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Tripolar Concentric Ring Electrode Encephalography Reduces Muscle Artifacts for BCI Applications

P. Steele[1], R. Bartels[1], W. Besio[1,2*]

[1]CREmedical Corp, Kingston, RI, USA;[2]University of Rhode Island, Kingston, RI, USA

*4 East Alumni Ave, Kingston, RI, USA. E-mail: besio@uri.edu

Introduction: Brain-computer interfaces (BCIs) are systems that allow communication between the brain and the external world. Brain signals related to human intention are collected via electroencephalogram (EEG) and translated into control signals. The EEG is sensitive to muscle activity, electromyography (EMG), related artifacts that occur from user movement. Besio developed tripolar concentric ring electrodes (TCREs) that closely approximate the Laplacian using the derivation 16*(M-D) – (O-D) where M, D, and O are the potentials on the middle ring, central disc, and outer ring, respectively [1, 2]. This formula is incorporated into our t-Interface 20. By taking the difference between closely spaced (1.0mm) sensing elements, the common noise to each element is cancelled. This is different than the typical monopolar (disc) EEG signal, which is derived from the difference in potentials between a recording electrode and a reference electrode. Conventional disc electrodes are centimeters apart and sharing less common noise, thus, the noise is not cancelled. In previous research, we found that EEG with TCREs (tEEG) has significantly better signal-to-noise ratio, less mutual information, and higher spatial resolution [1,2]. We also found that the outer ring of the TCRE can be used to emulate the disc electrode [3]. Further, real-time center-out cursor control with tEEG was significantly better than with EEG [4]. The current experiment compares the effectiveness of tEEG and EEG for attenuating muscle artifacts.

Material, Methods and Results: We recorded tEEG and outer ring EEG in 5 healthy participants. The tEEG was preamplified (gain of 187) and the EEG was buffered both with our custom preamplifier the t-Interface 20. We placed 20 TCREs in each location of the 10/20 system, ground on the forehead, and reference as an average of the left and right mastoid processes and the occipital region (near Oz). Data were recorded (400 S/s, 1 to 100 Hz) in each participant using the following protocol: one 30-second segment of rest, ten 30-second segments of right head turn, ten 30-second segments of left head turn, and ten 30-second segments of jaw clench.

Signals from tEEG and EEG were band filtered from 10-100Hz, and a signal to noise ratio (SNR) was calculated by taking the ratio of the average power of the movement segment to that of the rest segment for each electrode location in each movement trial for both the tEEG and EEG signals. We then took the mean of those ratios for tEEG and EEG across all participants for each movement category: right head turn, left head turn, and jaw clench. For right head turn, the mean ratios were 3.3±5.0 and 16.1±14.7 for tEEG and EEG respectively. For left head turn, the mean ratios were 3.9±7.4 and 21.7±23.6 respectively, and for the jaw clench the mean ratios were 11.9±28.9 and 35.9±80.7 respectively. In each movement category, the mean ratio was smaller for the tEEG than the EEG, indicating less movement artifact in the tEEG signal. This difference was found to be statistically significant (Wilcoxon signed rank test, p-value <0.0001).

Discussion: Fig. 1, from Pz, exemplifies that TCREs significantly reduce muscle artifact in tEEG recordings when compared to EEG. Local muscle artifacts from directly under the TCRE are sensed, however distant muscle artifacts are attenuated sharply. In the future we will compare more participants and other artifacts.

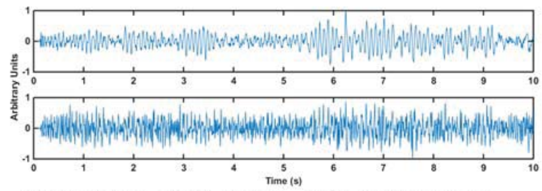

Figure 1. *Top – tEEG, Bottom – EEG. Right head turn with eyes closed. Notice prominent alpha waves in the tEEG while the EEG is contaminated with muscle artifacts.*

Significance: One of the factors negatively influencing BCI performance is the presence of muscle artifacts in EEG signals and being able to reduce these artifacts with a TCRE could prove an efficient tool to improve BCI performance.

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