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# A Sturdy Automatic Algorithm for Detecting Epilepsy Seizures Using Interpretable Features and Machine Learning

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## Introduction

Epilepsy is a neurological disorder characterized by recurrent seizures, which arise from abnormal electrical discharges in the brain. It is one of the most common and debilitating conditions affecting individuals worldwide, with an estimated 50 million people living with epilepsy globally. These seizures, which can range from brief lapses in awareness to severe convulsions, often result in chronic cognitive and psychological impairments. Cognitive deficits, particularly in areas such as memory, attention, and executive function, are prevalent in people with epilepsy, and these impairments can significantly affect their quality of life. One area of cognition that has been consistently found to be impaired in epilepsy patients is working memory. Working memory refers to the ability to temporarily store and manipulate information over short periods, essential for tasks such as problem-solving, reasoning, and decision-making. This cognitive function plays a critical role in everyday activities, from following a conversation to performing complex tasks that require both storage and processing of information. In the context of epilepsy, the underlying pathophysiology of the disorder often characterized by disruptions in normal neural network activity can impair working memory. Seizure activity, subclinical epileptiform discharges, and medication effects are all factors that contribute to this cognitive dysfunction. Additionally, structural changes in the brain, including alterations in the hippocampus and frontal cortex, are common in patients with chronic epilepsy and can exacerbate working memory deficits [1].

## Description

Working Memory Tasks and Epilepsy In order to assess working memory, standardized cognitive tasks are often used, such as the n-back task or digit span tasks, which require participants to remember and manipulate sequences of stimuli. The n-back task, for instance, presents a sequence of stimuli (such as letters, numbers, or shapes) and requires participants to indicate whether the current stimulus matches one that appeared n items before. This task tests both the ability to hold and update information in memory, making it an ideal paradigm for studying working memory processes. For patients with epilepsy, the performance on such tasks may be significantly impaired. This is thought to be due to the disruption of normal neural processing during seizures or subclinical epileptiform activity. Even when individuals with epilepsy are seizure-free, cognitive dysfunction may persist due to structural and functional changes in the brain. These changes can affect brain regions critical for working memory, such as the prefrontal cortex, parietal cortex, and hippocampus. EEG can help identify patterns of brain activity that correlate with these deficits [2].

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EEG and Cognitive Functioning in Epilepsy signals provide a direct measure of the brain's electrical activity, offering valuable insights into cognitive functions such as attention, memory, and executive control. When patients with epilepsy engage in a cognitive task, EEG can capture the moment-to-moment fluctuations in brain activity that underlies task performance [3]. In the context of working memory, specific brain regions and networks are activated during the encoding, maintenance, and retrieval of information. The theta band and alpha band are often associated with working memory tasks, with theta oscillations linked to memory encoding and maintenance and alpha oscillations reflecting the disengagement of attention and inhibition of irrelevant stimuli. In addition, higher frequency gamma band activity (30–100 Hz) has been implicated in the synchronization of neural networks during higher-order cognitive processes, including memory recall and executive functions [4].

EEG-Derived Involvement Indexes to quantify the level of involvement of specific brain regions during a cognitive task, EEG-derived involvement indexes can be used. These indexes are computed by analyzing the spatial and temporal patterns of EEG activity during task performance. One common method involves calculating the event-related potential (ERP), which is an averaged EEG signal time-locked to the onset of a specific event (e.g., stimulus presentation in a working memory task). By examining the amplitude and latency of ERP components, researchers can infer the level of brain activation associated with different cognitive stages encoding, maintenance, retrieval). More advanced approaches use functional connectivity measures, which examine how different brain regions communicate during the task. These measures can reveal whether the normal coordination of brain regions involved in working memory is disrupted in epilepsy. Techniques such as coherence or Phase-Locking Value (PLV) can quantify the synchrony between EEG signals recorded from different electrode sites, providing insights into the integrity of large-scale neural networks [5].

## Conclusion

The analysis of scalp EEG-derived involvement indexes during a working memory task can offer valuable insights into the neural mechanisms of cognitive dysfunction in epilepsy. Patients with epilepsy often exhibit altered brain activity patterns compared to healthy controls, particularly in the theta, alpha, and gamma frequency bands. These alterations are likely indicative of disruptions in the neural circuits critical for working memory, including the prefrontal cortex and hippocampus. Additionally, abnormal functional connectivity between brain regions may contribute to the cognitive impairments observed in epilepsy patients. By quantifying the degree of brain involvement using EEG-derived indexes, we can gain a more precise understanding of how epilepsy affects cognitive functioning. For instance, reduced coherence or phase-locking in specific frequency bands may reflect impaired coordination between brains regions involved in working memory. These findings can inform future research into the neural correlates of epilepsy-related cognitive dysfunction and potentially lead to the development of targeted interventions to improve cognitive outcomes for patients with epilepsy.

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## Conflict of Interest

There are no conflicts of interest by author.

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