Over-Representation of Speech in Older Adults Originates From Early and Late Responses in Auditory Cortex

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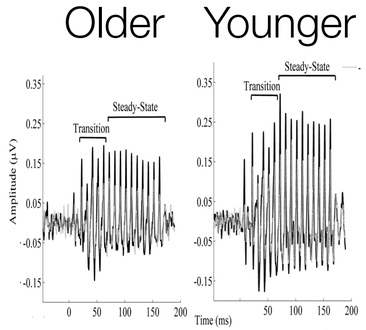
CHSCOM, Linköping 11 June 2019

Overview

Puzzle

- Compared to young adults, older adults exhibit:
  - ***Impaired*** auditory temporal processing
  - ***More difficulty*** comprehending speech in challenging circumstances
  - ***Decreased*** subcortical responses, esp. Frequency Following Response (FFR)



- Yet, the speech envelope can be reconstructed ***more accurately*** from their cortical responses, recorded with MEG

Presacco et al.,
J Neurophysiol, 2016a

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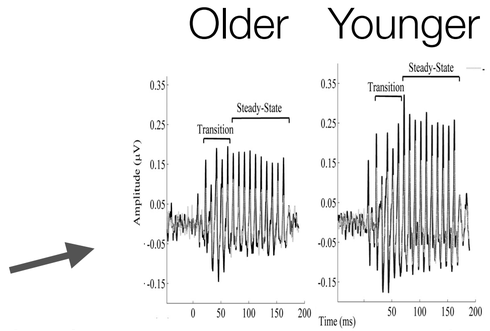

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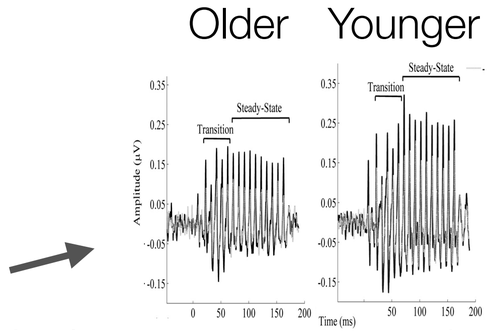

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This talk

- Localize cortical responses to speech of younger and older adults
  - Anatomy: localization in cortex
  - Time: latency at which information is represented

Brodbeck et al., Acta Acust united Ac, 2018

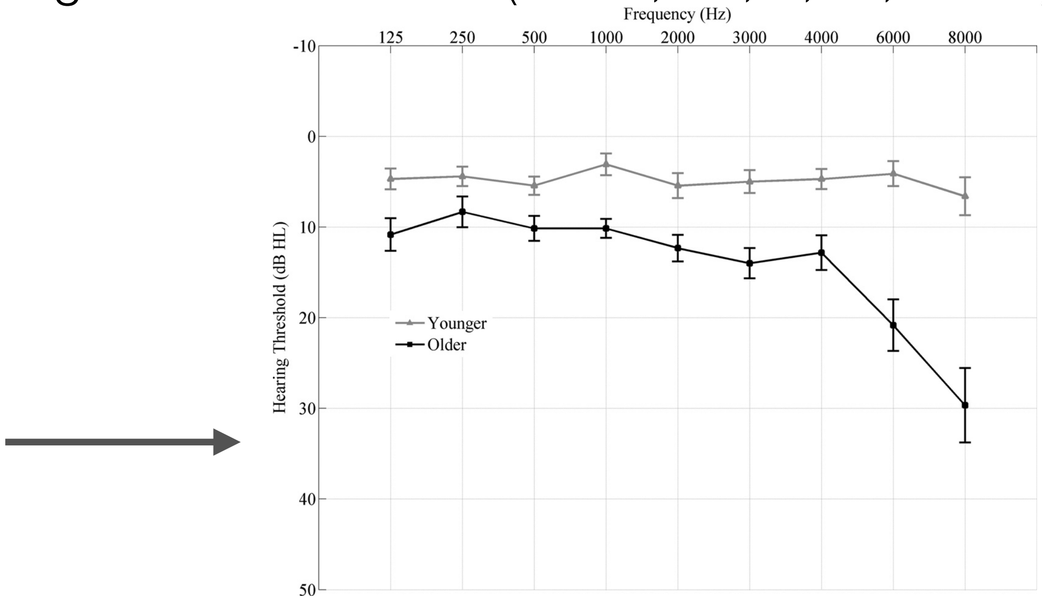
Methods (Initial Study)

Design

- 60 s long audiobook excerpts, 3 repetitions each
- 2 excerpts were clean speech
- 8 excerpts with second speaker at different signal to noise ratios (SNRs; +3, 0, -3, -6 dB)

Participants

- 17 young adults (aged 18-27 years)
- 15 older adults (aged 61-73 years)
  - Cognitive screening
  - Clinically normal audiogram



MEG data

- KIT MEG Lab at University of Maryland, 157 axial gradiometers
- Band pass filter **1-8 Hz**

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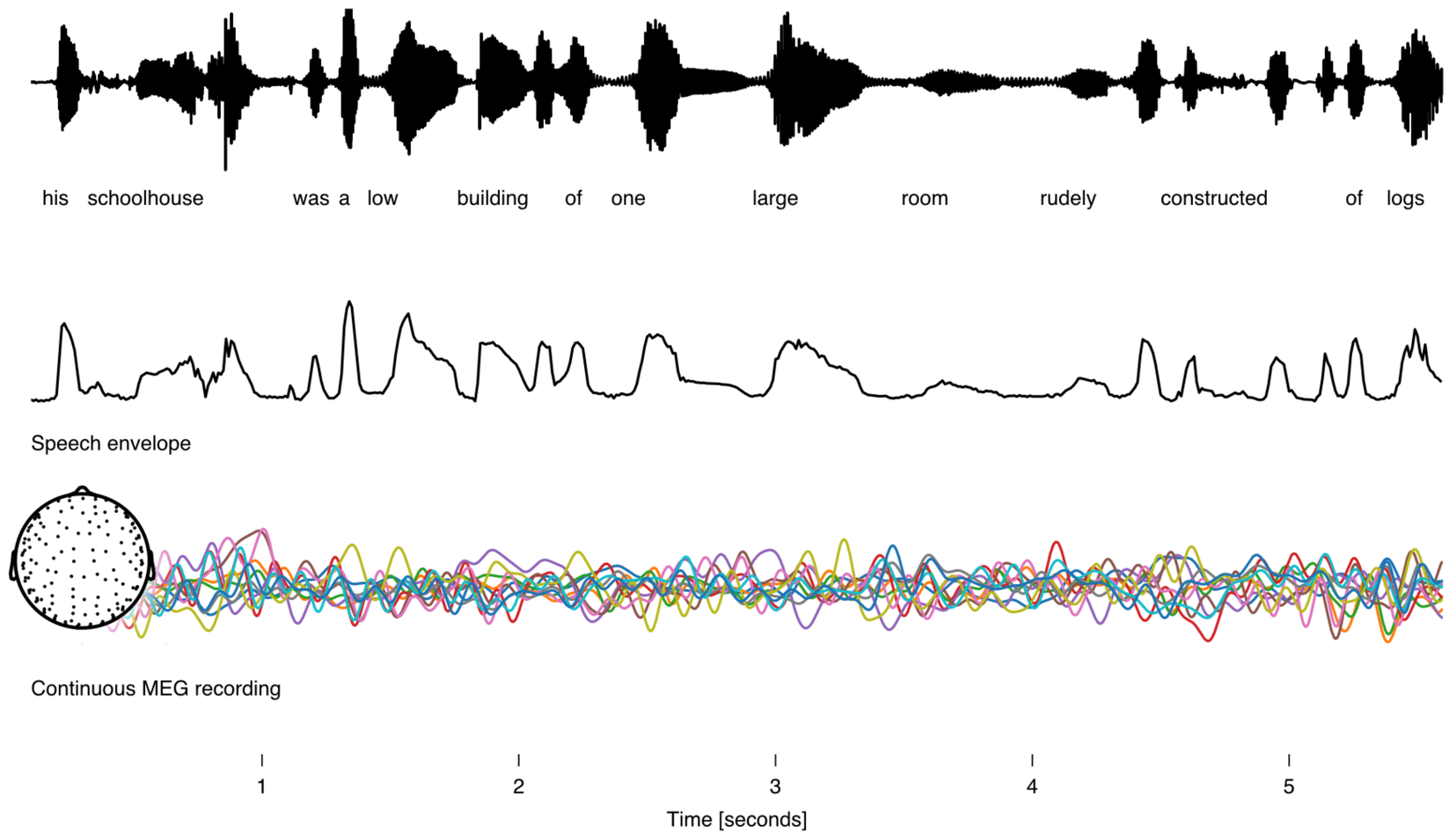
J Neurophysiol, 2016a

Background: Decoding Model



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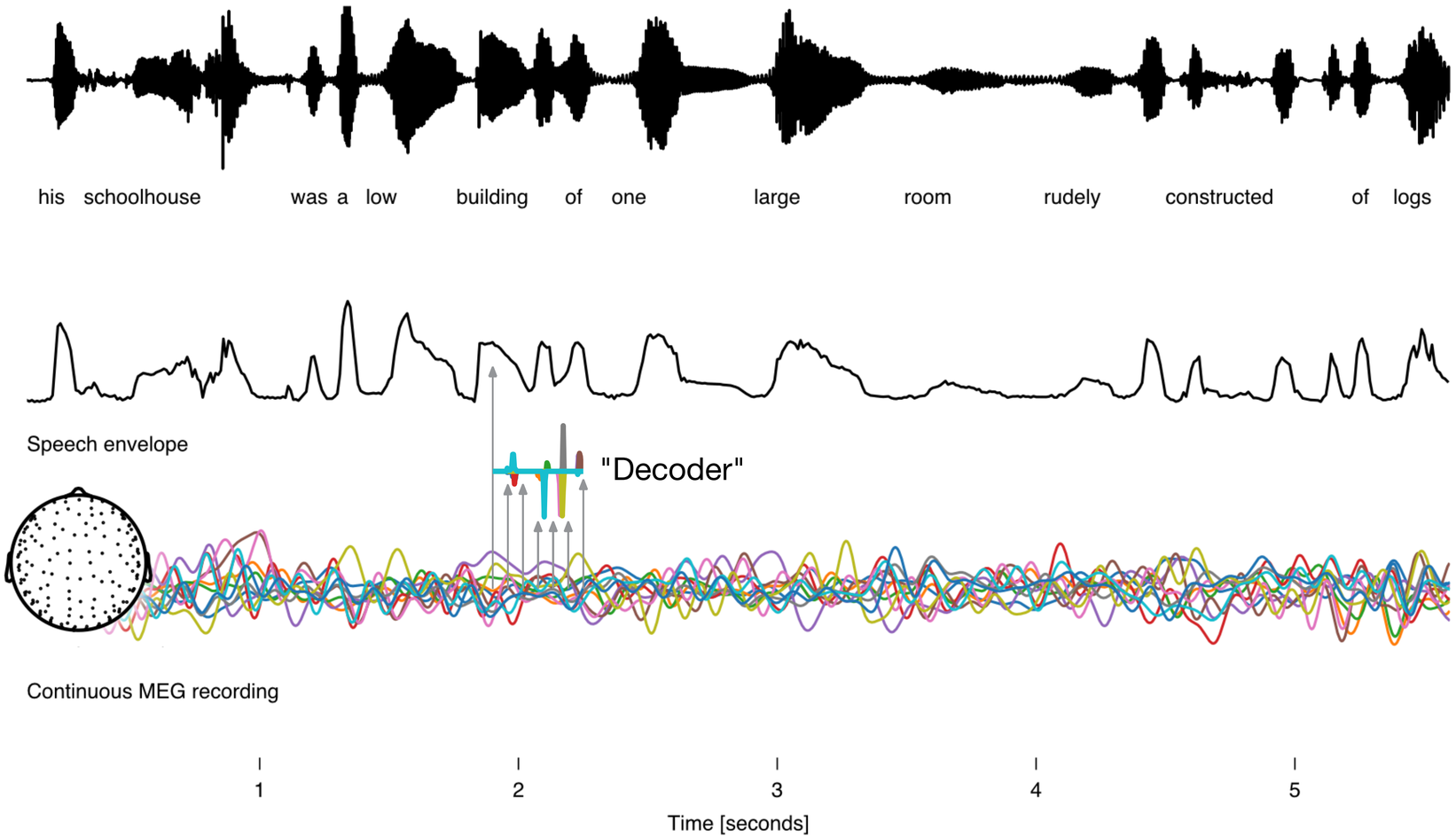

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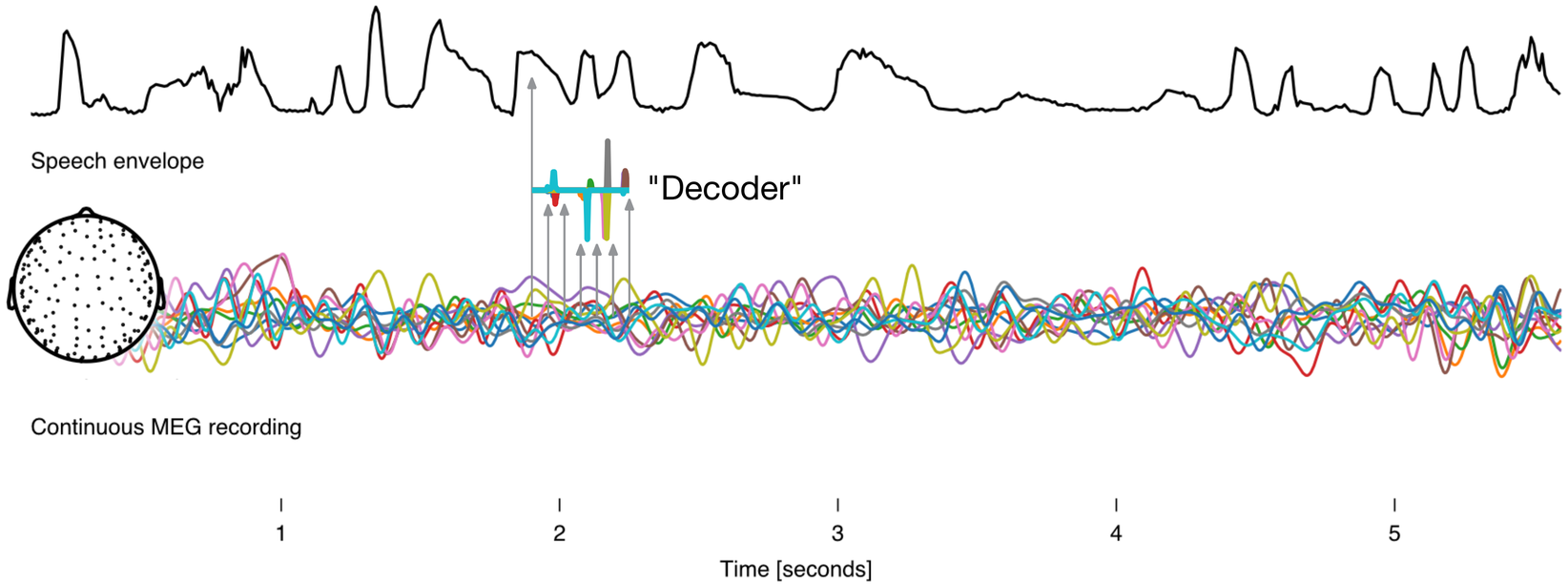

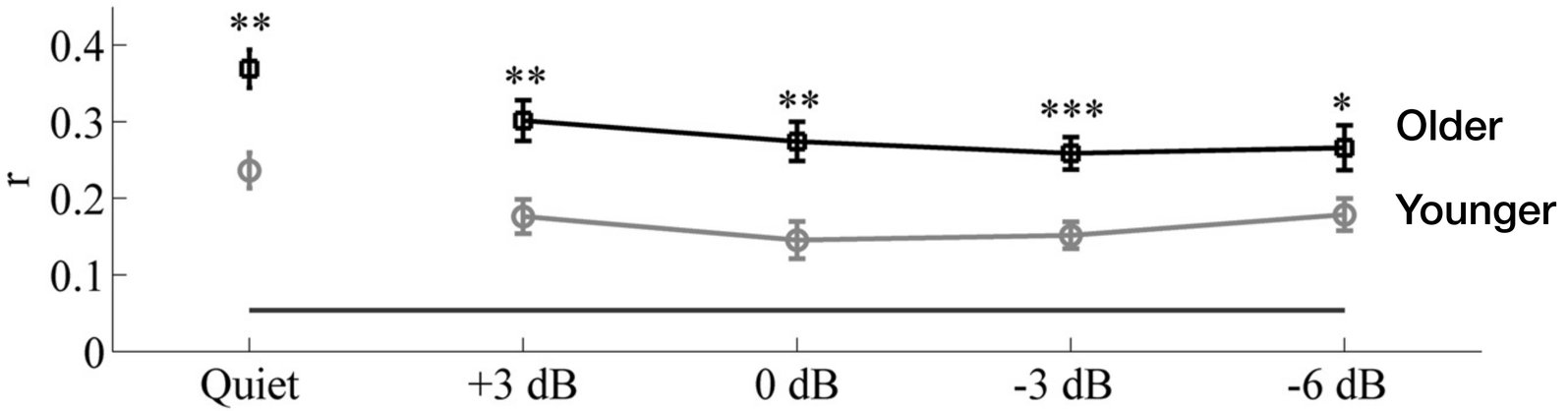

Alex Presacco

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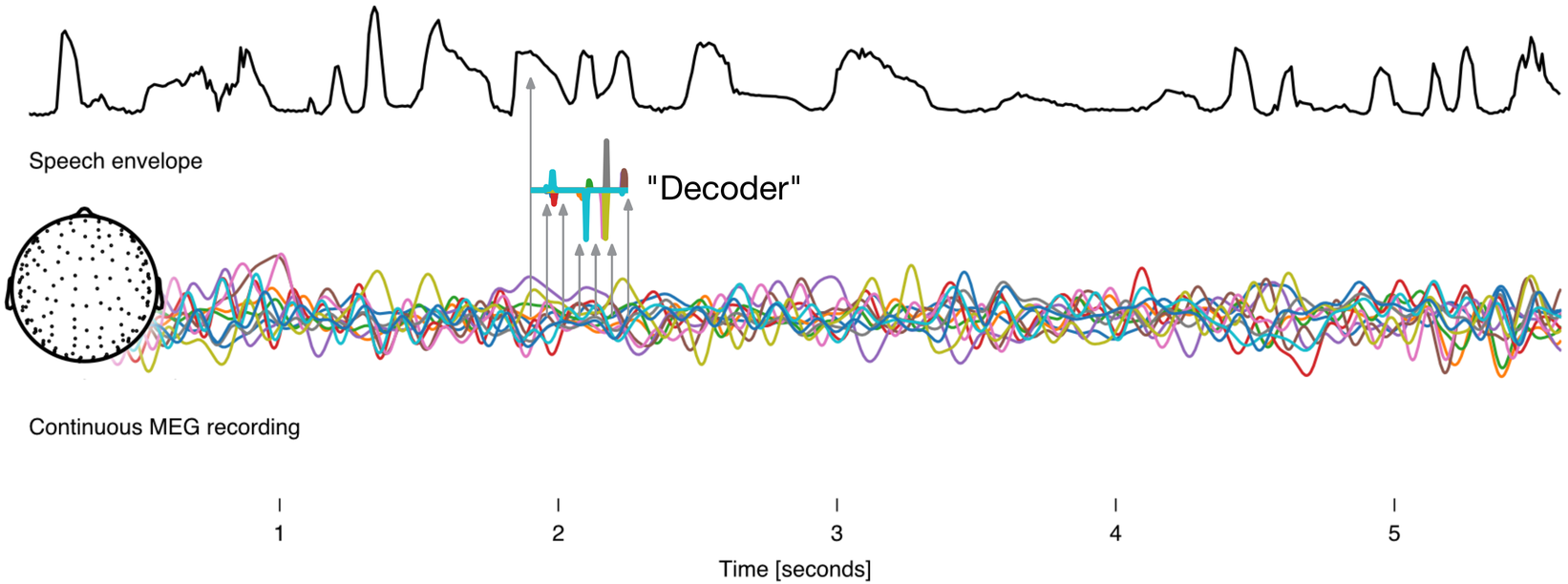
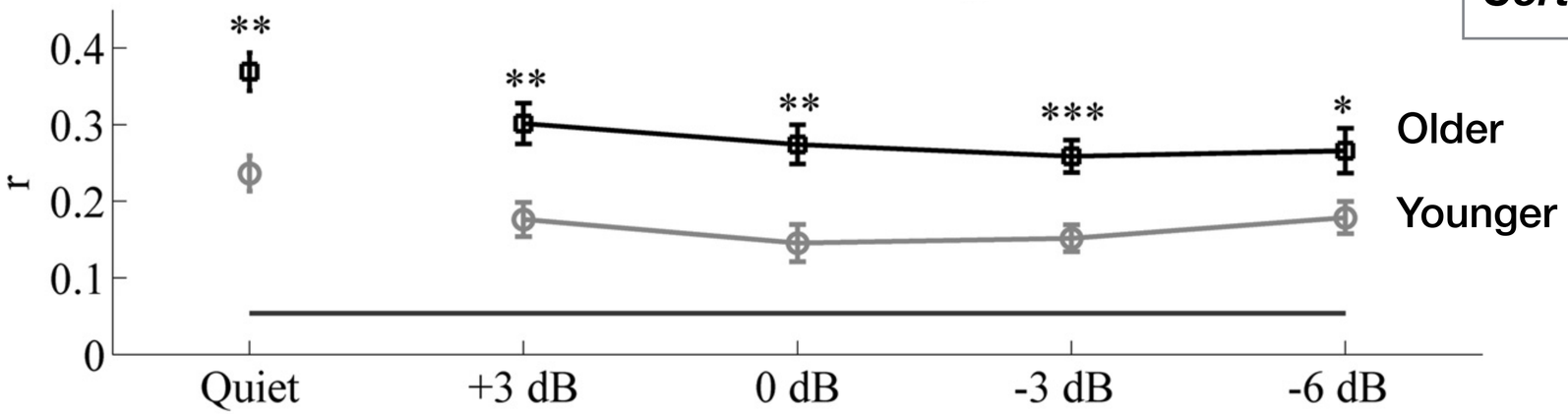


Cortex: older > younger



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Possible explanations

Increased cortical gain for early bottom-up responses

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Top-down/strategic later processing

- Compensate for degraded input from the periphery
- Recruitment of additional frontal and temporal regions (Peelle et al., 2010)
- Increased attentional gain?
- ***Prediction***: Response enhancement, possibly from higher order regions

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Low level physiological change: excitation/inhibition imbalance

- Reduction in inhibitory neurons in A1 (de Villers-Sidani et al., 2010)
- Increased firing rates in A1 (Overton & Recanzone, 2016)
- Faster recruitment of higher order regions (Engle & Recanzone, 2013)
- ***Prediction***: Enhanced early responses, possibly with higher order regions

Methods (with additional subjects)

Participants

- 17 young adults (aged 18-27 years) & **23** older adults (aged 61-73 years)

MEG source localization

- Minimum norm estimates with depth weighting; empty room noise covariance
- **Source-localized spectro-temporal response functions (STRFs)** estimated via Boosting (David et al., 2007)
  - Minimizing $\ell 1$ error & stopping based on cross-validation

Evaluate model predictions:

- At each source element: Pearson correlation *r*(predicted response, measured response)

Bias-correction:

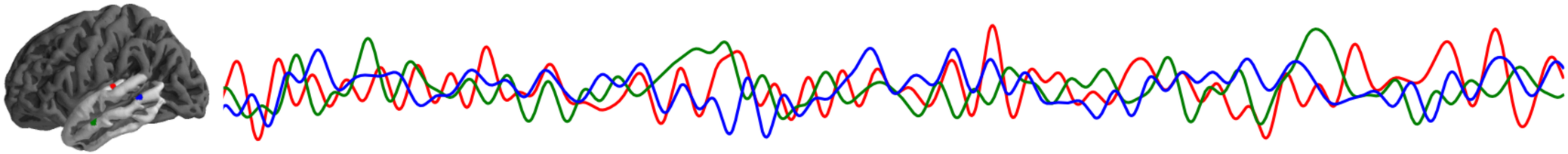
- Compute *r* of a temporally shuffled model & test for better *r* of the true model

Significance test:

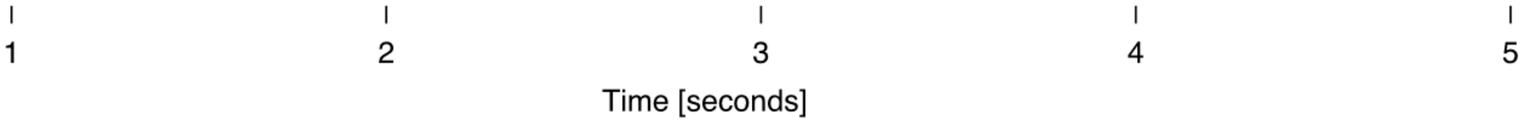
- Mass-univariate *t*-test (Smith & Nichols, 2009)
  - Threshold-free cluster enhancement & max statistic distribution; 10,000 permutations

Encoding model

Speech envelope **per spectral band**



Continuous MEG source estimates



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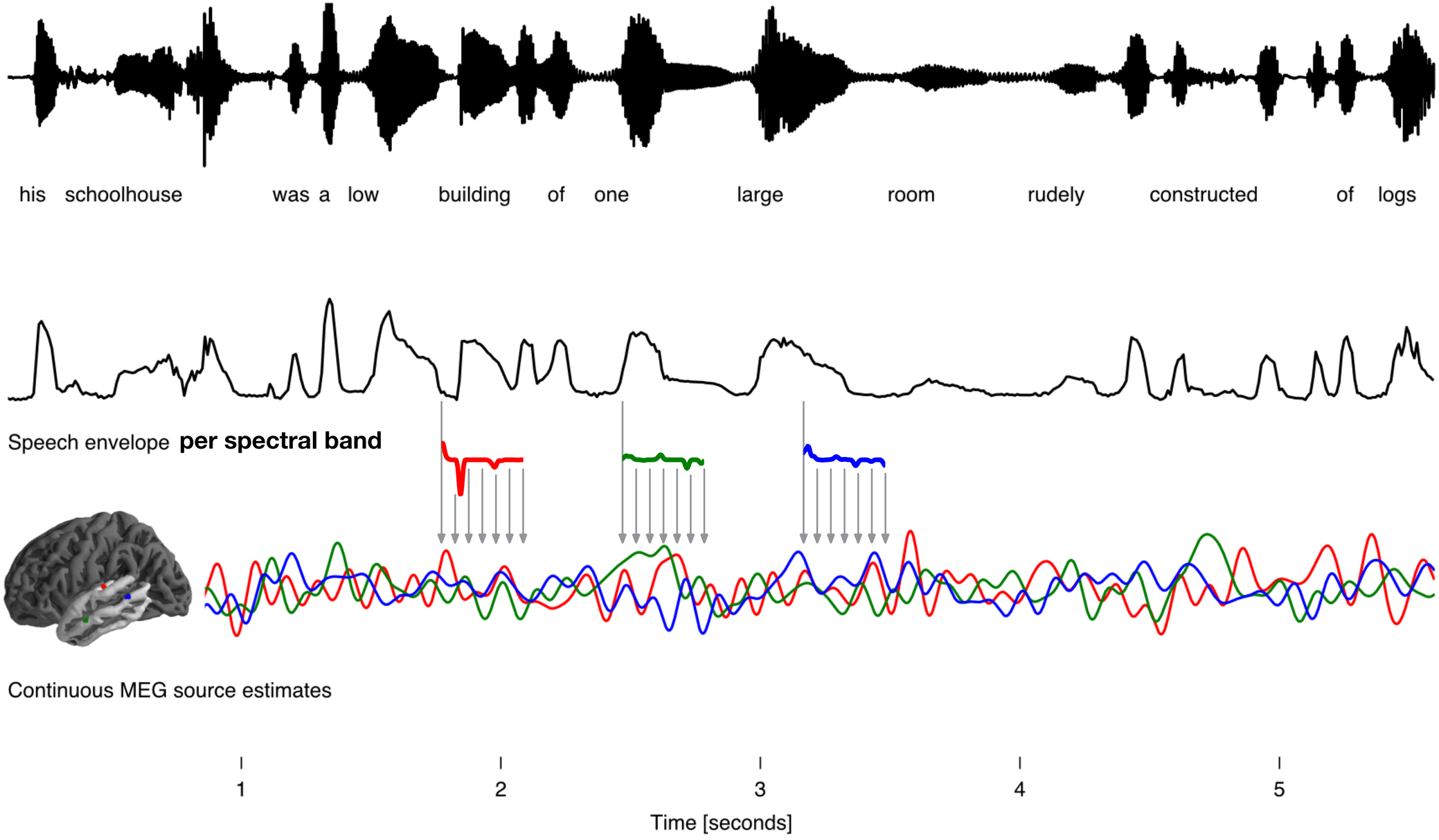

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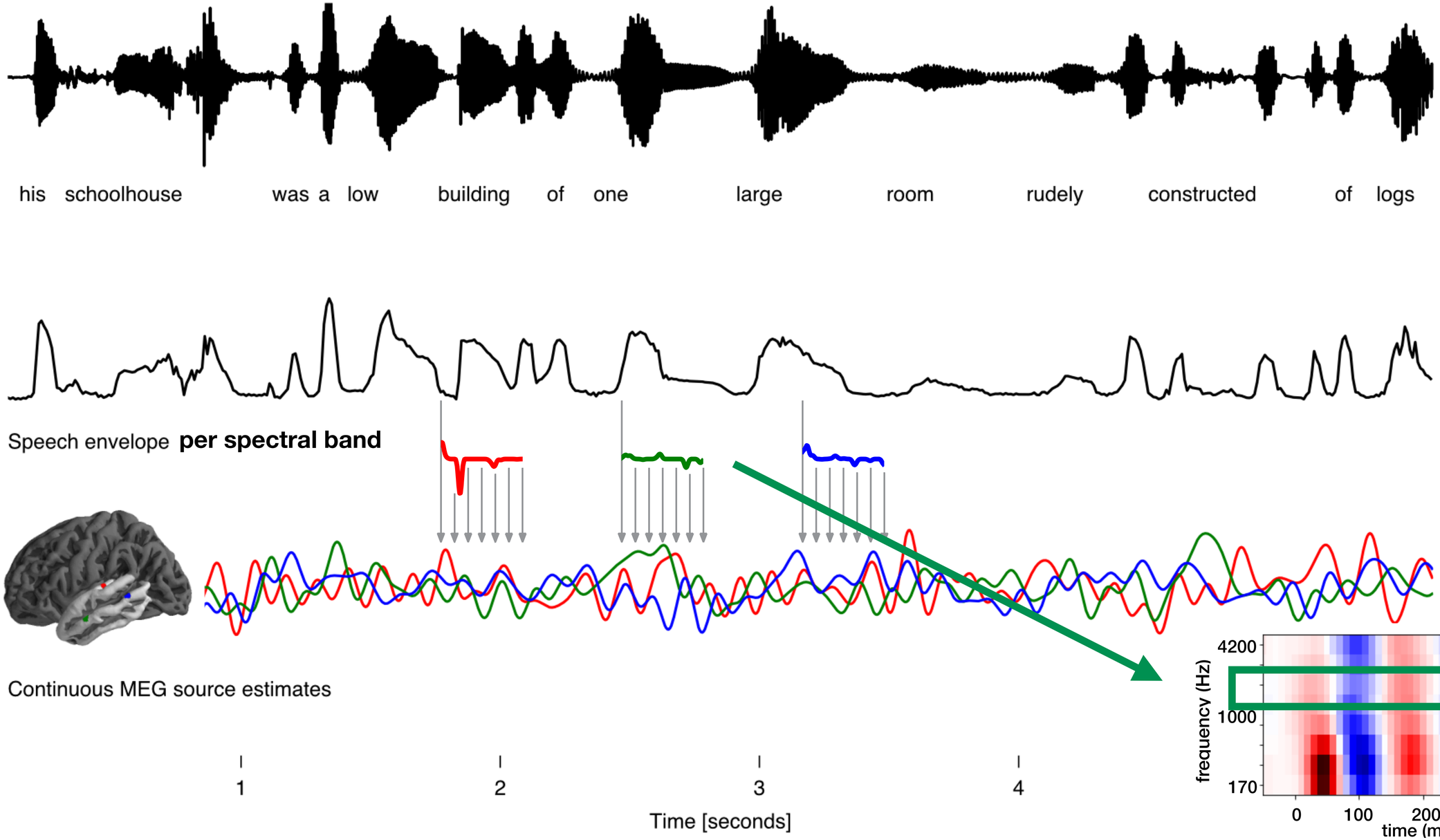

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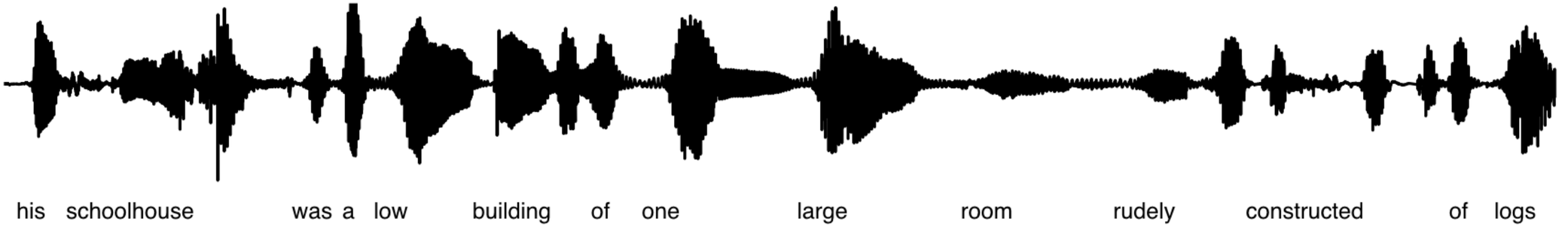

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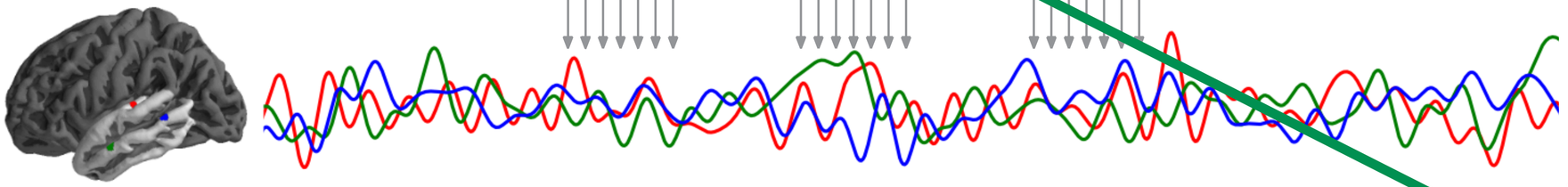
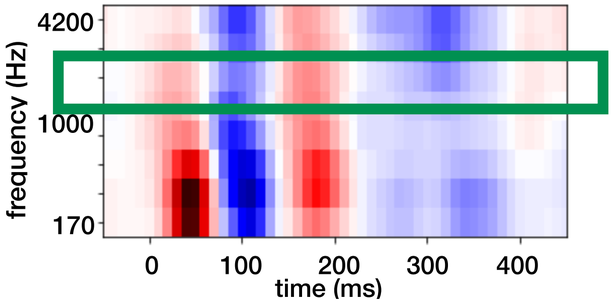


Continuous MEG source estimates

1 2 3 4

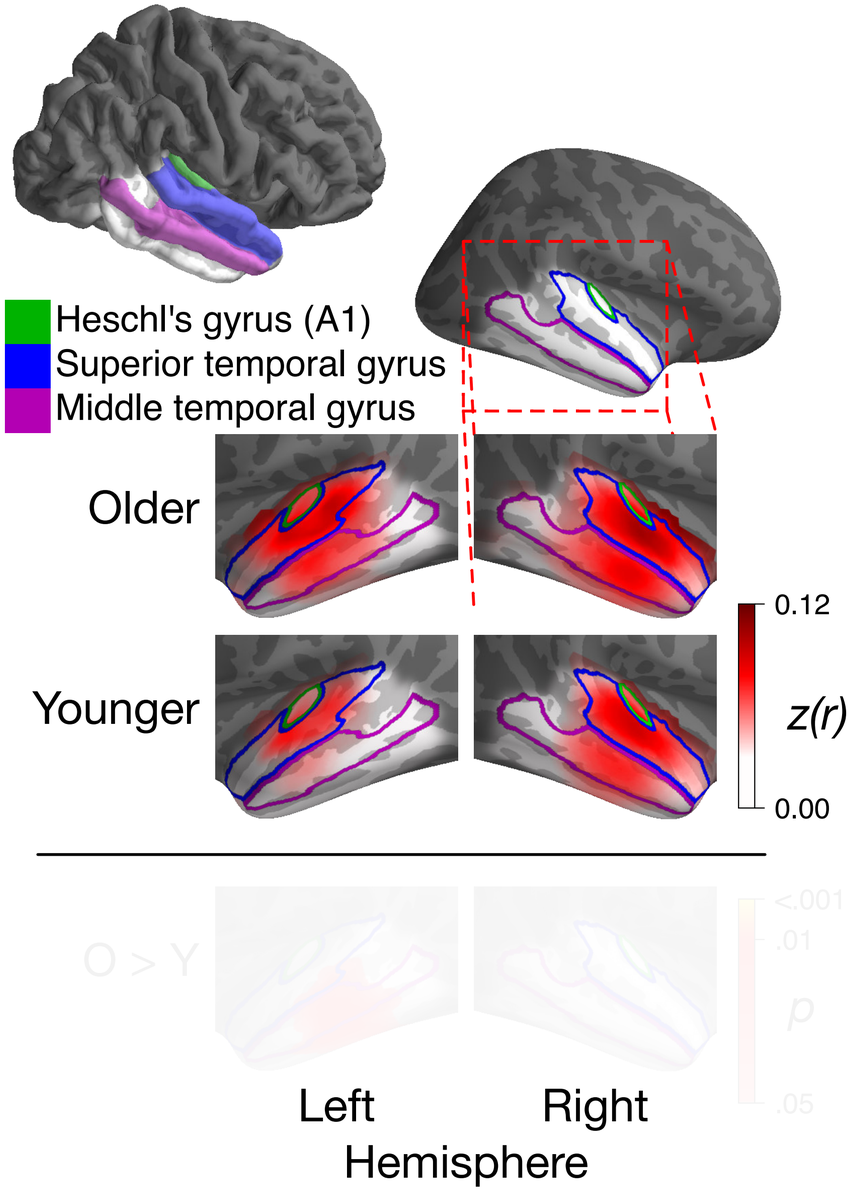
Time [seconds]

Spectro-Temporal Response Field (STRF) for **each neural source**



Brain activity (MEG source estimate) predicted from acoustic envelope

- Maps of correlation (*r*) between actual and predicted neural time course

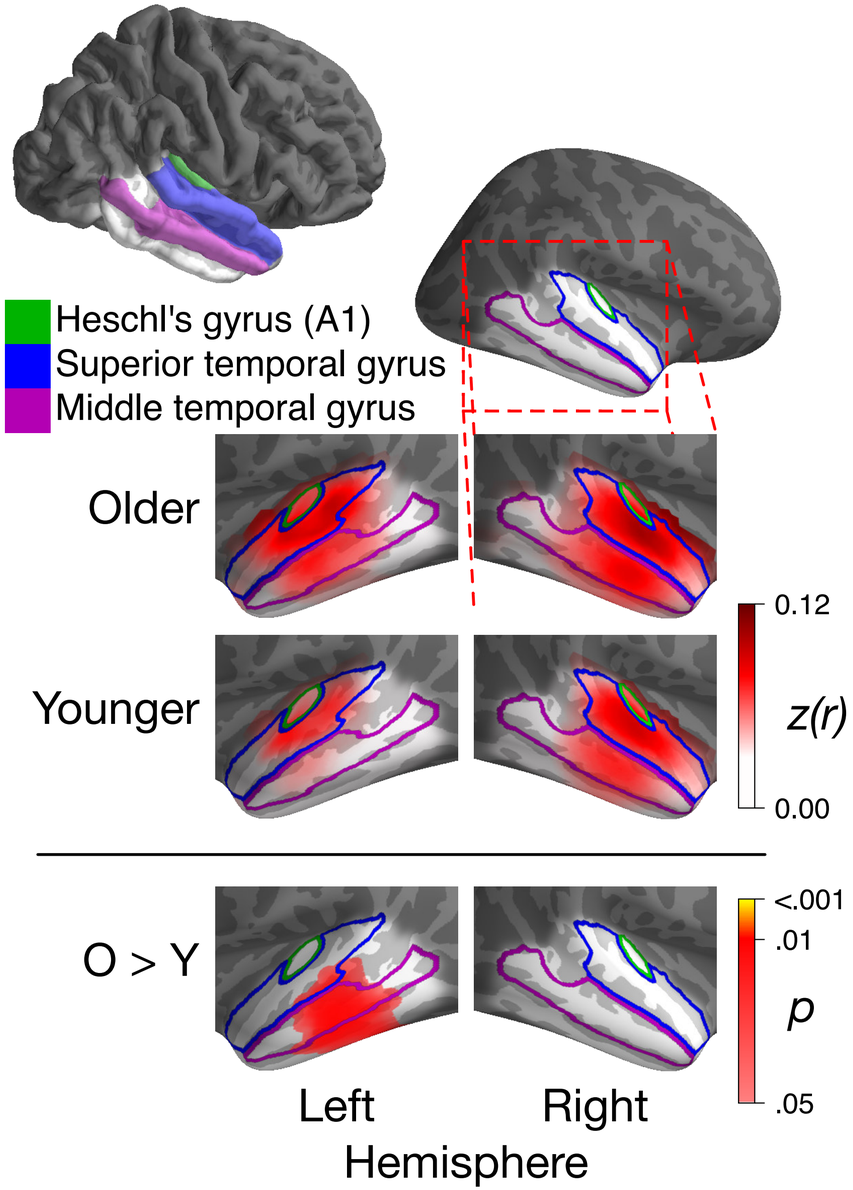


Brain activity (MEG source estimate) predicted from acoustic envelope

- Maps of correlation (*r*) between actual and predicted neural time course

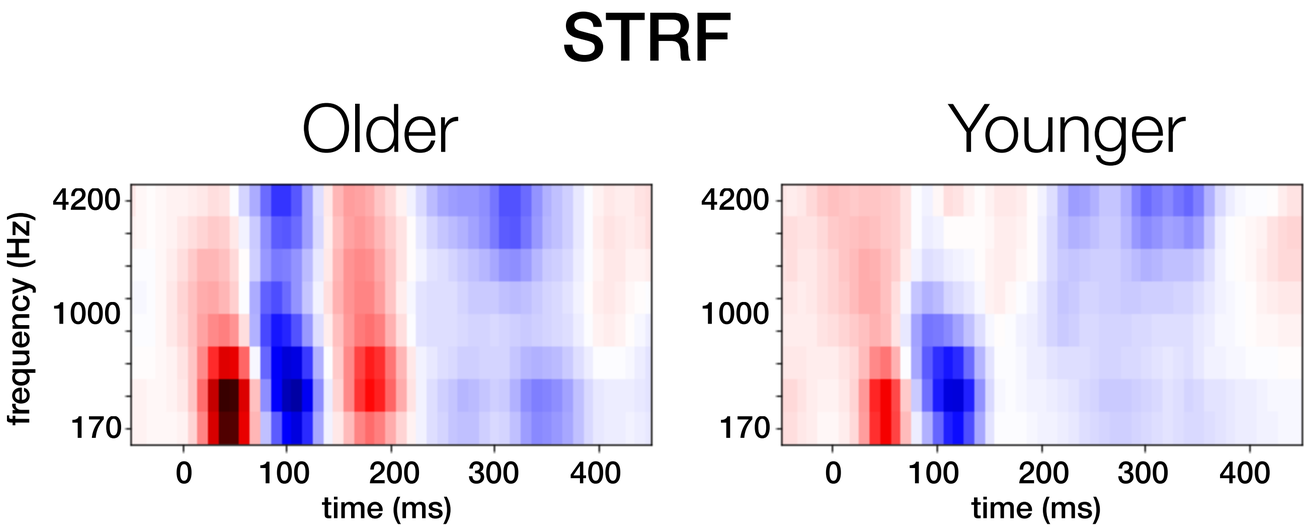
Older > Younger

- Significant difference ventral to core auditory cortex
- No significant difference between hemispheres



Christian Brodbeck

Spectro-temporal response function



Spectro-temporal response function (STRF)

- Response to an elementary stimulus *spectro-temporal* feature
- Time axis: latency between acoustic feature and response

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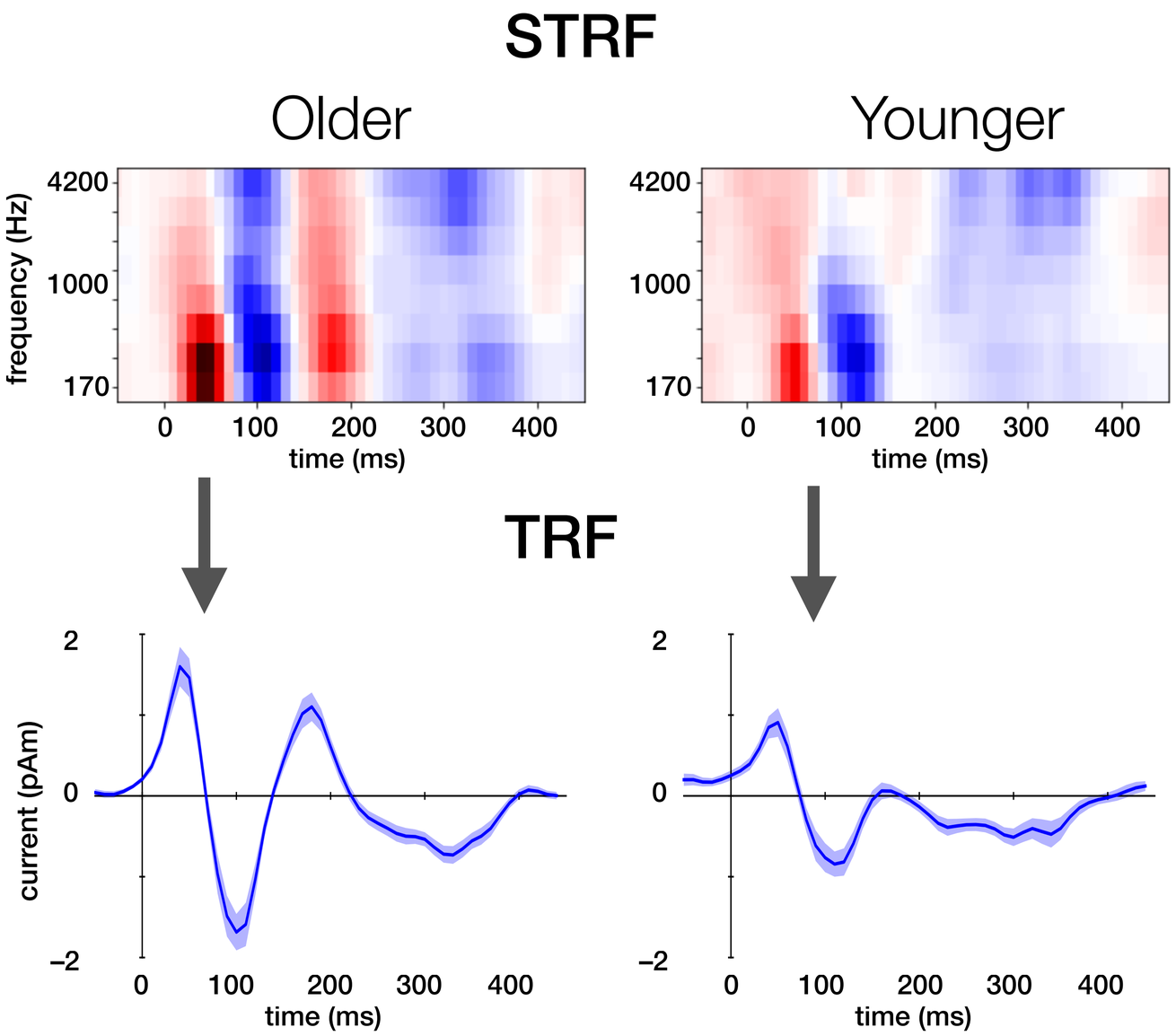


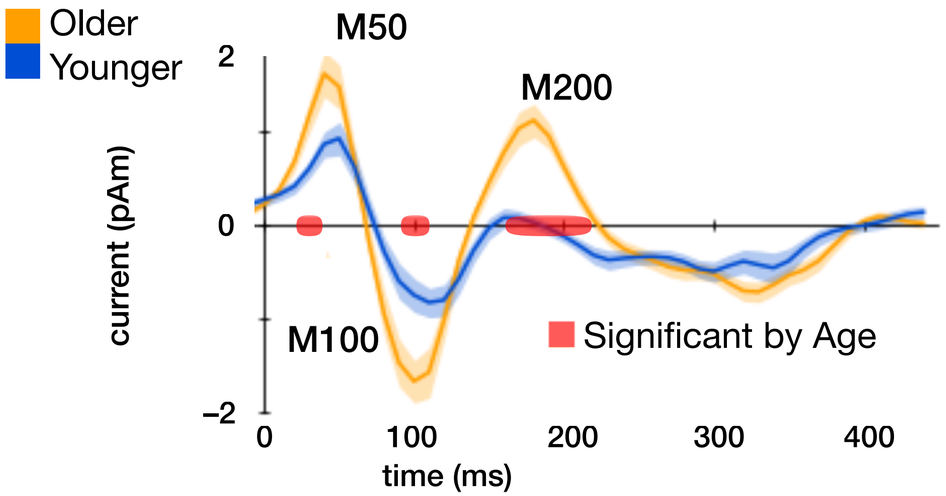
Spectro-temporal response function (STRF)

- Response to an elementary stimulus *spectro-temporal* feature
- Time axis: latency between acoustic feature and response

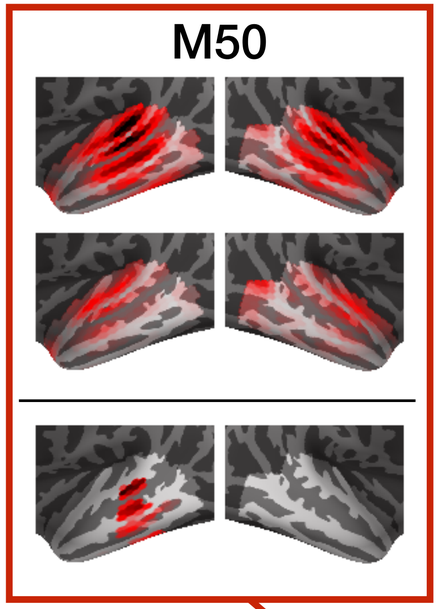
Temporal response function (TRF)

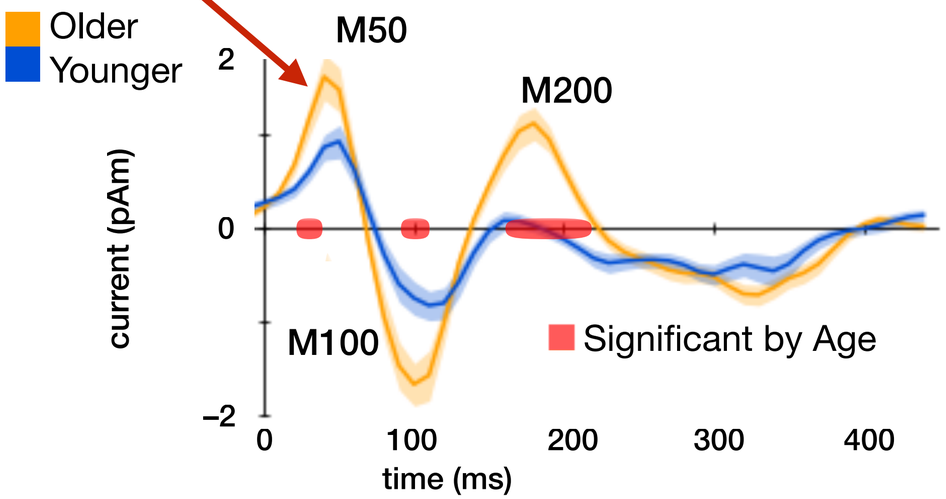
- STRF summed across frequencies
- Response to a elementary stimulus *temporal* feature
- Time axis: latency between acoustic feature and response

Temporal response function



Temporal response function



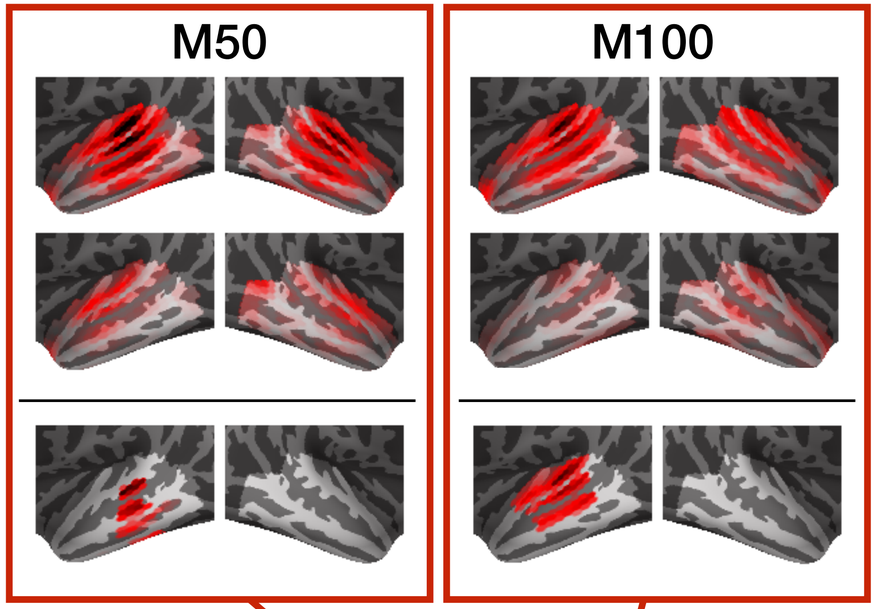


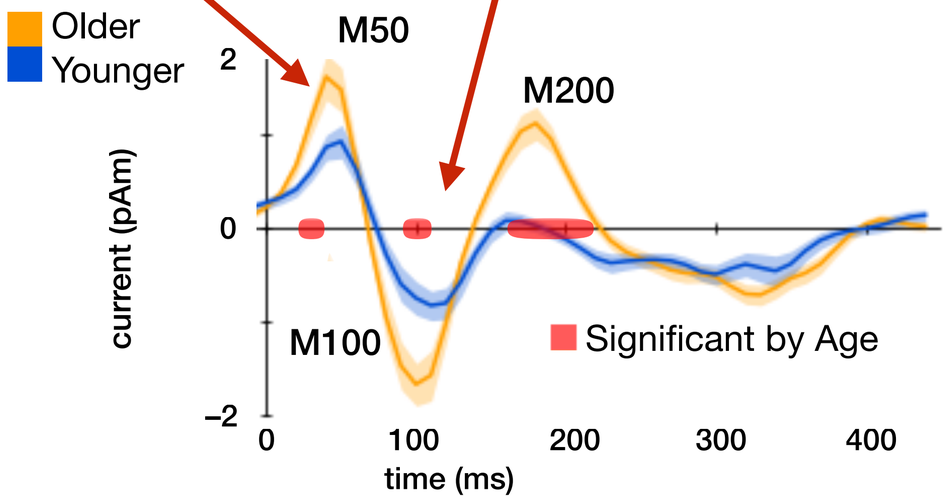
M50

- ~~Increased gain~~ (involving non-core area)
- ~~Top-down~~ (early)

➡ Consistent with excitation/inhibition imbalance

Temporal response function





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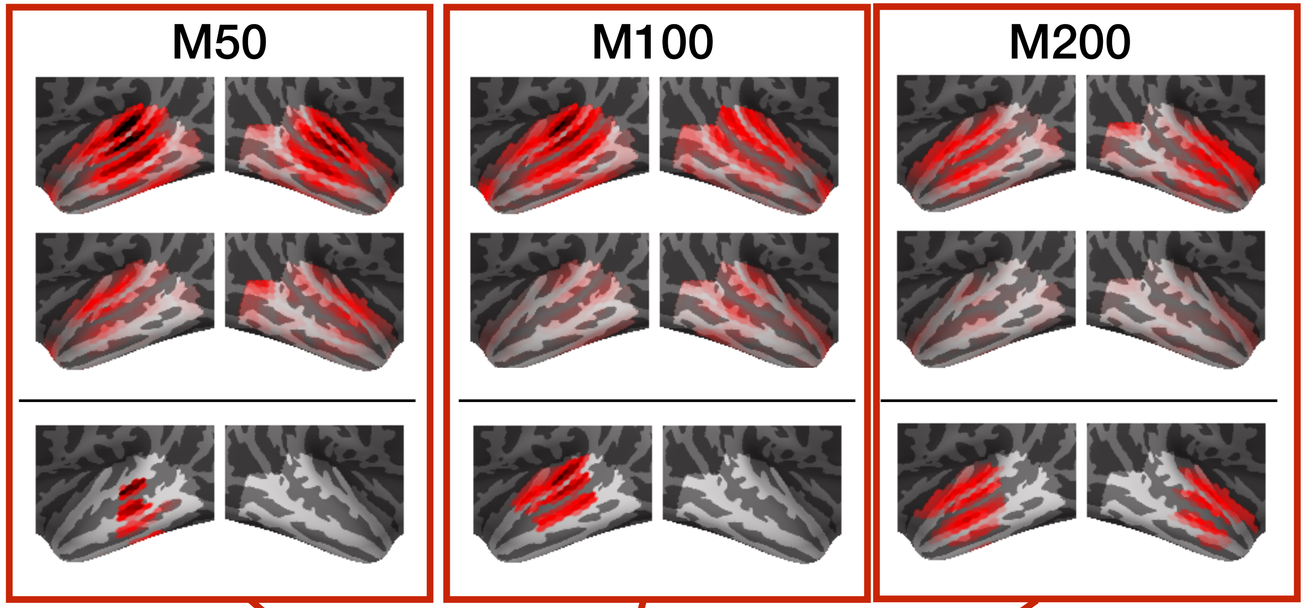
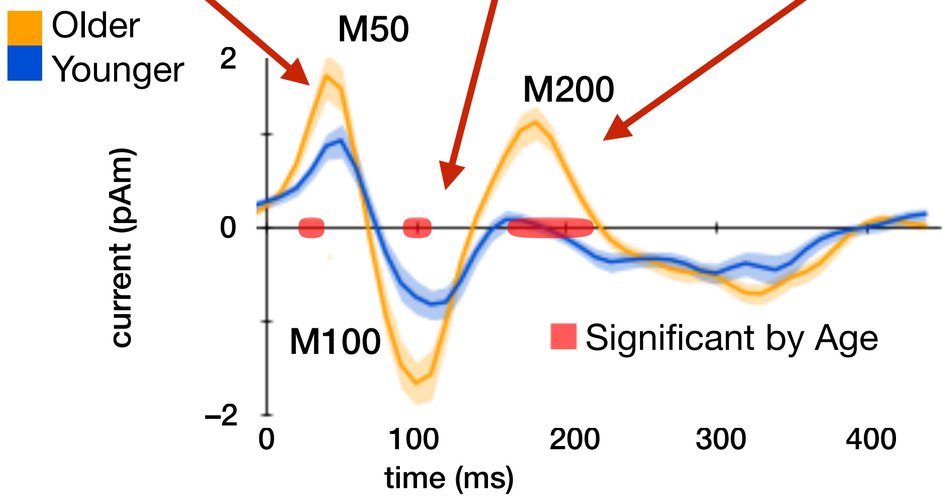
M100

- Increased gain?
- Top down? (M100 associated with attention)

Temporal response function





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M100

- Increased gain?
- Top down? (M100 associated with attention)

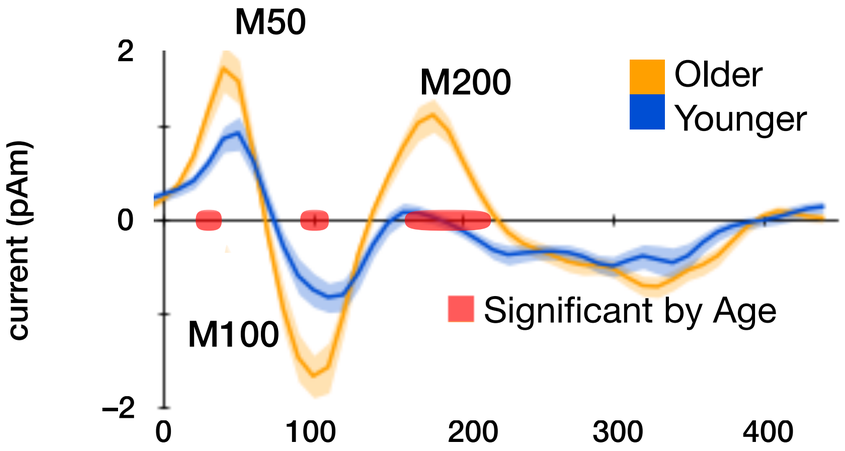
M200

- ~~Increased gain~~ (no comparable response in younger subjects)

➡ Recruiting additional neural resources?

New results: influence of attention

Single Speaker



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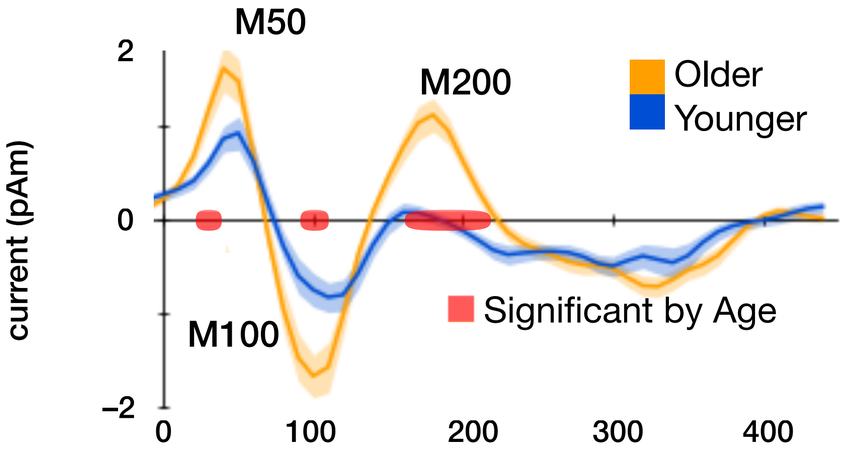

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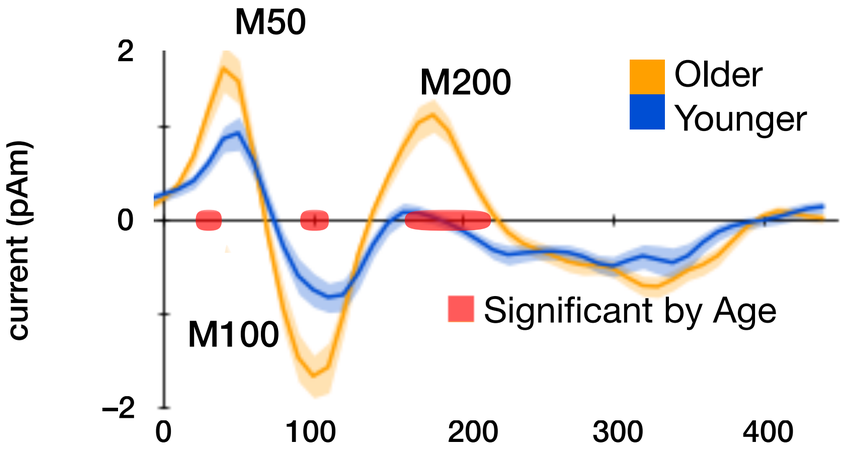

Competing Speakers

How does the brain listen to two speakers?

- M50 dominated by acoustic signal (mixture)
- M100 dominated by attended speaker

Puvvada & Simon
J Neurosci, 2017

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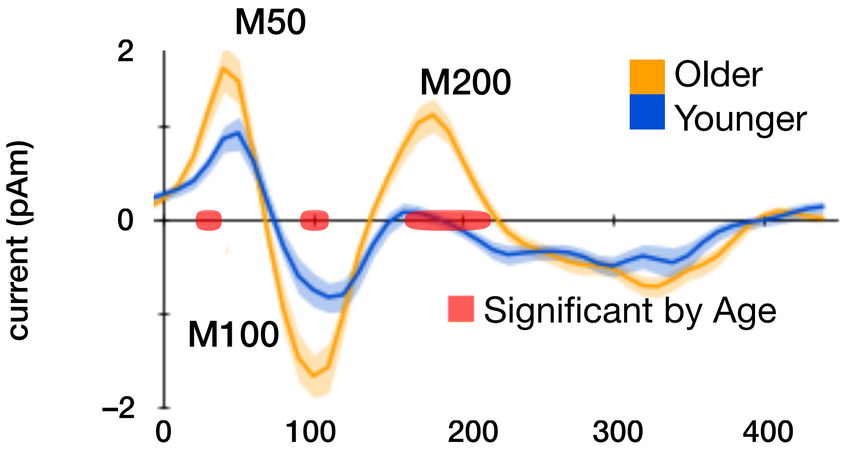
Single Speaker

Competing Speakers

- Acoustic Mixture
- Attended Speech



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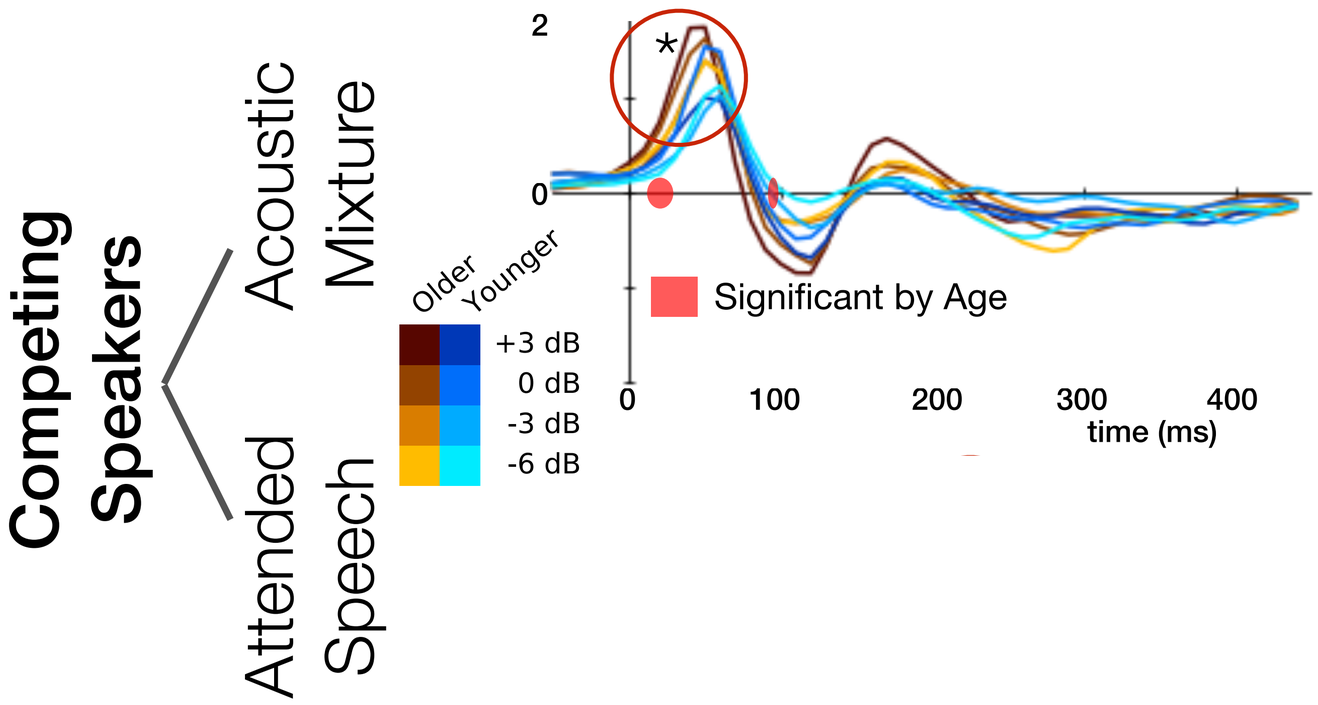

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temporal response functions

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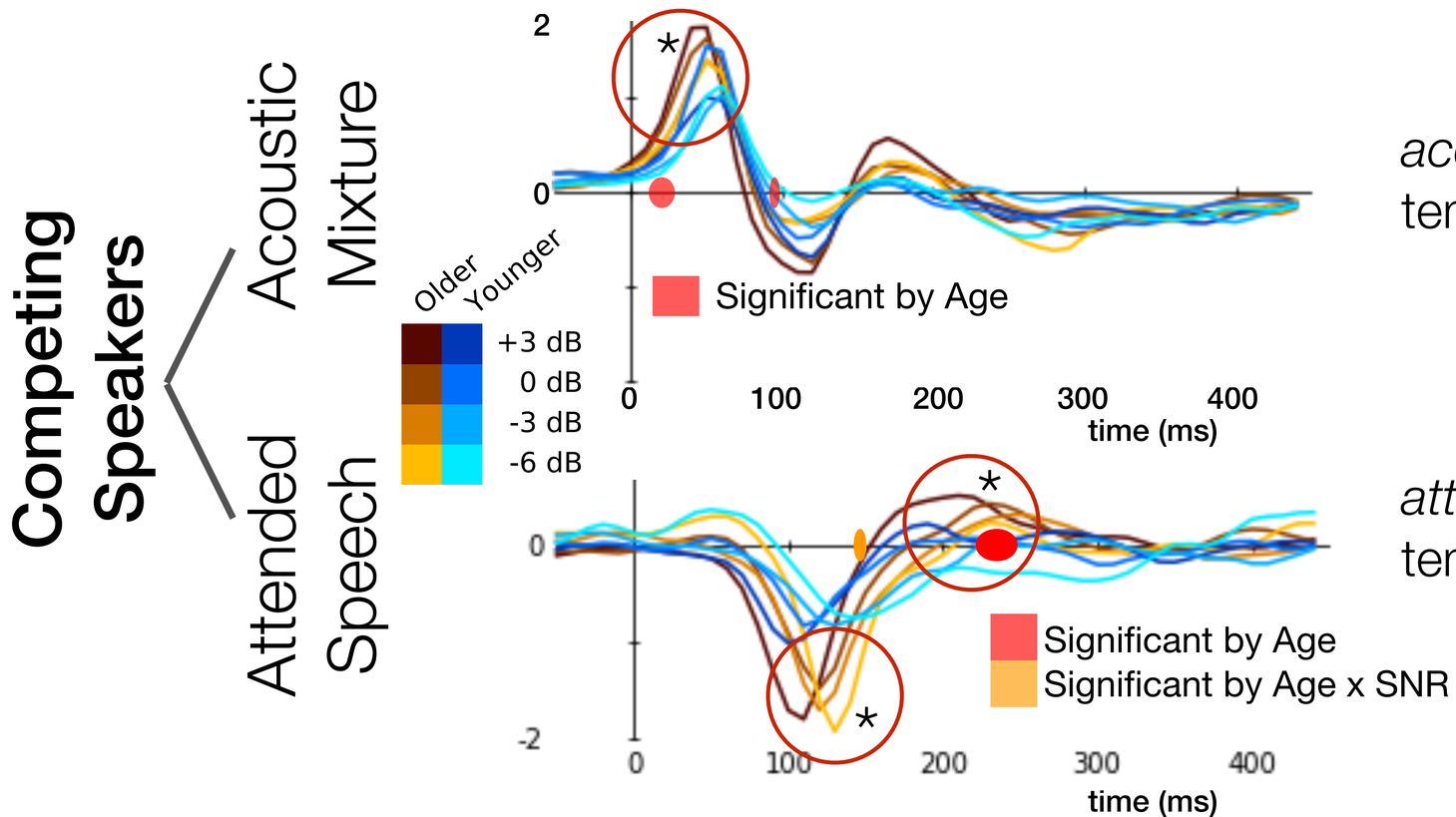

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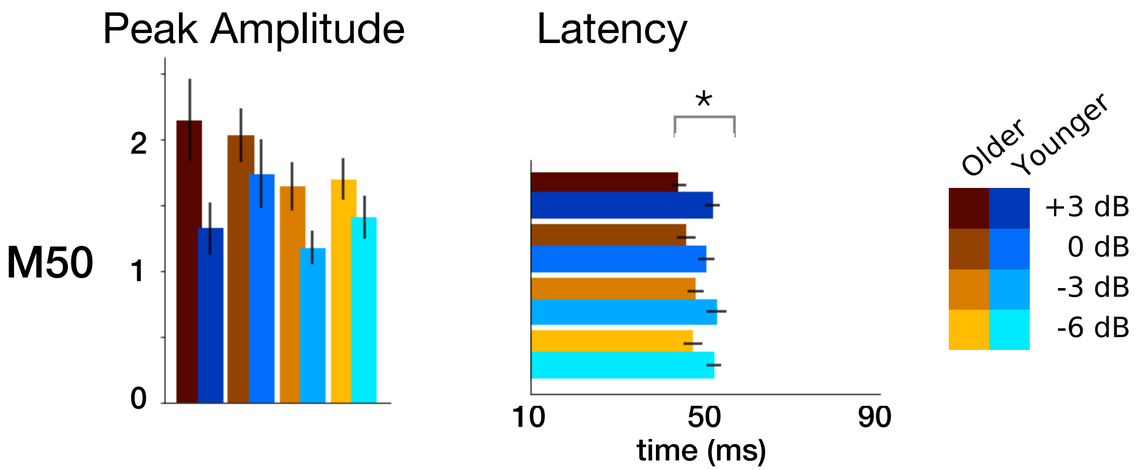

M50

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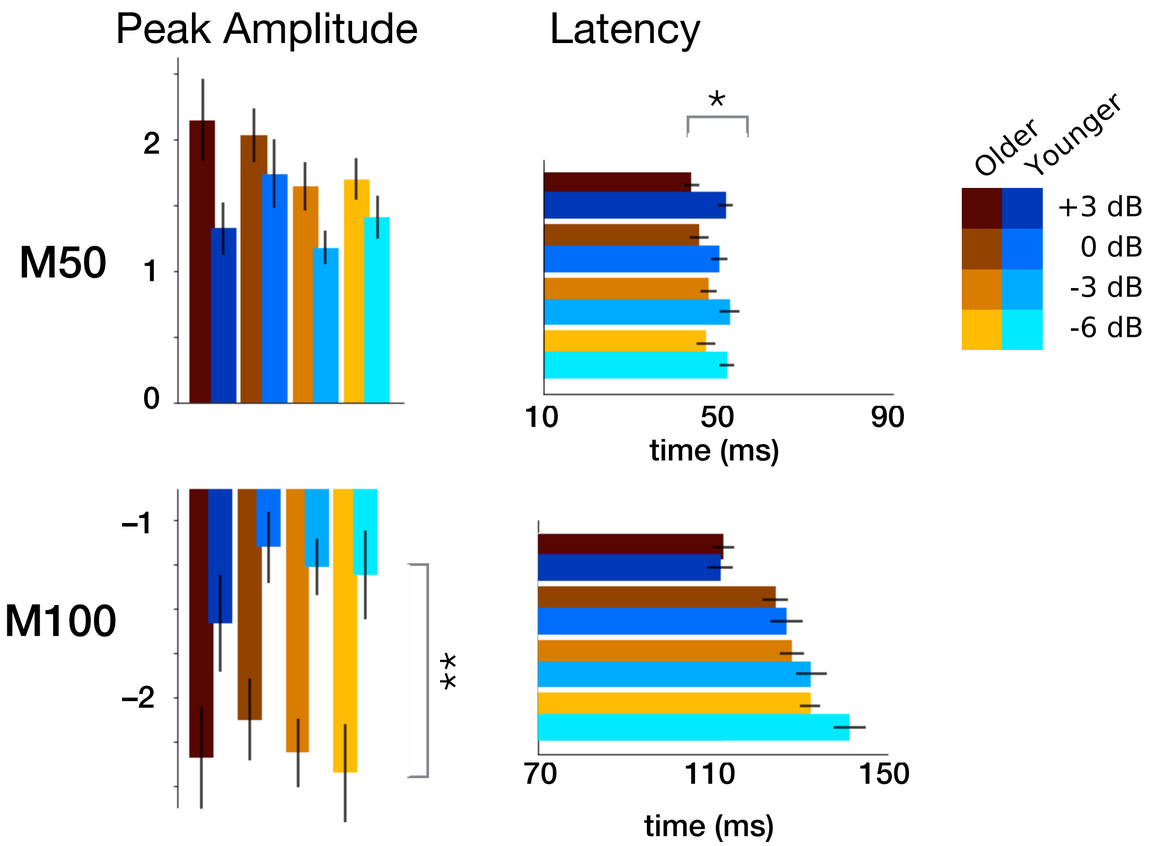

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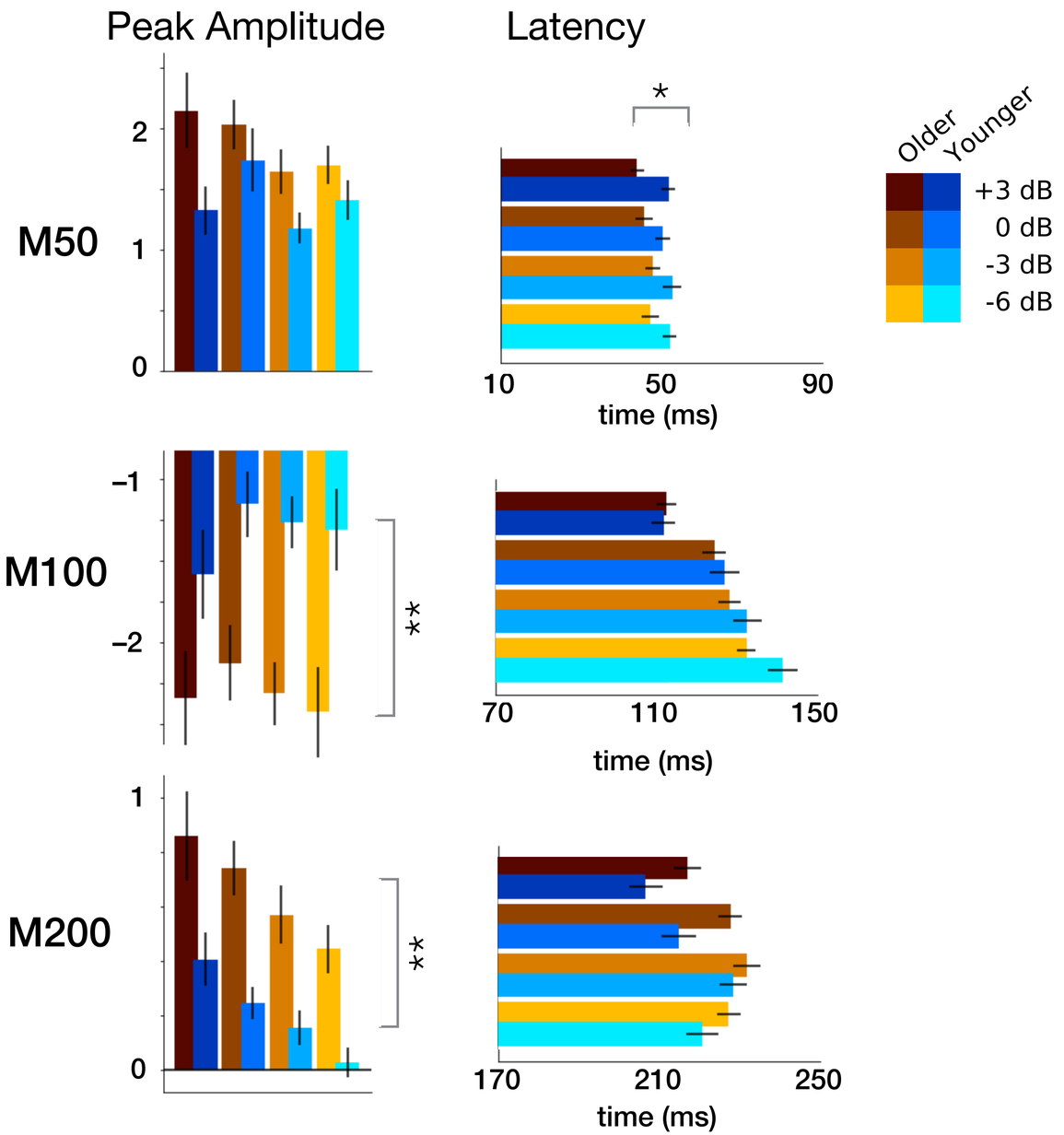
New results: influence of attention



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M200

- Continued tracking of attended speaker
- Responses practically absent in younger listeners

Summary

Cortical over-representation of speech in older adults:

- Multiple sources of over-representation

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  - Short latency
  - Fast spread to areas outside core auditory cortex

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M100

- ~~Bottom-up cortical gain~~
  - Does not track bottom-up information
- Strategic/top-down processing
  - Increase in task related activity (attention to speech)
- ? Low level change
  - Effect on task-related activity?

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M200

- ~~Bottom-up cortical gain~~
  - Response unique to older adults
- Enhanced attentional tracking compatible with cognitive effort/compensation
- Persistent task-related activity

Thank you

Current Lab Members & Affiliates

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Alex Presacco
Proloy Das
Jason Dunlap
Theo Dutcher
Alex Jiao
Dushyanthi Karunathilake
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Sina Miran
David Nahmias
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Pirazh Khorramshahi
Huan Luo
Mahshid Najafi
Krishna Puvvada
Jonas Vanthornhout
Ben Walsh
Yadong Wang
Juanjuan Xiang
Jiachen Zhuo

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Elizabeth Camenga
Katya Dombrowski
Kevin Hogan
Andrea Shome
James Williams

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

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