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The Application of Stereo-electroencephalography for Brain-computer Interfaces

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Introduction: Stereo-electroencephalography (sEEG) has grown to be the most prominent method in the treatment of medication-resistant epilepsy due to its minimally invasive nature and ability to target deep subcortical brain regions with high temporal resolution (Fig. 1). Despite its growing use in the clinic and in neuroscientific research, its potential for brain-computer interfaces (BCIs) has remained underexplored [1]. Over the past 5 years, our lab has investigated sEEG's potential in decoding a wide range of cognitive processes relevant for BCIs, including hand movement [2], speech [3], navigation [4] and decision-making [5]. We have also addressed key preprocessing challenges such as re-referencing, which arise from its unique electrode coverage.

Methods: We evaluated the impact of six re-referencing methods (bipolar, laplacian, electrode shaft, common average, common median, and a data-driven independent component-based method) on sEEG signal quality and decoding performance of two tasks in beta and broadband frequency ranges. Additionally, we applied machine learning techniques to evaluate the potential of decoding different cognitive processes from sEEG recordings: hand movement (grasping motion), speech (overt production), navigation (movement speed) and decision-making (arbitrary and informed decisions).

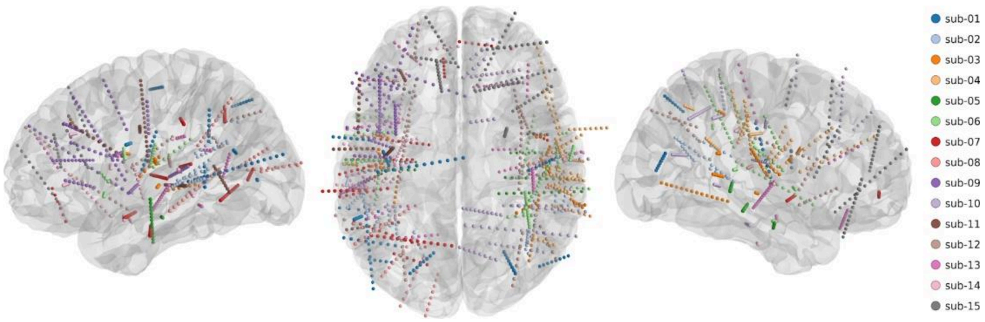

Figure 1: *Electrode locations on an averaged brain for the 15 stereo-electroencephalography participants included in the re-referencing analysis. Each color represents one participant and each sphere represents one electrode channel.*

Results and Discussion: We found that the optimal re-referencing method depends primarily on the frequency range of interest, where local references (bipolar, laplacian) are preferable for low-frequency activity and global references (common average, electrode shaft) for high-frequency activity. However, the choice should be tailored to the goal of the study. The remaining results show that we can decode meaningful cognitive states from sEEG data, across a wide range of different tasks and processes. The depth electrodes offer the benefit of reaching sulci and deeper nuclei that other common invasive neurotechnologies cannot reach.

Significance: This work provides valuable insights into re-referencing strategies and decoding applications for sEEG, highlighting its potential as a versatile tool for both clinical and BCI developments.

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