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# Geriatric depression symptoms coexisting with cognitive decline: A comparison of classification methodologies

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ABSTRACT

Geriatric depression is a pathological process that causes a great number of symptoms resulting in limited mental and physical functionality. The computation of oscillatory and synchronization patterns in certain brain areas may facilitate the early and robust identification of depressive symptoms. In this study electroencephalographic (EEG) data were recorded from 34 participants suffering from both cognitive impairment and geriatric depression (mean age 69.81) and 32 control subjects (mean age 70.33). Both groups were matched according to their cognitive status. The study aims at evaluating neurophysiological features of elderly participants suffering from depression and neurodegeneration. The current work focuses on the identification of depression symptoms that coexist with cognitive decline, the correlation of the examined neurophysiological features with geriatric depression combined with cognitive impairment and the investigation of the role of data mining techniques in the analysis of EEG data. The EEG features were estimated through synchronization analysis (Orthogonal Discrete Wavelet Transform). Depressive patterns were detected through data mining techniques. Random Forest, Random Tree, Multilayer Perceptron (MPL Network) and Support Vector Machines (SVM) were employed for data classification. The efficiency of the classifiers varied from 92.42 to 95.45%. Random Forest demonstrated the highest accuracy (95.5%). Both synchronization and oscillatory features contributed to the decision trees' formation, with the former prevailing. Moreover, synchronization features significantly contributed to the decision trees' formation. In line with previous neuroscientific findings, synchronization among right frontal–midline anteriofrontal regions showed great correlation with depressive symptoms. Evaluation of the classifiers indicated the Random Forest as being the most robust algorithm. Synchronization of certain brain regions is more indicative of identifying depression symptoms than oscillatory since synchronization features contributed the most to the formation of the classification trees.



## 1. Introduction

Geriatric depression is a pathological process, which is characterized by lower functioning and a great number of symptoms such as diminished interest or pleasure in activities, insomnia or hypersomnia, fatigue or loss of energy and observable psycho motor agitation or retardation [1,2]. Major depressive disorder has been shown to be the same for elderly as for young people, providing that physical illness and dementia are not taken into account [1]. The burden of depression in the elderly is high, though it is rather difficult to compare prevalence studies due to differences in terminologies and definitions [1]. The level of severity of depression is determined by each patient's unique characteristics, according to which specific treatment can be proposed. Geriatric Depression Scale (GDS) as a 30-item scale to screen depression was validated in nursing homes, but indicated poor sensitivity until patients with cognitive impairment were excluded [1]. The previous inference is justified by Guaguli et al., who suggest that cognitive impairment often coexists with depression in elderly patients [3]. Geriatric depression is often accompanied with cognitive impairments in multiple domains which may increase the risk of conversion to dementia and accelerate cognitive decline [4]. Cognitive deficits frequently accompany depressive symptoms in elderly people and the greater the severity of the symptoms; the more likely the consideration of pseudodementia becomes [1]. According to Unützer cognitive impairment, as well as chronic medical disorders, may

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complicate the diagnosis and treatment of geriatric depression, which is a rather hard task anyhow, even when cognitive deficit is considered mild. Failure to treat late-life depression can be correlated with increased morbidity and mortality from suicide in elderly populations [2]. The risk of suicide can be reduced through recognizing and treating depression. Geriatric depression as a presenting feature of a dementia is often resistant to treatment [2]. In elderly depressive patients suffering from Mild Cognitive Impairment (MCI) the probability of the initiation of the Alzheimer's disease clinical phase (AD) could be considered [5]. Regardless later manifestation of cognitive impairment, late-life depression may be considered as a risk factor or a potential prodromal state for AD [6]. Rapp et al. suggested that depression may affect cognitive decline in AD [4]. There is recent evidence that depression interacts with AD, since depressive elderly demonstrate increased amyloid pathology [6]. Wint suggested that the frequency of depressive episodes affects the possibility of developing AD, even though they have no shared pathology [7]. Consequently reliable diagnosis of depressive patients with MCI could result in early detection of neurodegenerative symptoms, thereby facilitating prompt commencement of intervention procedures.

According to several studies in middle-aged or younger participants neurophysiological data can facilitate depression diagnosis [8–11]. Neurophysiological findings in small samples of depressed as compared to healthy participants (12 patients; 10 controls; mean age 43 $\pm$ 14) through EEG brain oscillations during resting condition (closed eyes) have indicated that depression may affect brain activity in nearly the whole cortex, rather than only frontal or parietal areas [8]. The magnitude of the effect of depression was maximal in the posterior cortex and right hyperactivity in frontal, parietal and occipital brain areas was indicative of depression. Moreover depressed patients had more pronounced alpha and beta activity and less delta activity when compared to non-depressed controls [8]. Grin-Yatsenko et al. studied the spectral characteristics of resting EEG in a relatively large pool of some 111 adults (mean age 38.5) with mild depression and compared them with a large group of some 526 non-depressed participants (mean-age 35.1) [9]. The findings showed bilaterally increased occipital alpha activity, relatively higher alpha activity in the right parieto-temporal region, and increased theta values in the right and over the left hemisphere. Increases of beta power over the parietal region were proposed to serve as an informative parameter in diagnostics of the first stage of depressive disorder [9]. Leuchter et al., examined the resting state functional connectivity as measured by quantitative EEG in 121 non-medicated subjects with Major Depressive Disorder (MDD) (mean age 41.5) and 37 healthy controls (mean age 37.4) [10]. MDD subjects showed higher functional connectivity compared to controls and expressed higher theta coherence involved connections between prefrontal and temporal regions and higher beta coherence between EEG channels overlying the dorsolateral prefrontal cortical or temporal regions [10]. Differences in frontal alpha power and synchrony were shown between the two groups of participants. On the other hand, cognitive impairment also affected the brain and it was crucial to study neurophysiological data that combined depression with cognitive decline. Ahmadlou et al., in an effort to evaluate frontal lobe dysfunction, which was associated mainly with impaired cognition, investigated EEG findings of 12 participants suffering from MDD and 12 healthy participants (mean ages 20 and 28 respectively) [11]. The results showed higher complexity of left, right and overall frontal lobes of the brain in MDD subjects in beta and gamma sub-bands and that beta band was more discriminative than gamma band in identifying MDD.

Several studies have focused on EEG data evaluation of both physiological and pathological aging groups. Babiloni et al. recorded EEG data in normal elderly, mild cognitive impairment (MCI) and Alzheimer's disease (AD) patients [12]. In 155 MCI participants (mean age 72.1) occipital delta and alpha (8–10.5 Hz) sources in parietal, occipital, temporal and "limbic" areas had an intermediate magnitude, showing a decrease of alpha power compared to normal subjects. Abnormal EEG rhythms were observed in people with pathological aging. Enhanced high-band alpha was detected, which might be mediated by a decreasing number of synchronizing inter-neurons in the target cortical modules [12]. EEG coherence analysis in AD has been applied for the examination of the association of cognitive decline with changes in functional connections between cortical regions. In AD patients, a decrease of alpha and beta coherence has been demonstrated in various types of dementia between both close and distant channels, showing functional disconnections among cortical regions [13]. However, quantitative analysis of EEG in normal and impaired elderly and in patients with MCI either continuously deteriorating or compatible with dementia of the Alzheimer's type indicated increased theta and delta in later stages of deterioration [14]. Structural imaging studies in late-life depression have identified volume alterations in prefrontal cortex [14]. Ajilore et al., measured cortical–subcortical network properties associated with Late-Life Depression (LLD) using graph theory-based methods in 73 healthy subjects (mean age 70.6) and 53 patients suffering from LLD (mean age 69.4) [15]. According to these findings, cortical–subcortical network properties were altered in LLD subjects thereby reflecting the underlying neuroanatomical substrates of the disease.

According to the above studies, depression affected brain activity in frontal, prefrontal or temporal regions in middle-aged participants, who had also more increased beta activity when compared to non-depressed controls [8,10,11]. An increase of beta power over the parietal region was hypothesized to serve as an informative parameter in diagnostics of the first stage of depressive disorder [9]. In addition, depressive symptoms were correlated with relatively higher alpha activity in occipital and right parieto-temporal regions [9]. In elderly MCI participants [12] and AD patients [13] a decrease of alpha and beta coherence was computed in various brain areas. Moreover, in MCI or demented patients theta and delta power was indicatively high in later stages of deterioration [14].

Although the aforementioned studies provide essential information for the understanding of such mechanisms, to the best of our knowledge, there is no neurophysiological study focusing on geriatric depression combined with cognitive impairment in elderly using EEG data and pattern recognition techniques. So the overall aim of the current work was to evaluate neurophysiological features of elderly participants suffering from depression and neurodegeneration and to identify depression symptoms that coexist with cognitive decline. A successful decoding of these could enhance the, diagnosis of depression coexisting with cognitive deficits and would improve the diagnostic capacity may enhance the diagnosis robustness in clinical routine practice. This study is based on the evaluation of EEG data of elderly depressive subjects with cognitive deficits and elderly non-depressive subjects with cognitive deficits. Motivated from previous studies where several data mining techniques have been widely used over the years for classifications of medical data [16–19], this piece of work proposes the exploitation of resting state (eyes-closed condition) EEG recordings combined with pattern recognition techniques [20] in an effort to enhance the predictive power of daily (neurological/neuropsychological) practice. Classification methods were selected based on previous findings according to the classifiers accuracy and robustness. No feature extraction methods were applied. The primary features were $57 \times 57 = 3249$ and the 12 oscillatory and 9 synchronization features where selected based on previous studies. Our aim was to evaluate the 21 features, examine their correlation with geriatric depression combined with cognitive impairment and to investigate whether data mining techniques,