EEG Eye-Blinking Artefacts Power Spectrum Analysis

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Abstract: *Artefacts are noises introduced to the electroencephalogram's (EEG) signal by not central nervous system (CNS) sources of electric fields inside and outside subject's body. The artefacts impede the analysis of the signal and should be handled properly. The most common and characteristic kind of artefacts is the electrooculographic (EOG) ones, especially subject's eye-blinking artefacts. In this paper an analysis of the power spectrum of eye-blinking artefacts is described with a connection of using the EEG for brain-computer interface (BCI), working with α- and μ-rhythm (range 8-13 Hz) brain potentials.*

Key words: *BCI, blink artefact, EEG analysis, EOG, power spectrum.*

INTRODUCTION

One of the most important and distinguishing aspects of humans is the ability to communicate. Communication between people is richer and more complex than any other form of communication and plays a vital role in any relationship. Verbal and written messages are typically sent using the mouth and throat or the hands and are received by the ears or eyes, all of which are mediated by extensive processing mechanisms in the brain. While communication between humans has been extensively developed and studied, communication between people and devices – especially sophisticated electronic systems – is relatively embryonic. As brain science and computer technologies mature, it is inevitable that the ultimate intuitive interface will involve direct communication between the user's brain and a computer – brain computer interface (BCI).

Almost all of the BCIs studies are based on EEG, recorded from the scalp as a non-invasive and easy to use method, which does not require heavy and complicated equipment [10]. BCI consists of input part, processing part, output part and a protocol, which controls the process [9]. Until the user is performing a mental task, his/her mental effort changes the EEG potentials. Those changes are later recognised by a classificator and the result forms the signal for the output device's control.

Subjects taking a part in EEG experiments blink, move and glance about, as is expected of anyone asked to sit in a chair for a long time and engage in a repetitive task. Unfortunately, these movements may introduce periods of electrical noise - not CNS artefacts that may be difficult to discriminate from neural activity. Artefacts can dramatically alter the signal recorded at all scalp areas, especially those closest to the source of the noise [2].

Electromyography (EMG) of the face muscles could dominate in the frequency range of β- and μ-rhythms [6], measured in frontal placed electrodes, the eye-blinks could impact frequency range of θ- even μ-rhythm in frontal and central scalp areas [3, 7]. Like the user could control BCI out by rising eyebrows or by blink, the mentioned activity could disguise actual EEG control signal. These artefacts could bring to false results and beliefs during the study of EEG based BCI. Later studies [4], pretending neuroprosthesis control by EEG, recorded from frontal cortex, show this risk. Next study [5] proves that the frontal EMG has a big influence over the control.

First step of developing a BCI is finding the EEG pattern of some mental tasks and train the classificator. Important part of this work is to select a proper part of the EEG and clear it (as much as possible) from artefacts. Determining what is considered artefact, how much artefact is excessive, and removing artefacts from real data is a necessary stage in EEG (pre) processing, especially when prepare the data for training the BCIs cllassificator.

DATA PROCESSING

To find the eye-blinking artefacts influence on the EEG data in the range 8-13 Hz a comparison between averaged power spectrum of segments, containing blinks and segments laying just before is made.

A database recorded by Bsc. Mark Wessel, and Eng. Pavel Hrubes, PhD, during experiments in 2005 in Delft University of Technology, Department of MMI is used. The electrodes positioning corresponds to the international "10-20 system" [6]. To decrease the electrode-skin resistance an electrode cap with hollow electrodes filled by an electro technical gel [11] is used.

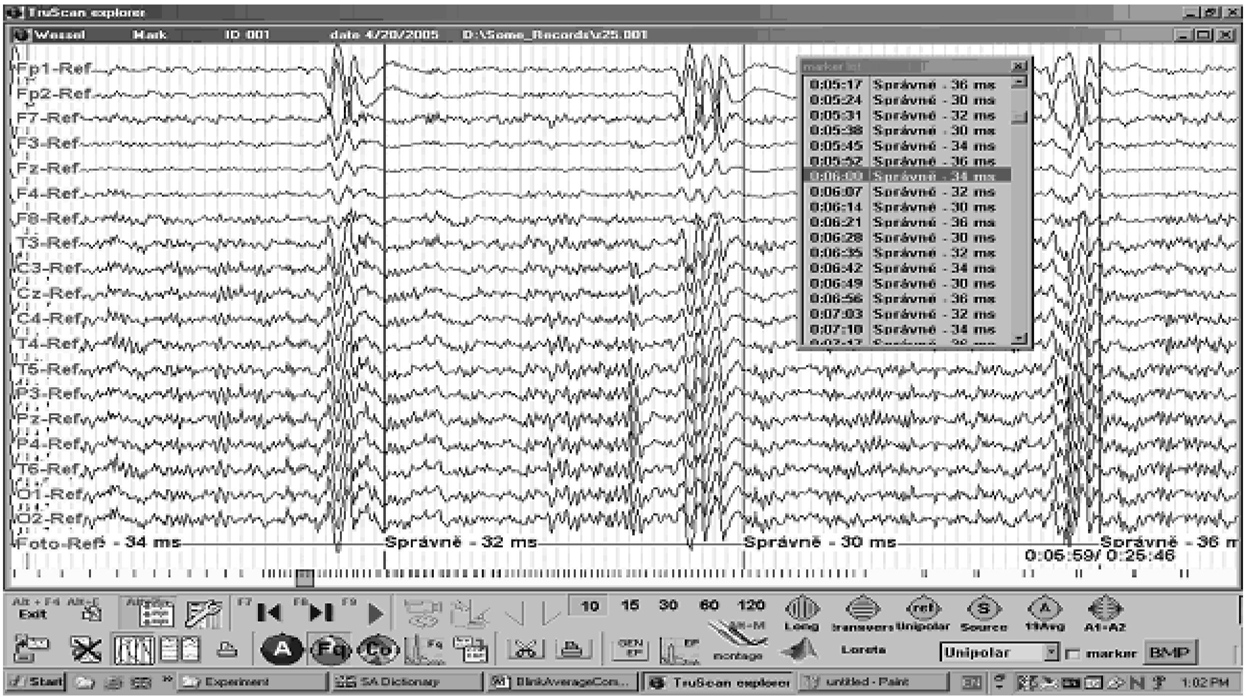

Fig. 1. EEG during performance of four different tasks with eye-blinks at every task's end (vertical line), view in TruScanExplorer [11].

The study is made on data, recorded during various mental tasks' performance in the frame of one session for the whole existing database, containing 40 sessions. According to the experiment's schedule for tasks 30, 32, 34, 36 – named respectively Visual presentation of "Yellow triangle", "Green dot", "Red cross" and "Blue lines" first 5 seconds from every task are "clean" data, namely data that do not contain blinks, the following 3 seconds contain a planned blink. Later the following task starts. The tasks alternate with each other in pseudorandom order, fig. 1. Every task repeats 5 times that is (4 tasks x 5 times) = 20 segments per one session. Averaging blinks, occurring during various mental tasks' performance is not a problem when the comparison goes with segments without blinks during these same tasks. From other side, according to a preliminary study, these four tasks have almost similar patterns. For the present study the electrode C3 is chosen, because it is placed above the central part of the brain (not too close to the blinks' artefacts sources).

Every blink is selected in three-seconds segment (768 samples of data), including EEG before and after the visible maximum of the blink in time domain – fig. 2. In time domain every blink has its own unique form, but the aim of the study is the power spectrum comparison. In all channels the amplitude of the blink is almost equal. In Fp1 and Fp2 the amplitude of EEG without blinks is lower (1) in comparison to other electrodes (not shown on a picture), which makes them usable for automatic blinks detection by simply controlling EEG amplitude in time domain. If the threshold is properly set, the probability of errors tends to zero.

$$U_{blink} = (3-5).U_{noBlink} \quad (1)$$

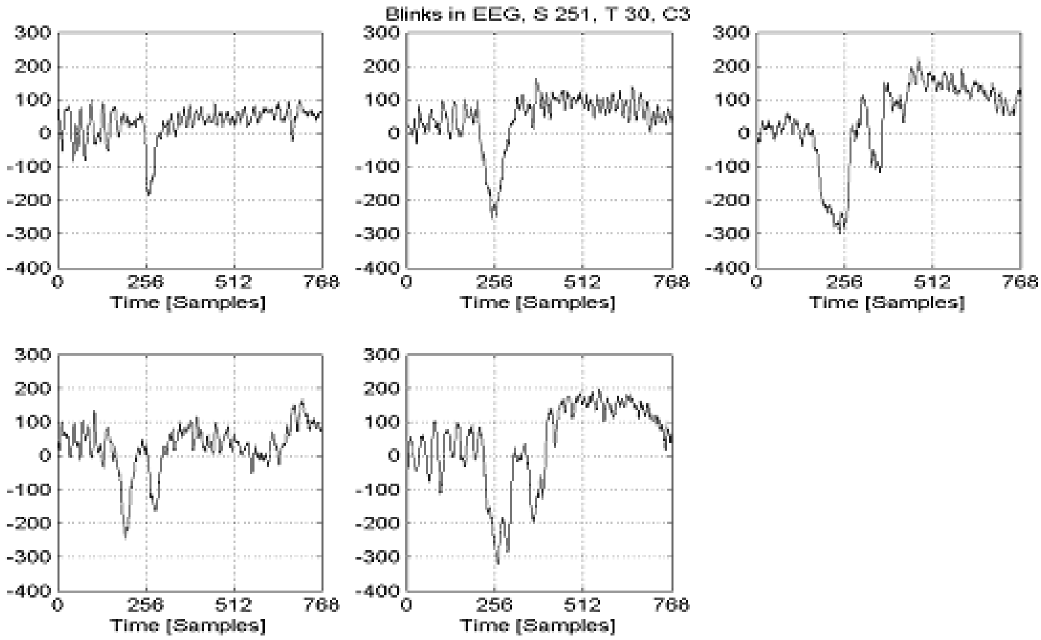

Fig. 2. EEG segments with blinks in channel C3 during task 30 (MATLAB).

For every three-second segment which contains a blink the Fourier transform and the power spectrum are calculated [1]. The results for frequencies up to 30 Hz are in PWR_{Blink} matrix. Every row ($pwr_{j,1}$ - $pwr_{j,91}$) contains one segment's power spectrum.

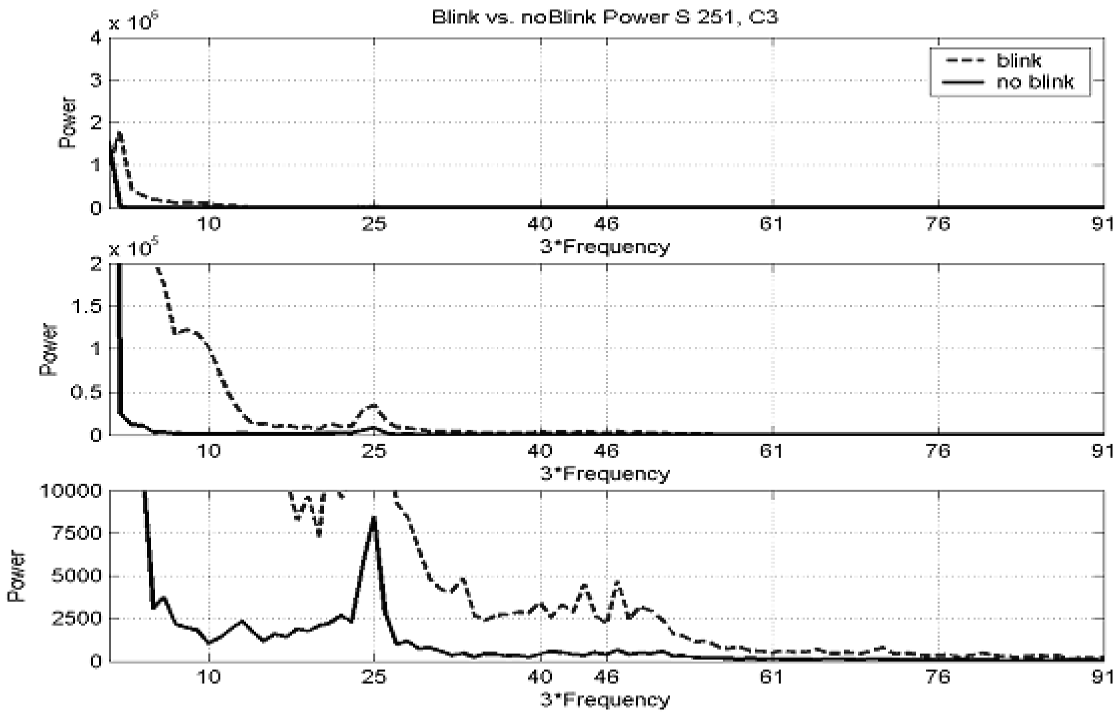

Fig. 3. Averaged power spectrum in C3 (MATLAB).

Averaging the power spectrum according to (2) is the array AvP which contains the averaged power spectrum for all segments with blinks. Averaging 20 segments results in $\sqrt{20}$ lower level of the white noise [8], which is a result of neighbor neurons activity [6].

The same is done on other 20 three-seconds segments just preceding the blinks in every task.

$$AvP_j = \frac{1}{20}\sum_{i=1}^{20} pwr_{ij} \qquad (2)$$

The results for border frequencies are in table 1.

Table 1.

Frequency [Hz]	3	8	13	15	20	25
Position on the plot, fig. 3	10	25	40	46	61	76
Blink power	101 340	34 935	3 446.8	2 194.8	487.3	327.85
No Blink power	1 016.5	8 490.9	400.48	415	140.02	74.726

The graphs of averaged power for segments with and without blinks are on fig. 3. In fact it is one graph in three scales.

From first graph one could compare the proportion between the powers. The low frequencies power of the data without blinks that could be seen in this small scale is only DC offset's power. According to table 1, below 3 Hz the power of containing a blink segment is more than 100 times higher. This regularity could be used for automatic blink detection.

On second graph one could see that the power of the blink is concentrated up to around 3 Hz (x-tick mark 10*).

The scale of third graph is chosen to see the power correlation in the range 8-13 Hz (between x-marks 25-40*). The conclusion is that the blinks' power in the range 8-13 Hz is much higher (see table 1) than the power in segments without blinks and could significantly contaminate the EEG.

Notice*: X-tick mark 1 is reserved for the DC-offset's power. As the Fourier transform of 3 seconds segment is done, the frequency resolution is 3 times higher, that sends 3 Hz to x-tick 10 (1+3x3) and respectively 13 Hz to x-tick 40 (1+13x3).

CONCLUSIONS AND FUTURE WORK

Eye-blinks power spectrum is concentrated in the range 0.5 to 3 Hz. There the power of blinks is much more (more than 100 times) higher than blinks-free EEG data. This could be used for automatic eye-blink detection.

The contamination of the EEG signal, caused by the blinks could be seen even above 13 Hz. In the range 8-13 Hz in most of the channels the power introduced by the blinks is times higher than the power of the "clean" EEG. This correlation could bring errors during the classification, considering the fact that the EEG patterns power is smaller. Therefore, in BCIs working with patterns in the range 8-13 Hz the eye-blinks artefacts should be eliminated.

This study will be used for preparing data for final mental tasks' selection. After choosing tasks with clear and expressive patterns from the existing database (and eliminating the others) the input vectors for the classificator of a BCI will be formed.

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