Computational
Sensorimotor
Systems Lab

Auditory Cortex Tracks Acoustic Onsets of Ignored Speech: a Potential Mechanism in Stream Segregation

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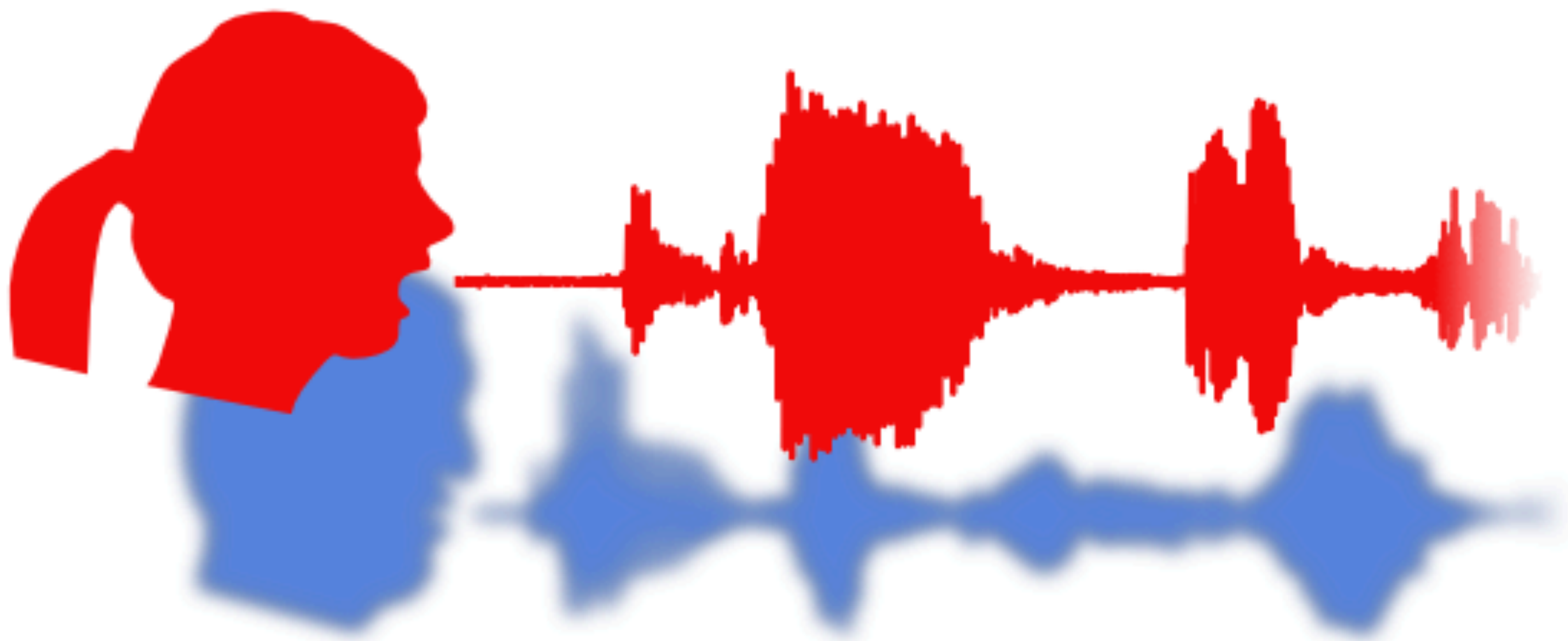
Outline

The cocktail-party problem

- Selectively listening to one of two talkers

Active processing of ignored speech?

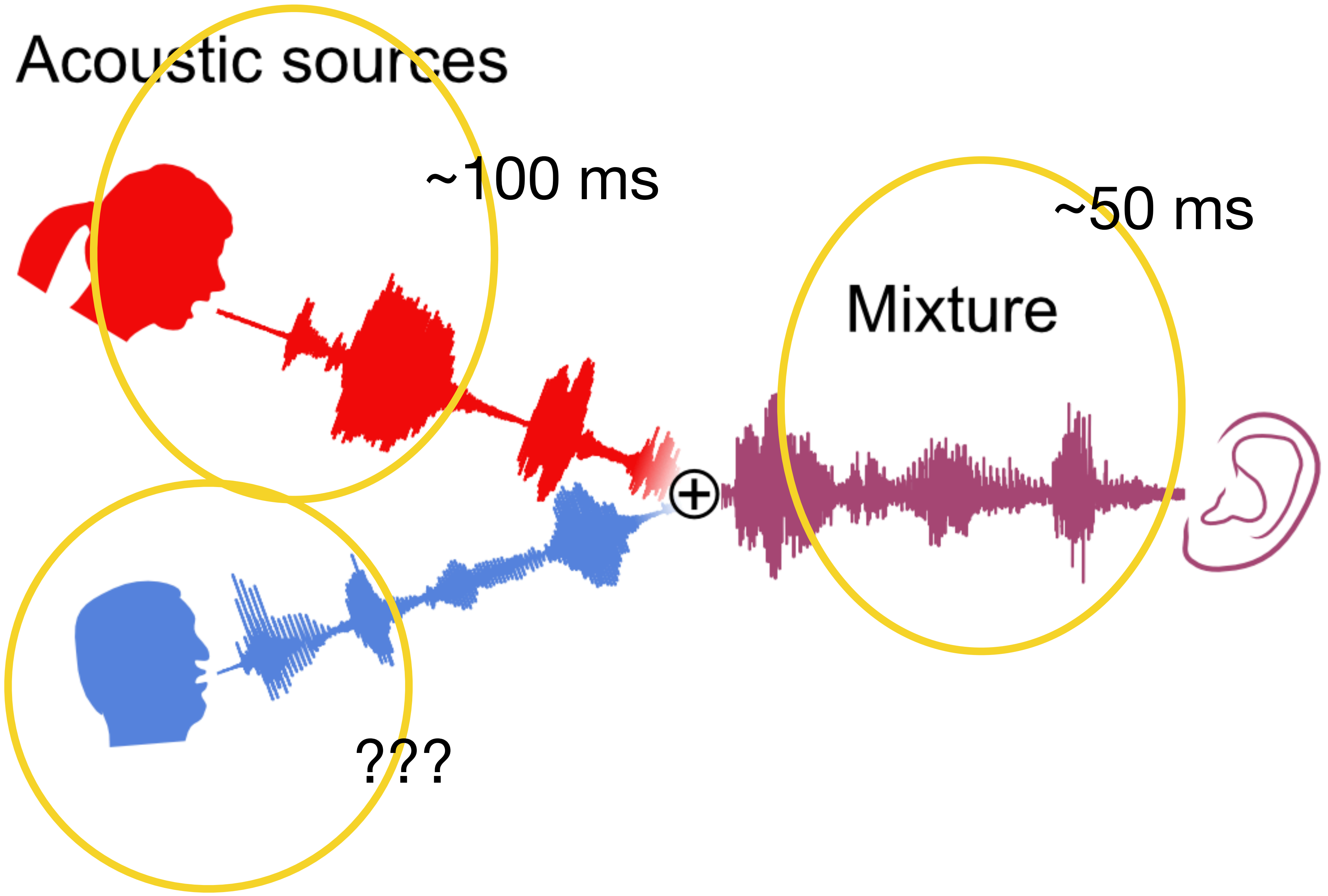
- Behavioral results suggest influence of higher order features
- Neural measures failed to find representations associated with lexical (Brodbeck et al., 2018) and semantic processing (Broderick et al., 2018)



MEG response to competing speakers

- Participants listen to two competing audiobook segments.
- Continuous neural response model
- MEG responses modeled to determine whether features of the ignored speech are represented

Cocktail party problem



Acoustic scene

- Acoustic mixture (acoustic scene, representation in auditory nerve)
- Acoustic sources (speakers)

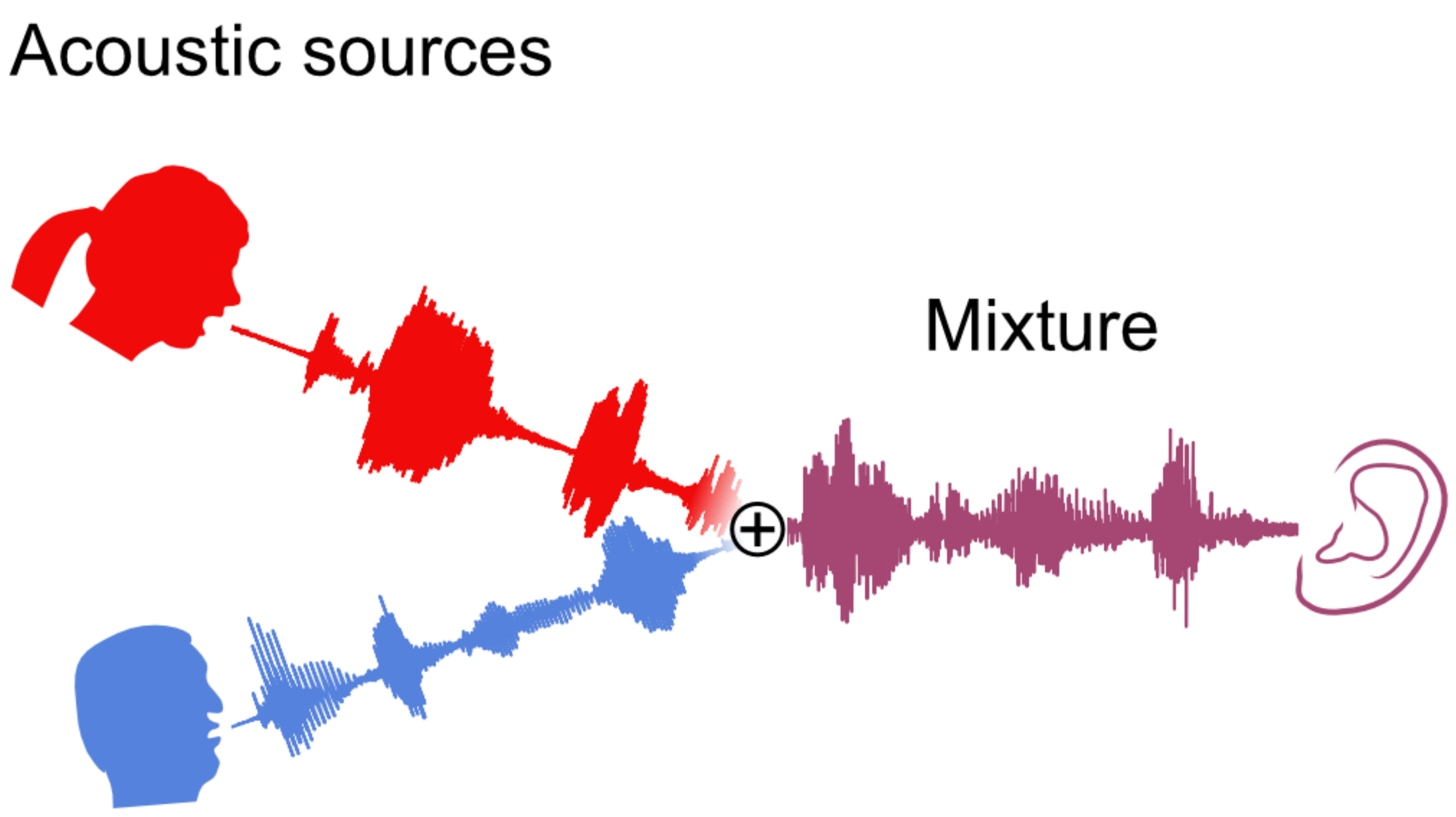
Cortical representations: Two-step model

(Ding & Simon, 2012; Puvvada & Simon, 2017; O'Sullivan et al., 2019)

- Early (~50 ms): spectra-temporal decomposition of acoustic mixture
- Later (~100 ms): preferential processing of the attended speech source

Is ignored speech actively separated from the mixture in auditory cortex?

Representation of ignored speech



Indirect evidence

- Your name may attract attention (Cherry, 1953)
- Background speech is more distracting than other noises (e.g. Brungart, 2001)
- But less so when you don't know the language in the background (Van Engen & Bradlow, 2007)
- Identity priming from unattended words (Rivenez et al., 2006)

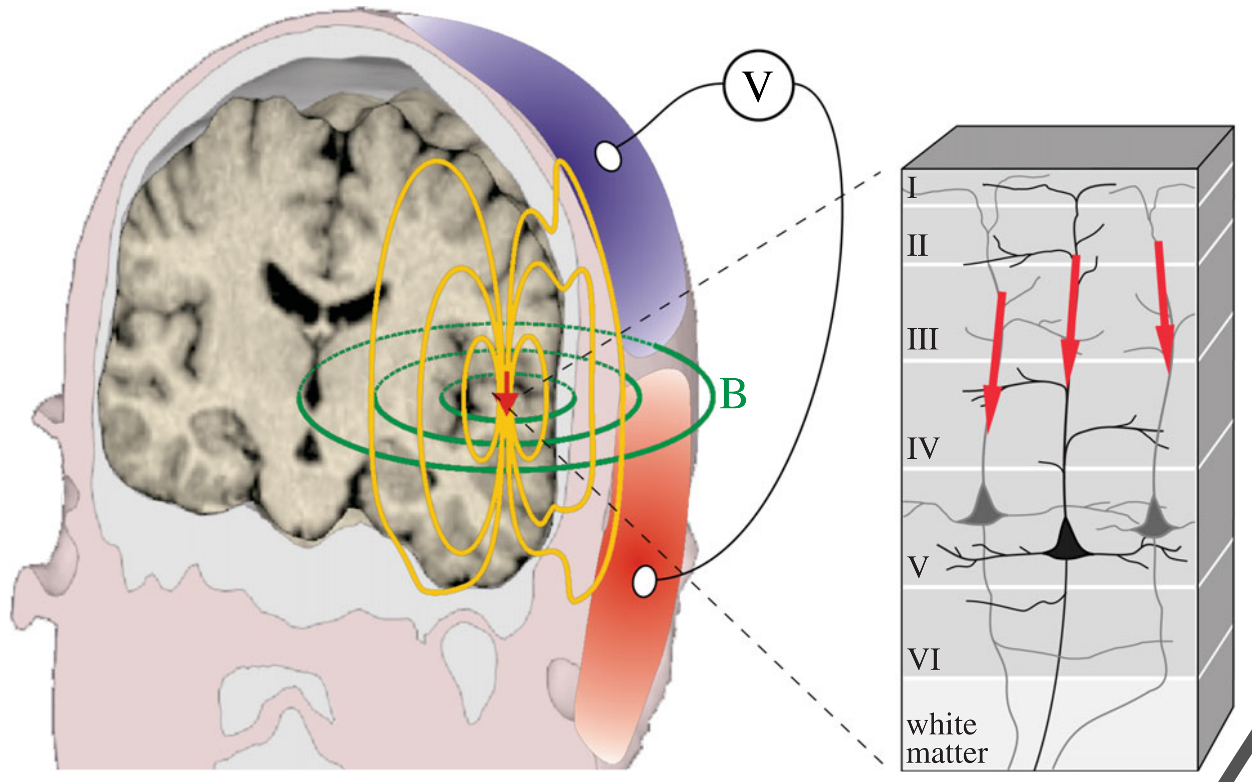
But

- Explicit access mostly limited to one speaker (Kidd et al., 2005)
- Hard to distinguish consistent lexical processing from attention switches
- No time-locked lexical processing based on MEG (Brodbeck et al., 2018)

Paradigm

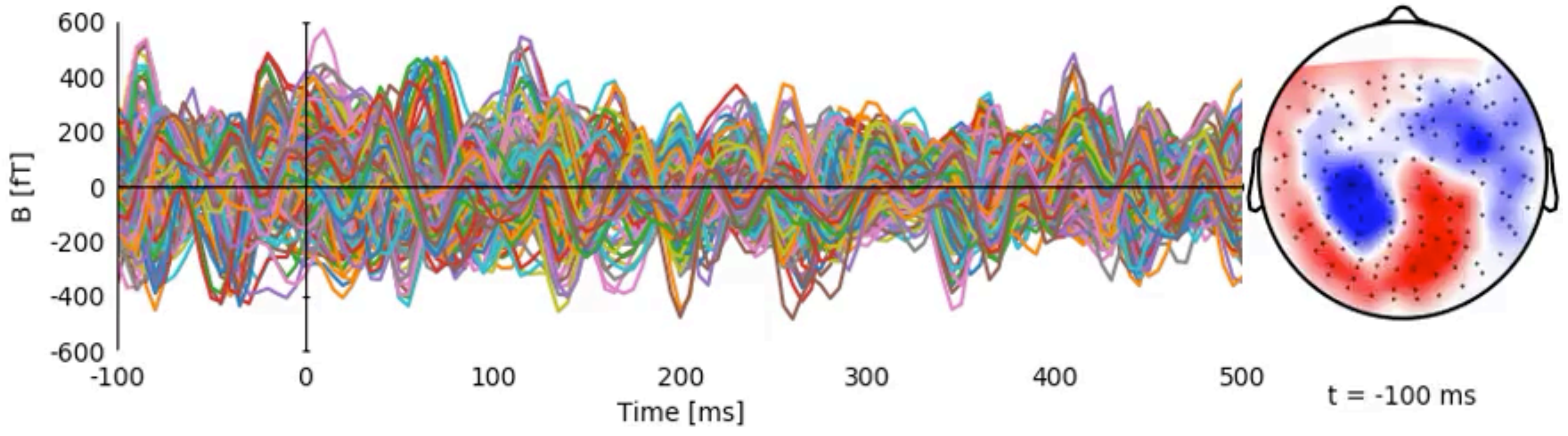
- Two speakers, equal loudness (female & male)
- Instructions: Attend to one, ignore the other
- Task: After each segment, answer a question about the content of the attended stimulus

MagnetoEncephaloGraphy (MEG)

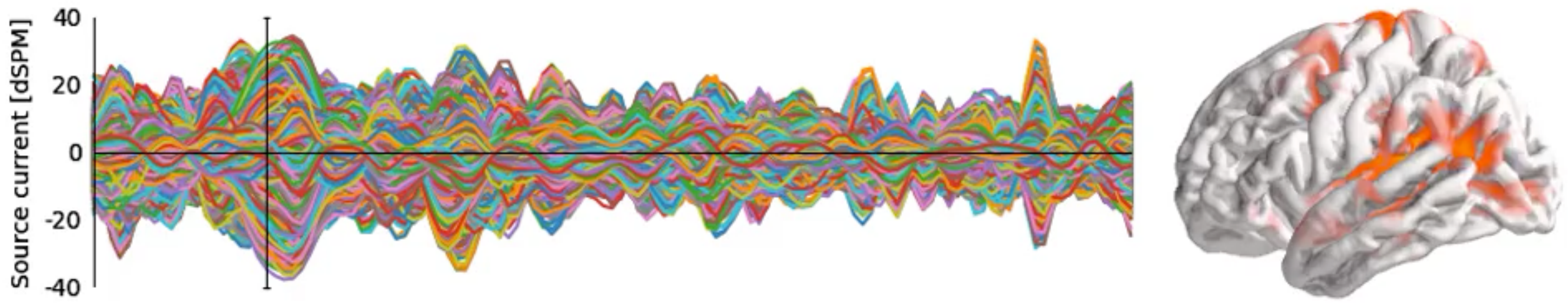


(Hari & Parkkonen, 2015)

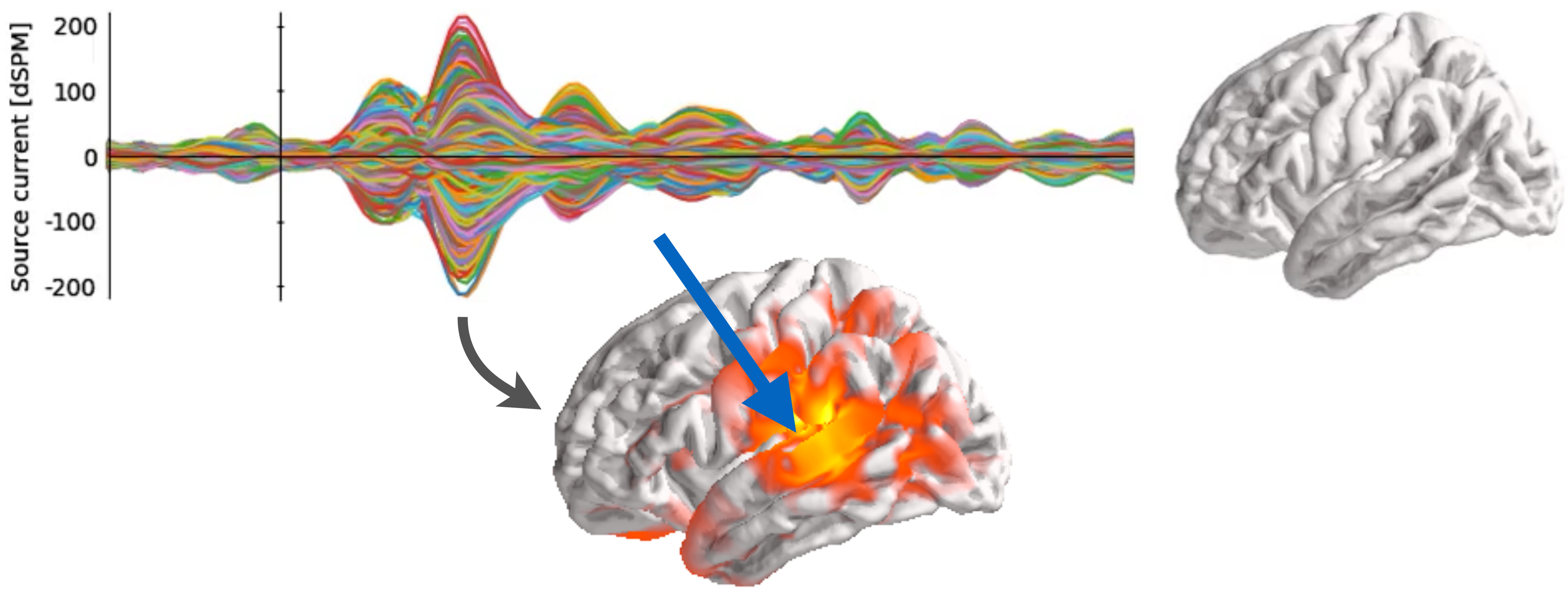
Single trial (pure tone)



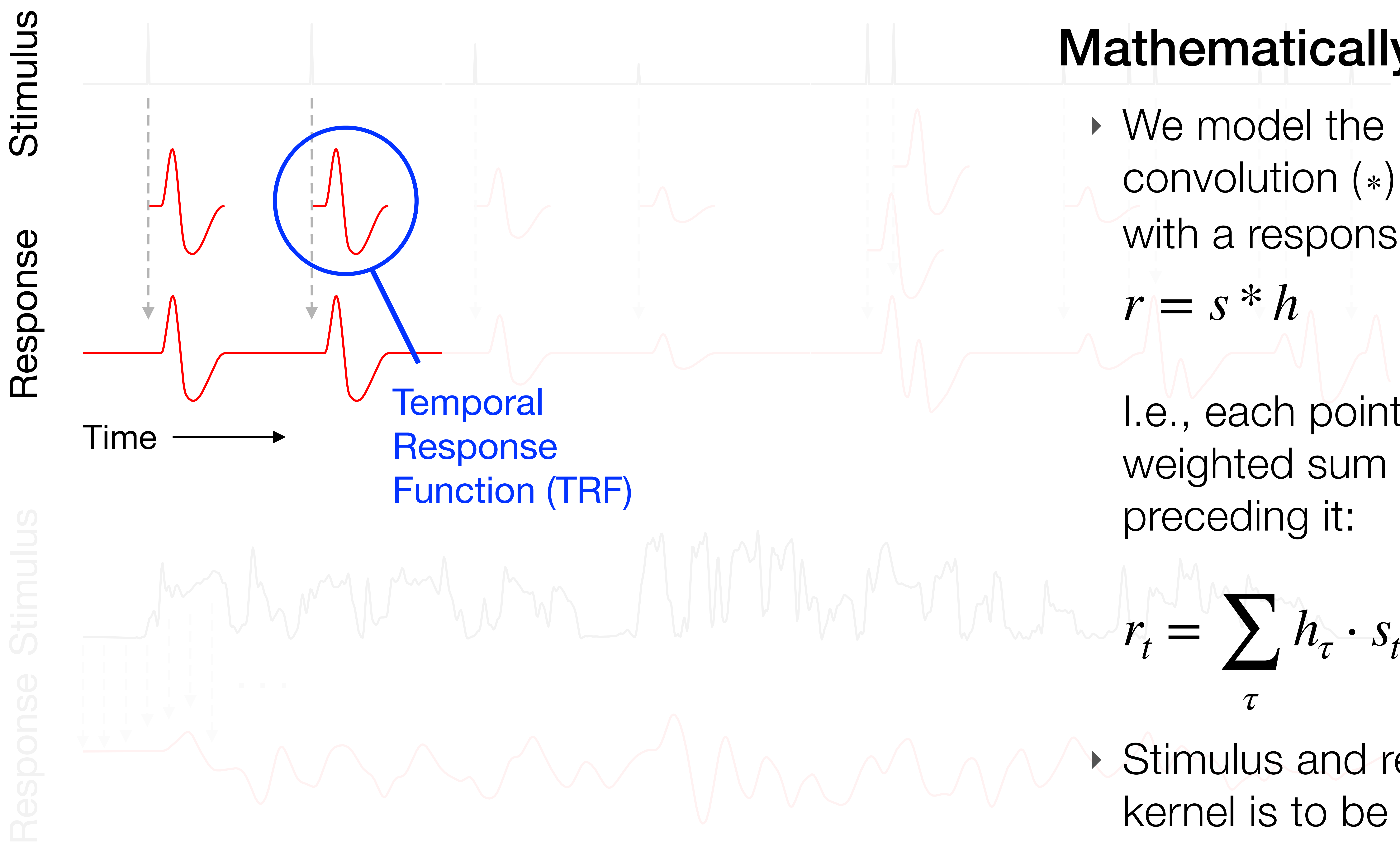
Minimum norm source estimates



Average (~100 trials)



Temporal response function (TRF)



Mathematically

- We model the response (r) as convolution ($*$) of the stimulus (s) with a response function (h):

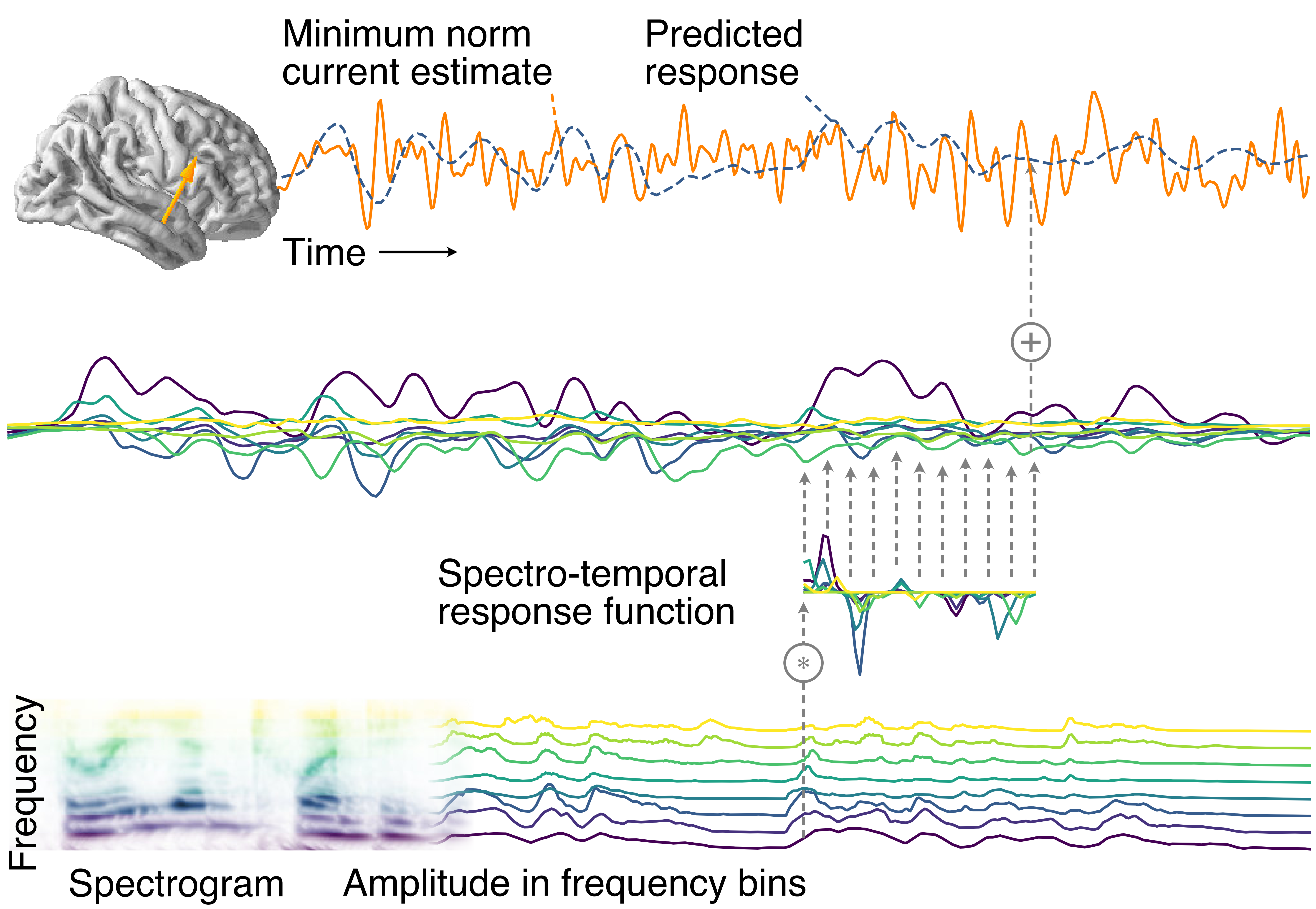
$$r = s * h$$

I.e., each point in the response is a weighted sum of the stimulus preceding it:

$$r_t = \sum_{\tau} h_\tau \cdot s_{t-\tau}$$

- Stimulus and response are known, kernel is to be estimated

Spectro-temporal response function (STRF)



Physiological motivation

- Neural sub-populations respond to different stimulus features
  - E.g. frequency tuning
- Electrical activity is locally additive

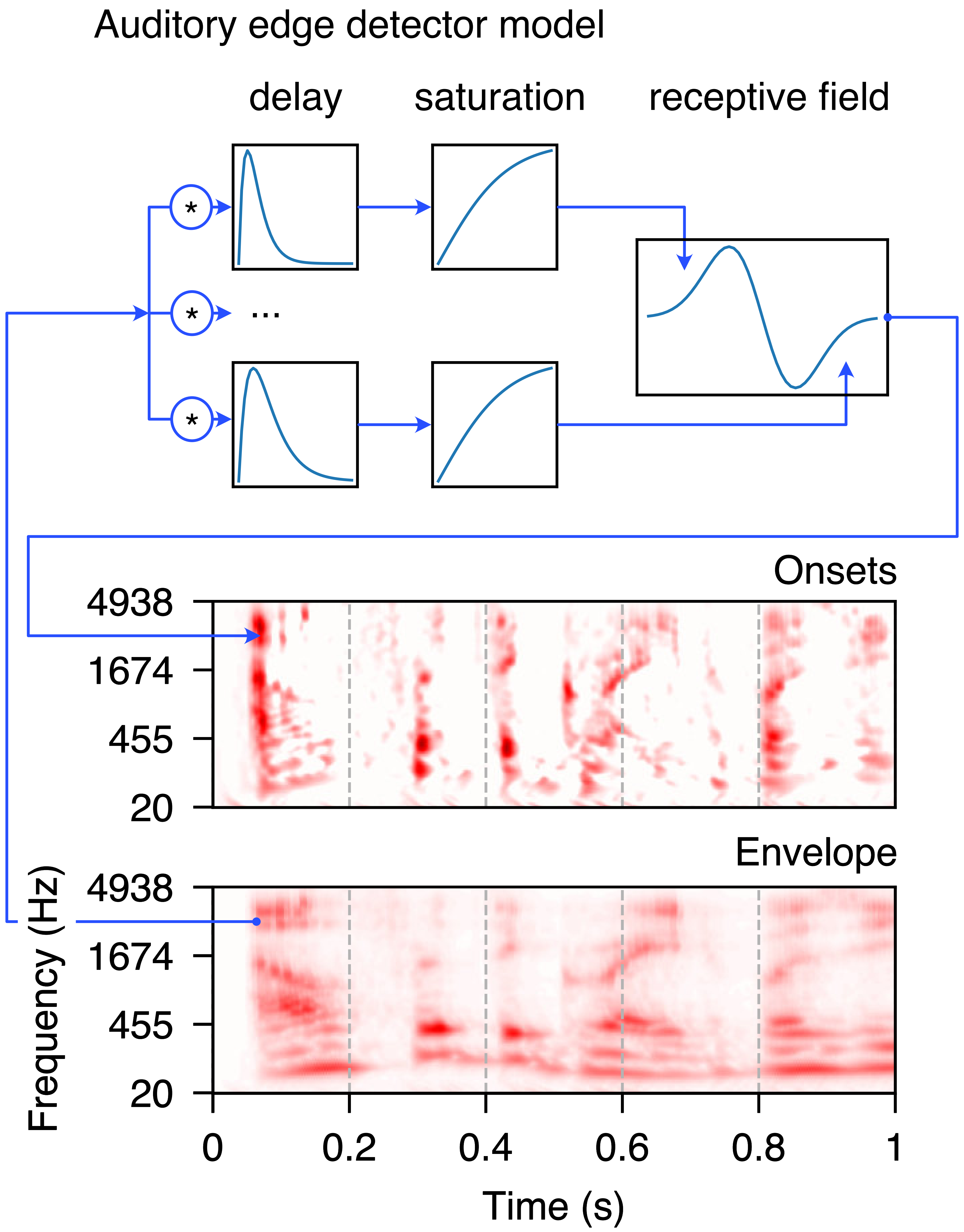
Multiple predictor variables

- The measured response is the sum of the individual responses

Spectro-temporal response function (STRF)

- Brain response to acoustic stimulus
- TRF can differ depending on the acoustic frequency

Single speaker



Spectrogram "envelope"

- Acoustic energy by frequency over time

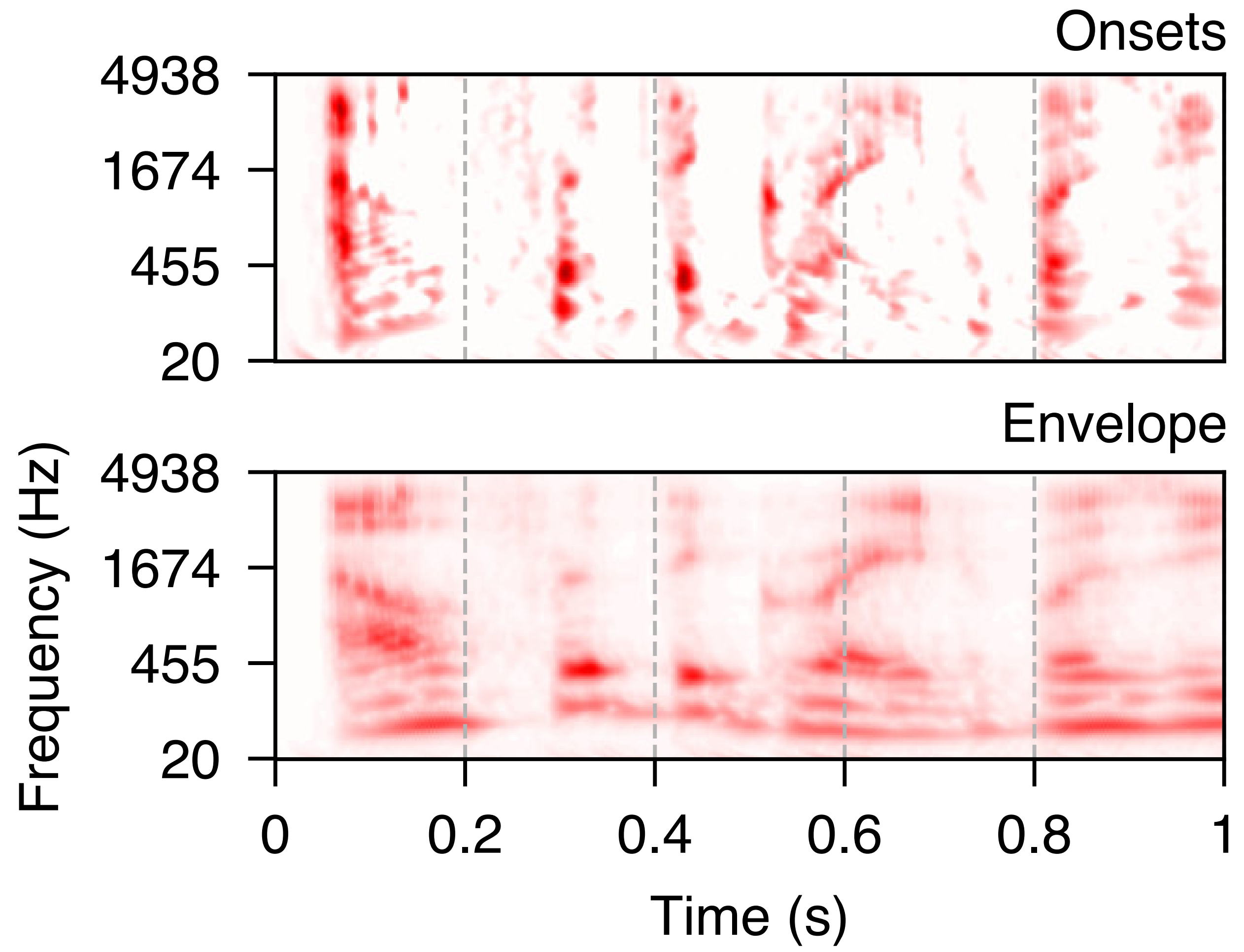
Acoustic "onsets"

- Local increase in acoustic energy
- Prominent cortical responses (Daube et al., 2018)
- Relevant for auditory object perception (e.g. Bregman et al., 1994)
- More distinctive between mixture and sources

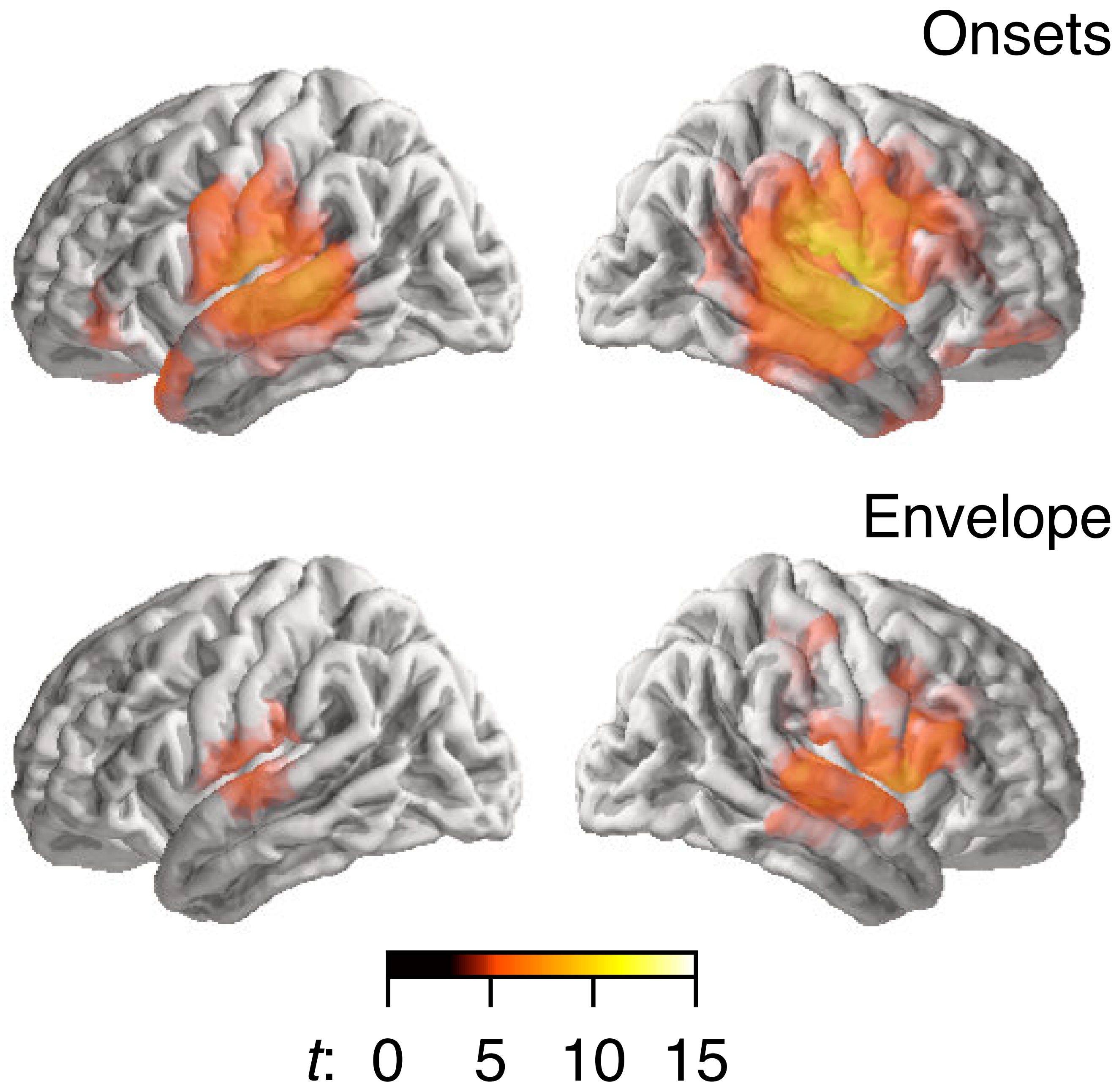
Implementation

- Acoustic edge detector model (Fishbach, et al., 2001)

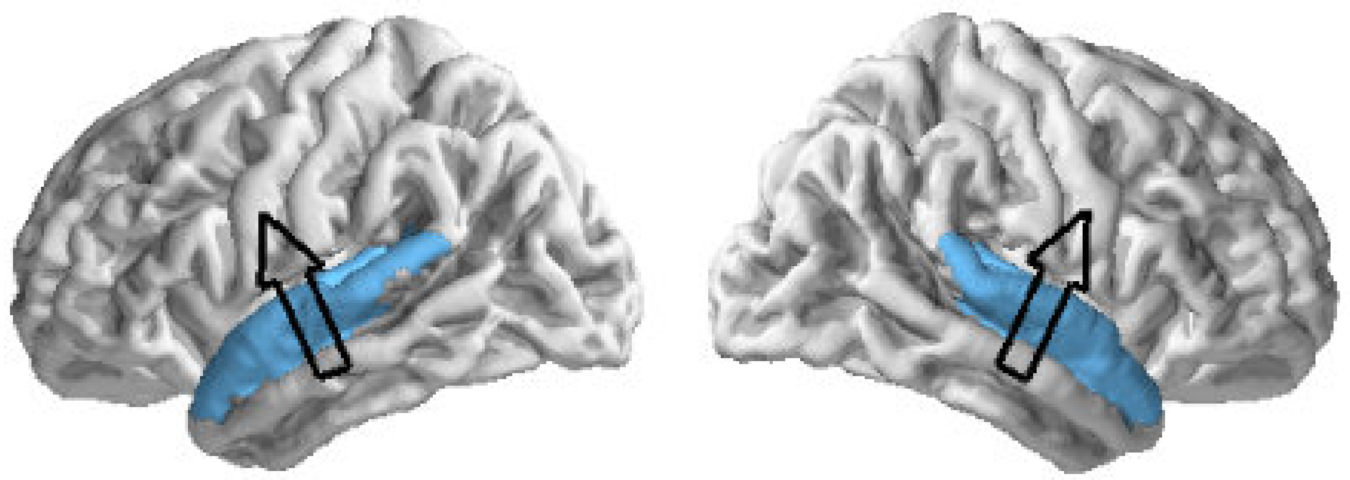
Single speaker



Significant prediction



ROI for TRF analysis

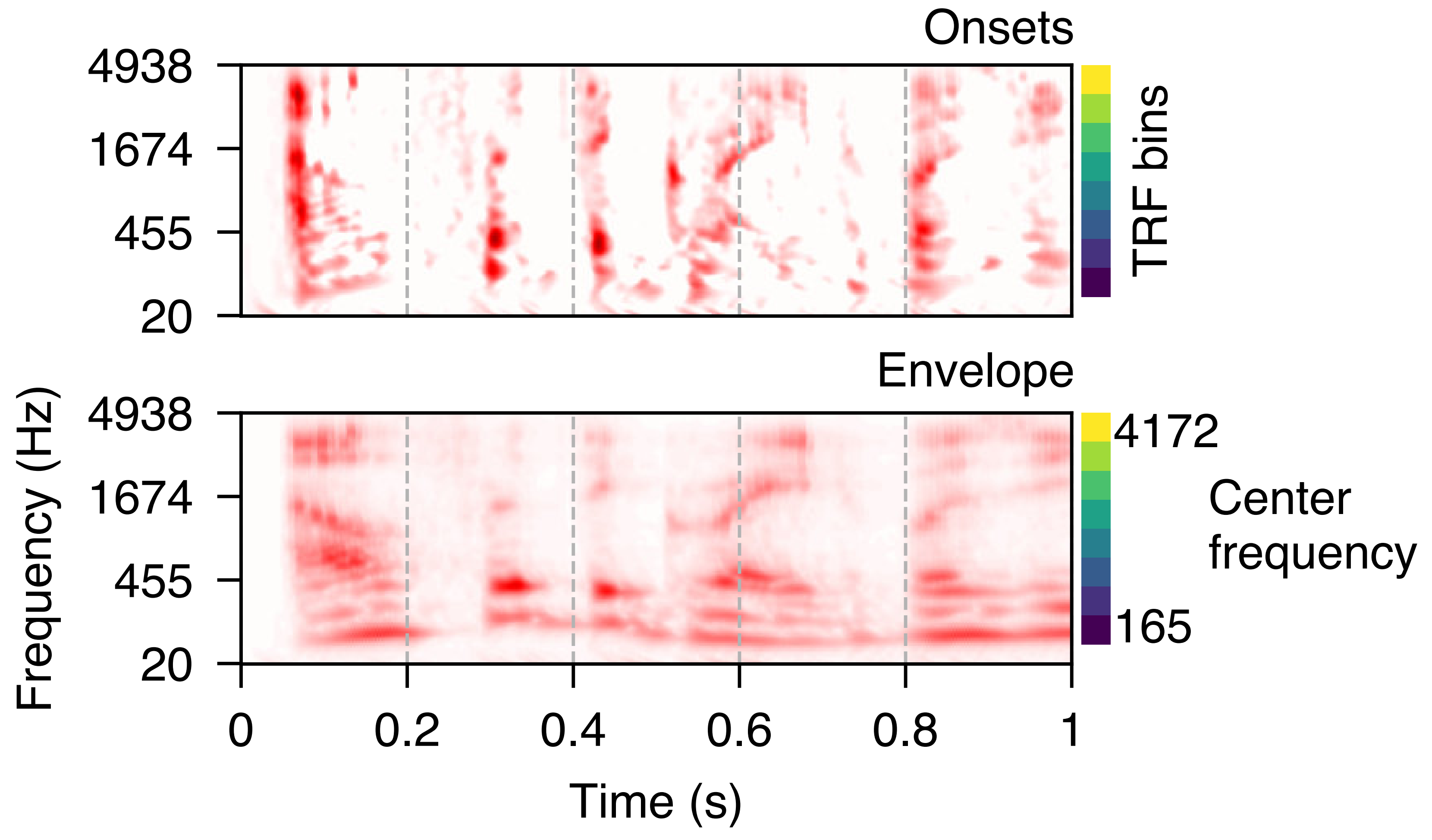


Source localization

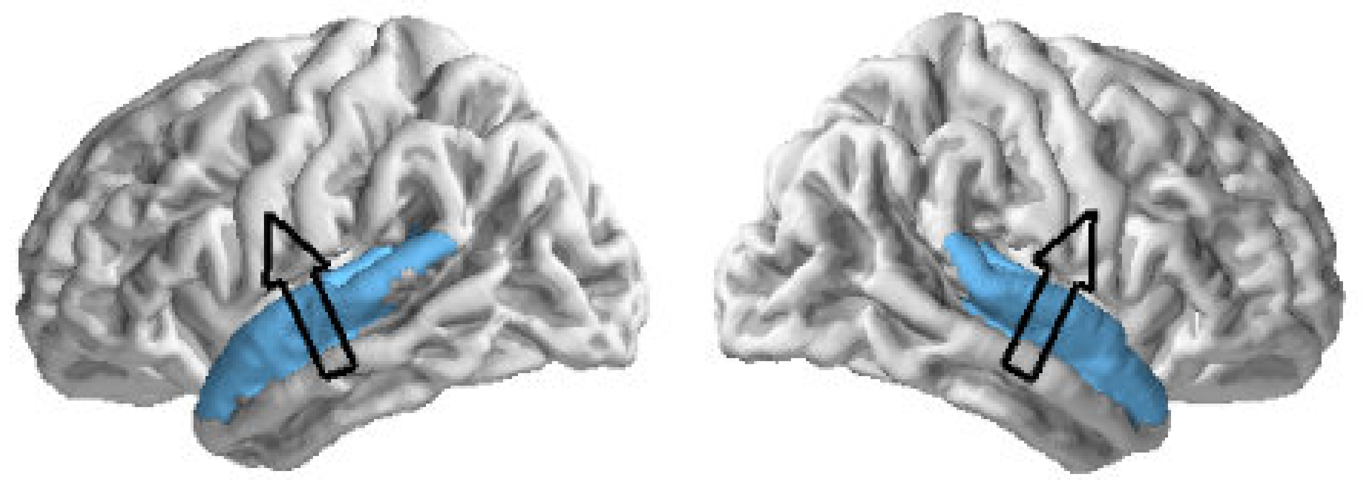
- Consistent with auditory cortex (Heschl's gyrus, superior temporal Gyrus)

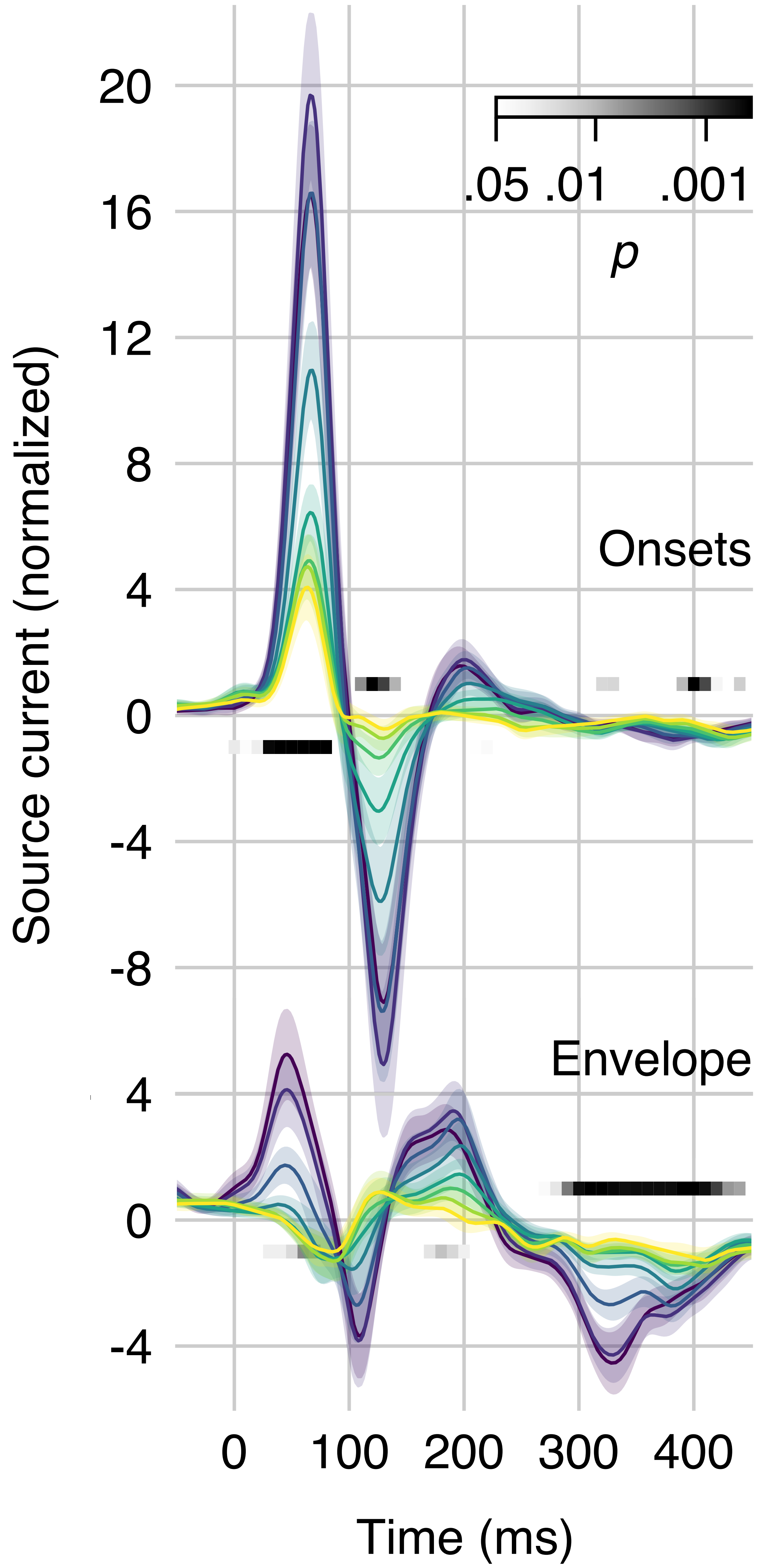
Brodbeck et al., biorxiv 2019

Single speaker



ROI for TRF analysis





Source localization

- Consistent with auditory cortex (Heschl's gyrus, superior temporal Gyrus)

Onsets

- Typical response pattern

  + peak

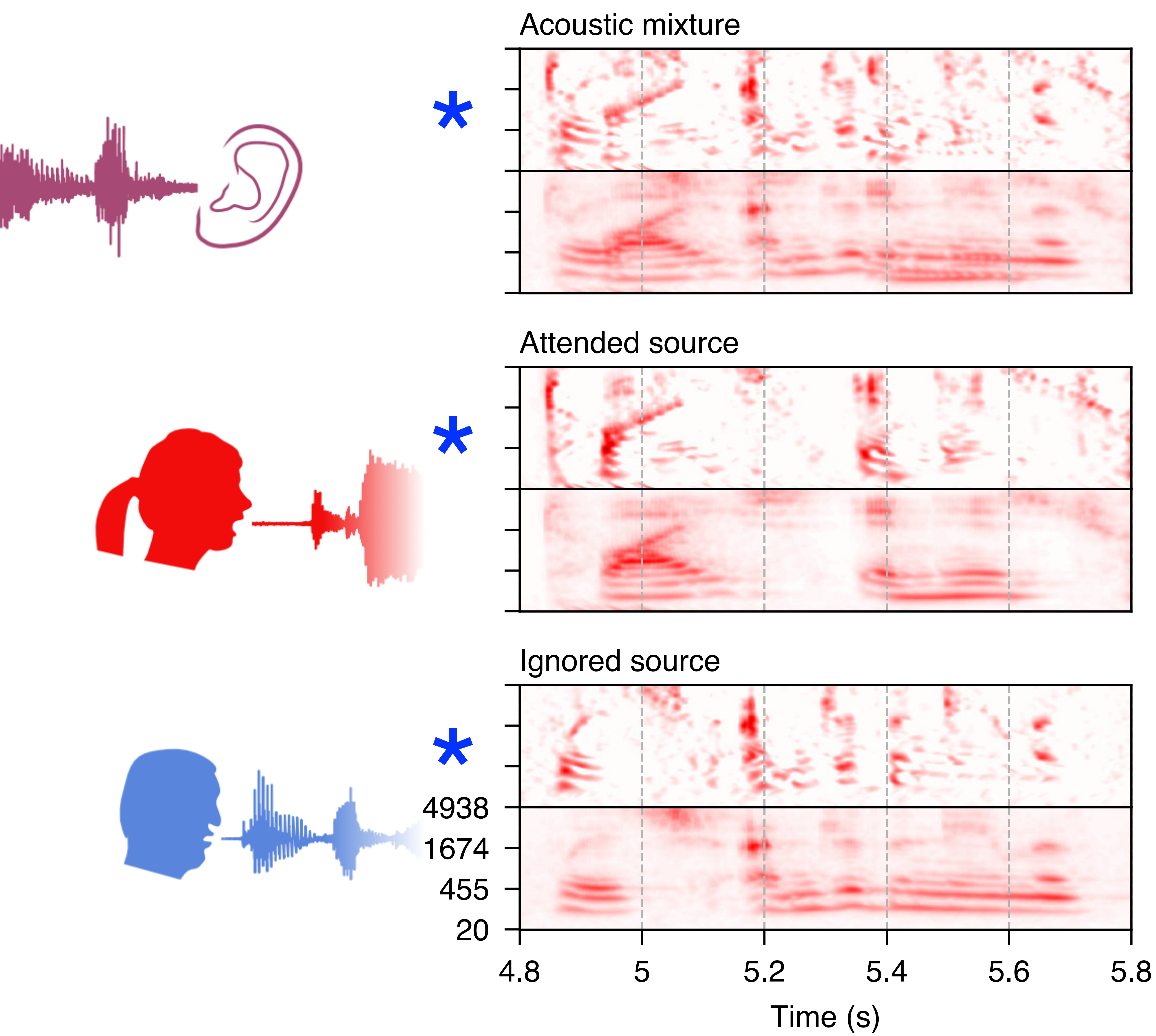
  – peak

Envelope

- Less defined

Brodbeck et al., biorxiv 2019

Two speakers



Potential representations

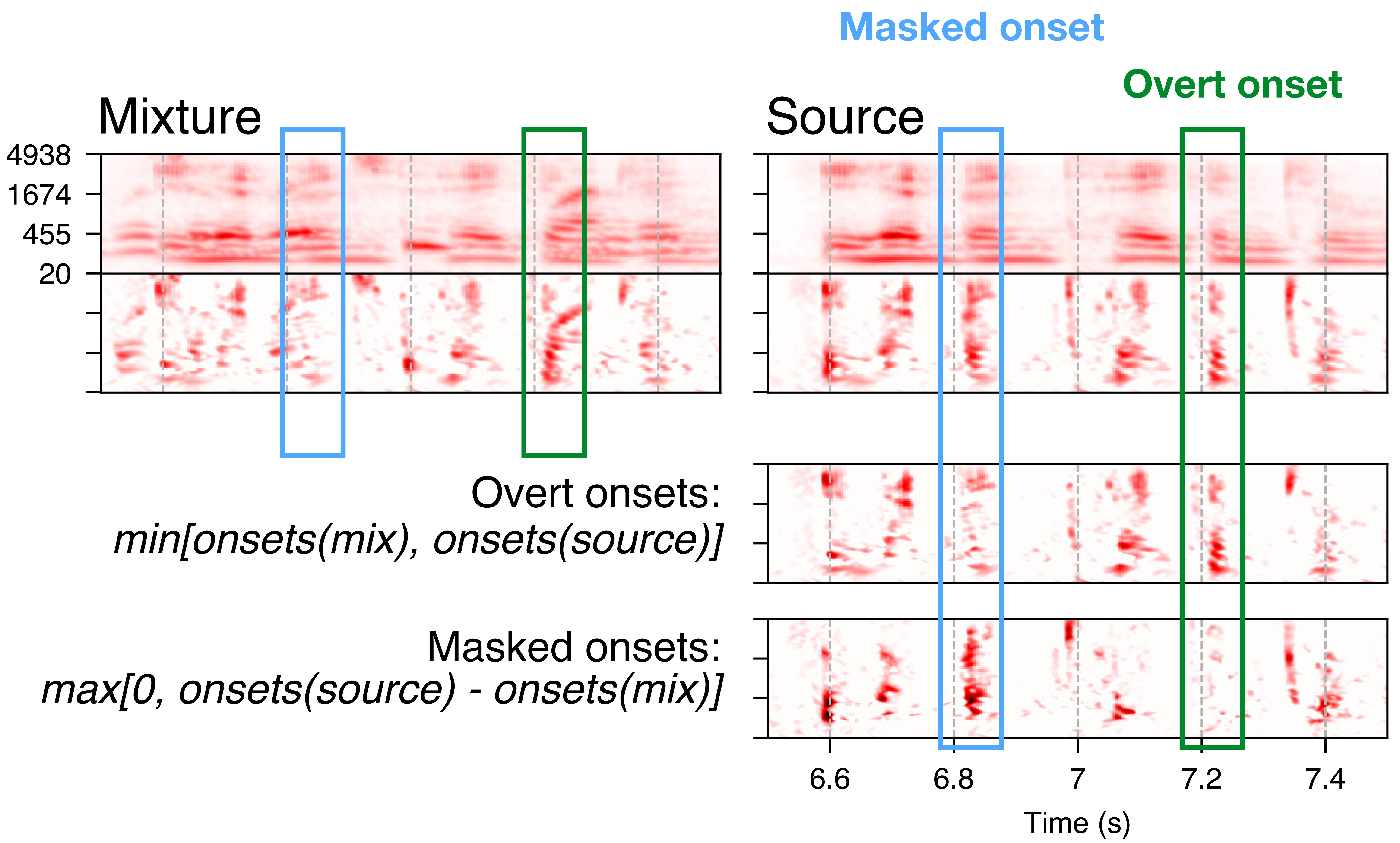
- Acoustic input (mixture)
- Recovered acoustic source signals
  - Attended speaker
  - Ignored speaker?

Significant responses

- Significant response to onsets in the ignored speaker
- After accounting for mixture and attended speaker

Brodbeck et al., biorxiv 2019

Masked onsets



Intuition

- Sources are represented in addition to mixture
- The auditory cortex has to recover features in the source that are masked in the mixture

New predictors

- **Overt onsets:** Onsets in a source that are visible in the mixture
- **Masked onsets:** Onsets in a source that are masked in the mixture

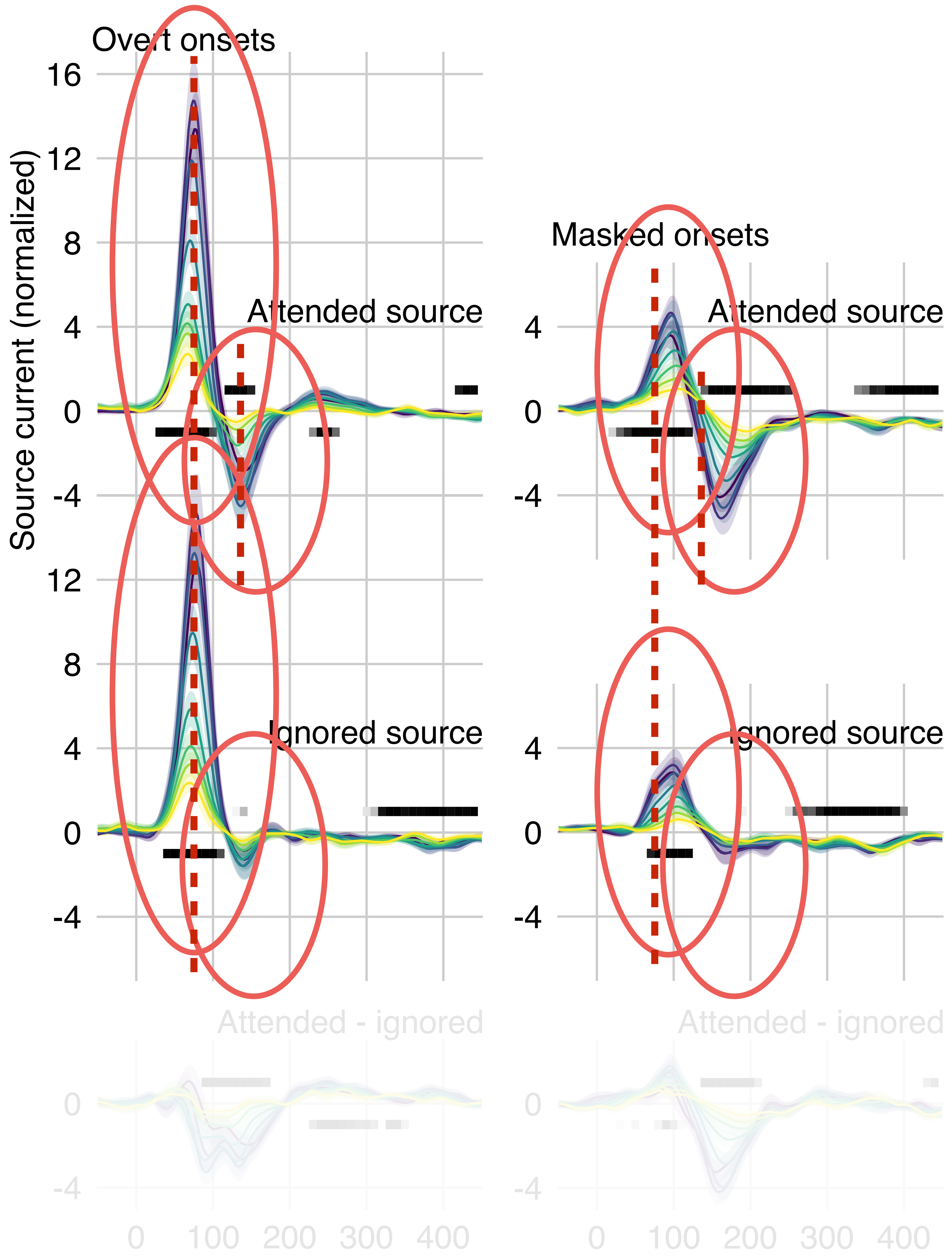
✱ Distinguishing masked and overt onsets improves model fit

→ New model

- Overtness (overt, masked) × Source (attended, ignored)

Brodbeck et al., biorxiv 2019

Masked onsets



+ peak: Overt > masked

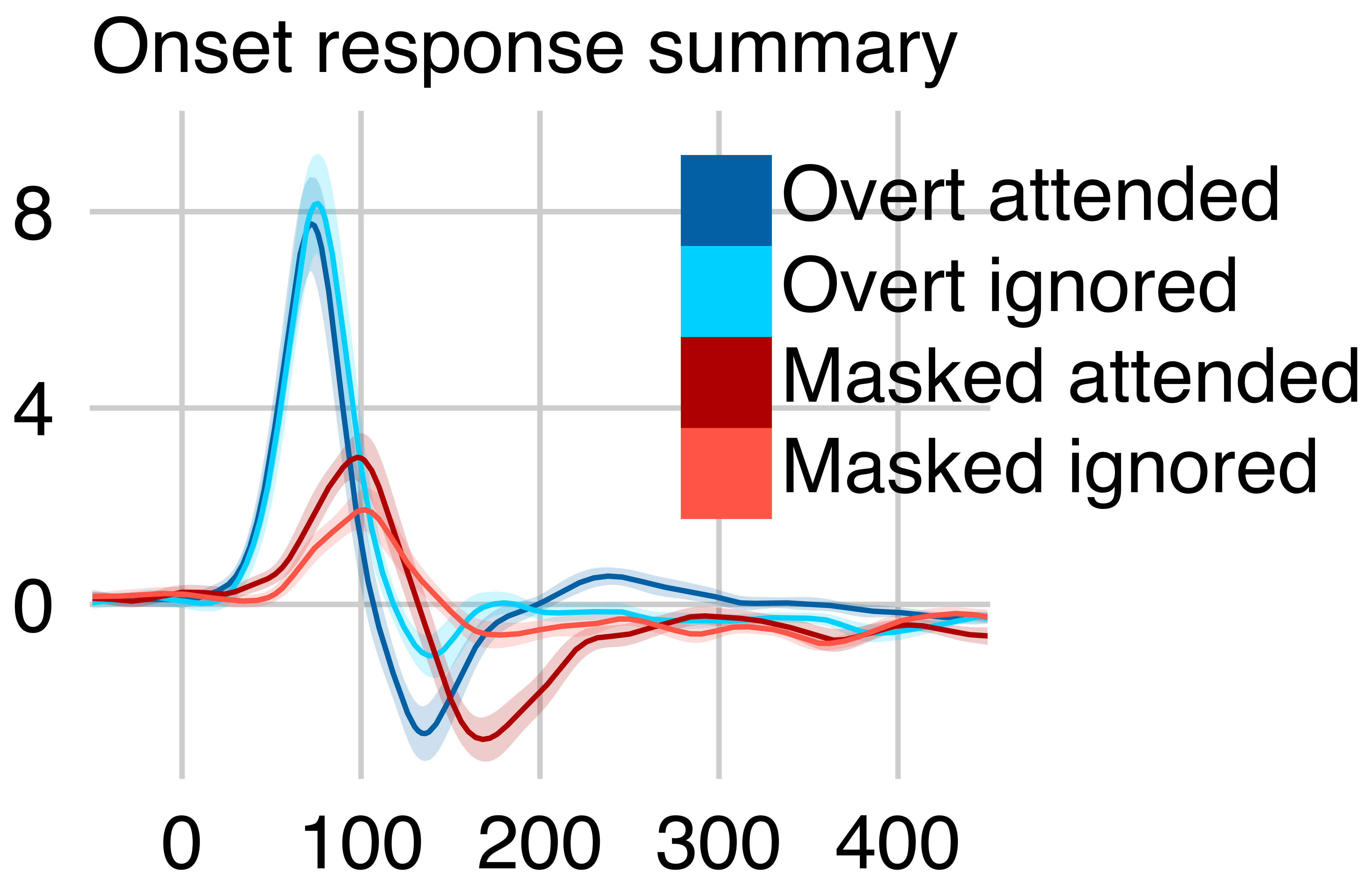
– peak: Attended > ignored

Delayed response to masked onsets

- Delay of responses in noise not uniform as previously assumed (cf. Ding & Simon, 2013)
- Suggests active (costly) processing of masked features

Brodbeck et al., biorxiv 2019

Summary



Increasing abstraction

- 74 ms: Bottom-up, stimulus-driven
- 93 ms: Reconstructed onsets
- >120 ms: Reconstructed onsets same amplitude as overt onsets
- Increasing selectivity for attended source

Active processing of ignored speech

- Representations of masked onsets in background speech
- Akin to neural filling-in (e.g. Leonard et al., 2016)

Local auditory objects

- Input for selective attention

Could explain behavioral effects

- Why speech is more distracting than stationary noise
- Intrusions from ignored speech (cf. Brungart, 2001)
- Detection of over-learned words such as one’s name (cf. Woods & McDermott, 2018)

Brodbeck et al., biorxiv 2019

Thank You!

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