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Analyzing the Performance of Dry Electrodes for P300 Brain-Computer Interfaces in Participants with ALS

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Introduction: P300-based BCIs typically utilize gel-based "wet" electrodes for EEG recording that require a substantial amount of time and expertise to set up. Although dry electrodes are much faster and easier to apply, reduced signal-to-noise ratios impede their widespread use. Without a stabilizing gel layer to keep the electrodes in good electrical contact with the skin, dry electrodes may be more susceptible to motion artifacts. We present a performance comparison between wet and dry electrodes for the P300 speller in participants with ALS, and investigate two artifact detection techniques to measure the difference in possible motion artifacts between the systems.

Material, Methods and Results: Eight participants with communication disabilities (ALS=7, PLS=1) completed this study. Each participant completed two P300 speller sessions; one using a passive wet electrode system and one using the g.Sahara dry electrode system. The average spelling accuracy was 87.9% using wet electrodes and 42.8% using dry electrodes, and the differences in accuracy were statistically significant ($p < 0.01$). Power spectral density estimates revealed an increase in low-frequency noise for dry EEG recordings, which suggest that transient voltages, such a motion artifacts, may be negatively impacting dry system performance. To measure artifact noise, two techniques were used to detect large transient voltages in EEG recordings during the periods between characters (no stimulus flashing, eliminating the possibility of inadvertently detecting P300s). The first technique used an autoregressive model. Given that transient artifacts are non-stationary phenomena, the model detected a large error (exceeding a given threshold) when an artifact may have occurred. The mean number of artifacts detected for a set of thresholds were averaged across the eight participants and the results are displayed in Figure 1a. The second technique used wavelet analysis. Peaks in the wavelet approximation coefficients above a certain threshold were measured as artifacts. The results were averaged across participants and are shown in Figure 1b. The results in Figure 1 show that for thresholds above 30μV, both techniques detect a larger number of possible artifacts in the dry electrode recordings when compared to the wet electrode recordings.

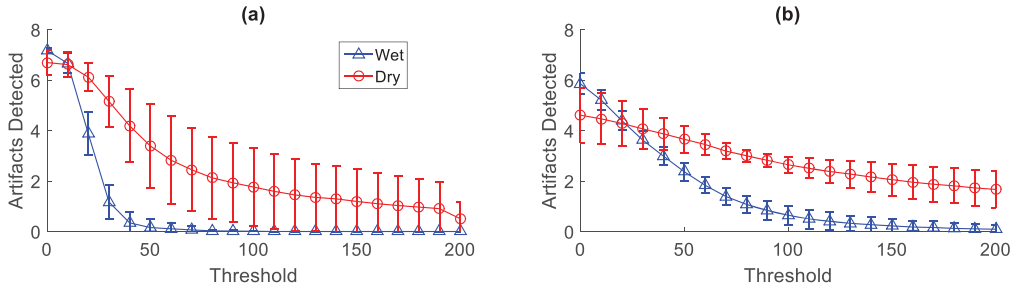

Figure 1. *Two techniques were used to detect possible artifacts during interstimulus durations: (a) autoregressive modeling and (b) wavelet analysis. The results in both plots were averaged across eight participants with communication disabilties. Each plot displays the number of possible artifacts detected (y-axis) for a threshold (x-axis) in the dry electrode recordings (circles) and the wet electrode recordings (triangles)*

Discussion: Two transient artifact detection techniques (i.e., autoregressive modeling and wavelet analysis) revealed an increased number of possible motion artifacts for the dry system when compared to the wet system. This indicates that decreased dry system BCI performance may be the result of artifacts incorrectly classified as target signals.

Significance: Dry electrodes would reduce set-up time and complexity for the P300 speller. However, dry systems often realize lower classification accuracies than conventional wet systems and the differences in performance are statistically significant. The results from this artifact detection study indicate that transient removal techniques may be needed to improve dry system performance.

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