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Mind in Sports: Contemporary Issues and Future Trends

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Cognitive and neuroscience science has been a promising approach in sport psychology. In particular, there has been increased attention given to the role of mind in sports. Although most empirical studies have pointed out the importance of cognitive function supporting sports expertise, the generalizability of current findings to applications in field settings has been limited, which may be due in part to lacking of a comprehensive review and practical guide on this topic. Accordingly, we conducted a systematic review to discuss the published literature regarding sports and cognitive neuroscience so as to understand the past and present in this field. This review then discussed the potential mechanisms explaining the existing research findings from the point of view from current hypothesis/models. Despite some inconsistency, the review of most of the previous studies reveals that individual differences in cognitive functioning may be related to sports type, expertise level, and playing position. Further, higher-order cognitive functions such executive functions or inhibition have been demonstrated to predict sporting performance. Despite these promising findings, the discrepancy in findings and the adaption of low ecologically valid experimental condition as well as cross-sectional design may impede the real-world application of research findings. Accordingly, this review also proposed the directions for future research and field applications.

Keywords: *sports, athletes, cognitive science, neuroscience*

Extended Abstract

Cognitive science and neuroscience have led to promising new approaches in sport psychology. In particular, they have drawn attention to the essential role of cognitive functions in sport. Empirical studies have demonstrated that, relative to novices or non-athletic controls, athletes have superior domain-general cognition, including executive function, selective attention, and processing speed. Specifically, recent research has provided evidence, albeit limited, of a relationship between cognitive functions and competitive sports performance. Although studies have revealed the importance of cognitive functions in sports, the application of these findings in field settings has been limited, perhaps due to the lack of a comprehensive review and practical guidance on this topic. Accordingly, this systematic review of the literature on sports and cognitive neuroscience provides a summary of this area.

The review is organized as follows. We first provide an overview of the recent issues in the study of sport and cognition, including experimental approaches, the relationships of sports type, expertise level, and playing position to athletic cognitive superiority, and the possible connection between cognitive ability and sports performance. We then discuss the mechanisms that could explain the research findings. We consider current hypotheses/models, including the cognitive skill transfer hypothesis, neural efficiency/proficiency hypothesis, and adaptive capacity model, which may provide insights into the relationship between cognitive neural plasticity and long-term sports participation. Finally, we propose possible directions for future research and field applications.

Summary of Literature Review

Studies using different experimental approaches (e.g., the expert performance or cognitive component skill approaches) have found that sports experts generally display superior task performance than their novice or non-athletic counterparts, suggesting that perceptual-cognitive expertise in sports may be both domain-general and domain-specific. Although studies using lab-based cognitive measures with varying levels of ecological validity have provided promising results, the role of the complex interaction between fundamental cognitive abilities and domain-specific knowledge in sporting performances remains unclear.

A number of studies have considered factors that contribute to athletes' cognitive superiority. First, sports type may play an important role in cognitive superiority, which may also help to explain the inconsistent findings across studies. In general, sports experts engaging in open-skill sports outperform those in closed-skill sports in tasks that use executive functions or selective attention. These results may be attributed to the different cognitive demands of different sports. A few studies have found that closed-skill sports players perform better than open-skill sports players in tasks requiring attentional inhibition. Accordingly, the difference in cognitive superiority across sport types may be task-dependent, possibly reflecting the specificity of processing characteristics. Second, cognitive functions might explain individual differences in expertise level; however, studies of the relationship between expertise and cognitive performance have not produced consistent findings. Although most studies have reported greater executive functions in elite athletes relative to sub-elite athletes, a few studies have demonstrated equal executive functions across athletes with different levels of expertise. More extensive studies are needed to better understand the role of cognitive functions in sports expertise. A number of studies have addressed whether playing position is related to differences in cognitive functioning. Recent research has reported that athletes playing at different positions in team sports (i.e., forward vs. defenders) exhibit different patterns of superior executive functions, possibly reflecting position-specific cognitive requirements. Finally, studies have demonstrated that higher-order cognitive functions such as executive functions and inhibition have the capacity to predict sporting performance, indicating their potential usefulness in talent selection.

A number of studies have examined the potential mechanisms through which cognitive functions affect sport performance. Recently proposed hypothesis/models include the cognitive skill transfer hypothesis, neural efficiency/proficiency hypothesis, and adaptive capacity model. First, according to the cognitive skill transfer hypothesis, cognitive skills may develop through long-term participation in sports training. Specifically, training-induced enhancements in cognitive skills may transfer to tasks outside the context of sports. This hypothesis could explain why athletes in open-skill sports have more evident cognitive superiority than athletes in closed-skill sports: if cognitive skills are much more complex in open-skill sports then playing these sports will produce greater cognitive benefits. The neural efficiency hypothesis claims that better cognitive performance may be related to more efficient brain functioning; that is, less brain resources are needed for optimal performance. However, recent research has revealed that cognitive expertise in sports is related to more flexible modulation of brain activities rather than to less brain activation. In other words, athletes' brain activation levels may change depending on the task difficulty or the required cognitive processes. The neural proficiency hypothesis may better explain the neural mechanisms underlying optimal performance. According to this hypothesis, high level performance is related to the proficiency of switches between optimal-automatic and optimal-controlled performance states. Finally, the adaptive capacity model highlights the close relationship between exercise behavior and brain functioning. According to this model, exercise intensity may play a crucial role in mediating cognitive enhancements, and greater cognitive benefits may be gained from exercise that combines high cognitive and physical demands. This model is consistent with the observed cognitive superiority of athletes in both closed- and open-skill sports, which may be a result of both cognitive and physical adaptation via high-intensity exercise training.

Future Directions

Despite the promising findings discussed above, the inconsistency in findings and the prevalence of studies with low ecological validity and the lack of longitudinal designs impedes the real-world application of these research findings. Accordingly, this review proposes several future directions for research. First, it is important to determine whether the inconsistent findings of previous studies are in part due to differences in the measurement instruments used in these studies. For example, most studies have adopted mean-level measures (e.g., mean reaction time, RT) to investigate the cognitive superiority of athletes. However, this may omit crucial information. This review proposes the potential utility of RT variability for exploring cognitive expertise in sports, given its sensitivity to individual differences in cognitive capacity. In addition, we also recommend using some non-parametric and theoretical analysis such as system factorial technology (SFT), which offers RT-based measures that allow inferences about the efficiency, architectures, decisional stopping rules, and the independence of information processing. Thus, SFT may provide deeper insights into the decisional processes of sports experts.

Moreover, we also recommend the use of a novel nonlinear analysis such as multiscale entropy (MSE) analysis of brain signals to explore the complexity of neural activities supporting the expert behavior of elite athletes. MSE has been associated with neural adaptability and cognitive learning, and thus can be used to investigate sport-training-induced changes in cognitive and brain functions. Specifically, changes in MSE have been demonstrated to be associated with learning-induced changes in neural efficiency. Thus, MSE may have the potential to provide evidence that supports the linear analysis of neuroimaging approaches.

To improve the applicability of lab-based research to the field, research could adopt experimental designs or technologies with more ecological validity. For example, the recently proposed mobile cognition model may be helpful for improving our understanding of complex behavior in the real-world. Further, recent progress in brain recording systems such as mobile electroencephalography (EEG) with dry electrodes may improve our understanding of the neural dynamics underlying behavior in real-world sporting activities. In terms of experimental design, this review recommends designing a prospective cohort study that traces the development of cognitive functions in young athletes. Doing so would not only strength our understanding of the causal relationships between cognitive abilities, expertise, and sports performance, but also address the nature-nurture debate about Olympic brains.

Finally, this review also proposes future directions for field-based applications. Given the utility of cognitive training and its effectiveness in clinical applications, it is worth considering the application of cognitive training to sports training. For example, it would be helpful to design a cognitively demanding skill training module for specific sports. Further, coaches or players already use wearable devices to detect and record biometric information during sports activities or to improve communication between players and coaches during a sporting event. It is worth incorporating cognitive or brain indexes into the wearable devices to monitor brain functioning during sports training. Finally, given the potential of cognitive skills to predict success in sports, it may be beneficial to apply cognitive and brain indexes to talent selection in sports.