Modulation of rhythmic brain circuitry alters the pattern of experience-based decision processing

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Abstract

Understanding and modulating cognitive aspects of decision-making and reinforcement learning are crucial for addressing neuropsychiatric problems like substance use disorders (SUD). We developed a non-invasive stimulation method to modulate theta phase synchronization between the medial prefrontal cortex and right lateral prefrontal cortex. Our EEG-informed modulation led to bidirectional changes in learning-based decision-making, including error-related components and brain signatures. In fact, by combining HD-tACS with mathematical modeling, we revealed that in-phase/antiphase HD-tACS over the mPFC and rPFC significantly altered (synchronized/desynchronized) theta phase coupling between these regions, influencing decision accuracy (improved/impaired), and neurocomputational parameters of learning-based decision-making. Additionally, this modulation rescued/disrupted the causal link between brain error monitoring and cognitive control systems in healthy/SUD participants, and reshaped punishment-guided decision and learning components. We concluded theta rhythms in the mPFC and mPFC-rPFC coupling play a unifying causal role in regulating choice, learning, and behavioral adaptation in both healthy and patient populations.

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