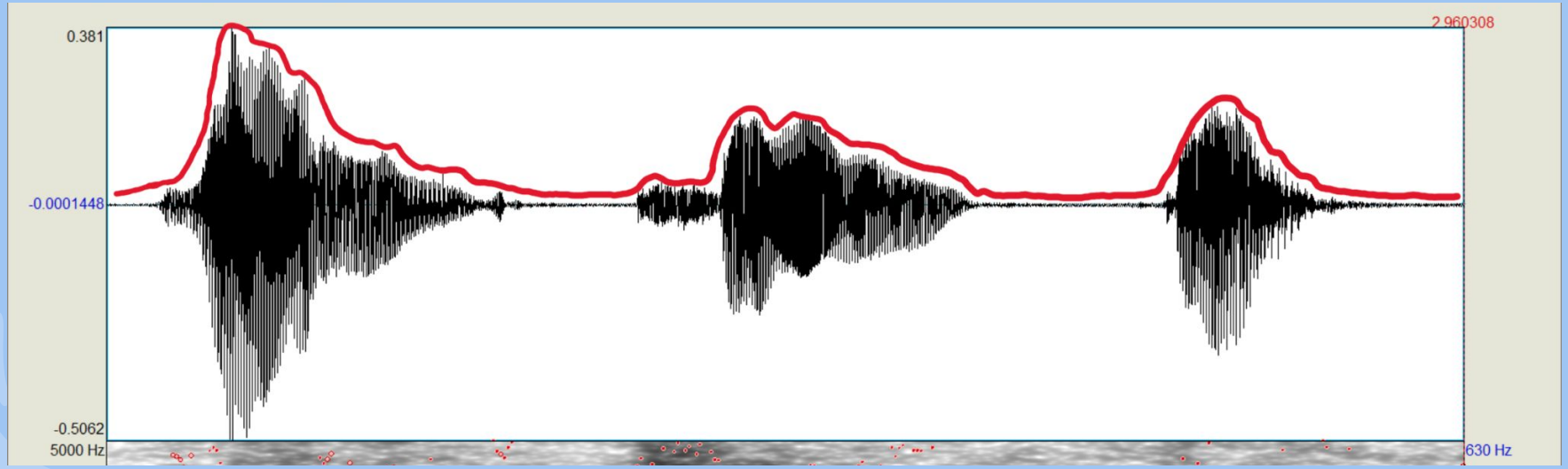
The Tracking of Speech Envelope in the Human Cortex

By: Kubanek et al.

What is the “speech envelope”?

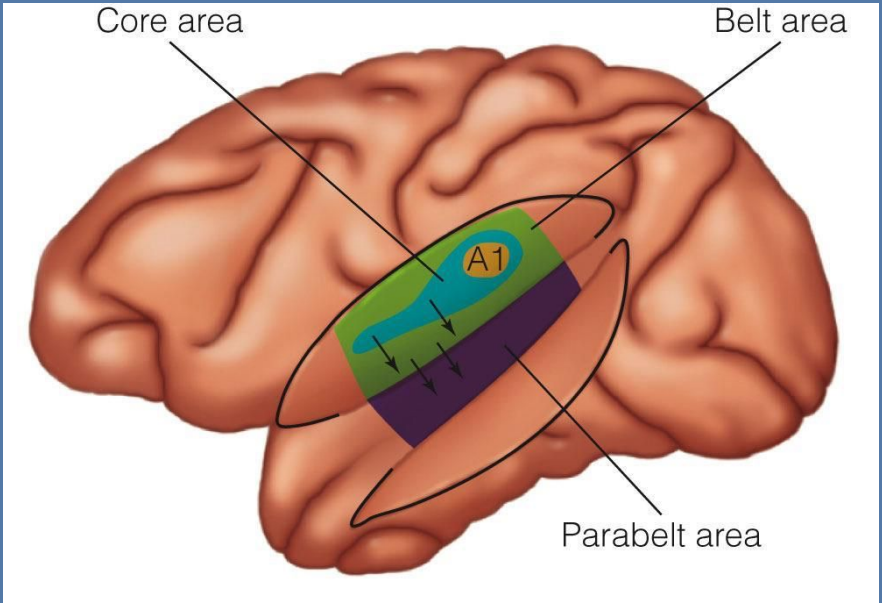
Waveform (time and amplitude) only referring to the positive amplitude fluctuations.

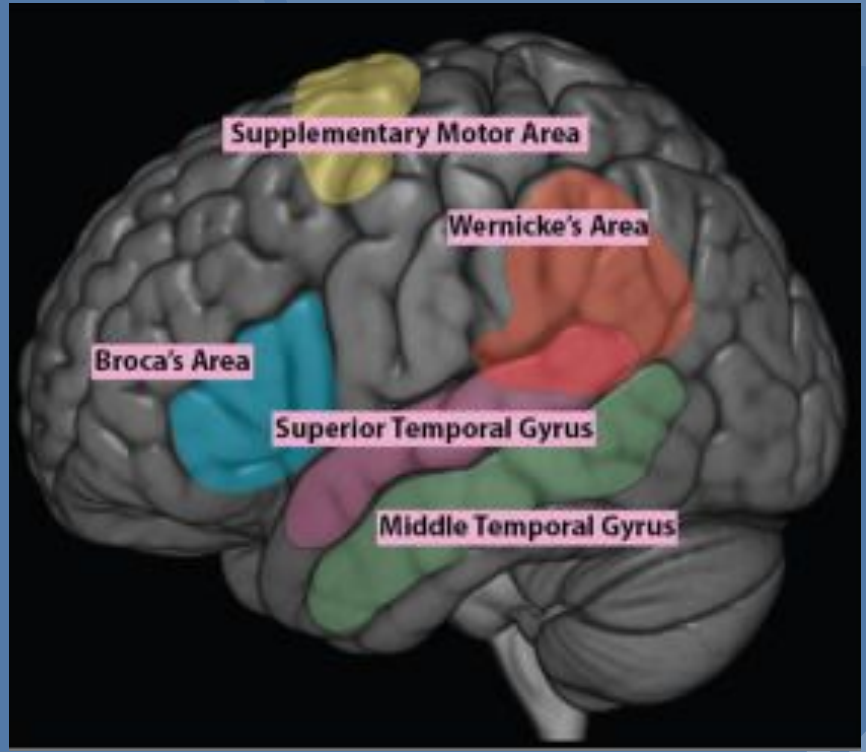


Previous Research

- Research has found speech envelope represented in the human auditory system
- Studies have been conducted where brain recordings determined that the speech envelope can in fact be tracked by electrical potential and currents in the human cortex. The study found the quality of this tracking predicts the quality of speech comprehension
- Such research **does not identify which cortical regions** track the speech envelope as these studies use either high temporal resolution or high spatial resolution
- This study uses electrocorticography (ECoG) which involves high temporal resolution and favorable spatial resolution

Brain Areas of Focus

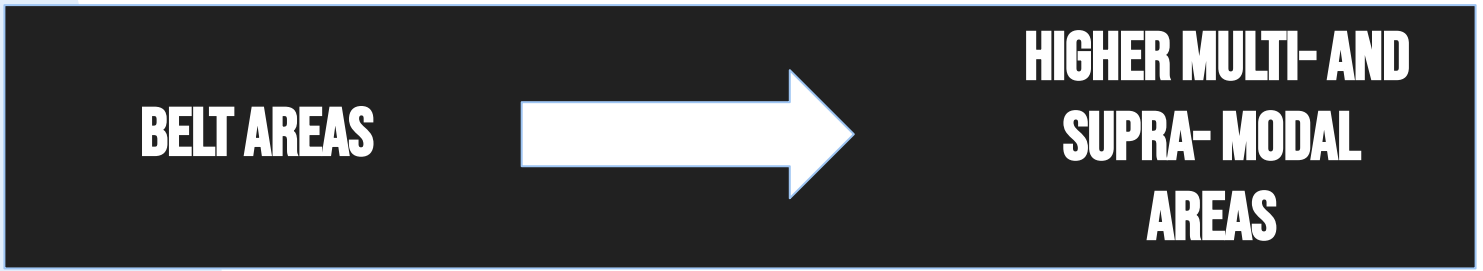




Research Question

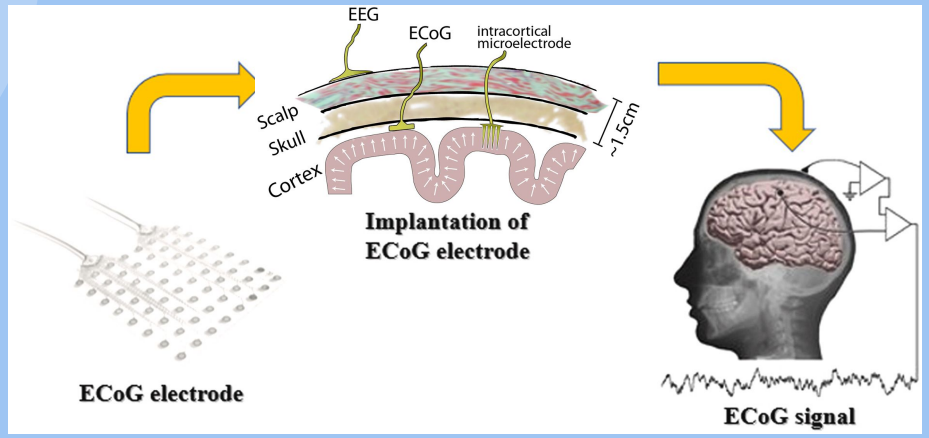
If and how the speech envelope is tracked in unisensory brain areas located early in the auditory pathway (belt areas) ***and*** in higher-order regions, such as the superior temporal gyrus (STG) and the posterior inferior frontal gyrus (Broca's region)

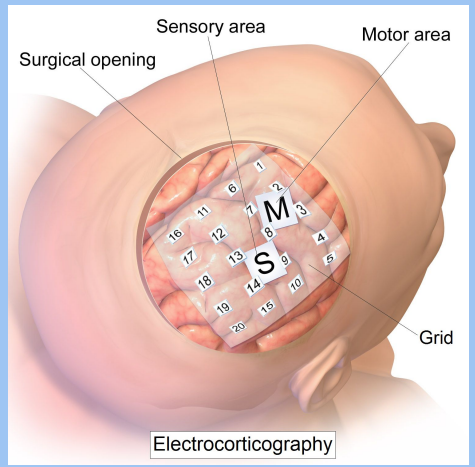
Flow of Auditory Information



Methodology

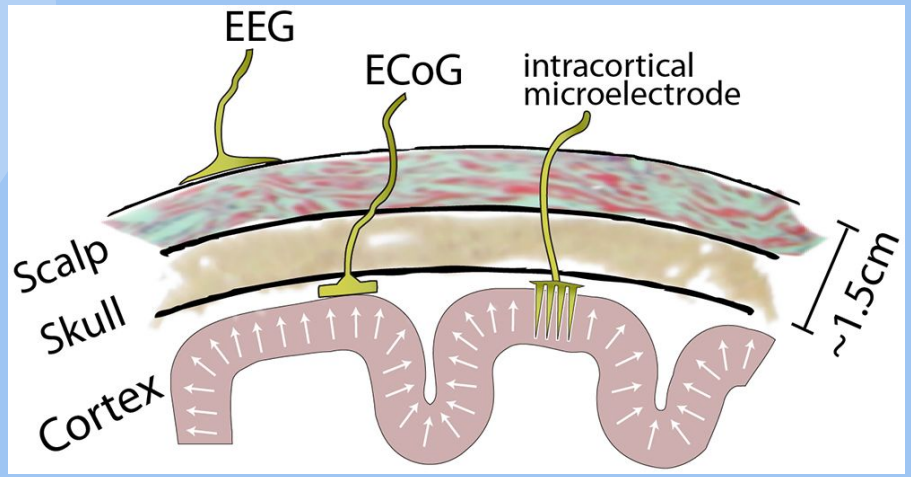
- 5 participants with epilepsy - 2 women, 3 men
- While listening to a spoken story, participants neural activity was recorded using electrocorticography (ECoG) electrode grids, which was placed on the left hemisphere
- Neural activity was recorded in the high gamma range (75-115 Hz)

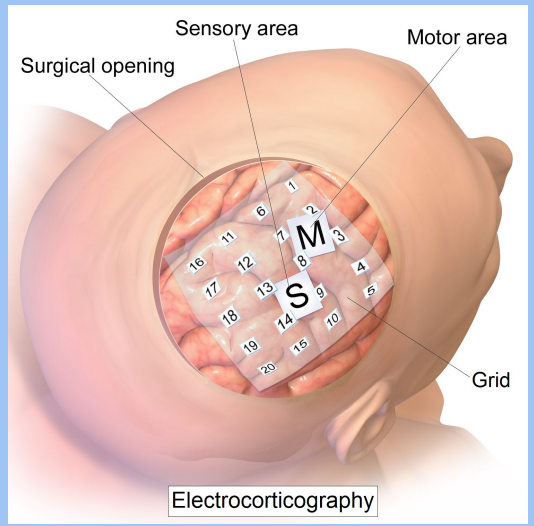




Methodology

- Researchers extracted the speech signal envelope at each frequency between 16 Hz to 16 kHz.
- At each frequency in this range, the correlation (p) between neural activity and speech envelope calculated

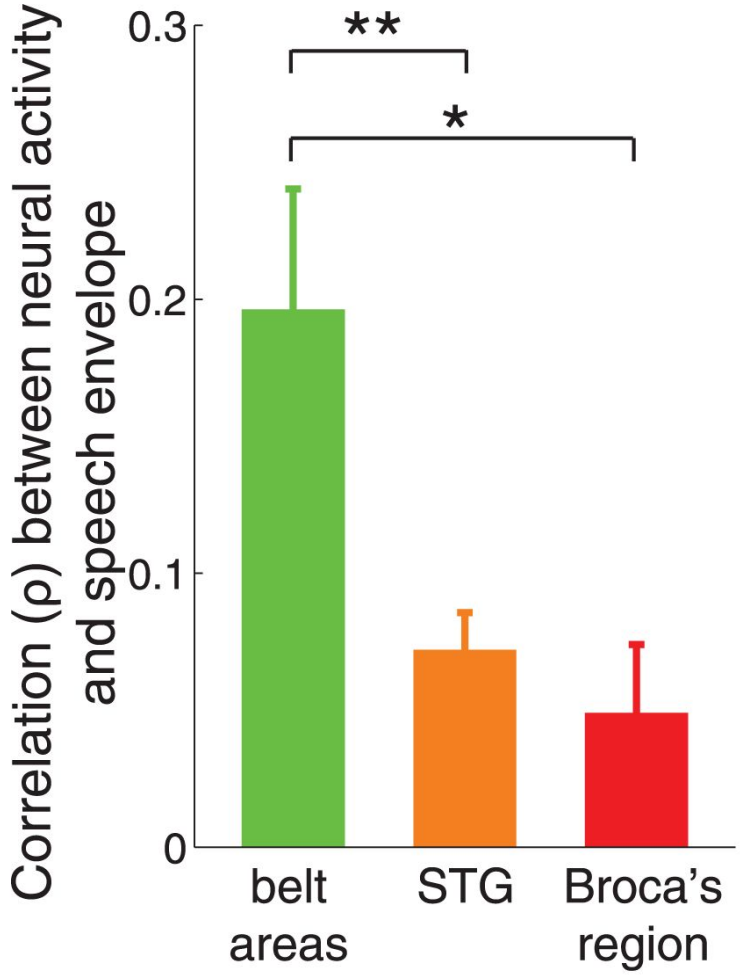




Results

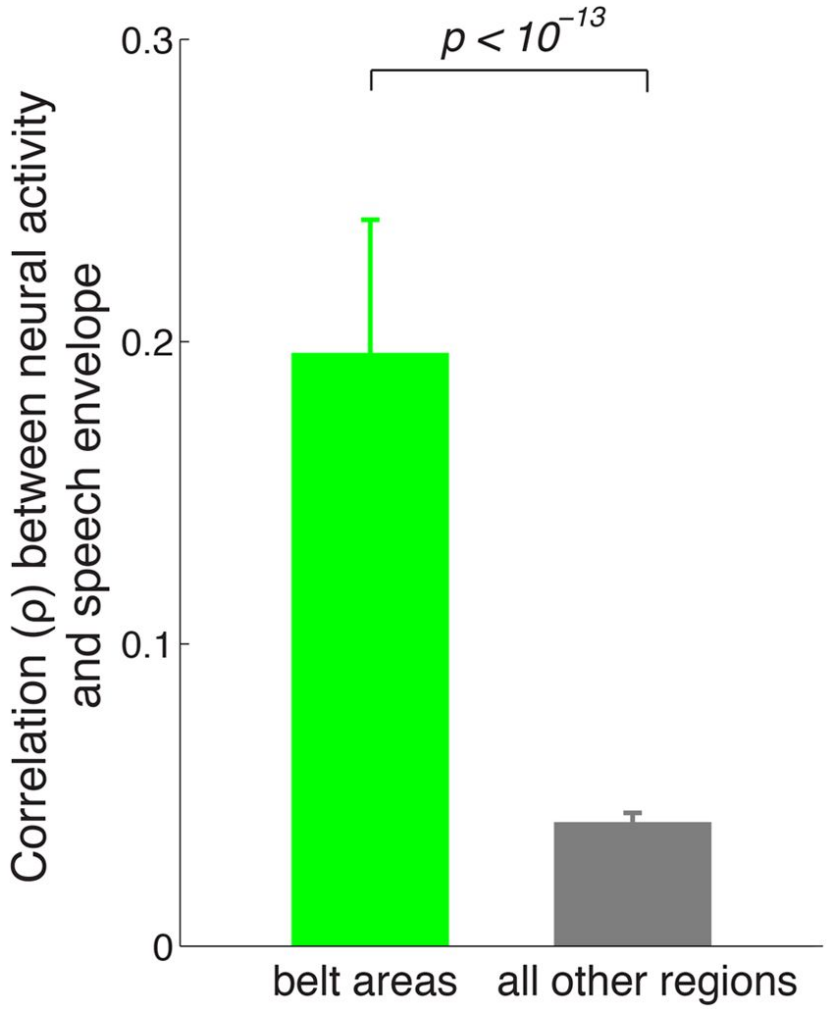
- Speech envelope is tracked by the human non-primary auditory cortex

- Speech envelope is predominately and significantly tracked better in belt areas than STG and Broca's region regardless of the frequency where the envelope is assessed



Results

- Therefore, tracking effects are stronger in areas located earlier in the auditory pathway (belt) as opposed to the higher-order regions (STG and Broca's region)



Supplementary Analysis -

Based on speech-unrelated stimulus

Research Question

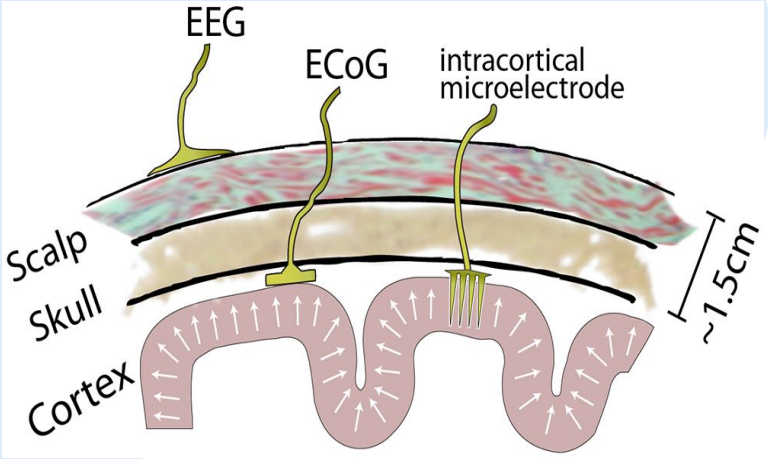
Is the auditory cortex exclusive to tracking speech or is it also responsible for tracking speech-unrelated stimuli sound envelope?

Speech-unrelated stimuli: areas in a song where no singing is present (melody)

Methodology

- The same subjected listened to a song

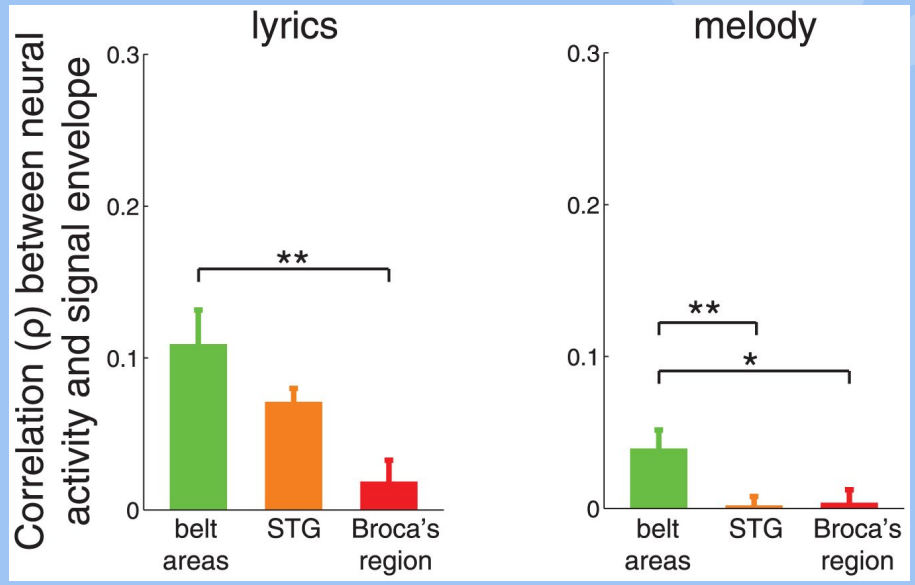
- The song was divided into sections:
  - Lyrical sections – periods of singing (speech-related stimuli)
  - Melodic sections – period where no singing occurred (speech-unrelated stimulus)



- Speech enveloped was tracked using ECoG grids – same way as the speech stimuli condition

Results

- Belt areas track envelope for speech-related stimuli (lyrics) and unrelated stimuli (melody). This is to a lesser degree than speech.
- Speech envelope for speech-related stimuli is tracked by STG and Broca's region. This is significantly weaker compared to the tracking effects of speech in the belt areas
- STG and Broca's region do not track speech unrelated stimuli



Conclusion

- High gamma activity in belt areas tracks the envelope of speech-related stimuli - tracking effect is strongest in this area
- Belt area also tracks envelope for speech-unrelated stimuli (melody) - to a lesser degree than speech stimuli
- STG and Broca's region only tracks the envelope of speech-related stimuli - much weaker than the tracking effect of the speech in belt areas

	Belt Areas	STG	Broca's Region
Speech	✔	✔	✔
Lyrics	✔	✔	✔
Melody	✔	X	X

Conclusion - What does this mean for the original questions?

- This indicates that all stimulus envelopes in the belt areas is expressed as an acoustic feature, as opposed to phonetic features specific to speech

- This is consistent with studies that found activation for both phonemic and non-phonemic sounds in regions in or close to the belt area

Conclusion - What does this mean for the original questions?

- This indicates that all stimulus envelopes in the belt areas is expressed as an acoustic feature, as opposed to phonetic features specific to speech
- This is consistent with studies that found activation for both phonemic and non-phonemic sounds in regions in or close to the belt area
- Since higher-order regions track only the envelope for speech and speech-related stimuli, this suggest that these regions encode speech envelope as a phonological feature as opposed to an acoustic feature
- This is in line with previous studies that indicated these higher-ordered regions specialize in higher-level (lexical, syntactic, semantic) and abstract speech analysis
- All research questions have been answered

Questions

Why do you think all participants used in the study have epilepsy?

What does this mean for lyrical music? Does this mean lyrics don’t pop out in our brain like speech does?

During higher-level and abstract speech analysis, do you think the belt areas or higher-ordered regions (STG and Broca’s region) would track the envelope stronger?

If and how well do you think these regions would track foreign language stimulus?