Harmony Plus: A User-Adaptive System for Neurocognitive Rehabilitation With Genetic Personalization and Real-Time Cognitive Load Monitoring in Bipolar Disorder

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Bipolar disorder (BD) complications extend beyond mood swings, with up to 60% of patients experiencing cognitive deficits even during euthymia. Key areas affected include attention, executive functioning, and memory, which worsens mood symptoms and impacts social and occupational life. Early intervention is crucial to prevent both mood and cognitive risks. This study proposes Harmony Plus, a hybrid adaptive system that offers multi-modal cognitive rehabilitation (CR) in a gamified group environment. Through it, patients engage in cognitive training tasks in an action and strategy game genre. Real-time pupillometry is implemented through deep learning and OpenCV to capture patients' event-related pupillary responses (ERPRs). Advanced signal processing and genetic algorithms personalize interventions to patients' cognitive profiles, dynamically adjusting task difficulty based on performance. An eight-week study was conducted with 12 BD patients (types I and II) to examine neuropsychological and neurophysiological changes using the ISBD BANC battery and Event-Related Potentials analysis. Between-group comparisons using the Mann-Whitney test showed that Harmony users had significant gains in neuropsychological composite scores ($p<0.05$), supported by Cliff's Delta compared to control group. Wilcoxon rank test revealed that Harmony users significantly improved processing speed, visual memory, and executive functions ($p<0.05$). Working memory showed marginal significance ($p=0.0625$), while sustained attention showed borderline significance ($p=0.0557$). The control group measures remained insignificant. Harmonizing episodes monitoring and tailored CR, Harmony plus not only enhances mood outcomes but also promotes neural plasticity and overall functional recovery in BD patients.

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