The Effects of Mindfulness-Based Music Therapy (MBMT) on Prefrontal Functional Connectivity in Healthy Young Adults Using Functional Near-Infrared Spectroscopy (fNIRS)

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Abstract

Background

Mindfulness-based interventions (MBIs) are well-established mind-body therapies for improving emotional regulation; however, the neurobiological mechanisms underlying their integration with music therapy remain underexplored. Existing studies predominantly rely on subjective scales, whereas functional near-infrared spectroscopy (fNIRS), a portable neuroimaging tool, enables real-time monitoring of prefrontal cortical activity, offering novel insights into the neural substrates of mindfulness-based music therapy (MBMT).

Methods

Nine healthy young adults (age: 21.78 ± 3.74 years; education: 16.56 ± 2.40

years) underwent a single-session 45-minute MBMT protocol divided into four phases: resting, inspiration, enhancement, and mindfulness. A 15-channel fNIRS system (NIRSIT LITE) was employed to record prefrontal oxygenated hemoglobin (HbO) concentrations. Functional connectivity between channels was analyzed using Pearson correlation coefficients (r) and linear regression models ($p < 0.05$). The experimental protocol included mindful breathing, music-guided reflection, and movement exercises, with synchronized neural activity markers throughout the session.

Data Analysis

Results demonstrated that MBMT significantly modulated prefrontal functional connectivity: 1) Mindfulness Phase: Strong correlations ($r > 0.8$) were observed between the dorsolateral prefrontal cortex (DLPFC) and prefrontal cortex (PFC) ($r = 0.884$) and between the left DLPFC and ventrolateral prefrontal cortex (VLPFC) ($r = 0.809$), indicative of selective neural circuit activation. 2） Phase-Dependent Dynamics: Neural synchrony progressively increased from resting (mean $r = 0.507$) to peak in the enhancement phase ($r = 0.702$; 77.14% of channel pairs significant), followed by a slight decline in mindfulness ($r = 0.576$; 56.19% significant). Zero-crossing rates further validated dynamic fluctuations, with resting phase signals showing the highest instability (0.0061 Hz) and inspiration phase the lowest (0.0024 Hz). 3) HbO Profiles: HbO concentrations during mindfulness (0.000228) were lower than in the inspiration phase (0.000240), yet enhanced functional connectivity patterns suggested efficient cognitive resource integration.

Conclusion

This study provides direct neurophysiological evidence that MBMT differentially regulates prefrontal functional connectivity across intervention phases. Selective connectivity strengthening during mindfulness may reflect optimized attentional control and enhanced emotional processing efficiency. Future research should integrate multimodal neuroimaging (e.g., fMRI) and expand

sample sizes to validate long-term intervention efficacy and individual-specific applications, advancing personalized mental health strategies grounded in neural mechanisms.