# Cortical Neural Coding of Speech in Simple and Complex Auditory Scenes


Nai Ding[1], Jonathan Z. Simon[1,2]

[1]Department of Electrical & Computer Engineering, [2]Department of Biology

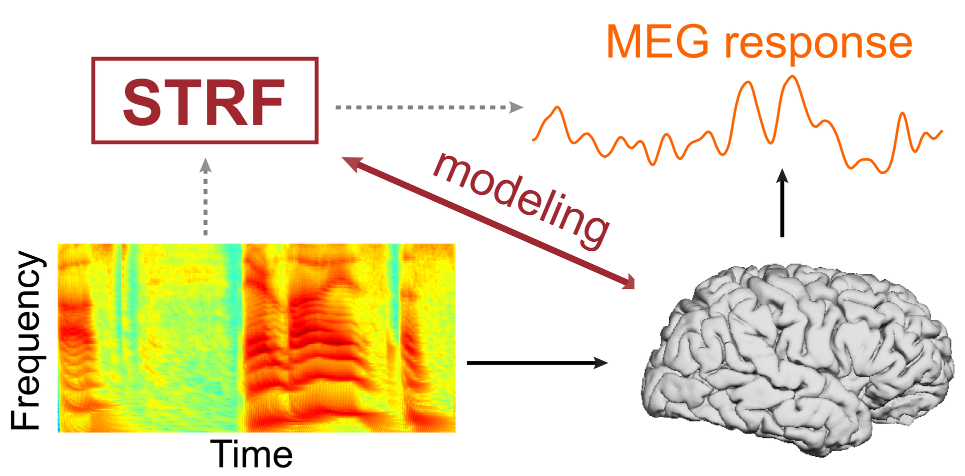
University of Maryland College Park

Computational Sensorimotor Systems Lab


## Introduction

1. **What is the neural code of spectro-temporal modulations of continuous speech in human auditory cortex?**
2. **How does human auditory cortex segregate and maintain attention on a speech target in the presence of a concurrent speech masker?**

These two questions are addressed by recording the *magnetoencephalography* (MEG) response from human subjects actively listening to spoken narratives. MEG is an non-invasive neural recording tool, with millisecond level time resolution.




The MEG response to natural spoken narratives is analyzed using the *Spectro-Temporal Response Function* (STRF), a counterpart of the spectro-temporal receptive field in single unit neurophysiology.

## Experimental Procedures

### ➢ Stimulus & Procedure

**Dichotic speech mixture**

• Two 2 minute long spoken narratives (from *the Legend of Sleepy Hollow*, by Washington Irving) were played simultaneously to the two ears respectively.
• The stimulus was played 6 times. The subjects focused on one ear at a time and switched focus after every repetition.
• After every minute, the subject were asked a question about the comprehension of the story attended to. 90% of the questions were correctly answered.

**Monaural speech**

• In a separate session, each spoken narrative was played monaurally 4 times.

### ➢ MEG Recording and Processing

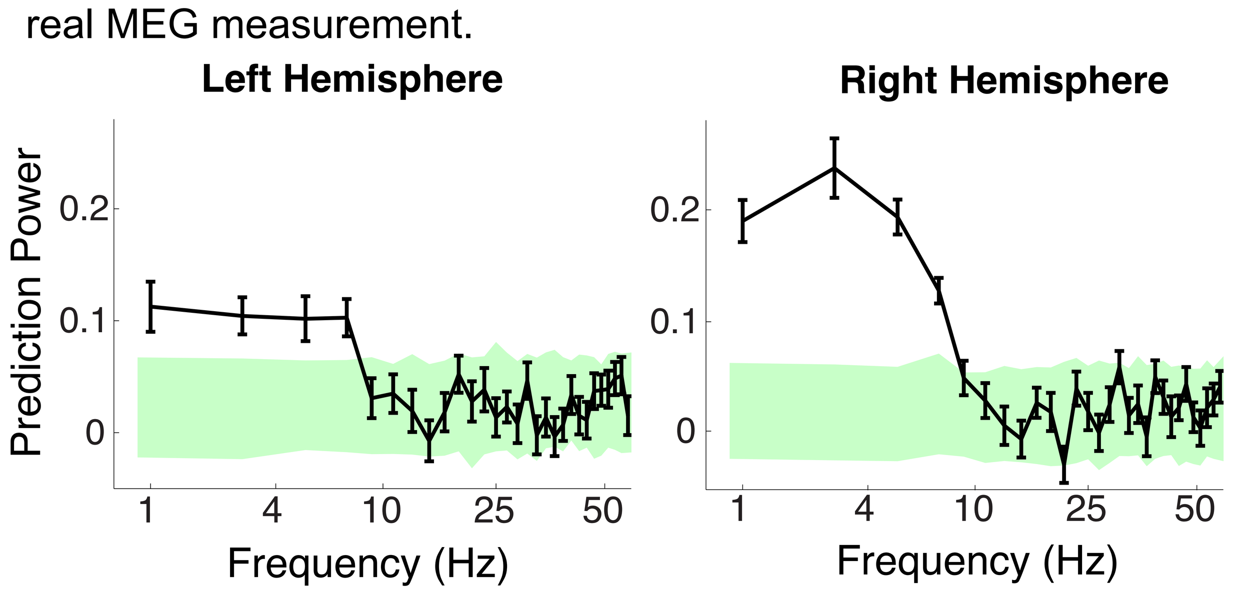
• 157 channel whole-head MEG system, sampled at 1 kHz, with a 60 Hz notch filter.
• Denoising Source Separation (DSS) assisted equivalent current dipole fitting localizes the neural source bilaterally to the *superior temporal gyrus*.
• The moment of the equivalent current dipole in each auditory cortex is reconstructed using the generalized least squares method, as a function of time.

### ➢ STRF

• The STRF is estimated using boosting with 10-fold cross validation, based on a sub-cortical spectro-temporal representation of speech.

## Neural tracking of slow modulations

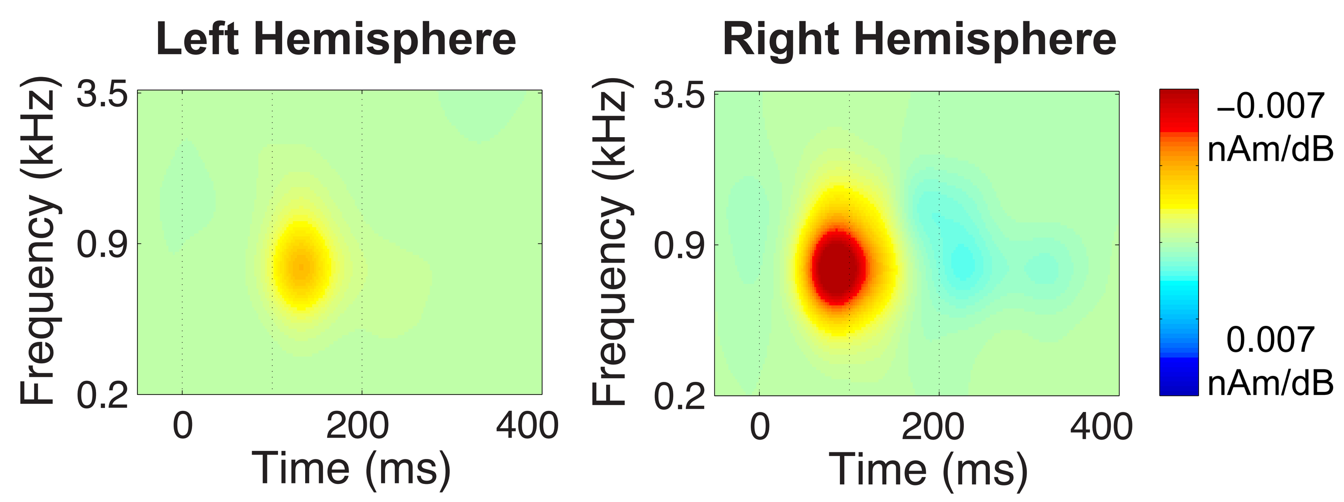
The **predictive power** is the correlation between STRF model prediction and real MEG measurement.




The right hemisphere encodes slow temporal modulations more precisely.

**In the low frequency region (<10 Hz), the neural response can be predicted by the spectro-temporal modulations of the stimulus speech, using the STRF.**

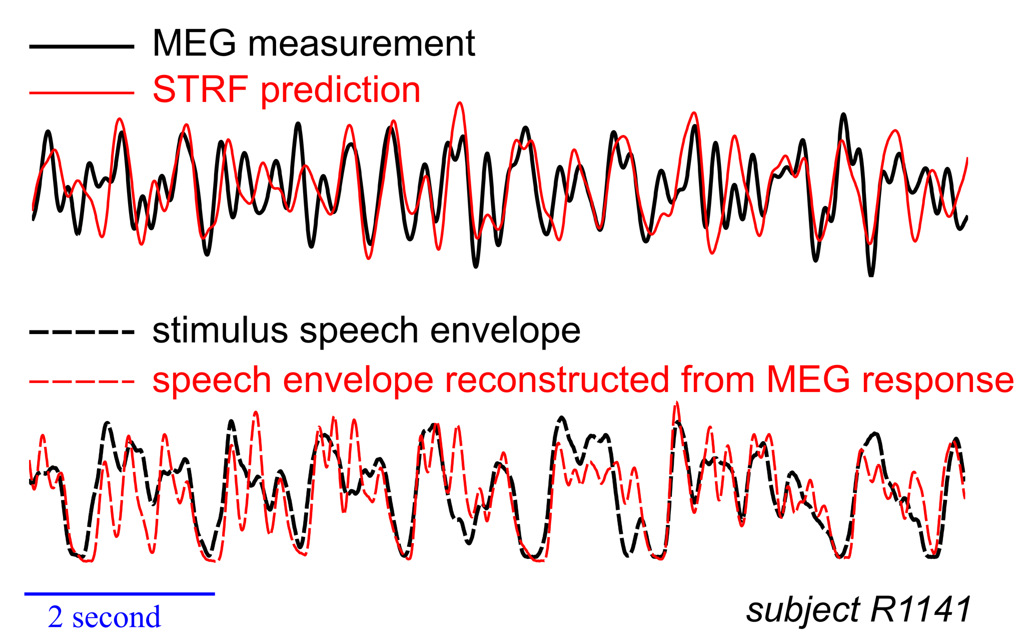
## Spectro-temporal response function for speech




The STRF for the speech signal **monaurally** presented to the left ear. (grand average)

The STRF indicates the neural response is following the spectro-temporal modulations of speech at latency of about 100 ms, where the contralateral response is enhanced.

The peak at about 100 ms is called the **M100-like response**.The polarity of this peak is the same as the polarity of the M100 (N1m) response to tone pip.

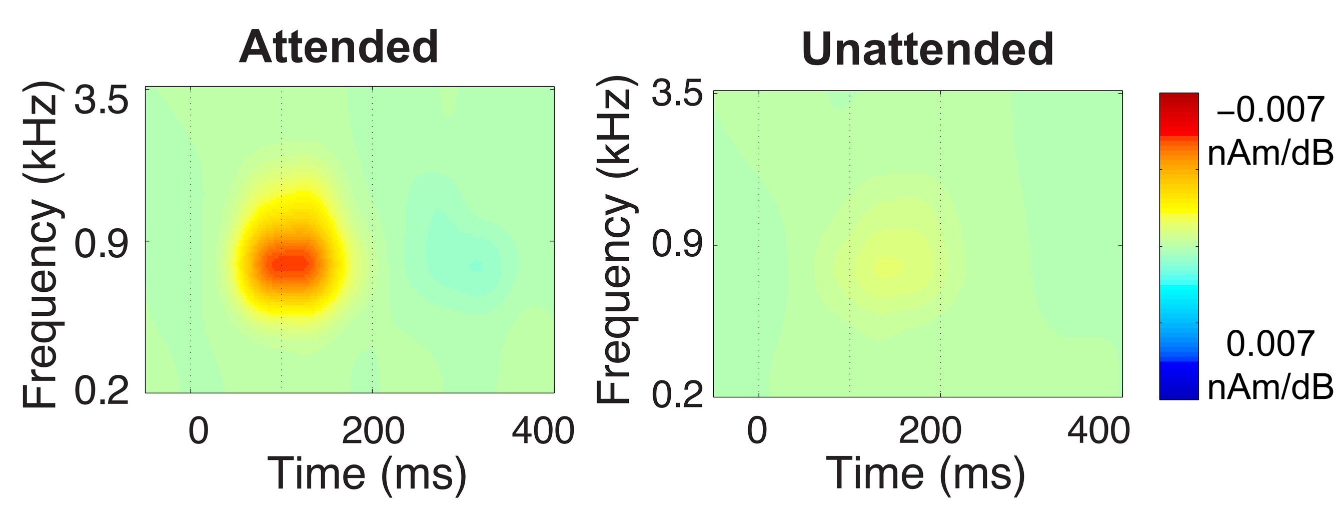



As a functional model of cortical auditory processing, the STRF can *predict* the cortical neural response based on the spectro-temporal representation of speech.

The inverse of the STRF can be used to *decode* the speech envelope information from the MEG response.

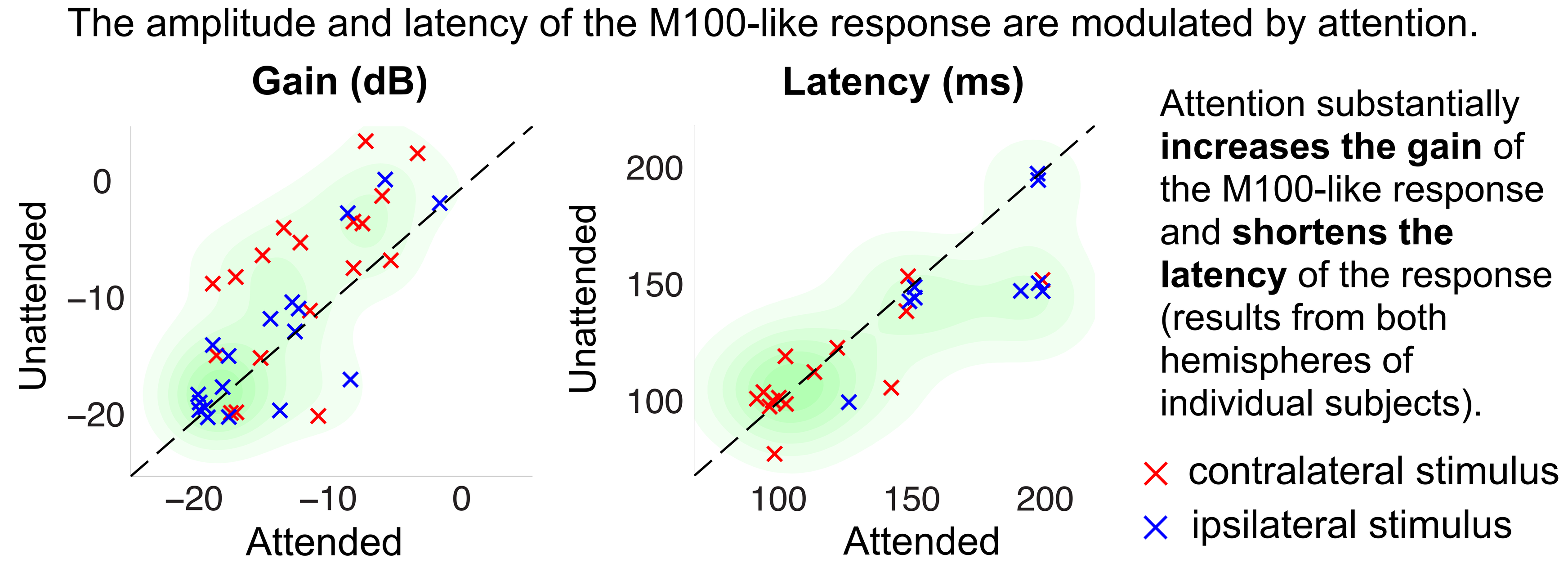
**The neural activity in human auditory cortex precisely encodes slow (<10 Hz) temporal modulations of speech.**

## Spatial cue based speech segregation




Right hemisphere STRF to speech from the left ear, during **dichotic listening** (grand average).

The amplitude and latency of the M100-like response are modulated by attention.

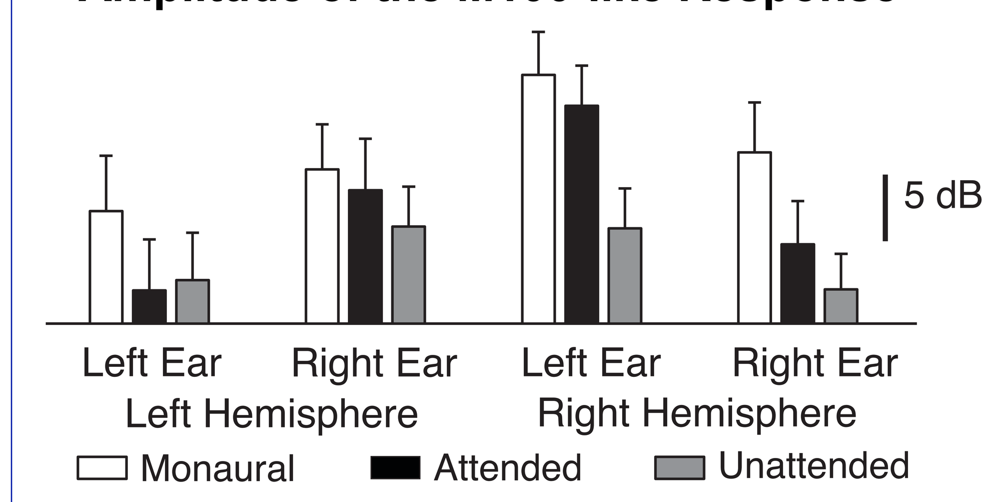



Attention substantially **increases the gain** of the M100-like response and **shortens the latency** of the response (results from both hemispheres of individual subjects).

**Purely spatial cue based speech segregation occurs in human auditory cortex, within 100 ms, reflected by the different attentional gains of the target and masker speech.**

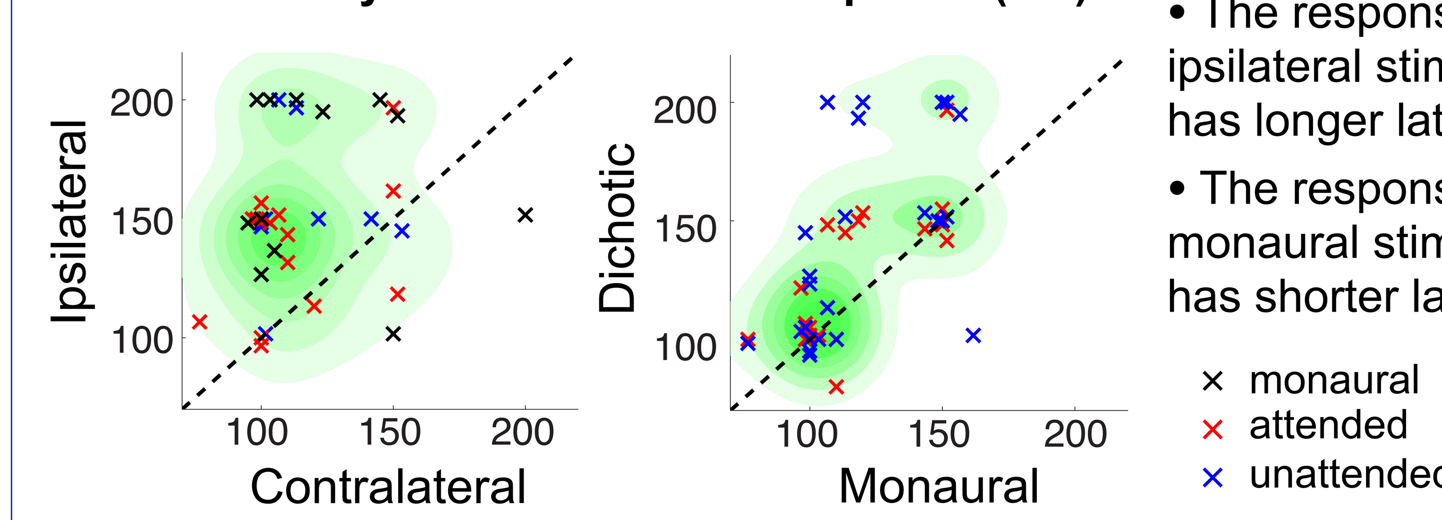
## Binaural interaction & Hemispheric lateralization

**Amplitude of the M100-like Response**




• The response is stronger in the right hemisphere.
• The response is stronger for monaural stimuli than dichotic stimuli.
• Each hemisphere is more responsive to the contralateral stimulus.

**Latency of the M100-like Response (ms)**




• The response to the ipsilateral stimulus has longer latency.
• The response to the monaural stimulus has shorter latency.

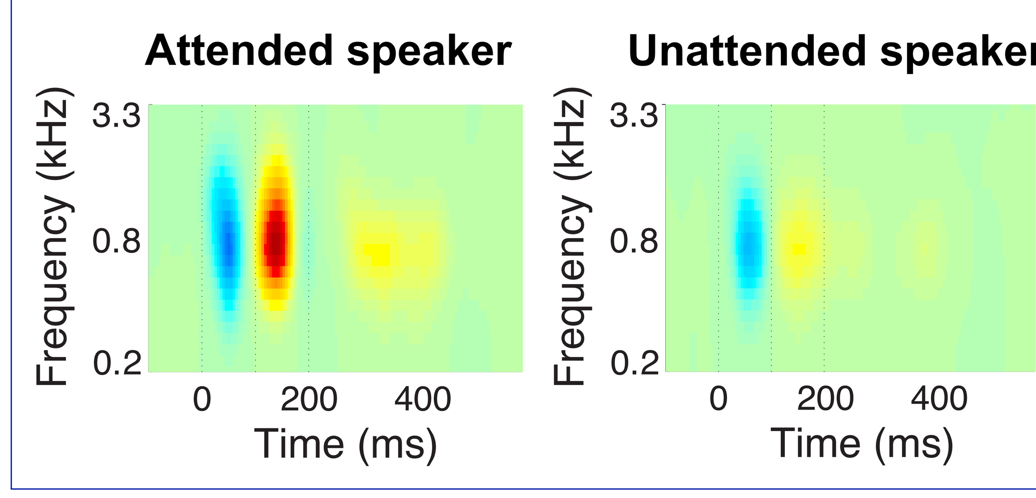
**Each hemisphere responds stronger and faster to contralateral stimuli. The response is weakened and delayed by stimuli in the other ear.**

## Summary & Future work

• **A faithful and robust neural coding of the temporal modulations of speech is observed using noninvasive neural recording methods. This neural code is strongly modulated by attention.**

• **A paradigm is provided to study the neural processing of continuous speech in various natural auditory scenes.**

To examine whether speech segregation as a general phenomenon occurs in human auditory cortex, we investigate the neural processing underlying ***speaker feature cue based speech segregation***.




***Stimulus***: a diotic speech mixture consisting of a male and a female voice

***Preliminary results***: The strong attentional gain effect suggests **collocated target and masker speech are represented separately in auditory cortex**.

## Reference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