ADS 1299-based Open Hardware amplifier from openbci.com: signal quality for EEG registration and SSVEP-based BCI

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1 OBJECTIVES

Owing to the recent progress in brain-computer interfaces (BCI), there is a growing interest in affordable solutions for EEG recording. Several competitively priced consumer products appeared on the market in the last decade, however they do not seem to offer neither the signal quality of professional systems nor the control required for scientific experiments. The appearance of the Texas Instruments ADS 1299 chip, containing an 8 channels, 24-bit analog-to-digital converter, paved the way for high quality, low-cost and low-energy solutions, like the OpenBCI recording board. In this study we compare its performance to a top-class commercial EEG amplifier from TMSi.

2 METHODS

There seems not to be any generally accepted method for comparing the overall performance and signal quality of EEG recording systems. We propose a direct comparison of signals recorded simultaneously by the two systems from one subject. We compare spectra of resting state EEG (eyes open / closed) and the quality of the signal used for BCI. As for the latter, the most common approach is P300-BCI (De Vos, 2014); however, this paradigm is the least demanding in terms of the signal quality. Therefore we choose the calibration procedure from the SSVEP-based (steady state visual evoked potentials) BCI, designed for assessing the expected performance of the BCI.

2.1 Hardware and Software

As the reference system we used the TMSi Porti 32 amplifier (resolution 22 bits, input impedance $>10^{12}\Omega$, active shielding of electrode cables) from Twente Medical Systems International and Open Source software from the OpenBCI.pl project (Durka, 2012). The tested system consisted of a 8-channel board and the software provided by the openbci.com project.

2.2 Experimental Setup

To provide possibly straightforward comparison, we recorded signals simultaneously from two separate sets of electrodes and grounds, placed close to each other in alternating occipital locations above the visual cortex. We used cup electrodes, Ag/AgCl on shielded cables for TMSi, while those included in OpenBCI Kit were gold-plated and connected with unshielded cables. We ran the recordings with all the available filters turned off, including the notch filters.

Sampling frequencies were 256 Hz for TMSi and 250 Hz for the OpenBCI board. It was not possible to use exactly the same sampling on both systems, so the signal from OpenBCI board was offline resampled up to 256 Hz before further processing and comparisons. Both signals were high-pass filtered at cutoff frequency 3 Hz. Power spectral analysis was performed by means of Welch's estimate.

To assess the potential performance in SSVEP-based BCI application we used the following procedure: different frequencies $f_1 ... f_8$ were simultaneously flashing on the neighboring fields of the BCI Appliance (Durka, 2012); subject was asked to concentrate on the square indicated by asterix, flashing with the target frequency f_t, while the other fields were flashing with different frequencies from the testing set of 10 frequencies from range 13-22Hz. 8 trials, each 5 seconds-long with 1 second break, were recorded for each frequency.

Spectral powers in all epochs for each frequency (except for the target frequency f_t) formed the distribution for the null hypothesis of a random guess of the target frequency. Z-score was computed for the target frequency as the difference between the mean of this distribution and the mean power computed for the non-target frequencies distribution, divided by the variance of the non-target distribution.

3 RESULTS

3.1 Technical remarks

The first and most noticeable advantage of the TMSi system is the immunity to movement artifacts stemming from the active shielding of the electrodes. In case of the tested system from openbci.com, neither the board nor the electrodes were shielded, so at the first attempt the signal was severely contaminated with the 50 Hz artifact from the mains. To cope with this problem we took advantage of it’s small footprint, allowing to keep it close to the body with entwined cables.

3.2 Spectra

Figures 1 presents the power spectral density of 60-sec epoch of the resting state EEG with eyes open and closed, recorded simultaneously from the same subject.

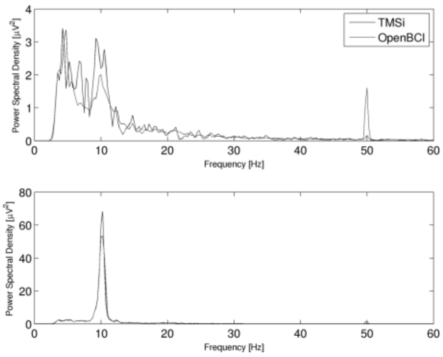

Figure 1: Spectra from the same 60-sec epoch of EEG recorded simultaneously. Upper panel - eyes open, lower panel - eyes closed.

3.3 SSVEP

To asses the potential performance in real world application of SSVEP-based BCI systems, we recorded the calibration session from the openbci.pl system. Figure 2 presents the Z-scores (Section “Signal Processing”) obtained from the signals recorded simultaneously by both amplifiers.

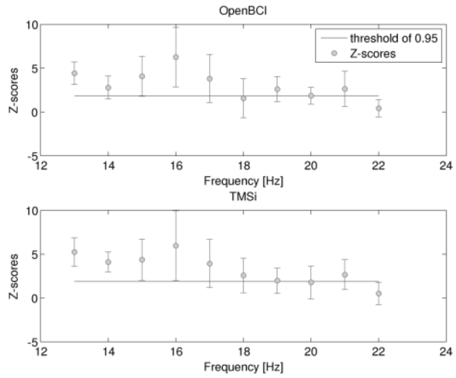

Figure 4: Z-scores for the differentiation of the SSVEP responses recorded by the OpenBCI (upper panel) and TMSi (lower panel) systems. The line indicates 5% significance of a correct determination of the target frequency by the BCI.

4 DISCUSSION

In this brief study, a reference EEG system from TMSi showed performance superior to the OpenBCI board in terms of suppression of the 50 Hz interference without notch filter and immunity to movement artifacts. Spectra of recorded signals and performance in laboratory recordings of SSVEP had similar properties. These preliminary results indicate, that ADS 1299-based Open Hardware systems may provide signal quality comparable to the top-class commercial EEG amplifiers, potentially sufficient for research and advanced BCI applications.

REFERENCES

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