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Ear-EEG Auditory Error-Related Potentials

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Introduction: Ear-EEG provides a comfortable, user-friendly alternative to traditional scalp-EEG, supporting the use of daily, wearable recording of EEG. By integrating custom 3D-printed earpieces with AIRTrode-sponge electrodes [1, 2], this study advances ear-EEG technology, enabling the recognition of error-related potentials (ErrPs) in real-time. ErrPs are neural correlates of error awareness [3].

Material, Methods and Results: Custom right-oriented earpieces were fabricated using flexible resin and embedded with AIRTrode-sponge electrodes for enhanced biocompatibility, contact quality, and long-term recording. The earpieces contained 4 electrodes. For all experiments, both ear-EEG and scalp-EEG were acquired. Characterization included recording impedance, changes in alpha rhythms, and auditory steady-state responses. Auditory ErrPs were elicited by subjects perceiving incorrect answers to questions delivered via audio. The brain-computer interface (BCI) relied on the AIRTrode-sponge electrodes and on a Riemannian geometry-based classification framework to decode auditory ErrP [4]. BCI output feedback was delivered via audio, indicating whether or not the classifier successfully decoded the subjects' EEG as either ErrP or correct depending on the trial. Ten healthy subjects participated in the experiments. Results showed that all 4 electrodes captured the ErrPs, albeit with different dynamics, thus, demonstrating the high spatial resolution of our AIRTrode-sponge electrodes. Furthermore, the BCI achieved a statistically significant online performance in the recognition of the presence or absence of auditory ErrPs, outperforming pseudo-online performance of a BCI that used scalp-EEG. Figure 1 displays the online performance of the ear-EEG ErrP BCI for each subject, as measured by Cohen's Kappa, indicating reliable accuracy for 9 out of 10 subjects.

Conclusion: The AIRTrode-sponge ear-EEG device successfully captured EEG signal including ErrPs, demonstrating its potential for BCI applications. To address reduced spatial coverage limitations and improve performance, future work will incorporate dual-ear devices and extend training sessions to multiple consecutive days. This study establishes a strong foundation for practical, long-term neural monitoring and BCI development using ear EEG recorded with AIRTrode-sponge electrodes.

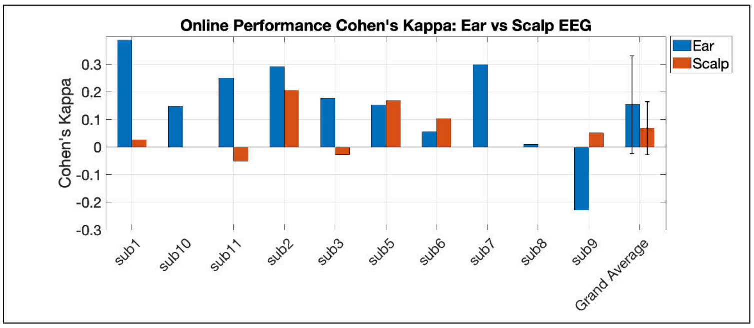

Figure 1: *Online and pseudo-online performance evaluation metric Cohen's Kappa of the auditory ErrP BCI using ear-EEG and scalp-EEG, respectively. The Cohen's Kappa value for each subject represents the grand average of all their corresponding runs in the online session. Scalp-EEG for subjects 7,8, and 10 were discarded due to poor quality.*

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