High Frequency Cortical Processing of Continuous Speech in Younger and Older Listeners

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Why Investigate This?

- Aging
  - subcortical *high frequency* EEG: younger > older
  - *cortical* low frequency MEG/EEG: older > younger
  - *cortical high frequency* MEG?
- How much of EEG FFR is actually cortical?
  - effects of attention, language, etc.
- Response contributions due to stimulus carrier vs. stimulus envelope

Outline

- Background & motivation
  - Frequency Following Response (FFR)
  - Cortical slow continuous-speech responses
    - EEG at FFR-like rates for continuous speech
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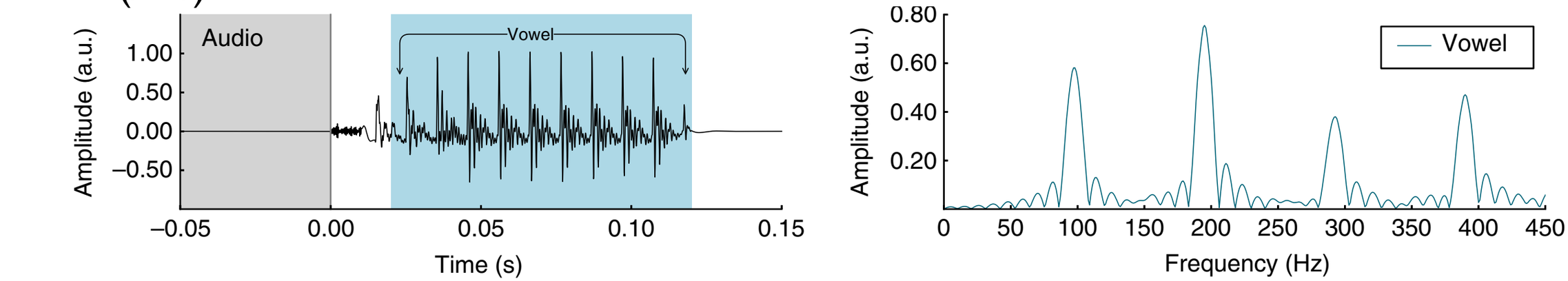
Frequency Following Response (FFR)

Audio (/da/)



Adapted from Coffey et al., Nat Commun (2016)

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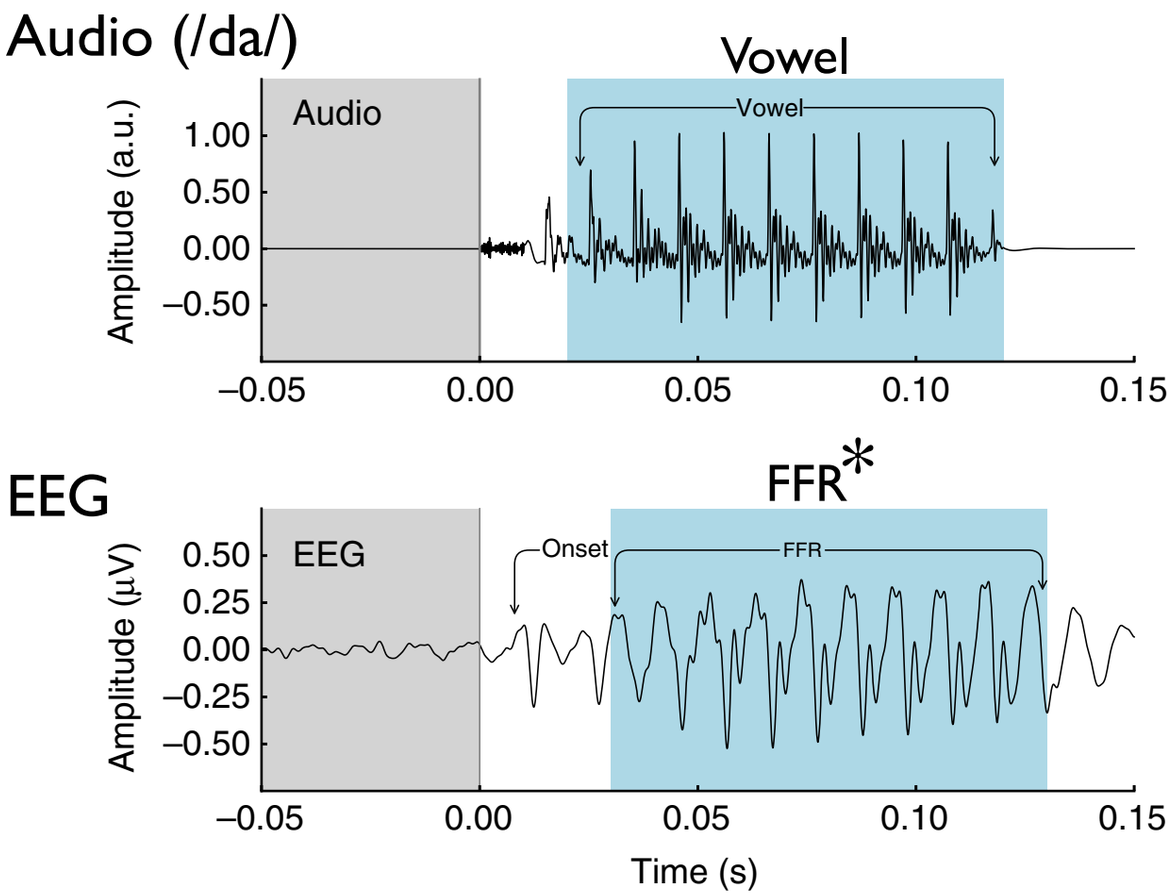

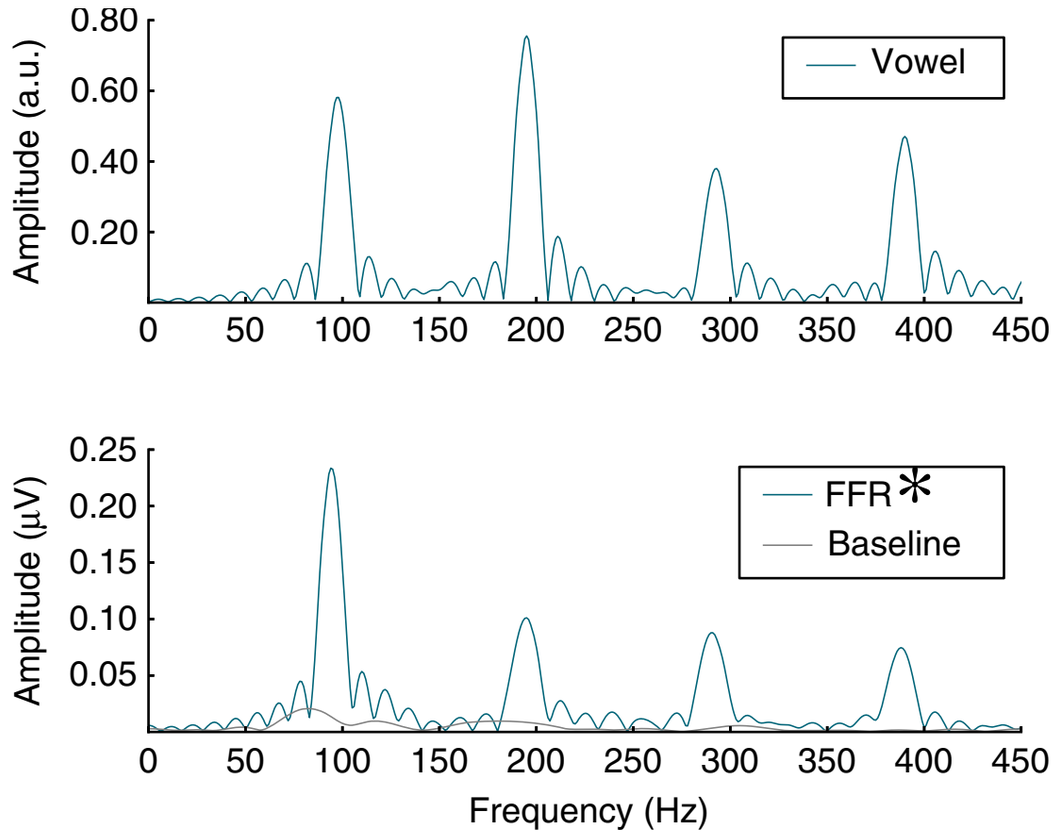

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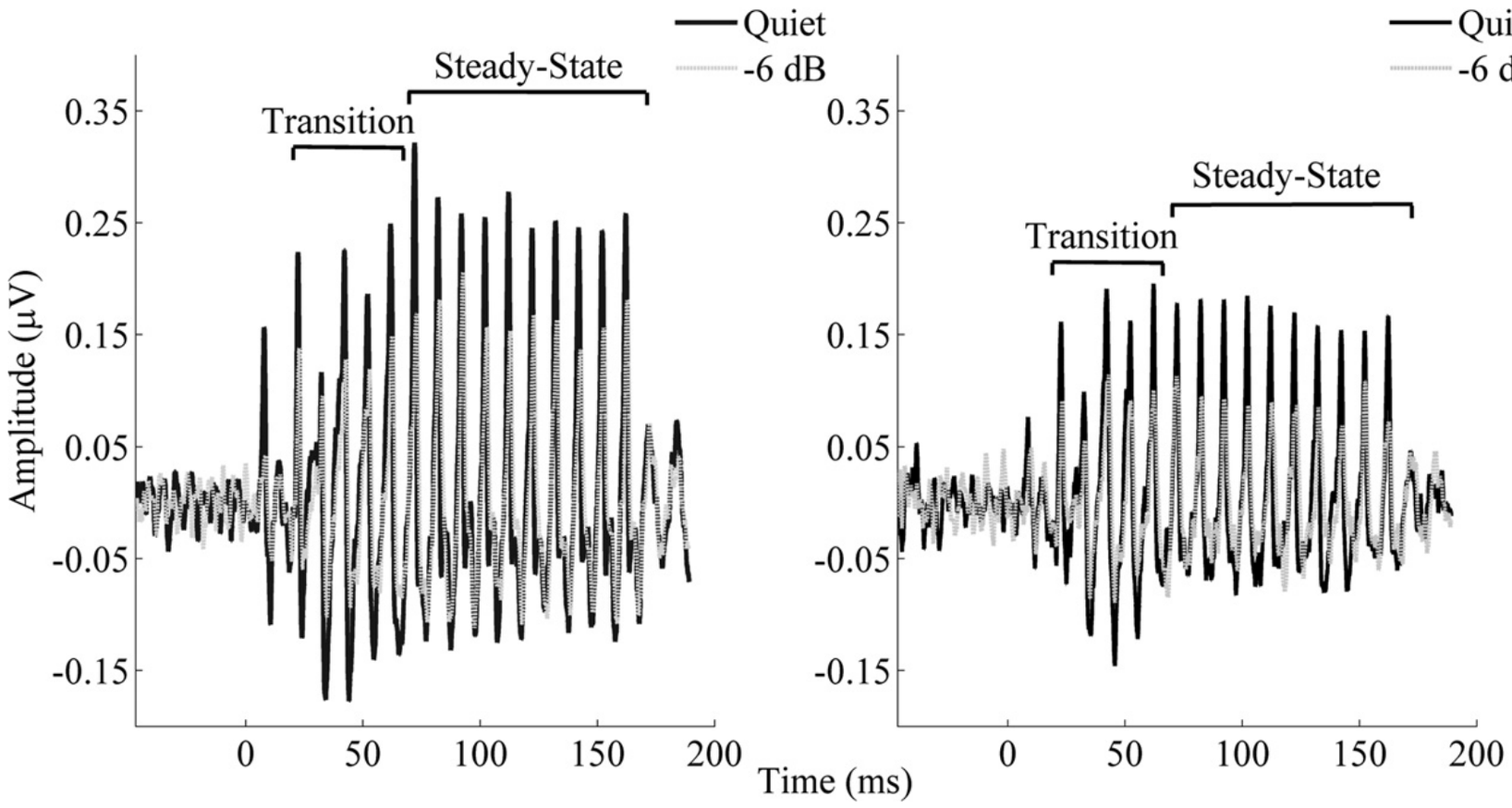
Frequency Following Response (FFR) & Aging

Younger

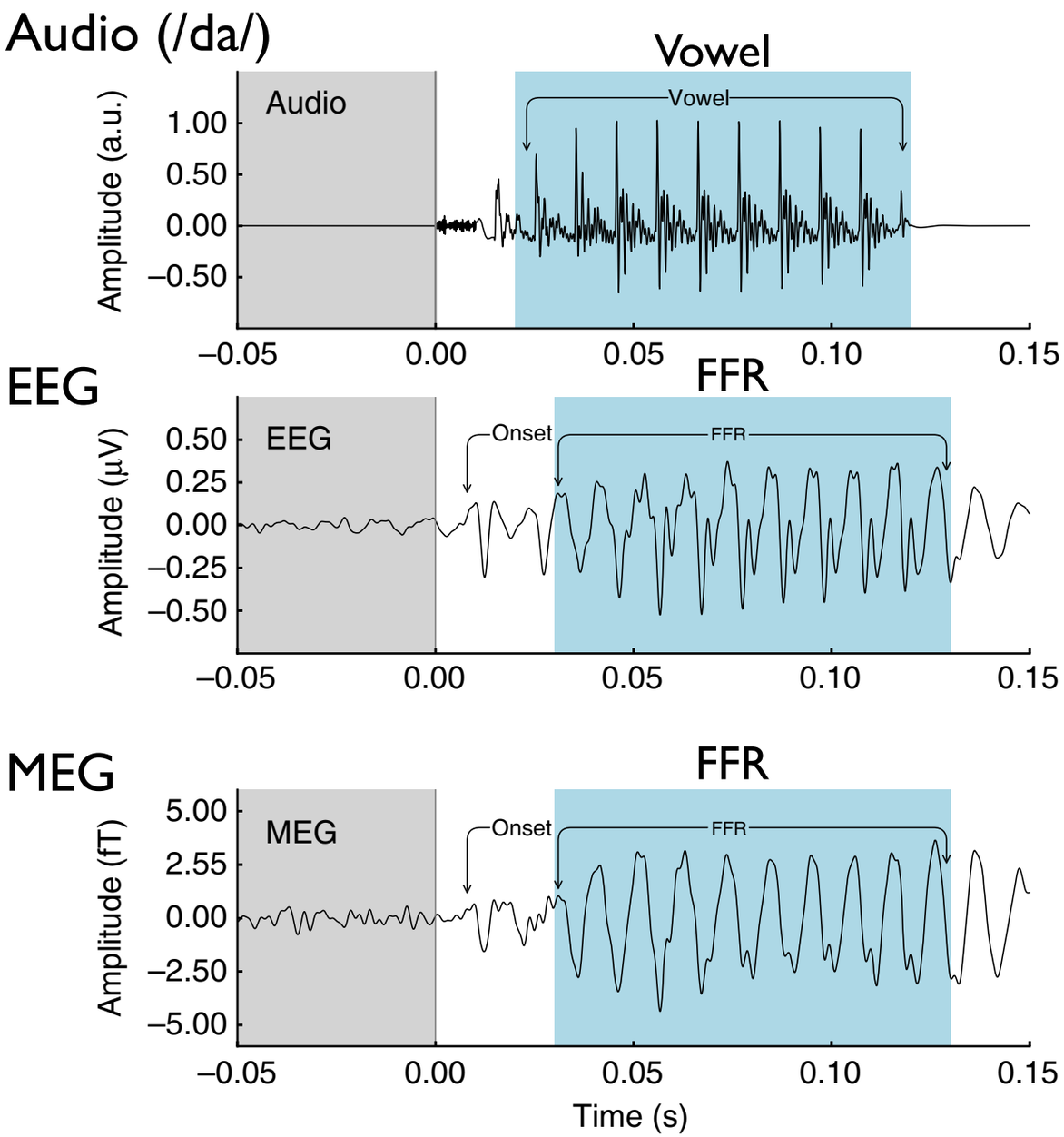
Older

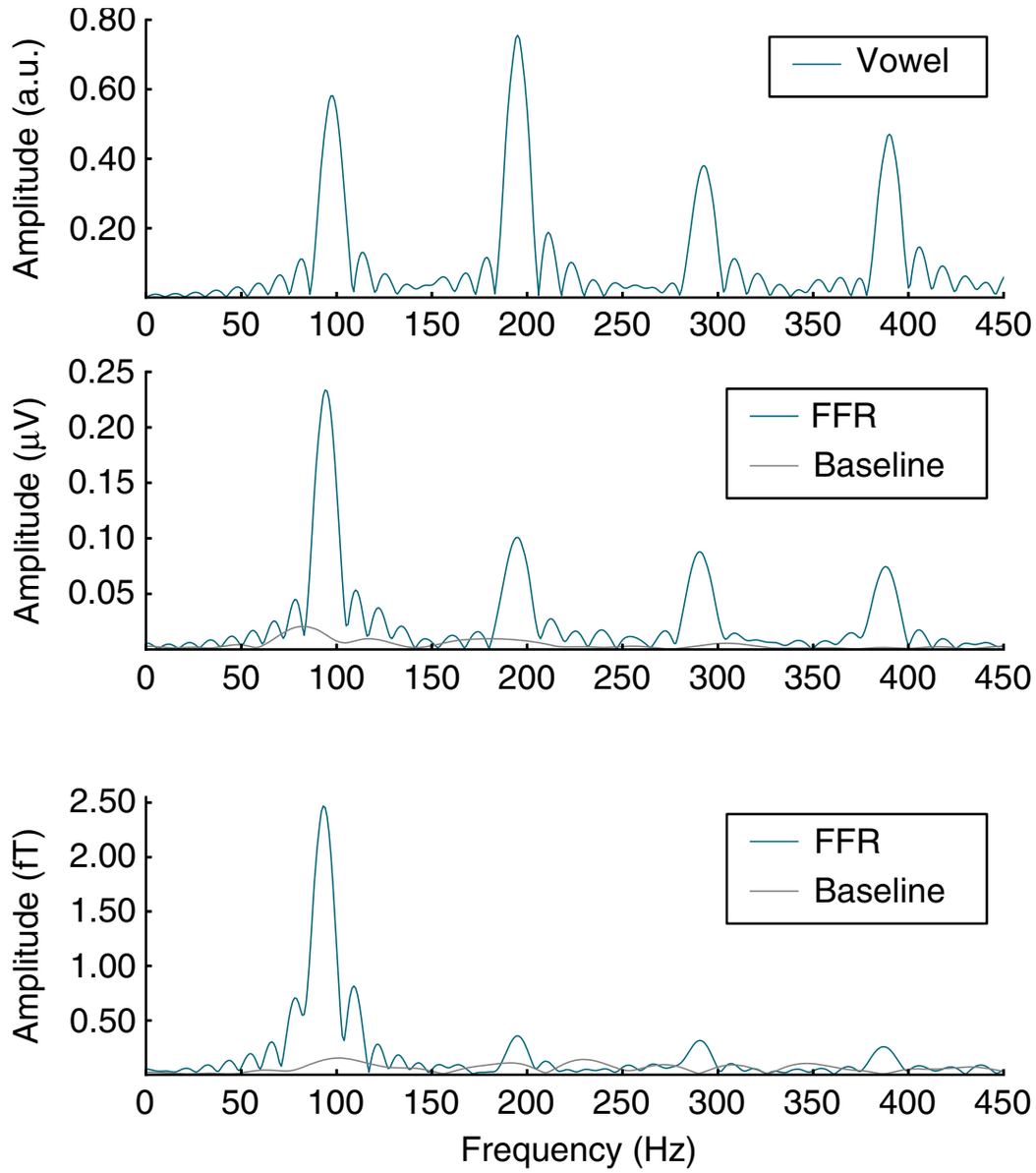


Younger > Older

Presacco et al. (2016a)

Frequency Following Response (FFR)





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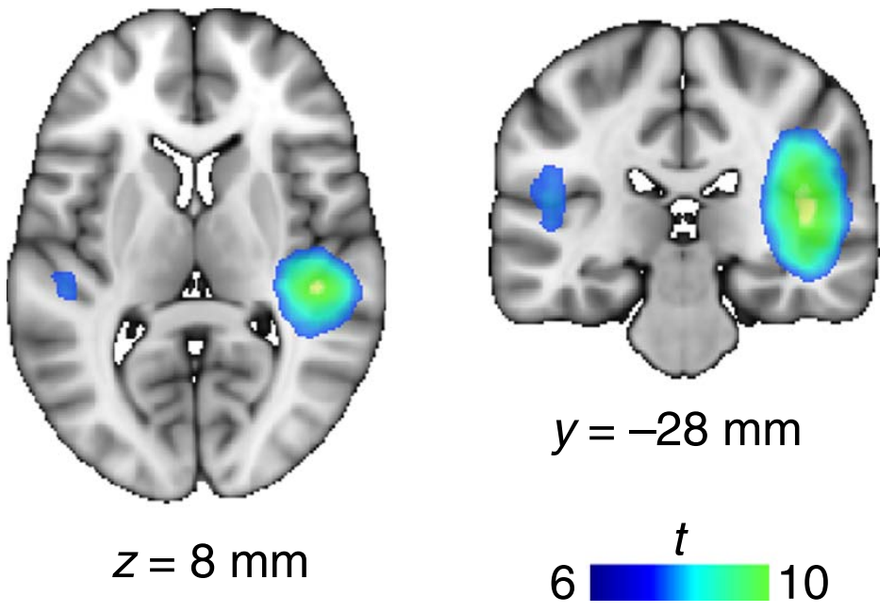
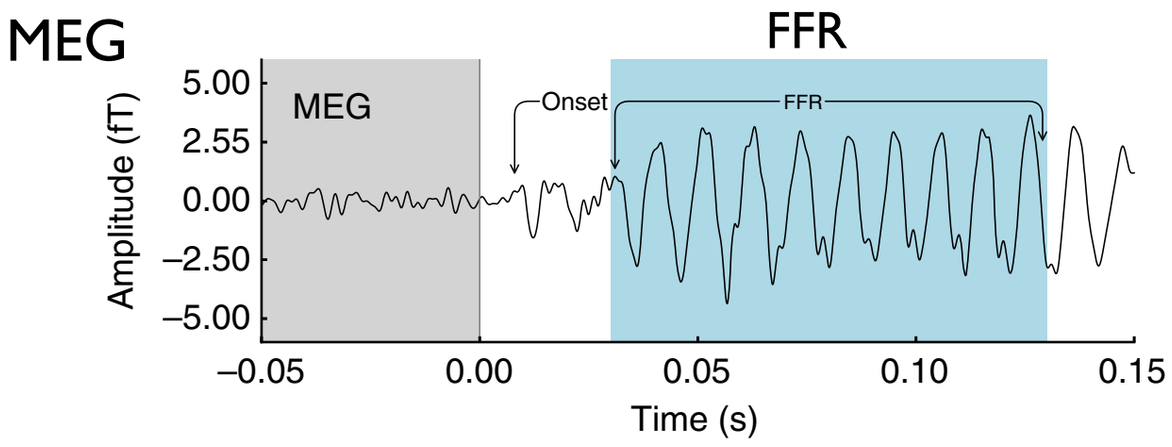
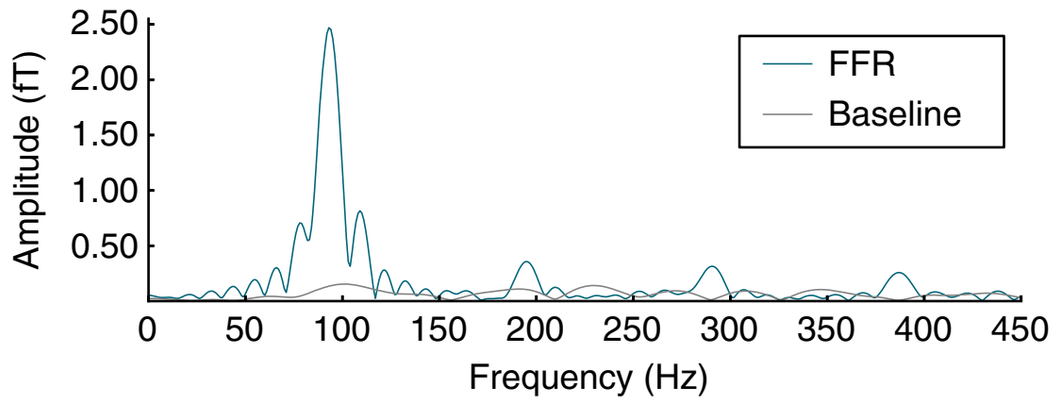


MEG responses dominated by cortical sources





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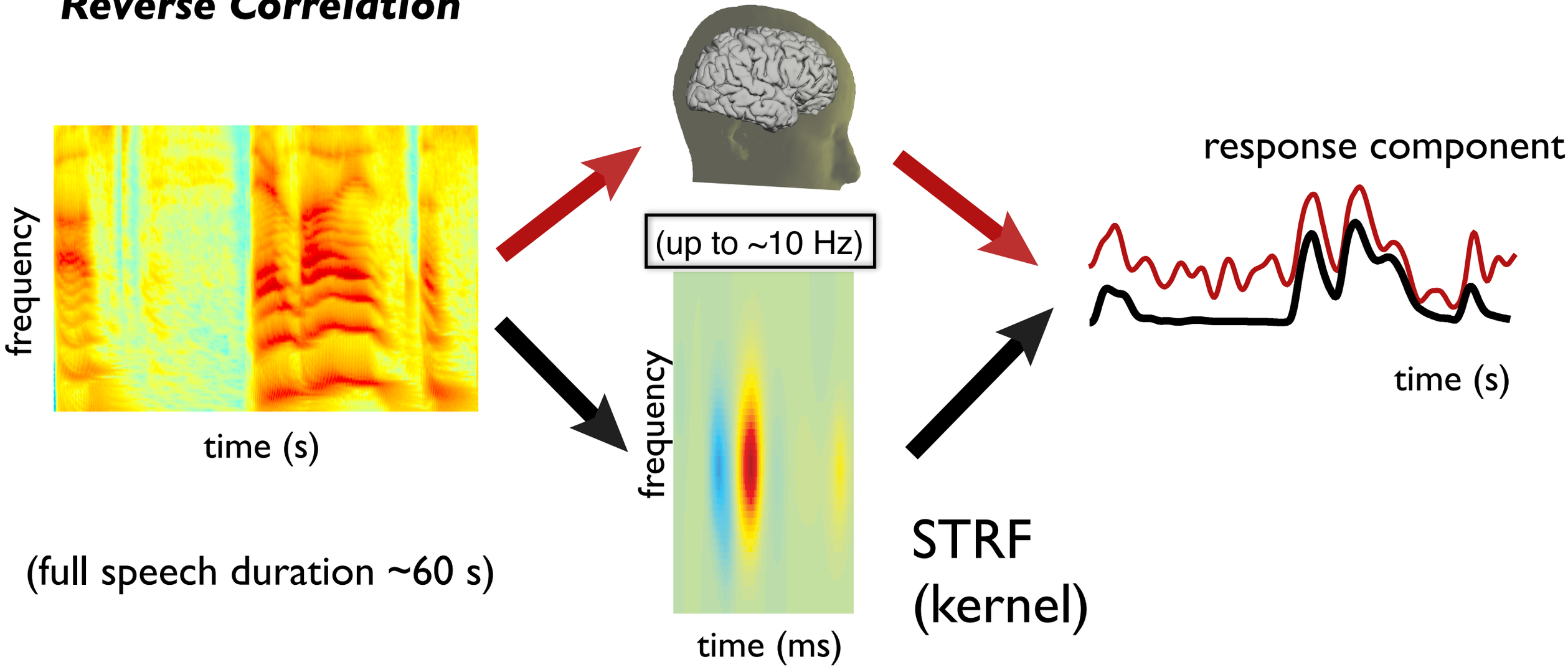
Spectro-Temporal Response Function (STRF)

Reverse Correlation

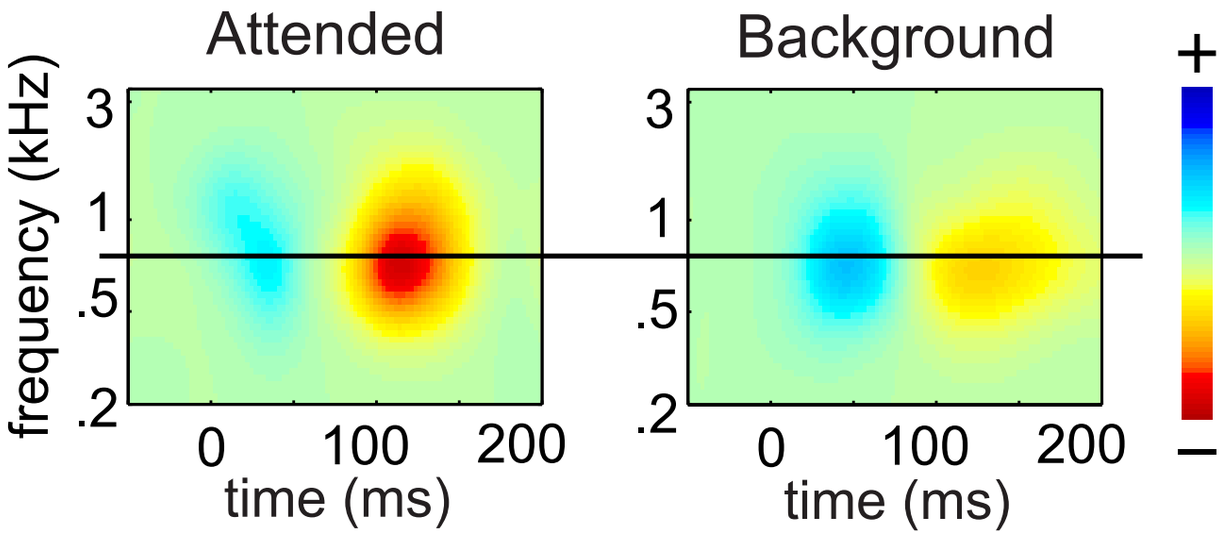


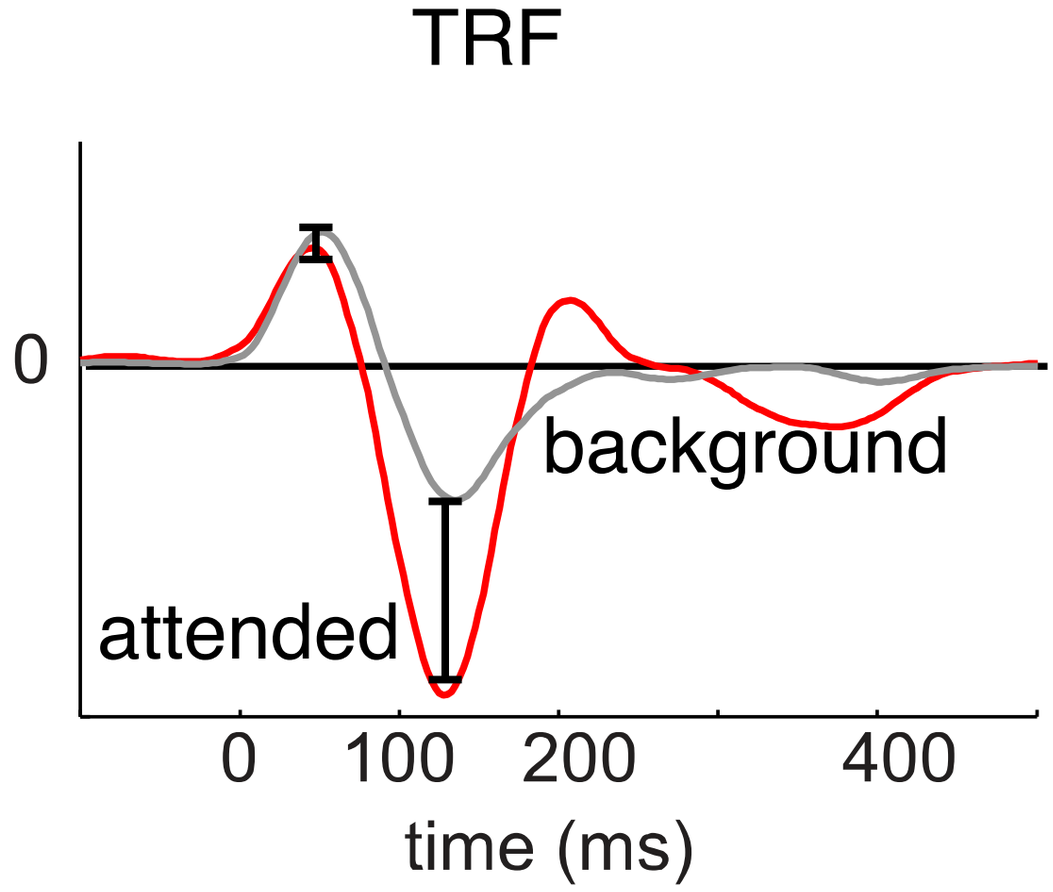
(full speech duration ~60 s)

STRF (kernel)

Ding & Simon, J Neurophysiol (2012)

Temporal Response Function (TRF)

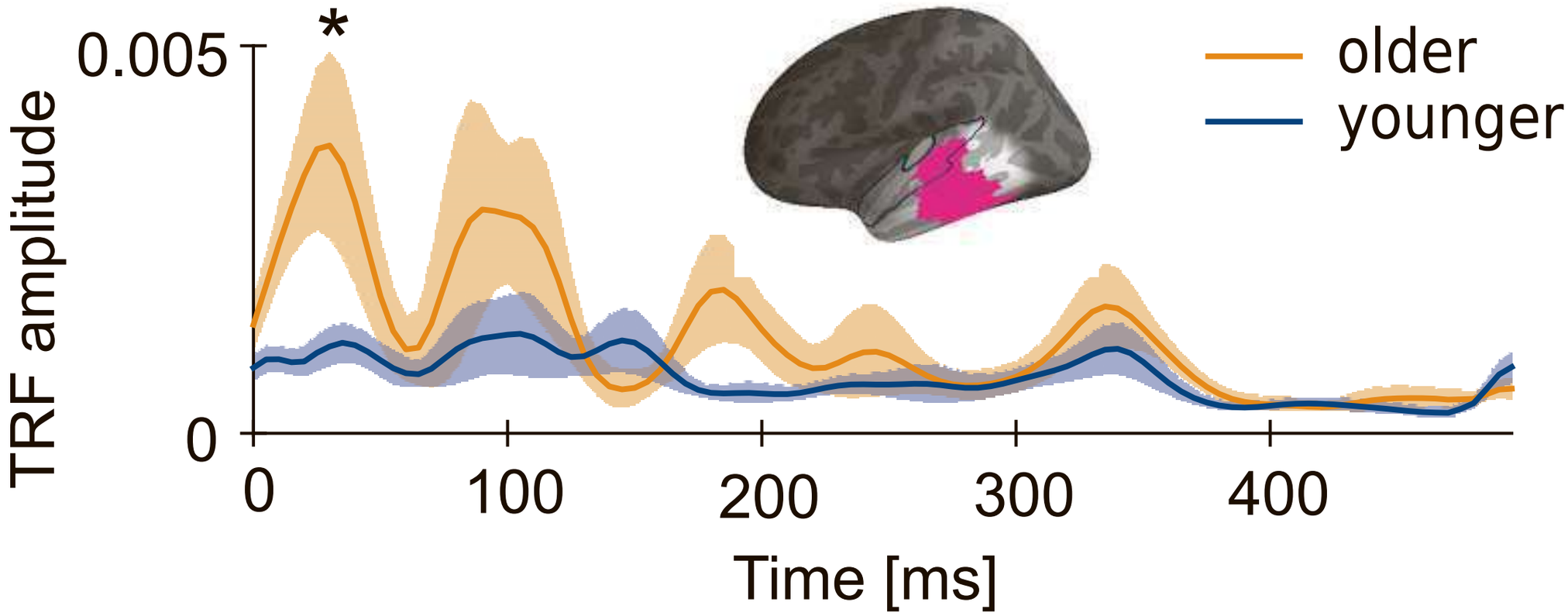




- STRF separable (time, frequency)
- 300 Hz - 2 kHz dominant carriers
- $M50_{STRF}$ positive peak
- $M100_{STRF}$ negative peak

Ding & Simon, PNAS (2012)

Temporal Response Function (TRF) & Aging



- Different latency peaks → different processing stages (areas)
- $M50_{TRF}$ ~ Heschl's Gyrus, Core Auditory Cortex (including A1)
- $M100_{TRF}$ ~ Planum Temporale, Associative Cortex (Belt/Parabelt)
- $M200_{TRF}$ ~ ?
- Older > Younger

Brodbeck et al. Acta Acustica (2018)

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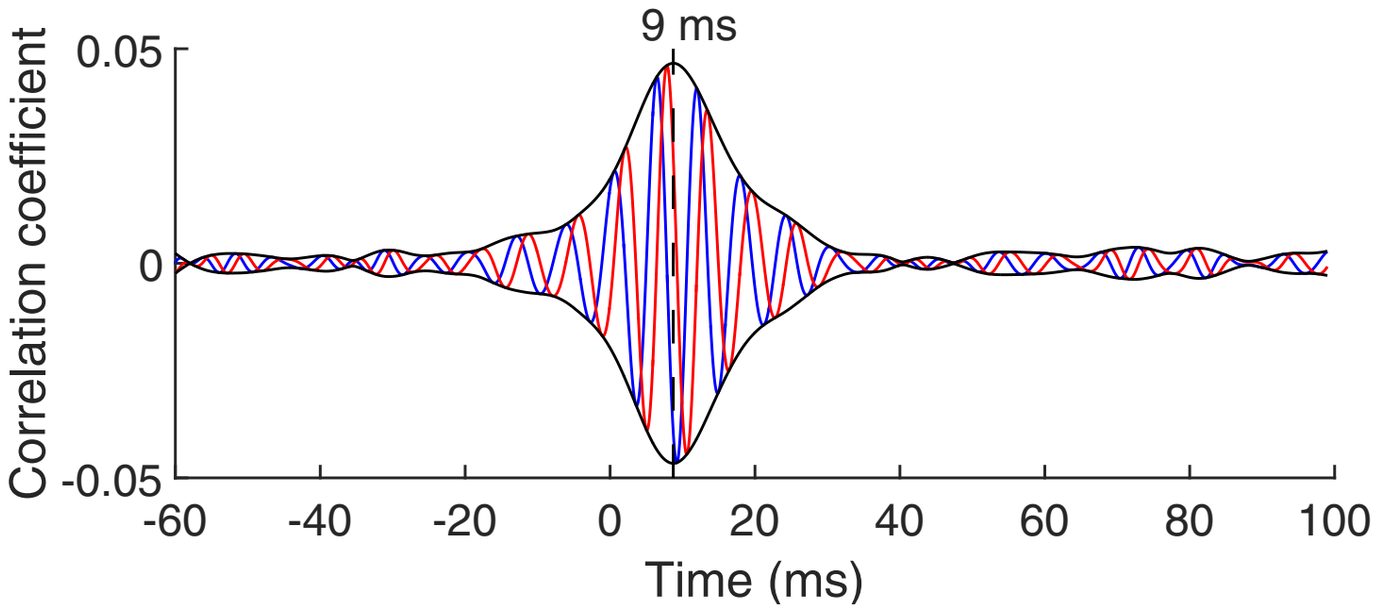
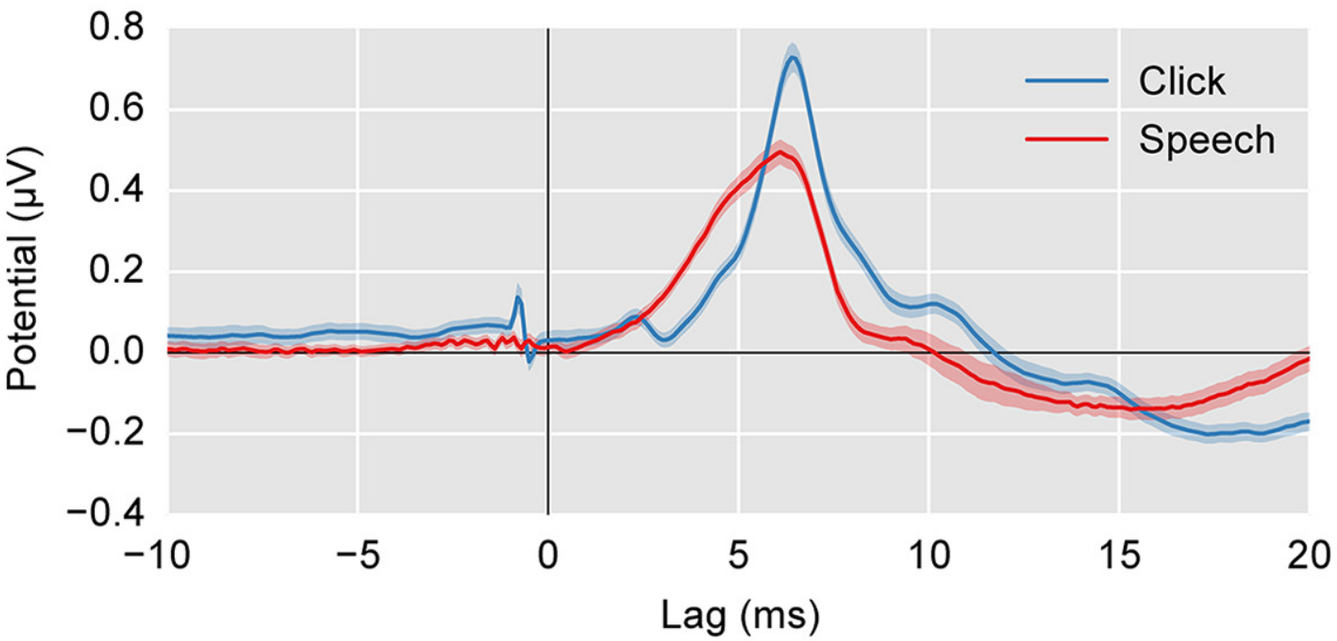
EEG FFR-like Responses to Continuous Speech



Forte et al., eLife (2017)

*Response modulated by selective attention



Maddox & Lee, eNeuro (2018)

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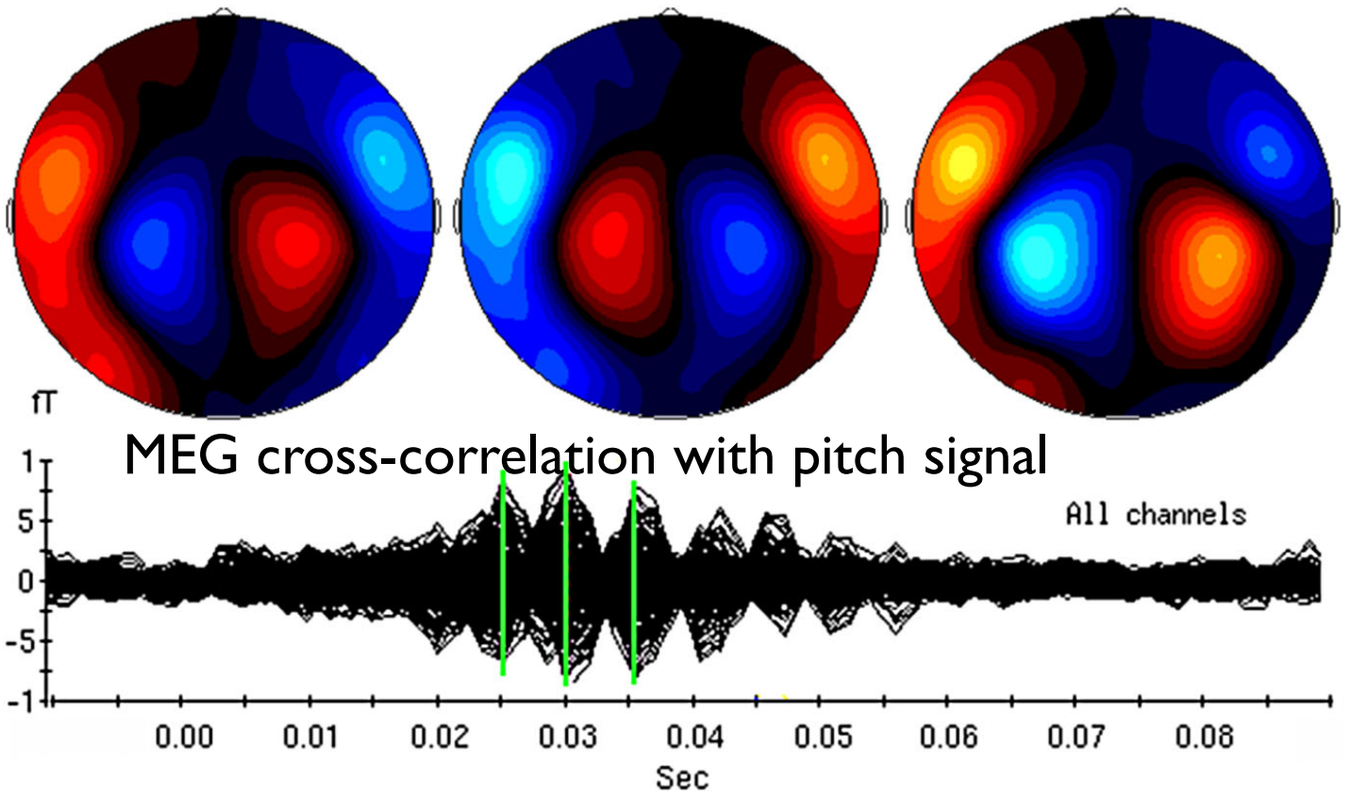
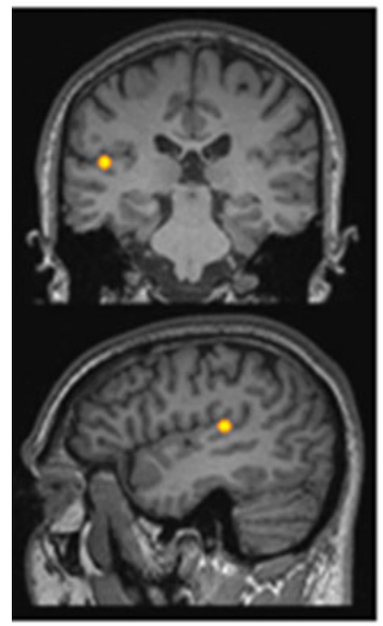
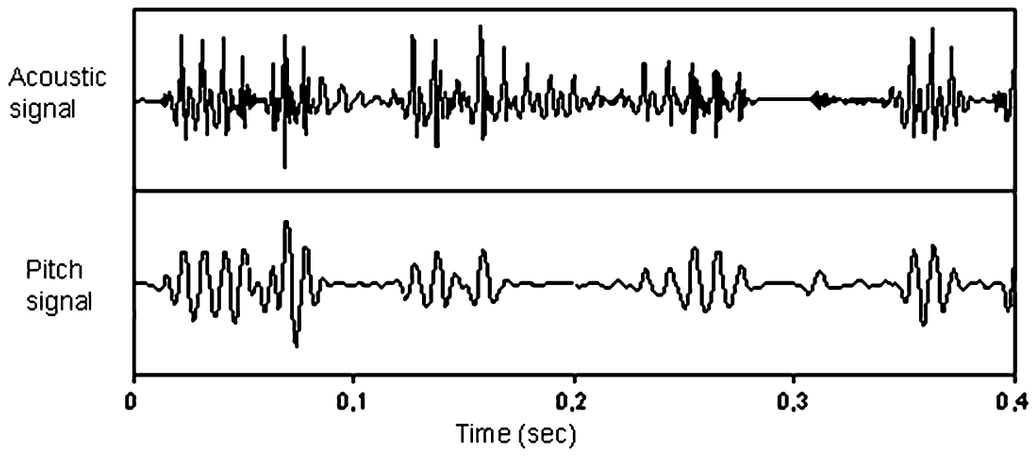
MEG FFR-like Responses to Continuous Speech



MEG cross-correlation with pitch signal





"pitch (ca. 100 Hz) elicited a neural resonance bound to a central auditory source at a latency of 30 ms"

Hertrich et al., Psychophysiology (2012[!])

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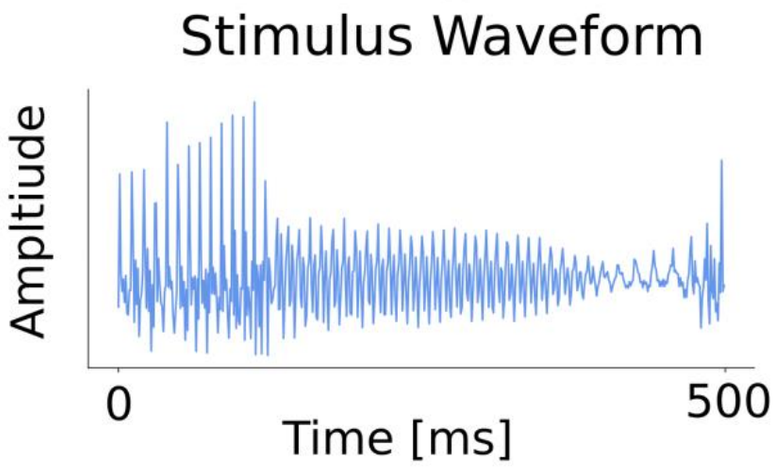
Methods

- 17 younger (18-27 yrs), 23 older adults (61-78)
- 2 spoken passages (male) x 60 s x 3 trials
- Previously acquired dataset (Presacco et al., 2016a, b)
- Neural source localized TRFs (Brodbeck et al., 2018)
- Regions of interests (ROIs)
  - cortical (temporal lobe)
  - subcortical (brainstem, inferior colliculus)

Speech Representations

- Two stimulus predictor variables
  - High frequency envelope (HFE)
    - use auditory spectrogram (Yang & Shamma, 1992)
    - extract 300 - 4000 Hz components, bandpass at 70 - 300 Hz, sum over bands
  - Carrier (70 - 300 Hz bandpass filter)

Speech Representations



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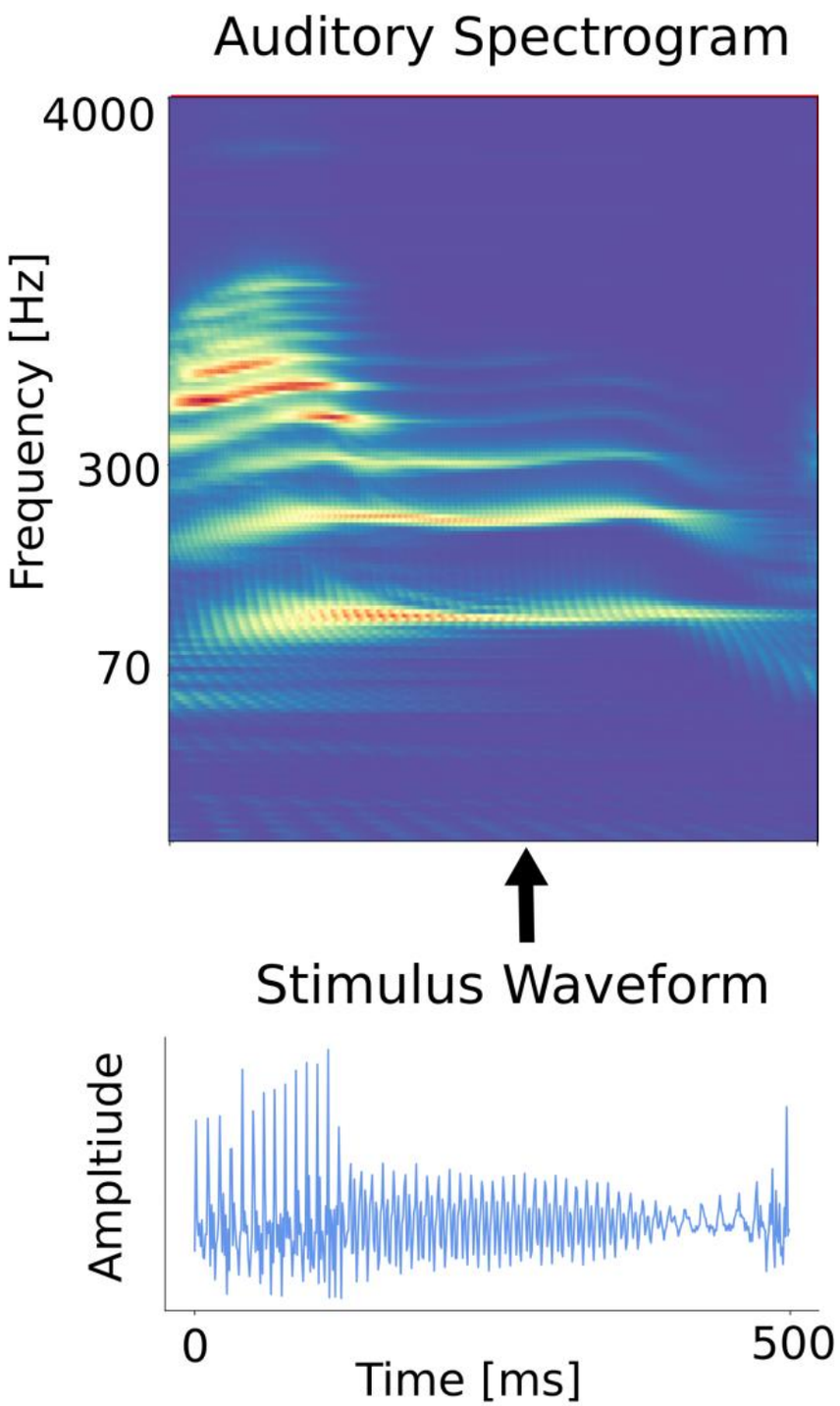

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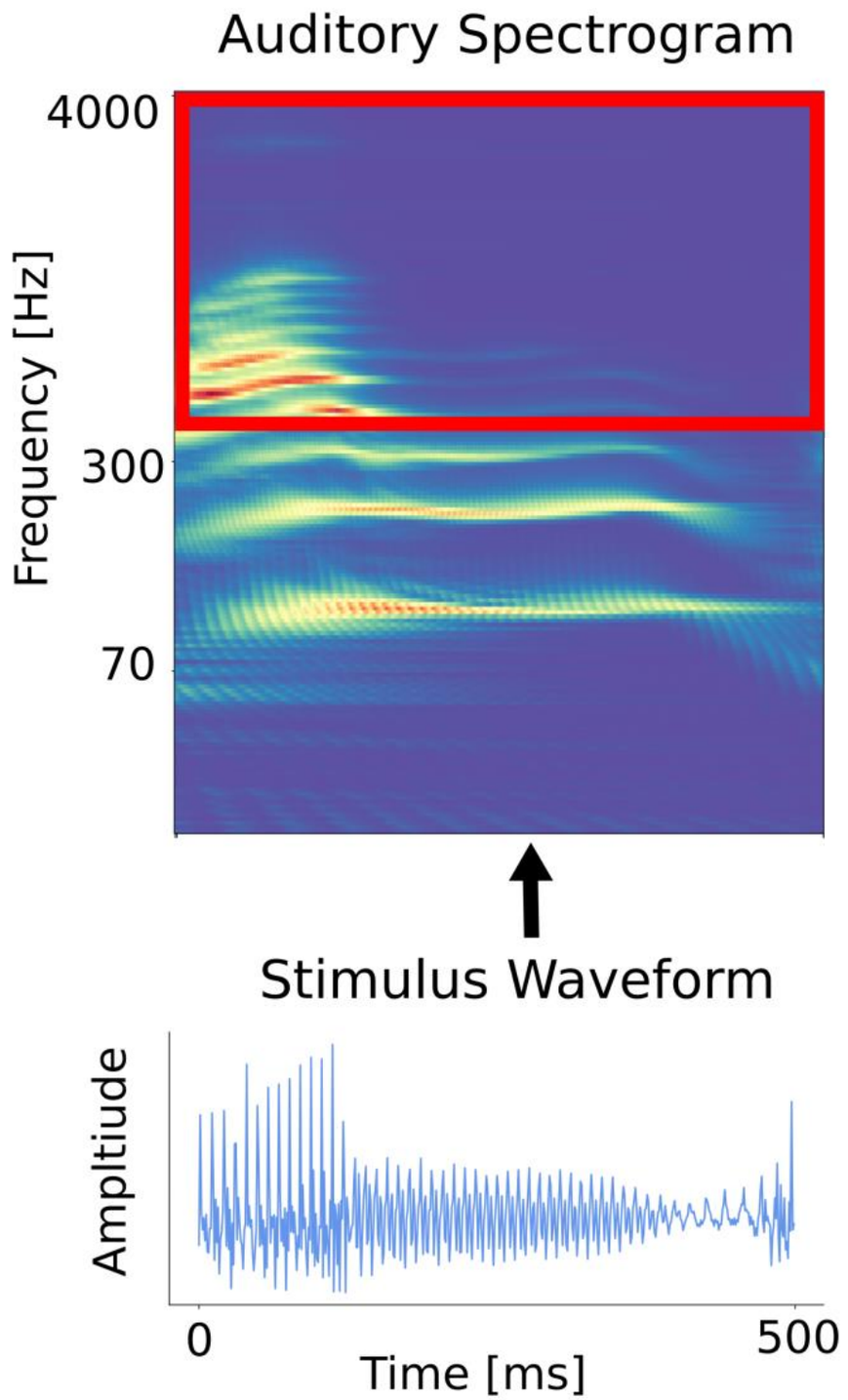
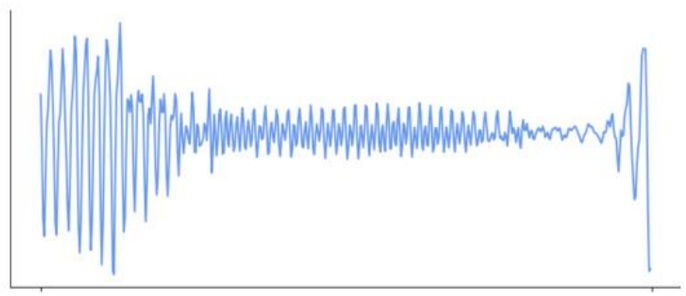
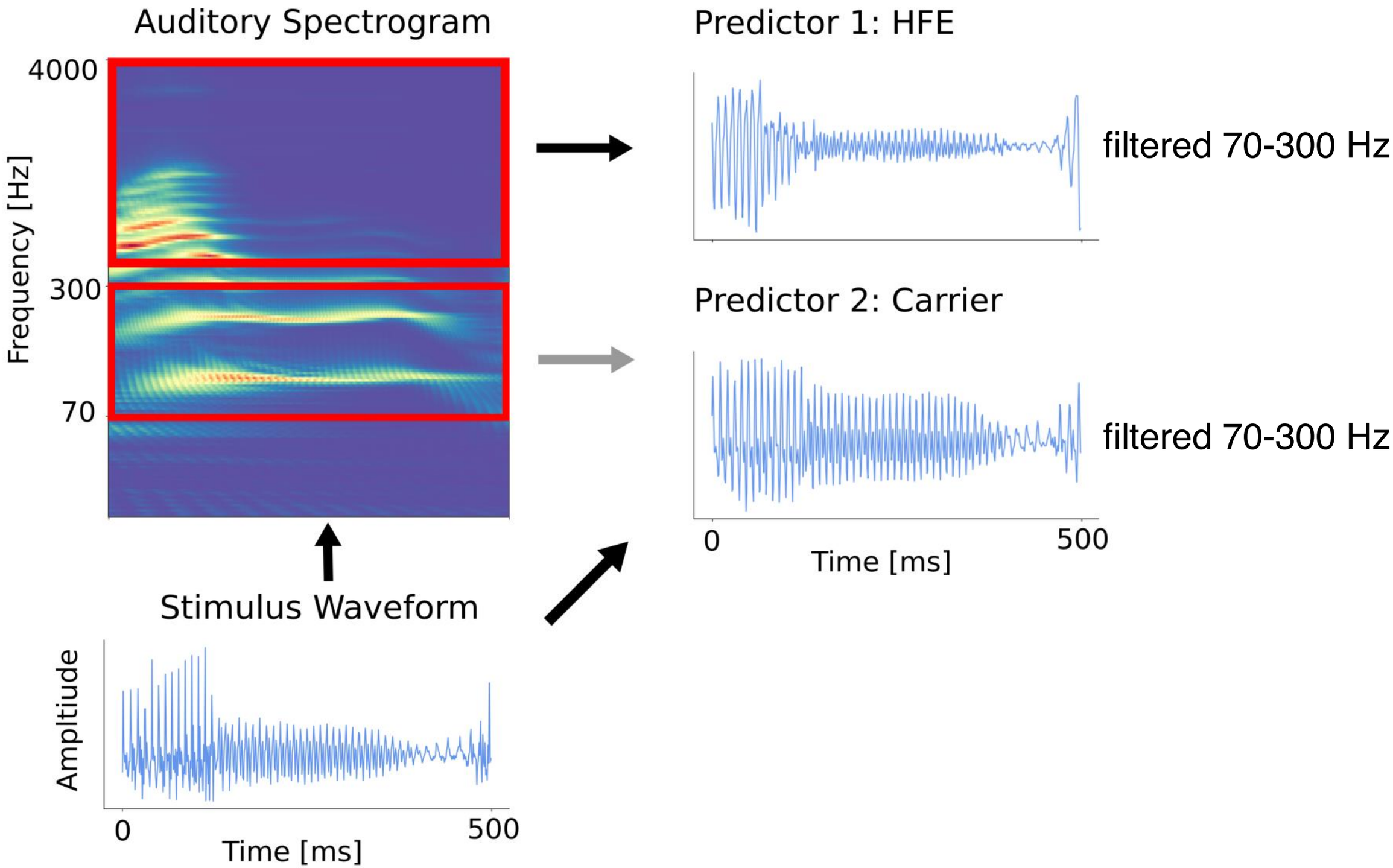




filtered 70-300 Hz

Speech Representations



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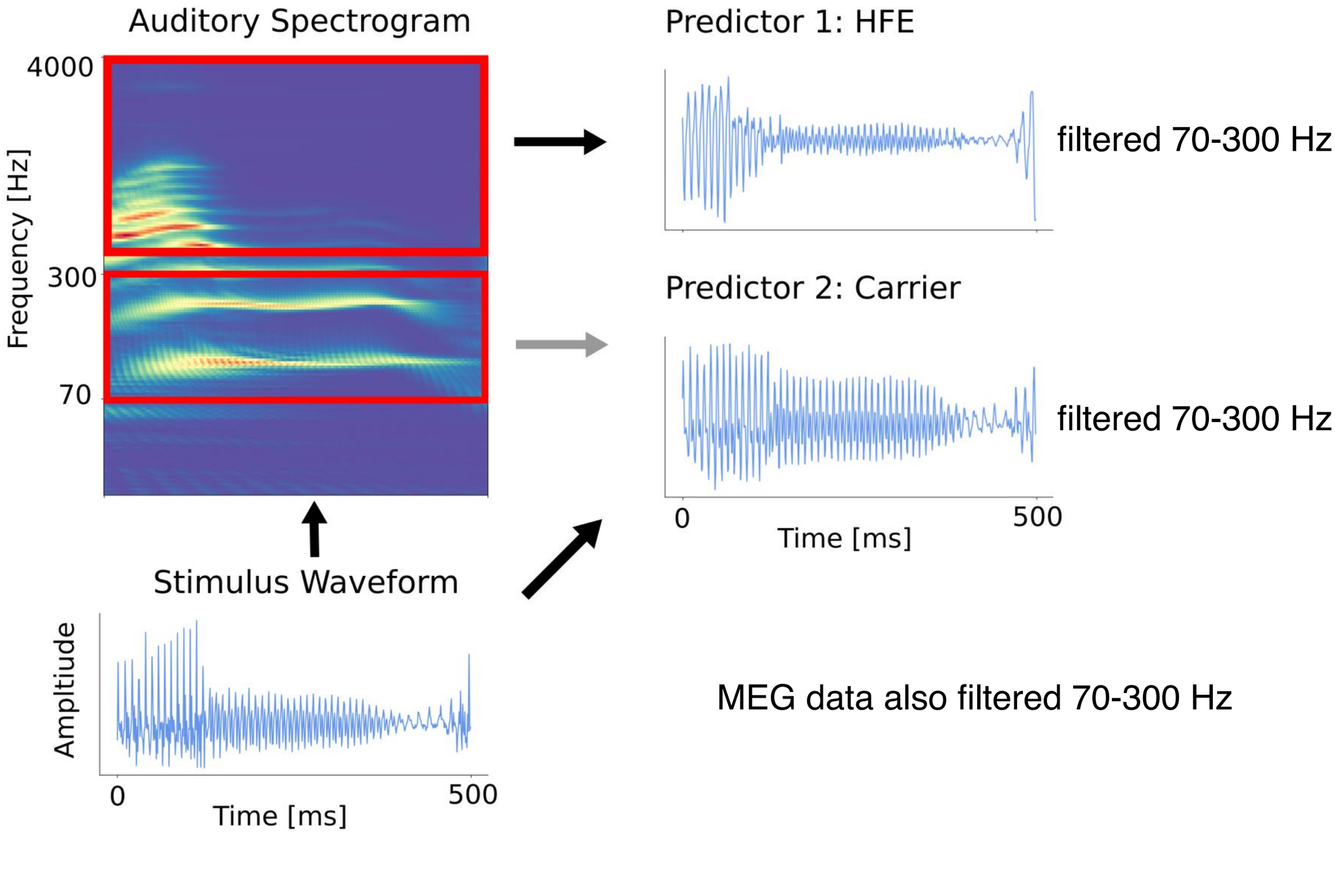

MEG data also filtered 70-300 Hz

Methods

- Neural source localized TRFs (Brodbeck et al., 2018)
  - Estimate TRFs with Boosting (temporally sparse)
  - TRF at every virtual source dipole (voxel) throughout the Regions of Interest
  - **HFE & Carrier compete against each other to explain response variance**

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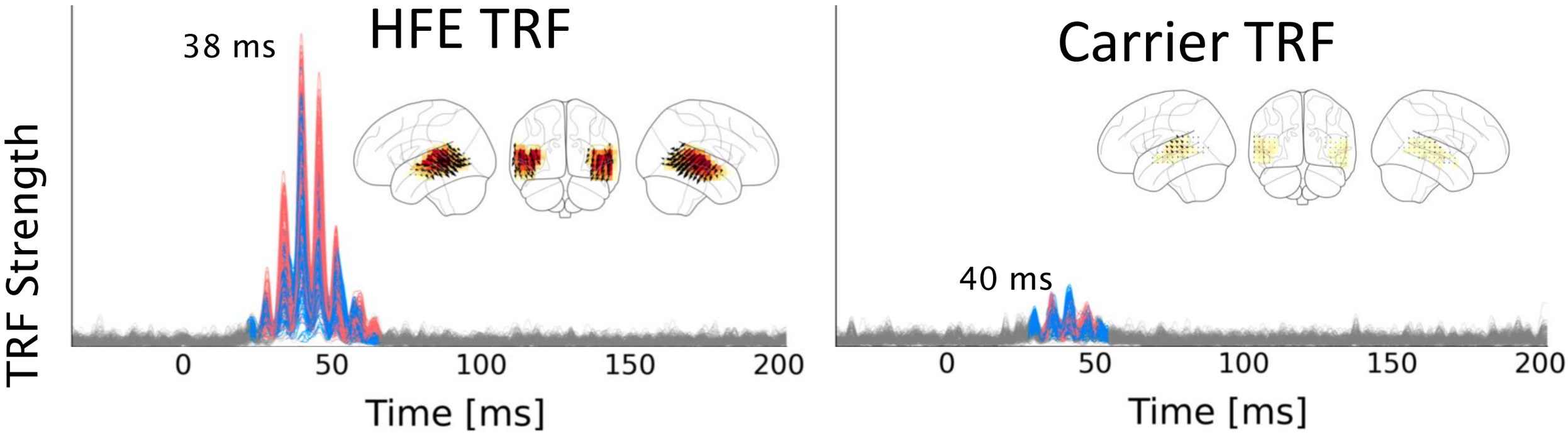
TRF Source Analysis

Envelope vs. Carrier

Cortical ROI



Envelope TRF stronger than Carrier TRF

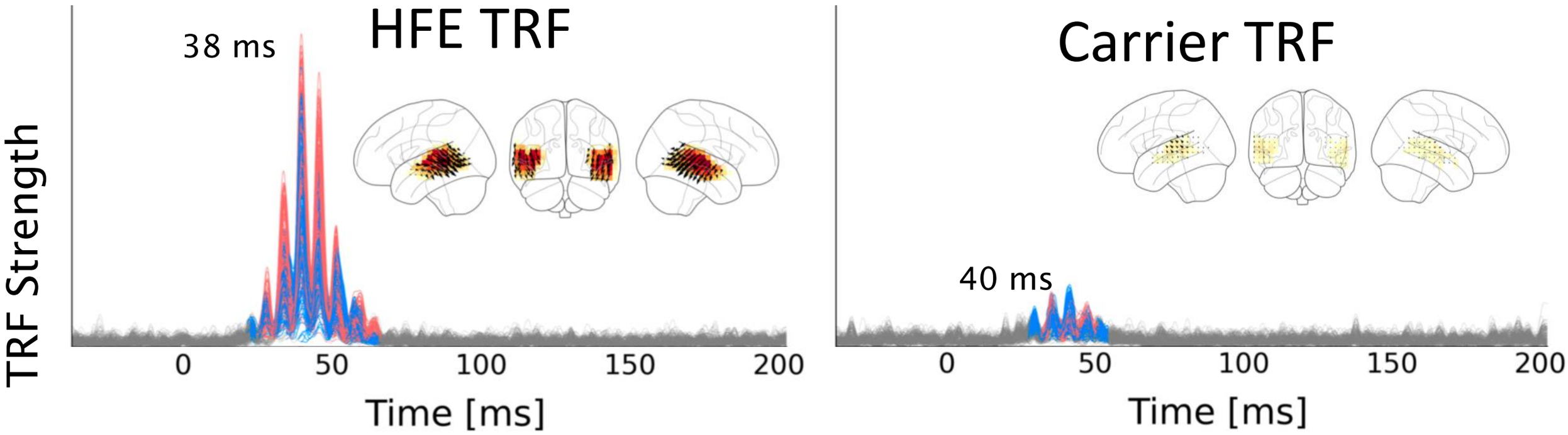
Stimulus Contributions

- Evidence for contributions from both Envelope and Carrier
  - Envelope > Carrier
  - Cannot yet rule out purely Envelope origin
    - Carrier is correlated with Envelope: small (~10%) but non-zero

TRF Source Analysis

Envelope vs. Carrier

Cortical ROI



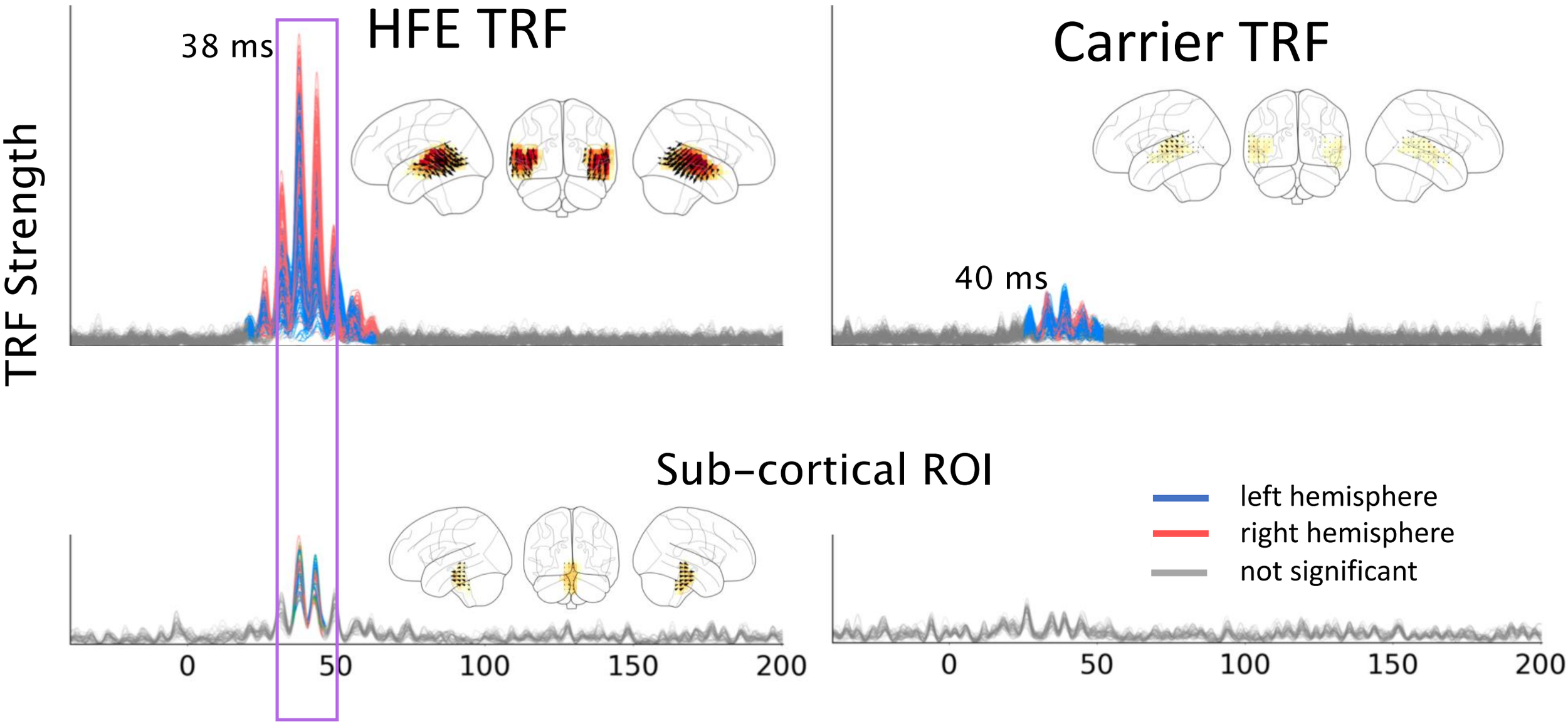
Envelope TRF stronger than Carrier TRF

TRF Source Analysis
Cortical vs. Subcortical

Cortical ROI

HFE TRF

Carrier TRF



Peak latency ~40 ms → Cortical Origin

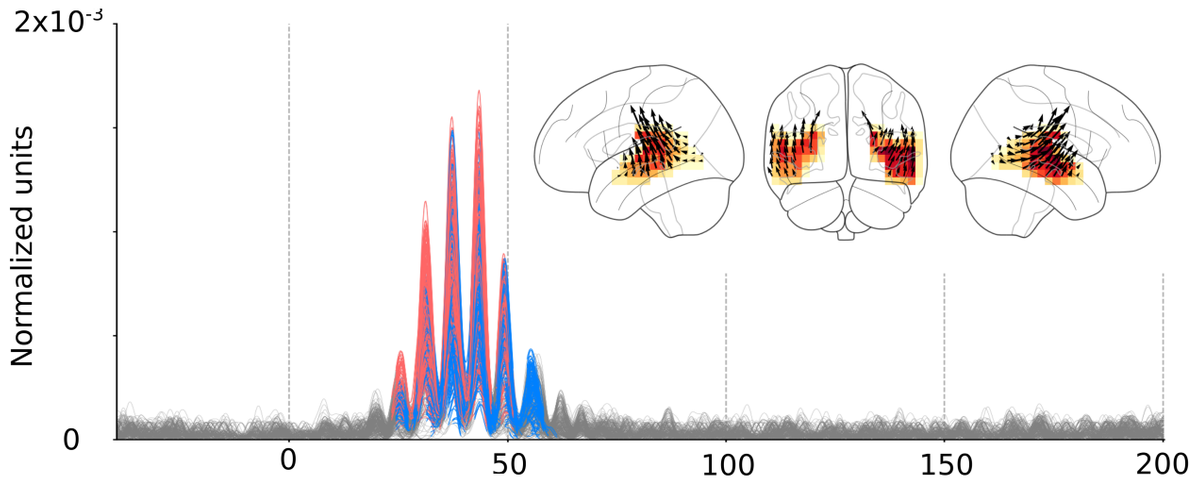
Source Localization

- Predominantly cortical origin
  - Cortical ROI amplitude >> subcortical ROI
  - Cortical latency (~40 ms) for both ROIs
    - Observed subcortical TRFs consistent with MEG-leakage-artifact cortical TRFs
- MEG subcortical contributions not ruled out
  - but much weaker than cortical
  - would need more statistical power to see
- Proceed assuming cortical origin
  - consistent with M50 neural source, Core AC

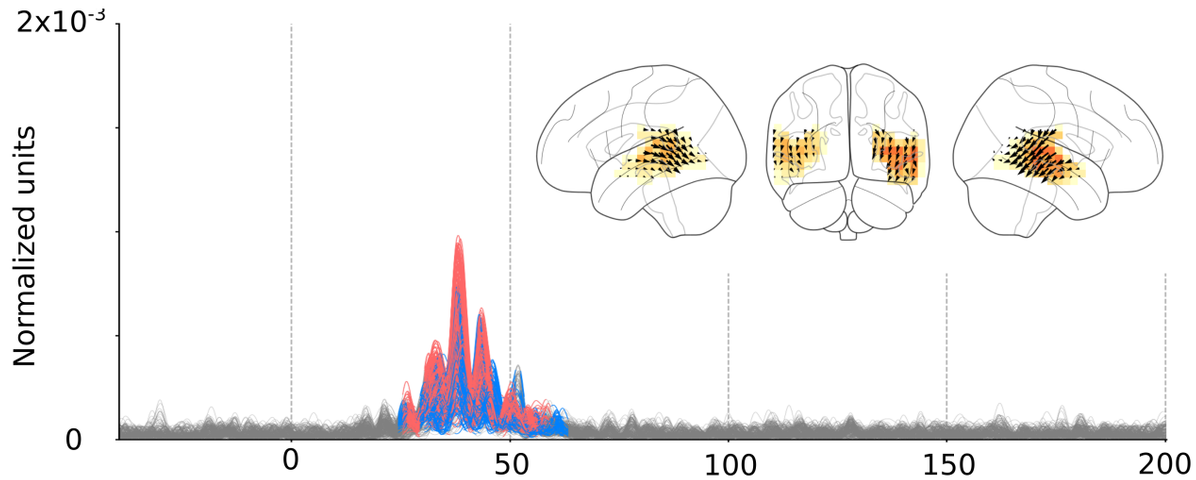
Aging Results: Envelope

Cortical ROI

Younger

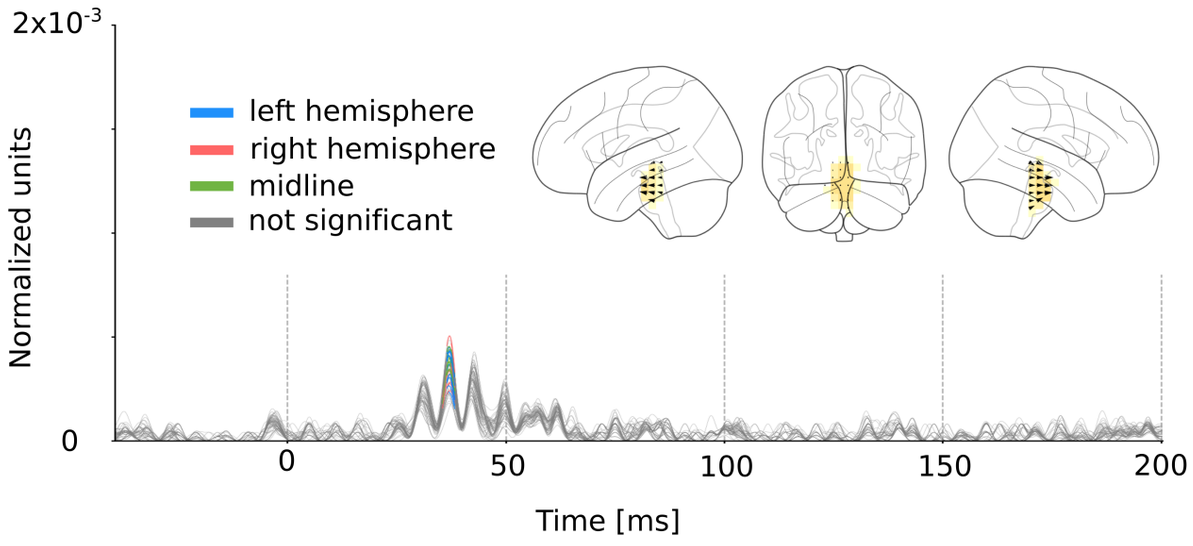


Older

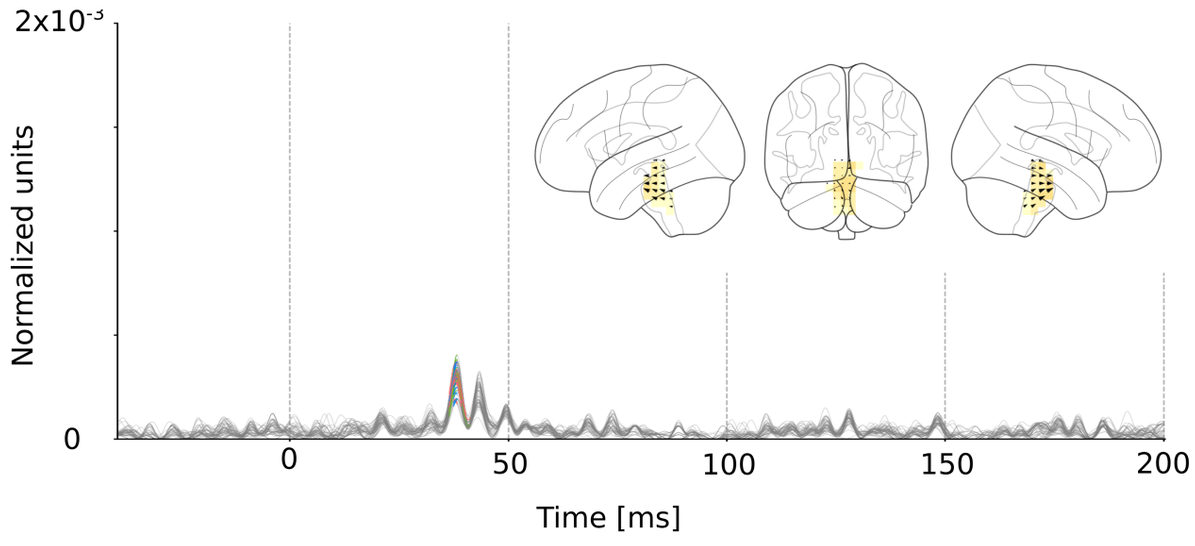


Subcortical ROI

Younger

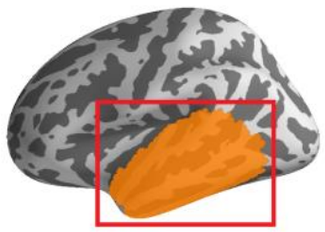


Older



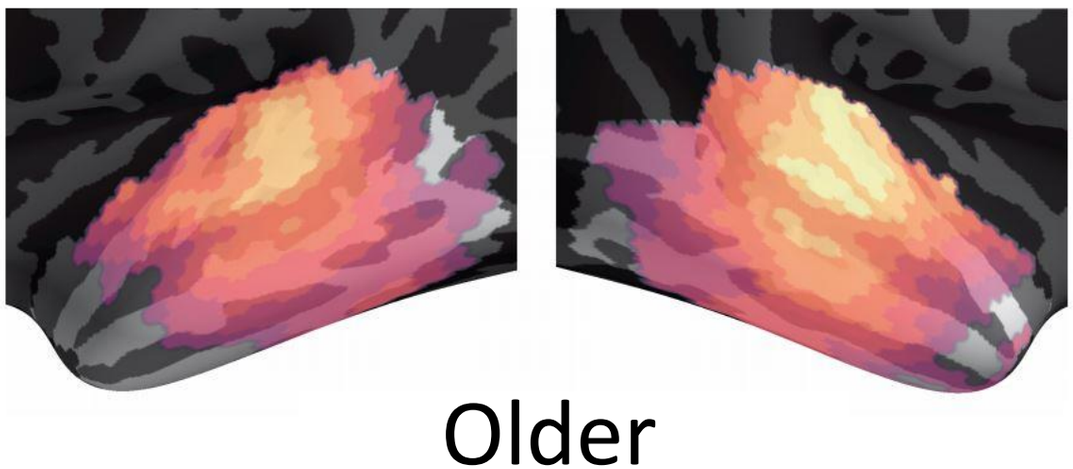
No significant age-related differences(!)

Aging Results

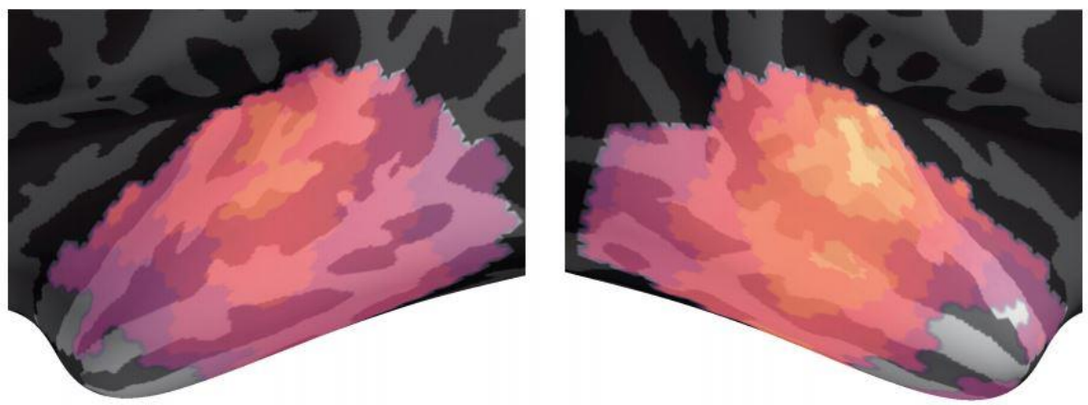


Response Model Fit

Younger



Older



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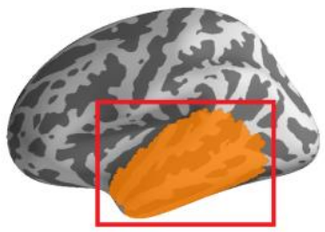

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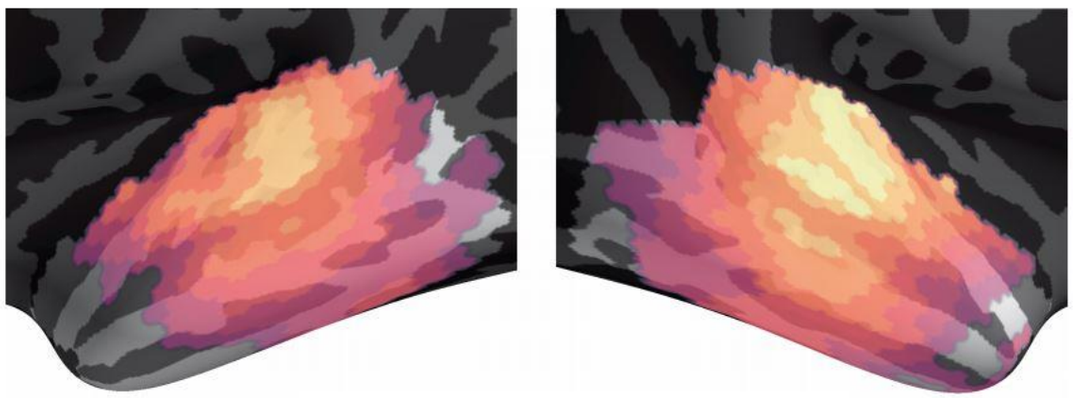

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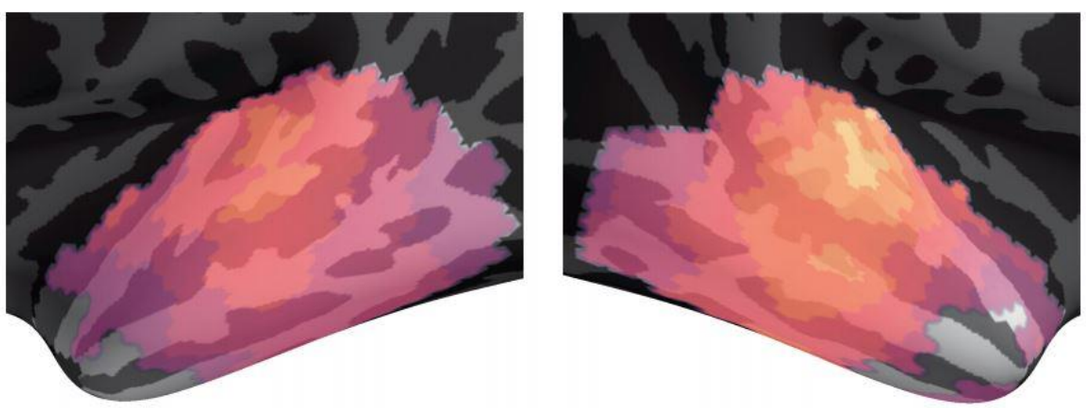
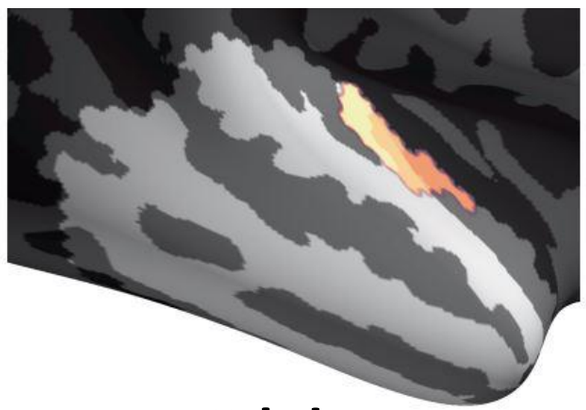


Lateralization

Younger

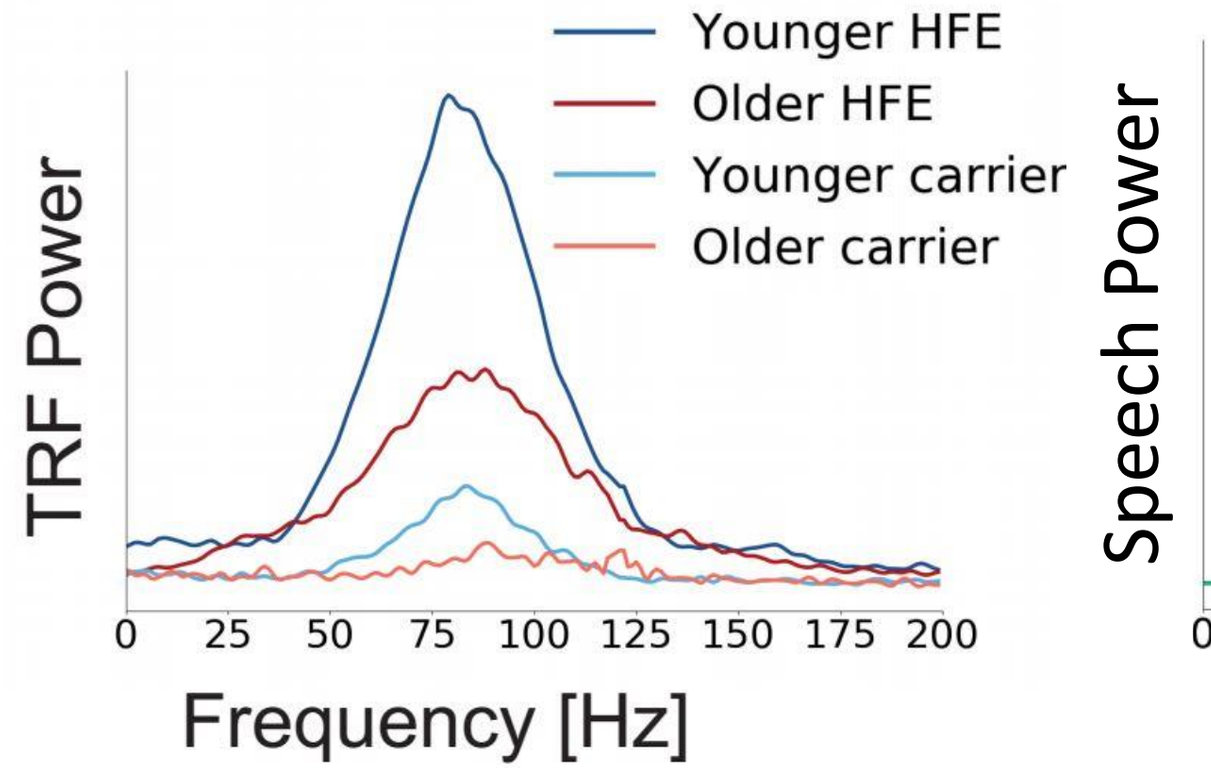


Older

No significant age-related differences(!)

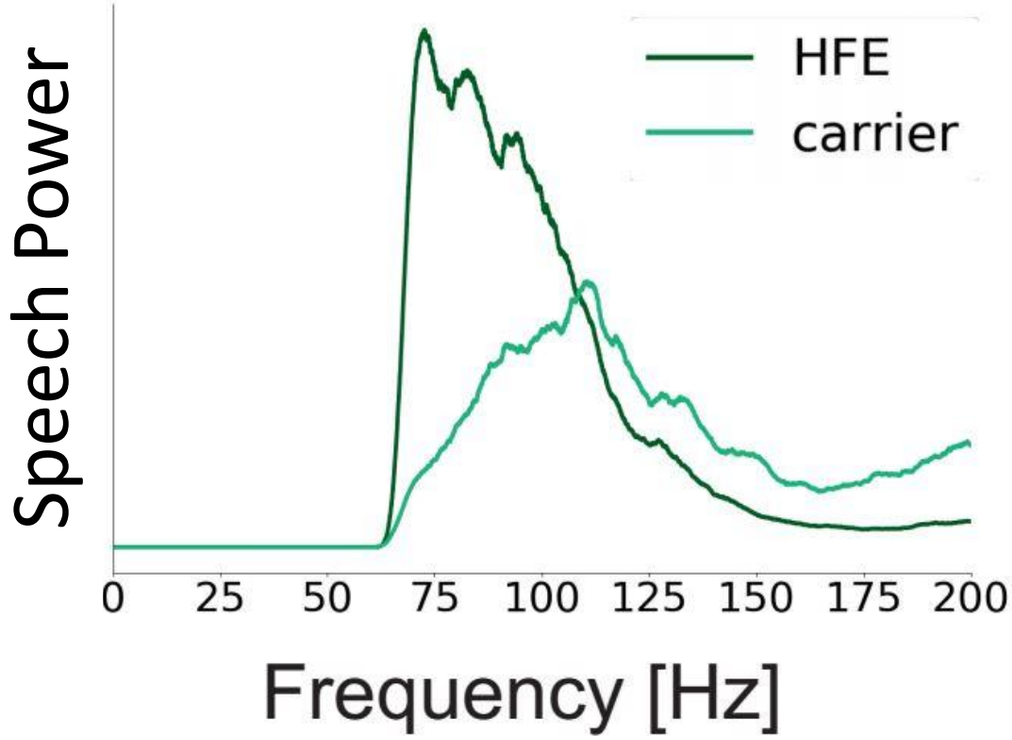
Frequency Distributions

TRF Frequency Responses



TRF peaks 80-90 Hz
Robust across age group & stimulus representation

Stimulus Representation Frequency Responses



Stimulus representations have different spectra
Different peak frequencies

TRF peak oscillation frequency arises from cortical constraints, not stimulus

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Summary I

- MEG responses to continuous speech dominated by cortical sources with peak frequencies 80-90 Hz
  - peak latency varies 30 – 40 ms across subjects
  - consistent with M50 origin, core auditory cortex
  - cannot rule out subcortical contributions
  - frequency specificity not driven by stimulus spectrum directly

Summary II

- Responses dominated by High Frequency Envelope more than Carrier
  - Perhaps entirely High Frequency Envelope
- Right hemisphere lateralization
  - Only significant for younger listeners
- Absence of age-related differences(!)
  - Disagrees with low frequency cortical responses
  - Disagrees with high frequency EEG responses

Thank You

Acknowledgements

Current Lab Members & Affiliates

Christian Brodbeck
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Sina Miran
David Nahmias
Peng Zan
Victor Grau-Serrat
Julian Jenkins
Pirazh Khorramshahi
Huan Luo
Mahshid Najafi
Krishna Puvvada
Jonas Vanthornhout
Ben Walsh
Yadong Wang
Juanjuan Xiang
Jiachen Zhuo
Mounya Elhilali
Tom Francart
Jonathan Fritz
Michael Fu
Stefanie Kuchinsky
Steven Marcus
Cindy Moss
David Poeppel
Shihab Shamma

Past Lab Members & Affiliates

Nayef Ahmar
Sahar Akram
Murat Aytekin
Francisco Cervantes Constantino
Maria Chait
Marisel Villafane Delgado
Kim Drnec
Nai Ding

Collaborators

Pamela Abshire
Samira Anderson
Behtash Babadi
Catherine Carr
Monita Chatterjee
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