Premotor Cortico-Subcortical Synchrony During Speech Perception and Production

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Objective – Determine the relationship between premotor, motor, sensory, and subcortical regions in speech perception and production.

Background

- Many speech impairments have been linked to damage in the basal ganglia[1], including aphasia, dysarthria, stuttering, and other disorders[2].
- Prior work in speech perception and production has focused on the cortex, but recent studies have shown the subcortex[3] plays crucial roles as well.
- Studying how the subcortical regions interact with cortical regions has been difficult due to the location and invasiveness of the recordings.
- By investigating the dynamic relationship between cortico-subcortical mechanisms, we can learn more about the speech perception and production mechanisms.

Methods

- **Participants:** 4 patients undergoing awake DBS implantation.
- **Task:** Hear and repeat consonant–vowel (CV) syllable triplets.
- **Recording:** High-density ECoG & DBS (1 kHz).
- **Preprocessing:** Morlet wavelet power in 200-ms windows centered on each syllable's transition zone.
- **Modeling:** GLM predicting power from phonological features or syllable position.
- **Stats:** Permutation testing via label shuffling to identify significant electrodes/frequency bands.
- **Connectivity:** Phase Locking Value (PLV) computed between significant cortico-subcortical contacts for perception/production epochs.

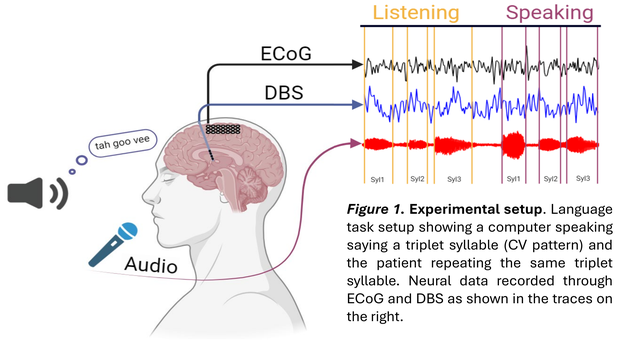

***Figure 1.* Experimental setup.** Language task setup showing a computer speaking saying a triplet syllable (CV pattern) and the patient repeating the same triplet syllable. Neural data recorded through ECoG and DBS as shown in the traces on the right.

Results

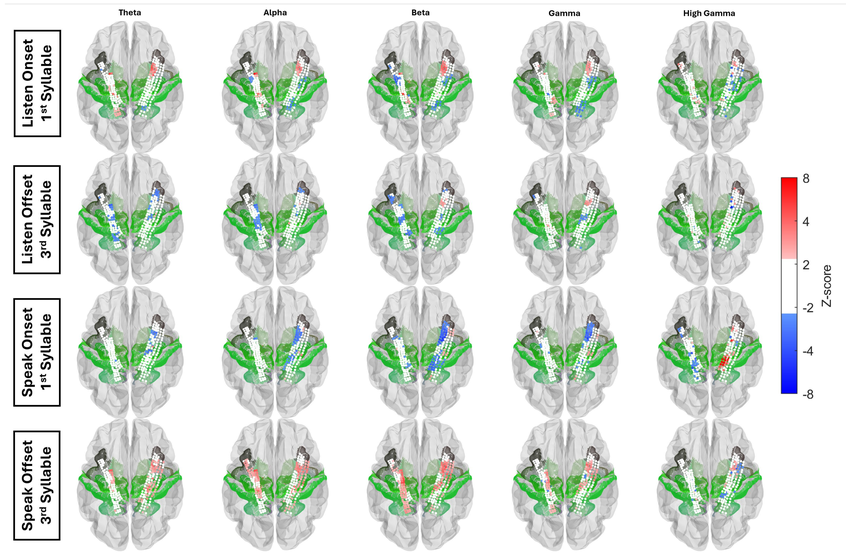

Figure 2. Premotor Region Activates for Initiating Listening and Stopping Speech. A large cluster of activation at the start of speech perception (first row) in the premotor region for frequencies θ to γ. Activation returns at the end of speech production (last row) across the same frequencies. Only channels surviving FDR correction ($z > 2.3$) are shown with deeper color showing more significance. Red represents activation while blue represents deactivation. The highlighted green regions are premotor, motor, and parietal regions where the ECoG array covers.

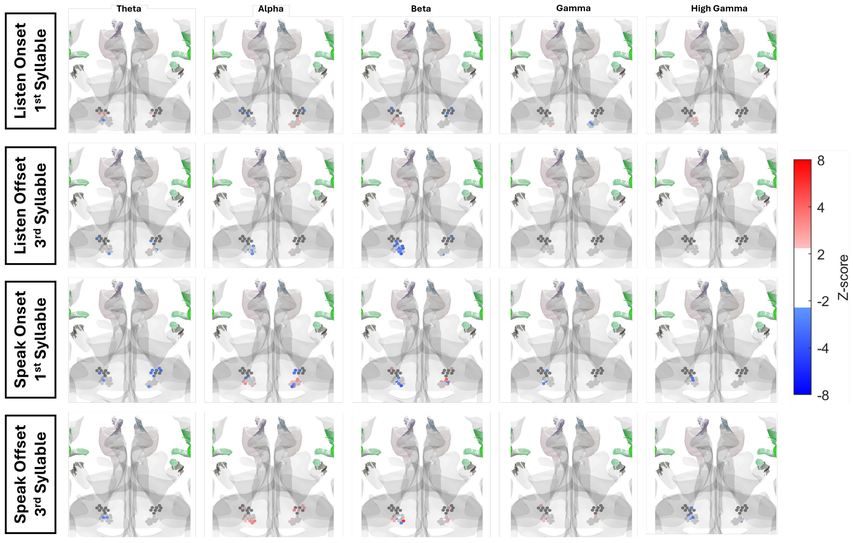

Figure 3. STN Consistent with Premotor Activation Patterns. By looking at the STN we see a cluster of activation at the start of speech perception in α and β frequencies. Activity does not return until the end of speech production in the same frequency bands. The lighter colored grey spheres represent the STN and the darker grey spheres represent the VIM. Only channels surviving FDR correction ($z > 2.3$) are shown with deeper color showing more significance. Red represents activation while blue represents deactivation. Point of view is a coronal slice with swapped right and left.

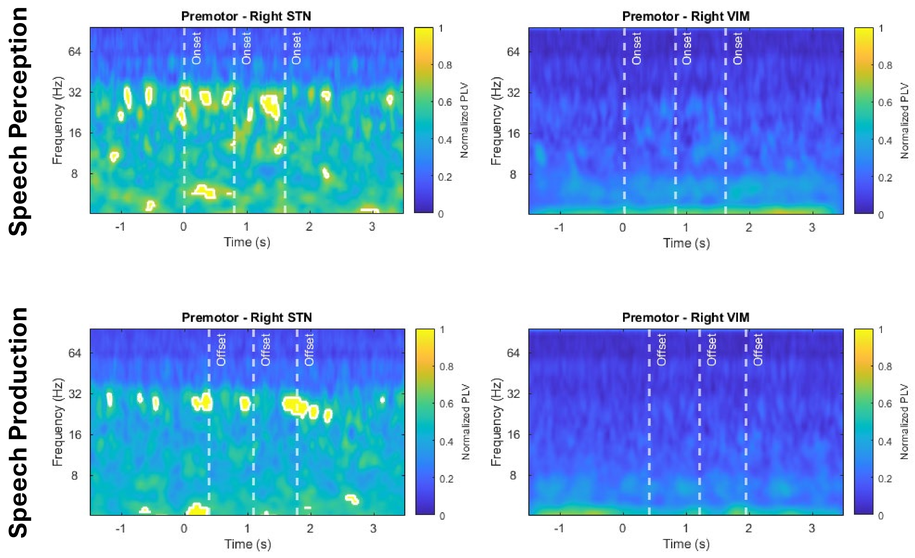

Figure 4. Premotor and STN Synchronization During Speech Perception and Production. Following significant channels in the GLM, phase locking value (PLV) was calculated between remaining channels and averaged by region. Above we see two patients (Left: PD; Right: ET) showing the average PLV between cortical and subcortical (premotor and right STN/VIM). On the left we see the STN synchronizing with the premotor channels at the onsets of speech perception and the offset of speech production. On the right we see no synchronization with the premotor channels and the VIM at either speech perception or production. Highlighted regions in white were calculated using cluster correction (*p-value* < 0.05).

Discussion

- **Premotor (BA6):** Significant spatiotemporal encoding at perception onset and production offset across bands. Suggests premotor involvement in initiating/terminating syllabic speech.
- **STN (beta):** Beta power increase at perception onset & production offset with decrease at perception offset & production onset. Consistent with premotor activity for syllabic speech.
- **Synchronization:** Beta-band PLV between premotor and STN increase at perception onset & production offset. Indicates coordinated cortico-subcortical coupling during syllabic speech.
- **Interpretation:** Results support a model where timing of syllabic speech sounds is encoded via dynamic beta modulation and synchronization in a premotor–STN loop.

References

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2. Ehlen F, Vonberg I, Kühn AA, Klostermann F. Effects of thalamic deep brain stimulation on spontaneous language production. Neuropsychologia. 2016 Aug;89:74-82. doi: 10.1016/j.neuropsychologia.2016.05.028. Epub 2016 Jun 4. PMID: 27267813.
3. Liu, J.R., Zhao, L., Hullett, P.W. et al. Speech sequencing in the human precentral gyrus. Nat Hum Behav (2025). https://doi.org/10.1038/s41562-025-02250-1