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BCI Games for Cognitive Assessment: A Scoping Review

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Introduction: Traditional assessment tools, such as the Montreal Cognitive Assessment and the Wechsler Intelligence Scale for Children, rely on verbal or motor responses, presenting challenges for individuals with limited communication or mobility [1], [2]. Brain-computer interfaces (BCIs) present a transformative solution, allowing direct measurement of brain activity, particularly through BCI games, promoting active participation without motor or verbal demands [3]. Despite their potential, there is limited research on BCI games, especially in understanding their applicability and effectiveness across diverse populations [4]. This scoping review investigates the current state of BCI games for cognitive assessment, analyzing their application across diverse populations, the cognitive skills measured, the types of games utilized, and the BCI technologies employed.

Methods and Results: 7 electronic databases were systematically searched using Arksey and O'Malley's scoping review framework and PRISMA-ScR guidelines. Studies implementing BCI games to assess cognition were included and reviewed, focusing on game types, BCI paradigms, electrode placement, brainwave frequency, and cognitive skills targeted. We synthesized data on study designs, population characteristics, and standardized assessments for comparison. Of 4735 studies in the title and abstract screening phase, 33 met the inclusion criteria, encompassing a total sample size of 694 individuals. Most studies investigated adults 61% and neurotypical individuals 76%, with 33% children and 6% older adults. Most of the participants were neurotypical individuals 72%, while fewer had conditions such as attention deficit hyperactivity disorder 18%, mild cognitive impairment 5%, autism and hearing loss 2% each, cerebral palsy 1%, and developmental disorders 1%. Most studies, with some examining multiple cognitive skills and others focusing on just one, focused on attention at 88%, followed by memory at 27%, inhibition at 18%, and spatial perception at 12%. Commonly used technologies included MindWave 39% and Emotiv EPOC+ 21%, highlighting a reliance on EEG-based devices for real-time monitoring of brainwave activity. β and θ brainwaves were the most analyzed. Nine studies compared BCI games to standardized cognitive assessments, with 67% demonstrating moderate to strong correlations. BCI games outperformed traditional tools in engagement and adaptability in some of those studies, achieving up to 98% classification accuracies in attention-related tasks.

Conclusion: This review underscored the potential of BCI games as inclusive and adaptive tools for cognitive assessment. Gamification using BCI enhances engagement, particularly in BCI applications, providing immersive environments for active participation. While validation against standardized tools remains limited, existing studies often demonstrate their validity. The current focus on healthy adults establishes a baseline for this emerging field, but future research should explore diverse age groups and conditions to address specific needs and ensure inclusivity. Predominantly assessing attention, BCI games align well with fundamental cognitive skills; however, broader evaluations of cognition are needed [5]. This review informs future research by addressing these gaps and paves the way for advancing BCI-based cognitive assessment tools.

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