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Enhancing Online Learning through Neuroadaptive Interfaces: The Role of Motivation and Task Load Adaptation

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Introduction: Online learning has emerged as a transformative medium, with 21.8% of Canadians engaging in formal online training in 2022 [1]. However, ensuring optimal learning outcomes in such settings remains challenging. An important aspect to effective learning is the Zone of Proximal Development (ZPD), which delineates the range of tasks learners can achieve with scaffolding [2]. In brain-computer interfaces (BCIs), neuroadaptive systems (NS) provide a promising method to adapt cognitive states, such as cognitive load and task load (TL), in real time to maintain learners within their ZPD [3,4]. Unlike cognitive load, which is influenced by many factors, TL focuses on the mental effort explicitly required to complete a computer-based task. This study examines motivation in an online learning task, comparing the effects of extrinsic motivation (EM) and neuroadaptive countermeasures on learning outcomes.

Material, Methods and Results: Fifty-one participants (M = 26.6 years) were assigned to one of three groups: control (C), reward-only (R), and neuroadaptive (N). A real-time NS was developed, which used EEG to calculate TL as the ratio of frontal alpha and parietal theta band powers from eight electrodes. Task load was classified as high or low based on 1st and 3rd quartile average theta-alpha ratios from the group C data, triggering changes in stimulus presentation speed. The task involved learning 32 constellations in four training blocks, with countermeasures for Group N and performance-based incentives for Group R. All groups demonstrated improved performance over time. Group R outperformed Group C and Group N in later blocks, reflecting the motivational benefits of rewards. Despite Group N achieving comparable results to Group C, EEG-based topographic maps revealed group-specific neural patterns, with Group N exhibiting more effective associative decoding than Group C providing evidence for TL's role in optimizing performance.

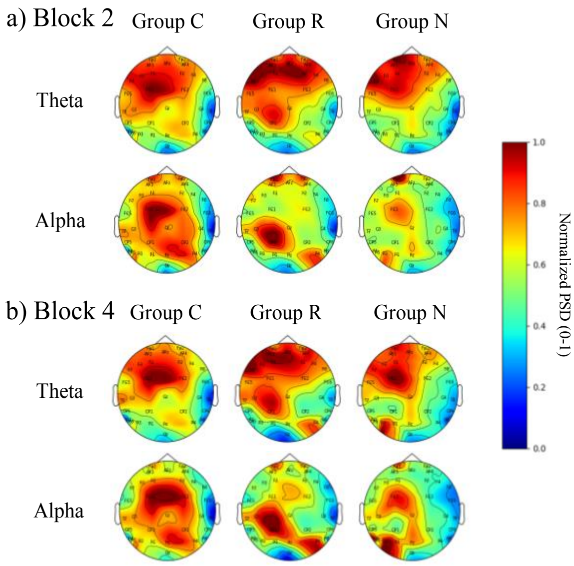

Figure 1: *EEG-based topographic maps displaying alpha and theta activity by group in the encoding phase of Block 2 (a) and Block 4 (b).*

Conclusion: This study advances understanding of TL's role in NS, highlighting its potential to enhance learning by using real-time interventions. By objectively measuring TL using EEG, this study provides a robust framework for future research and practical applications in education and beyond. Future research should focus on refinement and explore broader applications of a NS.

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