 16.12$, $p < .0001$, $\eta^2_p = .08$). Elite players employed a significantly higher number of fixations than non-elite performers, under low-intensity exercise. There was a significant group * intensity interaction ($F_{2, 188} = 29.97$, $p < .0001$, $\eta^2_p = .14$). Elite players decreased the number of fixations between low- and high-intensities demands, whereas the non-elite participants increased the NFs from low- to high-intensity exercise demands. Additionally, elite participants showed a significantly higher NF in low-intensity exercise, compared to their counterparts. There was no significant main effect for intensity ($F_{2, 188} = .83$, $p = .36$, $\eta^2_p = .004$).

Number of fixation locations

There was a significant main effect for group ($F_{1, 188} = 16.12$, $p < .0001$, $\eta^2_p = .08$). Elite participants fixated on more locations compared with non-elite performers, under low-intensity exercise. There was a significant group * intensity interaction ($F_{2, 188} = 29.97$, $p < .0001$, $\eta^2_p = .14$). Elite players employed more fixations in different locations under low-intensity than high-intensity exercise demands. In addition, non-elite participants increased the NFL between low- and high-intensity exercise demands, when compared with elite participants. There was no significant main effect for intensity ($F_{2, 188} = .83$, $p = .36$, $\eta^2_p = .004$).

Cognition

There were no significant main effects for group ($F_{1, 188} = .11$, $p = .92$, $\eta^2_p = .000$) and intensity ($F_{2, 188} = 1.8$, $p = .18$, $\eta^2_p = .009$), and no significant group * intensity interaction ($F_{2, 188} = .17$, $p = .68$, $\eta^2_p = .001$).

Evaluation

There was a significant main effect for group ($F_{1, 188}$ = 46.79, p < .001, η^2_p = .199). Elite participants verbalized significantly more evaluation statements than non-elite players, under both low- and high-intensity exercise. There was a significant group * intensity interaction ($F_{2, 188}$ = 4.05, p = .046, η^2_p = .021). Elite participants verbalized significantly more evaluation statements under both intensity demands compared to non-elite group (p < .05). There was no significant main effect for intensity ($F_{2, 188}$ = 1.75, p = .188, η^2_p = .009).

Prediction

There was a significant main effect for group ($F_{1, 188}$ = 17.32, p < .001, η^2_p = .084). Elite participants provided more prediction statements than their non-elite counterparts. There was no significant group * intensity interaction ($F_{2, 188}$ = 1.41, p = .236, η^2_p = .007), and no significant main effect for intensity ($F_{2, 188}$ = 3.73, p = .055, η^2_p = .019).

Deep planning

There was a significant main effect for group ($F_{1, 188}$ = 35.16, p < .001, η^2_p = .158). Elite participants made significantly more deep planning statements (p < .05). There was no significant group * intensity interaction ($F_{2, 188}$ = .98, p = .324, η^2_p = .005), and no significant main effect for intensity ($F_{2, 188}$ = 2.19, p = .140, η^2_p = .012).

We conducted a multiple linear regression to identify which perceptual and cognitive measures explained the variance in performance between elite and non-elite players, under low- and high-intensity exercise demands (Table 3).

TABLE 3- Multiple Linear Regression model for the perceptual and cognitive measures estimation of response accuracy percentage on elite and non-elite players, under low- and high-intensity exercise demands.

Exercise Demands	Group	Measures	β	95% Confidence Interval
Low-intensity	Elite	NF	1.5**	0.7; 2.4
	Non-elite	Cognition	3.5**	1.1; 5.9
		Evaluation	4.4*	0.9; 7.9
High-intensity	Elite	Evaluation	2.9**	0.8; 5.2
		Deep Planning	6.8**	2.2; 11.4
	Non-elite	Cognition	2.1*	0.1; 4.2

* $p < .05$; ** $p < .01$.

Under low-intensity exercise demands, the number of fixations employed by elite players accounted for a significant contribution of the anticipation performance (R = .48, R^2 = .23, $F_{1, 46}$ = 13.98, p = .001). In contrast, cognition and evaluation statements were significant related to non-elite group performance (R = .49, R^2 = .24, $F_{1, 45}$ = 6.23, p = .016).

When we analyzed the contribution of visual search rate and types of verbal statements in the anticipation performance under high-intensity exercise demands, the results revealed that for elite group the verbal statements coded as evaluation and deep planning had a significant influence on their performance (R = .52, R^2 = .27, $F_{1, 45}$ = 7.56, p = .009). In contrast, for non-elite group performance the only process-tracing measure that had a significant influence was the verbal statement coded as cognition (R = .29, R^2 = .09, $F_{1, 46}$ = 9.32, p = .043).

DISCUSSION

We examined the perceptual and cognitive processes underpinning anticipation performance in elite and non-elite soccer players under low- and high-intensity exercise demands. Subsequently, under both low- and high-intensity exercise demands, we hypothesized that elite players would demonstrate superior anticipation performance, when compared to non-elite players, mediated by more appropriate visual search strategies, more extensive task-specific retrieval structures, and by their strategy to allocate compensatory resources at high-intensity demands. Furthermore, we examined the contribution of visual search behaviours and cognitive processes in response to low- and high-intensity exercise for elite and non-elite players anticipation performance. We predicted that elite players performance would be associated on gaze behaviours employed around the visual display, whereas non-elite performance would be related to the contribution of verbalizing current actions or recalled statements about current events, under low-intensity exercise demands. Moreover, under high-intensity exercise demands, we hypothesized that elite players anticipation performance would be based on more evaluative and deep planning statements, and non-elite performance would still be related to their verbalizations on current events.

Firstly, the intermittent exercise protocol to mimic the physical demands of full 90-minute soccer game has been continuously improved in research, under laboratory settings (cf., Drust, Atkinson, & Reilly, 2007). Although some “real-world” displacements (backwards and sideways) were not included as a result of the technical limitations of the ergometer (Drust et al., 2000), and both activity pattern and speed duration were slightly different from a real soccer match (for review, see Bradley, Sheldon, Wooster, Olsen, Boanas, & Krustrup, 2009), the intermittent exercise protocol was a unique instrument to warrant reproducibility, control, safety, and reliability for this experimental design.

As expected, the results of the present study revealed that elite soccer players exhibited superior performance under both exercise intensities compared to their non-elite counterparts. Our findings are in agreement with other researchers that examined groups from different competitive levels (North et al., 2011; North & Williams, 2008; Roca et al., 2011; Ward & Williams, 2003; Ward et al., 2003; Williams & Davids, 1998). Other researches revealed that elite's superior performance were underpinned by a more refined underlying process-tracing highlighted by skill-based differences in gaze behaviours, and retrospective verbal reports, when compared to performance in simulated real-world situations between participants skilled levels (McRobert et al. 2009; North et al., 2011; Roca et al., 2011; Ward et al., 2003; Ward & Williams, 2003; Williams & Davids, 1998). In this sense, visual and cognitive data from elite participants, when compared to non-elite group, showed that they employed significantly ($p < .05$) more fixations of shorter duration in more informative visual cues, and activated more elaborate domain-specific memory representations (i.e. verbalized more evaluative, predictive and deep planning statements, $p < .05$), under low-intensity exercise.

Additionally, we observed a significant decrease in both group performances between low- and high-intensity exercise demands. Our findings support studies that have examined the quiet eye period of biathlon athletes after a stressful effort. For example, in biathlon the effect of progressive increases in workload varied across individuals with in most instances stress decreasing the quiet eye period, whereas the two most skilled shooters increased their quiet eye period (Vickers & Williams, 2007). According to ACT (Eysenck et al., 2007), the effect of stress will impair processing efficiency to a greater extent than performance effectiveness. Our findings are supported by ACT predictions, when we observed that high-intensity exercise demands could impair two of the three key functions of the central executive (i.e., inhibition and shifting), specifically when the players employ all the effort and available resources in the execution of the primary task. Elite players had superior performance, compared to non-elite players, even in stressful exercise demands by using compensatory resources strategies such as increased use of processing resources.

Another methodological improvement of the present study was to examine the contribution of both visual and cognitive processes in elite and non-elite anticipation performance, under low- and high-intensity exercise demands. As expected, elite players performance was associated on gaze behaviours employed around the visual display, probably due by using more appropriately the various sub-components of the visual field, such as fovea, parafovea and visual periphery (Williams & Ford, 2008). In contrast, non-elite performance was related to the contribution of verbalizing current actions and evaluative statements, under low-intensity exercise demands, and cognition statements under high-intensity exercise. Our findings suggested that non-elite players performance faced to a fewer semantic concepts or templates impaired them to pick up important relational information and to employ more distinctive surface features, when making such judgments. Moreover, statements coded as evaluations were associated with the non-elite performance, probably due to the fact that these players use search processes to work out the more effective option before deciding upon a course of action (Ward, 2003). Even when the exercise intensity demands increases, non-elite players were able to think only about immediately available surface information and commenting on ongoing events to perform the primary task, rather than planning ahead based on anticipated future developments.

Additionally, under high-intensity exercise demands, the results showed that elite players performance was based on more evaluative and deep planning thought processes. Our findings provide support for LTWM theory (Ericsson & Kintsch, 1995). This theory states that skilled participants' complex retrieval structures permit anticipatory encodings, allowing skilled participants to dynamically update their cognitive representations and verbalize these forward planning thoughts. Additionally, elite players have the ability to combine different process-tracing processes under low and high-intensity exercise demands increased the importance of experts bypass the limitations of short-term working memory. This means that elite participants acquired advanced skills that allow both rapid encoding of information in long-term working memory and selective access to this information when required, namely being more proactive. Although processing efficiency from elite players might be affected during high-intensity exercise (Eysenck et al., 2007), evidence suggests that even when the situational demands change elite participants are able to restructure, reorganize, and refine their representation of knowledge so they are able to adapt rapidly (Feltovich, Prietula, & Ericsson, 2006).

In conclusion, we presented evidence that elite players demonstrate superior anticipation performance mediated by a more appropriate gaze behavior, and a more extensive task-specific retrieval structures than non-elite players, under both low- and high-intensity exercise demands. Moreover, the performance of the elite players was sustained by their ability to alternate and adapt the perceptual and cognitive resources according to exercise intensities demanding, whereas, in contrast, the performance of the non-elite group was associated with processing current ongoing events.

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CHAPTER VI

GENERAL DISCUSSION

GENERAL DISCUSSION

Research is still being undertaken to better understand the perceptual-cognitive skills that facilitate anticipation performance in elite players. The results suggest that perceptual-cognitive skills from elite players are more refined, compared with non-elite players, which includes a more effective use of visual resources when scanning the environment (Williams et al., 2011), the ability to pick up advance information from the postural orientations and actions of an opponent (Williams et al., 2002), a capacity to recognize familiarity and structure based on the relational information that exists between team mates and opponents (North et al., 2009; Williams et al., 2006), and the capability to accurately predict the likely choice options open to an opponent at any given moment based on the availability of context-specific information (McRobert et al., 2011; Ward & Williams, 2003;).

The present study is based on the expert performance approach developed by Ericsson and Smith (1991). The proposed approach is illustrated in Figure 2.

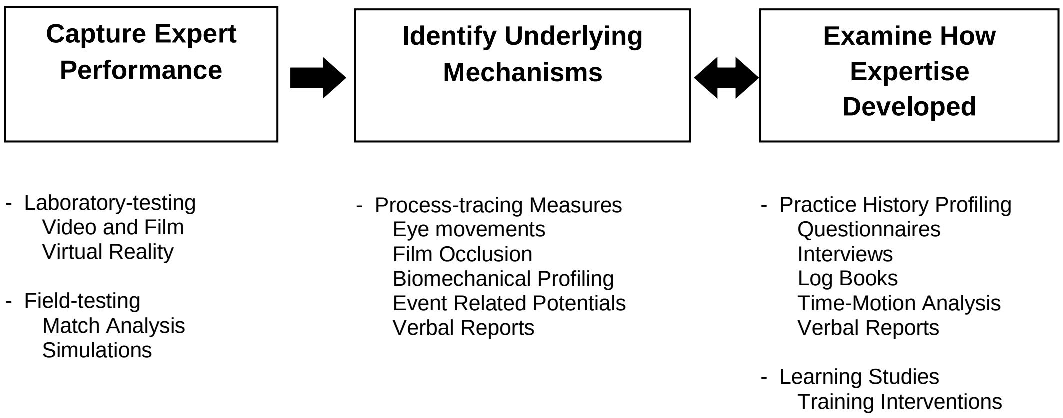

Figure 2- Expert performance approach and some of the methods and measures that may be used at each stage (adapted from Williams & Ericsson, 2005).

Researchers have tried to study anticipation in soccer players, but some methodological limitations could be pointed out, such as the perceptual test used in some experiments was non-soccer specific, the visual display was static, and the ecological validity of the simulations was dubious (for a detailed review, see Ali, 2011). According to the different methodological and measurements used, the first step in the thesis was to design a representative soccer task that allows anticipation skill to be faithfully reproduced in laboratory. The essence of capturing elite performance should be to provide precise and reproducible measurements so that the development of anticipation performance can be objectively evaluated. In this vein, the task-specific test created in this study, from a third-person perspective, addressed important guidelines in soccer investigation, that is, the entire footage were representative of a real soccer situation ending with an offensive action. The duration adopted for each clip maximized the participants' cognitive information, and player's field of vision in real life was minimized by using high-definition 16:9 ratio video cameras. However, when the collection of response accuracy includes movement and action, and laboratory dimension permits, as well, it is best to use a real-world first person viewing perspective, similar to that used by Roca and colleagues (2011). The authors combined a multidimensional approach by including video film sequences of 11 vs. 11 similar to the real-world setting, recorded from a first-person perspective.

In an attempt to determine the mediating mechanisms that account for superior performance, the second stage of the expert performance approach highlights the processes underpinning superior performance using process-tracing measures such as eye-movement recording and verbal protocol analysis. Additionally, to overview the notion that the relative importance of the perceptual-cognitive skills may vary based on a range of constraints related to the task, situation, and performer, Williams and Ward (2007) adapted a constraints-based model, initially proposed by Newell (1986), which is illustrated in Figure 3.

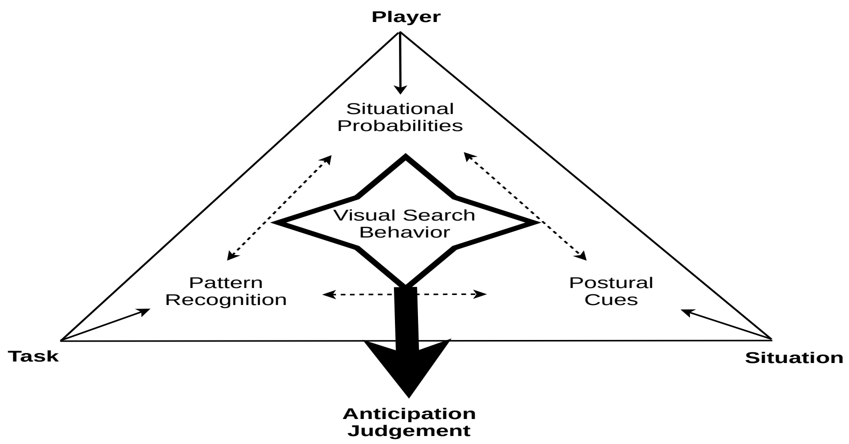

Figure 3- The interactive relationship between various perceptual-cognitive skills and constraints related to the task, situation, and player when making anticipation judgements (adapted from Williams & Ward, 2007).

The present study developed a novel methodological approach by recording multiple process-tracing measures simultaneously, in conjunction with a realistic test of anticipation (i.e. anticipating the decision of the player in possession of the ball, compared to actually happened in the match situation) and a soccer-specific exercise protocol (i.e. organismic constraint). The constraints refer to the unique structural characteristics of performers and include, for example, factors related to their physical, physiological, cognitive, and emotional make up (Williams et al., 2004).

Soccer is a team sport, where the athletes have to perform successfully under physical and physiological stress in a complex and variable environment. It is clear that the most realistic way of evaluating the physical and physiological demands of soccer-specific intermittent activity is to monitor during a real soccer game. But a range of difficulties is highlighted, such as the difficulties in carrying out physical and physiological assessment and ensuring appropriate experimental control of the environment (Drust et al., 2007). These limitations have resulted in the development of motorised and non-motorised treadmill laboratory protocols (for review, see Drust et al., 2007; Stølen et al., 2005). In this regard, the prolonged intermittent exercise protocol used in our experiment was originally developed and validated by Drust and colleagues (2000). The treadmill speeds assigned to each activity category were based on the time-motion data reported by Van Gool and colleagues (1988), increasing the ecological validity of the protocol. Moreover, the intermittent exercise protocol simulates different exercise activities with varying intensities, as observed during soccer match-play, and it has been adapted to simulate the physical demands of full 90-minute soccer game (Gregson et al., 2005). However, some movements observed during a soccer game were not included, such as backing, sideways and jumping movements, as a result of the technical limitations of the ergometer and the health and safety risks of changing orientation on the treadmill. In the present study, the heart rate and blood lactate concentrations data showed that prolonged intermittent exercise protocol induced an increase in the circulatory strain, in both elite and non-elite players, which are comparable to the observe during real soccer matches (Bangsbo, 1994; Krustrup et al., 2004).

Typically, response measures have highlighted the superior ability of elite players to anticipate the decision of the player in possession of the ball, when compared with non-elite counterparts. Moreover, distinct differences have been observed in both gaze behaviors and thought processes employed during performance between elite and non-elite players.

The eye-movement data demonstrated that elite players employed more fixations of shorter duration compared with non-elite participants, and on significantly more locations in the visual display at the beginning of each half. This search behavior is considered to be an advantage for elite players, since it enhances the player’s awareness of more pertinent or relevant information, and probably increases the role of peripheral vision (cf., Williams & Davids, 1998; Williams et al., 2004). However, at the end of each half, where the physical demands increased considerably, elite players employed significantly less fixations of longer duration to fewer locations compared to their non-elite counterparts. Another finding observed in the present study was that elite players maintained their time fixating on a greater number of locations compared with non-elite players, across the intermittent exercise protocol. Albeit elite players evidenced a different search pattern, when compared with non-elite players, the data highlighted the importance of using the visual system appropriately in stressful environments, guiding them successfully to the action.

Protocol analysis of retrospective verbal reports was simultaneously collected, in which the data revealed that elite players activate more elaborate domain-specific memory representations during the exercise intermittent protocol, when compared with non-elite players, leading to engagement of higher-level thought processes that enable events and potential outcomes to be anticipated. The elite players develop specific memory structures that allow rapid and reliable encoding and retrieval of information in long-term working memory, thus avoiding the capacity limitations of short-term memory and the difficulties of retrieval from long-term memory. In the present study, we used a retrospective verbal report protocol because the task was extremely demanding, and, since the data collection was immediately after, the players could draw from short- and long-term memory, minimizing the need for inferences to be drawn (Ericsson & Simon, 1993). Therefore, we summarized that elite players maintained performance effectiveness to a degree at the expense of a decline in performance efficiency, whereas non-elite players presented a decline in performance accuracy to levels significantly below chance.

When we examined the perceptual and cognitive processes underpinning anticipation performance in response to low- and high-intensity exercise, the results revealed that elite players demonstrated superior performance mediated by a more appropriate use of perceptual and cognitive processes. Even in high-intensities exercise demands, we observed that elite players increased the use of compensatory resources strategies, compared with their non-elite peers. Eysenck and colleagues (2007) stated that this behavior might be impaired in using two of the three key functions of the central executive (i.e., inhibition and shifting), specifically when the players have to employ all the effort and available resources in the execution of the primary task.

Another methodological improvement in the present study was the attempt to examine the contribution of both perceptual and cognitive processes in elite and non-elite anticipation performance under low- and high-intensity exercise demands. The results highlighted that elite players performance was associated on gaze behaviours, particularly the number of fixations employed around the visual display, whereas, in contrast, non-elite performance was related to the contribution of verbalizing current actions and evaluative statements, under low-intensity exercise demands. Moreover, when the exercise intensity demands increased, non-elite players were able to think only about immediately available surface information and commenting on ongoing events to perform the primary task, rather than planning ahead based on anticipated future developments. In contrast, elite players' performance was associated on more evaluative and deep planning thought processes. Although processing efficiency from elite players might be affected during high-intensity exercise (Eysenck et al., 2007), the results of the present study suggested that even when the intensity exercise demands increased elite players were suitable to reorganize, and refine their knowledge-specific representations so they might adapted rapidly regarding the constraints imposed by the task.

Although the present work was not designed to provide detailed information about the adaptive learning and explicit acquisition processes relevant to the development of sport expertise (Williams & Ericsson, 2005), the findings add new evidence that could be useful for coaching soccer players. Regarding the results of the present study, anticipation performance decreased during prolonged intermittent exercise and under high-intensity exercise, independently of soccer competitive level. Moreover, the mechanisms underpinning anticipation performance were distinct for the elite and non-elite players. Therefore, to maintain performance effectiveness and resource efficiency at the end of the game, training sessions must include soccer-specific games with high complexity in regards to their demands for anticipation and decision-making as well as having a high-level of exercise intensity, particularly late on in practice and in training matches, independently of the players' competitive level. The inter-relationship between action-perception-cognition is also highlighted by the findings of the present study. To achieve superior anticipation performance, the soccer players must be confronted with some practical interventions that could improve the memory knowledge structure, for example, training sessions must be prescribed to improve tactical and strategic knowledge in the field or using video simulations (coupled with appropriate instruction and feedback).

To better understand the decision made by soccer players, it is suggested that in future researchers: (i) study the importance of the peripheral vision to guide soccer players into the action; (ii) analyze the influence of others perceptual measures (such as fixation locations) that could be associated with superior anticipation performance; (iii) examine the effects of prolonged intermittent exercise on soccer players according to their position and role in the team; and (iii) test the perceptual and cognitive processes under a real world setting, since there now exist portable and reliable instruments to collect process-tracing measures during actual performance.

CHAPTER VII

CONCLUSIONS

CONCLUSIONS

According to results reported in the different studies presented in this thesis, it is possible to conclude that:

1. The scenarios created represented soccer match patterns are a useful tool to evaluate perceptual-cognitive expertise under controlled laboratory settings;
2. A novel method that involved a realistic test of anticipation and a soccer-specific exercise protocol was developed to examine how prolonged intermittent exercise influences the perceptual and cognitive processes underpinning performance, which might be a useful instrument to be applied in future research;
3. The elite soccer players exhibit superior anticipation and decision-making performance compared to their non-elite counterparts during prolonged intermittent exercise protocol and under both low- and high-intensity exercise demands;
4. The prolonged intermittent exercise and high-intensity exercise demands induced a decrement in anticipation performance of both elite and non-elite soccer players;
5. Adaptive changes in gaze behavior and cognitive processing (i.e., compensatory resource strategies) in elite players resulted in less marked decrements in performance across the intermittent exercise protocol when compared with their non-elite counterparts;
6. Non-elite players were more negatively affected by the intermittent exercise conditions, resulting in lower performance effectiveness (as demonstrated by accuracy scores below chance) and efficiency (as illustrated by negative changes to gaze behaviors and thought processes);
7. Under both low- and high-intensity exercise demands, superior anticipation performance of elite players is mediated by a more

appropriate gaze behavior, and a more extensive task-specific retrieval structures than non-elite performance;

8. The perceptual-cognitive ability of elite players is sustained in alternating and adapting the perceptual and cognitive resources according to exercise intensities demands, whereas, in contrast, the anticipation performance of non-elite group was associated with processing current ongoing events.

CHAPTER VIII

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CHAPTER IX

APPENDIX

Appendix 1. Publications and Scientific Meetings Presentations Related with the Thesis

Peer-reviewed Scientific Journal Published Article

Casanova, F., Oliveira, J., Williams, A. M., & Garganta, J. (2009). Expertise and perceptual-cognitive performance in soccer: a review. *Revista Portuguesa de Ciências do Desporto*, 9 (1): 115-122.

Peer-reviewed Scientific Journal Accepted Article

Casanova, F., Garganta, J., & Oliveira, J. Representativeness of offensive scenarios to evaluate perceptual-cognitive expertise of soccer players. *Open Sports Sciences Journal* (Special Issue - in press).

Peer-reviewed Scientific Journal Submitted Articles

Casanova, F., Garganta, J., Silva, G., Alves, A., Oliveira, J., & Williams, A. M. The effects of prolonged intermittent exercise on perceptual-cognitive processes in soccer players. Submitted.

Casanova, F., Garganta, J., Silva, G., & Oliveira, J. Dynamical decision-making task of soccer players, under low- and high-intensity exercise. Submitted.

Peer-reviewed Scientific Journal Published Abstracts

Casanova, F., Garganta, J., Williams, A. M., & Oliveira, J. (2011). Representativeness of offensive scenarios to evaluate perceptual-cognitive expertise of soccer players. *Revista Portuguesa de Ciências do Desporto*, 11 (supl. 4): 44.

Casanova, F., Garganta, J., Williams, A. M., Oliveira, J., Barreira, D., & Brito, J. (2011). Validation of offensive scenarios to evaluate perceptual-cognitive skills in soccer. *Football Science*, 8 (1): 166.

Poster Presentations

Casanova, F., Oliveira, J., Williams, A. M., & Garganta, J. (2009). Excelência e performance perceptivo-cognitiva no Futebol. Comunicação em poster apresentada no II Congresso Internacional de Deportes de Equipo. Universidade da Corunha, Corunha.

Casanova, F., Oliveira, J., Williams, A. M., & Garganta, J. (2009). Preliminary validation of attacking scenarios to evaluate perceptual-cognitive expertise of soccer players. In International Seminar: “Desafio às Ciências do Desporto”. FADE-UP, Porto.

Casanova, F., Oliveira, J., Williams, A. M., & Garganta, J. (2010). Validation Study of attacking scenarios to evaluate perceptual-cognitive expertise of soccer players. In *IJUP* 10. University of Porto, Porto.

Casanova, F., Oliveira, J., Williams, A. M., & Garganta, J. (2010). Excelência e performance perceptivo-cognitiva no Futebol. In *IJUP* 10. University of Porto, Porto.

Casanova, F., Oliveira, J., Williams, A. M., & Garganta, J. (2010). Validation study of attacking scenarios to evaluate perceptual-cognitive expertise of soccer players. In Second World Conference of Science and Soccer. Nelson Mandela Metropolitan University, South Africa.

Casanova, F., Garganta, J., Williams, A. M., Oliveira, J., Barreira, D., & Brito, J. (2011). Validation of offensive scenarios to evaluate perceptual-cognitive skills in soccer. In VIIth World Congress on Science & Football: 2011. Nagoya, Japan.

Casanova, F., Garganta, J., Williams, A. M., & Oliveira, J. (2011). Representativeness of offensive scenarios to evaluate perceptual-cognitive expertise of soccer players. In 3rd International Congress of Sports Games. Faculty of Sport, University of Porto. Porto.

Abstracts in Proceedings

Casanova, F., Oliveira, J., Williams, A. M., & Garganta, J. (2009). Excelência e performance perceptivo-cognitiva no Futebol. In Abstracts Book of the II International Congress of Team Sports, 5F. University of Corunha, Corunha.

Casanova, F., Oliveira, J., Williams, A. M., Garganta, J. (2010). Validation study of attacking scenarios to evaluate perceptual-cognitive expertise of soccer players. In the Second World Conference Book of Science and Soccer (abstract number 125). Nelson Mandela Metropolitan University, South Africa.

Casanova, F., Garganta, J., Williams, A. M., Oliveira, J., Barreira, D., & Brito, J. (2011). Validation of offensive scenarios to evaluate perceptual-cognitive skills in soccer. In Abstracts Book of the VIIth World Congress on Science & Football, 8 (suppl. 1): 166. Nagoya, Japan.

Appendix 2.

FACULTY OF SPORT – UNIVERSITY OF PORTO

Center of Research, Education, Innovation and Intervention in Sport

REPRESENTATIVENESS OF THE OFFENSIVE SCENARIOS

NAME:______________________ LICENCE:_________ EXPERIENCE:________

Clip	**Likert Scale**				
	Totally Disagree	Disagree	Neither Disagree or Agree	Agree	Totally Agree
01					
02					
03					
04					
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Appendix 3.

LIVERPOOL JOHN MOORES UNIVERSITY

School of Sport and Exercise Sciences

PARTICIPANT INFORMATION SHEET

Title of Project: Specific perceptual-cognitive expertise in soccer players

Researcher: Filipe Casanova

Supervisor: Professor A. Mark Williams

Please take time to read the following information. If you do not understand or if you would like more information, then please ask to the researcher.

The purpose of the study is to examine game intelligence skills in football, such as anticipation and decision-making, during pre and post fatigue situations. The scientific term for these skills is perceptual-cognitive skills. We will examine the relative interaction between each these skills and if they are influenced by different states of fatigue. The findings from this study will contribute our understanding of expert performance during a football match.

Participation in this study is voluntary. You have the right to withdraw from the study at any time without prejudice.

The experiment itself will be approximately 210 minutes (fatigue state- specific-soccer protocol) in duration. A number of video clips of 11 v 11 match-play that have been filmed from above and behind the goal giving you a birds-eye view of the game from a defender's perspective- red team. Each trial will last approximately 5 seconds. The trial will end when a black screen with "RESPOND NOW" appears. The last frame of each trial will show the player in possession of the ball about to either do pass, shoot at goal or retain possession. When that image disappears and the black screen appears, you will be required to provide a verbal report at the first, fifth and tenth clip.

Prior to the experiment you will undertake approximately 30 minutes of training on how to provide verbal reports.

The supervisor has ensured that the premises to be used for this study are appropriate and that any potential risks for you have been minimised. As a volunteer in this study you will incur no cost. The results of this study may be published in the public domain.

Your confidentially will be maintained at all times. To achieve this we will use a coding system to identify you, rather than your name. All information related to the study will be locked in a secure cabinet and will only be available to the principal researcher.

Contact Details of Researcher

Filipe Casanova

School of Sport & Exercise Sciences

The Henry Cotton Campus,

15-21 Webster Street,

Liverpool, L3 2ET

+351 912 787 206

F.Casanova@ljmu.ac.uk

Appendix 4.

LIVERPOOL JOHN MOORES UNIVERSITY

School of Sport and Exercise Sciences

CONSENT FORM

Title of Project: Specific perceptual-cognitive expertise in soccer players

Researcher: Filipe Casanova

1. I confirm that I have read and understand the information provided for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and that this will not affect my legal rights. ☐

3. I understand that any personal information collected during the study will be anonymised and remain confidential. ☐

4. I agree to take part in the above study. ☐

Name of Participant (full name)*	Date	Signature
______________________	____________	____________

Name of Researcher	Date	Signature
Filipe Casanova		
______________________	____________	____________

**please print in block capitals*

Note: When completed 1 copy for participant and 1 copy for researcher.

Appendix 5.

LIVERPOOL JOHN MOORES UNIVERSITY

School of Sport and Exercise Sciences

Football Experience Questionnaire

What is your name?

____

What is your date of birth?

____

Current team(s) played for and level?

____

___years old when you first started playing any type of football (i.e., first kicked a ball) ___have never done it

___years old when first played in an organized youth football league ___have never done it

___years old when first took part at youth County level ___have never done it

___years old when first took part at School of Excellence level ___have never done it

___years old when first took part at Academy level ___have never done it

___years old when you first started playing adult amateur football ___have never done it

___years old when you first started playing semi-professional football ___have never done it

___years old when you first started playing professional football ___have never done it

___years old when last took part at School of Excellence level ___have never done it

teams (and duration): _________________________________ ___still playing

___years old when last took part at Academy level ___have never done it

teams (and duration): _________________________________ ___still playing ___years old when last played adult amateur football ___have never done it

___still playing

___years old when first took part at adult County level ___have never done it

___still playing

___years old when you last played semi-professional football ___have never done it

teams (and duration): __________________________________ ___still playing

___years old when you last played professional football ___have never done it

teams (and duration): __________________________________ ___still playing

Have you played (or are playing) any other sports regularly? Please list (and level):

____

____

Appendix 6.

LIVERPOOL JOHN MOORES UNIVERSITY

School of Sport and Exercise Sciences

VERBAL REPORTS SCRIPT

(Adapted from Ericsson & Kirk, 2001)

Researcher: ***Filipe Casanova***

Liverpool, June 2009

I) INTRODUCTION

First of all, I would like to thank you for taking part in this research study. **Before we begin the experiment, please can you read participation sheet and then sign the consent form.**

As you have read in the information sheet, the main purpose of this study is to examine game intelligence skills in football, such as anticipation and decision-making, under pre and post fatigue states using a specific-soccer protocol. In this experiment you are going to watch a number of short 11 v 11 football clips on the life-size video screen. The following clips are filmed from above and behind the goal giving you a birds-eye view of the game from a defender's perspective – red team. After the first, fifth and tenth trials you will be required to provide a verbal report on the actual thought that you have out loud.

So, you are going now to receive training on how to provide verbal reports before we begin the experiment. These instructions will be read out for you from a pre-written script.

II) GENERAL INSTRUCTION

I will start by familiarising you with the procedure for giving verbal reports. We are interested in knowing your thoughts as you come up with the answers to the problems in this experiment. In order to do this, I'm going to ask you to think aloud as you work on the answers to some practice questions. What I mean by "think aloud" is that I want you to say your thoughts out loud from the moment you finish hearing a practice question or after viewing a video clip, until you say the final answer. I would like you to talk aloud as much as you comfortably can during that time. Don't try to plan or explain what you say. Just act as if you're alone and speaking to yourself. Keep talking while you're coming up the answer to each question. **If you're silent for a long time, I'll remind you to think aloud**. Do you understand what I'd like you to do? We'll begin with a practice question. First, listen to the question, and then answer it as soon as you can. If the answer comes to mind immediately, just say it. Are you ready? This will be a letter task.

QUESTION 1: ***What letter comes immediately after A? <response>***

Ok. It's likely that the answer **"B"** occurred to you as soon as you heard the question, yes? You probably didn't have to really think about it. Consequently, there wouldn't have been any other thoughts that you could or should have reported besides the letter **"B"**. When I ask a more difficult question, the answer won't always occur to you as quickly or as easily. You'll have to think about it before you find the answer, so there will be thoughts that you should report besides the answer, and I want you to think those thoughts out loud as they occur to you. Listen to the next question and try to generate the answer as soon as you can. If thoughts occur to you as you're coming up with the answer, say them out loud. Is that clear? Are you ready?

H; I; J; K; L

QUESTION 2: ***What is the fourth letter <u>after</u> H? <response> "Think Aloud"***

Thank you. **Now I want to see how much you can remember about your thoughts**, those intermediate steps you went through in your mind, as you answered the last question.

Do you remember the exact thoughts you had while answering **"What's the fourth letter after H?"** ***<response>*** Thank you.

Can you recall any other thoughts? ***<response>*** How did your thoughts differ when solving this question compared to the previous question (What letter comes immediately after A)?

So, to clarify, in the **"*letter after A*"** question, you thought of the answer **"B"** without any additional thoughts, right? ***<response>*** But in the **"*fourth letter after H*"** question, you reported the actual thoughts you had while getting to the answer **"L"** ***<response>***.

When you report your thoughts after the task this is called a "retrospective report". When giving this type of report don't try and guess what you might have been thinking about. Also, don't try to summarise your actual thoughts. **Tell me only the actual thoughts you can recall, and are confident that you had during the task**. Begin your retrospective report by recalling the first thought that you can remember after hearing the question, then move on to the following thought, then the next, and so on. Let your recall follow the sequence of actual thoughts**.**

(**Experimenter**: Use the participant's **actual response** when illustrating the retrospective report in the next sentence.)

For example, if your actual thoughts when finding the **fourth letter after H were H, followed by I, J, K, and then L**, **then your retrospective report**

would be H, I, J, K, L. It's likely that your retrospective report will be very similar, if not identical to, the thoughts you reported while solving the problem. Don't worry about repeating the information again. We're interested in knowing as many specific thoughts as you can actually recall. It is not necessary for you to restate the question; we are only interested in the thoughts that followed it.

Let's try another question. Think aloud while you generate the answer, then immediately start giving me a retrospective report starting with "**The first thought I remember was,**" as long as you can recall at least one thought. Otherwise say, "**I can't recall any thoughts.**" Are you ready?

N; O; P; Q; R

QUESTION 3: ***What is the fourth letter <u>after</u> N? <response>***

Please give a retrospective report starting with "**The first thought I remember was,**".... Thank you. Can you recall any other thoughts?

Experimenter: Use the participant's **actual reports** when illustrating the difference between summarizing and reporting actual thought sequences in the next sentences.

If you **had summarized** your thinking during the last question rather than reporting the sequence of actual thoughts, you **(might have)** said that you found the letter **R** by **counting through the alphabet**. But, when people solve this problem out loud, **they usually say a sequence of individual letters**, such as "N, then O, P, Q, before the answer, **R**". In this case, their retrospective **report would have been just N, O, P, Q, R**, since those were their actual thoughts while solving the problem. Because we are interested in knowing the thoughts you had as you answered the question, **we would like to have the most detailed report of thoughts you can accurately recall, instead of a summary of those thoughts**. To make sure that you fully understand, can you please explain the **difference between summarizing and reporting your thoughts**?

Experimenter: If the point still isn't clear after the subject has answered, use the example of their think aloud report: "**M, N, O, P, Q, R**" compared to "**counting through the alphabet: summary**".

One more point about reporting sequences of thoughts: If I asked you "Which is the third letter following A?," you might try to think of something and come up with D. You might remember thinking A and then D, but feel unsure of whether some thought occurred in between. In that case, you'd only report A and D. On the other hand, if you had answered the question by thinking A followed by B and then C and then D, you would report A, B, C, D. Only if you can distinctly recall thinking a thought should you report it. Try to report as many thoughts as you accurately remember. Don't report unclear thoughts or thoughts you think you may have had.

Now I will give you a few more practice questions before we begin the video-based practice and the main experiment. Think aloud while you generate the answer, then immediately start giving me a retrospective report starting with **"The first thought I remember was…"** …that is, as long as you can recall at least one thought. Otherwise say, **"I can't recall any thoughts"**. Are you ready? ***<response>***

I'm going to show you some dot grids and then I'll ask you a question.

QUESTION 4: <Present the 18-dot grid> How many dots are there? <response>

Start with **"The first thought I remember was…"**. Thank you. **Can you recall any other thoughts? *<response>* Any questions? *<response>***

Experimenter:

1. **Summarising only:** Show the grid again and restate their think aloud report as an example of their actual thoughts while answering the question. Contrast with think aloud report if they re-summarise.
2. **Combination of summarising and reports:** Ask if they can tell which parts of their retrospective report are summary and which are actual thoughts.
3. Think aloud **report** = **accurate** reflection of thoughts: Retrospective report should closely resemble it.

(Follow the same procedure when answering the following question)

Ok. Next question. Remember to think aloud, then immediately recall your thoughts starting with **"The first thought I remember was…".** Are you ready? ***<response>***

QUESTION 5: < *Present the 2-dot grid* > *How many dots are there? <response>*

“The first thought I remember was…”

Thank you. Ready for another? ***<response>*** Remember to think aloud as you answer it, then give a retrospective report.

QUESTION 6: ***< Present the 27-dot grid > How many dots are there? <response>***

“The first thought I remember was…”

Ok thanks.

Let's try this problem. ***Again, think aloud then give a retrospective report after answering the question. Are you ready? <response>***

Here is another practice problem before the video-based practice.

(Experimenter: Decide whether to use extra practice problems).

Please think aloud as you answer it, and then give a retrospective report.

Jan; Jun; July

QUESTION 7: How many months begin with the letter J? <***response***>

“The first thought I remember was…”

Thanks.

Note: The retrospective report was very similar, if not identical to, the thoughts you reported while solving the problem **as well as** was also a very detailed report of the thoughts you had while getting to the answer. So, this is what we would call an ideal retrospective report.

EXTRA GENERAL PRACTICE TRIALS

1. *How many days of the week end in Y?*

2. *What is the second letter <u>before</u> G?*

3. *What are examples of three different team sports?*

4. *What are three animals that you would expect to find in the zoo?*

Any questions?

SHORT BREAK

III) INTRODUCTION TO THE TASK & PRACTICE / TEST TRIAL

<u>VIEWING PERSPECTIVE</u>

You are now going to watch a short 11 v 11 football clip on video. The following clips are filmed from above and behind the goal giving you a birds-eye view of the game from a defender's perspective.

All of the sequences of play are ending to attack the goal at the bottom of the screen, but they could begin with your team in the possession of the ball *(indicate direction of play manually on screen)*. In the practice trial, as we have mentioned, your team are defending (up screen). For the moment, I want you to imagine that you are a defender –red team. I want you to actively scrutinize the game in the same way as you would if were playing rather than as a passive spectator. OK so far? ***<response>***

Start by watching the action clip, which is approximately 5 seconds long. To help orientate you to the action, just before the start of each clip a small circle surrounding de ball appears on screen to indicate the area of is first appearance. The clip will unfold, and then it will end with the player in possession of the ball about to either do pass, shoot at goal or retain possession, at which point, the screen will turn to black. Have you got that? **<response>**

When the black screen appears, you must immediately have to give:

(Retrospective Report)

The first task is to give as soon as possible a retrospective report, starting with **"The first thought I remember was …"**

(Anticipation task – What happens next?)

The second task is to indicate what you think the player in possession of the ball *actually did* next. For example, did he pass? If so which player did he pass to? Or did he shoot or retain possession? I'll help you to clearly mark your answers as we go through. OK? Any questions so far? ***<response>***

PRACTICE TRIAL

We'll try the first practice trial with a verbal reporting. There is no pressure, we will run through this trial again anyway. I'll prompt you as we go through. But, firstly remember to:

1. Watch the clip from a defensive perspective

-----Screen blank – ***Pause*** – Blank replica--------

2. Report verbally only the actual thoughts you can distinctly and confidently recall. Try to report as many thoughts as you can accurately recall in sequential order, starting with **"The first thought I remember was …".**

3. Highlight what actually happens next (**P**ass, **R**etain possession, **S**hoot)

Are you ready for the first practice trial? <*response*>

Trial 01: ***< Play practice trial 01 now >***

1. Watch the clip from a defensive perspective

-----Screen blank – ***Pause*** – Blank replica--------

2. **"The first thought I remember was …".**
3. Highlight what actually happens next (**P**ass, **R**etain possession, **S**hoot)

   Thanks. Any questions? **<*response*>**

(***Experimenter***: CHECK SUMMARY v REPORT or EXPLAINING/COMMENTARY)

< Present checklist to participants >

Checklist:

<u>Things to remember or do whilst watching the game and solving these problems:</u>

1. Immediately after the clip has finished, give a retrospective report.
2. Report **only** the actual thoughts you can distinctly and confidently recall
3. Don't report unclear thoughts or thoughts that you think you may or should have had.
4. Don't worry if your thoughts sound illogical, incoherent, or ungrammatical.
5. Try to report as many thoughts as you can accurately recall in sequential order, starting with the first thought you can remember.

IV) TEST VIDEO:

Test Trials 1 – 10; 11 – 20; 21 – 30; 31 - 40:

Team attacking the goal - Black, Team defending the goal - Red. You are a defender

The test is exactly the same as the last practice trial. To summarise everything you need to do: View the clip from a defenders perspective, if you feel more comfortable think aloud whilst you watch the action unfold do it. When the screen went black give us a retrospective report starting with **"the first thought I remember was…"**. Then indicate us what did you think actually happened next or which are the best options for the player in possession. Continue to think aloud throughout each of these tasks.

Any questions? Remember to give a retrospective report before you've completed the tasks. Ready for the first test clip?

<Play video clip>

1. Watch the clip from a defensive perspective

----Screen blank – ***Pause*** – Blank replica------- PROMPT TO THINK ALOUD

2. Retrospective report:
   Start with **"the first thought I remember was…".**

3. What actually happens next? (**P**ass, **R**etain possession, **S**hoot)

----------------------- Freeze frame ------------------

Thank you. Can you recall any other thoughts? **<response>**

****

That's the end of the session! Thanks for participating.