Neural Representations of the Cocktail Party in Human Auditory Cortex

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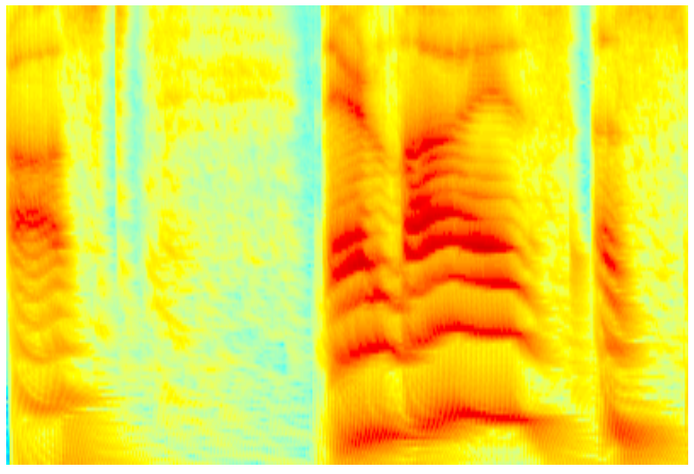
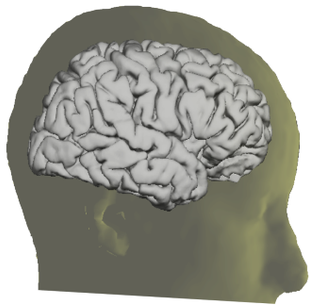
Introduction

- Magnetoencephalography (MEG) & Speech
- Speech as example of Auditory Object
- Neural Representations of Auditory Objects (e.g., speech) in Auditory Cortex

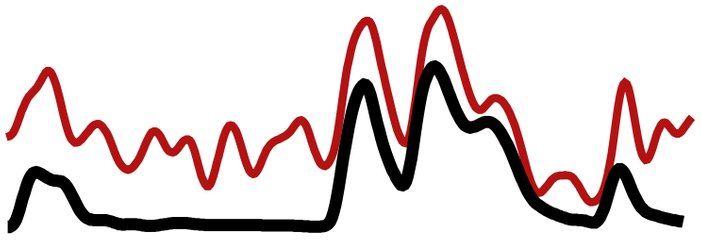
MEG Responses to Speech



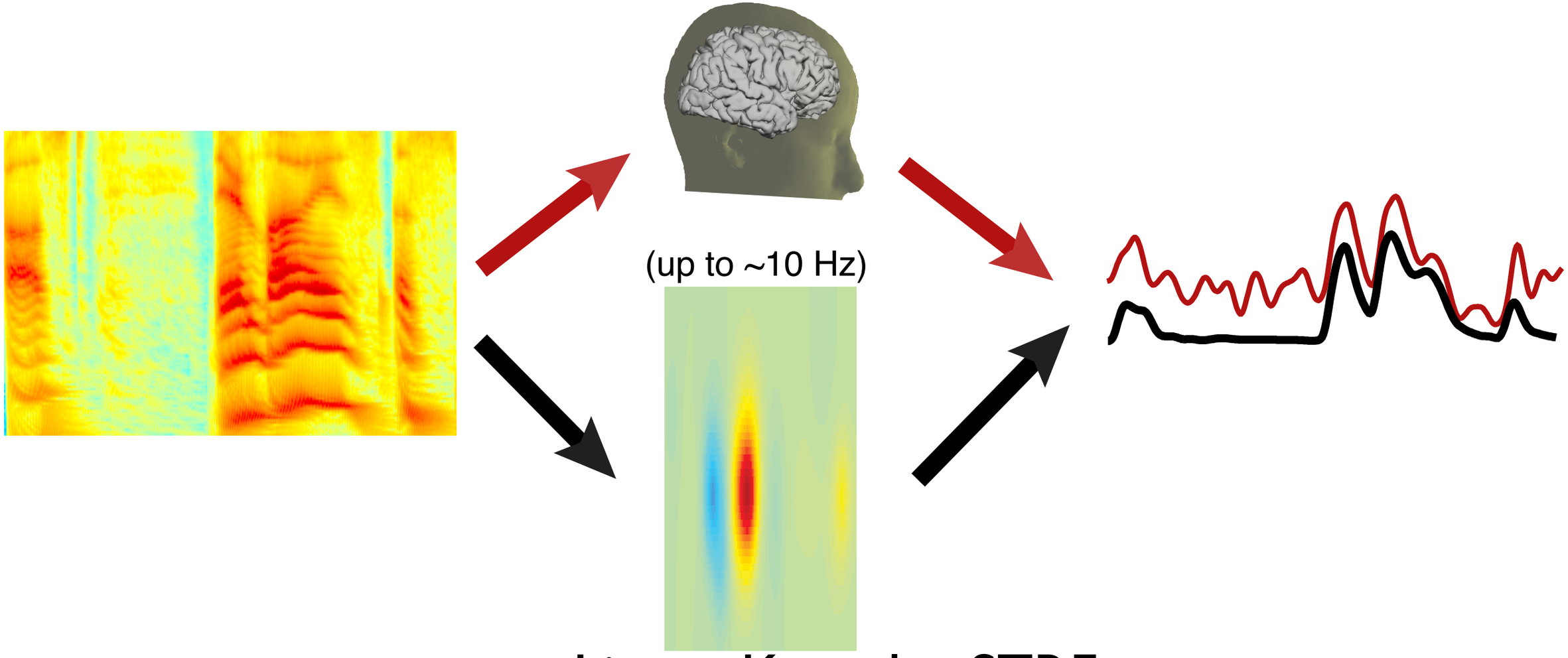


(up to ~10 Hz)

Auditory Model



MEG Responses Predicted by STRF Model

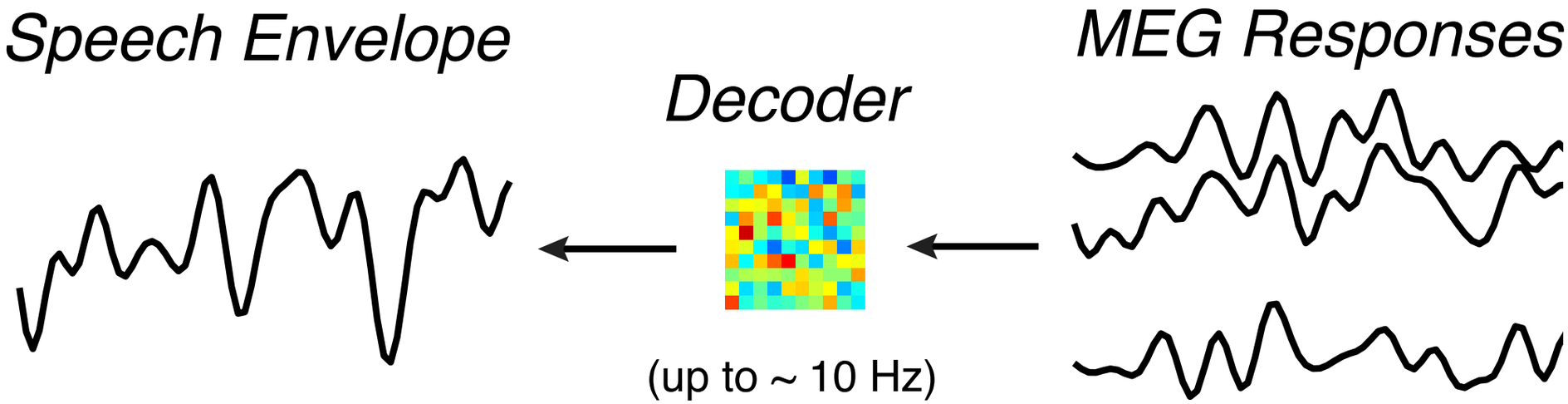


Linear Kernel = STRF

"Spectro-Temporal Response Function"

Ding & Simon, J Neurophysiol (2012)

Neural Reconstruction of Speech Envelope



Auditory Objects

- What is an auditory object?
  - perceptual (not neural, not acoustic)
  - commonalities with visual objects
  - example: speech stream (“voice”)
  - several formal definitions

Auditory Object Definition

- Griffiths & Warren definition:
  - corresponds with *something* in the sensory world
  - object information *separate from* information of rest of sensory world
  - abstracted: object information *generalized over particular* sensory experiences

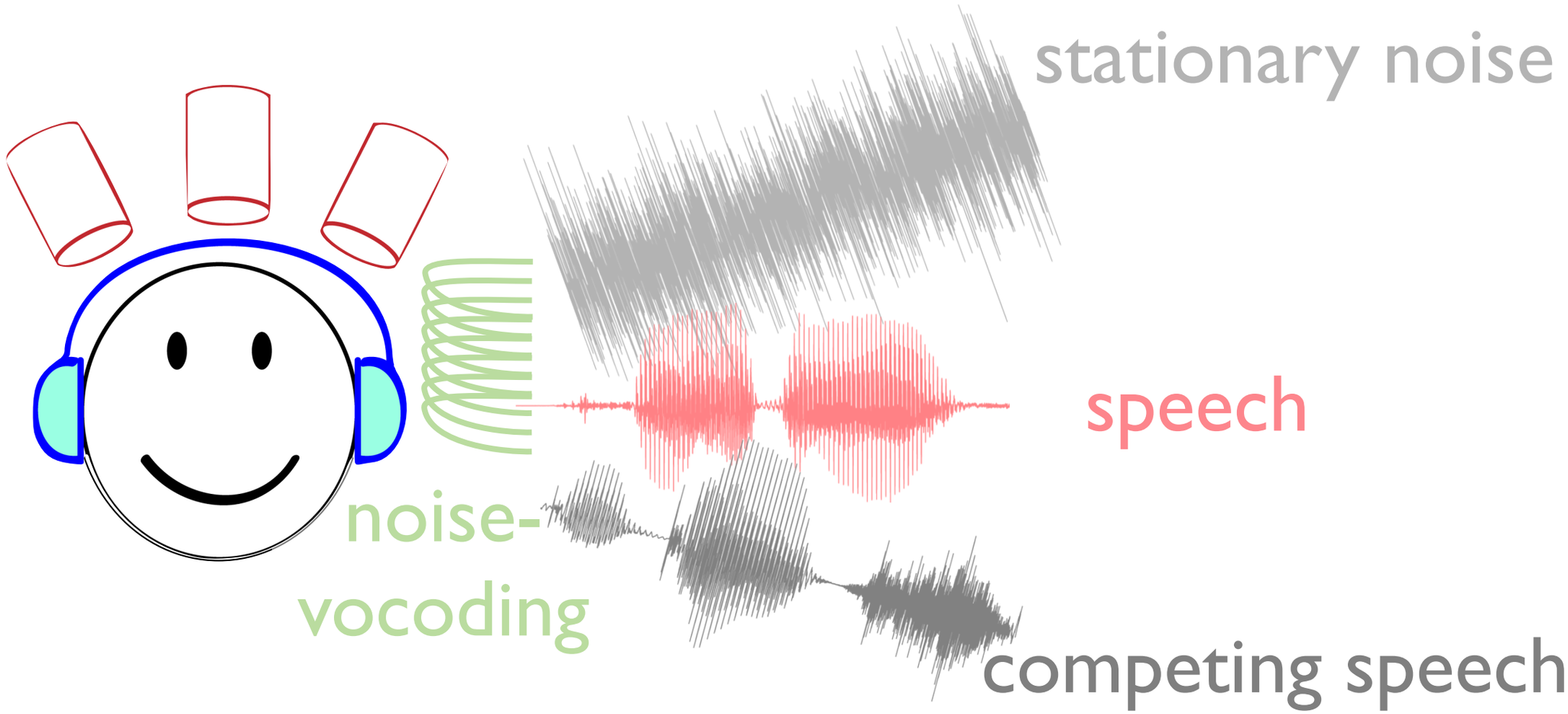
Auditory Objects at the Cocktail Party

Alex Katz,
The Cocktail Party

Auditory Objects at the Cocktail Party

Alex Katz,
The Cocktail Party

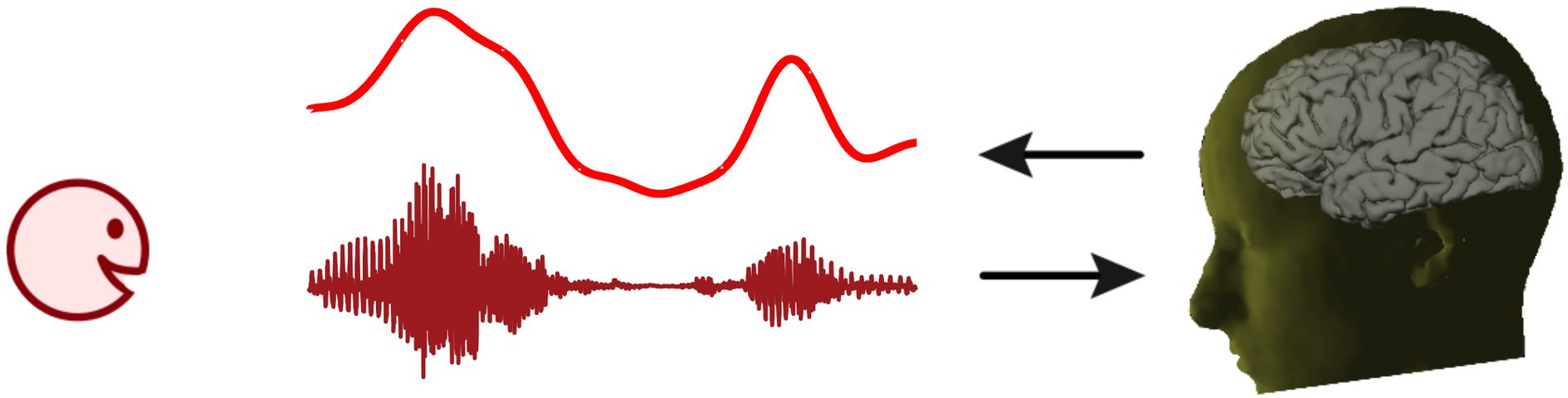
Experiments



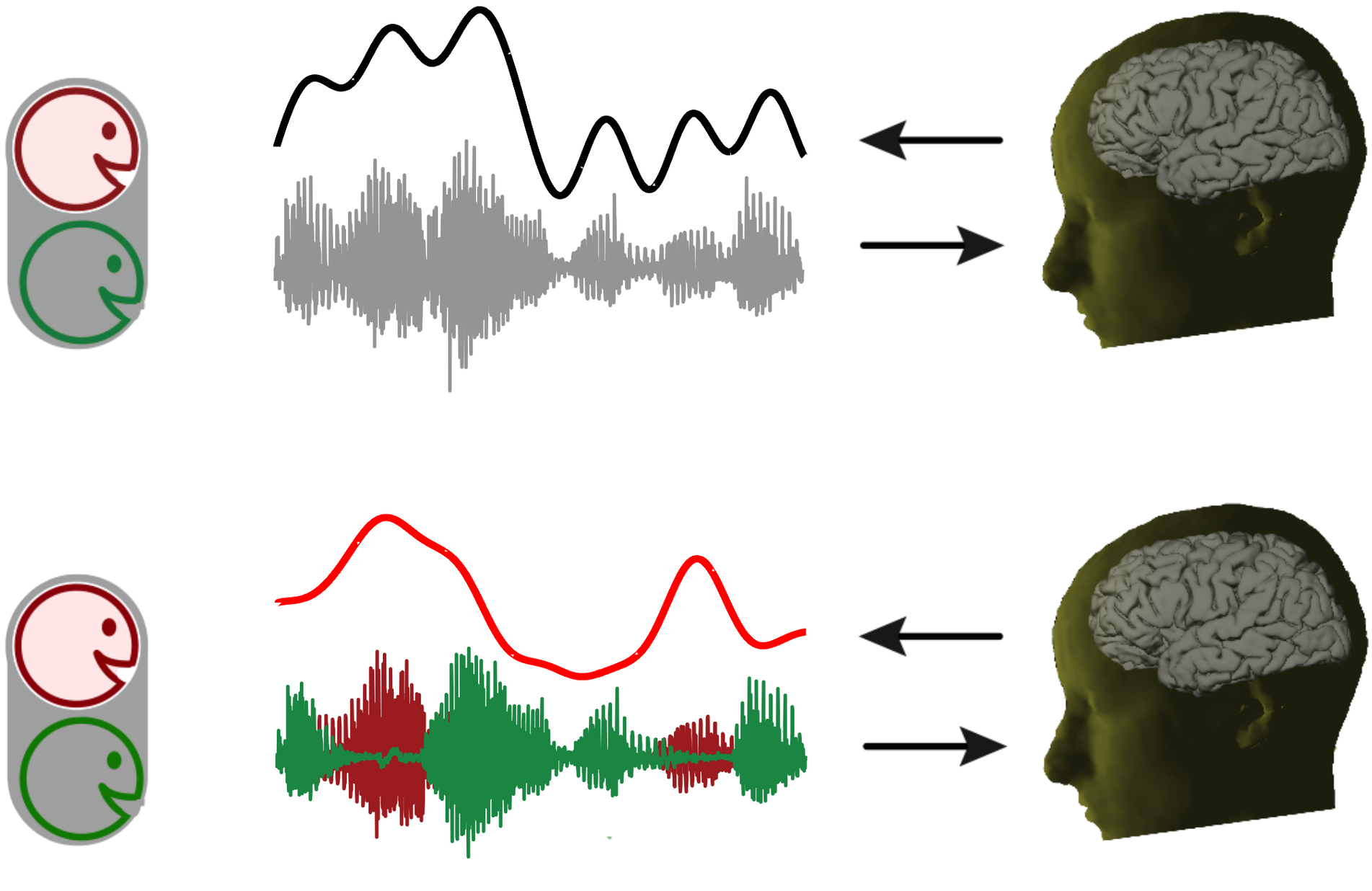
Neural Representation of an Auditory Object

- neural representation is of something in sensory world
- when other sounds mixed in,
  neural representation is of that auditory object, not entire acoustic scene
- neural representation invariant
  under broad changes in specific acoustics

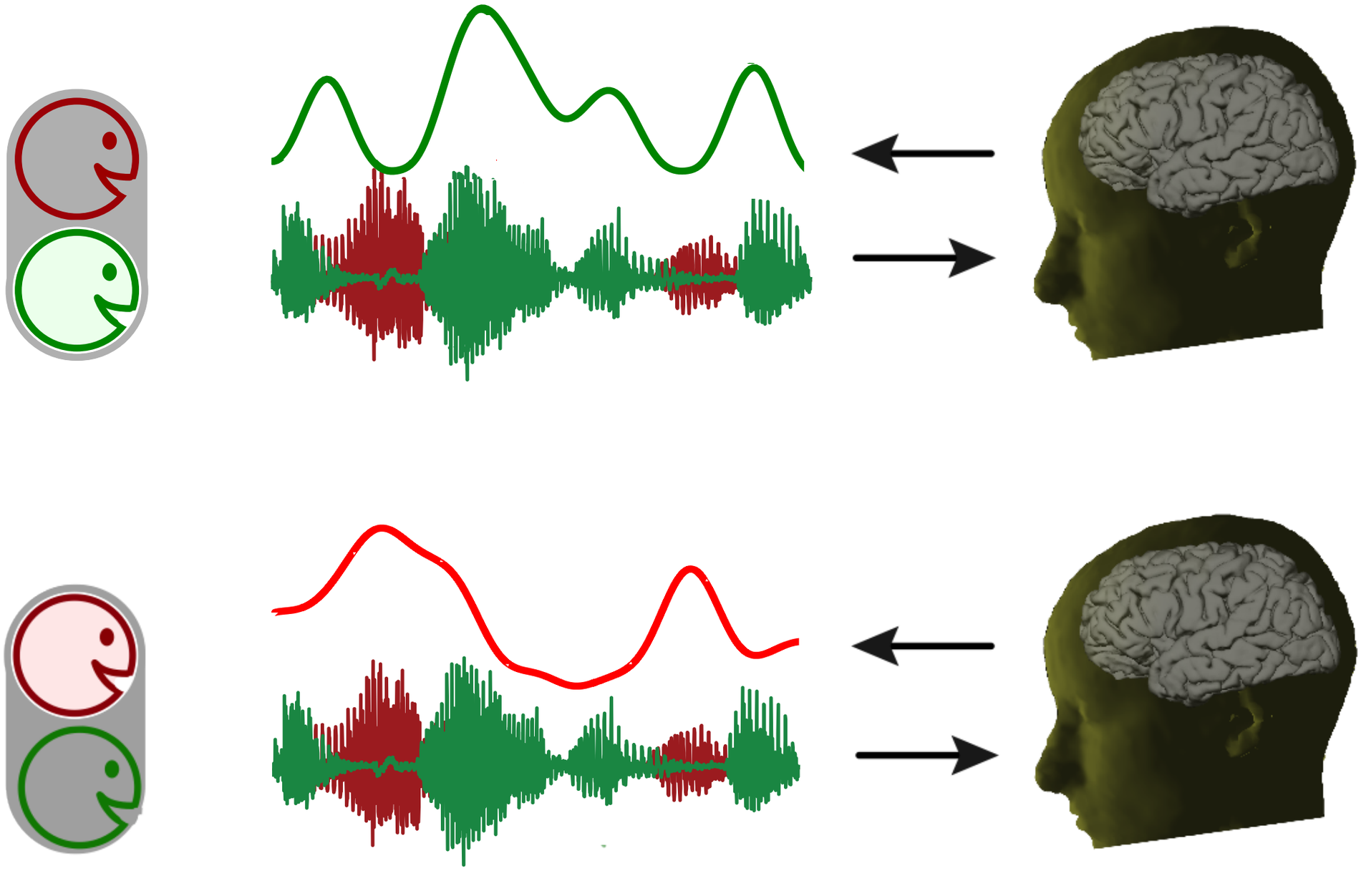
Selective Neural Encoding



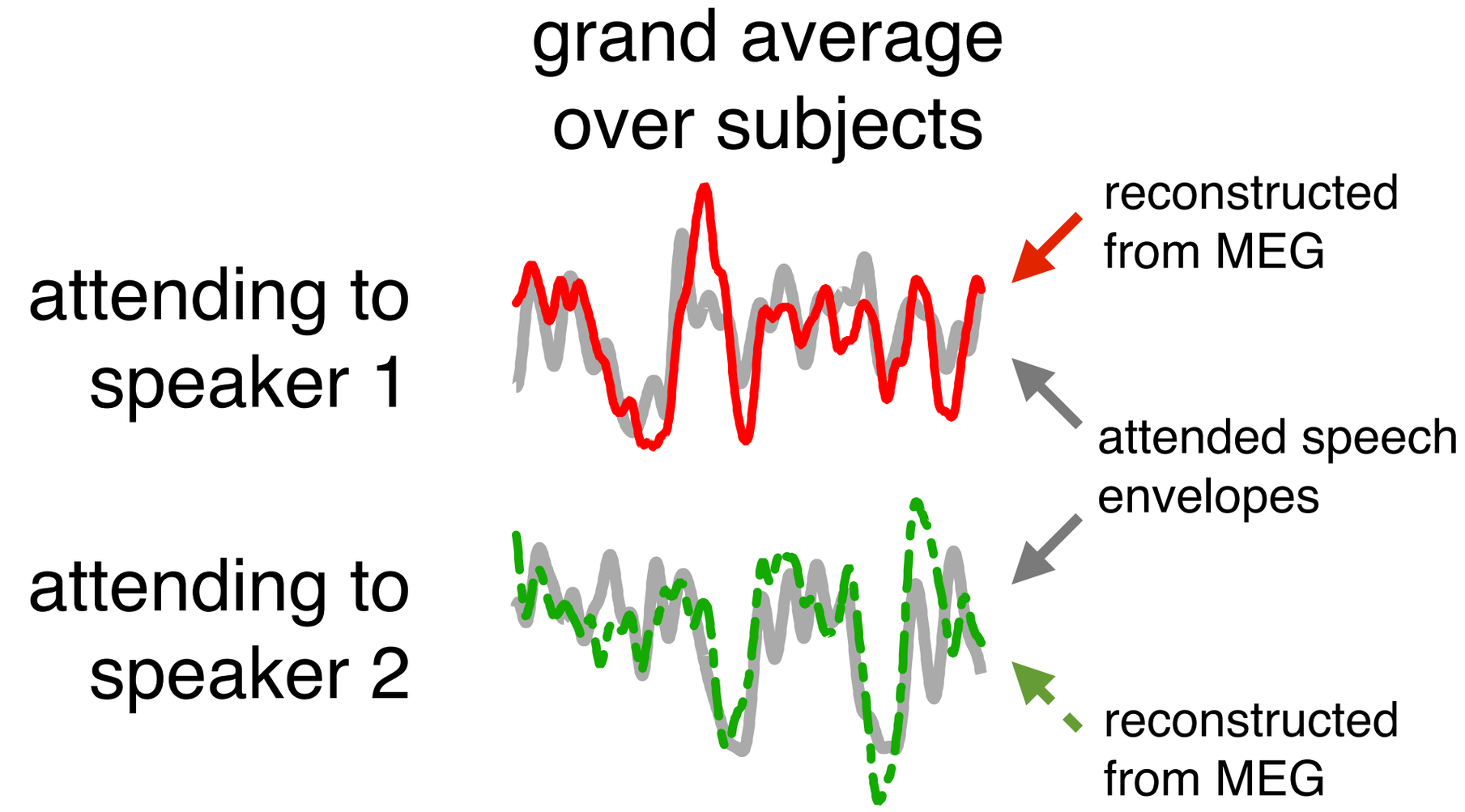
Unselective vs. Selective Neural Encoding



Selective Neural Encoding



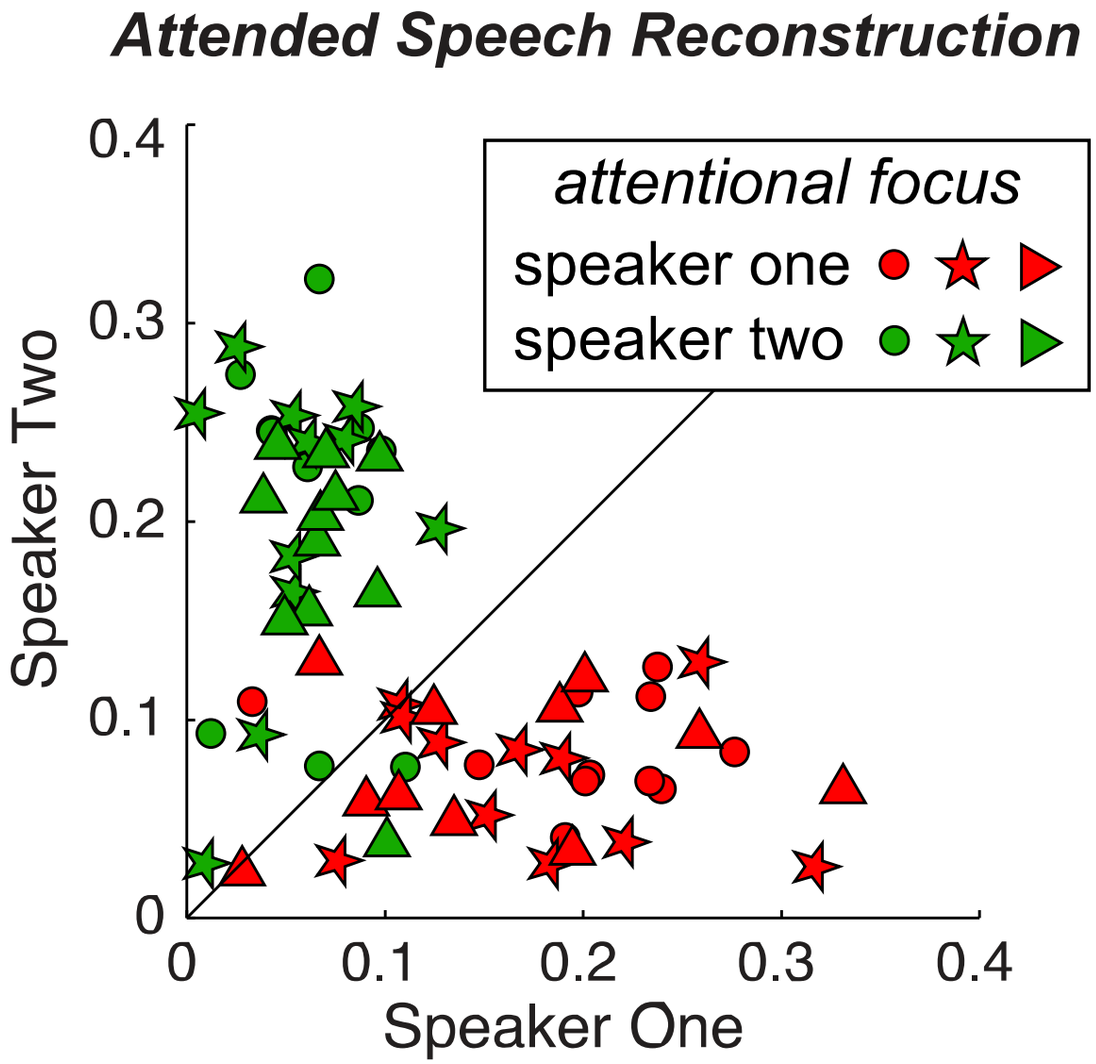
Stream-Specific Representation



Identical Stimuli!

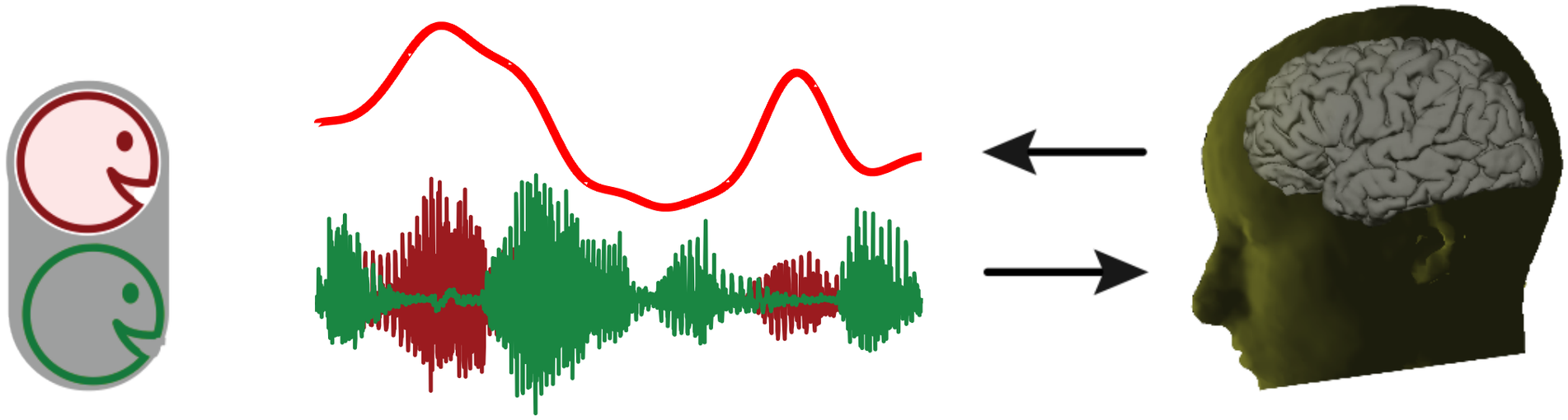
Ding & Simon, PNAS (2013)

Single Trial Speech Reconstruction



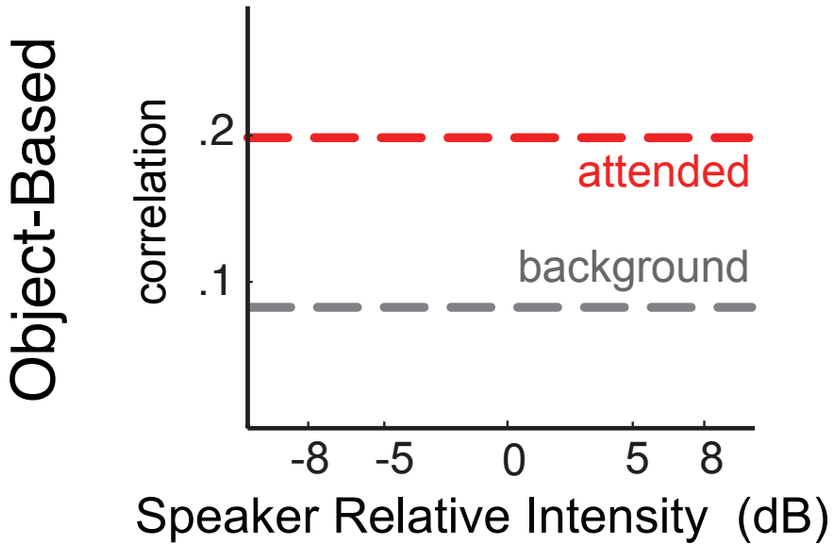
Ding & Simon, PNAS (2013)

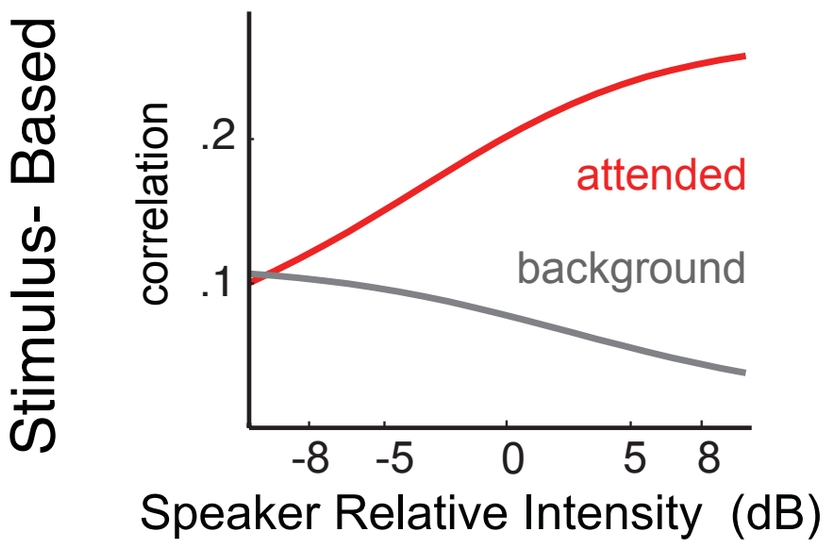
Invariance Under Acoustic Changes



Independence from Acoustic Specifics

Neural Response vs. Acoustics





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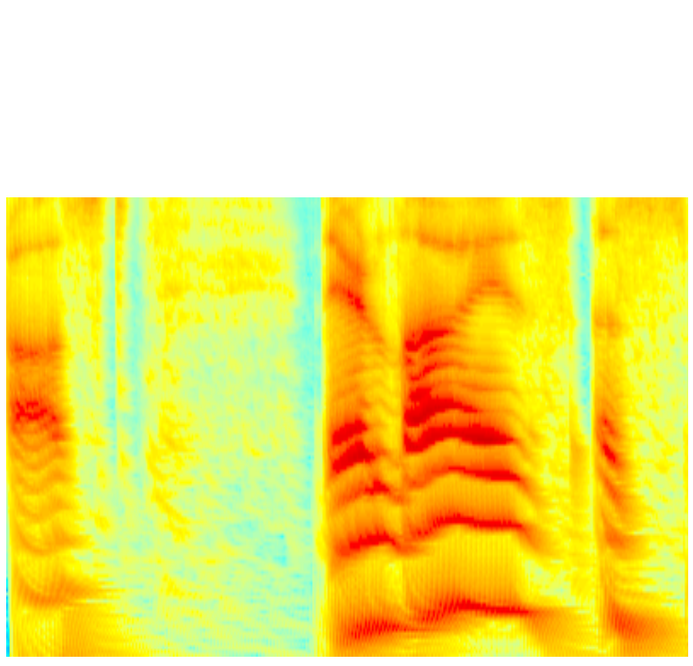
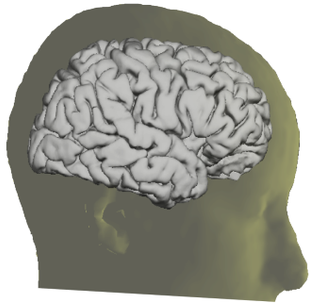
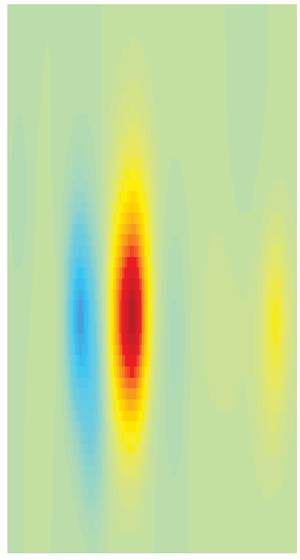
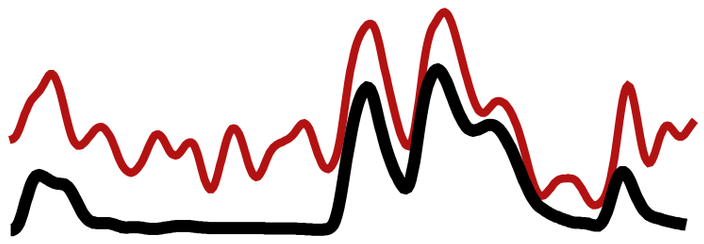
Forward STRF Model



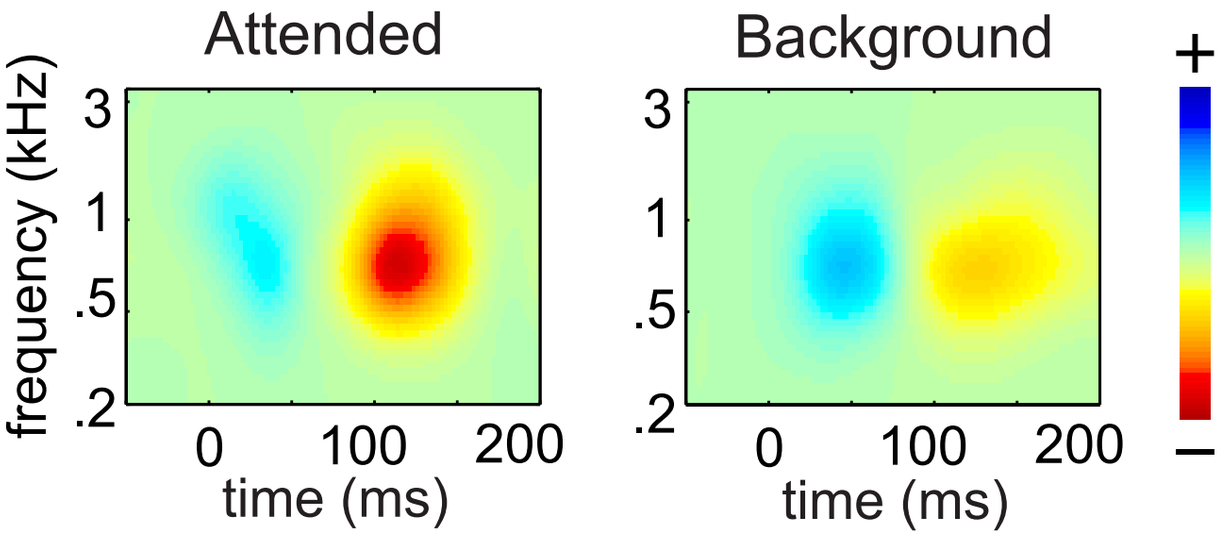






Spectro-Temporal Response Function (STRF)

STRF Results



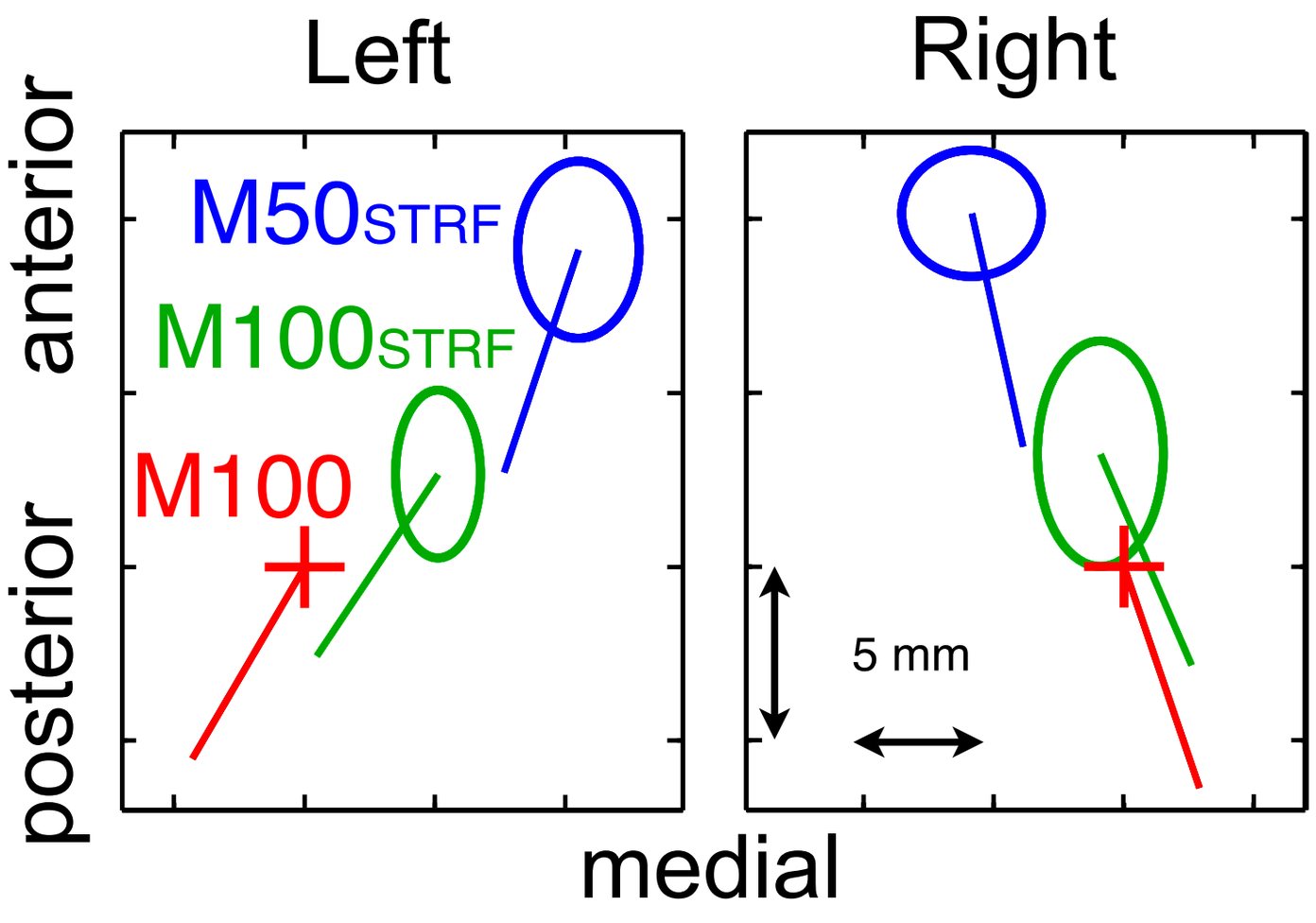
- STRF separable (time, frequency)
- 300 Hz - 2 kHz dominant carriers
- $M50_{STRF}$ positive peak
- $M100_{STRF}$ negative peak

- **$M100_{STRF}$ strongly modulated by attention, *but not $M50_{STRF}$***

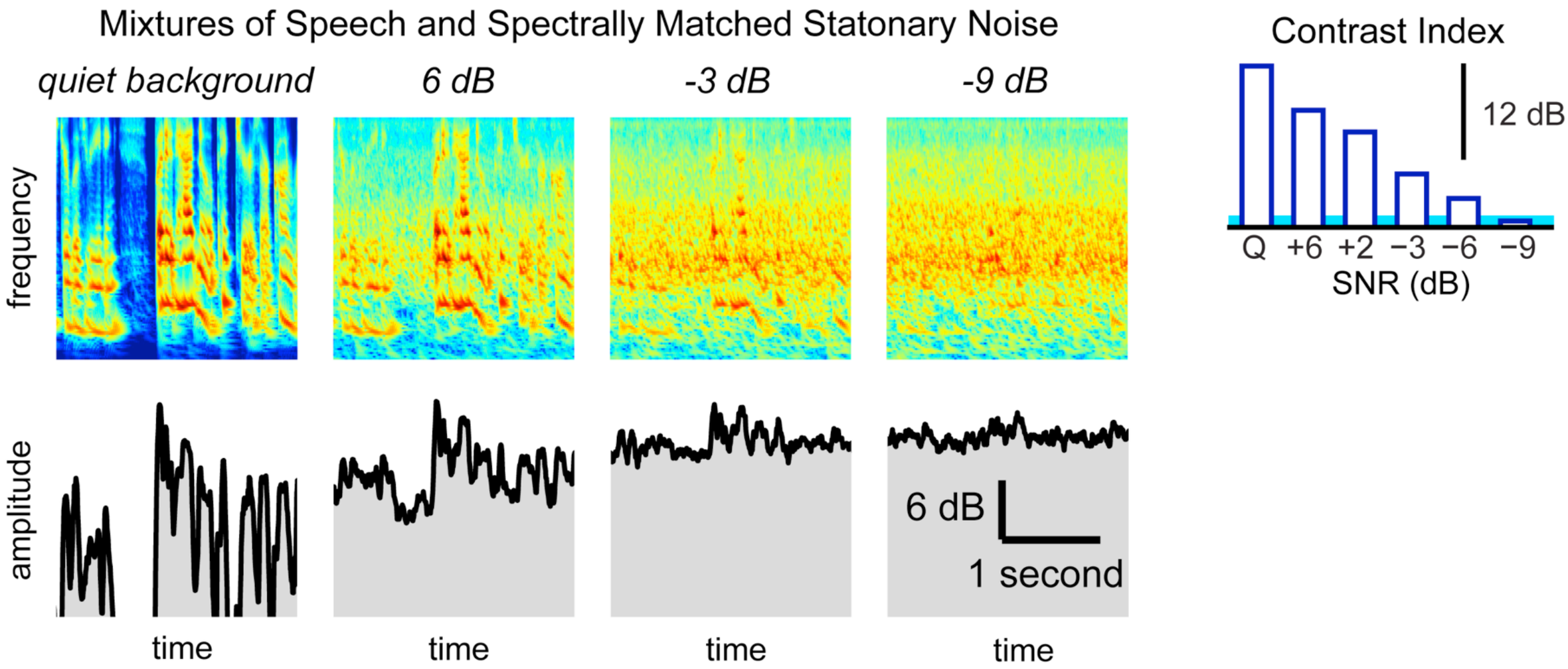
Neural Sources

- M100$_{STRF}$ source near (same as?) M100 source: Planum Temporale

- M50$_{STRF}$ source is anterior and medial to M100 (same as M50?): Heschl's Gyrus

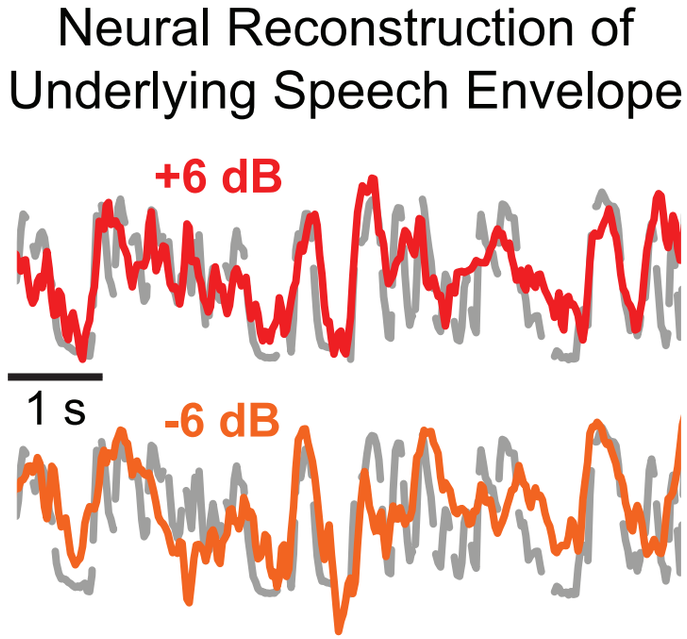


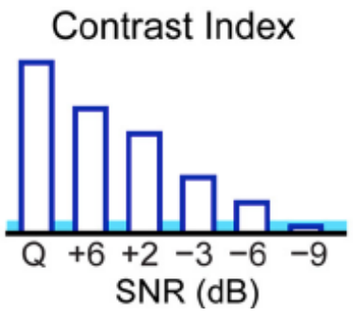
Speech in Noise

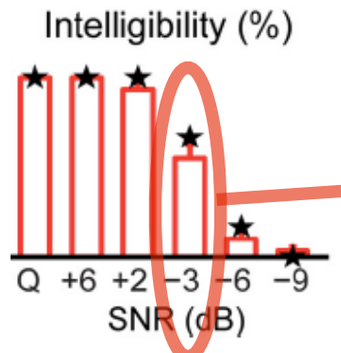


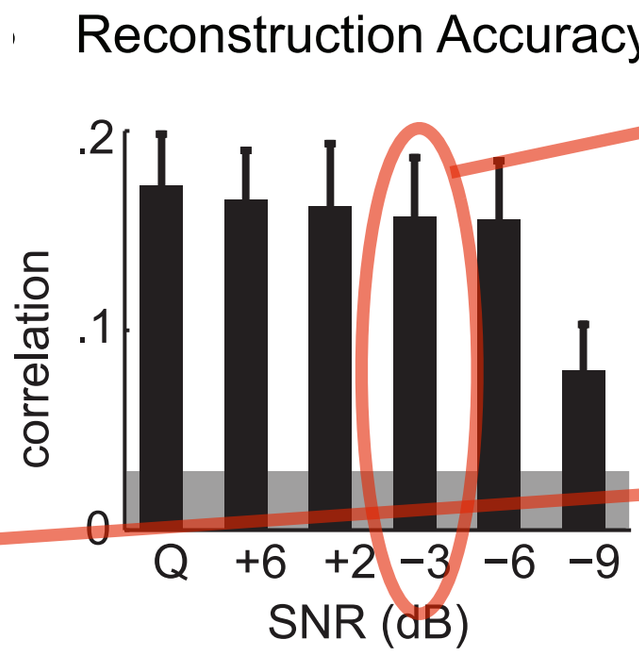
Ding & Simon, J Neuroscience (2013)

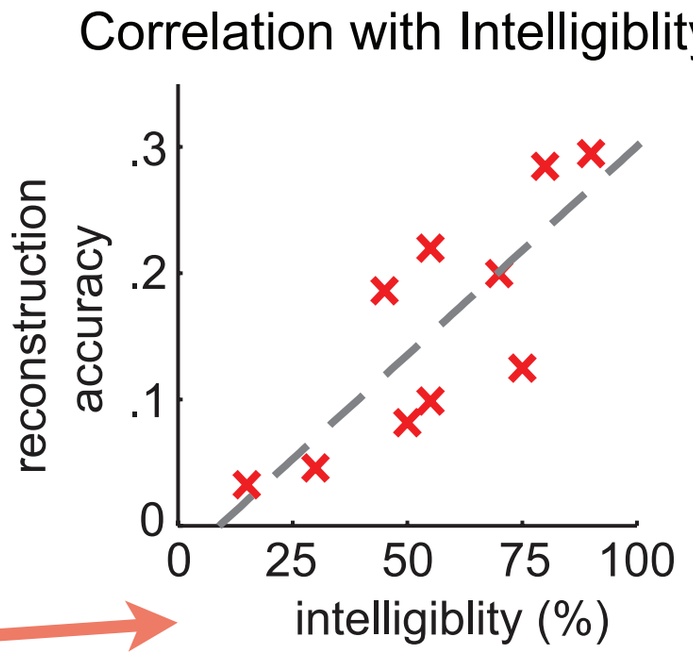
Cortical Representation of Speech in Noise



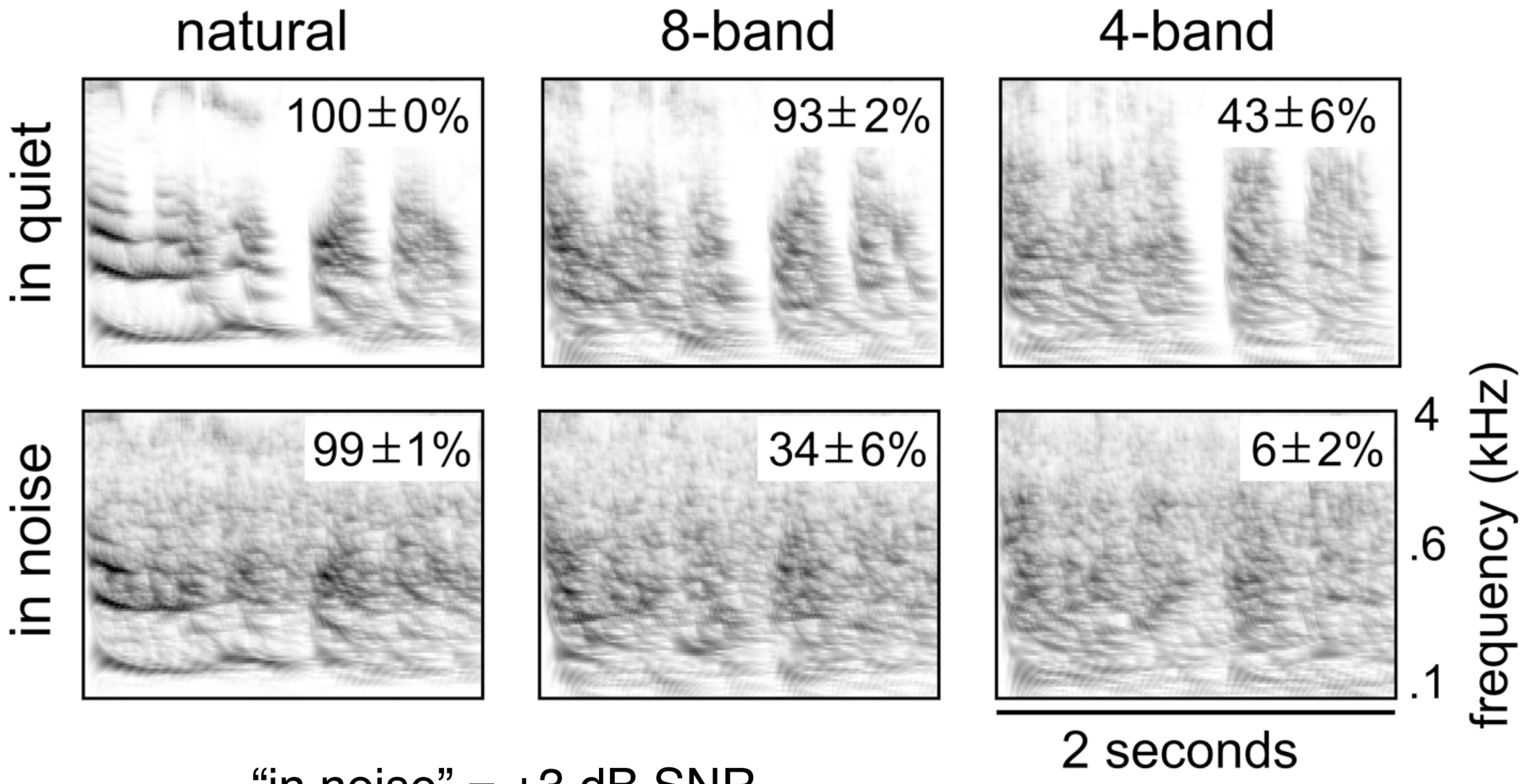








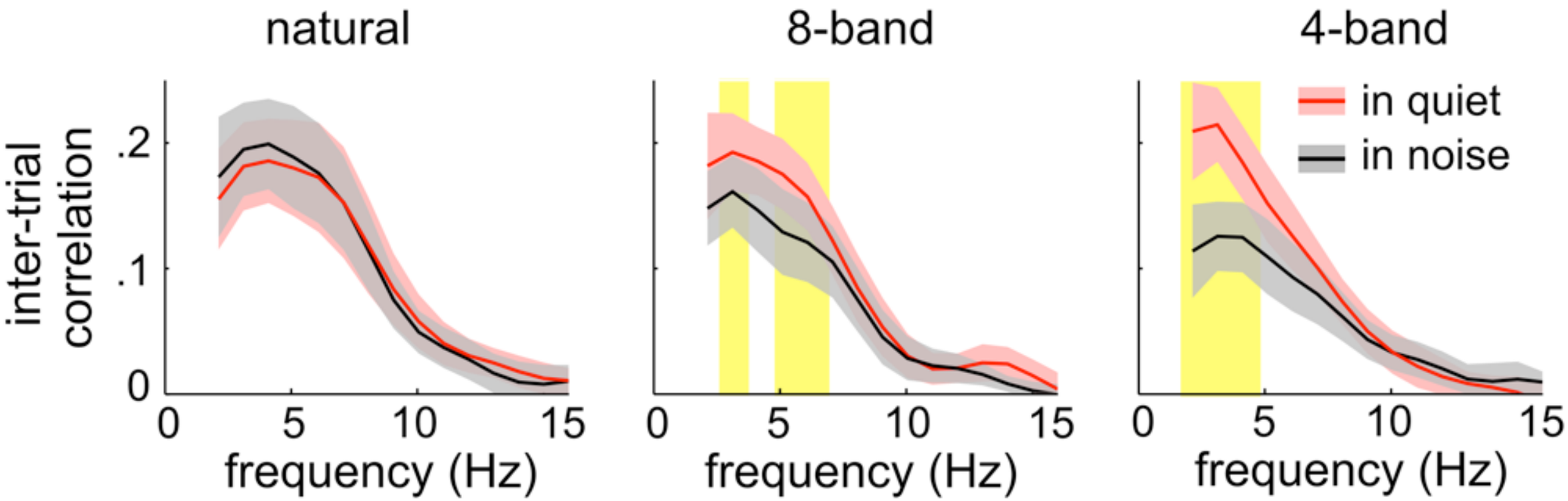
Noise-Vocoded Speech



"in noise" = +3 dB SNR

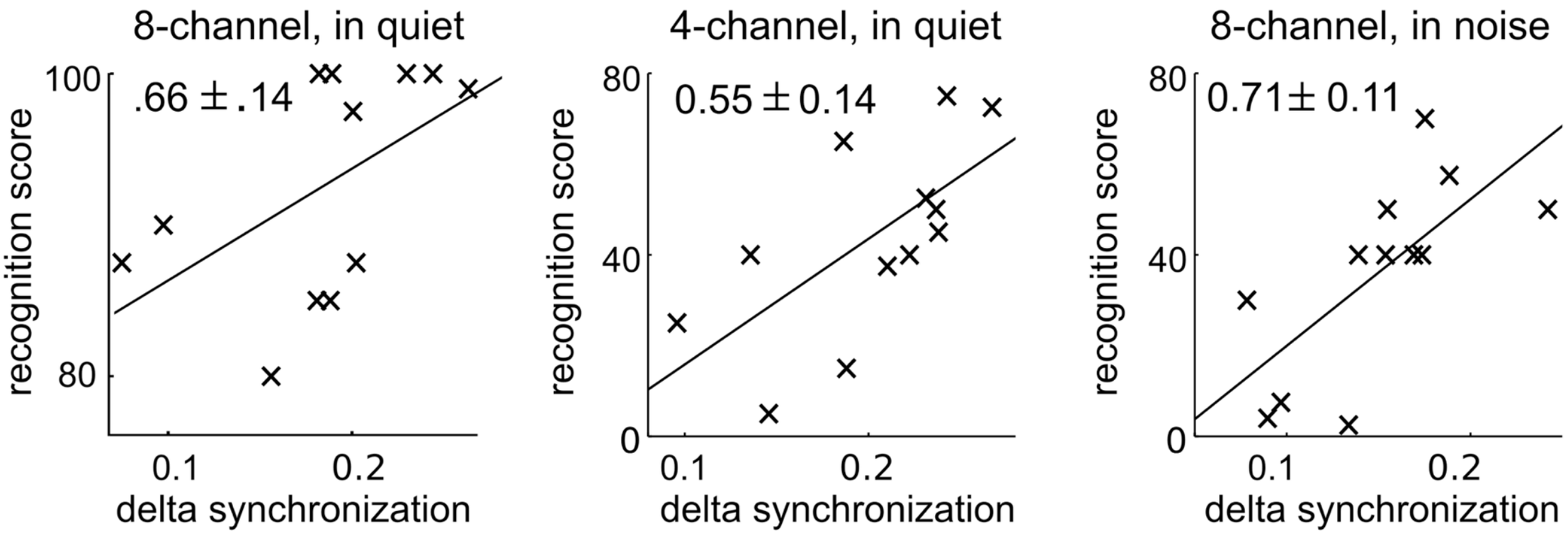
Ding, Chatterjee & Simon, NeuroImage (2014)

Noise-Vocoded Speech: Results



- Cortical entrainment to natural speech robust to noise
- Cortical entrainment to vocoded speech is not
- Not explainable by passive envelope tracking mechanisms
  - noise vocoding does not directly affect the stimulus envelope

Noise-Vocoded Speech: Results



Summary

- Cortical representations of speech found here:
  - ✓ consistent with being *neural* representations of auditory *perceptual* objects
    - ✓ very robust to noise (~intelligibility)
    - ✓ relies on *spectro*-temporal fine structure
    - ✓ explicitly temporal representation
- Object representation at 100 ms latency (PT), but not by 50 ms (HG)