Increased speech representation in older adults originates from early and late responses in auditory cortex

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Overview

Puzzle

- Compared to young adults, older adults exhibit:
  - *Impaired* auditory temporal processing
  - *More difficulty* comprehending speech, especially in challenging circumstances
- Yet, the speech envelope can be reconstructed *more accurately* from their cortical responses, recorded with MEG (Presacco et al., 2016)

Different possible explanations, for example...

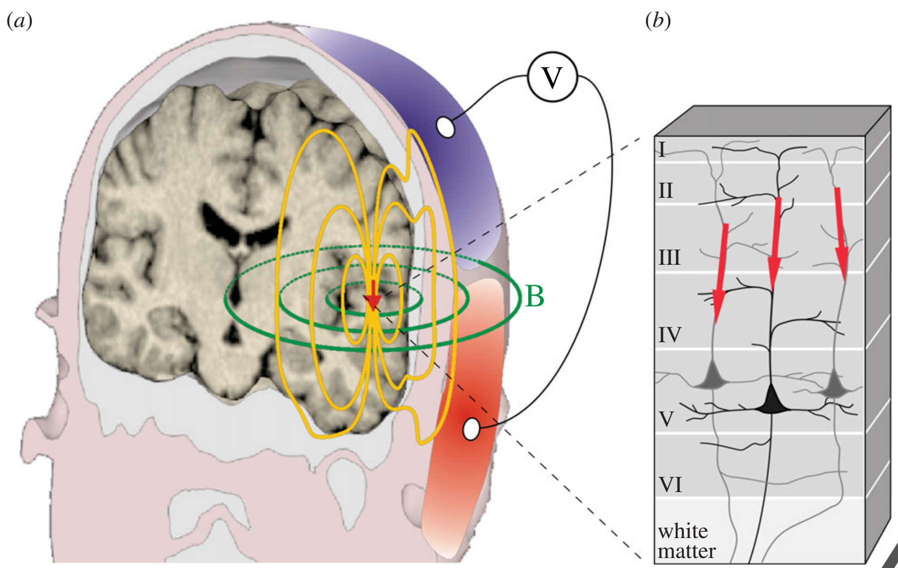
- Increased cortical gain of bottom-up responses
- Recruitment of additional top-down resources
- Physiological changes, e.g. excitation-inhibition imbalance

This talk

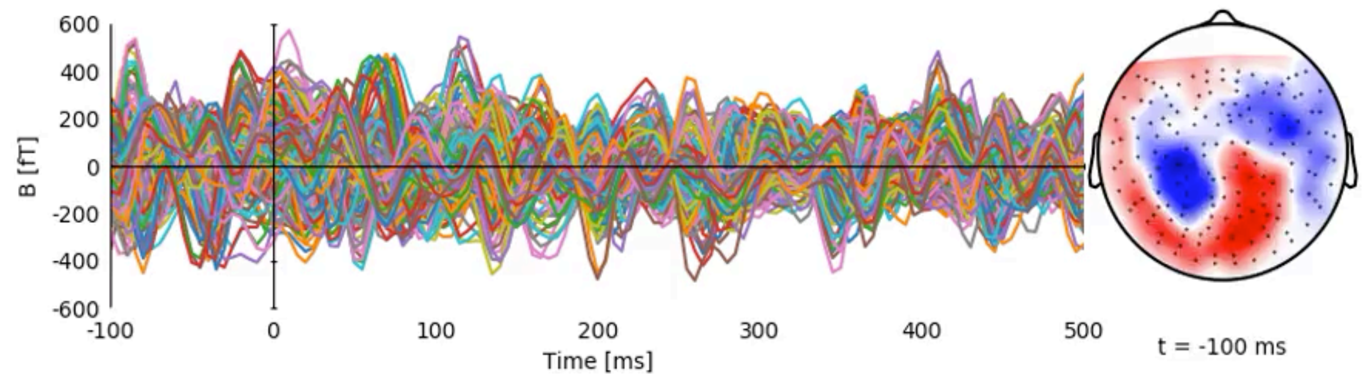
- Localize cortical responses to speech of younger and older adults
  - Anatomy: localization in cortex
  - Time: latency at which information is represented

Brodbeck, C., Presacco, A., Anderson, S., & Simon, J. Z. (2018). Over-Representation of Speech in Older Adults Originates from Early Response in Higher Order Auditory Cortex. Acta Acustica United with Acustica, 104(5), 774–777.

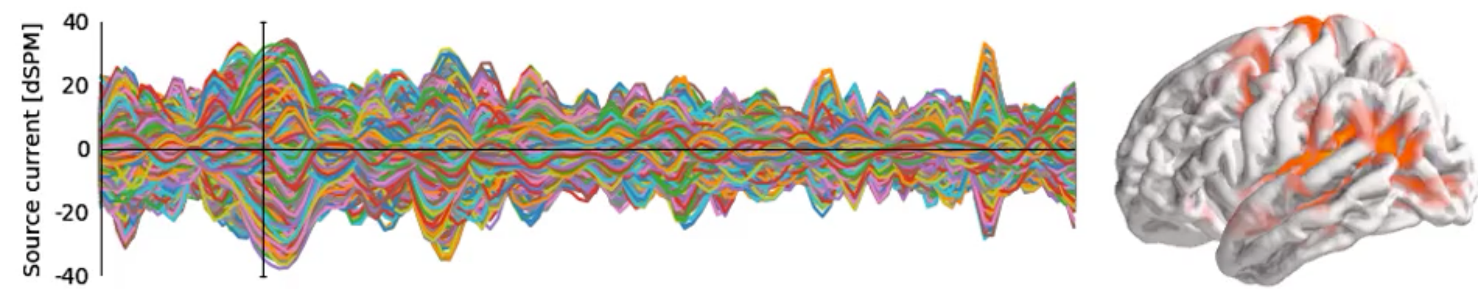
MagnetoEncephaloGraphy (MEG)



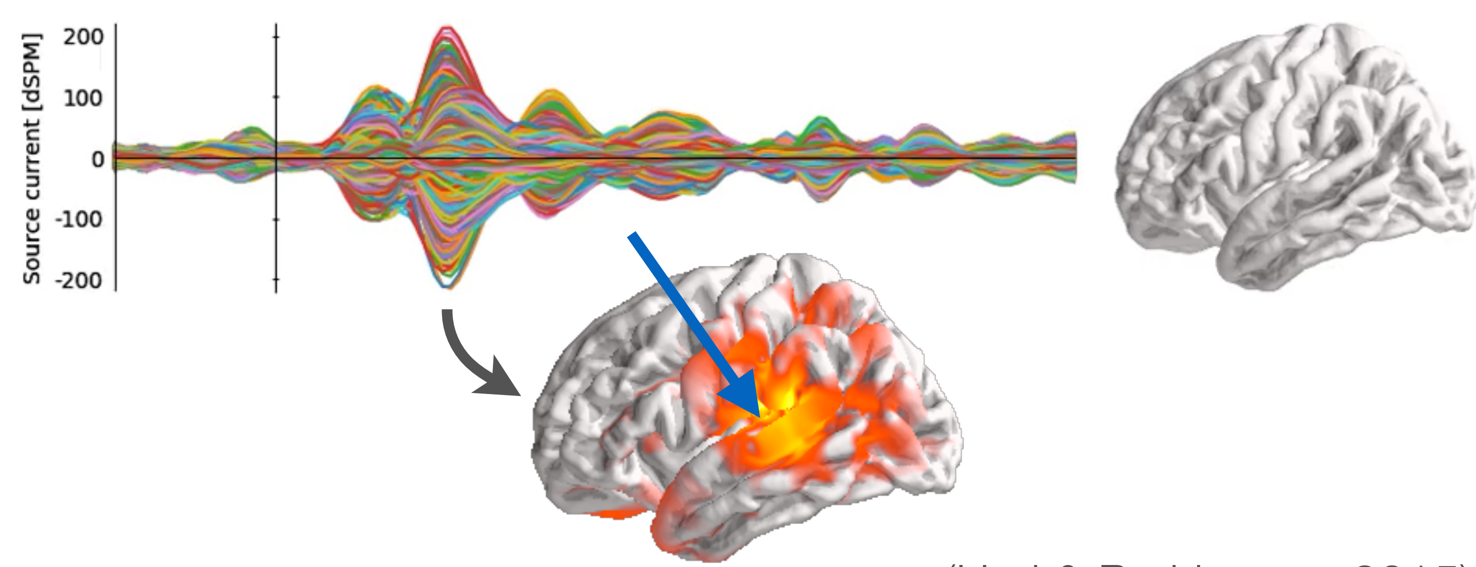
Single trial (pure tone)



Minimum norm source estimates



Average (~100 trials)



(Hari & Parkkonen, 2015)

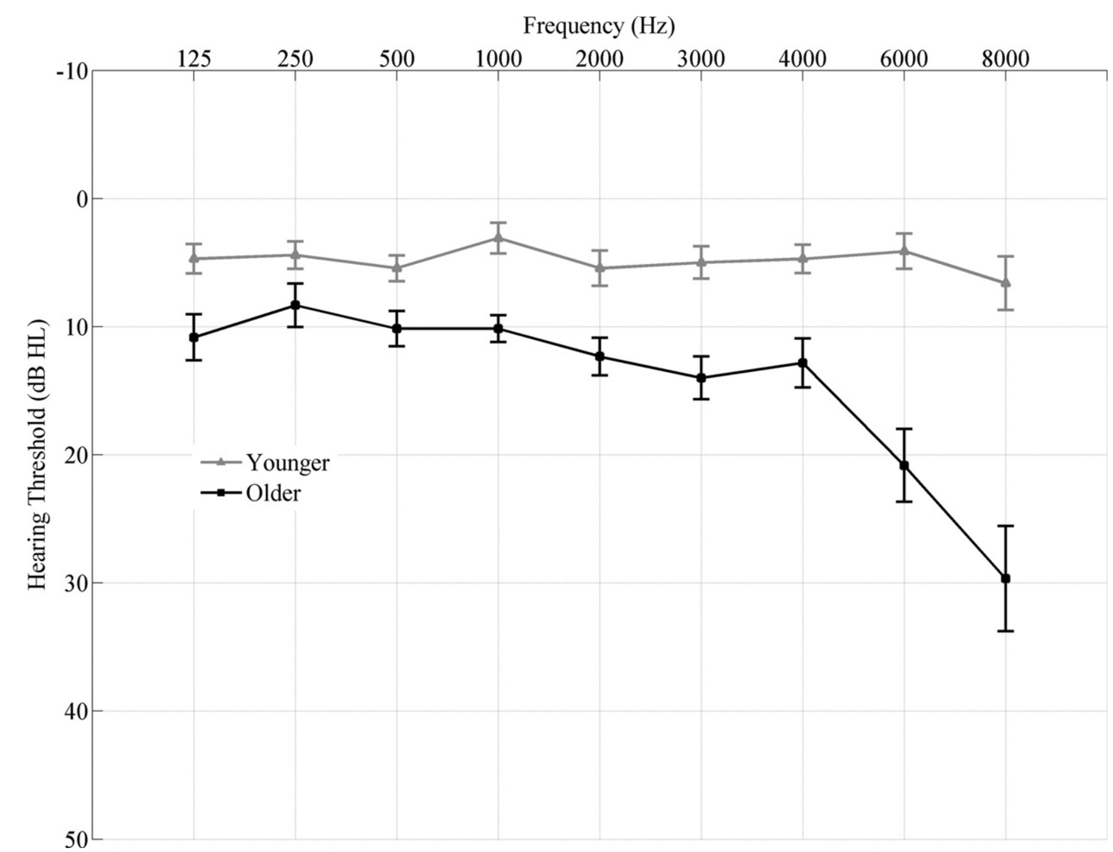
Methods (Presacco et al.)

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

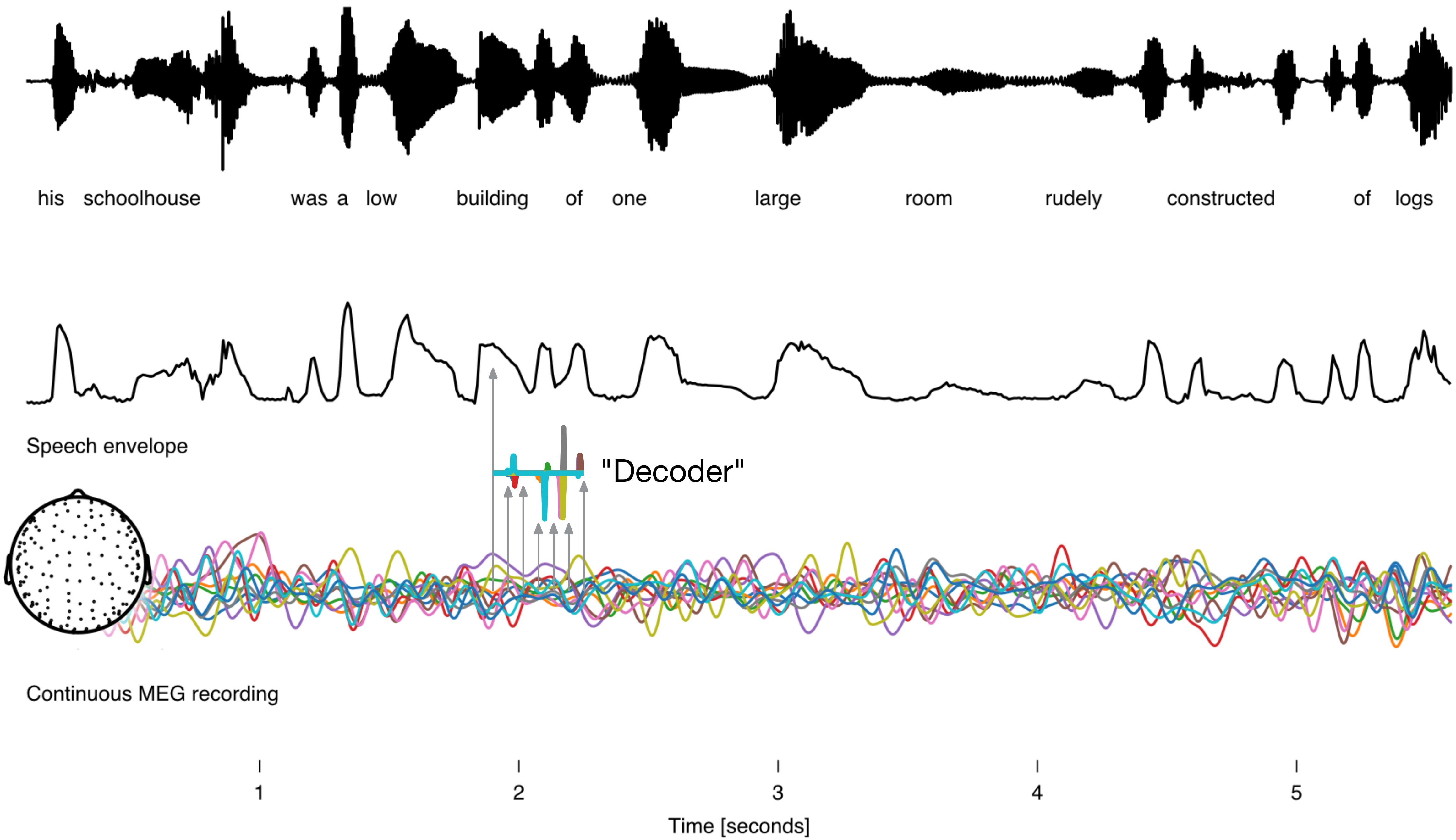


MEG data

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

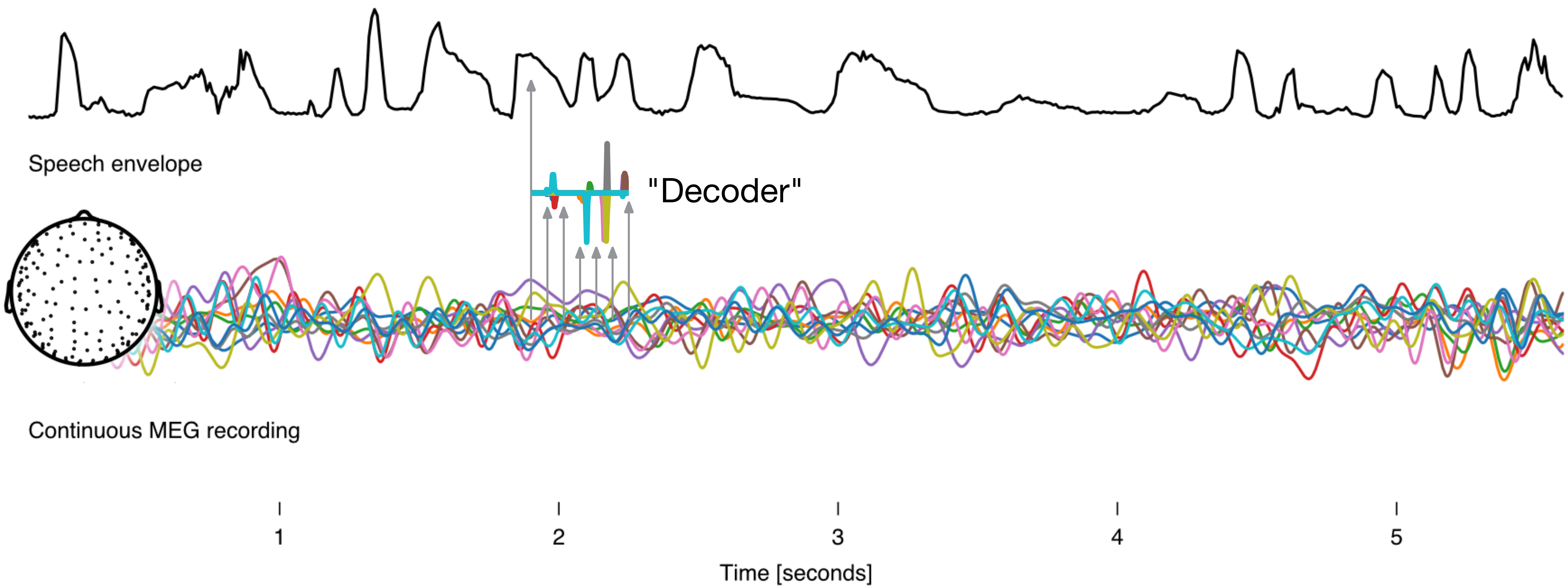
(Presacco, Simon, & Anderson, 2016)

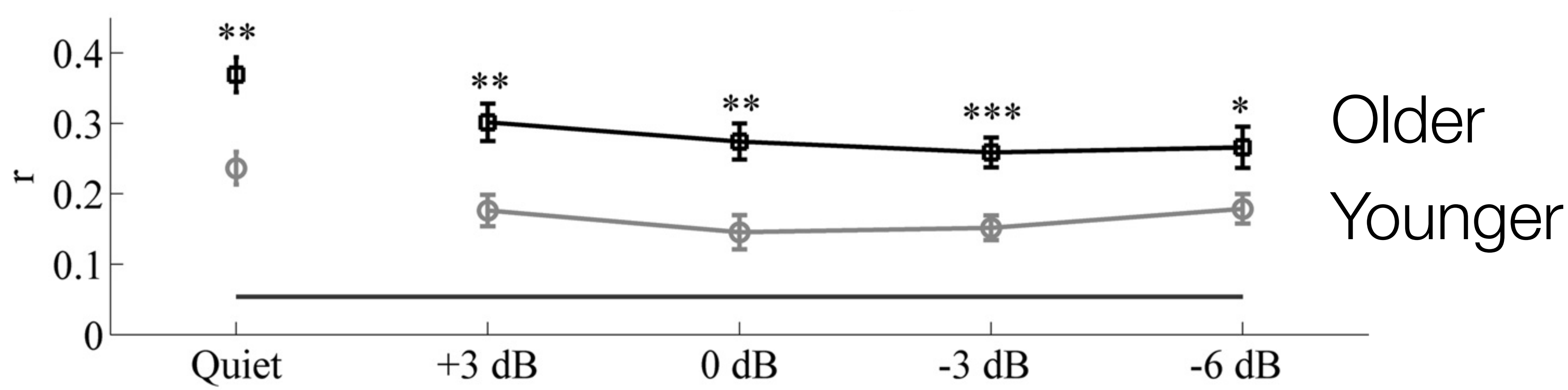
Methods (Presacco et al.)



(Presacco, Simon, & Anderson, 2016)

Results (Presacco et al.)





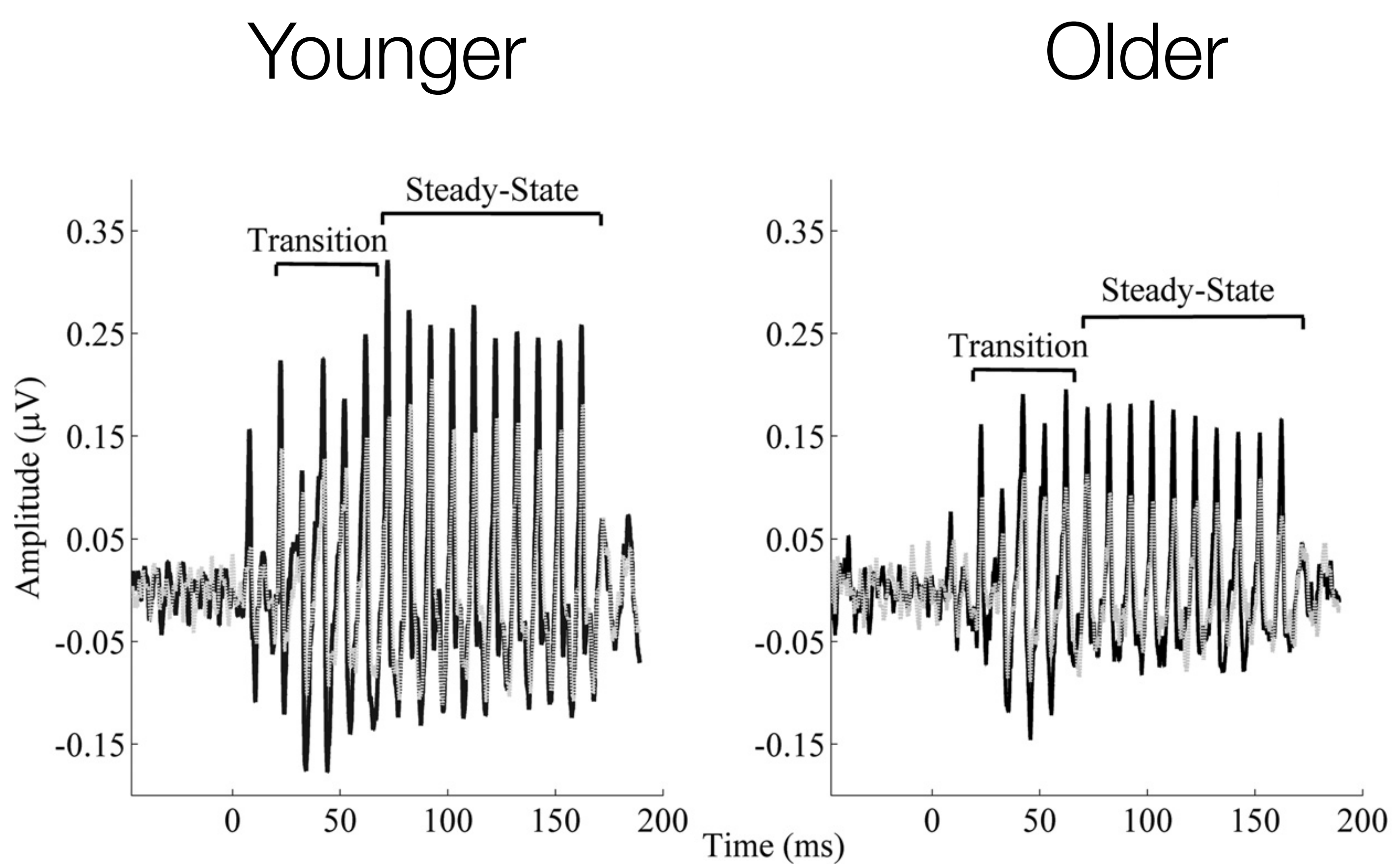
Cortex: older > younger

(Presacco, Simon, & Anderson, 2016)

Midbrain (Presacco et al.)

Midbrain

- Older listeners have reduced frequency following response (FFR)
- Increased cortical responses not due to stronger input from midbrain



Midbrain: younger > older

(Presacco, Simon, & Anderson, 2016)

Possible explanations

Increased cortical gain for bottom-up responses

- Prediction: same origin, more current

Top-down/strategic processing

- Compensate for degraded input from the periphery
- Recruitment of additional frontal and temporal regions for complex sentences (Peelle et al., 2010)
- Prediction:
  - Response enhancement at longer latencies, e.g., 100-200 ms

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 low latency responses, e.g., 30 ms
  - Potentially involving higher order regions

Methods

Participants

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

MEG source localization

- Empty room noise covariance
- Minimum norm estimates with depth weighting
- Temporal response functions estimated with coordinate descent algorithm (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)

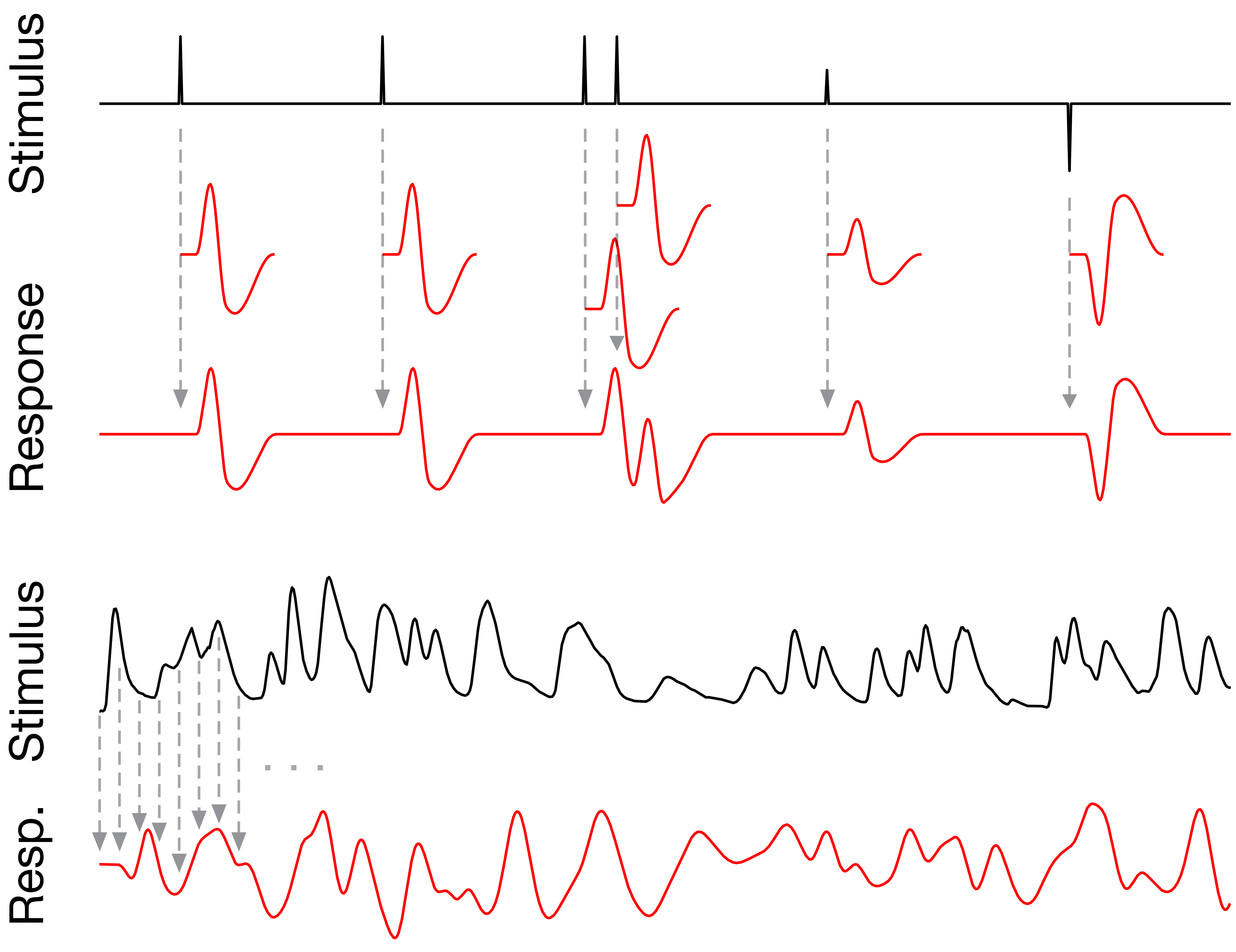
Bias-correction:

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

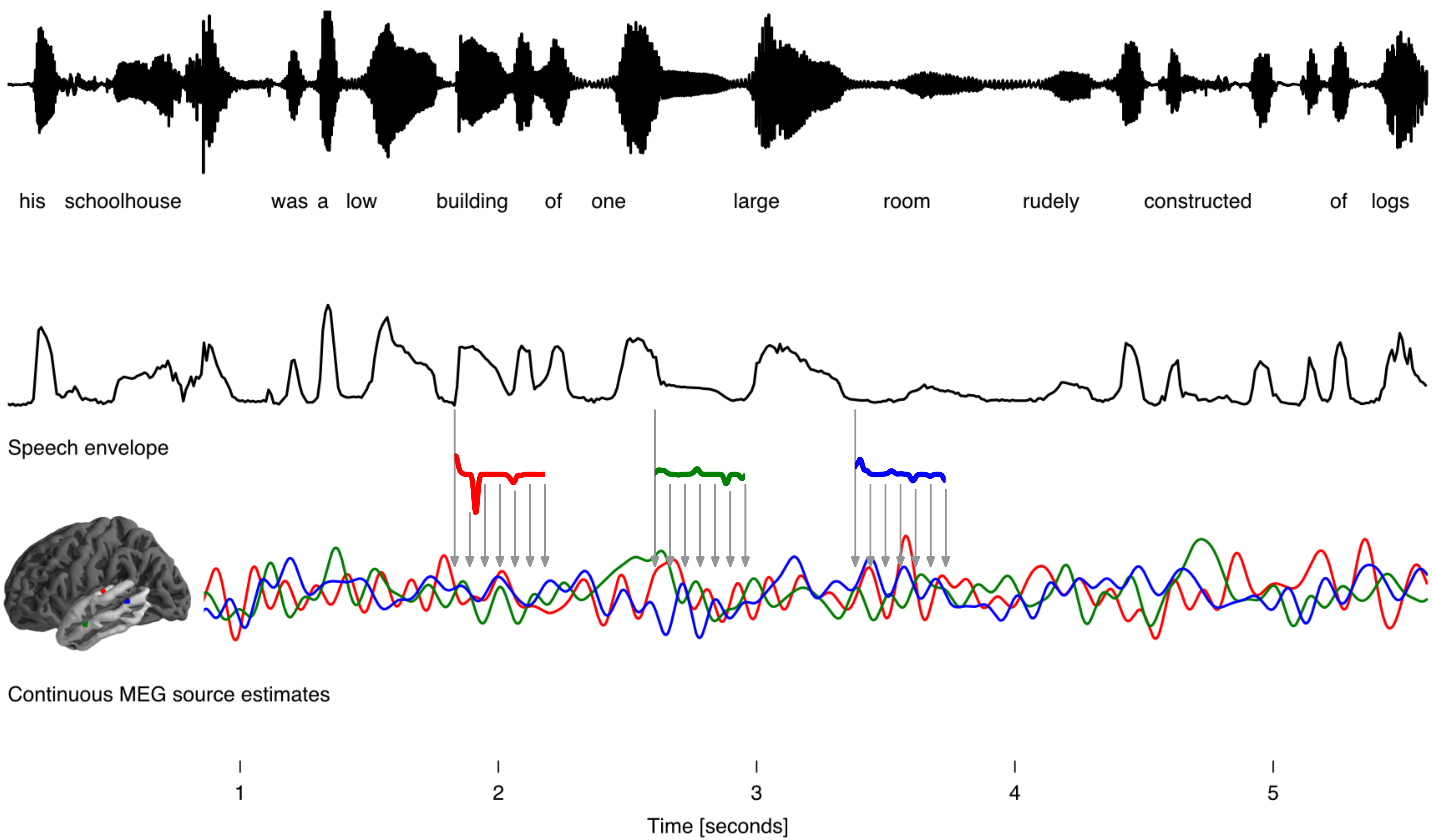
Significance test:

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

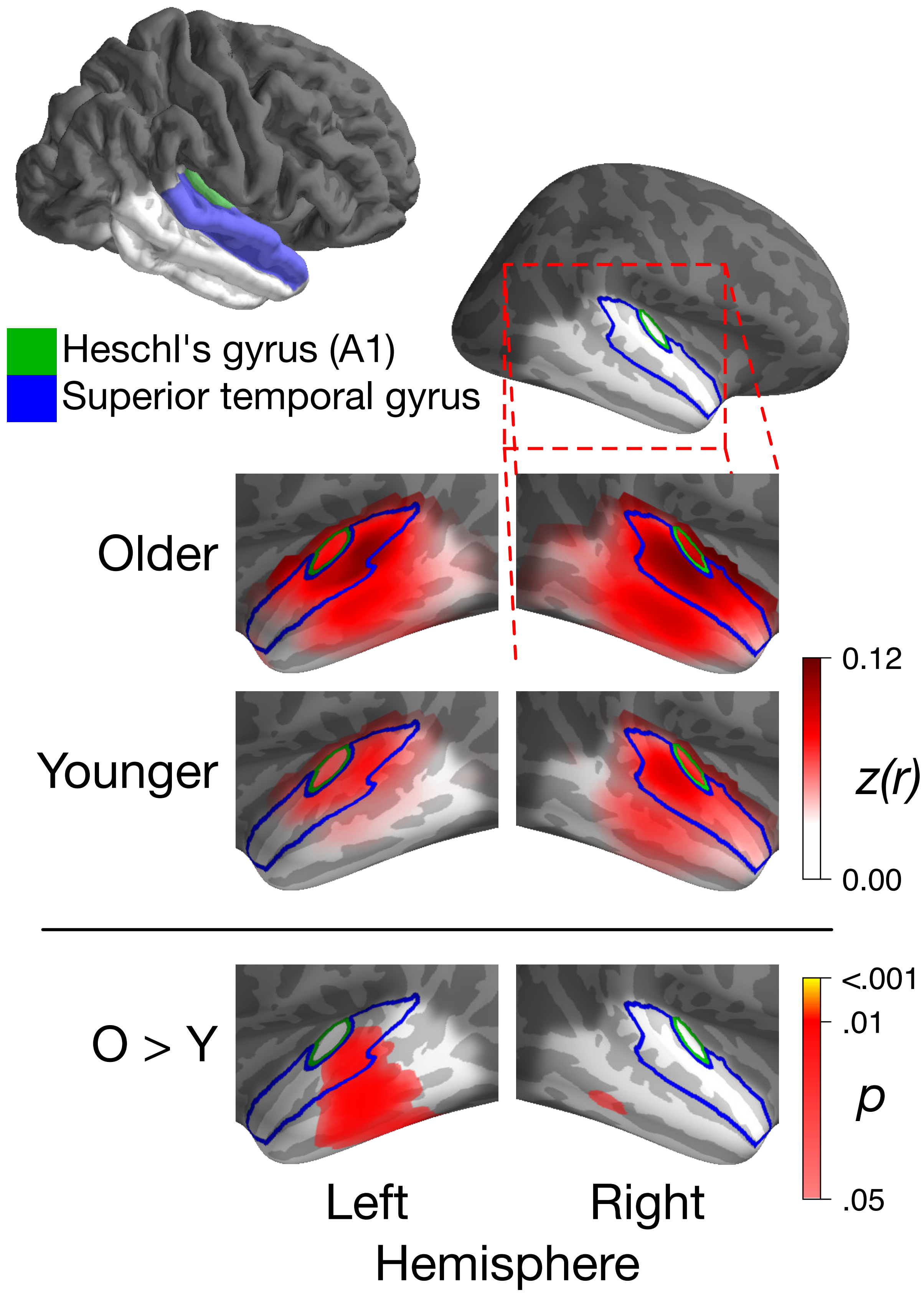
Temporal response function



Encoding model



Clean speech: neural localization



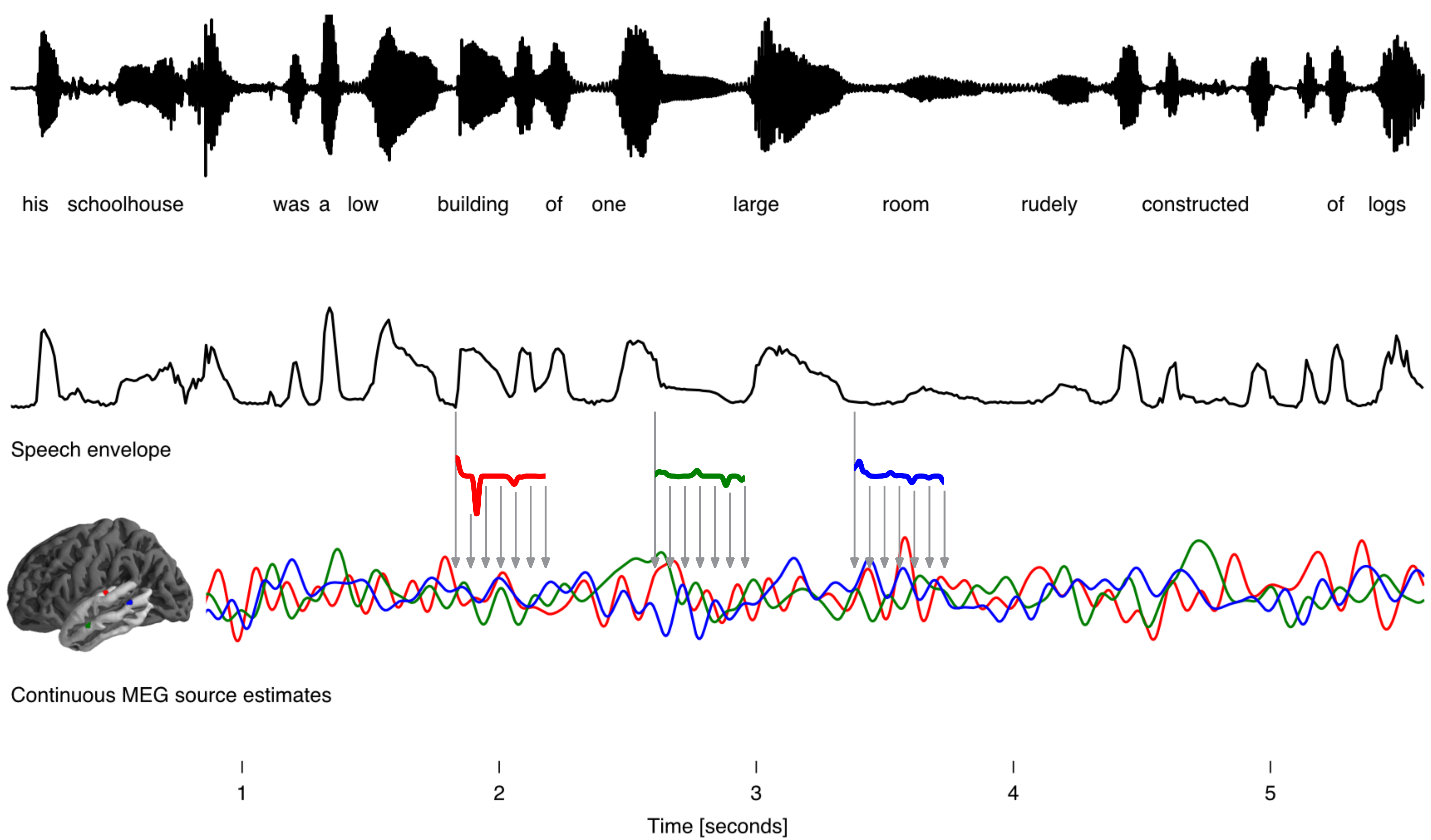
Brain activity (MEG source estimate) predicted from acoustic envelope

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

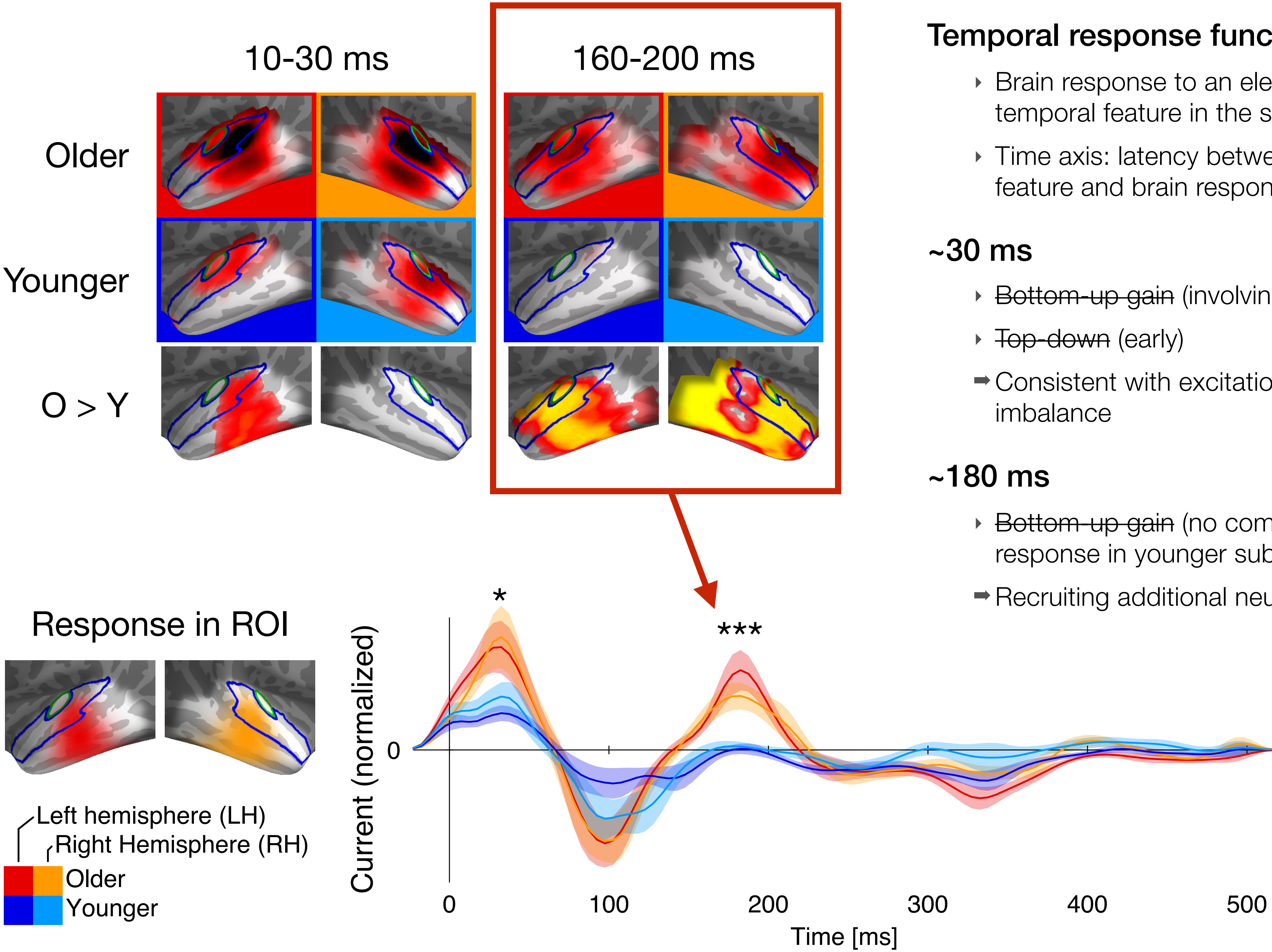
Older > Younger

- Ventral to core auditory cortex
- No significant difference between hemispheres

Temporal response function



Temporal response function



Temporal response function (TRF)

- Brain response to an elementary temporal feature in the stimulus
- Time axis: latency between acoustic feature and brain response

~30 ms

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

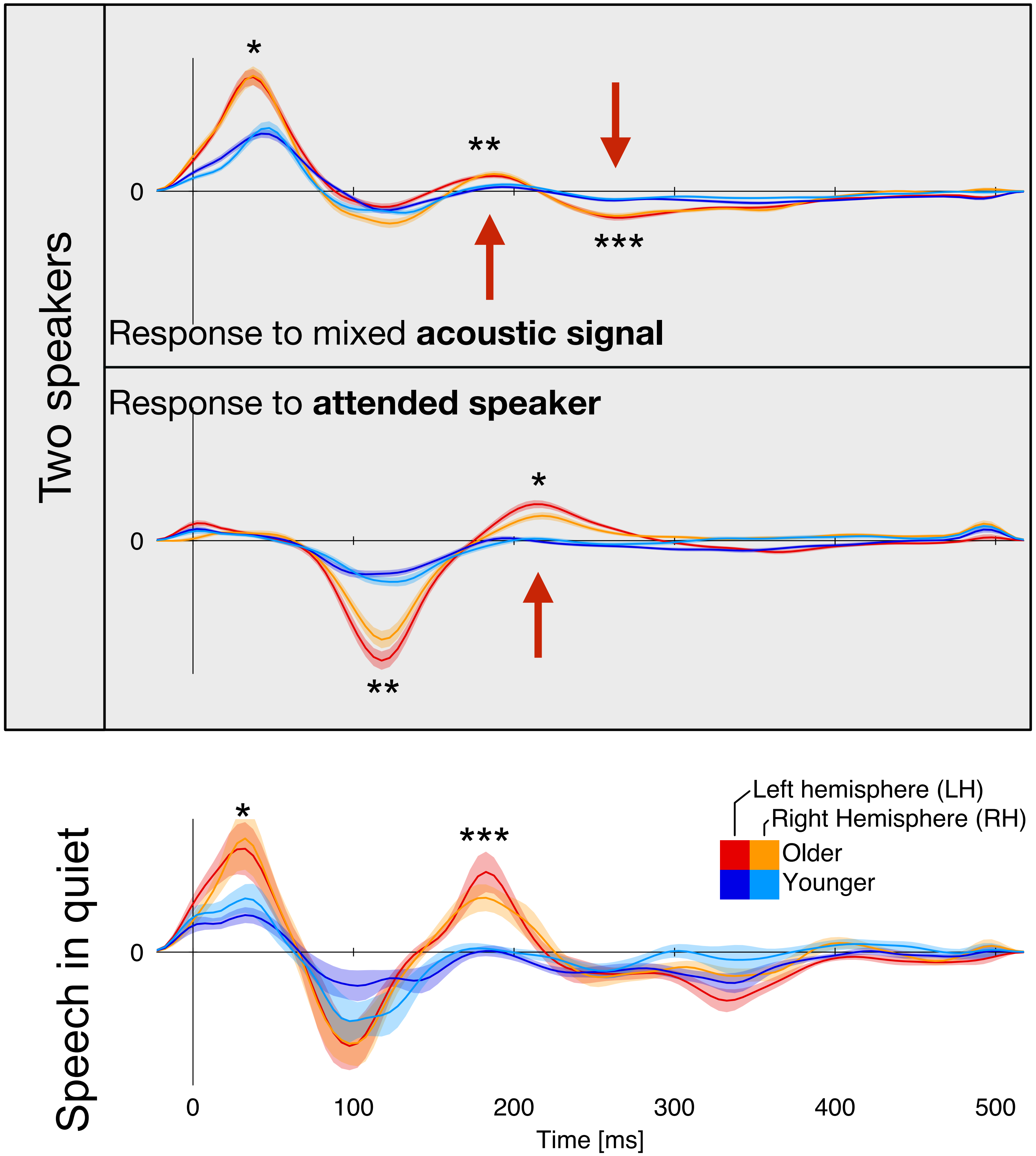
➡ Consistent with excitation/inhibition imbalance

~180 ms

- ~~Bottom-up gain~~ (no comparable response in younger subjects

➡ Recruiting additional neural resources?

New results: influence of attention



Listening to two speakers (Puvvada & Simon, 2017)

- Early responses track the acoustic signal (~50 ms)
- Later responses track the attended speaker (~100 ms)

~30 ms

- Stimulus-driven
- ➡ Consistent with excitation-inhibition imbalance

~120 ms

- Increased attentional modulation
- ➡ Consistent with increased task-related processing

~180 - 250 ms

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

Summary

Cortical over-representation of speech in older adults:

- Multiple sources of over-representation

~ 30 ms

- ~~Bottom-up cortical gain~~
  - Main difference outside of core auditory cortex
- ~~Strategic/top-down processing~~
  - Latency too short
- Low level physiological change; excitation/inhibition imbalance
  - Short latency
  - Fast spread to areas outside core auditory cortex

~ 120 ms

- ~~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?

Later responses

- ~~Bottom-up cortical gain~~
- Enhanced attentional tracking compatible with cognitive effort/compensation
- Persistent stimulus-driven as well as task-related activity

Thank you!

Coauthors

- Alessandro Presacco
- Stefanie Kuchinsky
- Samira Anderson
- Jonathan Z. Simon

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