Identifying sEEG Contacts with Auditory Perception and Speech Production Information: A Pilot Study

P. Z. Soroush[1*], C. Herff[2], J. Shih[3], T. Schultz[4], D. J. Krusienski[1]

[1]Virginia Commonwealth University, Richmond, VA, USA; [2]University of Maastricht, Maastricht, Netherlands; [3]UCSD Health, San Diego, CA, USA; [4]University of Bremen, Bremen, Germany;

[*]ASPEN Lab, Virginia Commonwealth University, 737 N 5th St, 23219, Richmond, VA, USA. Email: zanganehp@vcu.edu

Introduction: Brain-Computer Interfaces (BCIs) have shown promise for restoring communication to those who have lost this ability as a result of a neurological disease or injury. For those who have completely lost the ability to speak, the ultimate objective is to synthesize acoustic speech directly from brain activity associated with imagined speech [1]. One of the main challenges of designing a practical speech-BCI is the uncertainty about the brain regions and processes associated with imagined speech production. This pilot study examines stereo electroencephalographic (sEEG) data [2] and suggests that the vicinity of the auditory cortex and belts, previously believed to be predominantly associated with auditory perception, exhibit information relevant to imagined-speech BCI.

Materials, Methods, and Results: sEEG recordings were obtained from seven patients being monitored as part of treatment for intractable epilepsy at UCSD Health. The number of sEEG electrodes varied between 70-232 across participants and was solely based on clinical need. For the experiment, participants were presented with a short sentence on a monitor and simultaneously narrated via speakers. Participants were cued to overtly speak the sentence, followed by a cue to imagine speaking the sentence, while their voice was recorded simultaneously with the sEEG signals. The audio from the overt speaking trials was used to label the data as 'speech' from the onset to offset of the acoustic speech or 'non-speech' otherwise. The average onset timings and durations of the overt speech intervals were used to define surrogate 'speech' and 'non-speech' intervals for the imagined speech trials.

The channels in the vicinity of the auditory cortex and belts exhibiting large relative correlations between broadband gamma activity and audio recordings of the narrated sentences were identified as perceptual channels based on cross-correlation between the Hilbert amplitude envelopes of the audio file and the channel's broadband gamma power [3]. Channels exhibiting correlations above two standard deviations ($p<0.05$) from the mean across all channels were marked as predominantly perceptual channels (40 out of over 800 channels).

For both overt and imagined speech trials, the signal energy of each perceptual channel was calculated in theta (4-8 Hz), alpha (8-12 Hz), beta (12-30 Hz), and broadband gamma (70-170 Hz) bands in 10-ms steps from 200 ms before the speech-onset to speech-offset. These features were used to train a causal logistic regression model and a 10-fold cross-validation analysis to predict speech activity [4]. While all perceptual channels had significantly above chance performance for overt, only 16 of the 40 perceptual channels exhibited performance significantly above chance for imagined ($p<0.05$).

Discussion: Despite the absence of auditory feedback, channels in or proximal to auditory cortex detected speech activity during imagined speech trials significantly better than chance. This is consistent with previous studies showing activation in the auditory cortices during imagined speech or imagined hearing, regardless of the presence of an auditory stimulus [4-6].

Significance: The results of this pilot study suggest that brain regions in or around the auditory cortex, may exhibit information associated with imagined speech production that could inform the development of refined speech synthesis models.

References:

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