Preliminary study of Alzheimer's Disease diagnosis based on brain electrical signals using wireless EEG

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Abstract. This research aims to study brain's electrical signals recorded using EEG as a basis for the diagnosis of patients with Alzheimer's Disease (AD). The subjects consisted of patients with AD, and normal subjects are used as the control. Brain signals are recorded for 3 minutes in a relaxed condition and with eyes closed. The data is processed using power spectral analysis, brain mapping and chaos test to observe the level of complexity of EEG's data. The results show a shift in the power spectral in the low frequency band (delta and theta) in AD patients. The increase of delta and theta occurs in lobus frontal area and lobus parietal respectively. However, there is a decrease of alpha activity in AD patients where in the case of normal subjects with relaxed condition, brain alpha wave dominates the posterior area. This is confirmed by the results of brain mapping. While the results of chaos analysis show that the average value of MMLE is lower in AD patients than in normal subjects. The level of chaos associated with neural complexity in AD patients with lower neural complexity is due to neuronal damage caused by the beta amyloid plaques and tau protein in neurons.

1. Introduction

Alzheimer's Disease (AD), a type of dementia, is a progressive neurodegenerative damage that affects many people aged 65 years and above. The disease is generally characterized by declining memory function caused by damages in nerve cells (neurons). Neuronal damage is caused by the accumulation of beta-amyloid plaque attached to the nerve cells and neurofibrillary tangled inside the nerve cells [1]. Early diagnosis of AD is a very important step in order to be able to immediately provide an effective treatment when symptoms appear early. Doctors usually perform diagnosis based on several tests such as physical and neurological examination, neuropsychological tests, blood and spinal fluid tests, mental status tests [2].

In the last few years, significant developments in the diagnosis of dementia have been conducted through biomarkers. Biomarkers are molecular markers concentrated in the brain, physiological or anatomical variables that can be used to diagnose and assess disease progression in therapy response. There are several types of biomarkers that can be used to help diagnose: biochemical marker, genetics biomarkers, neuroimaging biomarkers and neurophysiological biomarkers [3]. Neuroimaging

biomarkers, structural and functional, are widely used in detecting AD. Structural imaging such as computed tomography (CT) and magnetic resonance imaging (MRI) can detect the type of athropy and morphological changes in the damaged areas. Meanwhile, functional imaging such as positron emission tomography (PET), single photon emission computed tomography (SPECT) and functional magnetic resonance imaging (fMRI) can detect AD based on the parameters of brain metabolism [4]. Despite having a high spatial resolution, this technique has drawbacks such as low temporal resolution, high prices and the effects of radiation exposure to the patient.

Currently, the development of diagnostic technology is directed towards non-invasive, rapid detection, inexpensive and reliable method. This technique includes the category neurophysiological biomarkers based on observations on neural activities in the brain that produce electrophysiological signals such as action potential and post-synaptic potential [5]. One of the neuroimaging modalities which can detect neural changes is electroencephalography (EEG). EEG is capable to read brain by electrical signals generated by neurons measured through scalp. In this paper, we will assess the use of EEG for the study of AD diagnosis based on the brain's electrical signals.

2. Methods

2.1. Participants

Subjects of this study consisted of five patients with Alzheimer's Disease and five healthy subjects as control, aged between 50-70 years. Ascertained control subjects were healthy, have not experienced neurological and physiological disorders and have never experienced brain injuries. The recording process was done in a relaxed condition (eyes closed) for a duration of 3 minutes.

2.2. EEG Measurements

EEG recording using Emotiv Epoc (BCI & Scientific Contextual EEG) 14 channels plus 2 channel references that have a sampling frequency of 128. Based on the results of previous research, there are three characteristics that play recorded brain electrical signals from the AD patient: a shift in the spectrum of low brain waves (delta and theta frequency), low levels of chaos and low synchronization signals between brain regions and others. In this study, EEG's data is processed using power spectral analysis, brain mapping and chaos analysis with MMLE (Moving Maximum Lyapunov Exponents). The selected power spectrum method is periodogram Welch that has a level of precision better than the other methods. MMLE chaos level calculation is developed by using Rosenstein techniques [6].

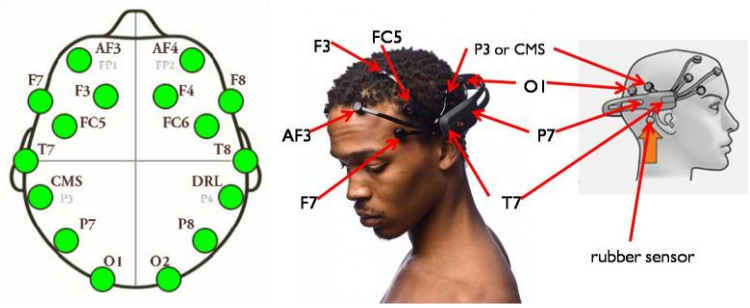


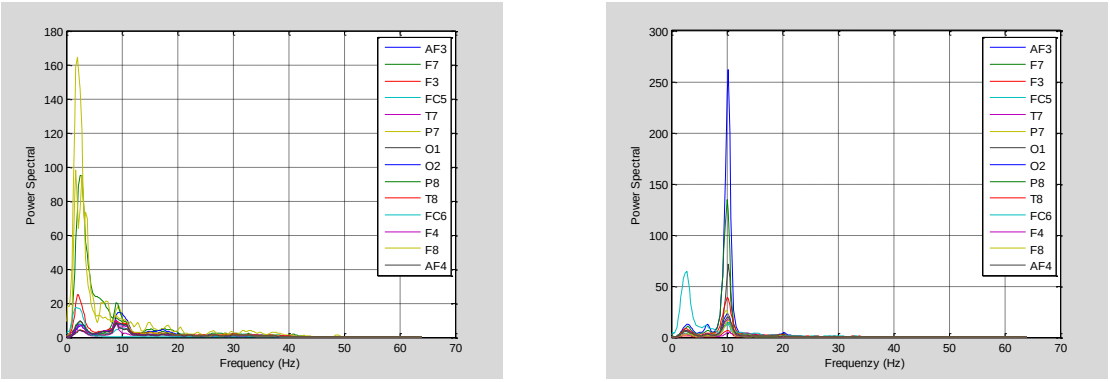
Figure 1. The position of the electrode on the Emotiv Epoc 16 channels.

3. Results

EEG signals in patients with AD are found to be slower, which means that the EEG power spectrum is concentrated at lower frequencies. The charts in figure 1 show (a), an overall power spectral in the delta frequency band (1-4 Hz) and theta (4-7 Hz) in patients with AD. Conversely, a decrease occurs in the power spectral in alpha (7-13 Hz) and beta (13-30 Hz) frequency band. Delta waves which have a voltage amplitude range between 20 μV to 200 μV occur in a deep sleep condition and the people who have the disease (abnormality) of the brain [7]. For adults, these waves

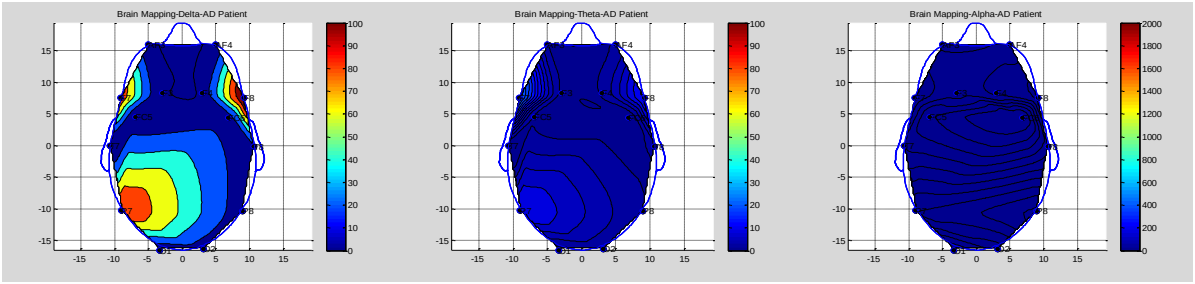
are recorded on the frontal part of the brain. The graph shows that F8 has the highest amplitude, followed by F7 and P7. Theta waves which have a voltage amplitude range between 5 μV to 10 μV are recorded on the temporal and parietal areas [7]. This wave spreads on the scalp corresponding to drowsiness, alertness, cognitive impairment and dementia.

EEG's signals in normal subjects under relaxed conditions are dominant at alpha frequency (7-13 Hz). Alpha brain waves appear when under the conscious condition, relax and closed eyes. The voltage range for the alpha waves is between 20 μV to 200 μV [7]. Alpha waves are mostly observed in the posterior area of the head. The chart in figure 1(b) shows that the electrodes O2, P8 and O1 have a high amplitude corresponding to the occipital and parietal lobes (located in the posterior part of the head).



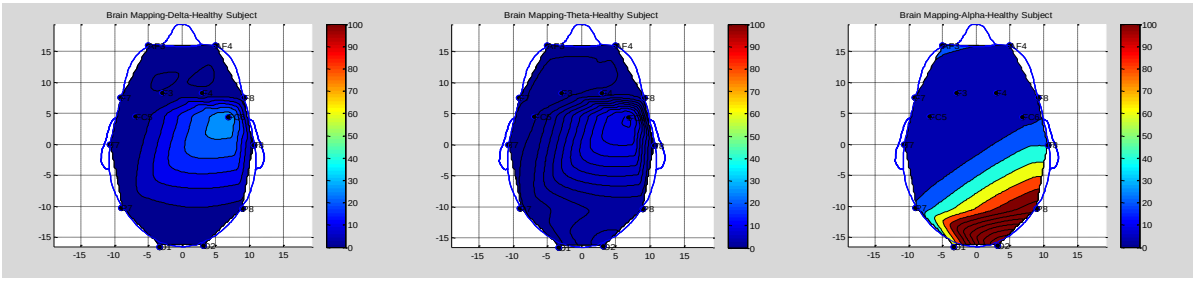
(a) (b)

Figure 2. Graph of EEG's power spectral in (a) AD patients and (b) normal subjects.



(a) (b) (c)

Figure 3. Brain mapping of power spectral (a) delta wave (b) theta wave and (c) alpha wave in AD patients.



(a) (b) (c)

Figure 4. Brain mapping of power spectral (a) delta wave (b) theta wave and (c) alpha wave in normal subjects.

The result of brain mapping show that in patients with AD (figure 3), brain waves are dominant at the delta frequency, while in the normal subjects, brain waves are dominant at alpha frequency.

Table 1 shows the comparison of average MMLE values between normal subjects and AD patients. It shows that the average MMLE normal subjects on channel AF3, F7, FC5, O1, P8, T8, F4, F8 and AF4 has a higher value than the average MMLE in AD patients. The examples of EEG raw data and estimation MMLE chart are shown in figure 5.

Table 1. Average MMLE value for normal subjects and patients with AD

Channel	MMLE of each subject	
	AD	Normal
AF3	0,069	0,115
F7	0,035	0,100
F3	0,098	0,014
FC5	0,033	0,107
T7	0,165	0,032
P7	0,117	0,051
O1	0,042	0,064
O2	0,044	0,036
P8	0,026	0,121
T8	0,008	0,029
FC6	0,231	0,172
F4	0,030	0,052
F8	0,037	0,107
AF4	0,069	0,135
Average MMLE	0,071	0,081

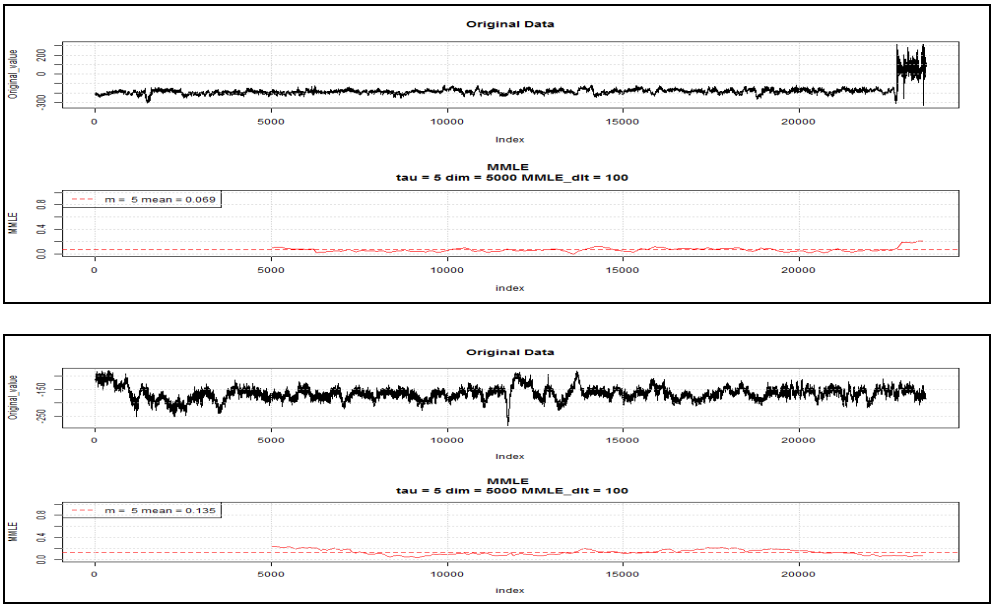


Figure 5. Raw data EEG and estimated MMLE graph at channel AF4 for AD patients (top) and normal subjects (below).

Based on theoretical review, the chaos level of normal subjects is higher than that of patients with brain abnormalities, including patients with AD. Brain signals are the sum of the electrical potential of a number of nerve cells in the cerebral cortex which are recorded through the scalp. Brain signals show macroscopic characteristics of brain function. For patients with AD, there was atrophy in the prefrontal areas related to the ability of concentration, the ability of thinking, decisions-making, and the emotional personality. The temporal lobe is associated with memory function.

4. Discussion

AD patients suffered damage or dysfunction in the cerebral cortex. Abnormality of electric potential recorded by EEG in the cortex is directly related to the pathological changes of the structure and function of cortical layers in AD [8]. Currently, the analysis of EEG abnormalities of AD patients based analytic techniques can be divided into three techniques, namely (a) time-frequency analysis, (b) wavelet analysis, and (c) chaos analysis. The marker most observed in EEG for AD patients is the reduction of high-frequency content which is called EEG slowing. This is the result of the increase in power at a low frequency band and a decrease in power at a high frequency band. Power on the frequency band represents activities on the frequency band. AD patients are characterized by the increase of theta activity and the decrease of alpha and beta activities. The increase of delta activity occurs at an advanced stage. The increase of EEG slowing rate is reported by some researchers where the increase occurs in the right postero-temporal region, the occipital region, the left frontal and the temporal lobes [9]. The result of this research found an increase of delta activity in the frontal lobe and an increase of theta activity in the left parietal area. The dominance of alpha activity in the posterior area is weak in AD patients.

Analysis of chaos can be used to identify certain characteristics of the EEG which are not visible to the naked eyes. Many researchers focus on quantitative measures of EEG complexity, as another marker of abnormality. The result has reported a decline of average MMLE in AD patients compared to the normal subjects. This neuropathology is related to cognitive deficits, which reduces neural complexity due to the decreased ability in processing information. This damage is associated with neuronal damages due to the presence of beta-amyloid plaques and tau protein in the nerve cells.

5. Conclusion

EEG's brain signals can be used as a marker for brain abnormalities and distinguish the abnormalities from normal conditions. Analytical techniques such as time-frequency analysis and chaos analysis can be used for data processing of EEG. Results of the analysis of the data show the shift of the frequency of the EEG in AD patients in comparison with normal subjects. Power spectral shifts occur at lower frequencies (delta and theta) under relaxed condition, while the results of the chaos analysis show that the complexity of neural chaos in AD patients is low compared to the normal subjects represented by average MMLE. This is consistent with the characteristics of AD where the deterioration of cognitive abilities occurs due to damage nerve cells in the brain.

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