PERSONALIZED NEUROREHABILITATION FOR PATHOLOGICAL ADDICTION: A COMPUTATIONAL FRAMEWORK INTEGRATING BRAIN MAPPING AND NEUROFEEDBACK

A Precision Model for Addiction Recovery Through Digital Twin Technology

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Abstract

Pathological addiction represents a complex dysfunction of reward circuits and prefrontal cortex functioning. This paper proposes a personalized neurorehabilitation program integrating multimodal Brain Mapping and Neurofeedback within a predictive mathematical framework. Using Digital Twin systems, the protocol utilizes qEEG and sLoreta to identify individual biomarkers. Data feeds into a Wilson-Cowan neural mass model on The Virtual Brain platform. NF training targets impaired Credit Attribution in striatal circuits using a Bayesian approach that updates reinforcement thresholds in real time.

Theoretical Foundation

• Mathematical Framework: Based on Dasilva et al. (2026) precision model utilizing the Clinical Deviation Index (CDI) to measure distance from normative states.
• Technical Implementation: Powered by Fractal Resonance Model (FRM) prototype software

Methodology: Two-Stage Protocol

1

Stage I: Local Stabilization (Pascal-Vector Model)
• Objective: Stabilize motor-cognitive integration, reduce craving
• Targeting: Mu rhythm (8–13 Hz), SMR (12–15 Hz) at C3, C4, Cz

2

Precision Metrics:
• i-APF & Better Frequency: Neural Clock calibration
• CDI Subtraction: Real-time Z-score distance calculation

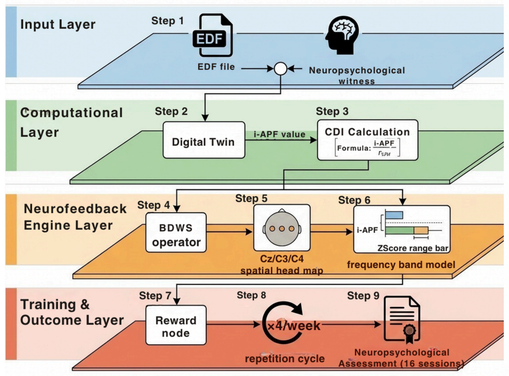
3

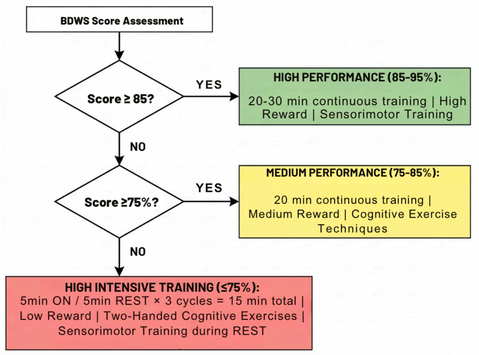
Stage II: Global Coherence (Fibonacci Sequence)
• Objective: Restore network efficiency, resolve existential void
• Method: NF targets impaired Credit Attribution in striatal circuits

4

• Fibonacci Connectivity: Connecting cortical nodes (Parietal to Frontal) following sequence 2, 3, 5, 8...

• Dynamic Recalibration: Bayesian approach updates reinforcement thresholds in real-time for healthy neural rhythm relearning





Preliminary Results

• Synaptic Restoration: In silico results indicate restoration of inhibitory synaptic weights through this multidisciplinary approach.
• System Stability: Model stabilizes brain against intense craving by strengthening neural attractors.
• Clinical Goal: Personalized path to overcome addiction by stabilizing system and reducing trigger vulnerability.

Clinical Impact

This framework offers a personalized neurorehabilitation pathway through neurobiological reappropriation. By creating patient-specific Digital Twins and applying precision neurofeedback protocols, clinicians can:
• Target individual biomarkers of addiction
• Monitor real-time progress toward normative states
• Adapt treatment dynamically based on neural response
• Provide evidence-based intervention with measurable outcomes

Conclusion

This multidisciplinary computational framework integrates Brain Mapping, Digital Twin technology, and Neurofeedback to provide personalized addiction treatment. Preliminary results demonstrate restoration of inhibitory synaptic weights and system stabilization against craving, offering a precision medicine approach to neurorehabilitation.

References

Dasilva, V., et al. (2026). A Precision Computational Framework for sLORETA Neurofeedback in Mild Cognitive Impairment: Integration of qEEG 3 Biomarkers and Neuropsychological Metric . MDPI - IJERPH (Under Review).

Zenodo. https://doi.org/10.5281/zenodo.18821732 | The Virtual Brain Platform | Wilson-Cowan Neural Mass Model