Quantum-Inspired Models of Neural Coherence and Decoherence in Emotional Dysregulation: A Systems Neuroscience Approach to Clinical Psychology

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Abstract
Emotional dysregulation can be regarded as a transdiagnostic concept that underlies various mental disorders, which may be associated with disruptions of brain activity regulation. The present paper elaborates on a novel quantum-inspired neuroscience theory of emotional dysregulation based on two key concepts – neural coherence and decoherence. In such terms, neural coherence implies the synchronization of brain oscillatory activity and efficient functioning of neural networks associated with the integration of information across prefrontal, limbic, and salience as well as default mode networks in response to the regulation by neuromodulators, normal excitation-inhibition dynamics, and effective synaptic plasticity. Neural decoherence denotes the disruptions of the integrative functions and is associated with neuroendocrine impact of stress responses, changes in neurotransmitter release, disruption of the network organization and cross-frequency coupling. Emotional dysregulation can be seen as an unstable and repeated transition from neural coherence to neural decoherence involving prefrontal cortex, amygdala, anterior cingulate cortex, insular cortex, and hippocampus. On a concluding note, the key aspect of this paper is that it emphasizes emotional dysregulation as the product of failure of integration in contrast to a fundamental deficit. It provides a coherent framework for conducting research from a transdiagnostic approach.

Keywords: Neural Coherence–Decoherence, Emotional Dysregulation, Systems Neuroscience

1. Introduction

The concept of emotional dysregulation has become an emerging framework that explains the development of various psychological disorders, including mood, anxiety, trauma, and personality disorders. This term describes challenges in regulating one's emotional reactions in a way that is consistent with the environmental demands, leading to increased emotional sensitivity, poor impulse control, and fluctuating emotions. Modern clinical psychology understands this concept not just as a behaviour problem but as a manifestation of neurological disturbances within the brain regions responsible for emotion production, processing, and regulation **(Beauchaine & Thayer, 2015; Gross, 2015)**.

In terms of systems neuroscience, emotional regulation can be considered effective only if the coordinated action of different neural networks is involved. This includes prefrontal, limbic, salience, and default mode networks that work based on neural oscillations in sync, excitation-inhibition balance, synaptic plasticity, and neuromodulation. The neural networks use these processes to integrate emotional and cognitive functions. This notion is explained in the article attached where the term 'neural coherence' is used to refer to the state of coordinated brain activity when emotional regulation becomes adaptive due to the flexible regulation of emotions based on the effective processing both top-down and bottom-up **(Shori, n.d.)**.

On the other hand, the paper presents neural decoherence as an impairment of such integrative processes in the brain. In particular, neural decoherence involves the impairment of network communication, disturbances in neurotransmitter secretion, lack of cross-frequency coupling, and the influence of chronic stress on neuro-endocrine mechanisms. Such changes make it impossible for the brain to effectively control emotions; hence, causing excessive emotional fluctuations and improper strategies of coping with stressful experiences. In turn, emotional dysregulation refers to a recurring process of transitioning from a state of neural coherence to neural decoherence, as opposed to a fixed defect. This is especially true in disorders associated with emotional lability and susceptibility to stress.

Using this knowledge, the authors introduce an innovative theoretical model based on concepts from quantum mechanics. Though the model does not use actual quantum mechanics, it employs notions of coherence and decoherence, allowing us to explore probabilistic, non-linear, and dynamic shifts in neural activity. This model is consistent with contemporary viewpoints in clinical neuroscience that focus on complexity, dynamics, and states rather than cause-and-effect mechanisms. The idea of viewing emotional instability as a dynamic system provides a new angle from which to examine the issue **(Shori, n.d.)**.

On the whole, this integrative model provides an interface between clinical psychology and systems neuroscience through its connection between emotional dysregulation and the disruption of neural coherence within the brain's networks. This has major implications for research on transdiagnostic psychopathology, the advancement of diagnostic models, and interventions that target neural integration and emotional regulation. Through this integrative model of emotional dysregulation based on coherence-decoherence processes in neural systems, this study provides a step forward in the effort to shift from symptomatic models to biologically driven processes.

2. Literature Review

In modern literature on psychology and neuroscience, emotional dysregulation is seen as a transdiagnostic phenomenon rather than a symptom of a specific disorder. Indeed, there is general agreement that emotional dysregulation entails the inability to regulate the emotional experience in terms of both its level and expression according to situational requirements. Review articles focus on the role of emotional dysregulation as an important factor contributing to functional impairments associated with mood, anxiety, trauma, and personality disorders, thus pointing out the importance of emotional dysregulation as a core process in different types of psycho-pathology.

A considerable number of studies utilizing neuroimaging and electrophysiology techniques have shown the significance of large-scale brain network interactions for regulating emotions. Functional integration between the prefrontal, limbic, salience, and default mode networks underlies successful emotional regulation and allows integrating cognitive control and emotional processes. On the contrary, emotional dysregulation involves abnormalities in functional connectivity, synchronization of brain waves, and network instability. In contrast to theories proposing that dysregulated emotions result from aberrant functioning in isolated brain areas, evidence suggests that emotional dysregulation results from disrupted coordination between cortical areas and subcortical structures involved in affect.

The recently developed models of theory view emotional regulation as related to neural coherence, which implies that neural activity is synchronized and coherent, leading to flexibility in emotional regulation. Emotional dysregulation, on the other hand, is linked to neural decoherence, which involves disruption of neural communications, changes in neurotransmitter activities, and loss of inter-coupling frequencies. From such a perspective, emotional dysregulation can be seen as a dynamic process where one transitions repeatedly from neural coherence to decoherence. Such dynamism accounts for the fluctuations in the emotional symptomatology of patients and provides support for a systems neuroscience perspective.

Besides central nervous system factors, there is evidence that the functioning of the autonomic nervous system is also involved in the process of emotional regulation. Dysregulated emotions have been found to be related to low levels of parasympathetic tone, abnormal reactions to stress, and lack of physiological flexibility. The implication is that the regulation of emotions is achieved through brain-body communication, where the regulation of the autonomic nervous system contributes to the integration of neural processing. This means that any disturbance in physiological coherence will worsen neural coherence, resulting in high emotional reactivity and poor regulation of emotions.

Studies related to psychotherapy and neuro-modulation, on the other hand, also serve as additional evidence supporting the use of network-oriented and systemic approaches in understanding dysregulated emotions. Functional connectivity in emotion-regulation neural circuits, especially the ones related to the interactions between prefrontal and limbic structures, seems to change in response to intervention-based treatment. Effective emotional regulation is associated with greater coherence and synchronization of emotion regulation circuits, as well as better top-down control over one's emotional reactions.

In summary, the literature reviewed here seems to agree that emotional dysregulation is the result of functional alterations in brain and bodily integrative processes and not structural impairments. Conceptual, neuroscience, and treatment models seem to highlight the importance of instabilities in brain networks and coherence-decoherence changes, among other aspects, that may lead to insights into the development, manifestation, and treatment of emotional dysregulation.

3. Methodology

The current research design is characterized by theoretical and integrative research design, based on systems neuroscience and clinical psychology. Primary data were not collected. The current research design is characterized by conducting a review and synthesis of current scientific publications concerning issues of emotional regulation, functioning of neural networks, stress reactions and brain-body interactions.

Concepts inspired by quantum theory were used as a heuristic model in explaining the dynamics of changes in brain functioning. Concepts of neural coherence and neural decoherence were used in order to model non-linear, probabilistic and state-dependent dynamics of brain networks functioning. Such an approach to research methodology allows viewing emotional dysregulation as a dynamic systems issue, and not as a static neurobiological issue.

4. Conceptual Framework

The theoretical framework suggests that the process of emotional regulation relies upon achieving neural coherence, which involves synchronization of oscillations, balance in excitation-inhibition, proper neuromodulation, and neural network interaction between the prefrontal cortex, limbic system, salience network, and default mode network. Neural coherence makes it possible for adaptive emotional regulation by ensuring effective top-down and bottom-up processes.

On the contrary, emotional dysregulation occurs when the system becomes incoherent with the breakdown of neural communication, disintegration of cross-frequency coordination, and neuroendocrine and autonomic nervous system disturbances due to stress. Emotional dysregulation can be seen as a repeated cycle between neural coherence and decoherence, rather than a constant malfunction. The transdiagnostic approach considers emotional dysregulation as an emergent phenomenon arising from compromised neural integration.

5. Major Findings from Reviews

S. No.	Title	Author	Year of Publication	Summary
1	Quantum-Inspired and Non-Classical Approaches to Consciousness: Models, Evidence and Constraints	Elías Manjarrez, Emmanuel Ortega-Robles, Oscar Arias-Carrión,	2026	It is concluded that while quantum approaches can be effective ways to model the cognitive processes as integrative, context-dependent, and probabilistic, there is no evidence to support the idea that our brain retains any quantum state, such as entanglement or coherent states. The majority of results described as quantum-like are at the early stage of development and can be explained classically. An important aspect highlighted by the paper includes the need for proper verification and replication before making conclusions about quantum mechanisms of the mind.
2	Quantum-Inspired Cognition: A Unified Model of Learning, Thinking, and Memory in Biological and Artificial Intelligence	Douglas C. Youvan	2025	This paper introduces a quantum analogy theory of cognition, describing processes associated with learning, reasoning, memory, creativity, and cognitive conflict in both humans and computers. It claims that classical theories do not provide an adequate explanation of cognition and asserts that analogies related

				to quantum mechanics, including superposition, collapse, entanglement, decoherence, and tunneling can provide such an explanation. Learning is based on keeping and associating several concepts, reasoning consists of a collapse of probabilities into decisions, memory depends upon coherence and correction of errors, creativity occurs as a result of non-linear conceptual jumps, and cognitive dissonance takes place because of interference between conflicting beliefs.
3	Exploring Quantum-Inspired Encoding Strategies in Neuromorphic Systems for Affective State Recognition	Fang Wang, Xiaoqiang Liang, and Xingqian Du	2026	The paper discusses an algorithm of spike coding using quantum mechanics inspired concepts like superposition and entanglement of adjacent features for spiking neural network applications to enhance the energy efficiency of affect recognition tasks. Using the concepts of quantum mechanics, the algorithm uses the simulated quantum computation method to translate continuous features into spiking sequences. When applied to the CMU-MOSI and IEMOCAP data sets, the proposed algorithm has been found to perform significantly better in terms of information density versus sparseness compared to the temporal code.

4	Revisiting the Quantum Brain Hypothesis: Toward Quantum (Neuro)biology?	Peter Jedlicka	2017	According to the paper, quantum phenomena may affect brain operations, contrary to the common assumption that such phenomena do not have any impact on biological systems. The authors make use of insights provided by quantum biology to assert that small-scale quantum phenomena may survive inside living organisms and may be magnified inside the brain due to its highly non-linear and critical nature, thus affecting brain fluctuations and information processing. Rather than advancing quantum theories of consciousness, the authors recommend empirical studies focusing on the interaction between quantum phenomena and classical brain processes.
5	Quantum-inspired Neural Network for Conversational Emotion Recognition	Qiuchi Li, Dimitris Gkoumas, Alessandro Sordoni, Jian-Yun Nie, Massimo Melucci	2021	The authors present a quantum-inspired neural network approach for multimodal emotion recognition in conversations, where emotion recognition is seen as a quantum measurement task. The utterances are encoded as quantum states that integrate textual, visual, and audio modalities, and the evolution of emotions in the conversation is modeled by a quantum-like recurrent neural network using unitary transformations. The experiments conducted on the

				IEMOCAP and MELD benchmark datasets show results equivalent to the current state-of-the-art methods.

6. Discussion

This article presents a theory in quantum systems neuroscience, which describes emotional dysregulation as a dynamic phenomenon that arises from the cycling of brain states between coherence and decoherence. Instead of considering emotional dysregulation as a disorder-related impairment, this approach defines the phenomenon as an emergence that arises from disruptions of large-scale integration of neural function in support of affective and cognitive regulation.

In this context, neural coherence refers to a state where the brain operates in an organized manner by exhibiting oscillation synchronicity and integration between prefrontal, limbic, salience, and default mode networks. This promotes the ability of an individual to modulate their emotions in an adaptive manner. On the other hand, neural decoherence is a scenario where the brain loses its organized structure, leading to a disruption in connectivity, excitation-inhibition, and inter-neuronal communication at different neural frequency levels.

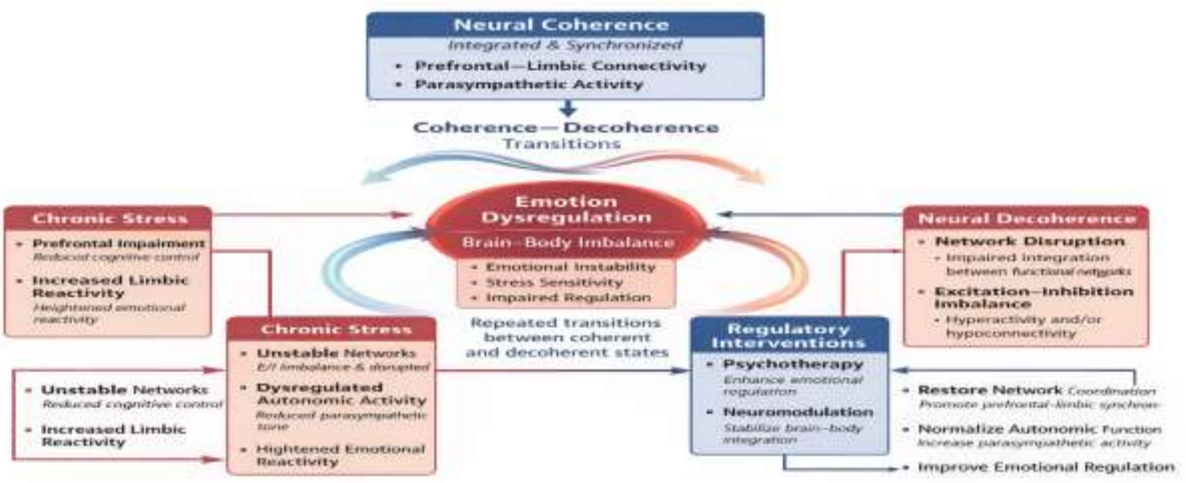
Another critical aspect of the model is how it defines emotional dysregulation as a state-dependent and temporally unstable process. Instead of viewing emotional lability, stress reactivity, and other common phenomena as static neural deficits, the model views them as recurrent breakdowns in maintaining integrated network states, especially when stressed. This theory serves as a straightforward way of explaining why certain emotional symptoms occur and why they depend on context.

Finally, the model accounts for autonomic nervous system dynamics, integrating emotional regulation into a wider neurovisceral system. Rather than treating failures in neural coherence in isolation, the model places them within larger disruptions in brain-body coupling, where low physiological flexibility increases susceptibility to emotional dysregulation.

Translating to practice, the model shifts the focus from symptom reduction to the stabilization of neural dynamics by means of interventions. Both psychotherapy and neuro-modulatory treatments may influence the individual by enhancing coherent network activity and re-establishing flexibility in regulation. While theoretical in nature, the model produces falsifiable predictions about the timing of both neural integration and emotion regulation processes. Further investigation using longitudinal and multimodal assessment is capable of testing those predictions, which would result in a more refined understanding of emotional dysregulation mechanisms.

7. Conclusion

The present paper introduces a quantum-inspired approach to systems neuroscience which views emotional dysregulation as a complex process of switching from neural coherence to neural decoherence. Through its consideration of large-scale brain network dynamics in addition to regulatory processes between the brain and body, the proposed model shifts away from etiological explanations based on symptoms or disorders towards a process-based view of emotional dysregulation. Emotions and their regulation are seen as a result of impaired neural and neurovisceral integration during states of stress rather than a neural dysfunction itself. Despite being largely theoretical at this point, the model is relatively simple yet mechanism-driven and makes several empirically verifiable predictions.



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