J Neurol Neurosci©
16 (01) 2025 : 001-002 • Opinion

The mechanisms of alpha rhythm modulation in the cortical motor area: Insights from neural mass modeling

Messina Robinson*
Department of Neurosurgery, Xuanwu Hospital, Capital Medical University, Beijing 100032, China

INTRODUCTION

Alpha rhythms are a prominent feature of brain activity, most commonly observed in the Electroencephalogram (EEG) in the frequency range of 8–12 Hz. These rhythms are generally associated with relaxed, alert states, particularly when a person is awake but not actively engaged in cognitive tasks. While alpha rhythms are often discussed in the context of sensory processing and cognitive control, their role in motor control is increasingly being recognized. The cortical motor areas, responsible for planning, executing, and controlling voluntary movements, are thought to be modulated by these rhythms, influencing both motor output and motor learning.

Understanding the mechanisms of alpha rhythm modulation in the cortical motor area is essential for gaining insights into how the brain coordinates motor function. Neural Mass Modeling (NMM) is a mathematical and computational approach that allows researchers to simulate the collective dynamics of neuronal populations. By applying NMM to the study of motor cortical activity, it is possible to explore how alpha rhythms are modulated and how this modulation relates to motor control. This article explores the mechanisms underlying alpha rhythm changes in the cortical motor area and how neural mass modeling can provide insights into these processes [1].

Alpha rhythms are most prominently observed in the posterior regions of the brain, particularly in the occipital lobe, which is involved in visual processing. However, they are also present in the motor cortex, particularly during periods of rest or when motor tasks are not actively being performed. In the motor cortex, alpha rhythms have been shown to reflect a state of readiness or inhibition, influencing the capacity for movement initiation and execution. High-amplitude alpha oscillations in the motor cortex are often linked to states of motor inhibition, where the brain is preventing unwanted movements. This is particularly important when maintaining posture or when fine-tuning the coordination of ongoing motor tasks. Lower amplitude alpha rhythms or their suppression, on the other hand, may signal the brain's preparation for voluntary movement initiation. [2].

DESCRIPTION

Neural Mass Modeling (NMM) is a computational approach that simulates the collective activity of large populations of neurons. These models aim to capture the behavior of neural systems at a macroscopic level by using equations that describe the interactions between different neuronal groups. NMM offers a way to understand the dynamics of brain rhythms, including alpha rhythms, by representing how neural populations

Address for correspondence:

Messina Robinson
Department of Neurosurgery, Xuanwu Hospital, Capital Medical University, Beijing 100032, China
E-mail: Robin@edu.cn

Word count: 1048 **Tables:** 03 **Figures:** 06 **References:** 05

Received: 30.01.2025, Manuscript No. ipjnn-25-15566; **Editor assigned:** 01.02.2025, Pre QC No. P-15566; **Reviewed:** 14.02.2025, QC No. Q-15566; **Revised:** 20.02.2025, Manuscript No. R-15566; **Published:** 27.02.2025

generate oscillatory activity and how these oscillations are modulated by external or internal inputs. In the context of motor control, neural mass models can provide valuable insights into how alpha rhythms are modulated during different stages of movement. These models typically involve simplifying assumptions about the connections and interactions between different cortical regions, with an emphasis on the motor cortex and its interactions with other brain regions involved in motor control, such as the premotor cortex, basal ganglia, and cerebellum. The modulation of alpha rhythms in the motor cortex is influenced by various factors, including sensory feedback, cognitive load, and the motor task being performed. Neural mass modeling has helped elucidate several mechanisms by which these rhythms can be altered [3].

The balance between excitatory and inhibitory inputs in the motor cortex plays a key role in modulating alpha rhythms. Alpha oscillations are thought to arise from the dynamic balance between excitatory pyramidal neurons and inhibitory interneurons. When the inhibitory inputs are strong, they can suppress excitatory activity, leading to an increase in alpha rhythm amplitude. Conversely, when excitatory inputs dominate, alpha rhythm amplitude tends to decrease, allowing for more active motor processing. In neural mass models, this balance is often modeled using a combination of excitatory and inhibitory neuronal populations, where the firing rates of each population are governed by a set of differential equations. The strength of inhibitory connections can be adjusted to simulate different states of motor readiness. For example, a decrease in inhibition (i.e., less alpha activity) may correspond to a state in which the motor cortex is preparing for action, while increased inhibition (i.e., stronger alpha rhythms) may represent a state of motor inhibition or quiescence.

The basal ganglia, a group of subcortical nuclei involved in motor control and movement initiation, also play a crucial role in modulating cortical alpha rhythms. The basal ganglia communicate with the motor cortex via the thalamus, and their activity is known to influence the amplitude and frequency of alpha rhythms in the motor cortex.

In healthy individuals, the basal ganglia help regulate motor inhibition by suppressing unwanted movements and facilitating the initiation of voluntary actions. Neural mass models that include basal ganglia circuits can simulate how disruptions in these circuits (such as those seen in neurodegenerative diseases like Parkinson's) can lead to abnormal alpha rhythm modulation, resulting in difficulties with motor initiation and movement control. The basal ganglia's influence on alpha rhythms in the motor cortex is thought to be mediated by feedback loops involving the direct and indirect pathways. These pathways help balance the excitation and inhibition in the motor cortex, thus regulating the motor readiness of the brain. The model of these interactions is crucial for understanding how motor impairments might arise from changes in basal ganglia function and how this might alter the modulation of alpha rhythms [4].

Alpha rhythms in the motor cortex are not only modulated by internal motor processes but also by sensory feedback from the body. This feedback can influence the way the motor cortex prepares and executes movements. For instance, sensory input related to proprioception (the sense of body position) and kinesthetic feedback (feedback from muscles and joints) can alter the state of alpha rhythms in the motor cortex. Neural mass models that include sensory input pathways can simulate how changes in feedback—such as during a movement task—might influence the modulation of alpha rhythms. The model can account for how sensory signals modulate cortical excitability and how this affects motor output. The feedback from proprioception can suppress or enhance alpha rhythms, depending on whether the motor cortex needs to focus more on motor planning or if it can return to a more relaxed state during post-movement processing [5].

CONCLUSION

The modulation of alpha rhythms in the cortical motor area is a dynamic process that is influenced by a variety of factors, including excitatory-inhibitory balance, basal ganglia activity, sensory feedback, and cognitive load. Neural mass modeling provides valuable insights into these mechanisms by simulating the collective dynamics of neuronal populations in the motor cortex. Through these models, researchers can better understand how alpha rhythms contribute to motor control, from movement preparation to post-movement evaluation. As we continue to refine neural mass models and integrate them with experimental data, these models will help guide the development of more targeted therapies for motor disorders. Understanding the precise mechanisms underlying alpha rhythm modulation can also improve our approach to neurorehabilitation, potentially allowing for the development of interventions that optimize cortical reorganization and enhance motor recovery in individuals with neurological conditions.

REFERENCES

1. **Cao L, Hao D, Rong Y, et al.** Investigating the modulation of brain activity associated with handgrip force and fatigue. *Technol Health Care*. 2015 1; 23(s2):S427-433.
2. **Ortiz O, Kuruganti U, Chester V, et al.** Changes in EEG alpha-band power during prehension indicates neural motor drive inhibition. *J Neurophysiol*. 2023; 130(6):1588-1601.
3. **Klug M, Kloosterman NA.** Zapline-plus: A Zapline extension for automatic and adaptive removal of frequency-specific noise artifacts in M/EEG. *Hum Brain Mapp*. 2022; 43(9):2743-58.
4. **Gonsisko CB, Ferris DP, Downey RJ.** iCanClean improves independent component analysis of mobile brain imaging with EEG. Sensors. 2023; 23(2):928.
5. **Nakayashiki K, Saeki M, Takata Y, et al.** Modulation of event-related desynchronization during kinematic and kinetic hand movements. *J Neuroengineering Rehabil*. 2014; 11:1-9.