Faster hemodynamic response latencies to speech in posterior superior temporal gyrus

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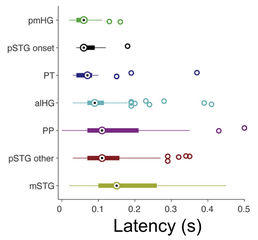
Summary

Recent electrocorticography (ECoG) recordings of speech processing in superior temporal gyrus (STG) have found evidence of neural selectivity to speech onsets in posterior STG (pSTG), with response latencies like those in Heschl's gyrus (HG) [1]. The high spatiotemporal resolution of ECoG enables precise determination of the latency and spatial encoding of fast and transient speech features, such as speech onsets. However, the invasive nature of ECoG limits its applicability to a broader population. In this study, we investigate the hemodynamic response to speech onsets using functional magnetic resonance imaging (fMRI) across areas in STG. Here we explore the location and timing of brain activation to speech onsets. Models of speech onsets during a passive listening task show a significant response to speech onsets in pSTG, with predicted hemodynamic responses peaking faster in pSTG and HG than aSTG.



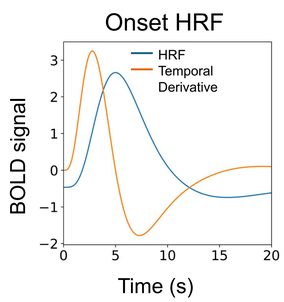
Methods

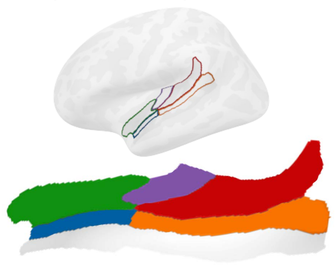
Participants: 19 adult native English-speaking controls, with normal speech, language, hearing, and reading abilities.

Language-Localizer Task : Participants listened passively to audio recordings of natural speech (podcasts, interviews) in 18-s blocks of intact and acoustically degraded conditions.

MRI Data Acquisition: Whole-brain structural and functional data were acquired using a 3T Siemens Trio Scanner. EPI fMRI parameters: TR=750ms, 45 axial slices, 5-slice SMS, 3mm^3 voxels, 484 TRs.

Data Analysis: Speech onsets from the "speech" blocks of the language localizer were automatically defined by periods of 750 ms or more of preceding silence. The onsets were convolved with a canonical hemodynamic response function (HRF) and its temporal derivative, which accounts for the rate of change in the hemodynamic response. These speech onsets were incorporated into a mass univariate linear model. Fitted responses with higher temporal derivative beta values indicate hemodynamic responses that peak faster.

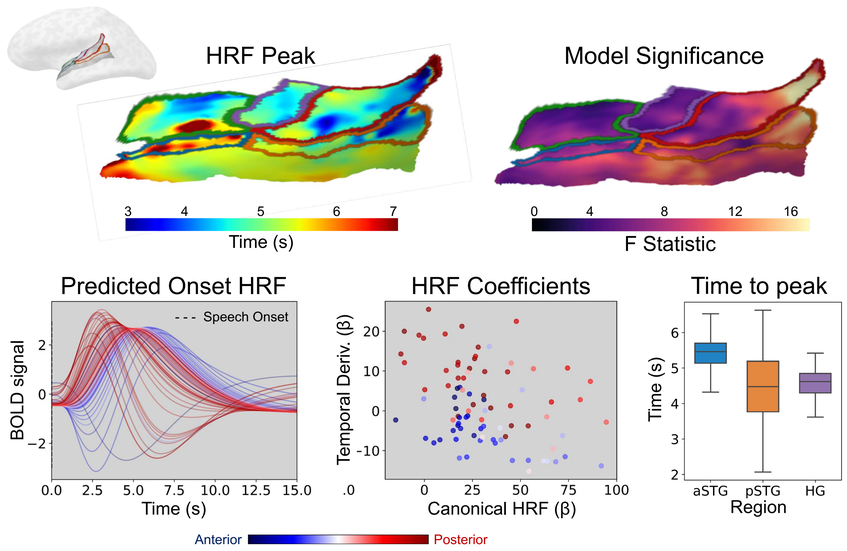




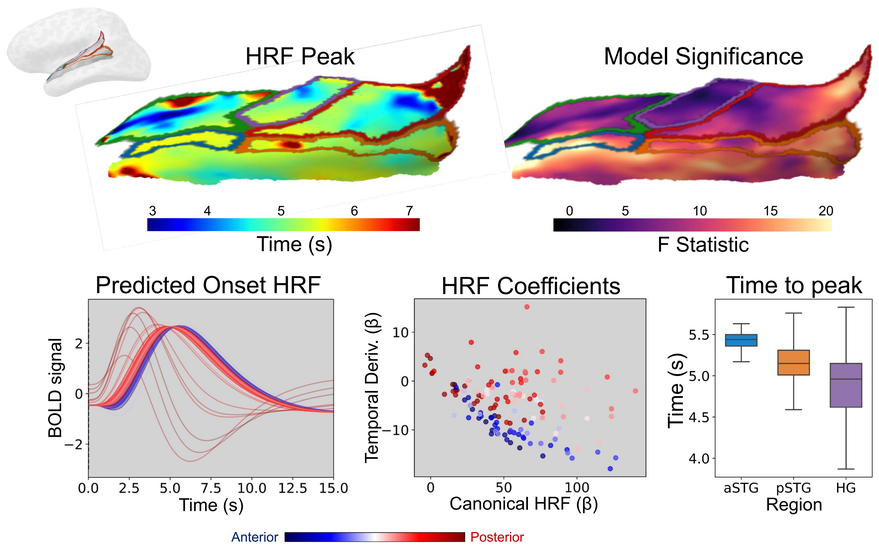
We focused on 3 principal anatomical regions of interest: **HG**; **pSTG**; and **aSTG**. [2]

Fast hemodynamic response latencies to speech onsets in pSTG

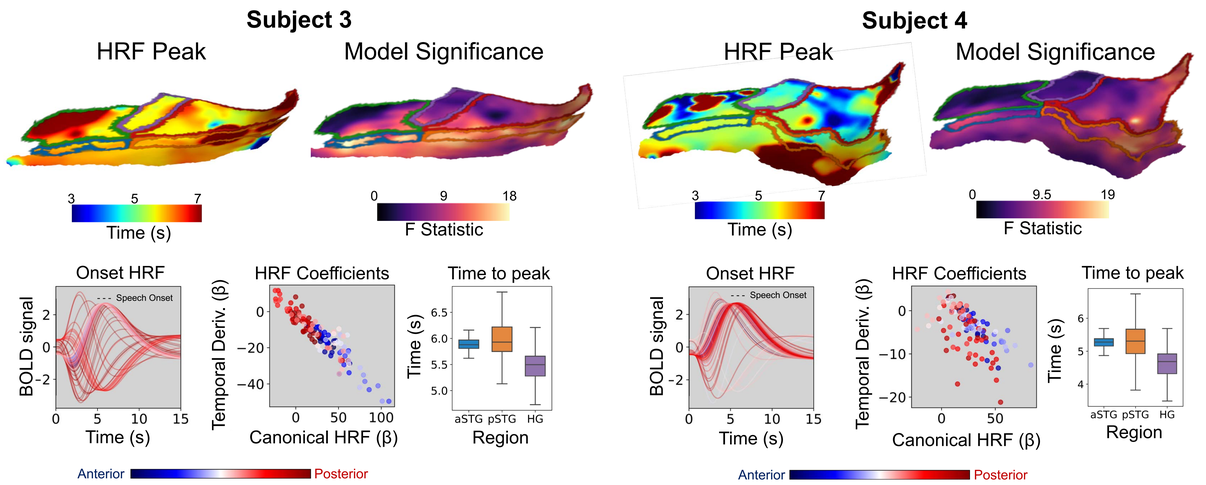
Subject 1: The profile of strong model significance suggests speech onsets are good predictors of BOLD responses in **pSTG**. The temporal derivative parameter of the HRF was generally higher in **pSTG** than **aSTG**, and the time to peak tended to be earlier in **pSTG** and **HG** than in **aSTG**.



Subject 2: The model again showed high significance in **pSTG**, suggesting responsiveness to speech onsets. The temporal derivative parameter of the HRF tended to have higher values in **pSTG** than **aSTG**. In this subject, time to peak tended to be earlier in **HG** than **pSTG**, but both of these were faster than **aSTG**.



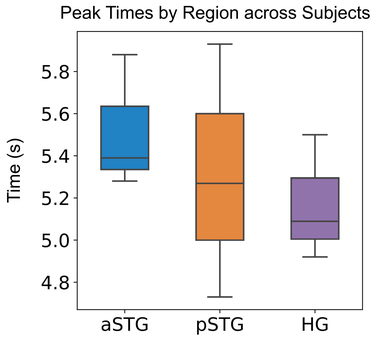
Variable speech onset responses across subjects



Subject 3 & Subject 4: Speech onset models continue to explain activation in **pSTG** well; however, the pattern of fitted HRFs differs from those of Subjects 1 and 2. Subject 3 showed HRFs with negative responses, and Subject 4 showed no clear relationship between the HRF coefficients and faster peak times in **pSTG**. For these subjects, the fastest times to peak were in **HG** with no overall difference between **aSTG** and **pSTG**. In future work we will consider alternative HRF basis sets to better characterize neural responses to fast speech events [3].

Discussion

This investigation provides preliminary evidence of faster hemodynamic responses to speech onsets in pSTG, consistent with findings in previous ECoG studies. The models demonstrated that speech onsets are good predictors of BOLD responses in pSTG, suggesting fMRI may be a useful tool for measuring the rapid and transient speech features like speech onsets. While not all subjects show speech onset responses with shorter mean peak times in pSTG than aSTG (or comparable to HG), the average peak times across subjects do show this trend. Our future work will examine whether more temporally sensitive hemodynamic models can better assess response latencies to speech onsets across STG using fMRI.



References:
[1] Hamilton et al. (2021). *Cell*;
[2] Tourville et al. (2019). *J. Speech Lang. Hear. Res.*
[3] Polimeni and Lewis (2021). *Prog. Neurobiol.*
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