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Single channel EEG analysis for detection of depression

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ABSTRACT

Purpose: This study is aimed at finding a simple method for detection of depression based on the analysis of single channel short-term EEG signals.
Materials and methods: The accuracy of linear, spectral asymmetry index (SASI), and nonlinear, detrended fluctuation analysis (DFA), methods for differentiating depressive and healthy subjects was compared. The eyes closed EEG was recorded from 18 common reference (Cz) channels for 34 subjects (17 depressive and 17 control). The signals were stored at 400 Hz sampling frequency and digitally filtered with cutoff frequencies at 0.5 Hz and at 40 Hz. The first 5 min of each recording was selected for further analysis.
Results: The experiments indicated maximum difference for SASI values in channel Pz and for DFA values in channels Pz and O2. Therefore, channel Pz was selected for comparison of two methods. The results of statistical analysis show that SASI values are significantly higher for depressive than for control group ($p = 3.577e{-}05$), while DFA values are significantly lower for depressive group ($p = 0.033$). SASI has superior discrimination ability with classification accuracy of 76.5%, while the classification accuracy of DFA was 70.6%. Linear combination of SASI and DFA resulted in 91.2% classification accuracy.
Conclusions: Our results demonstrate that the analysis of single channel signal can provide high accuracy of differentiation depression EEG.

1. Introduction

Fast rhythm of life and everyday stress raised significantly the role of mental disorders in our society. Nowadays, unipolar depressive disorder is a leading cause of burden of disease in high- and middle-income countries and it is projected to take the first place in the world in 2030 [1]. Therefore, the early detection of depression based on objective measures is of high importance.

The diagnosis of depression is based mainly on evaluation of the intensity of subjective symptoms using questionnaire and interview. Currently no objective criteria for evaluation of depression exist in clinical practice. Screening of population based on objective measures would be helpful to detect declinations before the subjective symptoms of disorder appear. For this purpose, a method for evaluation of depression is required suitable to be integrated in a low-cost stand-alone portable device designed for regular brain screening, for example, with the help of a family doctor.

Any declinations in the brain functioning and mental state are expected to be reflected in the brain bioelectrical activity. Electroencephalography (EEG) is easily available, cost effective technique, providing high temporal resolution for evaluation of the dynamics of bioelectric activity of the brain. Therefore, EEG is a valuable method for getting objective information about changes in brain physiology specific in depression and suitable for wide screening of population.

The novel method for detection of depression, spectral asymmetry index (SASI), was recently proposed in our previous studies [2,3]. SASI reflects the dynamics of EEG evaluating the balance between the powers of the higher and lower EEG frequency bands. SASI provided high accuracy differentiating healthy controls and depressive subjects [2]. However, currently the method is proved on lengthy EEG recordings (30 min) not suitable for regular brain screening. Therefore, the effectiveness of SASI should be evaluated on shorter EEG signals and compared to other methods previously successfully applied for EEG analysis.

SASI employs linear approach to EEG analysis. Since EEG exhibits complex behaviour [4,5], a nonlinear measure could be a valuable supplement enhancing the accuracy of SASI. However, classical nonlinear measures, as correlation dimension and Lyapunov exponent, are applicable only in case enough stationary data is available [6,7], which is not usually the case with bioelectrical signals and require long duration of data. Wavelet entropy (WE) and relative wavelet entropy (RWE) as the methods for analysis of short duration brain electrical signals have been proposed [8]. However, the

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applicability of the WE and RWE method for evaluation of depression is still not approved. The detrended fluctuation analysis (DFA) as a modified root mean square analysis of a random walk allows detecting power-law long-range correlations in a seemingly non-stationary time series [9]. As DFA systematically eliminates trends of different order, it is not so susceptible to noise. Additionally, DFA has been proven being successful for detection of depression [10–12] and consequently applicable at reasonable durations of the signal. Therefore, DFA was selected for comparison with SASI.

DFA was first applied to DNA sequences by Peng et al. [9] and shortly the method was applied to the analysis of heart rate time series [13]. To this day DFA has been applied to a variety of different physiological data [14–21], including EEG studies [22–25]. Some of those indicate that DFA is able to discriminate between health and pathology. For example the DFA scaling exponents differ in Alzheimer disease [26,27] and schizophrenia [25] compared to controls. DFA has also proven successful in EEG sleep studies in depression [10]. Lee et al. [11] recorded resting eyes closed EEG and applied DFA to synchronization likelihood averaged over pairs of channels. Hosseinifard et al. [12] recorded eyes closed multichannel EEG and calculated several linear and nonlinear measures, DFA as one of those. However, neither the parameters for DFA calculation nor the resulting DFA values for depressive and control group were presented. The emphasis was solely on classification. The accuracy of 90% was achieved combining 14 features: several EEG channels; linear and non-linear features – including DFA. Due to numerous channels and features, the used approach would not be the best practice for a simple screening device.

The aim of this work is to compare effectiveness of linear SASI and nonlinear DFA methods for detection of depression EEG utilizing single channel short-term signals. For this purpose, SASI and EEG long range correlations in depression are evaluated using the same signals of 5 min length from various EEG channels. The spatial distribution of sensitivity of the measures is analyzed and optimal channel selected. The classification accuracy was selected for comparison of the effectiveness of the measures.

2. Methods and equipment

2.1. Subjects

The experiments were carried out on a group of 17 female patients with major depressive disorder and 17 female age-matched control subjects. The average age was 39 years, with standard deviation 12 years. Subjects with depressive disorder without antidepressant treatment were selected from a hospital inpatient unit. Subjects with nonpsychotic depressive disorder as defined by ICD-10 criteria and determined by 17-item Hamilton Depression Rating Scale (HAM-D) score higher than 14 were eligible.

The study was conducted in accordance with the Declaration of Helsinki and was formally approved by the local Medical Research Ethics Committee.

2.2. Experimental procedure and EEG recording equipment

The experimental procedure for a subject included continuous EEG recording during 30 min between time interval 9 a.m. to noon. The subjects were lying in relaxed position with closed eyes during the recording. The room was dark but no other special conditions were provided. The subjects were lying in a relaxed position, eyes closed and ears blocked during the experiments.

Cadwell Easy II EEG measurement equipment was used for the EEG recordings. The EEG was recorded using 18 common reference (Cz) channels, which were placed on the subject's head according to the international 10-20 electrode position classification system. The ground electrode was placed to site AFz. Vertical and horizontal electro-oculograms were recorded.

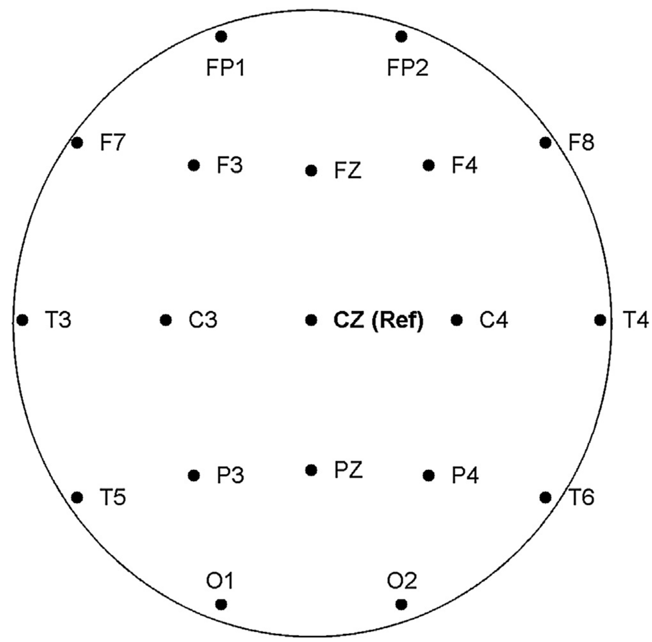

Fig. 1. 18-channel EEG electrode positions recorded with a common reference Cz.

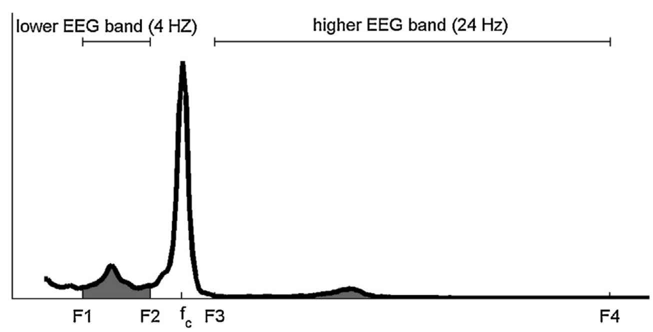

Fig. 2. Grey areas represent a subject's individual lower and higher frequency band powers used to calculate SASI. fc is the individual alpha frequency peak. F1, F2, F3 and F4 are the lower and higher frequency band boundaries calculated for a subject according to the individual alpha frequency peak fc.

Fig. 1 indicates the electrode positions used for EEG recordings. Raw EEG signals were recorded within a frequency band of 0.3–70 Hz. The impedance of recording electrodes was monitored for each subject prior to data acquisition and it was always below 5 kΩ. The sampling frequency was 400 Hz. Epochs containing artifacts (e.g. eye movements, muscle activity) were visually detected and discarded. 5 min duration eyes closed EEG without artifacts was selected for further analysis. The raw EEG signals were further digitally filtered with cutoff frequencies at 0.5 Hz and at 40 Hz. EEG analysis was performed using Matlab software.

2.3. EEG analysis – SASI

SASI is calculated from power spectral density of EEG signal in a single channel [2]. The method excludes the individual alpha frequency band and characterizes the EEG spectral asymmetry by calculating the relative difference between the higher and the lower EEG frequency band power. For the lower EEG frequency band a 4 Hz bandwidth (close to traditional theta bandwidth) was selected,