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Frontiers in applied implication and research on combining sports science and cognitive neuroscience: Where are we heading?

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1.0 INTRODUCTION

In recent years, there has been a remarkable merging of sports psychology and cognitive neuroscience, unveiling unprecedented understandings of human capabilities, skill acquisition, and psychological resilience in sports endeavours (Hernández-Mendo et al., 2019; Kalén et al., 2021; Raza et al., 2020). This convergence has captured the attention of scholars, coaches, athletes, and observers alike, presenting a rich environment for innovative discoveries and practical implementations. In this editorial, we delve into the significance of this interdisciplinary synergy, highlighting pivotal research areas, emerging trends, and potential implications for practitioners and athletes.

Research examining the significance of cognitive abilities in sports has predominantly centred on disparities in anticipation and decision-making among athletes with varying levels of proficiency (Müller et al., 2006; Murphy et al., 2018). To enhance the methodological robustness of these studies, they commonly incorporate crucial elements of the sport into their experimental designs, such as the presentation of stimuli and the nature of the response required (Araujo et al., 2007; Fahmie et al., 2023). Participants typically select how to "react" within two paradigms: the temporal occlusion paradigm, which involves videos paused at specific points during an opponent's action, and the spatial occlusion paradigm, which involves videos with concealed segments of the action. Responses may include replicating actual movements (Murphy et al., 2018) or generating and selecting options (Musculus, 2018). Across these sport-specific cognitive skill assessments, individuals with higher skill levels typically outperform those with lower skill levels (Farrow et al., 2018; Travassos et al., 2013).

2.0 RECOGNIZING THE CONNECTION BETWEEN THE BRAIN AND BODY

Neuroscience has made significant strides in elucidating the functioning of the brain across various contexts and its evolution throughout an individual's lifespan (Cabeza et al., 2018). This understanding of brain function has been incorporated by researchers in sports science, who utilize it to elucidate how cognitive processes may enhance performance in specific domains of sports (Fink et al., 2018; Hsu et al., 2018). Techniques such as electroencephalography (Gutmann et al., 2018), functional magnetic resonance imaging (Chen et al., 2016; Rosenberg et al., 2020), positron emission tomography (Boecker & Drzezga, 2016), single photon emission computerized tomography (Shih et al., 2019), and magnetoencephalography (Huang et al., 2016) have significantly enhanced the visualization and comprehension of cognitive processes elicited and refined within sports contexts. Their primary contributions lie in observing how various tasks

modulate brain activity during sports, the resultant improvements in physical condition, and the implications of these findings (Jonasson et al., 2017).

Rosenberg et al. (2020) indicate that behavioural analyses reveal a strong correlation between working memory, linguistic proficiency, fluid intelligence, and performance on various cognitive tasks. Children with higher working memory capacities excel in these activities. Frontoparietal activation in response to a specific working memory challenge is a reliable indicator of working memory capacity, as demonstrated by fMRI analyses of the emotional n-back task, Stop Signal Task (SST), and Monetary Incentive Delay (MID) task data.

In professional sports, athletes often exhibit significant variability amongst themselves. Both technical staff and research groups have endeavoured to assess and identify the factors influencing this diversity despite the inherent challenge of fully mitigating performance uncertainties. Hence, the extensive research delving into psychological effects, technical and tactical considerations, and physical conditioning is no surprise (Dalen et al., 2021; Henriksen et al., 2019; Kuan & Kueh; 2015). Recent studies indicate that certain cognitive abilities in athletes may enhance their effectiveness and improve their chances of success (Hernández-Mendo et al., 2019; Kuan & Kueh; 2015). Participants who received the EEG-MUSE neurofeedback intervention achieved higher game scores than the control group, although this difference was not statistically significant (Raza et al., 2020).

3.0 ENHANCING SKILL DEVELOPMENT AND PROFICIENCY

Enhancing skill acquisition and cultivating expertise among athletes across diverse disciplines stands out as one of the most compelling applications of this interdisciplinary approach. Studies have indicated that football players with higher executive functioning scores exhibit greater success and proficiency (Huijgen et al., 2015; Verburgh et al., 2014). Conversely, Roca et al. (2018) proposed that their attention span could influence the inventiveness of adult football players in decision-making. Moreover, exceptional athletes often demonstrate superior performance on assessments of cognitive processing speed and other attention-related tasks, as Voss et al. (2010) observed. Similar conclusions were drawn by Wagner and colleagues (2014), who found that executive functioning and attentional capacity are cognitive factors influencing the athletic performance of handball players. Additionally, brain plasticity emerges as a fascinating predictor of on-field player behaviour, with Hänggi et al. (2015) noting that an athlete's brain structure can provide insights into their operational efficiency.

4.0 INTEGRATING PERFORMANCE OPTIMIZATION AND MENTAL RESILIENCE

Considering the interplay between various cognitive abilities and functions and their impact on athletic performance is crucial from both practical and theoretical perspectives. Recent studies suggesting that general cognitive assessments can predict sports performance have led to premature recommendations for their application in practical settings (Sakamoto et al., 2018; Vestberg et al., 2017; Yau et al., 2021). For example, athletes who practised Mindfulness Acceptance Commitment (MAC) reported an enhanced sense of well-being. Triathletes noted that MAC helped them focus on what matters, manage their anxiety, and stay driven by their values. These techniques improved their performance during training and selection trials (Yau et al., 2021). Additionally, they applied the skills learned from MAC to other areas of their lives, which enhanced their ability to concentrate on better training (Yau et al., 2021). In particular, this has fuelled the commercialization of tools measuring general cognitive function, such as executive functions, aimed at aiding clubs in the identification and selection of athletes for structured elite training programs targeting young individuals deemed "talented" (Mann et al., 2017).

However, Beavan et al. (2020) and Renshaw et al. (2019) have raised doubts regarding the validity of this methodology. Renshaw et al. (2019) concluded that these methods lack "specificity of transfer" for contextualizing real performance behaviours. At best, they might offer some "general transfer" of underlying processes to specific sports situations. A significant shortcoming of process training approaches is their limited impact on enhancing performance in body "modules" (e.g., eye, brain, memory, anticipatory subsystems). There is insufficient evidence on how these separate components are modified and interact with other process "modules," which are considered fundamental to athletic performance. Research approaches must consider the ambiguity of various limiting factors in the performance environment. Moreover, Beavan et al. (2020) discovered that the developmental trajectories of soccer players' executive functions (EFs) align with those of the general population, despite prolonged exposure to soccer-specific training and gameplay. These findings question the relationship between high-level experience and EFs

and cast doubt on the inclusion of EFs in talent identification processes.

Interest among researchers has grown in exploring cognitive functioning within the realm of high-performance sports. Studies conducted by Vestberg et al. (2017) and Policastro et al. (2018) have illustrated that enhanced brain functioning among both male and female athletes correlates with competition success and improved performance. There is a prevailing notion that sports characterized by open environments necessitating sustained attention, multitasking, or adaptive responses may particularly benefit from this cognitive prowess (Verburgh et al., 2014; Williams et al., 2011). Furthermore, in domains where precise attentional control and concentration are paramount but minimal variability, possessing robust cognitive functioning can confer a competitive edge (Memmert, 2009).

5.0 CHALLENGES AND ETHICAL CONSIDERATIONS

Despite the promising advancements in integrating sports science and cognitive neuroscience, several limitations warrant attention. One area for improvement is the complexity of translating neuroscientific findings into practical and actionable interventions for athletes. While research on brain-body interactions provides valuable insights, applying such knowledge in real-world sports settings requires careful consideration of individual differences, training contexts, and ethical considerations. Another limitation lies in the accessibility and feasibility of neuroimaging technologies and cognitive assessments in sports environments. High-cost equipment, specialized expertise, and logistical challenges may hinder the widespread implementation of neuroscientific techniques in athlete training and performance settings.

Additionally, ethical concerns related to privacy, data security, and informed consent require robust guidelines to ensure the ethical conduct of research at the intersection of sports science and cognitive neuroscience. Addressing the limitations and challenges inherent in this interdisciplinary field will be crucial for advancing our understanding of brain-body interactions in sports and harnessing this knowledge to empower athletes to reach new heights of excellence. Embracing the evolving landscape of sports science and cognitive neuroscience promises to unlock opportunities for enhancing athletic performance, cultivating mental resilience, and shaping the future trajectory of sports performance optimization.

6.0 CONCLUSIONS

Integrating sports science and cognitive neuroscience presents a multifaceted approach to enhancing athletic performance and promoting holistic well-being in athletes. By bridging these two disciplines, researchers can uncover new avenues for optimizing training methods, maximizing skill development, and cultivating mental resilience in athletes across various sports domains. This interdisciplinary synergy opens up exciting possibilities for future research, innovation, and practices in sports science and cognitive neuroscience.

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