

# Electroencephalogram Signal Analysis in Alzheimer's Disease Early Detection

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## ABSTRACT

The World's health systems are now facing a global problem known as Alzheimer's disease (AD) that mainly affects the elderly. The goal of this work is to perform a classification methodology skilled with Artificial Neural Networks (ANN) to improve the discrimination accuracy amongst patients at AD different stages comparatively to the state-of-art. For that, several study features that characterized the Electroencephalogram (EEG) signals "slow-down" were extracted and presented to the ANN entries in order to classify the dataset. The classification results achieved in the present work are promising concerning AD early diagnosis and they show that EEG can be a good tool for AD detection (Controls (C) vs AD: accuracy 95%; C vs Mild-cognitive Impairment (MCI): accuracy 77%; MCI vs AD: accuracy 83%; All vs All: accuracy 90%).

## KEYWORDS

Alzheimer's Disease, Artificial Neural Networks, Classification, Early Diagnosis, Electroencephalogram Signals, Features, Stages

## INTRODUCTION

The age structure of the world population has changed dramatically in recent decades especially in developed countries, and this reality is mainly due to the fertility decline and the longevity increase (Ballard, et al., 2011; Machado, 2002). Therefore, the aging population has become a fact of scientific interest because the elderly is most vulnerable to the onset of certain degenerative diseases (Jonker, Launer, Hooijer, & Lindeboom, 1996). Alzheimer's disease (AD) is a progressive neurodegenerative brain disorder and is currently the most common cause of dementia in the elderly (Ballard, et al., 2011). It destroys memory and several mental functions, and it causes a progressive and irreversible deterioration of several cognitive functions leading to a situation of complete dependence. AD represents 60% of elderly diseases and in 2010 AD reached more than 35,6 million affected people around the world (Prince, et al., 2015). As it is a cortical and progressive brain disorder, gradually, over time, most parts of the brain will suffer damage, and AD symptoms will severely increase (Blennow, Leon, & Zetterberg, 2006). AD origin remains unknown, and there is not a prospect of a cure shortly despite the efforts made by several researchers in this regard (Prince, et al., 2015).

AD progression can be classified into four different stages. The first stage or the pre-dementia stage is known as Mild Cognitive Impairment (MCI). The MCI is known as a transitional stage between

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natural aging and AD (Nestor, Scheltens, & Hodges, 2004). It corresponds to a variety of symptoms: difficulty in remembering recent events, subtle changes in behavior, discrete loss of autonomy in daily life activities, disorientation in time and space and personality changes (Nestor, Scheltens, & Hodges, 2004). Even though the MCI confers an increased risk of developing AD, at this stage only between 6% and 25% of people develop AD (Shimokawa, et al., 2001). The Mild and Moderate AD stages are characterized by increasing cognitive deficits and dependence on caregivers (Gwyther, 2001). In the Advanced stage, monitoring becomes constant and strictly necessary because patients are unable to perform any tasks and so assistance is inevitable (Mesulam, 2000). Senile plaques and neurofibrillary tangles in the medial temporal lobe and cortical areas are two pathological hallmarks of brains ravaged by AD (Blennow, 2005; Mattson, 2004). These two abnormal structures are responsible for damaging and killing nerve cells (Cummings, 2004). Parts of the brain start to shrink because the brain's nerve cells die. In the last stage of AD, the damage is generalized, and the brain tissue has decreased significantly in volume (Blennow & Zetterberg, 2010). In fact, amyloid plaques and neurofibrillary tangles are clearly visible by microscopy in brains of patients with AD (Tiraboschi, Hansen, Thal, & Corey-Bloom, 2004).

It is not yet known why the brain cells deteriorate as AD progresses and many risk factors are associated to AD development. Thus, aging is considered the principal factor given that the disease mainly affects people over 65 years. Family history is another factor pointed out because people who have a close relative who developed AD have a slightly higher risk to develop the disease themselves (Blennow, 2005). However, other factors beyond genetics are pointed out in the course and development of AD, for example, heart disease, diabetes, obesity, stress, smoking and lower educational qualifications. Most people with Down syndrome develop AD as well as people who had severe head injuries (Blennow, Leon, & Zetterberg, 2006; Lahiri, Farlow, Greig, & Sambamurti, 2002).

The development of methods that can assist in AD diagnosis may lead to the reduction of high costs associated with this illness (Lahiri, Farlow, Greig, & Sambamurti, 2002; Ferri, et al., 2005). AD represents a public health problem and a challenge to the scientific community to find solutions to minimize its socio-economic effects (Machado, 2002). Although the progress in better understanding the AD stages, the researchers have not yet discovered a good treatment for this complex and stressful disease and neither have found a reliable method to make an accurate AD diagnosis (Ballard, et al., 2011). The early diagnosis accuracy is low, and there is not a biomarker able to detect AD without invasive tests. It is often difficult to diagnose AD, and the diagnosis is made by excluding other possible causes of dementia symptoms (Porth & Matfin, 2009). A brain biopsy or autopsy is the effective way to make a correct and definitive diagnosis. An effective diagnosis can provide opportunities for AD patients to get involved in clinical trials and to get the best treatment (Ballard, et al., 2011).

Several tools and methods may be used to diagnose AD. In the beginning, AD presents subtle symptoms that may be confounded to others presented by people with a normal aging (Waldemar, 2007). The most common neuropsychological test for AD screening is the Mini-Mental State Examination (MMSE) that evaluates skills such as reading, writing, orientation and short-term memory. However, diagnosis is also made through personal history, Biomarkers, EEG, Magnetoencephalogram (MEG) and several techniques of brain imaging that are used to show brain changes, namely: Magnetic Resonance Imaging (MIR), Positron Emission Tomography (PET) and Computed Tomography (CT) (Weiner, 2009; Prichep, 2007).

The EEG played an important role as regards dementia diagnosis for several decades. Therefore, it may be an important tool to assist in AD diagnosis. The EEG can record the electromagnetic fields produced by brain activity with good temporal resolution. This non-invasive and cost-effective technique that presents no side effects is widely extended in clinical settings (Sanei & Chambers, 2007; Jeong, 2004; Stam, 2005). EEG is typically divided into different conventional frequency bands, such as delta ( $\delta$ , 1-4 Hz), theta ( $\theta$ , 4-8 Hz), alpha ( $\alpha$ , 8-13Hz), beta ( $\beta$ , 13-30 Hz), and gamma ( $\gamma$ , 30-40 Hz). AD seems to affect the signal power in those different bands. The major effect is known as the EEG "slowing", that means a power decrease in higher frequency bands such as alpha, beta

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