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

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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
  ‣ MEG FFR for Continuous Speech

• Methods

• Results

• Summary
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Frequency Following Response (FFR)

Audio (/da/)

Adapted from Coffey et al., Nat Commun (2016)
Frequency Following Response (FFR)

Audio (/da/)

Amplitude (a.u.)

Time (s)

FFR

Amplitude (µV)

Onset

EEG

Amplitude (µV)

Time (s)

Adapted from Coffey et al., Nat Commun (2016)
Frequency Following Response (FFR)

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

Adapted from Coffey et al., Nat Commun (2016)
Frequency Following Response (FFR)

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**Audio (/da/)**

**EEG**

**MEG**

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Adapted from Coffey et al., Nat Commun (2016)
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Spectro-Temporal Response Function (STRF)

(full speech duration ~60 s)

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

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MEG FFR Responses to Continuous Speech

“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[1])
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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

- **Stimulus Waveform**
- **Auditory Spectrogram**
- **High frequency envelope (HFE)**
  - Frequency range: 70 - 300 Hz
- **Carrier**
  - Frequency range: 70 - 300 Hz
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 much larger for cortical than subcortical regions

For younger adults only: prediction accuracy larger for right hemisphere
TRF Results
High Frequency Envelope

Cortical ROI

Younger

Older

Sub-cortical ROI

Response latency and amplitude ➔ predominantly cortical origin

older vs younger not significantly different
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 comparable across age groups

For younger adults only: prediction accuracy larger for right hemisphere
Cortical TRF Results

**High Frequency Envelope**

*Younger*

- Carrier
- Left
- Right
- n.s.

**Older**

- Carrier
- Left
- Right
- n.s.

35 ms
time (ms)

*older vs younger not significantly different*

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

Cortical response driven predominantly by High Frequency Envelope
Frequency Distributions

TRF Frequency Responses

Stimulus Representation
Frequency Responses

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

Stimulus representations:
higher, and different, peak frequencies

TRF peak frequency arises from cortical constraints, not stimulus
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• 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
Acknowledgements

Current Lab Members & Affiliates

Christian Brodbeck
Alex Presacco
Proloy Das
Jason Dunlap
Theo Dutcher
Kevin Hu
Dushyanthi Karunathilake
**Joshua Kulasingham**
Natalia Lapinskaya
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
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Maria Chait
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James Williams

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Pamela Abshire
**Samira Anderson**
Behtash Babadi
Catherine Carr
Monita Chatterjee
Alain de Cheveigné
Stephen David
Didier Depireux

Funding

NIH (NIDCD, NIA, NIBIB); NSF; DARPA; UMD; USDA