Over-representation of speech in older adults originates from early response in higher order auditory cortex

Christian Brodbeck, Alessandro Presacco, Samira Anderson & Jonathan Z. Simon

Overview

Puzzle

- Compared to young adults, older adults (60+) 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)

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Different possible explanations, for example

- Low level deficit, e.g. excitation-inhibition imbalance
- Recruitment of additional top-down resources
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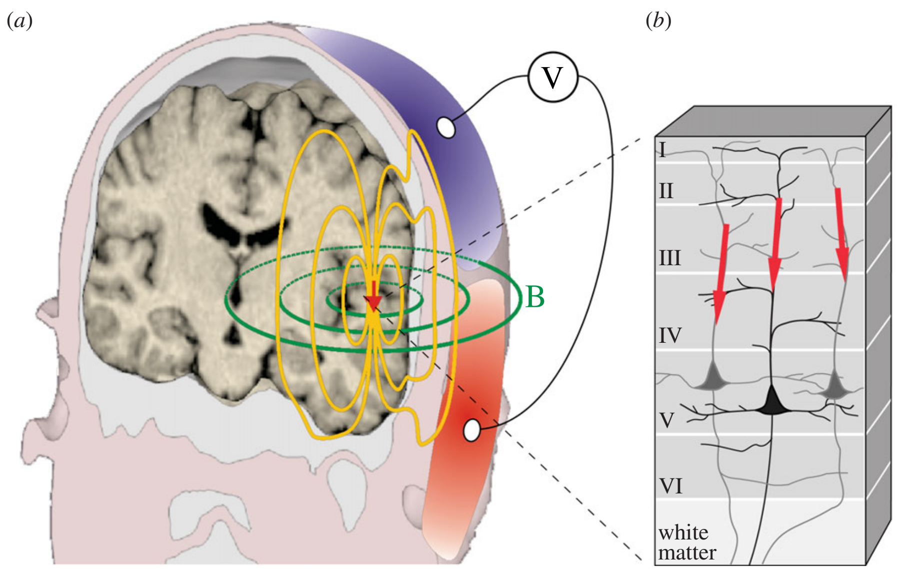
This talk

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

MagnetoEncephaloGraphy (MEG)



(Hari & Parkkonen, 2015)

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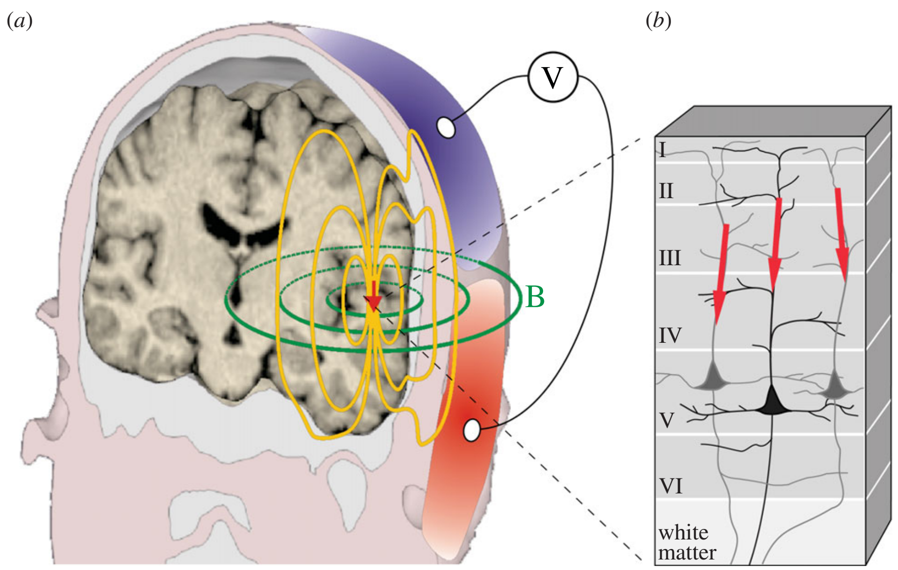
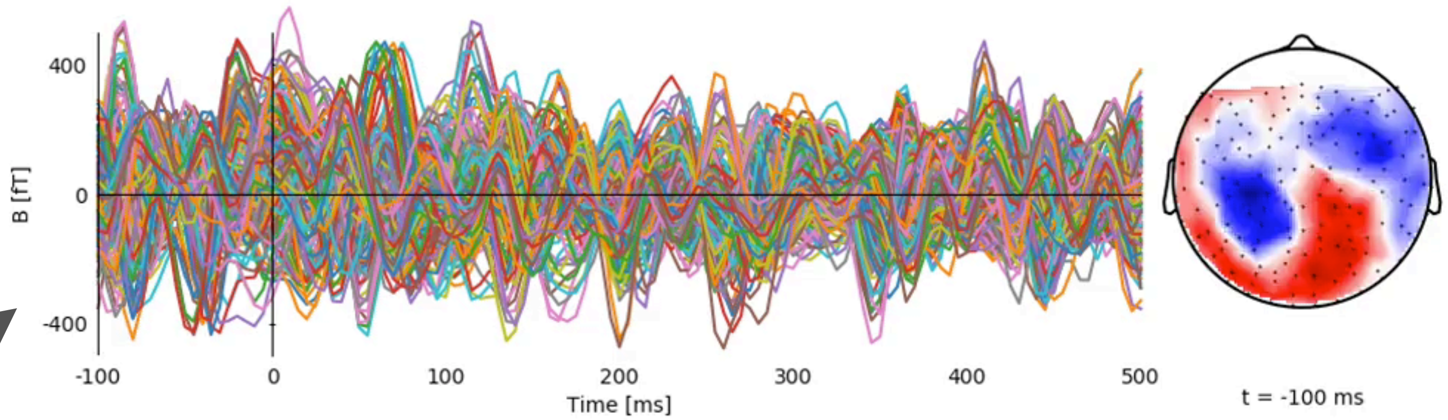


Single trial (pure tone)



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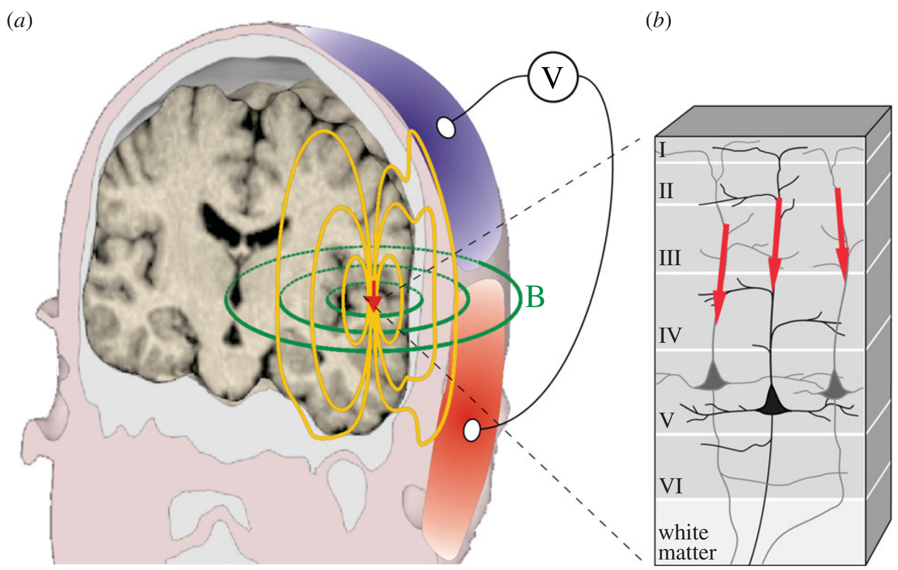

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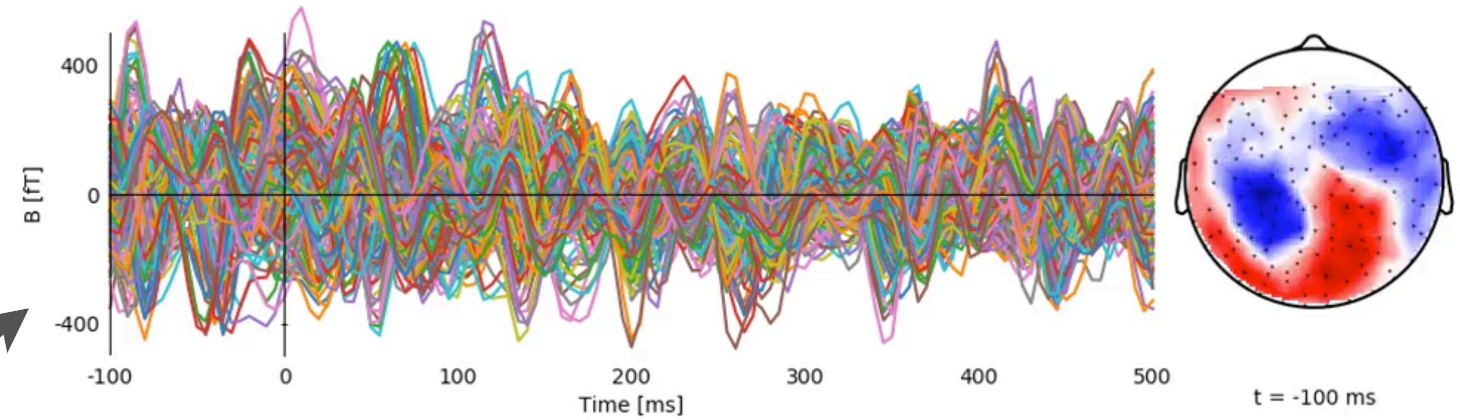
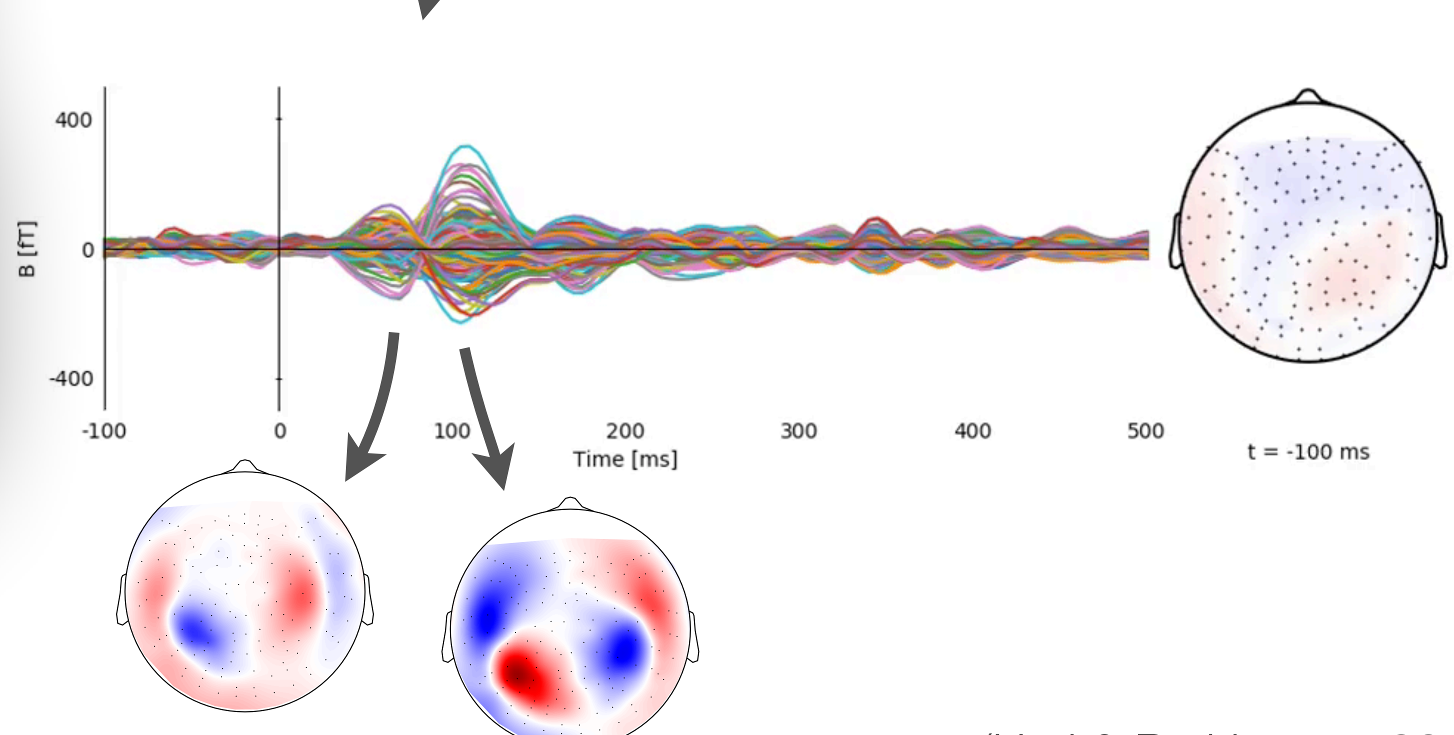


Average (~100 trials)



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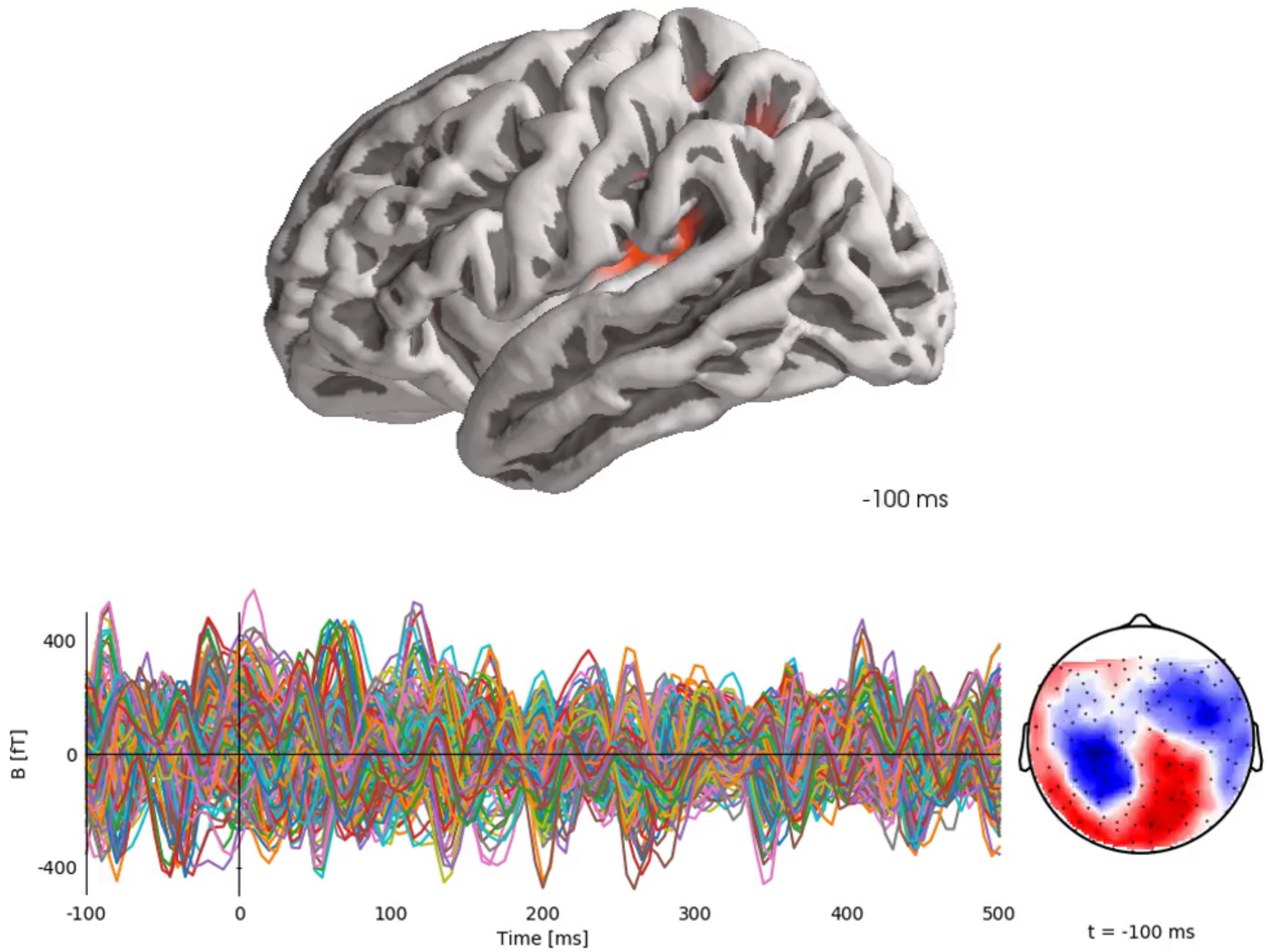
Neural source localization



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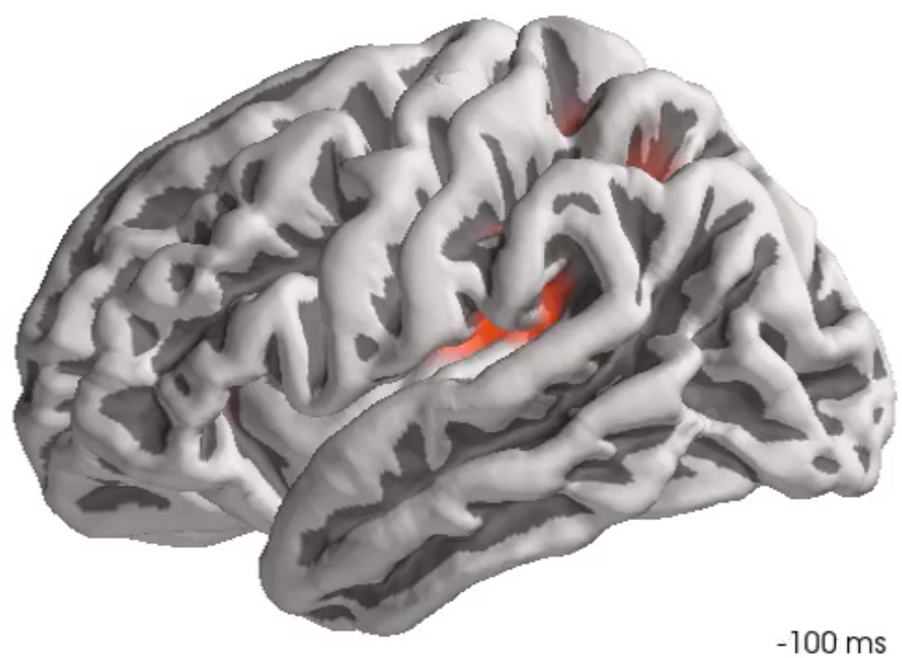
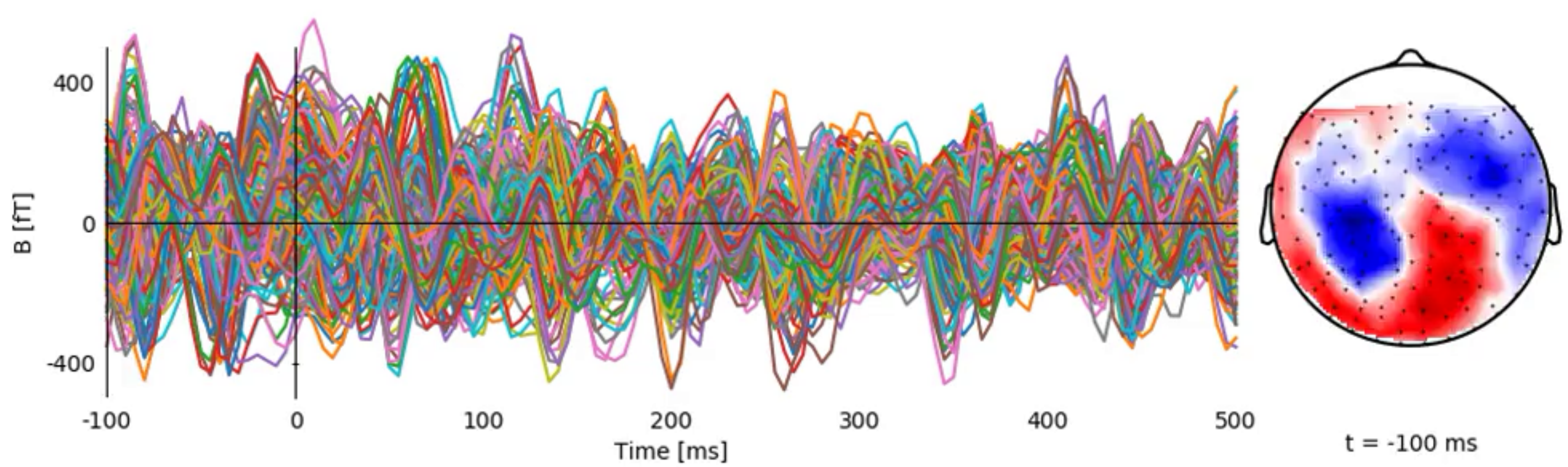
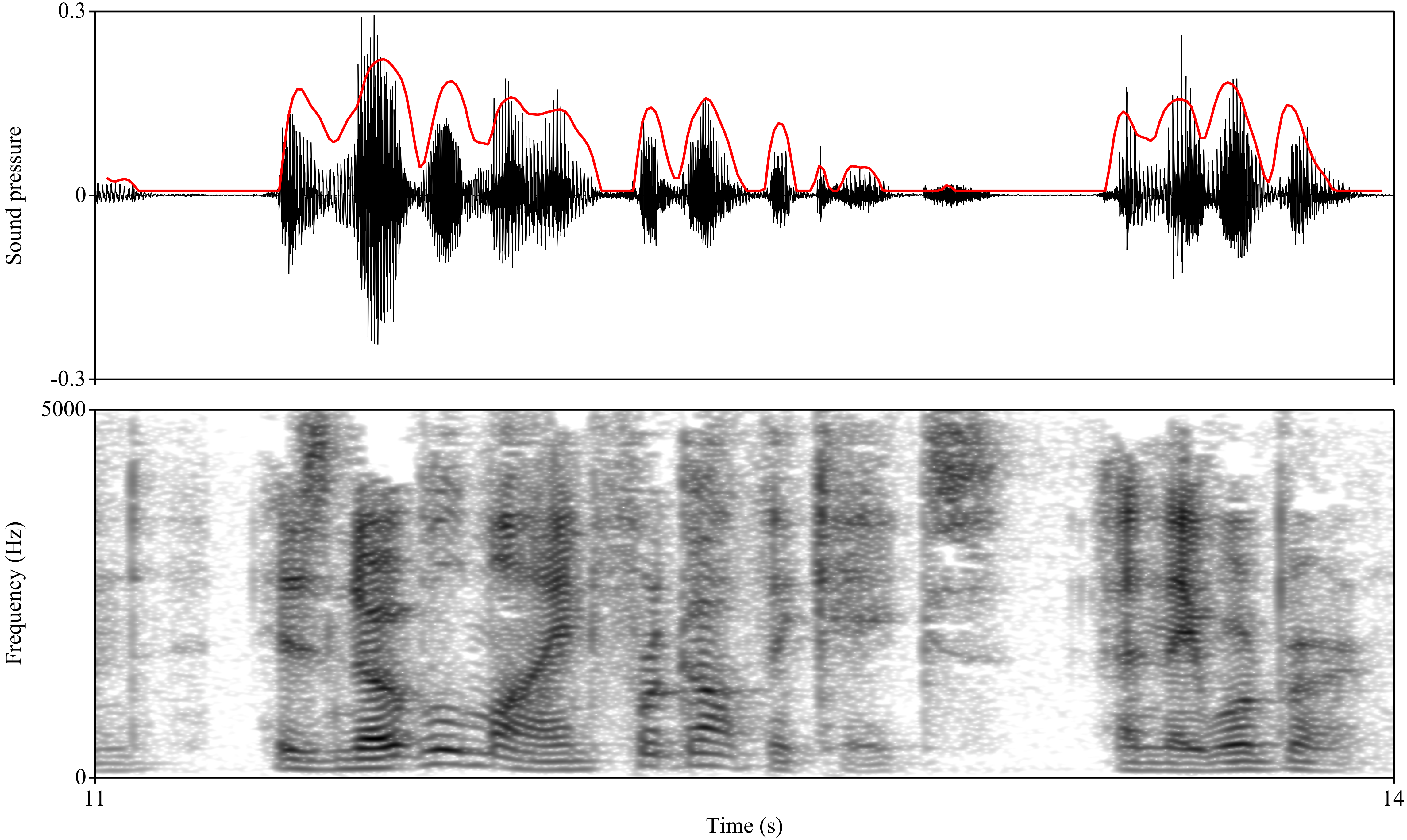
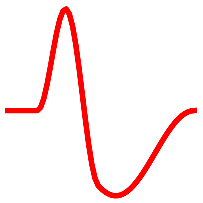


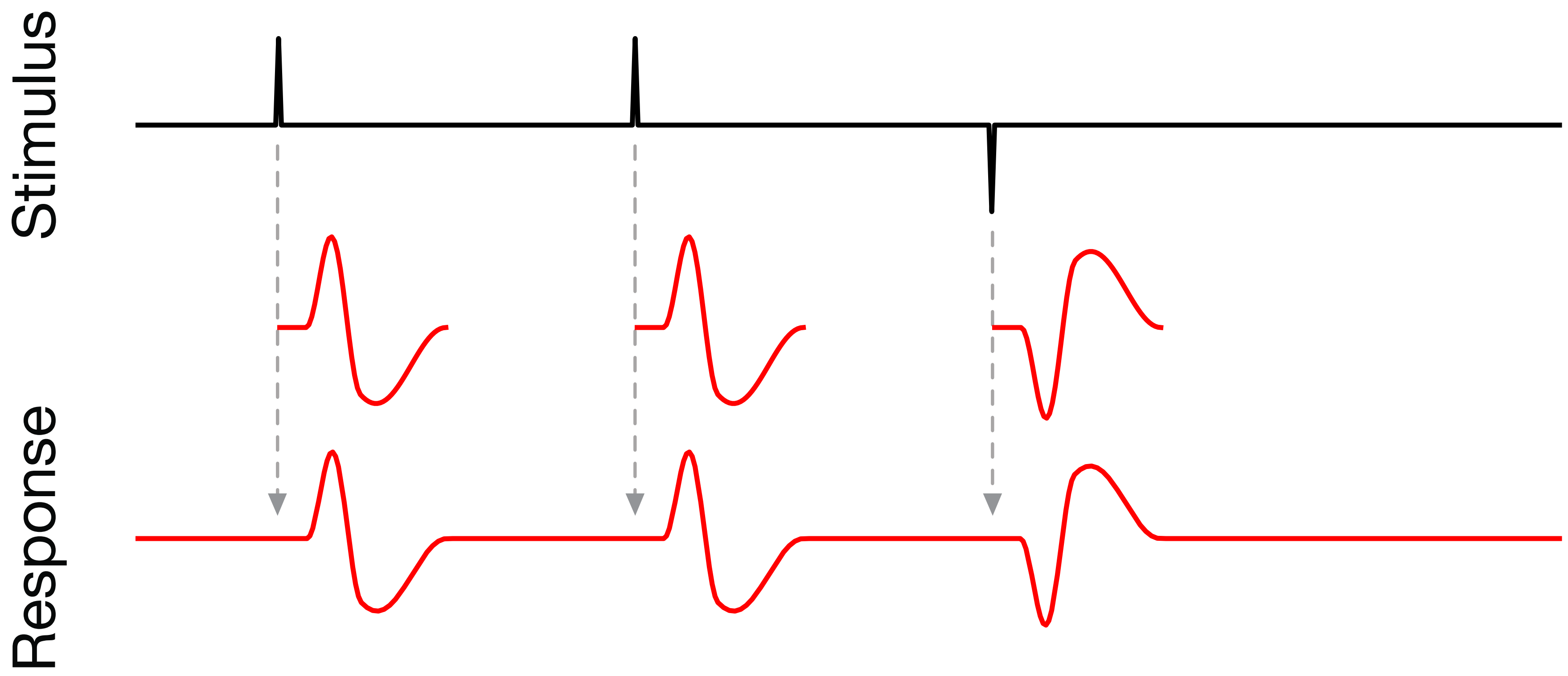


Continuous Speech



Linear convolution model

Convolve (∗) a response function  with a sparse signal



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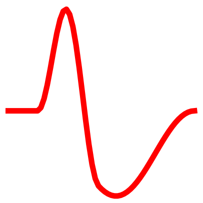
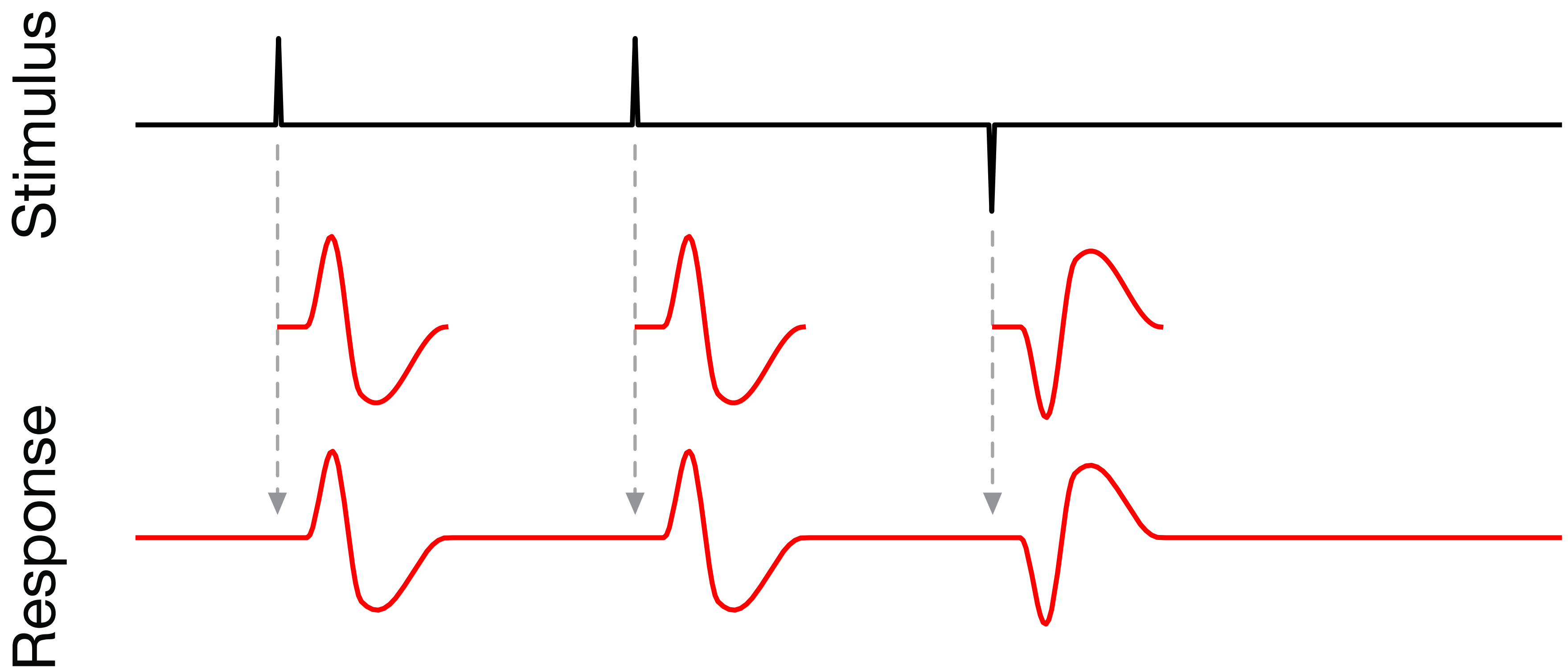
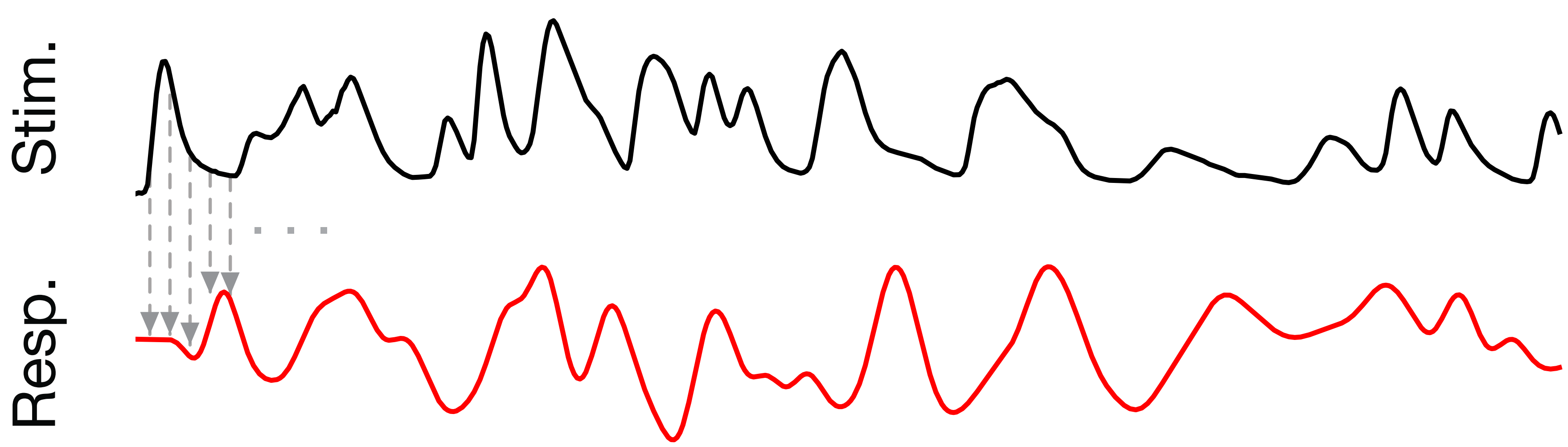
Convolve (∗) a response function  with a sparse signal



The same response function with a more dense signal:



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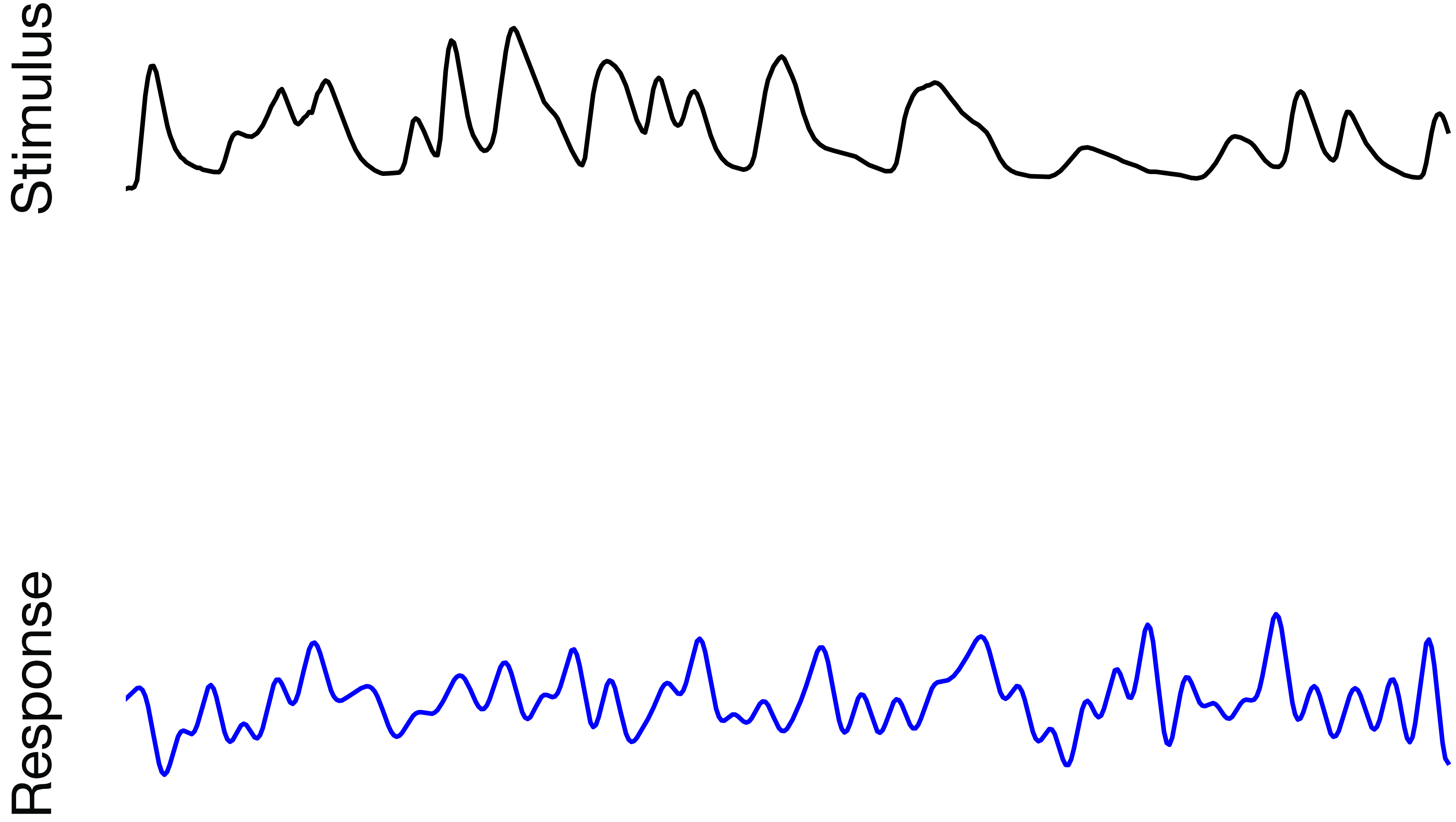
Stimulus and response are known; find the best response function to produce the response from the stimulus:



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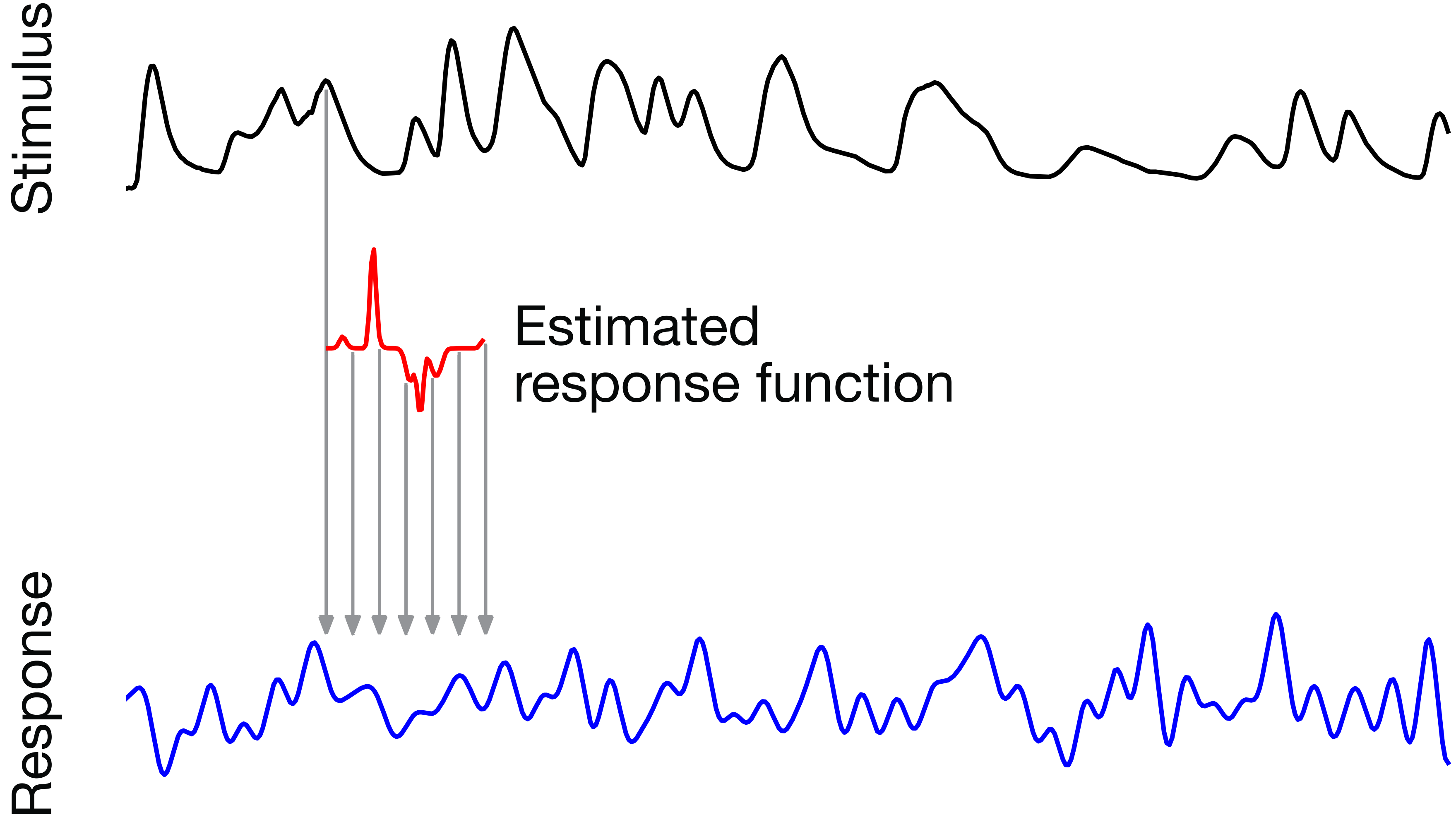

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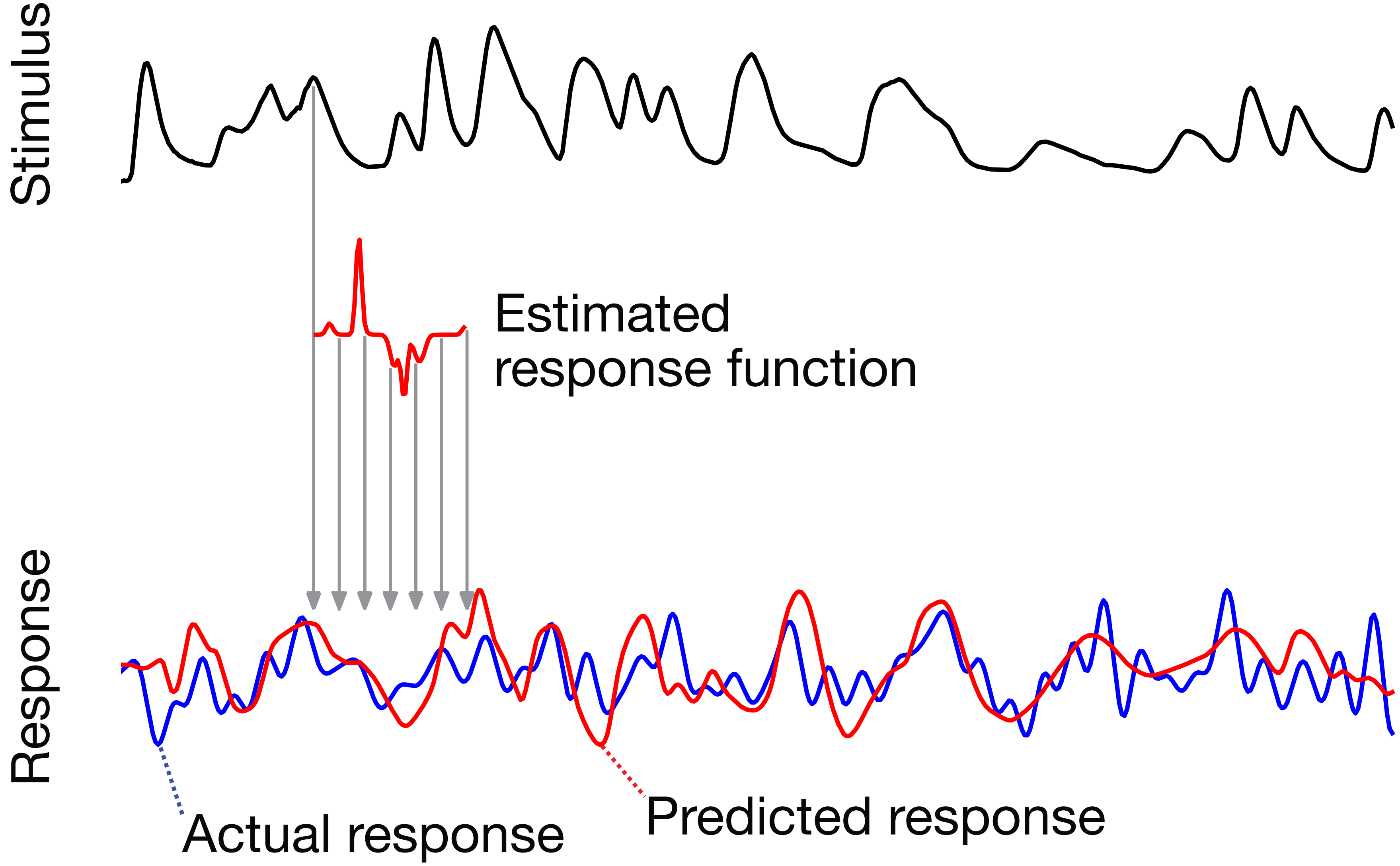

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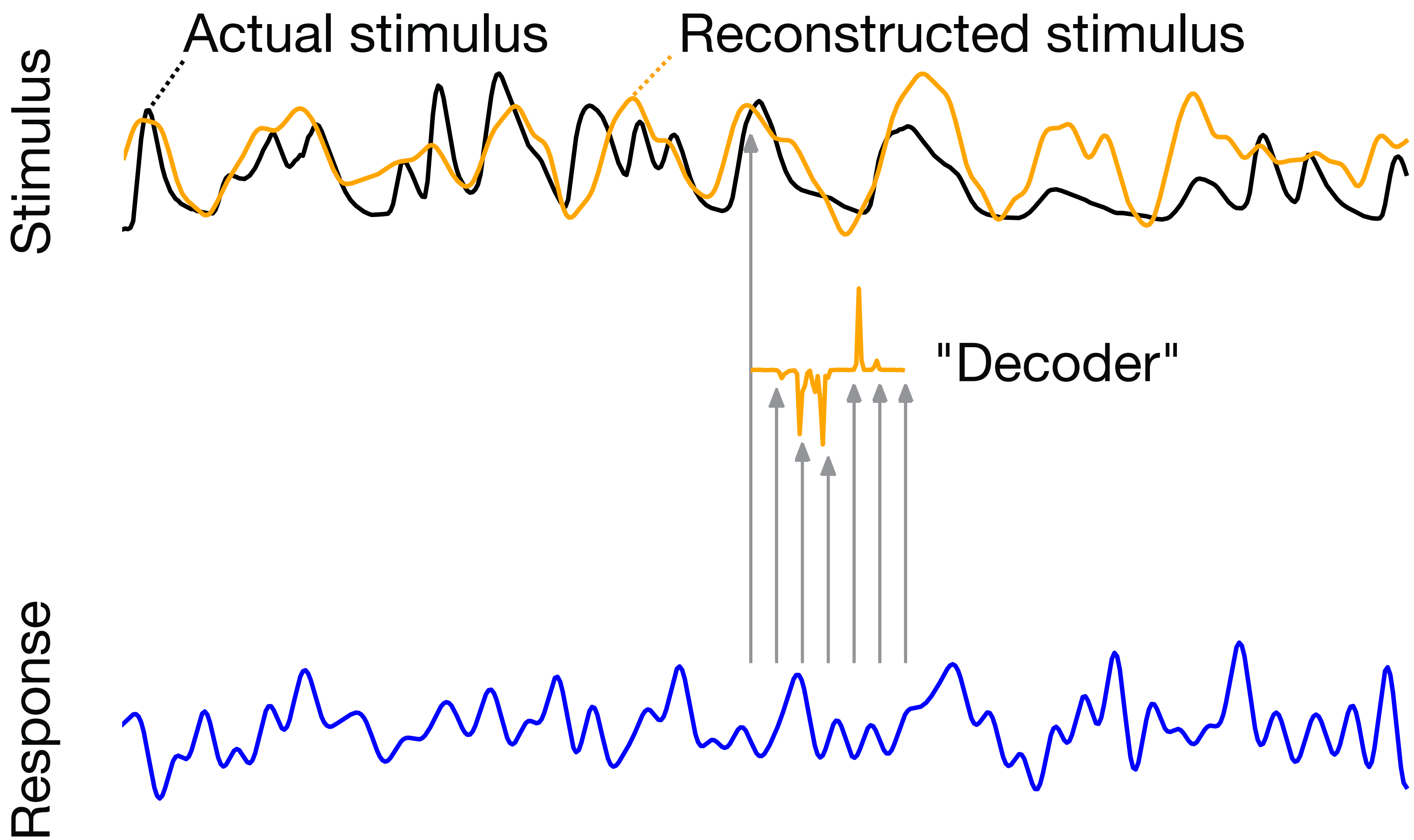


Methods

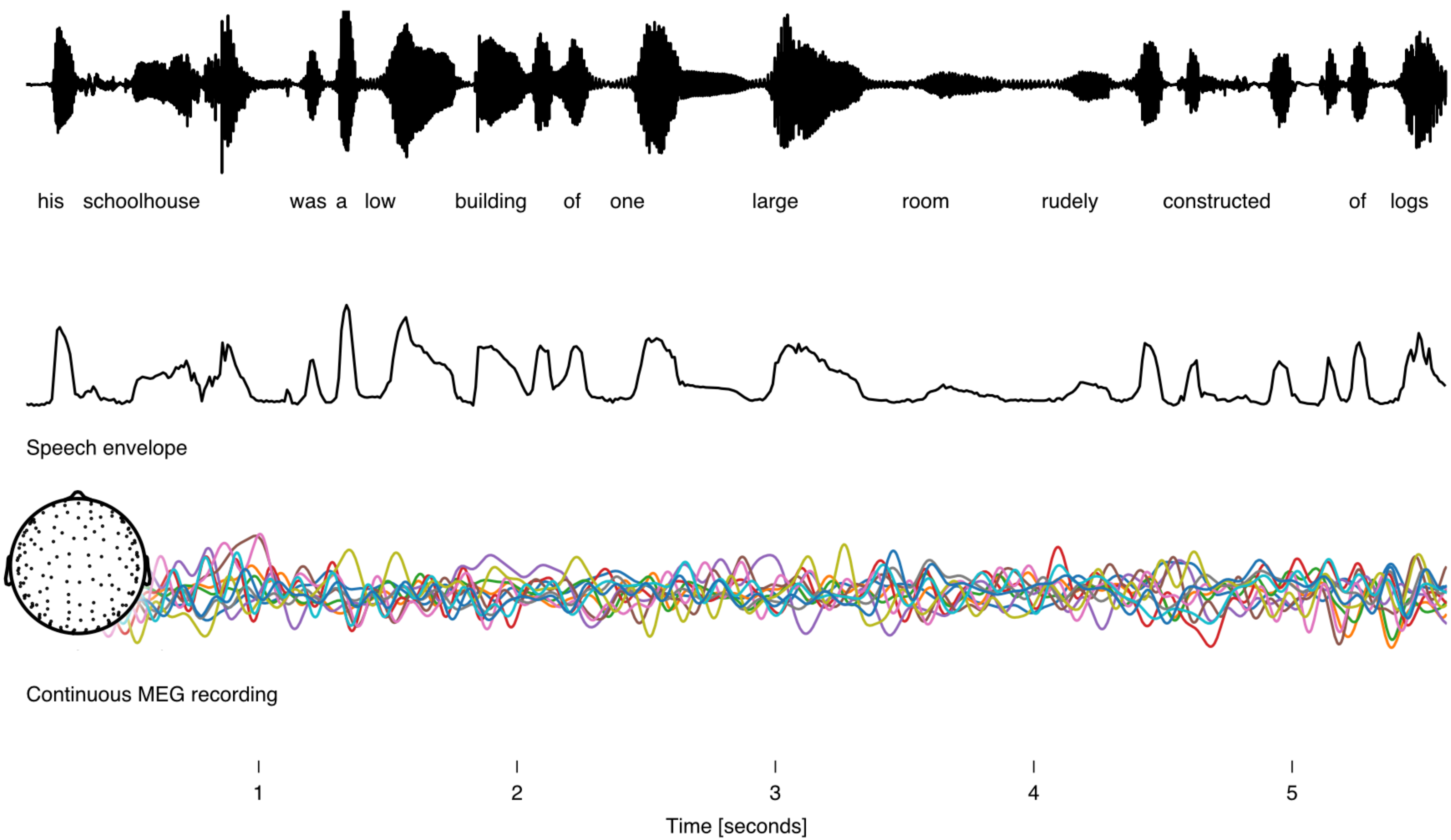
Design

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

Participants

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

Reconstructing speech envelope



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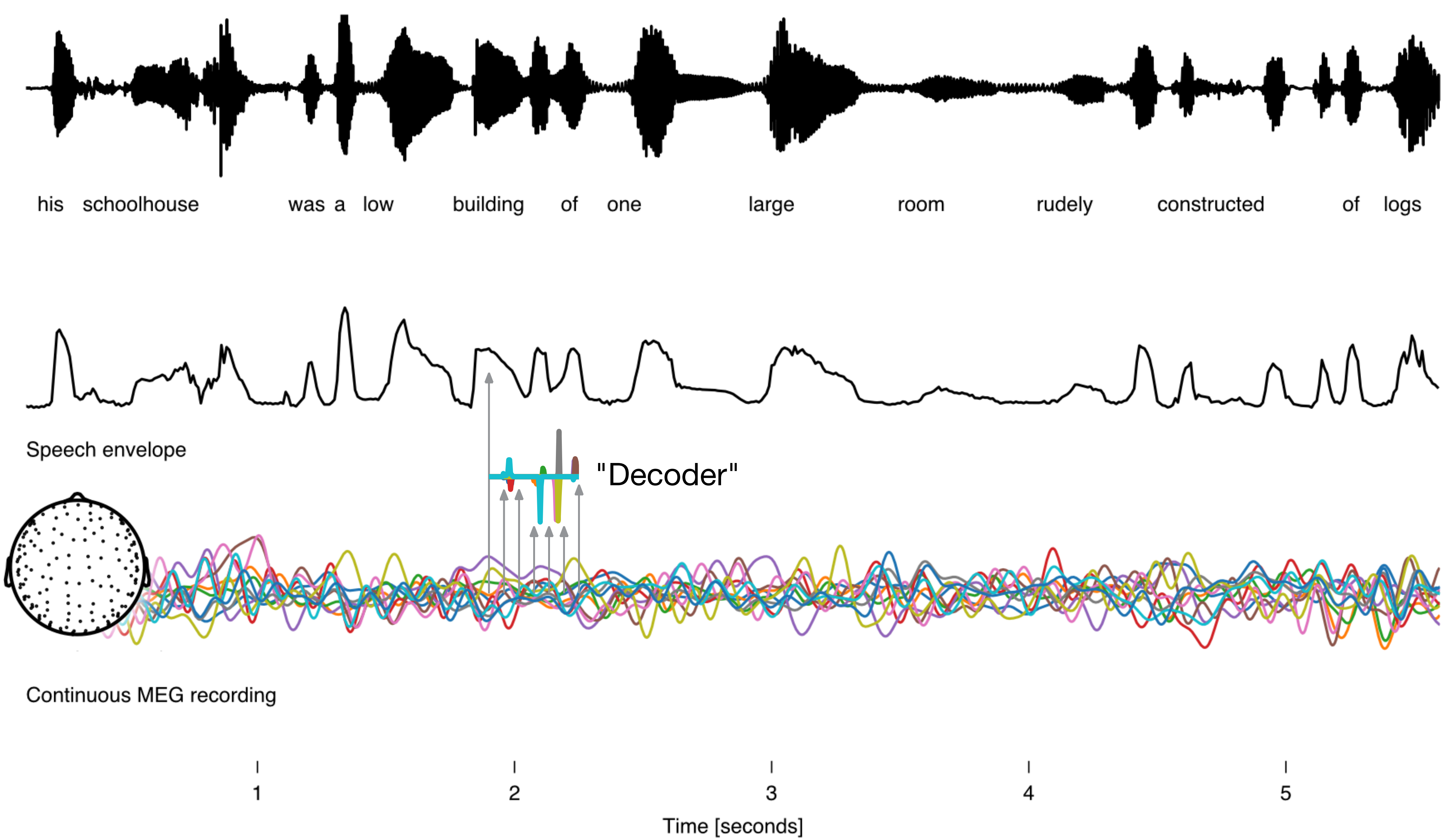
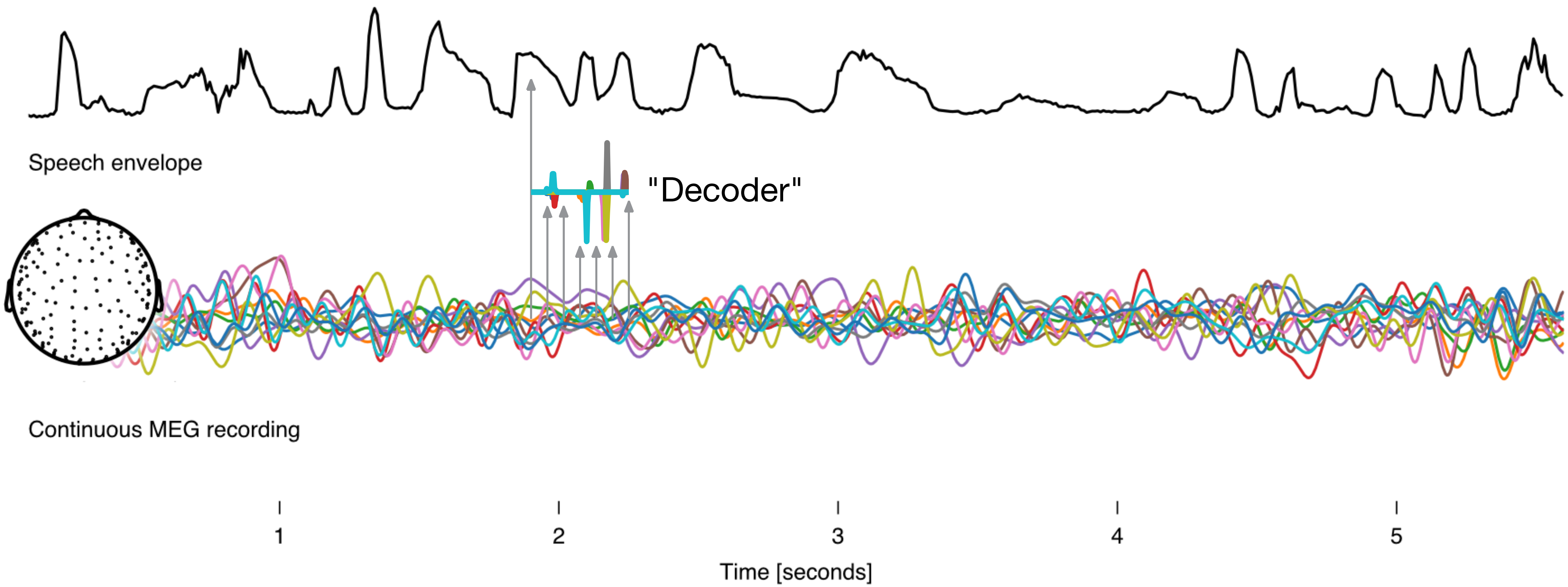
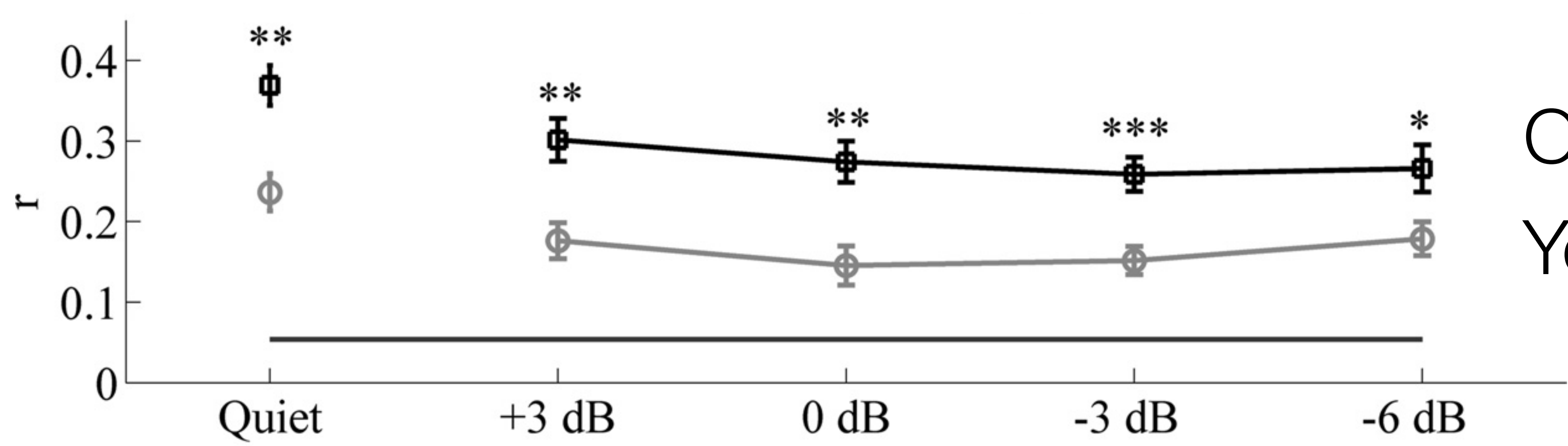


Decoding speech envelope





Older

Younger

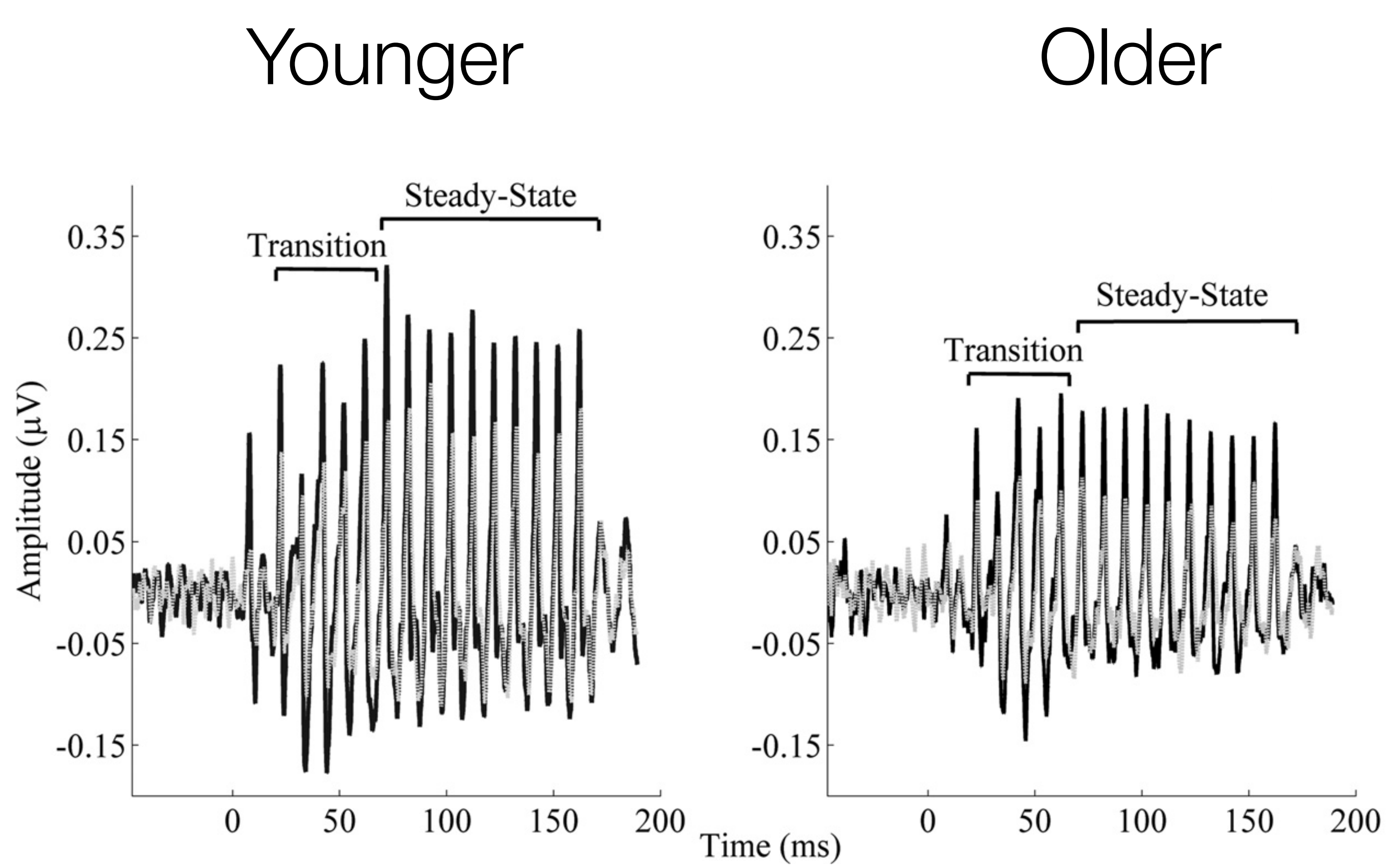
Cortex: older > younger

(Presacco, Simon, & Anderson, 2016)

Midbrain

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

Low level change, e.g., excitation/inhibition imbalance

- Decrease in cortical inhibition could lead to stronger evoked responses
  - Reduction in inhibitory neurons in A1 (de Villers-Sidani et al., 2010)
  - Increased firing rates in A1 (Overton & Recanzone, 2016)
- Prediction:
  - Even low latency responses show enhancement in older listeners, e.g., 30 ms

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- Higher level processes recruited to compensate for degraded input from the periphery
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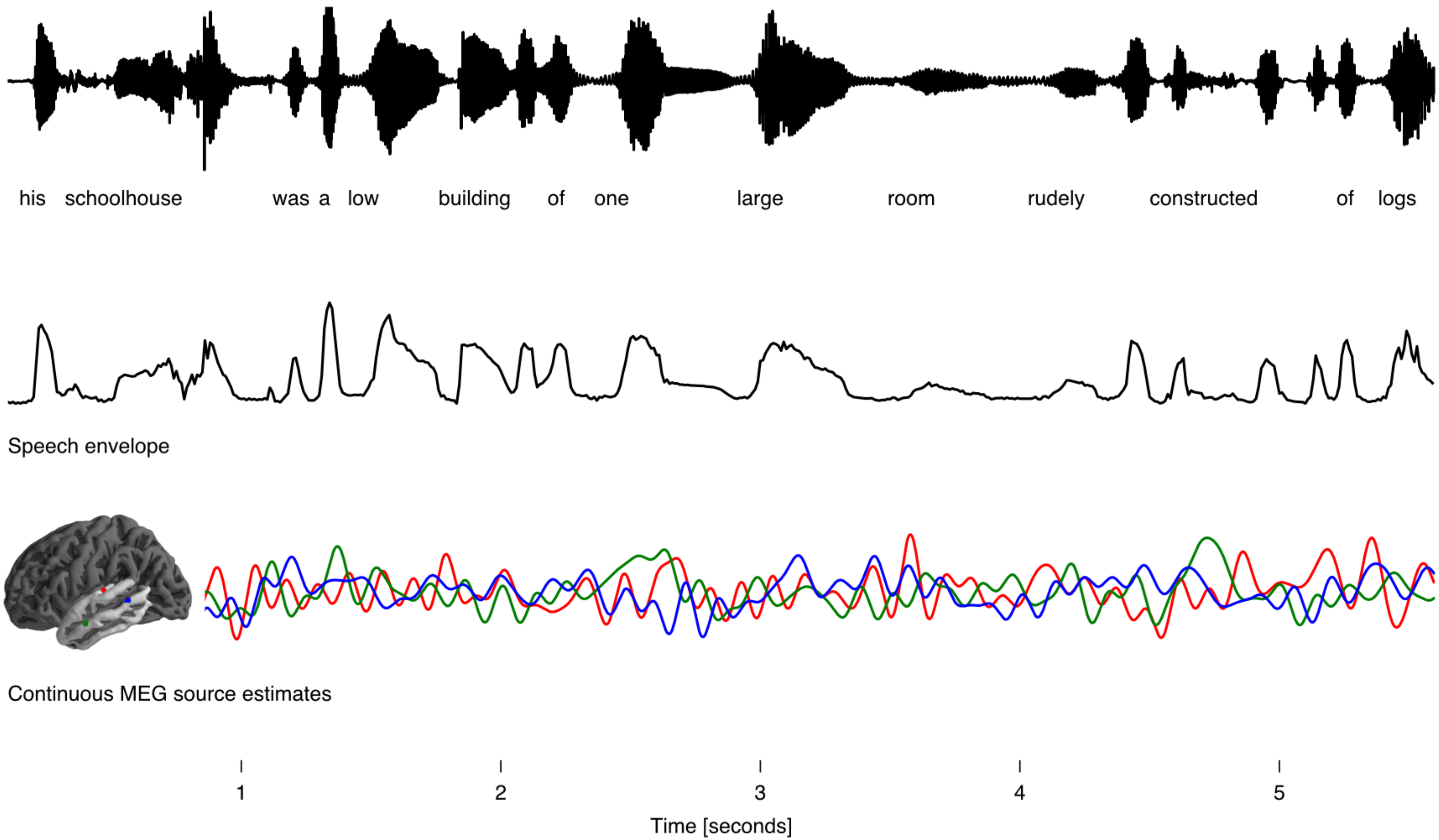
Attention

- Increased attention associated with stronger responses
  - Attention increases MEG response amplitudes with similar field topography (Woldorff et al., 1993)
- Prediction:
  - Similar spatial distributions of responses, but overall enhancement in older adults
  - More activity in core auditory areas

Encoding model



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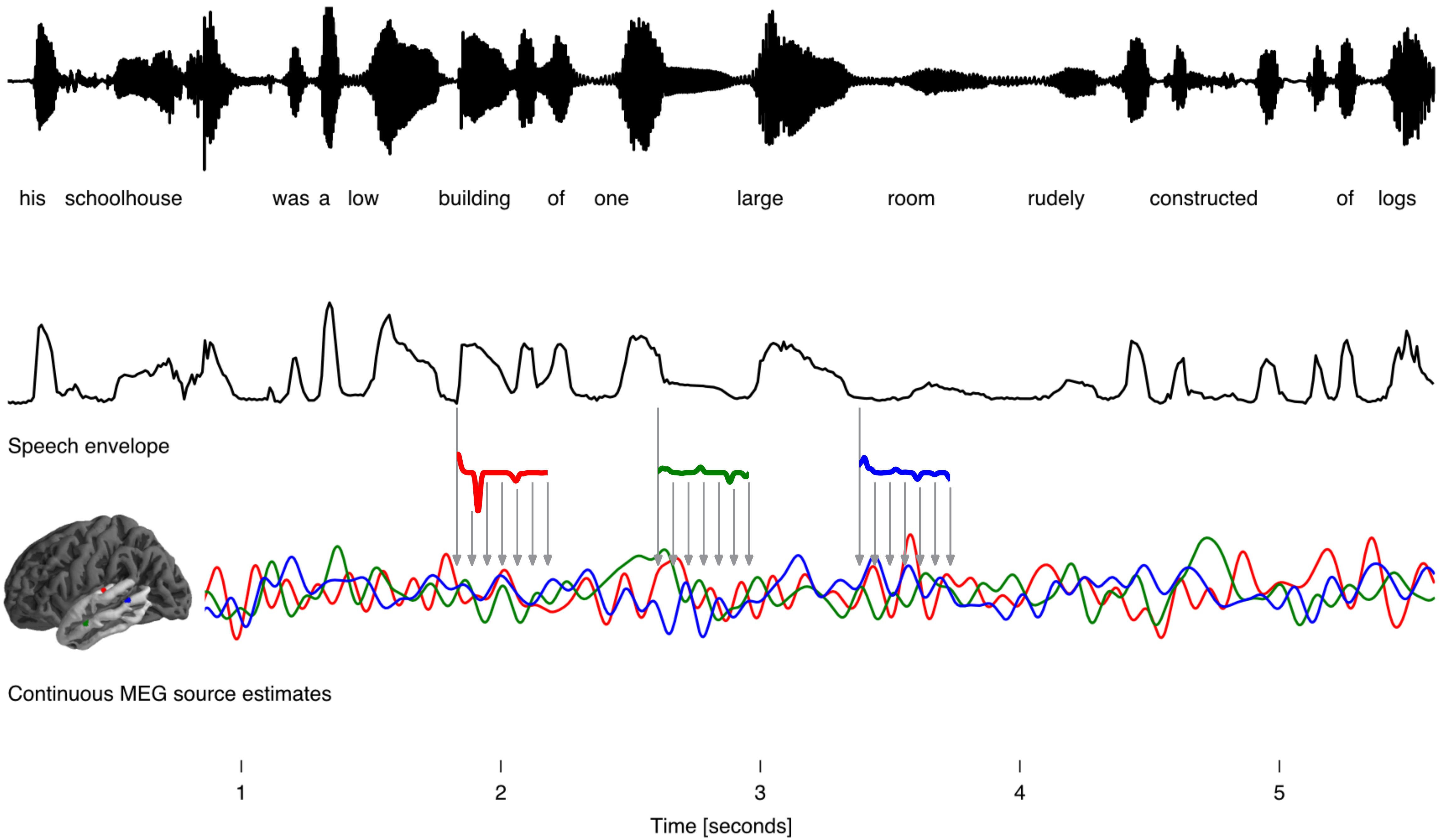


Statistics

Evaluate model predictions:

- Pearson correlation:
  r(predicted response, measured response)

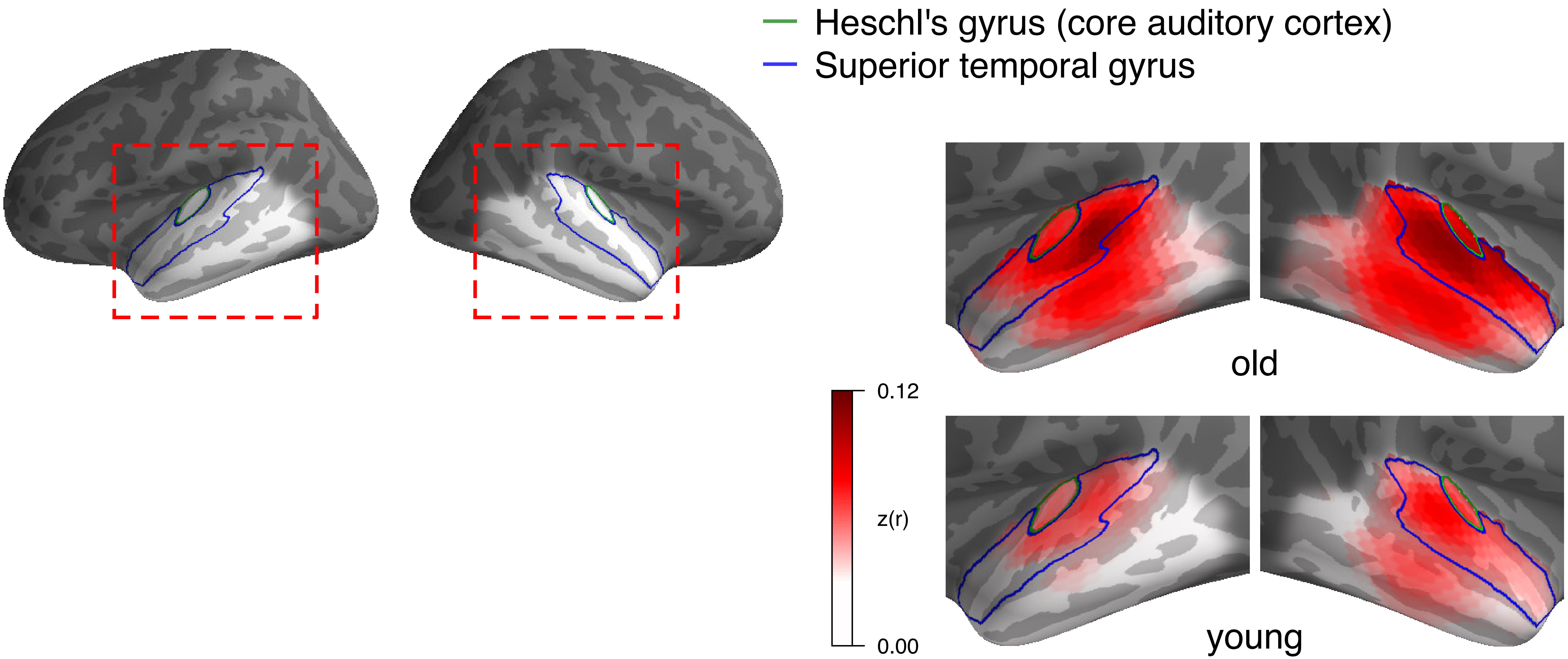
Bias-correction:

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

Significance test:

- Mass-univariate t-test
- Threshold-free cluster enhancement
- Max statistic distribution with 10,000 permutations

Localization



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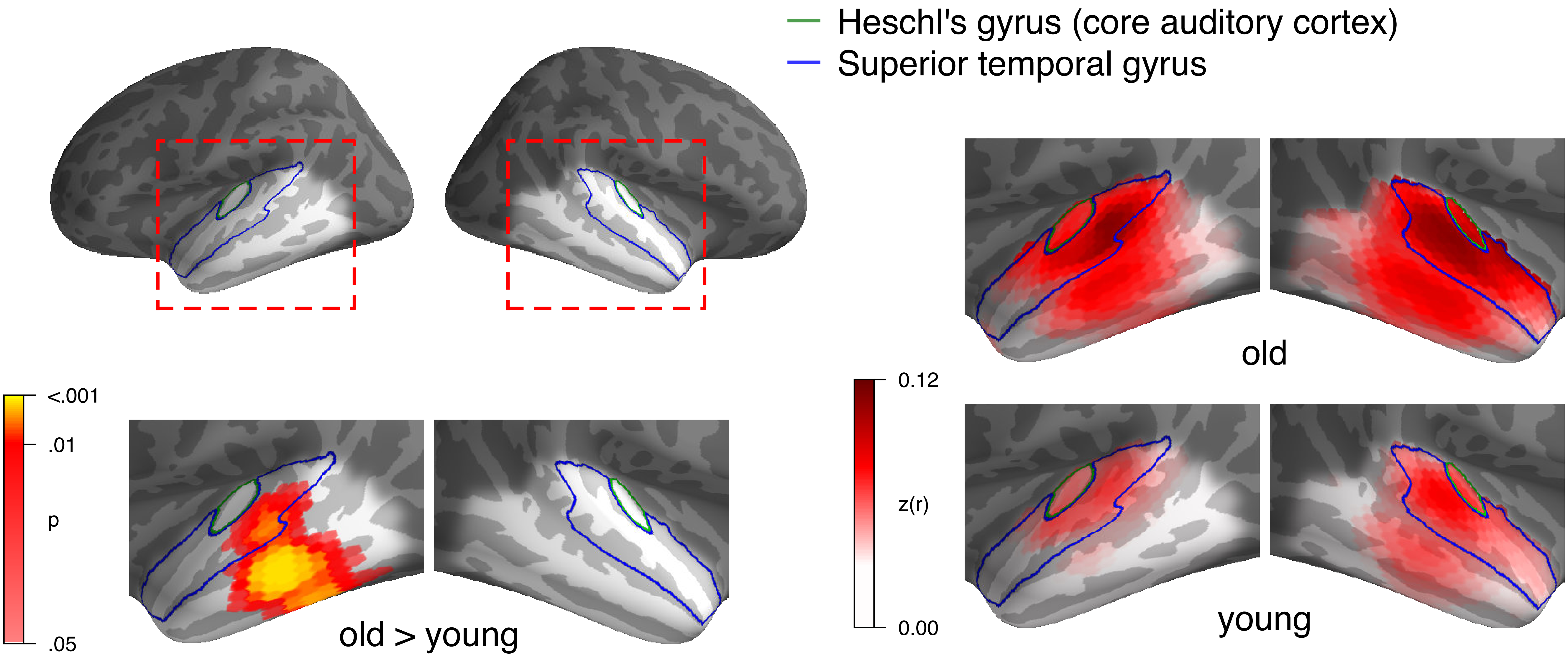

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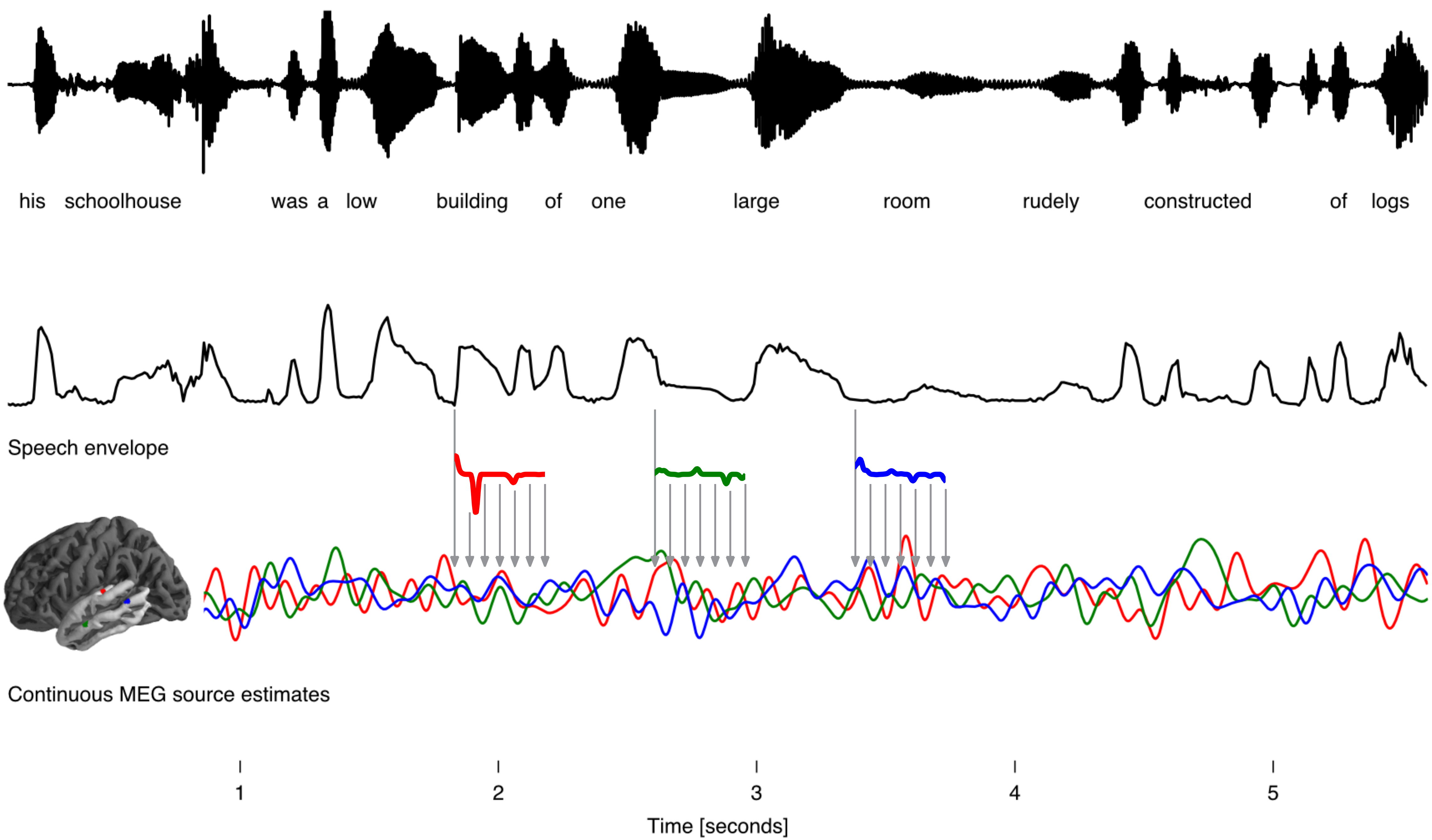
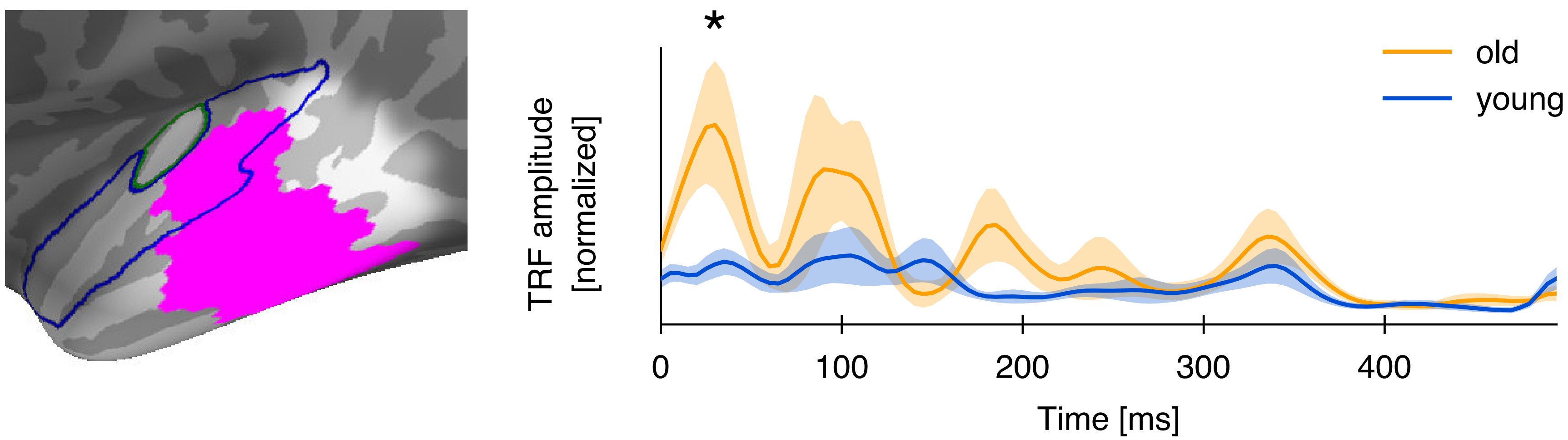


Temporal response function

Temporal response function (TRF)

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



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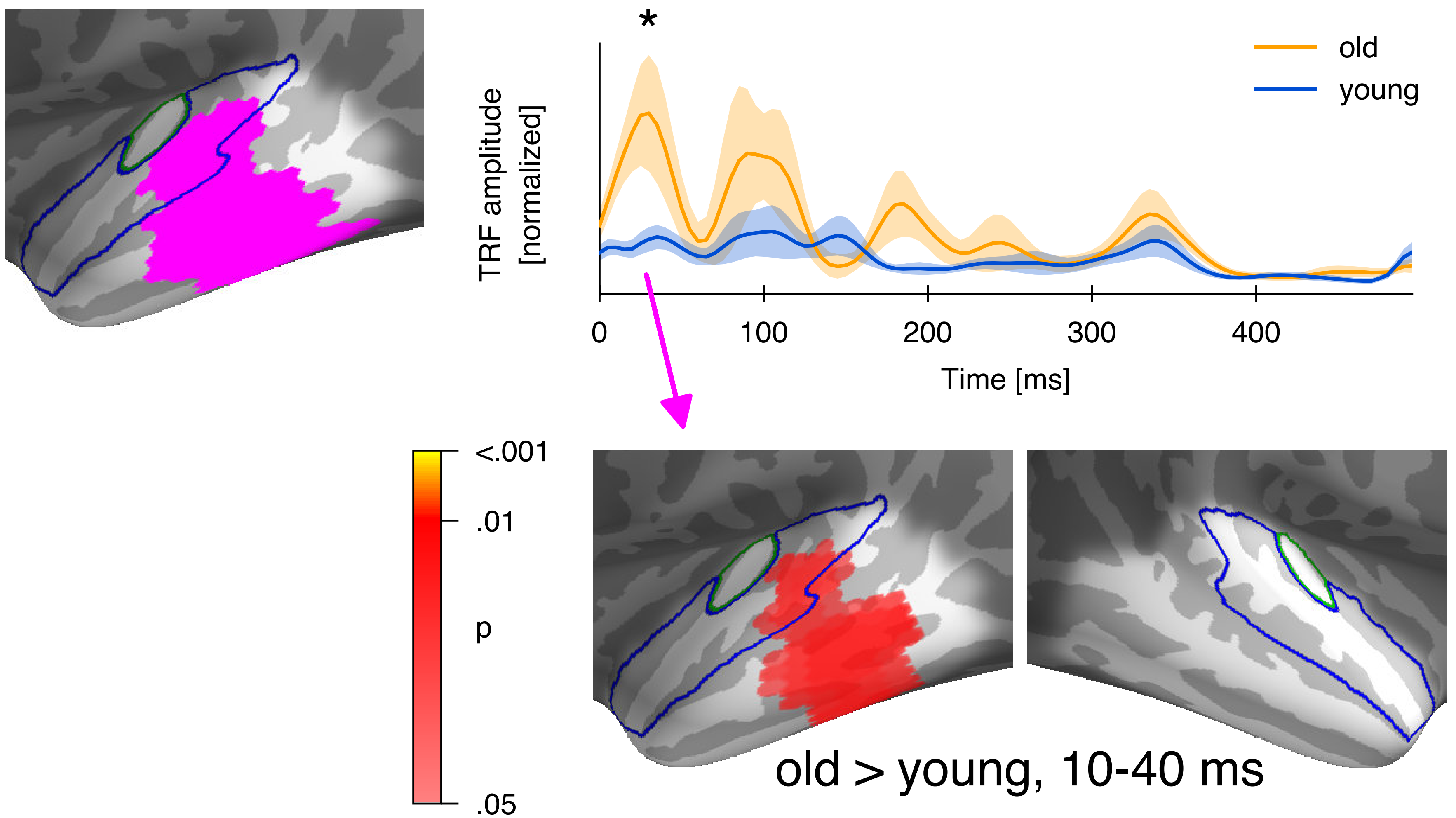


Summary

Over-representation of speech in older adults originates from early response in higher order auditory cortex

- Temporal lobe, outside of core auditory cortex
- Primarily affecting earliest cortical responses

~30 ms response

- ~~Strategic/top-down processing~~
  - Latency too short
- ~~Attention~~
  - Localized outside of core auditory cortex
- Low level change, e.g., excitation/inhibition imbalance
  - Short latency
  - Fast spread to areas outside core auditory cortex

Funding

NIH

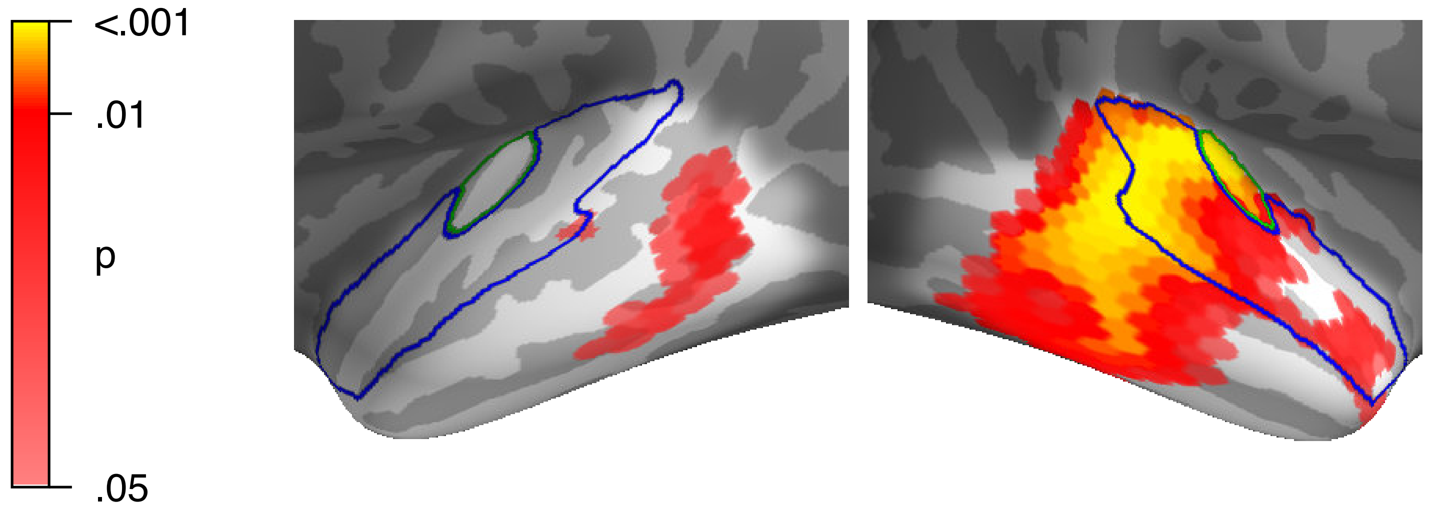
- Grant P01-AG055365

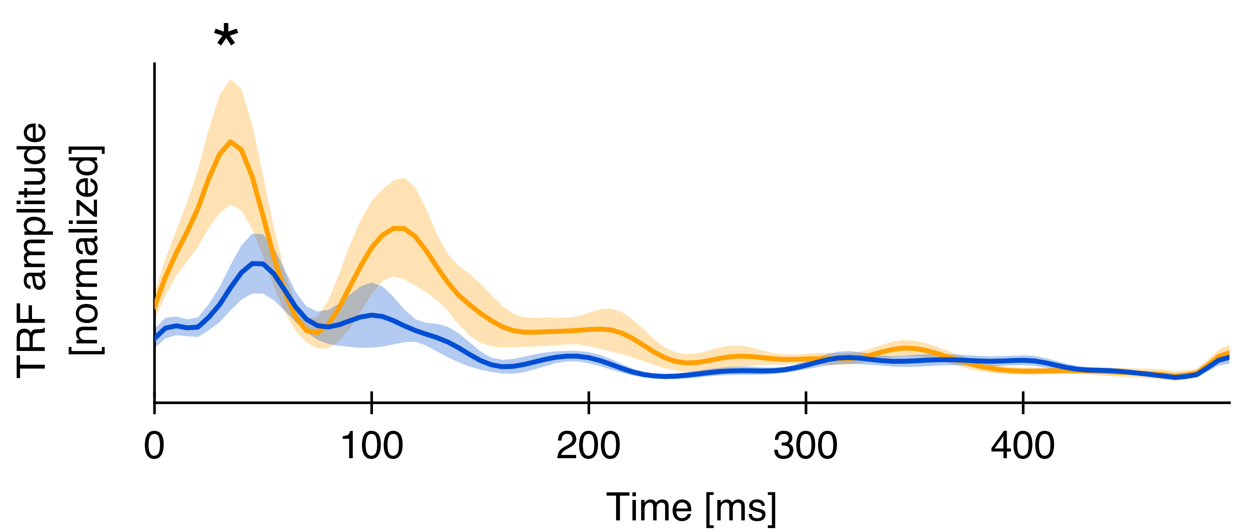
Appendix

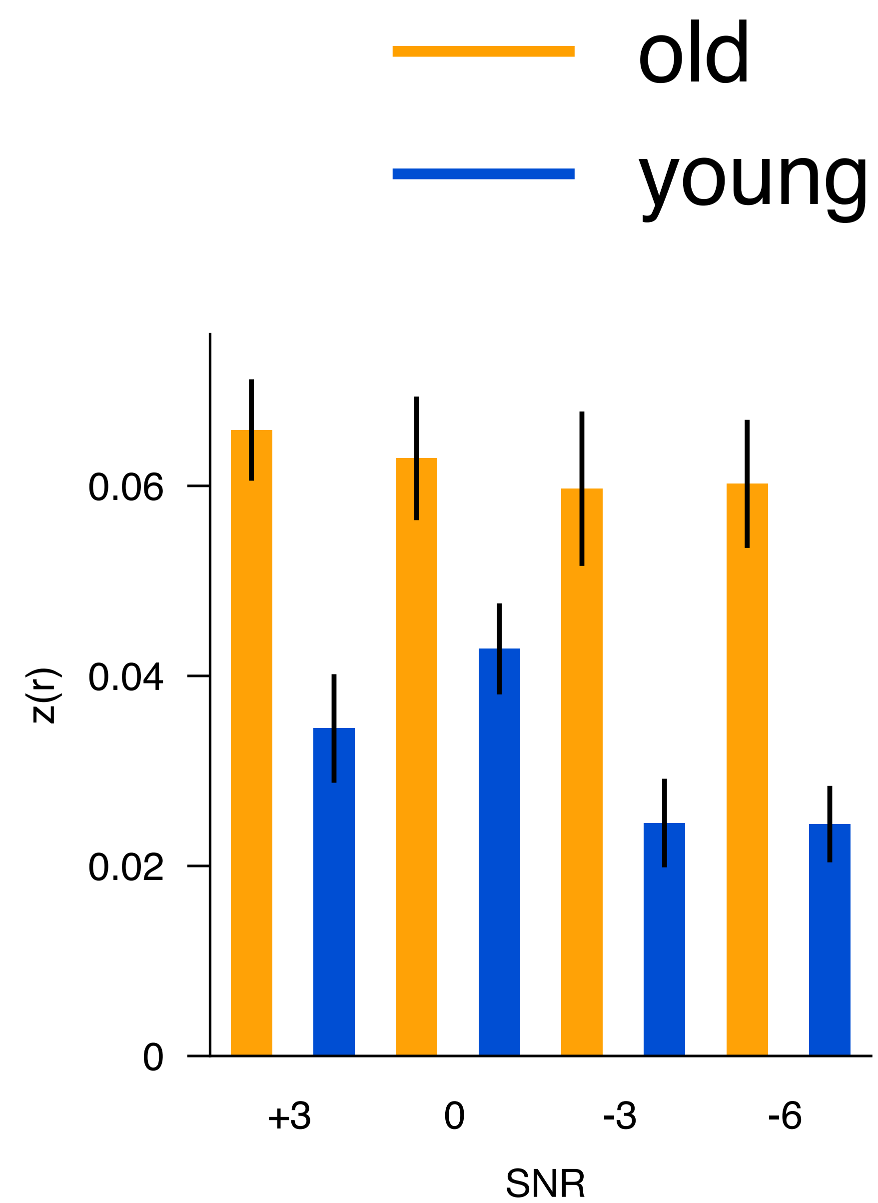
Mix of 2 speakers

ANOVA: Age (2) × SNR (4)

- Main effect of Age







MEG

Properties of MEG:

- Excellent temporal resolution (magnetic fields)
- Mediocre spatial resolution (inverse problem)
  - Relatively good estimation of center
  - Spatial dispersion

Simulation (Minimum Norm Estimates):