Quantum Simulation of Brain Network Dynamics in Psychological Disorders

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***Abstract*—Psychological disorders are increasingly conceptualized as disruptions in large-scale brain network dynamics rather than impairments confined to isolated neural regions. Although classical computational and statistical approaches have advanced the study of neural connectivity, they often fall short in representing the nonlinear, probabilistic, and context-dependent characteristics of brain activity. Quantum simulation offers an alternative modeling framework by employing quantum-inspired mathematical principles—including superposition, entanglement, and interference—to describe complex neural interactions and their temporal evolution. This paper investigates the potential of quantum-inspired simulation techniques to model brain network dynamics associated with psychological disorders such as depression, anxiety, schizophrenia, and neurodevelopmental conditions. By representing neural systems as probabilistic networks capable of occupying multiple functional states simultaneously, quantum-based models provide a powerful means of capturing cognitive variability, network instability, and pathological state transitions. Drawing on insights from neuroscience, quantum cognition, and computational psychiatry, the study highlights how quantum-inspired simulations may contribute to improved mechanistic understanding, predictive modeling, and personalized approaches to mental health treatment.**

Psychological disorders present a profound challenge for contemporary neuroscience due to their complexity, heterogeneity, and dynamic nature. A growing body of research suggests that many mental health conditions—including mood disorders, anxiety disorders, schizophrenia, and autism spectrum conditions—emerge from altered patterns of interaction across distributed brain networks rather than dysfunction within single anatomical regions [6]. These conditions are often characterized by unstable neural coordination, atypical information integration, and fluctuating cognitive states that vary across time and context.

Traditional approaches to modeling brain function, such as graph-theoretical analyses, classical dynamical systems, and probabilistic network models, have yielded important insights into neural organization and dysfunction [5]. However, these frameworks frequently rely on simplifying assumptions, including linear interactions, fixed network structures, or static probability distributions. Such assumptions limit their ability to represent the highly variable, parallel, and context-sensitive processes that characterize neural activity in psychological disorders [1]. As a result, there is increasing interest in alternative modeling paradigms capable of accommodating uncertainty, nonlinearity, and high-dimensional state spaces.

Quantum-inspired simulation has emerged as a promising framework for addressing these limitations. Importantly, the application of quantum formalisms to neuroscience does not imply that neural processes

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