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

Joshua P. Kulasingham[1], Christian Brodbeck[1],
Alessandro Presacco[1], Stefanie E. Kuchinsky[2,1],
Samira Anderson[1], Jonathan Z. Simon[1]

[1] *University of Maryland*
[2] *Walter Reed National Military Medical Center*

Cortical MEG FFR TRFs in Younger and Older Listeners

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Why Investigate This?

- Aging
  - *subcortical fast EEG* responses: younger > older
  - *cortical slow MEG/EEG* responses: older > younger
  - cortical fast MEG?
- How much of EEG FFR is actually cortical?
  - effects of attention, language, etc.
- Contributions to responses from stimulus carrier vs envelope

Outline

- Background & motivation
  - Frequency Following Response (FFR)
  - Cortical Continuous Speech Responses
  - EEG FFR for Continuous Speech
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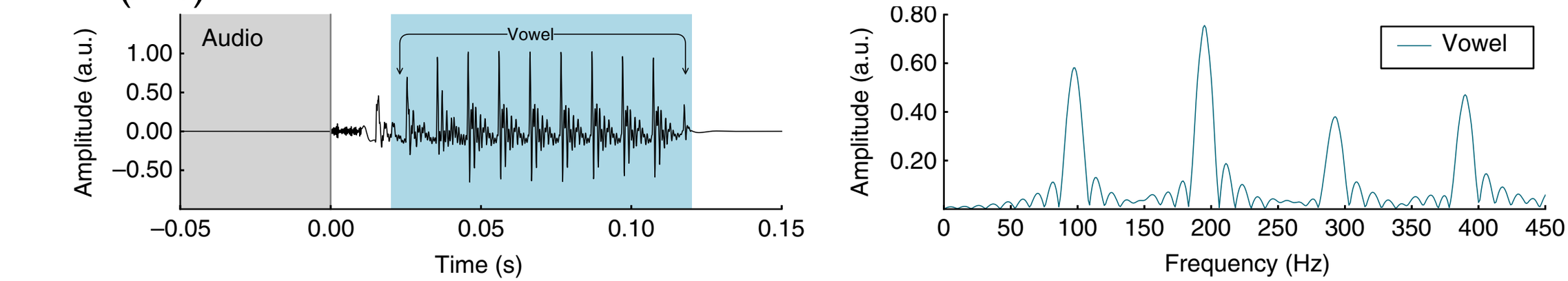
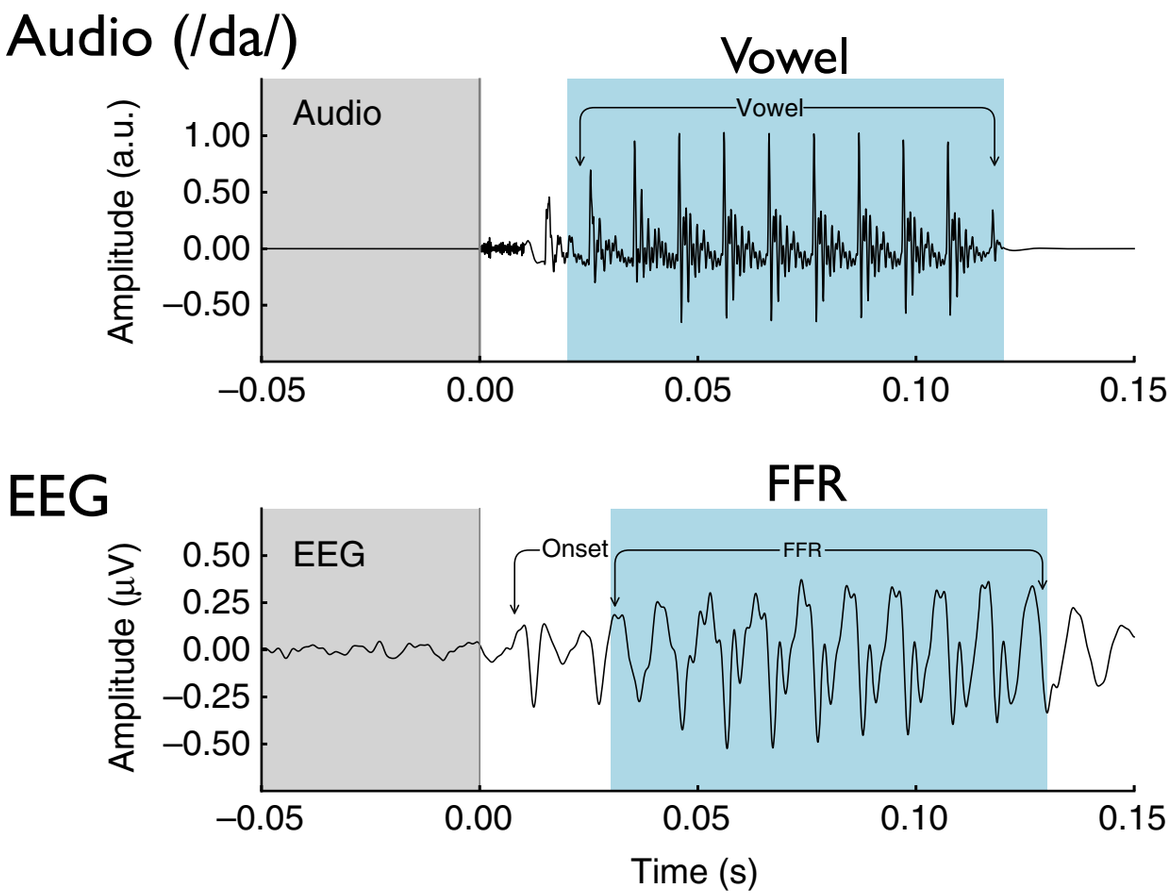
Frequency Following Response (FFR)

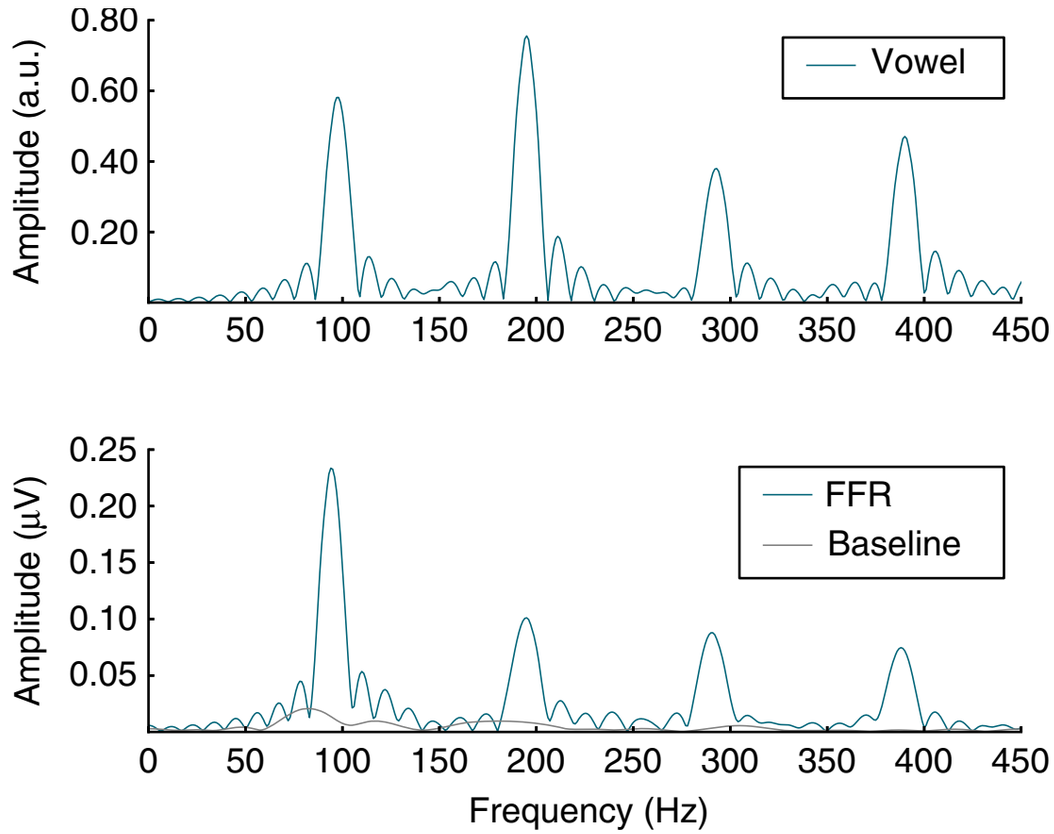
Audio (/da/)



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

Frequency Following Response (FFR)





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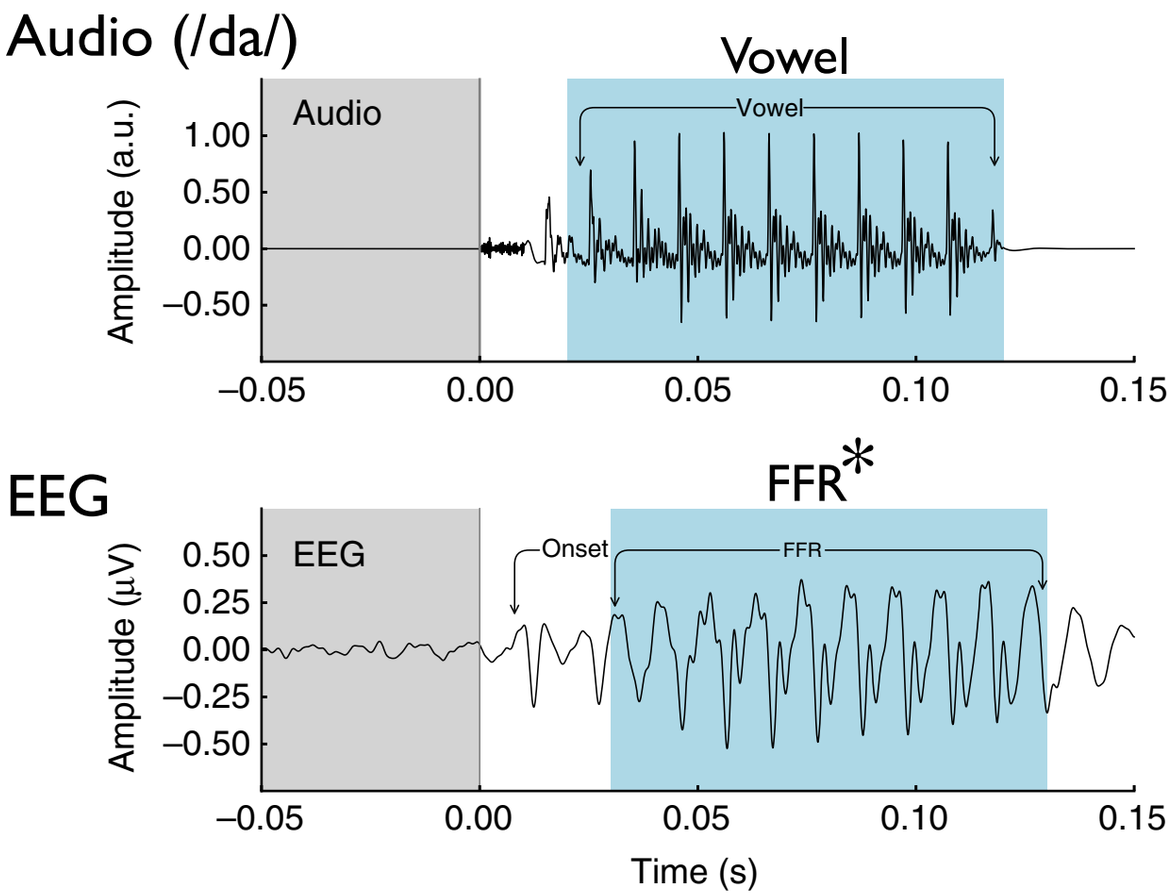

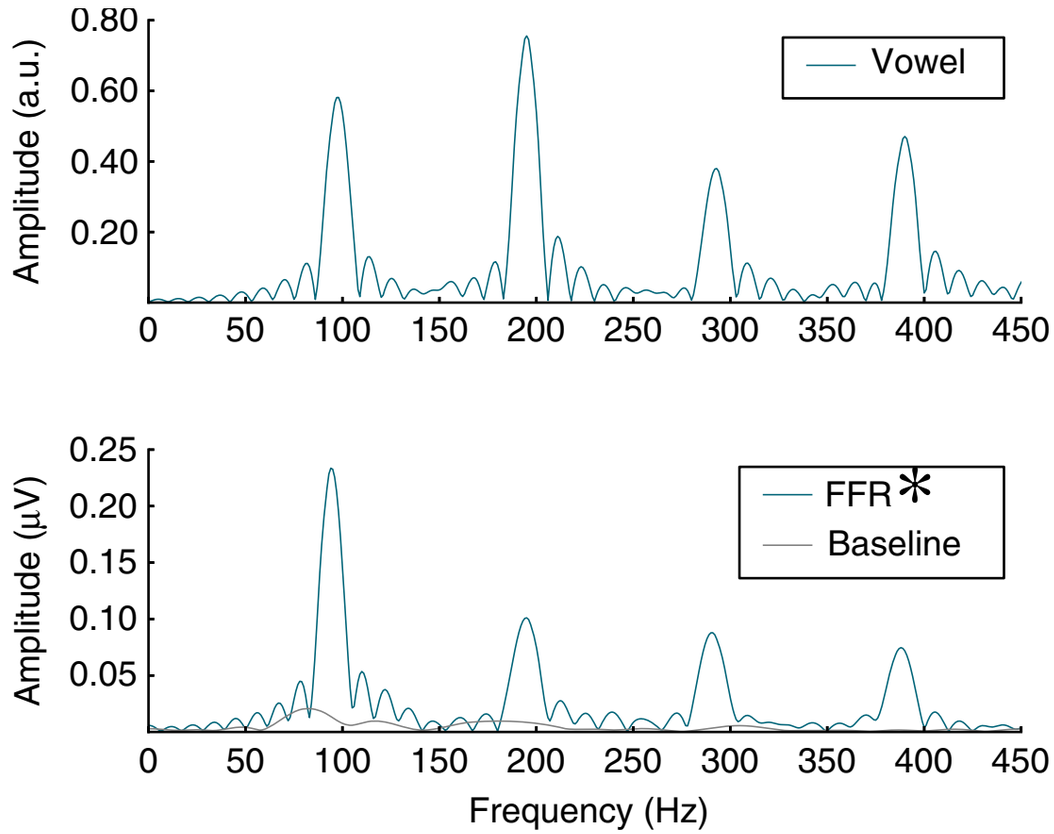

* EEG response is technically "Envelope Following Response", since stimuli were presented with alternating polarity

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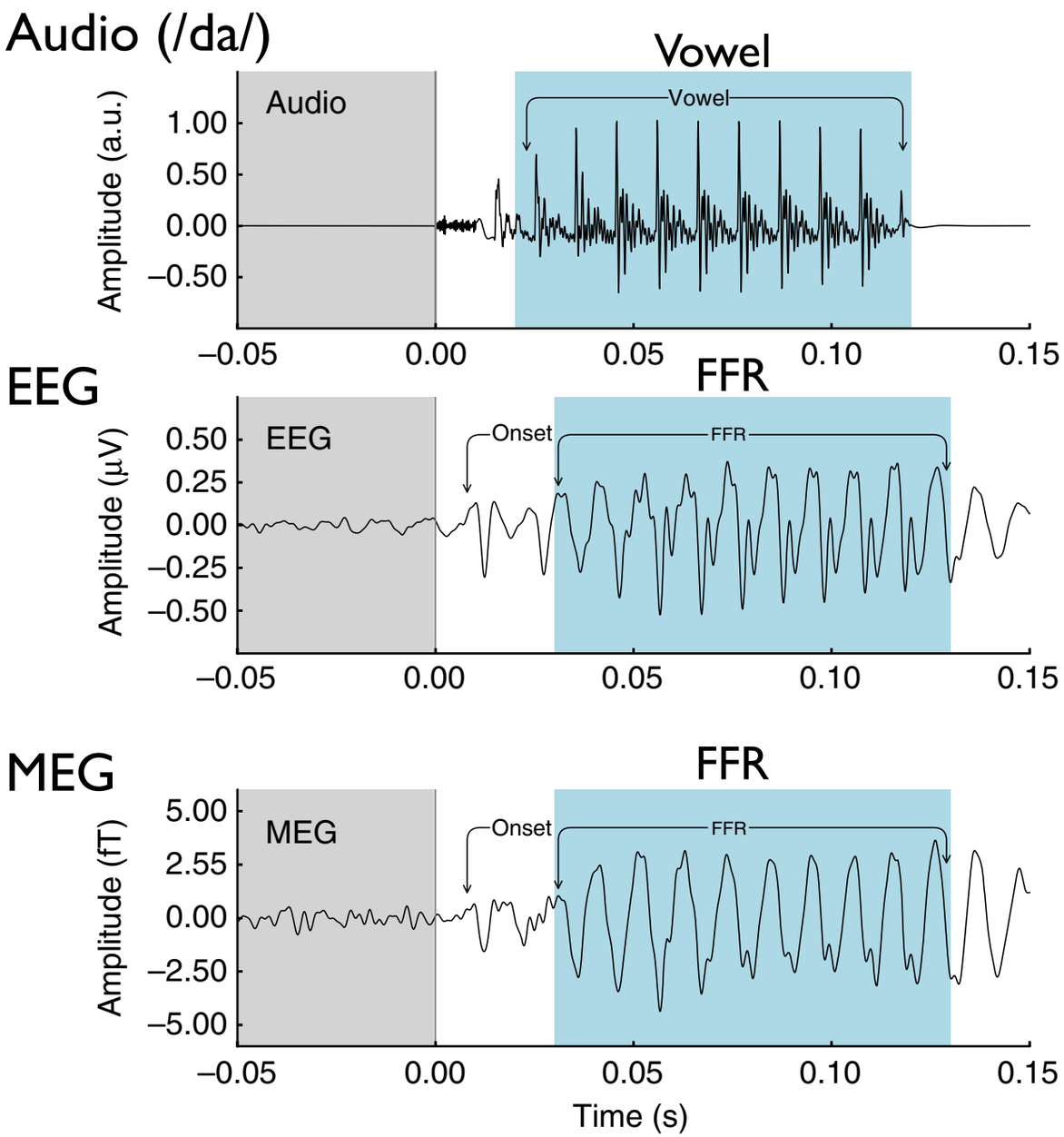
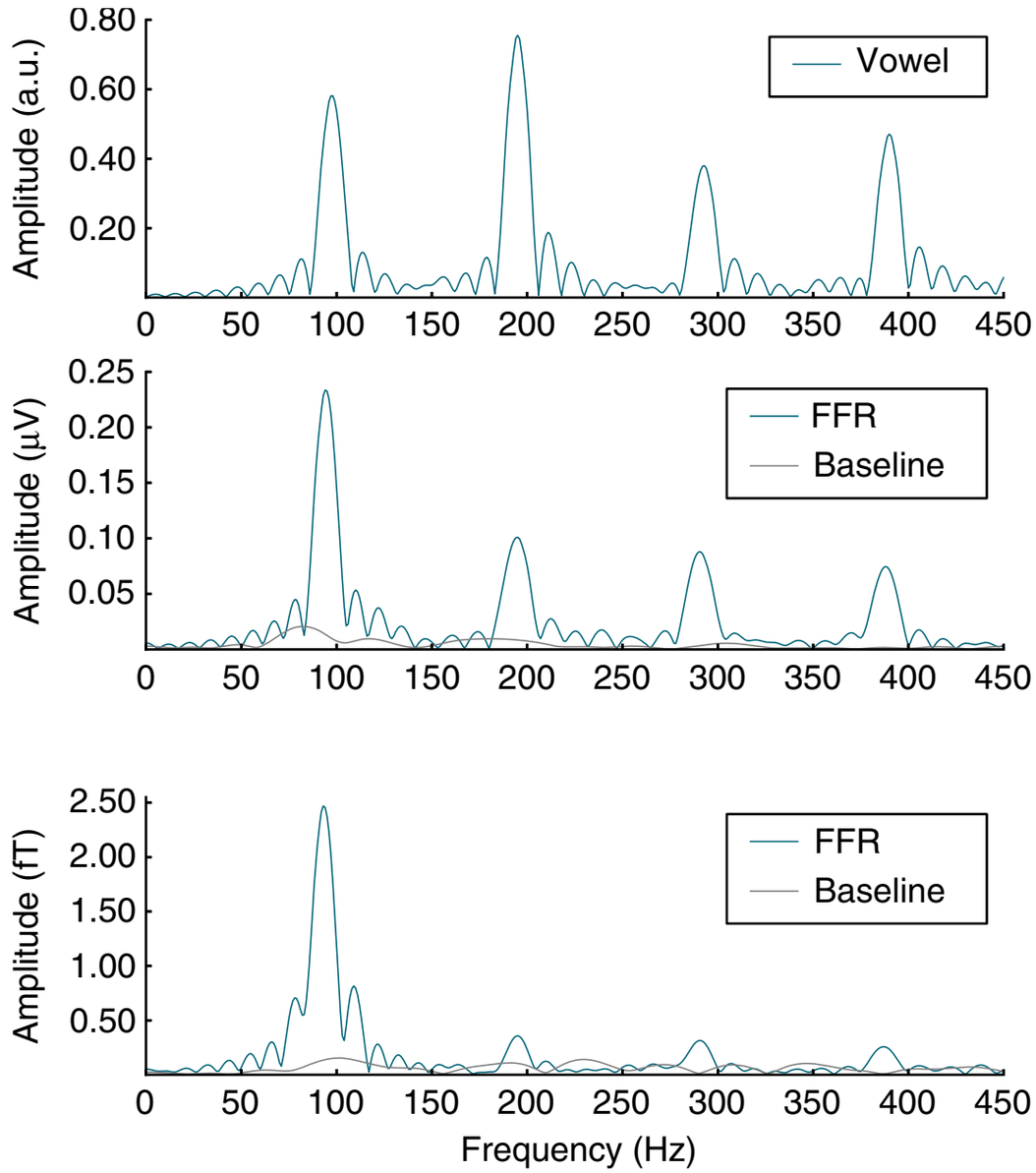
Frequency Following Response (FFR)





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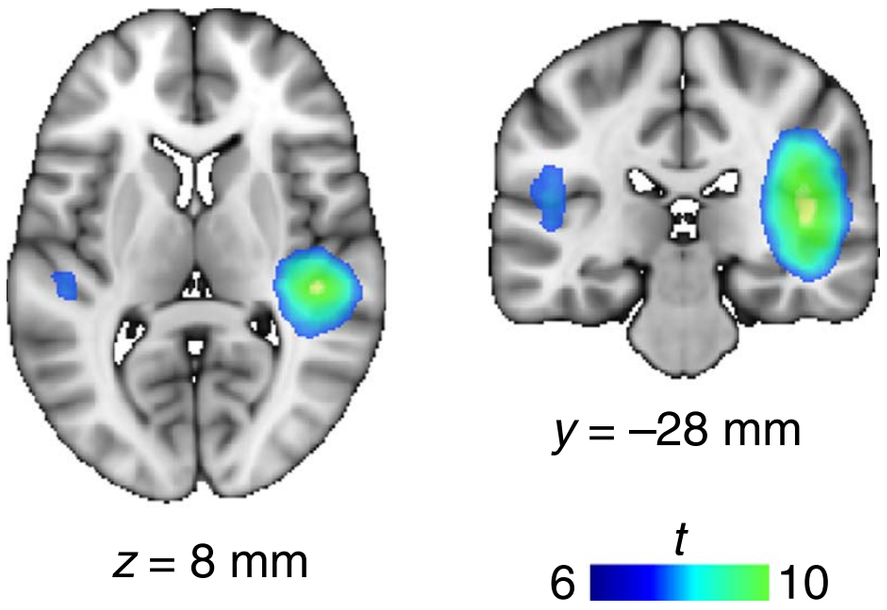
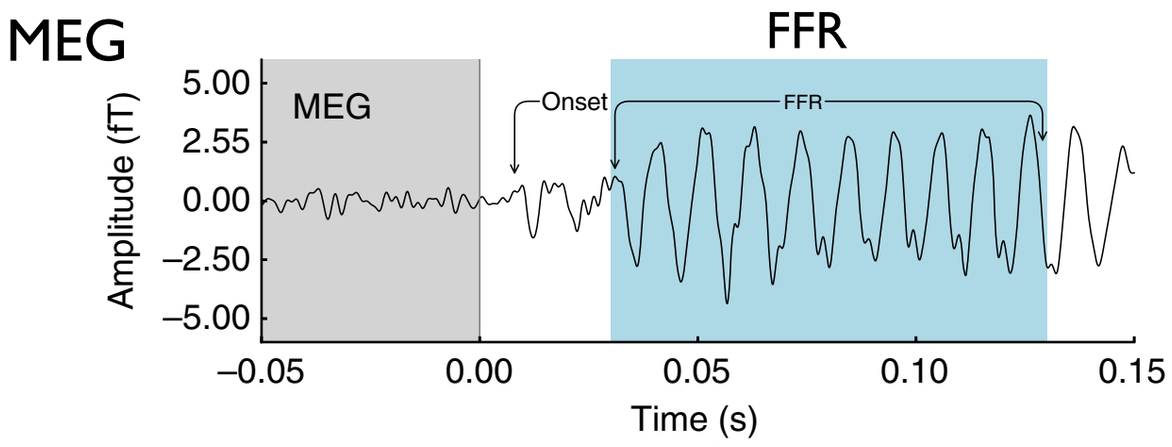
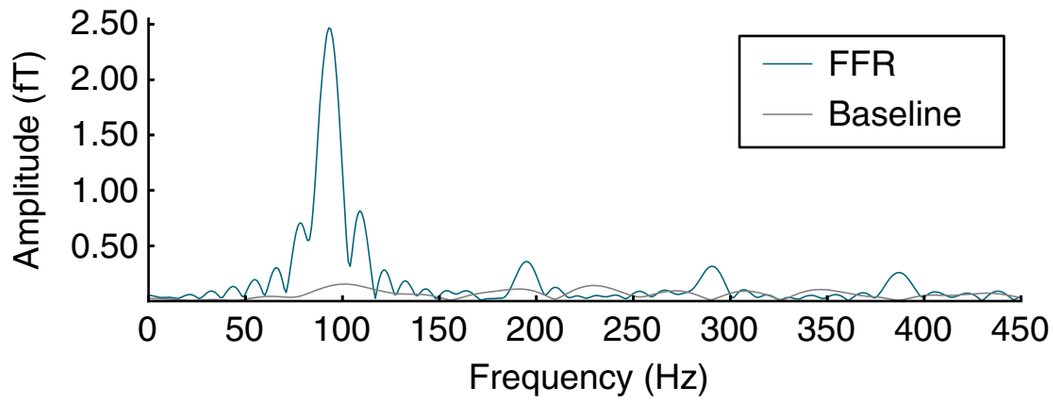


MEG responses dominated by cortical sources





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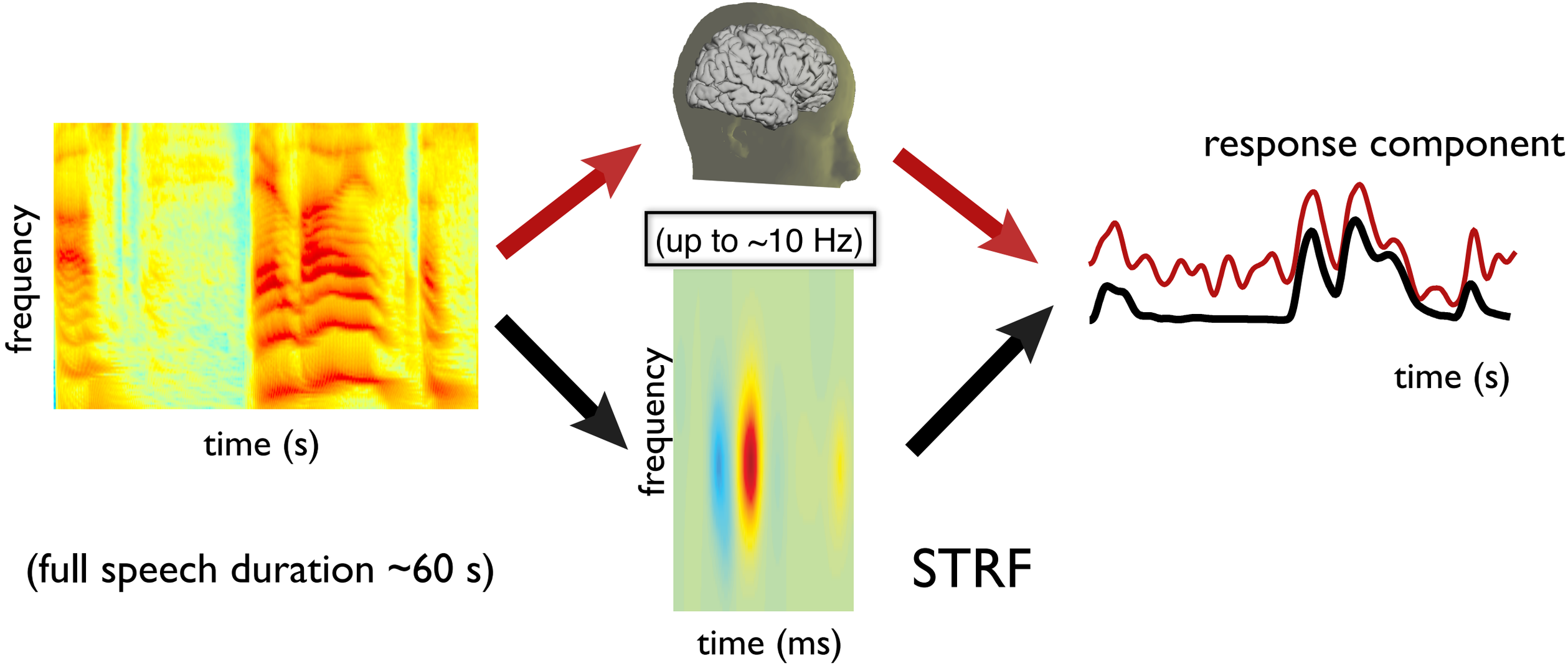
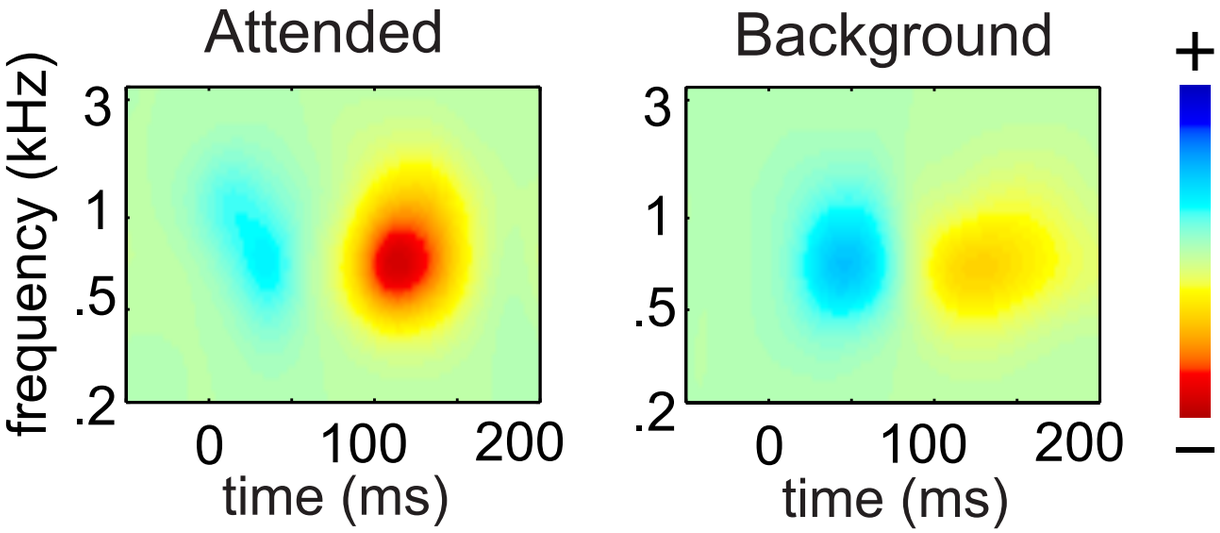
Spectro-Temporal Response Function (STRF)

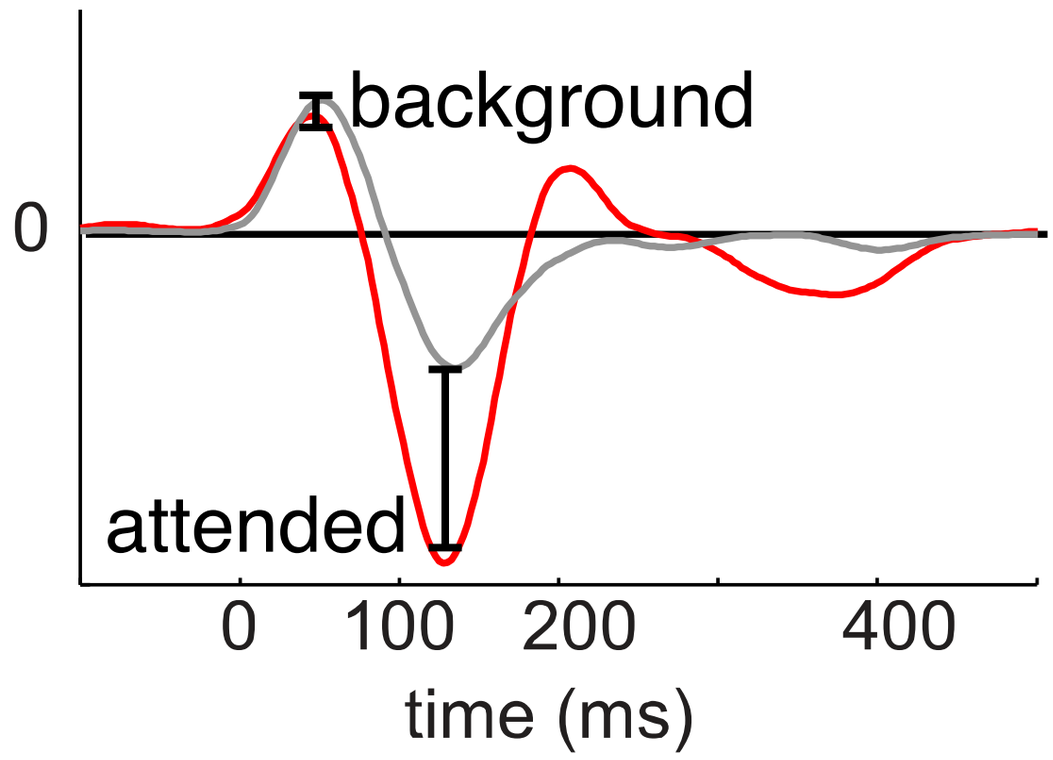


Ding & Simon, J Neurophysiol (2012)

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)

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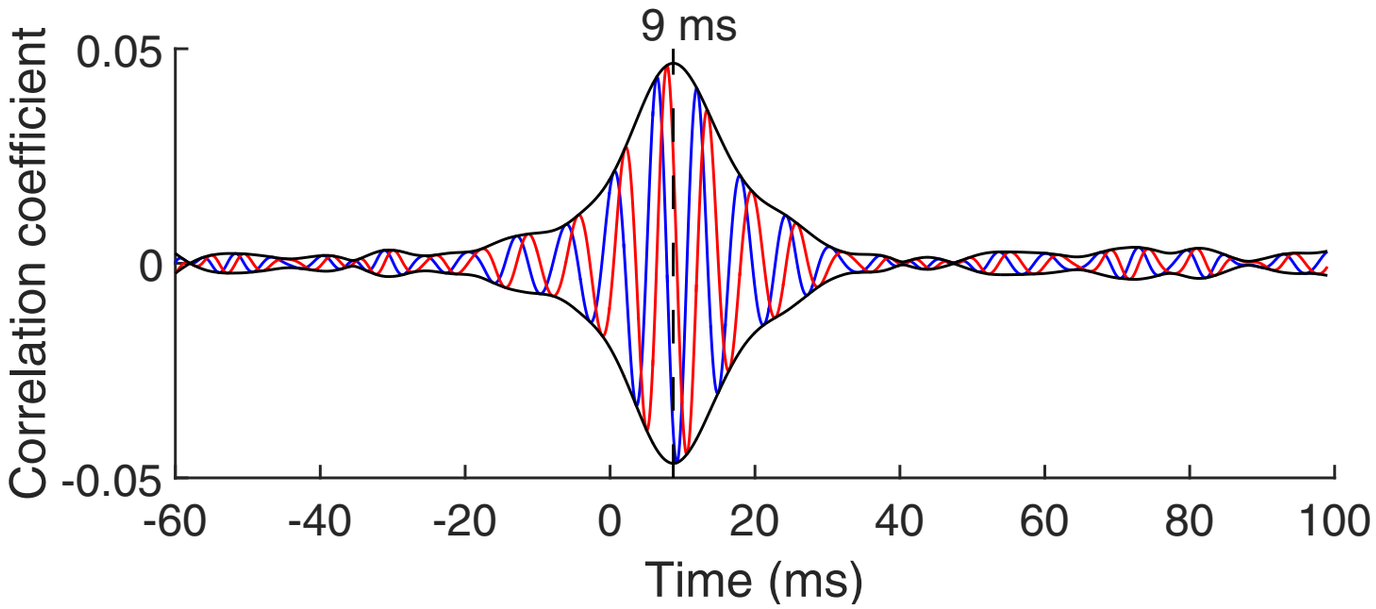
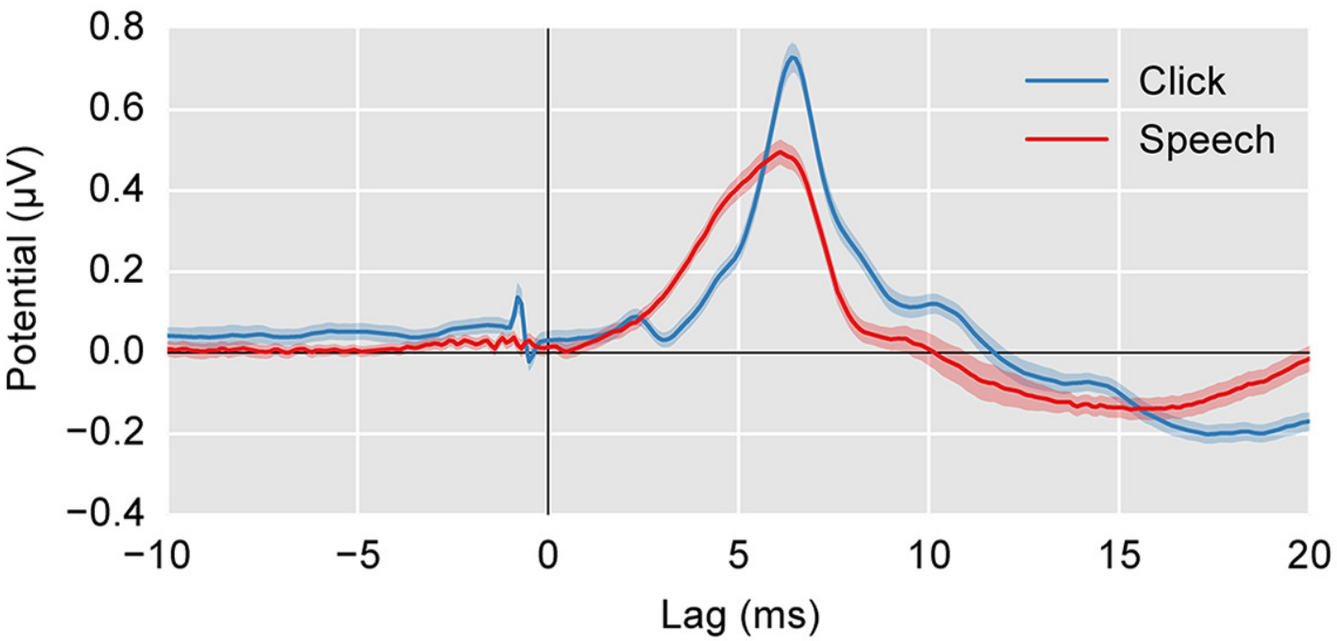
EEG FFR Responses to Continuous Speech



Forte et al., eLife (2017)

*Response modulated by selective attention



Maddox & Lee, eNeuro (2018)

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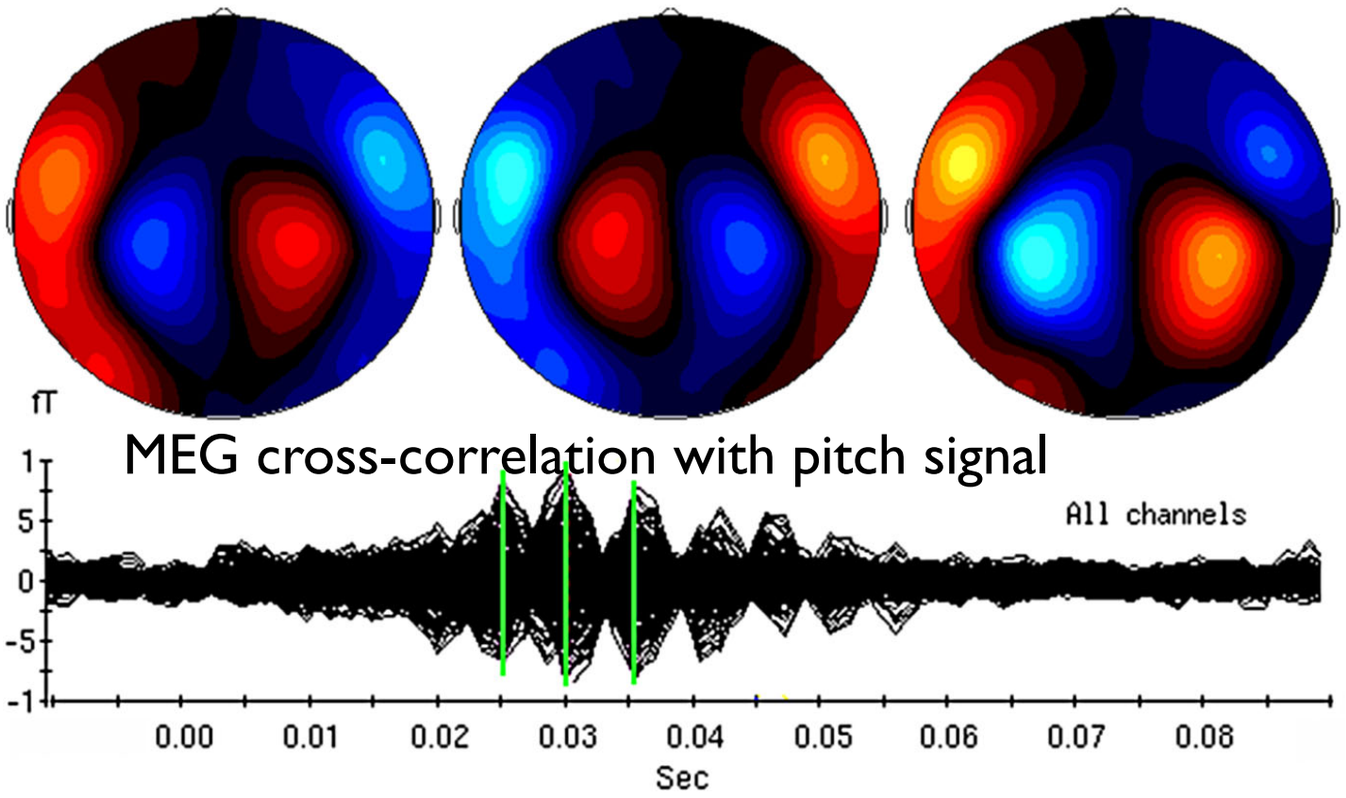
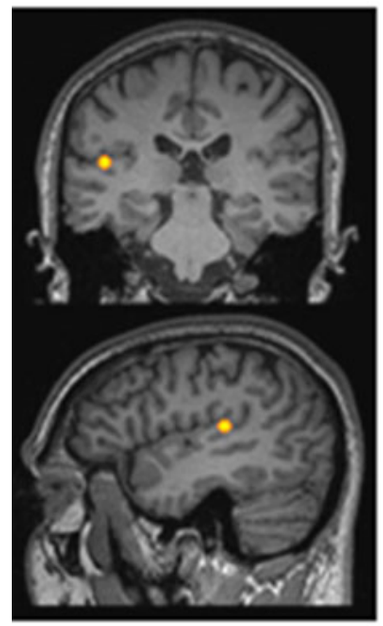
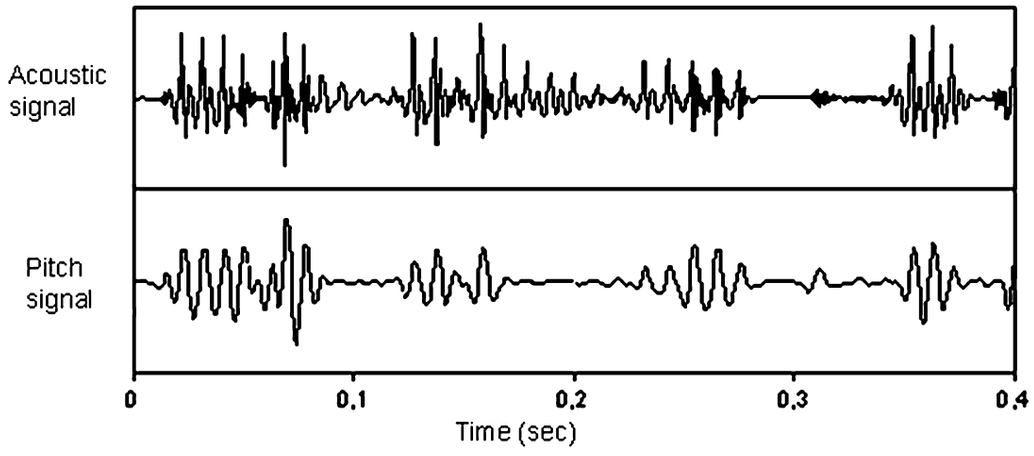
MEG FFR Responses to Continuous Speech



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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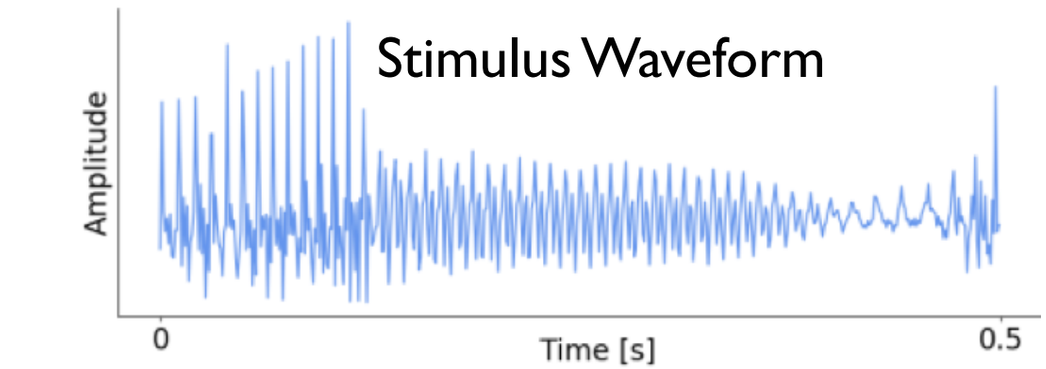
Methods

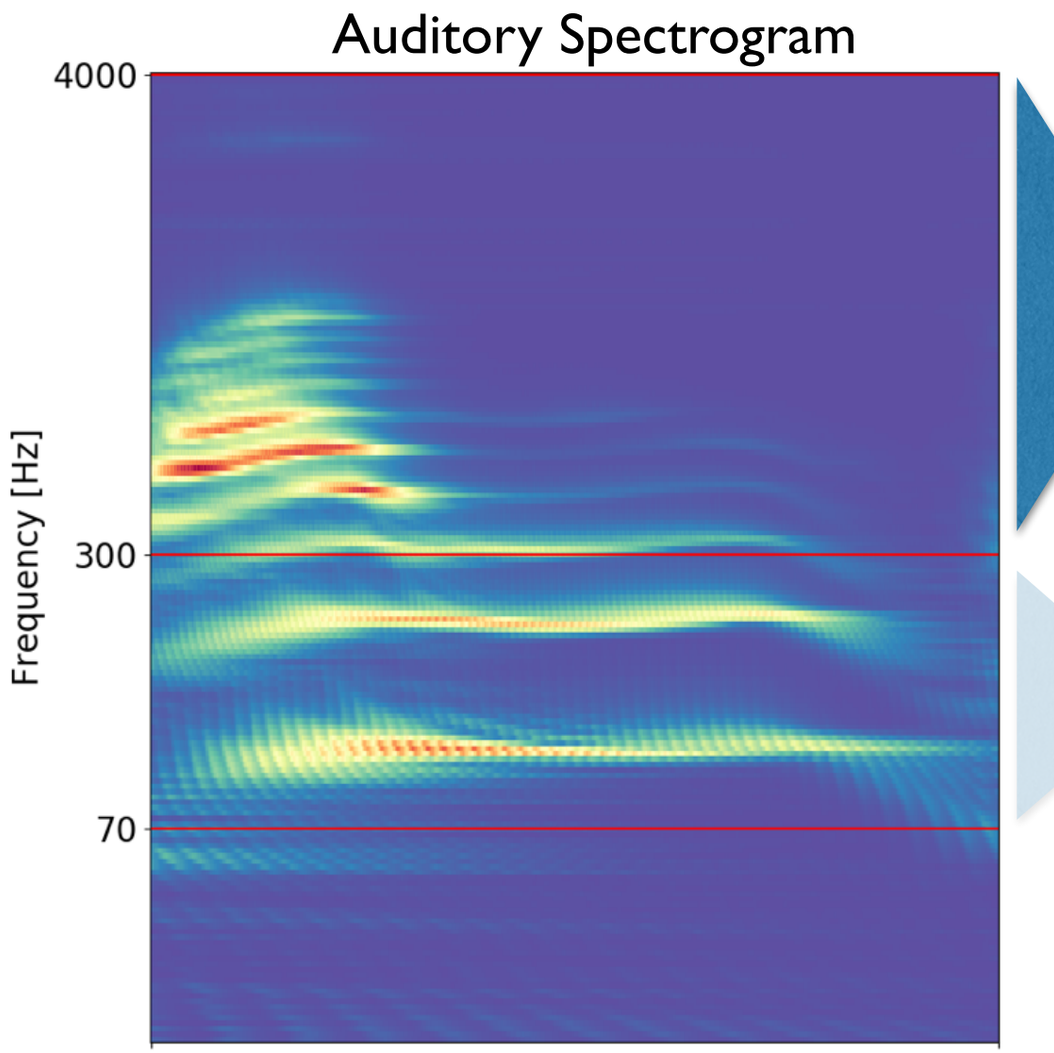
- 17 younger (18-27 yrs), 23 older adults (61-78)
- 2 spoken passages (male) x 60 s x 3 trials
- Previously acquired dataset (Presacco et al., 2016a, b)
- Neural source localized TRFs (Brodbeck et al., 2018)
- Regions of interests (ROIs)
  - cortical (temporal lobe)
  - subcortical (includes brainstem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

Speech Representations

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

Speech Representations





Methods

- Causal IIR filter with minimum phase distortion
  - Bessel filter (3rd order)
  - Maximally flat group delay*
- 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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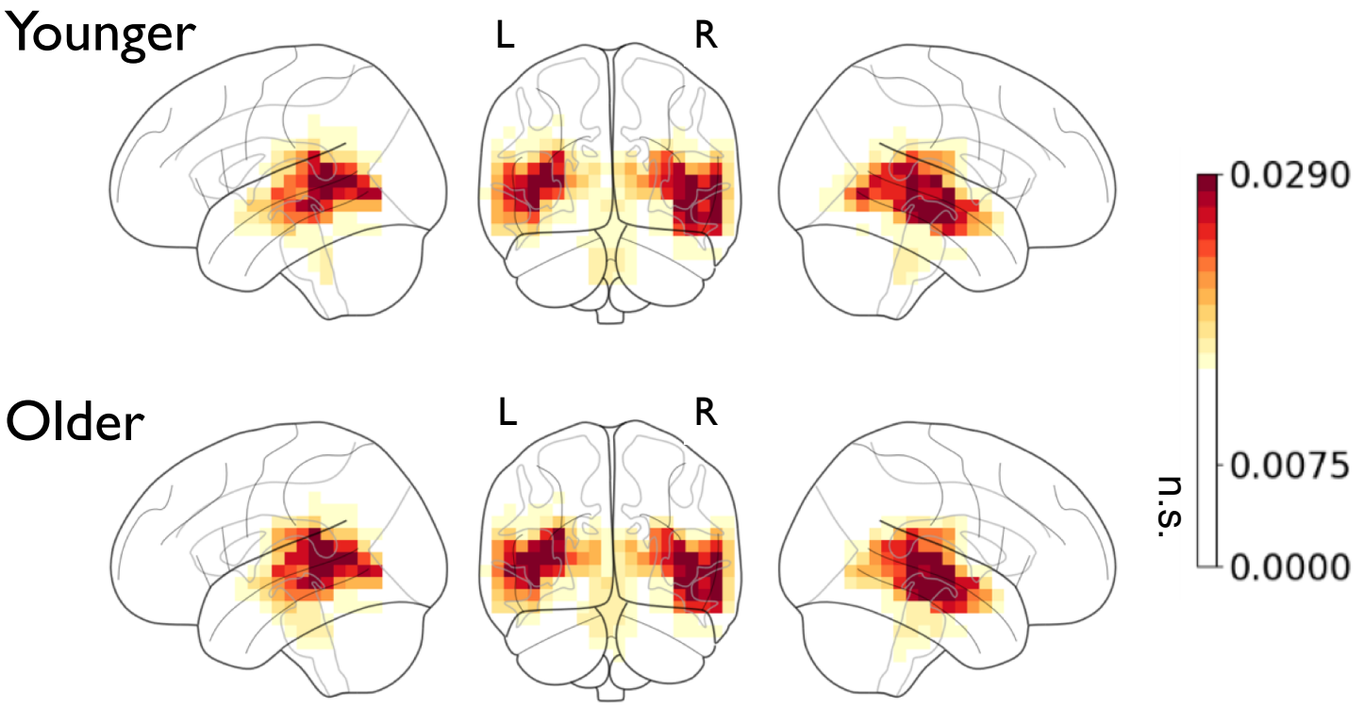
TRF Source Analysis (volume space)

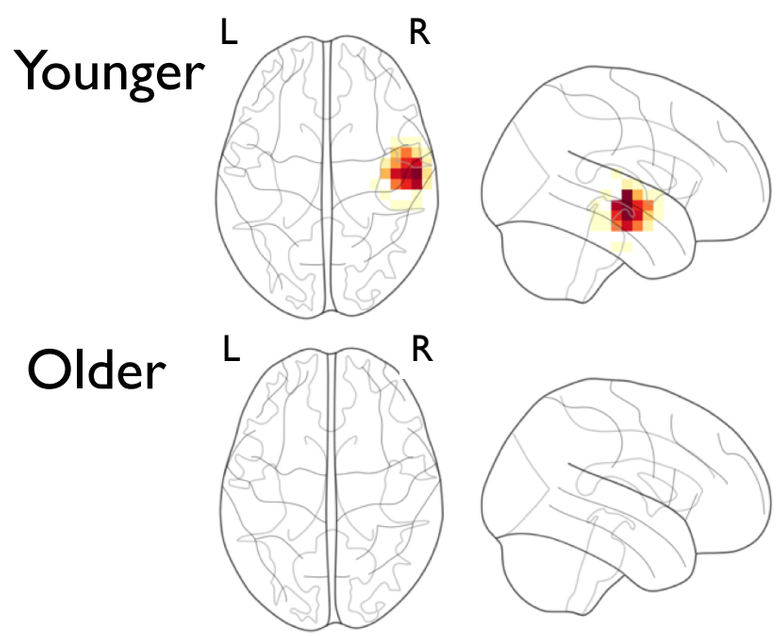
Prediction accuracy



Prediction accuracy much larger for cortical than subcortical regions

For younger adults only: prediction accuracy larger for right hemisphere

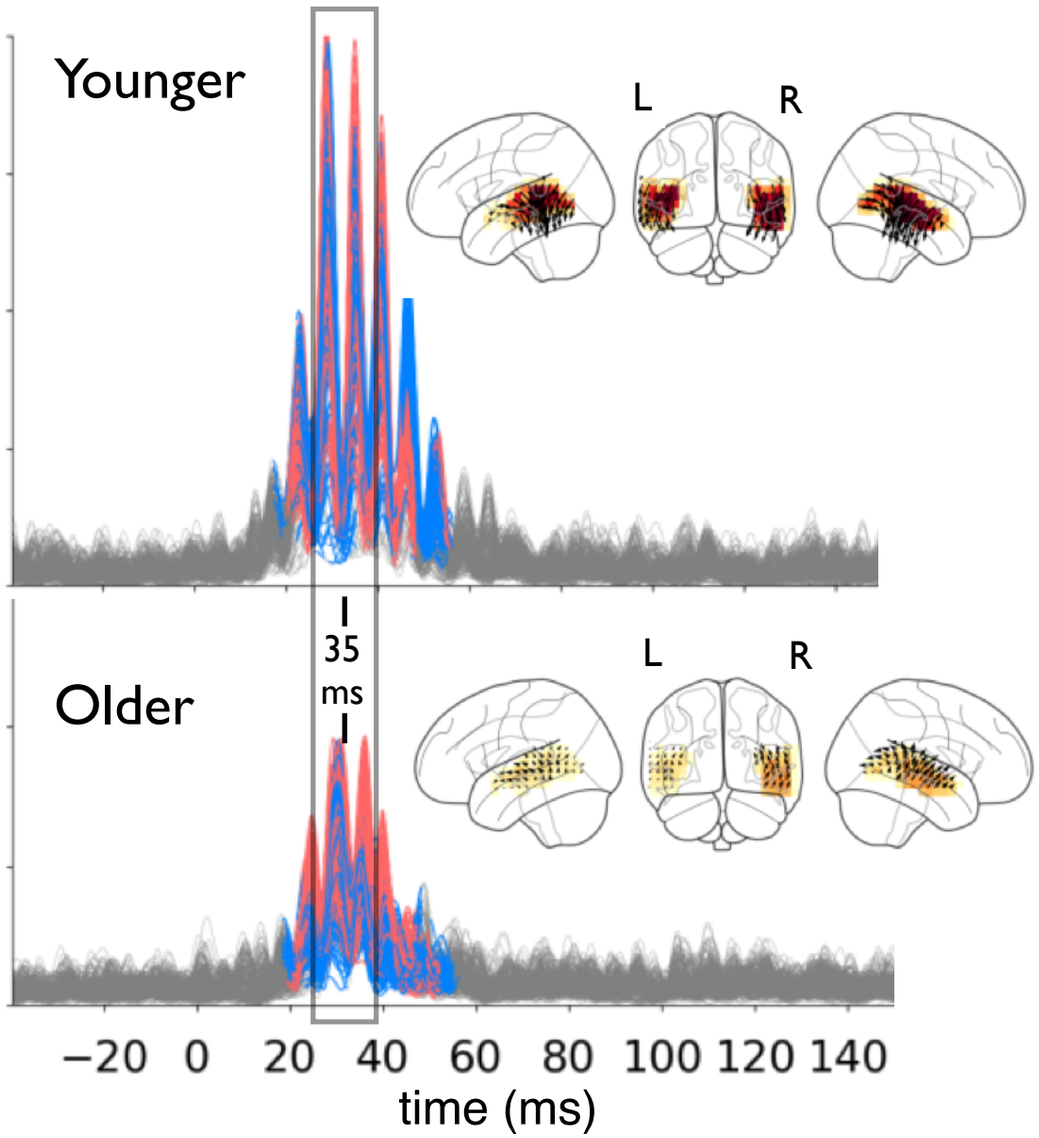
Lateralization



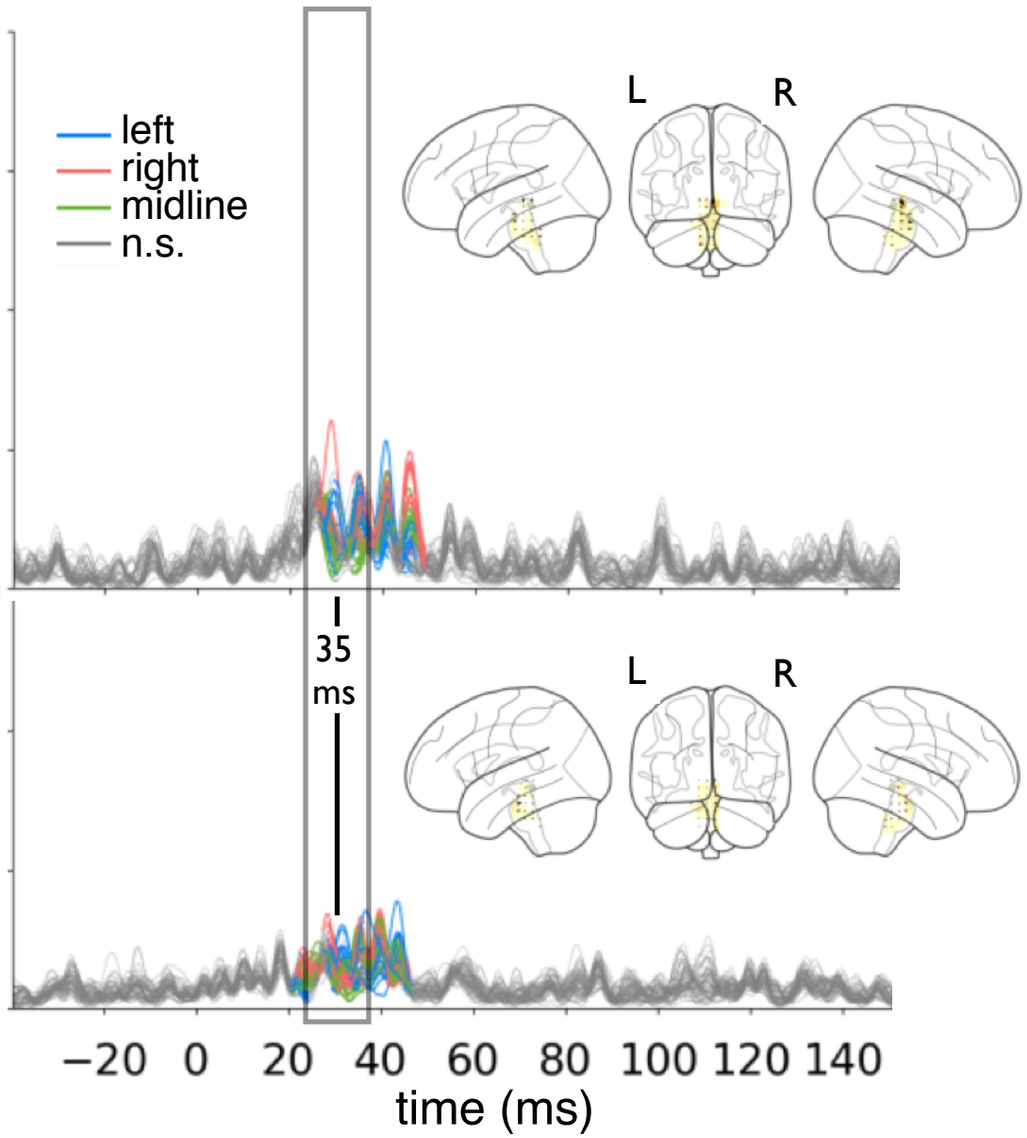
TRF Results

High Frequency Envelope

Cortical ROI



Sub-cortical ROI



older vs younger not significantly different

Response latency and amplitude ➡ predominantly cortical origin

Source Localization

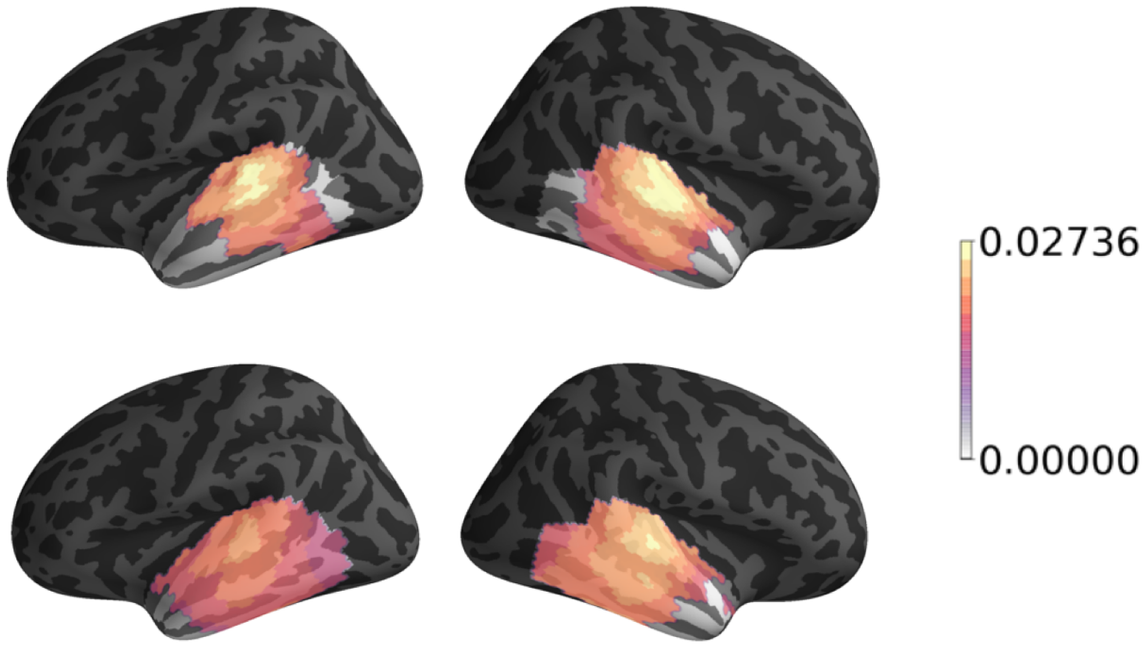
- Predominantly cortical origin
  - Cortical ROI amplitude >> subcortical ROI
  - Cortical latency (~35 ms) for both ROIs
    - Observed subcortical TRFs consistent with MEG-leakage-artifact cortical TRFs
- MEG subcortical contributions not ruled out
  - but much weaker than cortical
  - would need more statistical power to see
- Proceed assuming cortical origin
  - consistent with M50 neural source, Core AC

TRF Source Analysis (cortical surfaces)

Prediction accuracy

Younger

Older



Prediction accuracy comparable across age groups

For younger adults only: prediction accuracy larger for right hemisphere

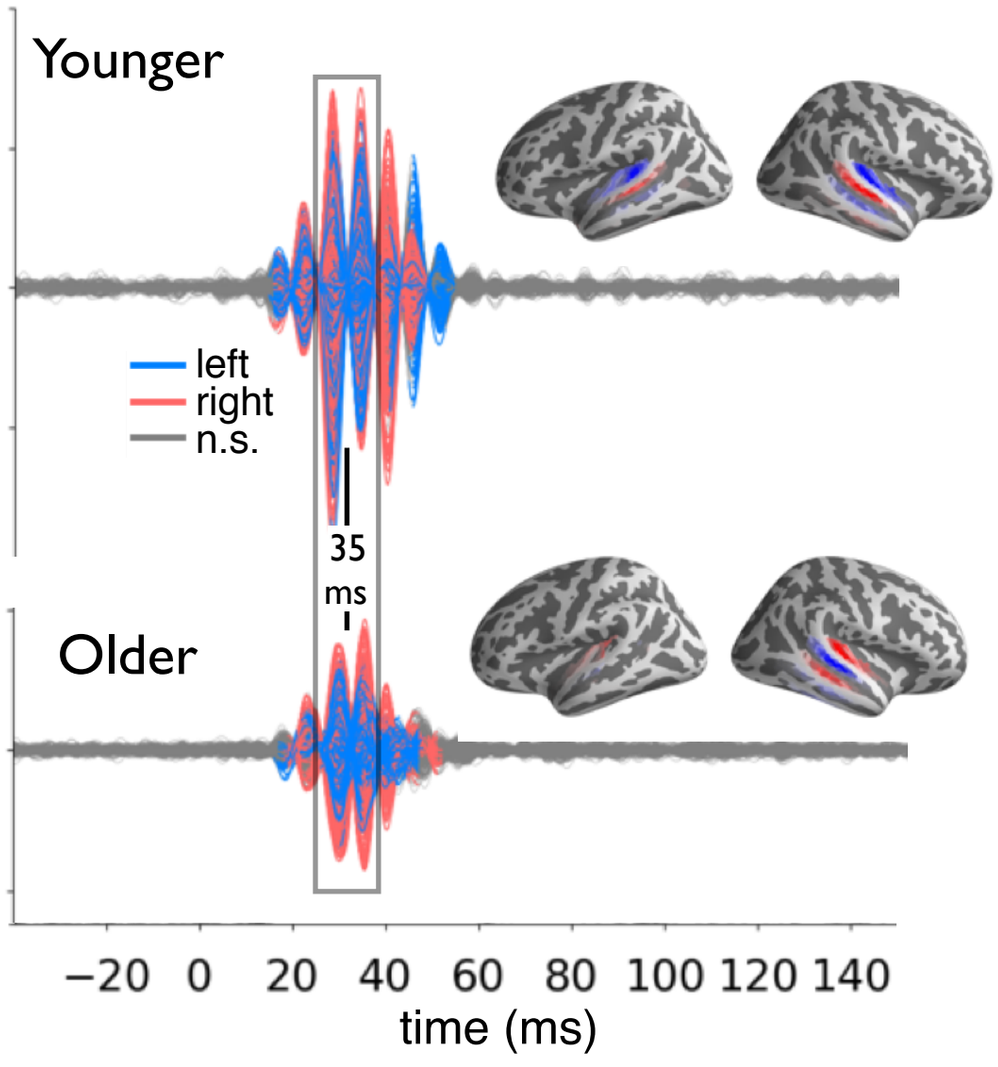
Lateralization

Younger

Older

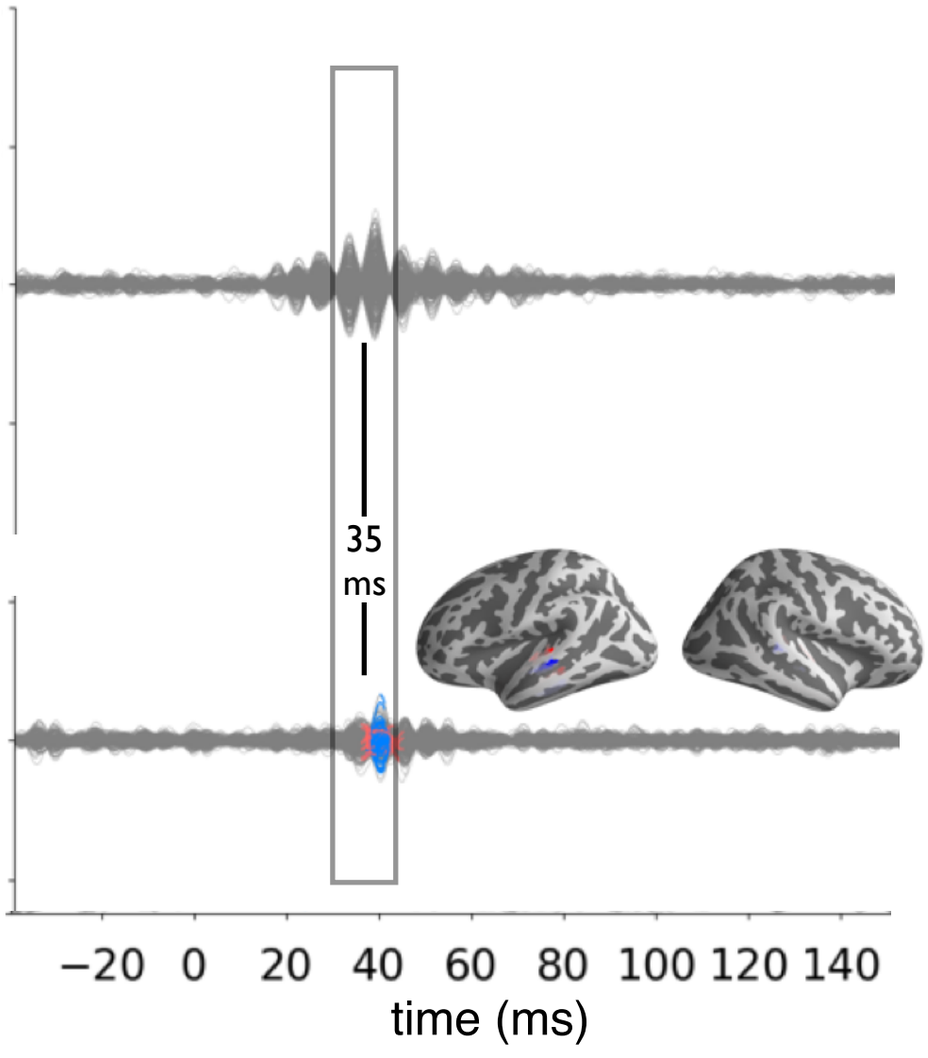
Cortical TRF Results

High Frequency Envelope



older vs younger not significantly different

Carrier

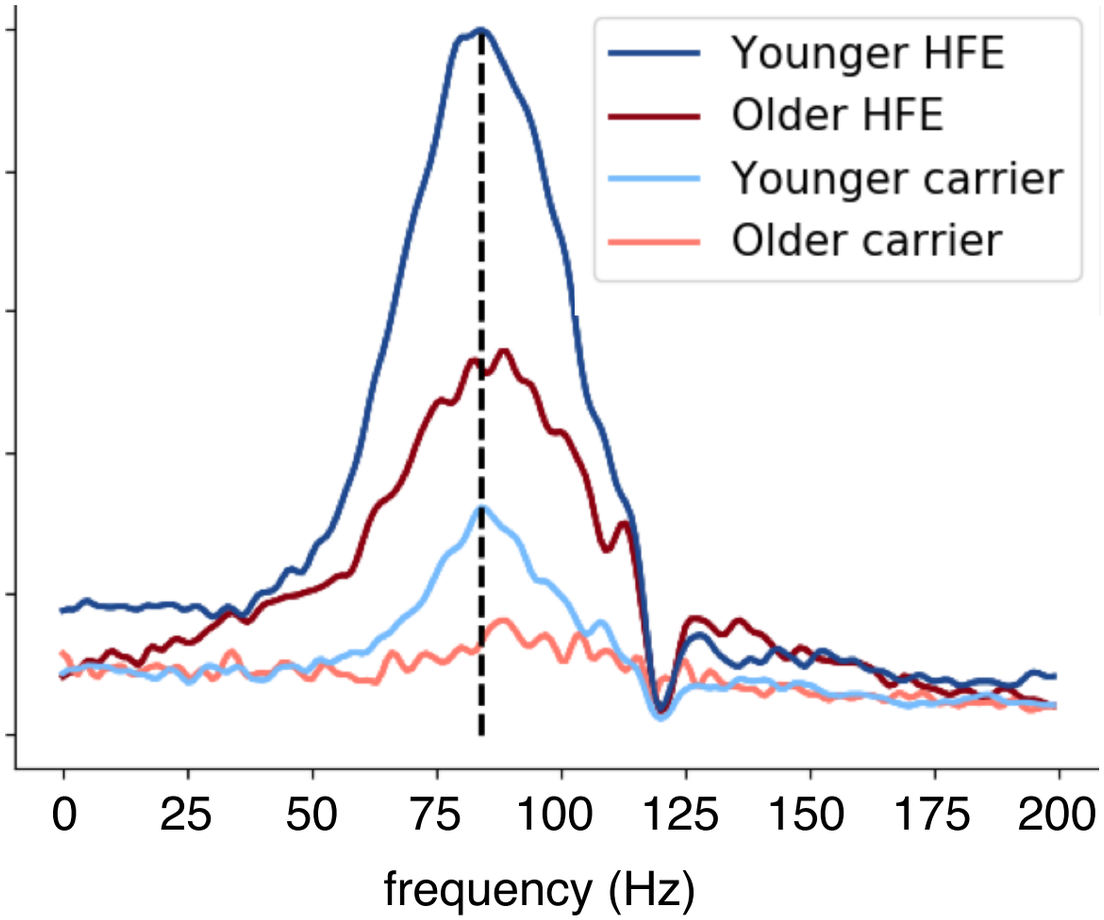


HFE TRF significantly greater than carrier TRF (old & young)

Cortical response driven predominantly by High Frequency Envelope

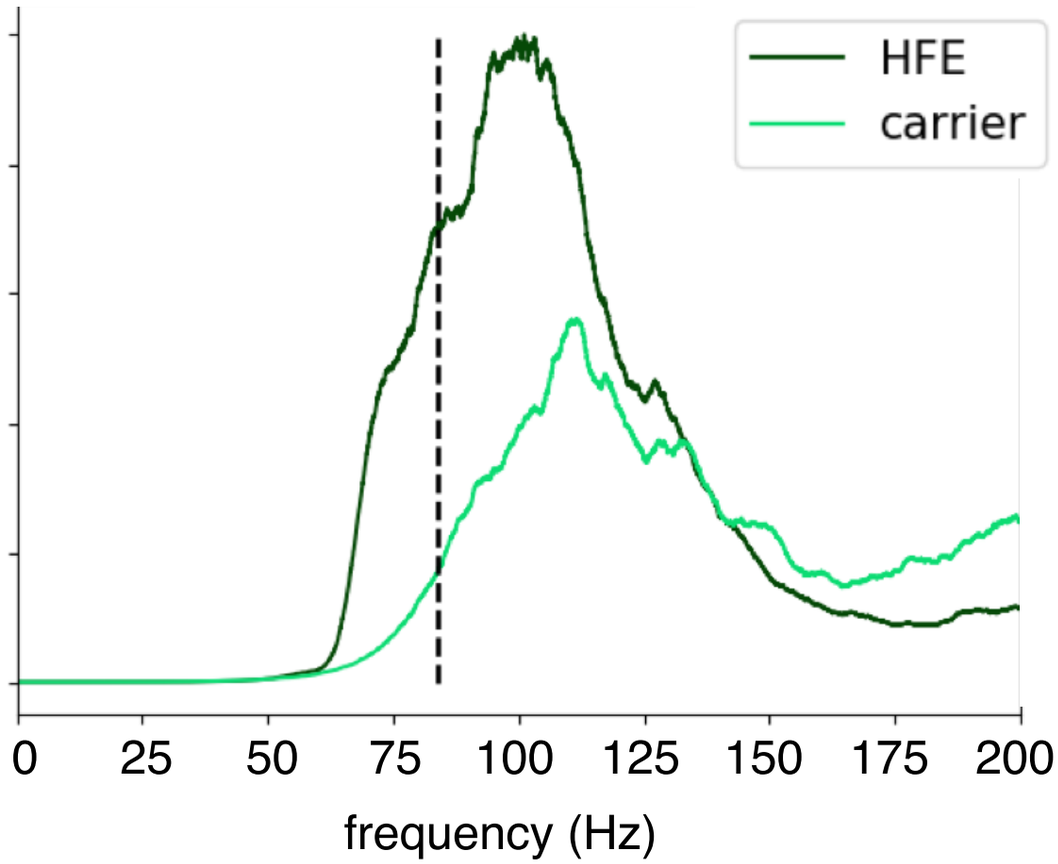
Frequency Distributions

TRF Frequency Responses



TRF peak at ~84 Hz
Robust across age group & stimulus representation

Stimulus Representation Frequency Responses



Stimulus representations:
higher, and different, peak frequencies

TRF peak frequency arises from cortical constraints, not stimulus

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Summary I

- MEG responses to continuous speech dominated by cortical sources with peak frequency ~ 85 Hz
  - peak latency varies 30 – 40 ms across subjects
  - consistent with M50 origin, core auditory cortex
  - onset significant at 13 ms
  - 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

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Current Lab Members & Affiliates

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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

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Marisel Villafane Delgado
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