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Attention allocation in elite football refereeing: conceptual, empirical, and applied considerations*

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ABSTRACT

Football referees at the elite level are required to meet high-performance standards, physically, behaviourally, and mentally. These may pose considerable cognitive load which necessitates expert ability of gaze behaviour, perception, and attention allocation. In this article we aim to model the array of professional and psychological factors that impact referees' performance, leading to optimal and non-optimal performance states. We initially discuss the cognitive demands of football refereeing. The structure of this article is as follows: (a) defining the demands of refereeing task; (b) providing the conceptual basis for understanding the attentional process within the football refereeing context; (c) reviewing empirical data concerning several potential factors influencing attention in football refereeing (i.e. gaze behaviour, inattentional blindness, external distractors, pressure, exertion, self-control, and VAR); (d) modelling attention allocation in football refereeing under normal and highly demanding match conditions; (e) providing practical recommendations for improving refereeing attentional performance, and (f) offering specific suggestions for future research in this area.

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Cognitive load; soccer; officials; gazing behaviour; exertion; self-talk

Elite football (soccer) referees have a complex task. They must be sufficiently fit to meet the high physiological demands to be able to keep up with the players' exceeding pace (Bloß et al., 2020; Weston et al., 2012). They face hundreds of decision moments per match (e.g. Neville & Salmon, 2016a), related to field position, visualisation fixation, and match infringements, and then execute these decisions using technical protocols (e.g. whistling, issuing sanctions, managing free kicks and penalties; see Samuel et al., 2021). Also, they need to apply game-management strategies (Raab et al., 2021) and engage in verbal and non-verbal management of all match stakeholders, including players and coaches, while also making executive decisions concerning crowd irregular behaviours (Cunningham et al., 2018). Likewise, they need to communicate and manage the referee team and interact effectively with the video assistant referee (VAR; see Aragão e Pina et al., 2021; Sánchez Cid & García García, 2020). On top of these match-related demands, as elite performers, they also need to self-regulate and control their physiological, mental, and emotional states (Samuel et al., 2018).

As the attentional demands of the refereeing task are high, an important question is: How exactly elite football referees are able to simultaneously engage in running, gazing, anticipating, and detecting potential events/infringements while under considerable physical and mental strain? In this article, we attempt to address this question by reviewing conceptual and empirical knowledge on football refereeing, to provide evidence-based information for both researchers and practitioners who support referees. The structure of this article is as follows: (a) defining the demands of refereeing task; (b) providing the conceptual basis for understanding the attentional process within the football refereeing context; (c) reviewing empirical data concerning several potential factors influencing attention in football refereeing (i.e. gaze behaviour, inattentional blindness, external distractors, pressure, exertion, self-control, and VAR), (d) modelling attention allocation in football refereeing under normal and highly demanding match conditions; (e) providing practical recommendations for improving refereeing attentional performance, and (f) offering specific suggestions for future research in this area. It should be emphasised that we conducted a

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*The authors confirm that the data supporting the findings of this study are available within the article.

narrative review, not a systematic review of the literature on attentional processes in football referees. Furley and Goldschmied (2021) commented that narrative review is (a) a valid method to establish an authoritative argument that consists of published primary evidence and to enhance understanding of a topic and theory development and (b) it may or may not use systematic search methods with fixed inclusion/exclusion criteria. Thus, our aim was not to identify all research about football refereeing but to present the research that is relevant for understanding the role of attention allocation in football refereeing, including the potentially associated factors.

Cognitive demands of football refereeing

Elite football referees have two main tasks, namely decision-making (DM) and game management (Samuel, 2020). Considering the first task, Samuel et al. (2021) presented a model of DM in football refereeing, according to which referees engage in a repetitive and sequential DM process throughout the match. In each event/infringement, referees go through a series of decisions and actions, including (1) where to run (positioning)? (2) where to gaze? (3) what to anticipate? (4) identifying the event/infringement, (5) what to call? (6) keep or change my decision? and (7) execute the decision. The model further specifies the operational mechanisms and influencing factors associated with each decision/action.

The referee begins this DM process in each match attack by deciding where to run and position themselves on the field of play. They typically use a diagonal pattern to cover the field, but this might change based on the tactical arrangement of the teams and how the match is played. Considering that referees might have several visual search strategies, they then scan the field of play, looking for the attacking and defensive players. Specifically, they estimate who has an advantage over the other, anticipating one-on-one moves, attacking passes, and also defending moves. Then, they shift their attention to identifying potential infringements (i.e. fouls, handballs). When such an infringement occurs, they would need to decide whether it constitutes a foul or other violation of the "Laws of the Game" (IFAB, 2023) or not, and whether they should issue a card, and which card (i.e. yellow, red). Then, the VAR would replay the event and recommend to on-field referee whether to open an "on-field review" or to maintain the original decision. Then, the referee executes the relevant match protocols, for example, a free kick or a penalty kick. Referees execute this sequential decision process repeatedly throughout the match, over potentially hundreds of events/infringements. This can potentially result in fatigue, both physically and mentally as the match develops (Samuel et al., 2024). However, the evidence concerning these effects remains inconclusive, especially with regard to internal loads of mental fatigue (Bloß et al., 2020).

As part of the sequential DM process, referees need to encode the relevant environmental cues by applying perception and attention strategies (i.e. visual scan, attentional focus, anticipation of events). Also, they must process complex information through an ongoing interaction between working memory and long-term working memory (LTWM; Ericsson & Kintsch, 1995) to induce action-related DM. Finally, they need to execute their actions while maintaining optional modifications, e.g. changing one's call when the VAR intervenes (see Samuel et al., 2021). Indeed, research supported the idea that experienced referees show better DM-related skills, as well as general accuracy levels, than less experienced referees or novices (MacMahon et al., 2015; Spitz et al., 2018).

The second task of football referees is to control and manage the game (Raab et al., 2021; Samuel, 2020). Expert referees tend to make decisions that are specifically appropriate for the match, allowing it to flow and intervening only when the consequences of not doing so may adversely affect the game (Mascarenhas et al., 2002). In two experiments, Unkelbach and Memmert (2008) showed that the referees used both calibration of the fouls' scale and deliberate game management in their issuance of yellow cards. Russell, Renshaw, et al. (2019) added to this line of work by investigating referees' perceptions about their use of DM strategies. Their analysis revealed that DM were used strategically to maintain control of the game and to preserve the integrity of the game, through four "pillars" of the game – safety, fairness, accuracy, and entertainment – which varied in importance depending on the state and context of the game. So, for example, a yellow card issuance might not only relate to making an "accurate" decision but is also, as a game management technique, related to the referee's aim to avoid other unwanted outcomes in the game.

As part of their game management, referees communicate with the players and coaches (Schnyder & Hossner, 2016; Slack et al., 2013). Cunningham et al. (2018) suggested that referees communicate under time pressure in dynamic circumstances that demand spontaneous responses to players. They showed that referees adapt and modify their on-field identity and messages (i.e. maintaining various social "faces") appropriately for different players and contexts, by (1) anticipating players' reactions and modifying the presentation of one's social self, (2) asserting and preserving the referee's own social "face", and (3) giving and restoring players'

social "face". Therefore, much of the referee's attention is allocated to managing the game, through identifying contextual factors and through communicating with players, coaches, and the referee team.

Recently, two models were suggested in an attempt to account for the two refereeing tasks (i.e. DM and game management). Raab et al. (2021) developed a threshold process model for DM in sport games. This perspective considers the importance of context in refereeing (e.g. the score, the time of play) as well as individual differences among referees in rule application (e.g. a "law enforcer" referee vs. a "game manager" referee). According to this model, referees use a subjective threshold to apply game management, which may explain their DM behaviour. If game dynamics require a stricter application of the rules, then the referee is under the threshold of applying game management. However, as soon as a subjective threshold is met, referees apply game management to either let the game flow (e.g. less stoppage of the match) or if aggression increases – make a call earlier (e.g. using preventive refereeing or an earlier foul call). Likewise, Schrödter & Klatt (2022) introduced a decision-flow model consisting of three stages that affect each other: (1) The referee's fast, intuitive decision after a situation, (2) the referee's slow, deliberative evaluation of the decision, and (3) the chosen compensation if, in retrospect, the previous decision is considered an error by the referee. If the referee decides to compensate with consistency, the calibration of the judgment scale must be adjusted, and by doing this, the game manager consciously influences future intuitive decisions.

In a nutshell, the football refereeing task is highly demanding from an attentional standpoint, as these performers must balance between law enforcement and game management while under physical and mental strain (Samuel, 2020). This entails attention allocation between various task demands which can certainly account for errors when making decisions concerning low infringement and players' disciplinary behaviours. Following, we discuss several conceptual frameworks that can account for referees' attentional processes.

Conceptual frameworks of attention

In this article, we focus on elite football refereeing, and not on refereeing in general or amateur football refereeing. To this extent, research suggests that perceptual-cognitive skills in sports are task-dependent and skill-level related (Brams et al., 2019; Ziv et al., 2020). Therefore, it was suggested that elite football refereeing is different than other refereeing tasks (e.g. basketball or volleyball refereeing), in both the task demands and the referees' skill set (Samuel et al., 2021). Therefore, a conceptual framework on football refereeing must be relevant to account for the demands of the task and the skill set of these unique performers. As Furley and Wood (2016) suggested after reviewing several theories of attention in the sports domain: "Every sport is different and will require a different skill set and therefore different abilities might be beneficial for performance" (p. 421).

According to Moran (2014), attention refers to "the process of exerting mental effort on specific features of the world around us or on our own thoughts and feelings" (p. 39). The main dimensions of attention are selective attention (i.e. the referee's perceptual ability to zoom in on task-relevant information while ignoring distractions), divided attention (i.e. the referee's ability to coordinate two or more actions at the same time), and concentration (i.e. a referee's decision to invest mental effort in what is most important in any situation). In fact, football referees use all three dimensions as part of their performance, as they need to select which environmental (e.g. where are the players and the ball are located) or internal (e.g. strategy, fatigue) cues to attend, they need to allocate attention between several concurrent actions (e.g. running purposefully to a location, gazing and scanning the environment, cognitive processing and scene meaning, communicating internally and externally), and upon identifying an event/infringement they must concentrate to produce the most appropriate decision for the match context.

It was further suggested that sports performance expertise is associated with the development of "psychomotor efficiency" (also known as neural efficiency) – the cortex becomes relatively quiescent, thus minimising interference with the central neuromotor processes (see Filho et al., 2021; Hatfield, 2018; Hatfield et al., 2020). However, under the mental stress of performing in a social-evaluative environment, the brain might revert to heightened cortical activity and elevated connectivity, possibly due to "overthinking" or "reinvestment of attention" (see Bertollo et al., 2016; Masters & Maxwell, 2008). It appears that stress manifests as heightened cognitive load, which can alter the quality of motor performance (Filho et al., 2021; Hatfield et al., 2020). Therefore, according to this view, elite referees perform much of their habitual on-field behaviours with little or no conscious effort, including running, positioning, and signalling. However, under high stress, they must divert more attention to running, positioning, and signalling, and this may debilitate their DM and game management efforts.

Filho et al. (2021) conducted a meta-analytical review and concluded that the effective execution of highly complex tasks required both the downregulation (quiescence of irrelevant areas of the brain, i.e. *neural*

efficiency) and the upregulation (activation of relevant neural networks supporting task execution, i.e. *neural proficiency*) of the brain. In complex tasks, such as elite refereeing, the cognitive demands of the control systems involved in the task will influence referees' efficient and effortful processing during performance. Therefore, under conditions of fatigue or emotional stress (i.e. internal distractors) or if the match difficulty is high (i.e. external distractors), we might see a reduction in referees' ability to efficiently allocate their attention and produce on-task focus, potentially leading to erroneous DM.

Another relevant framework to football refereeing is attentional control theory: sport (ACTS, Eysenck & Wilson, 2016) that expands Attentional Control Theory (ACT, Eysenck et al., 2007). Attentional control refers to the goal-directed allocation of cognitive processing resources to internal and external stimuli. ACTS distinguishes between performance effectiveness (e.g. the referee's correct decisions) and processing efficiency (e.g. how mentally fatigued the referee is). Processing efficiency can be reduced by worries or performance concerns (e.g. the referee is concerned about making a DM error and attracting public scrutiny). It is suggested that anxiety impairs processing efficiency more than performance effectiveness, as anxious referees would often try to compensate for the negative effects of pressure on processing efficiency by utilising additional processing resources or effort (e.g. run more effectively, communicate better with the assistant referees). Moreover, ACTS suggests that human behaviour is controlled by two attentional systems: (a) a goal-directed attentional system used in the top-down control of attention and involving the prefrontal cortex, and (b) a bottom-up system that is guided by salient stimuli in the environment (Eysenck & Wilson, 2016; Furley & Wood, 2016). Performance pressure causes an imbalance between these two systems in favour of the bottom-up system, which can probably be considered an evolved mechanism intended to detect threatening stimuli (Eysenck et al., 2007). ACTS further suggests that inefficient attentional control is sporadic and is most likely to occur at those moments in the match associated with the highest levels of anxiety (e.g. immediately after making a wrong critical decision that is overturned by the VAR). Thus, it is expected to notice much performance variability among elite referees in big matches with high pressure.

A final assumption of ACTS is that many negative effects of anxiety on processing efficiency are mediated by the working memory system, specifically the central executive (Eysenck & Wilson, 2016). This system includes the *inhibition function* that allows referees to prevent irrelevant stimuli or responses from influencing performance (e.g. not getting distracted by the sound of the crowd when making a critical decision) and the *shifting function* that allows referees to optimally allocate their attention within and between tasks (e.g. running, positioning, and scanning the field of play). Related to these executive functions is the elite referees' ability to shift their attention to relevant match cues (e.g. the contact between the defender's leg and the striker's foot) through the activation of a quiet eye (Vickers, 2007). In fact, it was found that performance in many sports (e.g. basketball, football) is more effective when the quiet-eye period is of sufficient length to ensure effective motor programming and control (Lebeau et al., 2016). ACTS predicts that anxiety should reduce the duration of the quiet eye and so impair performance (Eysenck & Wilson, 2016).

Finally, according to Eysenck and Wilson (2016), expert performers (e.g. elite football referees) should have attentional control superior to that of non-expert ones (e.g. amateur football referees). For example, experts have faster first fixations on task-relevant information and fewer fixations on task-irrelevant visual areas, suggestive of more efficient attentional control (Gegenfurtner et al., 2011). Also, expert sports performers should have a more efficient shifting function than non-expert ones (Han et al., 2011). Nevertheless, in their review of attention models in sports, Furley and Wood (2016) concluded that "currently the evidence does not suggest that superior attentional control capacities significantly contribute to sport expertise" (p. 421).

In the last decade we have witnessed the integration of dual-processing frameworks of attentional control into the sports domain (see Furley et al., 2015). It was suggested that skilled sports performers are required to alternate between different modes of processing to meet the complex demands presented by performance environments. Within this line of thought, the default-interventionist model (Evans & Stanovich, 2013a, 2013b) is an attention framework that is relevant for understanding football refereeing (e.g. Helsen et al., 2019). Initially, Evans and Stanovich (2013a) proposed two distinct types of cognitive processing, namely Type 1 and Type 2. Type 1 processes are intuitive and autonomous; they are initiated and completed in the presence of relevant triggering conditions and do not require working memory. The response to a situation/problem has become part of its cognitive representation resulting from learning experiences. Type 1 processing efficiency stems from its fast and effortless execution of behavioural responses and the integration of a large amount of information. It is not an efficient solution for novel problems though, such as adjusting the referee's tactical approach to a match. Type 2 processes are

reflective and controlled (i.e. require effort and time) and require working memory for hypothetical thinking and mental simulation. For example, to override a triggered response or to offer a new solution to a first-encountered problem (Furley et al., 2015). Following, Evans and Stanovich (2013a, 2013b) suggested that Type 1 processing is the default mode; always activated when the individual is confronted with a given situation or problem.

In sports contexts, Type 1 processing is efficient in the automatic activation of well-learned motor skills (i.e. procedural knowledge) which leads to a desired outcome. Type 1 processes are distinguished from Type 2 processes by the assumption that the response/solution to a problem has become part of its cognitive representation. For example, when the ball crosses the goal line near the corner area, a skilled referee would almost automatically know how to differentiate between a corner and out-of-play. The solution to the problem is triggered by the context of the match event, without requiring further controlled processing on behalf of the referee, as it is part of the cognitive representation of that problem – knowing the difference between the two decisions (Furley & Wood, 2016). Sports performers direct much of their training to consolidate their motor programmes so their behavioural execution is automatic (Schmidt & Wrisberg, 2004).

Type 2 processing is only additionally activated when Type 1 processing does not reach a solution or when there is additional contextual information. In football refereeing, much of the referee's task is actually dependent on Type-2 processing (i.e. identifying changes in the team's tactics, DM, game management). For example, football referees typically run in a diagonal pattern, crossing the field from one left side of the goal zone to the other (Samuel et al., 2021). This is their habitual behaviour that is automatic and does not require much effort. However, when the referee identifies (i.e. requires tactical awareness and reflective thinking) that much of the attacks of one of the teams are conducted on the right side of the field (i.e. new contextual information), her or she must break their habitual diagonal running, and use a more flexible running pattern, which requires the application of Type-2 processing (Furley et al., 2015).

We propose that the default-interventionist model (Evans & Stanovich, 2013a, 2013b) aligns well with Samuel et al.'s (2021) model of sequential DM in football refereeing, as referees use both Type-1 and Type-2 processing when performing. Specifically, referees rely on their expertise to execute some of the sequence almost automatically and with low mental effort (e.g. running form, positioning, signalling), mostly activating Type-1 processing. For example, when the referee assistant is deciding on out-of-play, the referee simply signals the direction of the play, without investing much effort. Referees shift to more controlled and effortful Type-2 processing when they: (a) need to make conscious decisions about their positioning, e.g. if it is not a typical diagonal pattern; (b) decide on match infringements, e.g. a reckless foul, a penalty; (c) become aware of the contextual situation (e.g. the underdog team is leading and stalling time) and adapting their tactical approach; and (d) actively manage the teams.

It should be acknowledged, however, that while the sequential model of DM (Samuel et al., 2021; Tenenbaum, 2003) uses the concept of LTWM to explain how referees overcome their limited working memory capacity, the default-interventionist model (Evans & Stanovich, 2013a, 2013b) does not refer to LTWM. Instead, the latter model suggests that Type-1 processing is associated with high memory capacity and Type-2 processing is associated with limited memory capacity. Moreover, these frameworks would also provide different explanations of referees' DM errors. In the sequential model of DM, errors might stem from poor decisions made in any stage of the sequence, for example, when referees do not position themselves in an angle that allows clear sight of the match infringement or if they do not match well enough between the event and the relevant low criteria (Johansen & Erikstad, 2021; Samuel et al., 2021).

It is also important to note that referees' ability to retrieve information using LTWM could be affected by their current stress levels and fatigue (i.e. physical and mental) as well as by environmental stressors, such as crowd noise and extreme weather conditions (Bloß et al., 2020; Gaoua et al., 2017; Picazo-Tadeo et al., 2017). Alternatively, in the default-interventionist model (Evans & Stanovich, 2013a, 2013b), referees' DM errors would most likely stem from the referee's inability to adapt to the match context and actively shift from Type-1 to Type-2 processing, thereby maintaining some stagnation to changes in the match (see Samuel et al., 2023 on fast adaptation in sports). Additional research is required to determine the thought processes of elite referees under different personal conditions and match contexts. Brain-related research (e.g. using EEG and fMRI) is particularly relevant to indicate when and how referees use the different neural networks (Furley et al., 2015).

Factors related to attention in football refereeing

In this section, we discuss several factors that were identified as related to referees' attentional processes (1) gaze

behaviour, (2) external distractors, (3) inattentional blindness, (4) pressure, (5) exertion, (6) self-control, and (7) the VAR. Similar to our conceptual analysis, we focus only on factors and relevant studies that examined football referees (see MacMahon et al., 2015; Samuel et al., 2021).

Gaze behaviour

Football referees substantially rely on visual information for their DM process (Samuel et al., 2021). Systematically reviewing 36 studies on gaze behaviour in sports, Brams et al. (2019) found that irrespective of the task, experts were more accurate and/or generated faster responses than their non-expert counterparts. Experts made more fixations and dwelled longer on relevant areas of interest than non-experts and they were also better at ignoring irrelevant areas of interest. Within this context, achieving a quiet eye (Vickers, 2007), and the ability to fixate on relevant environmental cues seem to be an important skill in football refereeing. Research found that expert referees use more effective gaze strategies than non-experts (e.g. they gaze toward fewer locations for a longer duration) as they select relevant information and ignore the irrelevant one (Spitz et al., 2016; Ste-Marie, 2003). Experts also use more efficient visual strategies than non-experts, such as peripheral vision, eye saccadic movements, and speed of recognition (Ghasemi et al., 2009, 2011).

Several studies evaluated football referees' gaze behaviours, most of them related to assistant referees' offside decisions (Ziv et al., 2020). For example, Hüttermann et al. (2018) suggested that when evaluating offside situations, football assistant referees (ARs) need to concurrently track all relevant players (i.e. the passer, the receiver, the line of defense) at the moment of the pass. To accomplish such a task, the AR shifts between an external wide and an external narrow focus of attention using both top-down processes – purposefully searching for desired targets as well as scene guidance – guiding attention towards potentially relevant areas of the field (see Lidor & Ziv, 2021). Using a computerised stationary setting, Hüttermann et al. (2018) showed that ARs who were more accurate in judging attention-demanding stimuli alongside the horizontal meridian of their attentional focus were less erroneous in an offside DM task. This study indicated the important linkage between attention capability and football DM performance. Still, the off-side DM performance was made with no physical or mental strain, such as fatigue, noise, or real-match stress.

Likewise, Spitz et al. (2016) examined the visual scan patterns of elite and sub-elite football referees while assessing foul play situations, using an eye-tracking monitor. Elite referees were more accurate than sub-elite referees in making a correct foul decision as well as in making a correct disciplinary decision. Also, it was found that the elite referees spent significantly more time fixating on the most informative area of the attacking player (contact zone) and less time fixating on the body part that was not involved in the infringement (non-contact zone). It was concluded that elite-level referees have learned to discern relevant from less-relevant information in the same way as expert athletes.

While Spitz et al.'s (2016) study was insightful, there were several ecological validity issues. First, as in many previous studies, the test setting involved a stationary non-stressful mode. Thus, the referees did not experience movement-related decisions or physical strain as they would in a real match. Also, the videos used were filmed from the fixed perspective of "an additional assistant referee left to the goal post". In a real match, the referees' viewing perspective is dynamic and may influence their attentional focus and consequently DM. For example, Johansen and Erikstad (2021) analysed 42 penalty decisions made by referees in the Norwegian Premier League and found that the highest rate of correct decisions was evident when the distance of the referee from the infringement was under 10 metres (83% correct decisions), in good angle (88%), and with good insight to the event (86%). In contrast, referees were poorly positioned in terms of angle and/or insight in nine of the 15 erroneous decisions made. However, the referees in Spitz et al.'s (2016) study knew they were watching clips related to foul infringements, so they could anticipate them and prepare their reactions. Moreover, there was no emotional stress involved in this test setting (i.e. no crowd, no real importance for performing successfully or poorly). Finally, the decisions were not made within a real match context including score, time of play, or previous decisions (for limitations of such conditions see Kittel et al., 2021).

More recently, aiming to overcome the above limitations, van Biemen, Oudejans, et al. (2022) examined referees' visual gaze patterns in real-life foul DM. Five elite and nine sub-elite Dutch referees wore mobile eye-tracking glasses in pre-season or mid-season real-life friendly matches, within their skill level. The researchers verified that the matches for the elite and sub-elite participants did not differ in the number of fouls per match or in-game pace. The results indicated that the elite referees were more accurate than the sub-elite referees ($87.8 \pm 10.6\%$ vs. $76.1 \pm 14.7\%$). Also, the elite referees performed significantly more fixations per second than the sub-elite referees (2.2 ± 0.06 vs. 1.7 ± 0.04). The elite referees' fixations were shorter (400 ± 18 ms) than those of the sub-elite referees (507 ± 12 ms). Hence, elite referees relied on a higher search

rate (more fixations of shorter duration) compared to sub-elites. The referees spent more time viewing the foul receiver's contact zone than all other areas of interest, except the foul committer's contact zone. However, there were no skill-level differences in gaze allocation, indicating that elites searched faster but did not necessarily direct their gaze toward different locations than sub-elites. Both elite and sub-elite referees decreased their search rate approximately 1 s in advance of the foul situation, suggesting that referees successfully anticipate the upcoming event and modify their search behaviour. Finally, correct decisions were associated with higher gaze entropy (i.e. less structure), suggesting that relying on more structured gaze patterns is associated with incorrect decisions as referees may fail to pick up information specific to the foul situation. This might indicate that rather than following a stereotypical repetitive gazing pattern, referees adjust their gaze to the unique characteristics of the match situation.

In a follow-up study, van Biemen, van Zanten, et al. (2022) analysed the visual anticipatory behaviour of four elite and eight sub-elite Dutch football referees while observing long passes on-field in real matches, using mobile eye-tracking glasses. The results indicated differences in the way that the elite and sub-elite referees tracked the ball and anticipated the outcome of the ball trajectories. Specifically, the elite referees used a lower search rate than the sub-elite referees (1.3 vs 1.8 fix/s; $p < .05$), suggesting that they were less likely to shift the direction of their gaze during the flight of the long passes. Also, the elite referees were more likely to direct their gaze toward the ball during the moment of kick (77% vs 52%; $p < .05$) and the early flight phase of the pass (68% vs 45%; $p < .05$). As a result, the elite referees produced earlier anticipatory eye movements to the player(s) receiving the ball (at 50% vs 60% of the ball flight; $p < .05$), thus facilitating the identification of relevant information about the receivers that could be important for potential infringement upon ball arrival. The sub-elite referees directed gaze towards the receiver later, and more often first allocated their gaze towards another attacker on the field other than the receiving player.

The results of the Van Biemen et al. (2022) studies provide support for the ideas advocated by Samuel et al. (2021) in that football refereeing requires an active cognitive effort. In fact, referees do not passively perceive events on the field of play, but actively seek to mentally anticipate (i.e. produce a mental probability for an event to occur) and visually search for potential events. It could be said that the elite referee is behaving almost like *a detective*, who actively seeks clues in the scene to be able to quickly interpret the situation.

Environmental distractors

Football matches are typically played in a "noisy" environment, with various auditory and visual distractors (e.g. crowd noise, pyrotechnical aids, media presence). Various studies demonstrated the potential influence of crowd noise and crowd density on referees' disciplinary decisions (e.g. Downward & Jones, 2007; Goumas, 2014; Picazo-Tadeo et al., 2017). For example, Picazo-Tadeo et al. (2017) analysed data from the Spanish La Liga between the 2022/2003–2099/2010 seasons, focusing on free-kick related foul decisions and related card bookings. Their analysis showed that on average, home and away teams were sanctioned fairly similarly by the referees (18.06 vs. 17.89 fouls per match, respectively). However, when card bookings were involved, the referees tended to issue the away team more yellow or red cards than the home teams. Furthermore, the researchers found that the size of the crowd in the stadium was significantly associated with the card booking difference. Therefore, while the referee has insufficient reaction time when calling a foul to be influenced by the crowd, once the decision was made, the referee is more susceptible to the crowd's reaction to that decision. When there is a large home crowd, the pressure on the referee increases, leading to potentially more bias in issuing cards against the away team. The authors concluded that this implies a social-pressure induced bias on the referees.

Inattentional blindness

Inattentional blindness is the incapacity to identify unexpected events in the visual field, where the attention of the individual is focused while engaging in a primary attention task. This happens because of a lack of attention which results in a perceptive error (Mack & Rock, 1998). This phenomenon is well-documented over a wide variety of lab-based and real-world settings as well as various stimuli (Ekelund et al., 2022). It has been demonstrated that inattentional blindness is significantly heightened when individuals perform under intense physical load (Hüttermann & Memmert, 2012). Also, while sport-related studies suggested that expertise might reduce the tendency to experience inattentional blindness (e.g. Furley et al., 2010; Memmert, 2006), a recent meta-analysis showed that across various domains, experts and novices differed little in rates of inattentional blindness (56% compared with 62%, respectively) and that the relevance of the unexpected stimulus to the experts' domain did not show any notable moderating effects (Ekelund et al., 2022).

Concerning football referees, using a stationary computer-based setting, Pazzona et al. (2018) showed that interregional football referees (72%) better identified an unexpected stimulus while attentive to both an easy and a difficult task, compared with referee observers (51%) or students (47%). However, the attention task was not performed under high physical or mental demands, as a real match would pose.

Pressure

Samuel et al. (2021) suggested elite football referees experience high pressure as they are under the scrutiny of professional factors (e.g. the match observer, the Referee Union Professional Committee), the sporting community (e.g. coaches, players, fans), and the media (e.g. Dawson, 2012; Johansen & Haugen, 2013; Page & Page, 2010; Schnyder & Hossner, 2016; Slack et al., 2013). For example, in a study that examined psychological issues faced by 23 European elite referees, one of the main difficulties identified for elite referees was pressure. The referees identified pressure from the media, the teams, the football association, as well as self-induced stress. Likewise, a qualitative study with 15 English Premier League referees also identified pressure as a main theme (Slack et al., 2013):

> You need to be mentally tough because the criticism you get from the media is not always positive. No one likes to hear or read negative comments about themselves. There's nothing worse than reading headlines saying "you should've done this, you should've done that" … Because it's not just the one man and his dog that reads the newspapers, it's everybody in the British Isles and sometimes the world. So there's a big pressure and a big demand from the media side of things. (p. 302).

Exertion

Several studies examined the relationship between referees' DM and physical load, as measured by indices such as match period, referee's velocity, referee's heart rate, distance covered, and lactate. Officiating at the elite level involves intense physical demands. During a competitive match, an elite referee may cover 9–13 km (4%–18% of the total distance is covered at high intensity) and reach approximately 85%–90% of maximal heart rate and approximately 70%–80% of maximal oxygen uptake. Also, blood lactate concentration has been reported to be in the range of 4–5 mmol/L (Castagna et al., 2007). Schmidt et al. (2020) suggested that when physical strain levels are high, norepinephrine and dopamine concentrations become excessive, leading to activation of lower affinity adrenoreceptors which results in reduced neuronal firing in the prefrontal cortex, potentially impairing attention and executive control. Also, referees may experience central nervous system fatigue as well as peripheral fatigue (i.e. an inability to maintain muscle power or force) that may also be associated with reduced attention performance. In addition, Gaoua et al. (2017) suggested that the thermal stress and fatigue experienced by referees in extreme (i.e. very hot or very cold) environments may further interfere with their cognitive resources such that overload may occur during hyper/hypothermia, resulting in decreased DM performance.

Samuel et al. (2019), for example, examined the usability of a DM simulator for training football referees. The refereeing task included running for 60 min (i.e. two separate 30-min sections) on a treadmill at a pace comparable to a real match while watching match events on a screen and loudly making decisions. The referees' perceived exertion increased significantly as the test progressed and their perceived exertion at 60th min was positively correlated to mental exhaustion. Also, there was a significant decrease in DM accuracy between the first and second quarters as well as between the third and the fourth quarters. The authors interpreted these results in that the referees changed from one section to another following 30 min, which challenged them to increase their concentration, and, as a result, their accuracy levels. This mental demand, together with the accumulated physical strain, subsequently resulted in a performance decrement.

Likewise, Pizzera et al. (2022) examined the influence of both physical and psychological stress on skilled and less-skilled football referees' decision-making performance while running on a treadmill and/or being exposed to auditory stress. The referees were more physically fatigued in the physical stress condition and psychologically stressed in the psychological stress condition, yet this did not influence their DM performance in the video test. Only at 60% of their VO_2max there was some reduction in DM accuracy compared with baseline level. This study, unlike previous ones, did not find an expertise advantage. However, it should be noted that the participants were not elite referees.

Schmidt et al. (2020) suggested that either the physiological stress from exercise (i.e. running, sprinting) or the psychological stressors (e.g. pressure from the crowd, self-induced pressure to be successful and not make errors) may impair attentional control leading to distractibility and difficulties in sustaining attention. These researchers examined attention performance in professional Brazilian referees ($n = 33$) and ARs ($n = 20$)

before and following a completion of a fitness test (FIFA test). Attention performance was assessed using the Continuous Visual Attention Test, which consisted of a 15-min Go/No-go task evaluating omission and commission errors, reaction time, and variability of reaction time. Before the FIFA test, all participants performed the first attention task. Those who succeeded both in the FIFA test ($n = 46$) and the first attentional test ($n = 36$) were submitted to the second attention test 3–7 min following the FIFA test (19 referees and 15 ARs). This test was conducted on the field, using a stationary computer-based setting. The results indicated that 44% (9 referees and 6 assistants) exhibited a performance decline in the second attention test. A significant increase in variability of reaction time was found after the high-intensity exercise which may reflect executive dysfunctions and lapses of attention.

Reviewing 11 studies on football refereeing, Bloß et al. (2020) found that most studies showed no relationship between physical load and referees' DM, 13 findings suggested a negative relationship and three findings indicated a positive relationship between physical load and referees' DM. Therefore, Bloß et al. concluded that the evidence concerning this relationship is still inconclusive. Most of the research examined focused on external load rather than internal load. Internal load reflects the referee's psychophysiological response to the performance external load (Impellizzeri et al., 2019), so different referees can experience the same external load (e.g. operationalised by match period) as differently exhausting (Impellizzeri et al., 2019). When considering referees' attention allocation, it is more advisable to refer to their internal load as this value can affect their ability to efficiently run while actively scanning the match scene (gazing) and making correct decisions.

Self-control

Samuel et al. (2018) suggested that football referees are challenged by physiological, professional, and mental demands that require them to exercise self-control for optimal performance. Self-control describes the ability to volitionally suppress or alter certain behavioural tendencies or impulses in order to achieve more desirable long-term goals (De Ridder et al., 2012). Acts requiring self-control in sports and exercise contexts include amongst others: attention regulation, emotion and stress regulation, physical regulation, coping with daily hassles, and DM. In sports, it has been shown that temporarily available self-control may serve as a buffer against the negative anxiety effects on subsequent motor performance (see Englert, 2016). Football referees at the elite level are under high scrutiny of professional factors (e.g. the match observer, the Referee Union Professional Committee), the sporting community (e.g. coaches, players, fans), and the media (Dawson, 2012; Page & Page, 2010; Schnyder & Hossner, 2016; Slack et al., 2013). Therefore, Samuel et al. (2018) applied the strength model of self-control (Baumeister & Vohs, 2016) to examine the relationship between self-control and performance in real matches. Sixteen Israeli referees completed measures of daily hassles prior to the match and state self-control prior to and after the match, over 2–4 matches. The results indicated that the referees exhibited higher levels of trait self-control, in comparison with professional football players and the general population. Even though they reported only moderate mental exhaustion following their matches, a noticeable decrease (10% or more) in state self-control was evident in almost half of the matches. This decrease in state self-control was associated with self-reported match difficulty and with lower self-rated match performance. Therefore, it seems that referees tend to use their self-control to cope with the physical and mental demands of the match. However, the underlying mechanism of this process, especially the self-regulation of fatigue and maintenance of appropriate attentional focus, is still unclear and requires additional research (Englert et al., 2020).

The video assistant referee – VAR

The VAR system presents a unique human-technology interface, in which the human factor (i.e. the video referee and the on-field referee) heavily influences the quality of the system (Skirbekk, 2023). Research on VAR typically focused on its effects on the game (e.g. time played) and on referees' decisions (e.g. Han et al., 2020; Lago-Peñas et al., 2019; Zhang et al., 2022) as well as on how VAR is perceived by fans and managers (e.g. Hamsund & Scelles, 2021; Scanlon et al., 2022). Still, less is known about the psychological and cognitive effects of VAR on referees. A recent review of 13 studies on VAR found that studies mostly examined the outcome of the DM processes rather than the referees' experiences using VAR (Skirbekk, 2023). To account for this gap, Samuel, Galily, et al. (2020) investigated the introduction of the VAR system in the Israeli league in terms of referees' perceptions and adaptation efforts. The Israeli referees perceived the VAR implementation as a moderate change-event in their careers. The largest effects were in pre-match preparation, players' management, public perception, and DM. Concerning the influence of the VAR system on the referees' perceptions of pressure, the study indicated complex dynamics. On one hand, the Israeli referees felt that they were

expected to adapt to having a "big brother" who watches their decisions and might intervene and correct them, thereby affecting their performance marks. They were required to adjust to a new situation in which every decision was not finite and could be corrected. They also must have adjusted to the on-field review, which required them to acknowledge a potential critical error and then quickly shift from an on-field DM to a video-based DM. Therefore, several referees wished to officiate the matches without getting corrected by the VAR and even did not accept the VARs' corrections in certain cases and maintained their original decision.

On the other hand, the Israeli referees generally reported that the integration of the VAR system decreased their pressure during the matches. While they were apprehensive about getting corrected by the VARs, they also preferred to end matches with a rectified critical error and not let such an error remain on the field, subjecting them to scrutiny by the teams, the fans, and the media. In this context, Lima et al. (2023) suggested that VAR can positively influence referees' mental health as it protects against critical errors. Thus, having the VAR as a backup DM system might decrease the referees' stress levels. Likewise, Dadi and Yildiz (2022) interviewed 20 Turkish referees of various levels about the VAR system and its education. Content analysis revealed that the positive aspects of the VAR system are that it contributes to making fair decisions in competitions, and to increasing confidence in the referee and his or her decisions. Moreover, the referees identified the positive mental effects of the VAR system; it provides referees the opportunity to correct wrong decisions so they can make their decisions confidently. It, therefore, reduces the referees' stress and anxiety due to reducing thoughts related to making errors.

Therefore, while the VAR system might add to the referees' confidence and reduce stress (e.g. Dadi & Yildiz, 2022; Samuel, Galily, et al., 2020), a VAR intervention typically means that the referee made a critical error, in most cases resulting in a low-performance mark (i.e. for an explanation of the refereeing performance mark see Samuel, Matzkin, et al., 2020). Such critical errors can negatively influence referees' subsequent match assignments and career development (e.g. Samuel et al., 2017). Within this context, a VAR intervention is a substantial match event that can have a mental influence on referees, especially when it overturns an active decision of the referee (e.g. the referee called for a penalty and the VAR indicates it is a wrong decision). Moreover, referees are typically required to maintain self-control for adequate performance (Samuel et al., 2018) and a VAR intervention can potentially increase such a demand. In the case of a VAR intervention, referees might need to apply self-control to efficiently maintain the DM process, as well as control the players' reactions and the referee's own psychological and behavioural responses following an intervention. It can potentially induce ineffective internal-narrow attention (e.g. focusing on potential errors) leading to additional poor decisions that can result in reduced match marks and professional and public scrutiny, and the reduction of within-match control. This can potentially lead to increased mental fatigue (Russell, Jenkins, et al., 2019; Samuel et al., 2024) and thus influence subsequent performance following a VAR intervention. Referees should mentally prepare for how to emotionally respond to potential VAR interventions, so they do not lose effective attentional focus or experience reduced self-efficacy that can result in additional DM errors.

Modelling attention allocation in elite refereeing

Integrating the previous sections of the article, we can conclude some principles concerning elite football referees' attention allocation. First, referees allocate attention among several concurrent tasks (i.e. internally and externally) to make accurate and appropriate decisions as well as manage the game. Second, as experts, elite referees can execute several psychomotor tasks automatically (i.e. mostly activating Type-1 processing), thereby reducing cognitive load and maintaining attention reserve for more demanding DM or game management tasks (i.e. activating Type-2 processing). Third, elite referees have superior gazing behaviours that allow them to focus on relevant environmental cues to produce accurate decisions (i.e. selectively allocating attention toward important task-related information). Rather than passively watching the match events, they apply a "detective mode" – actively seeking to mentally anticipate and visually search for potential infringements. Fourth, the physical strain and mental stress involved in the refereeing task may be associated with reduced attention capacity, requiring the application of self-control to maintain adequate performance and avoid performance reductions. While VAR might facilitate more accurate DM it can also increase the cognitive and emotional load, thereby influencing effective match attention. This is especially relevant for VAR interventions that challenge the authority of the referee. Finally, if match demands are very high, referees might lose effective attention when they are distracted by external or internal cues, mostly fatigue and stress.

Figure 1. Attention allocation in elite football refereeing under regular match conditions.

Note: The match is played under regular conditions; the home team is leading 1:0 in the first half. The referee is executing the habitual behaviours relatively automatically, preserving much attention to effective shifting between external and internal focus. The referee (R) is positioned close to the match play and is able to make accurate decisions.

Therefore, based on Hatfield et al.'s (2020) framework of psychomotor efficiency and the literature on football refereeing, we model attention allocation in elite refereeing under regular and highly-demanding conditions (see Figures 1 and 2, accordingly). When referees are performing optimally (see Figure 1), they allocate their attention to three concurrent tasks. Typically, they execute habitual behaviours, such as running, whistling, signalling, and match-related protocols (e.g. a corner kick) almost automatically, exerting a low cognitive workload. This allows for preserving most of the attention to the primary tasks of DM and game management; the referee effectively shifts between active gazing (i.e. external focus) aimed at identifying match-related events and internal processes aimed at anticipating infringements and then matching actions with law criteria and producing the most suitable decision for the context (Samuel et al., 2021). In moments when the referee is not actively making decisions, s/he is focused on strategy and game-management including understanding the match context, planning future actions, establishing foul calibration, and communicating with the teams (Mascarenhas et al., 2006; Raab et al., 2021). In addition, referees also exert self-control efforts aimed at regulating stress and fatigue (see Samuel et al., 2018).

As can be seen in Figure 1, under regular match conditions (i.e. the home team is leading 1:0 in the first half),

Figure 2. Attention allocation in elite football refereeing under highly demanding match conditions.

Note: The match is played under highly demanding conditions; the away team is leading 0:1 in the second half and the home team is playing with 10 players after a VAR intervention and a decision of a red card was made. The referee's attention to habitual behaviours is larger at the expense of the external and internal focus. Thus, the referee (R) is positioned far from the match play and misses the foul infringement and potentially a yellow card.

the referee experiences high perceived control and self-efficacy and thus much attention is directed to the interaction between active gazing (i.e. a "detective mode") as well as effective communication with the players and the referee team and internal processes that facilitate optimal performance (see Samuel et al., 2021). This facilitates adequate field position, allowing the referee to make accurate decisions.

However, when the match demands become taxing due to high pace, match context (Raab et al., 2021), or referee's emotional state (e.g. fear of failure due to a previous poor performance or reduced self-efficacy due to an error) the allocation of attention changes (see Figure 2). Habitual behaviours become less automatic and require more attention capacity (i.e. higher dependency on Type-2 processing). This comes at the expense of attention reserve directed at both gazing behaviour and internal processes. The referee may be more distracted by internal factors (i.e. physical and mental fatigue, pressure) and external cues (e.g. the teams, the crowd, the VAR) and, thereby, is less efficient in field positioning, gaze behaviour to identify match infringements, and communication with the players and the referee team. Moreover, considering the internal processes, the referee becomes less anticipative of potential match infringements and consequently less accurate in DM (i.e. less ability to upload optional decisions to LTWM, Samuel et al., 2021). Also, less attention is allocated to game-management tasks as the referee is attempting to maintain sufficient attention for the primary DM task. This can result in overlooking between-players disputes that can deteriorate the referee's control over the match. In addition, the referee maintains less than effective external-to-internal focus shift at s/he becomes too internally preoccupied with fatigue and/or stress, and may also be self-focused (Jones et al., 2019). This may ultimately result in reduced performance (Samuel et al., 2021). As can be seen in Figure 2, the match demands are high (the away team is leading 0:1 in the second half and the home team is playing with 10 players after a VAR intervention and a decision of a red card was made). In this case, the referee is less anticipative of the movement of the attacking play, his position on the field of play is too far from the potential infringement, and he might not identify the foul and potentially make an erroneous judgment.

Applied recommendations for elite referees

In this section, we integrate the conceptual frameworks discussed with the empirical knowledge on football refereeing to present several applied recommendations concerning the optimal mindset for refereeing performance. Specifically, this would entail: (a) maintaining task-focused attention rather than heightened consciousness about one's "self", (b) executing several on-field tasks using habitual behaviours, and (c) increasing effort-related volition and making active decisions using self-talk.

Maintaining a task-focused attention

There is much evidence to support the notion that optimal sports performance is associated with task-focused attention and minimal focus on one's "self". In fact, when sports performers become aware of their own perceptions to themselves or to others (private or public self-focus, Jones et al., 2019), they tend to exit a state of flow and potentially experience higher anxiety leading to choking under pressure (Gray, 2020; Jones et al., 2019). "Turning toward" theories of choking under pressure may suggest that match-related anxiety, typically associated with the referee's fear of making a major DM error, may cause referees to disrupt the automatic components of the action by consciously attending to and/or controlling their movements (i.e. "step-by-step" explicit control, Gray, 2020).

In refereeing, losing task-focused attention by becoming self-conscious may be manifested in poor running form or inappropriate field locations. The referee may become too self-aware of how s/he is being perceived by the teams, the crowd, and even the TV commentators. This can result in increased pressure and fear of error (Slack et al., 2013). The referee's attempts to resume flow (i.e. shifting from Type-2 Type-1 processing) may further lead to internal focus associated with reduced gaze behaviour and DM performance.

The issue of self-awareness in elite refereeing was also discussed in a study conducted during the Coronavirus pandemic period when matches were played without a crowd. Samuel et al. (2022) surveyed 198 referees and assistants from professional and non-professional leagues in Israel and Portugal concerning their adaptation to the pandemic. The results showed a minor positive influence for the absence of the crowd for "being conscious of myself and my actions throughout the match", which was also associated with better self-perception of their performance. In this particular case, the communication between the referees and the teams in the match was easily audible and any indiscretion would be picked up by the media. Therefore, the referees had to increase their consciousness of their own management behaviour to produce adequate performance. This, however, may also indicate that under

normal match conditions, with a large crowd, referees tend to be less conscious of themselves and their actions, as such attributes may increase the likelihood of self-focused anxiety and reduced performance. So, we must differentiate between a type of conscious behaviour that is effective for communication and game-management purposes and advances the referee's optimal performance and such a conscious mind that hinders the referee's performance. This would be the difference between having situation awareness (Neville & Salmon, 2016b) and being self-aware.

Finally, a VAR intervention might be associated with increased self-awareness of the referee's error in a critical decision. In those moments, much of the focus in the stadium is on the referee, who then becomes a central player in the social environment of the match. Referees might spend the moments following a VAR intervention in self-reflection of their own actions and thus find themselves not attending the match events.

Habitual refereeing behaviours

There are various on-field tasks that elite referees execute without much consciousness, including running form, whistling, signing, body language, and protocols (e.g. out-of-play, corner kicks). Skilled referees have officiated hundreds of matches over their careers, making much of these psychomotor skills automatic and requiring minimal consciousness. As research has demonstrated, individuals do not need to control the execution of a motor task consciously after it has become automated (Beckmann et al., 2013). This means that highly skilled referees can perform many of these tasks without being too self-reflective or self-aware (i.e. using Type-1 processing), or in need to exert internal attention, which lowers their tendency to underperform (these tasks) as a result of match-related stress (Jones et al., 2019; Wulf & Lewthwaite, 2020). This may also occur in elite referees, as they activate well-learned behaviours that require less consciousness. Therefore, referees who can spend no (or very little) conscious effort during a match to execute these tasks increase their chances of maintaining psychomotor efficiency and thus low cognitive workload (Hatfield et al., 2020).

Within this context, a novice referee would need to be conscious of how s/he performs these tasks, thereby allocating much of their attention reserve at the expense of the more demanding DM. This might explain why elite referees are more accurate in DM than novice referees (Spitz et al., 2016, 2018). Elite referees might also be more conscious of executing these habitual tasks early in the season (i.e. after their between-season break), as a result of lower fitness levels (Castillo et al., 2017) or if a major career change is introduced, such as transitioning to a higher level (Samuel, 2019). In such periods, elite referees must spend more of their cognitive workloads to attend to these tasks and might be more vulnerable to DM errors.

Attaining such habitual behaviours is the result of much deliberate practice invested in improving speed and endurance, technical skills, tactical skills, and DM skills (e.g. MacMahon et al., 2007; Samuel, 2017). One evidence that elite referees assimilate these skills to their habitual repertoire is that even the inclusion of the VAR system did not result in significant modifications in running patterns and locations or technical aspects of refereeing in a sample of elite referees (Samuel, Galily, et al., 2020).

Considering the development of motor skill expertise, Beckmann et al. (2013) suggested that during the learning of a novel motor task, there is increased prefrontal activity involving left temporal regions, including language centres (e.g. Lacourse et al., 2005). With practice, prefrontal activation decreases, and control passes to the motor areas of the parietal cortex (van Mier et al., 1998) and the basal ganglia (Lacourse et al., 2005). The left hemisphere becomes less active and visual-spatial processes located in the right hemisphere become more dominant (Salazar et al., 1990). Therefore, optimal performance is associated with right-hemisphere activation and left-hemisphere inhibition. When skilled performers are choking under pressure, however, higher left-hemispheric activation is evident (see Beckmann et al., 2013). However, it must be emphasised that this is mostly relevant for closed-motor tasks, such as golf putting and rifle shooting (Beckmann et al., 2013; Hillman et al., 2000). Also, we should acknowledge that depending on the task, sport-related performance may involve many areas of the brain. Beckmann et al. (2013) further suggested that hemisphere-specific priming, through left-hand squeezing of a soft ball prior to the execution of a skilled motor task (e.g. shooting football penalty shots or making badminton serves) might enhance right-hemispheric activation, thereby helping the visuospatial processes needed for successful performance to dominate (Beckmann et al., 2013). However, as the refereeing task is highly complex and involves various motor, cognitive, emotional, and communication elements, we must make such postulations with caution, as no studies yet examined elite referees' brain processing while physically performing.

Volition and decision-making

What happens when the match becomes highly demanding, both physically and professionally,

involving repeated high-speed running intervals and numerous decision moments, in addition to high pressure resulting from the match context (i.e. the score, the time of play), players' aggression, and crowd noise? How can referees maintain appropriate attention allocation in such conditions and not become too internally focused thereby reducing their running efforts or losing appropriate gaze behaviour? Referees might use motivational and instructional self-talk cues.

Self-talk can be defined as "the syntactically recognizable articulation of an internal position that is expressed either internally or out loud where the message-sender is also the intended receiver" (Van Raalte et al., 2016, p. 141). There is strong research evidence for the use of self-talk to increase the likelihood of optimal performance in sports (Hatzigeorgiadis et al., 2011; Tod et al., 2011). Hardy (2006) proposed several dimensions of self-talk, such as *valence, overtness*, and *function*. Valence refers to the bipolar descriptors of positive and negative self-talk, with research providing much support for the use of the former for successful performance. Overtness is related to how a sport performer's self-statements are verbalised – overtly or covertly. Furthermore, self-talk has motivational and instructional functions: motivational self-talk involves psyching up, maximising effort, building confidence, and creating positive moods, whereas instructional self-talk includes cues aiming at focusing or directing attention as well as providing instruction with regard to technique, strategy, or kinesthetic attributes of a skill. Instructional self-talk was found to be more effective than motivational self-talk for fine tasks requiring precision and accuracy and also compared with gross tasks (Hatzigeorgiadis et al., 2011). A study on the effect of a self-talk intervention on selective attention in individuals with lower levels of perceived available self-control strength found that instructional self-talk (i.e. attention-alerting and attention-directing cues) facilitated the performance accuracy of visual selective attention, using the Vienna Test System test battery (Gregersen et al., 2017).

Using Kahneman's (2003) dual-process theory, Van Raalte et al. (2016) presented a sport-specific model of self-talk. According to this model, System 1 self-talk involves an immediate, emotionally-charged reaction to situations (e.g. swearing in frustration to an error), and can be associated with negative affirmations. System 2 self-talk results from consideration and planning, and may lead to logical, instructional, task-focused, and motivational self-talk, as well as self-talk used for distraction purposes. It involves mental effort as it is influenced by new information and different perspectives, and it plays a role in monitoring self-talk from System 1. It is helpful in directing attention and enhancing performance, however, exclusive or extensive use of System 2 self-talk can deplete System 2 capacity, resulting in processing disruptions and performance decrements. In such situations, the sport performer may adhere to System 1 self-talk that may be ineffective for performance.

According to Marcora's (2019) psychobiological model, individuals react to exhaustion differently by making a conscious decision taken at the end of endurance exercise on the basis of the perception of effort. When they feel that they would not be able to sustain their pace, they reduce their effort. One of the ways found to be effective in countering this debilitative effect is motivational self-talk (e.g. Blanchfield et al., 2014). Therefore, during a high-pace match, under considerable physical strain referees can use both motivational and instructional self-talk cues to self-regulate themselves. When fatigued (i.e. high perceived effort), referees must internally fight the decision to reduce effort (Marcora, 2019). They can use motivational self-talk to commend themselves to "stay committed" or "give everything you got" as well as instructional self-talk to command themselves to "run to this location".

In addition, when referees experience internal focus following a DM error, they can stop being attentive to the match events (i.e. reduced gaze behaviour and anticipation) which can potentially lead to additional errors. Furley and Wood (2016) suggested that certain cue words can be used to "load working memory" and in turn induce an external focus of attention that is likely to be facilitative of performance and learning. Thus, during such moments, referees should commend themselves to "leave it" or "get back to the match". Likewise, when running in a fastbreak and anticipating a potential match infringement of DOGSO – denial of obvious goal score opportunity – referees can say "DOGSO" or "wait for it" to be ready to make a decision when necessary. Moreover, during a corner kick or a free kick, referees can remind themselves to maintain external focus and gaze their views on the relevant areas of the goal zone to anticipate a penalty situation, by saying "get focused now" or "look for it". During such instances, the physical or mental demand is too high to allow System 1 self-talk to take over, as this may result in negative self-affirmations (e.g. "I'm too tired" or "how did I get this wrong?"), potentially leading to an internal focus that is ineffective for performance and reduced self-efficacy (Guillén & Feltz, 2011). In such instances during a match, referees can give themselves commands to overcome their human tendency to reduce physical effort or to succumb to the pressure of the match.

Conclusions

Football referees at the elite level are required to meet high-performance standards. The integration of technology in recent years, particularly VAR, made their task even more complex, as they now need to control a larger referee team and maintain a greater span of attention. While previous publications focused on emotional (e.g. self-efficacy, stress), cognitive (e.g. attention, DM), or physical (e.g. fitness, training) aspects of the refereeing task, there are hardly any integrative and holistic accounts of this unique sport performance. Therefore, in this article, we aimed to present some of the mental challenges that elite referees face and how they may influence optimal performance.

Much of the research in the past was conducted in conditions that did not accurately represent the refereeing task (e.g. sitting in a stationary mode in front of a computer), therefore yielding unclear trends. However, more recent research better links physical and cognitive elements of the refereeing task (see Pizzera et al., 2022; Schmidt et al., 2020; Samuel et al., 2019) or measures it during actual matches (e.g. Samuel et al., 2018; Van Biemen et al., 2022). Still, we are missing more study designs that account for the full range of performance demands encountered by referees in real matches, including potential VAR interventions. We thus side with Kittel and colleagues' (Kittel et al., 2021, 2022) recommendations to include 360° virtual reality in referee research and training to better simulate the environmental cues (e.g. van Biemen et al., 2023). Still, such an application must acknowledge that real matches hold unique demands (e.g. travel time, stress) that can hardly be induced by a simulation.

Currently, we do not have studies monitoring referees' brain function during real performance (i.e. not in a stationary mode). For example, studies examining the interactions among the motor system (i.e. movement), the limbic system (i.e. emotions), the executive functioning system in the prefrontal areas (i.e. tactics, attentional control, DM, inhibition), and specifically, how do referees allocate attention in optimal and less than optimal conditions are warranted. Moreover, questions such as "what brain area is more dominant when referees become aware of a critical error through a VAR intervention", and "how do they regain control of the prefrontal areas to make subsequent decisions" should be explored. Also, would it be beneficial for referees to induce hemisphere-specific priming through left-hand squeezing of a soft ball prior to the commencement of the match or through holding the whistle in their left hand (Beckmann et al., 2013)? Therefore, we suggest a new line of research is needed to explore referees' brain activity and functioning, while under physical, emotional, and cognitive strain. Such research line is likely to become more viable as portable EEG and fNIRS systems are becoming increasingly available (Filho et al., 2021). A recent doctorate work by Elbanna examined referees' brain activity while making decisions, yet the sample included amateur referees who performed in a stationary mode (Elbanna, 2023).

We further postulate that to optimally function under the high demands specified herein, referees need to be task-focused (and not self-conscious), use their habitual refereeing behaviours to reduce cognitive load and maintain attention reserve for DM and game management, and increase effort-related volition to cope with fatigue and distractions. These suggestions also imply that referee training programmes should nurture such attributes and educate referees in relevant skills. For example, the use of effective self-talk (see Van Raalte et al., 2016), developing self-control-related skills (see Samuel, Matzkin, et al., 2020), training under fatigue (e.g. Samuel et al., 2018; Schmidt et al., 2020), and training visual search strategies and attentional control (see Kittel et al., 2021). In line with the new technology, and consequently new demands of the refereeing task, adjustments should also be made to the referees' mental preparation process (see Samuel, 2015).

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