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Comparison of a consumer grade EEG amplifier with medical grade equipment in BCI applications

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Introduction: The price of the hardware prevents the dissemination of non invasive BCI. Recently, more affordable EEG amplifiers appeared on the market. Among them, the OpenBCI board (http://www.openbci.com/) claims to bring BCI to the many. Enthusiasts and laboratories have started to use this board, but the quality of the recordings and the reliability of the resulting systems have yet to be assessed. In this study, we compare side by side the OpenBCI board with the g.tec g.USBamp amplifier (http://www.gtec.at/), a device commonly used in BCI research. Both OpenBCI and g.USBamp amplifiers can record up to 16 electrodes. This number of channels is sufficient to setup various BCI. We compared OpenBCI with g.USBamp for, on the one hand, P300 speller and, on the other hand, EEG-based workload monitoring using the n-back task [1]. Doing so, we could study respectively temporal and spectral features.

Material and Methods: As opposed to most of the literature, that compares electrodes (e.g. wet *vs* dry), in the present work we study amplifiers. Therefore, instead of complex montages [2] or between-subjects experimental designs [3], we used the same electrodes during simultaneous recordings to compare both. This setup ensures that the signal coming to each amplifier is exactly the same, avoiding any offset or bias regarding the source of the measures. For that purpose we crafted two adapters, with and without a circuit made of ideal diodes. We called those connections “direct” and “isolated” respectively. The ideal diodes montage, placed before amplifiers' inputs, prevented any current to flow in reverse direction from either amplifier to the adapter; it ensured that one set of recordings would not bias the other. One recording session occurred for each application and each condition. We acquired 16 EEG channels all over the scalp using the active g.Ladybird electrodes from g.tec – ground set to “bias” pin on the OpenBCI. Two kinds of analyses were performed. One compared how the amplifiers behaved in practice, when used for classification. The second then looked at the Pearson correlation between the acquired signals, on par with the literature – e.g. [4]. OpenViBE 1.0 was used to acquire signals for both amplifiers – 512Hz sampling rate for the g.USBamp, 125Hz for the OpenBCI. The visual P300 speller came from OpenViBE, with default settings. The protocol inducing workload was implemented following [1]. The signal processing pipeline for temporal and spectral features were analogous to [5].

Results: Direct connection: we tested classification accuracy for significance using Wilcoxon signed-rank tests – we repeated the classification ten times using randomized 4-fold cross-validation. There was a significant difference between amplifiers for the P300 tasks ($p < 0.01$, 48 target trials, 240 distractors). The AUROCC mean score for the g.USBamp was 0.961 *vs* 0.918 for the OpenBCI. There were no significance ($p = 0.079$) for the workload monitoring application, AUROCC scores were 0.89 *vs* 0.90 (180 trials in each 0-back and 2-back task). The Pearson correlation between temporal features of the P300 speller was statistically significant ($p < 0.001$), with a mean R score of 0.9965 over the 16 channels. There was also a significant correlation ($p < 0.001$) for the spectral features from the workload application, with a mean R score of 0.9983 for the 0-back task and 0.9979 for the 2-back task. Isolated connection: there was no significant differences between amplifiers' AUROCC scores, neither with the P300 speller nor for the workload application. As for the signals, there was significant correlations for temporal and spectral features ($p < 0.001$); R score of 0.8847 for temporal features, 0.9976 for spectral features during 0-back task and 0.9987 during the 2-back task. Note that for all applications and conditions AUROCC scores were far beyond chance level (which is 0.5).

Discussion: The correlation between temporal and spectral features tends so show that the signals acquired from the g.USBamp and the OpenBCI are, if not identical, very closely related. While there were no significant differences in classification of spectral features, the g.USBamp performed slightly better than the OpenBCI during the P300 speller task. The results with the “isolated” connections seems to support the similarities between both amplifiers. The weaker correlation compared to “direct” connections may be due to noise added by the ideal diodes circuit, as it did not translate into different classification accuracy – working BCI applications were produced still.

Significance: Overall, the results suggest that the OpenBCI board – or a similar solution also based on the Texas Instrument ADS1299 chip – could indeed be an effective alternative to traditional EEG amplifiers. Even though medical grade equipment possesses certification and still outperforms the OpenBCI board in terms of classification, the latter gives very close EEG readings. In practice, the obtained classification accuracy may be suitable for reliable BCI, widening the realm of applications and increasing the number of potential users.

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