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Evaluating implant locations for a minimally invasive speech BCI

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Introduction: Expressing thoughts through vocalizations is a natural form of communication that can deteriorate in individuals suffering from a stroke or a neuromuscular/neurodegenerative disease. Speech brain-computer interfaces (BCIs) have the potential to restore this communication channel by reconstructing speech directly from recorded neural signals. Many of the current feasible technologies require a relatively large craniotomy to implant the BCI device. Stereo-electroencephalography (sEEG), on the other hand, only requires small burr holes for implantation, thus reducing the risks associated with the surgical procedure. The sEEG electrodes have a viable potential for long-term BCI use, as the leads are similar to those used for chronic deep brain stimulation. They are routinely implanted in epilepsy patients to detect the epileptogenic zone, usually with a distributed coverage across multiple cortical and subcortical regions. Our large number of recordings with these patients allows us to investigate which electrode shaft location has the best potential for a speech BCI.

Methods: We collected overt speech production data in over 30 participants implanted with multiple sEEG electrode shafts (Fig. 1). Acoustic and sEEG signals were recorded simultaneously and were time-aligned. The sEEG signal was re-referenced to the average signal within each shaft. The neural signal was further divided using 50ms overlapping windows. We considered neural features up to 200ms prior to and including the frame aligned with the audio for reconstruction. We used a unit-selection approach in a 10-fold cross-validation for each individual shaft and each participant separately.

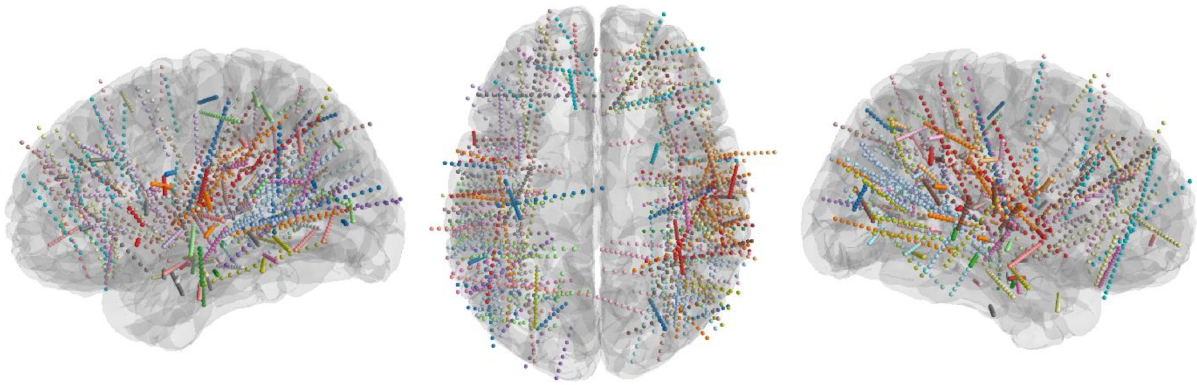

Figure 1. *Electrode shaft locations from included participants on an average brain. Each color represents one participant and each sphere represents one electrode channel.*

Results and Discussion: We evaluate the feasibility of reconstructing speech using a single sEEG electrode shaft by correlating the spectrogram of the original speech waveform to that of the reconstructed waveform. Electrode shafts covered nearly all regions of the brain (Fig. 1), although the occipital and frontal lobes were less densely covered than the temporal and parietal lobes. Electrodes were equally distributed between the two hemispheres. We investigate, across all participants and shafts, which location results in the strongest correlation. We focus on a comparison between hemispheres, lobes, depth and size of the electrode.

Significance: This work contributes to making an informed decision for the electrode placement of a (minimally invasive) speech BCI. Decreasing the necessary size of the craniotomy and the amount of implanted electrodes could reduce the burden on the patient.