

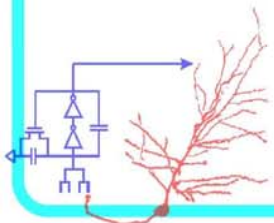
# Human Cortical Representations of Complex Temporal Modulations

Nai Ding, Jonathan Z. Simon

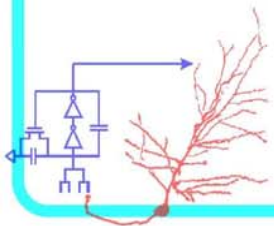
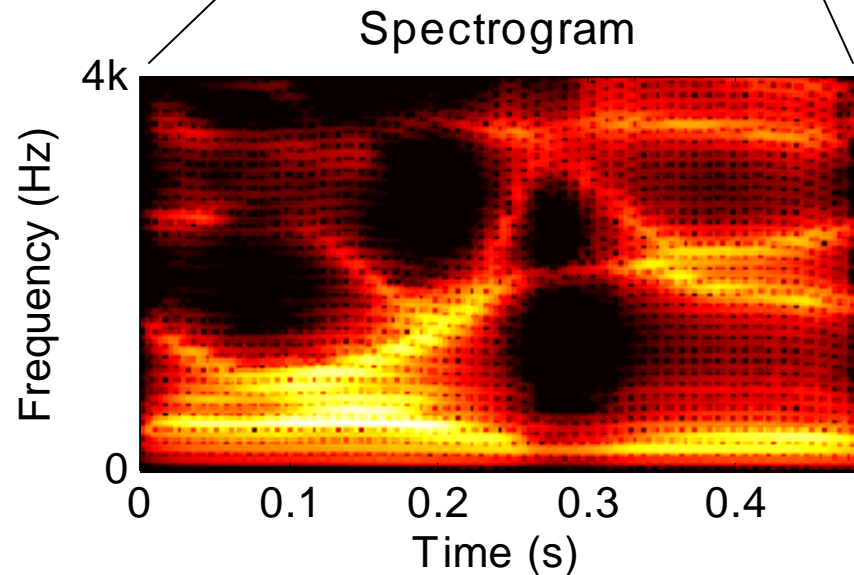
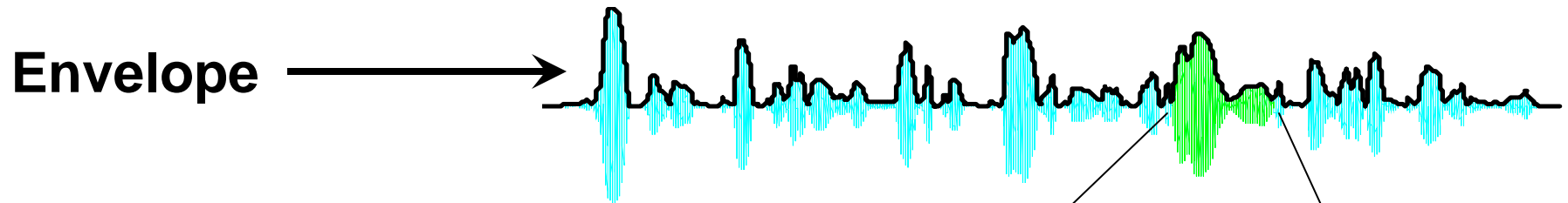
*C-CEBH*

*Electrical Engineering / Biology*

*University of Maryland, College Park*

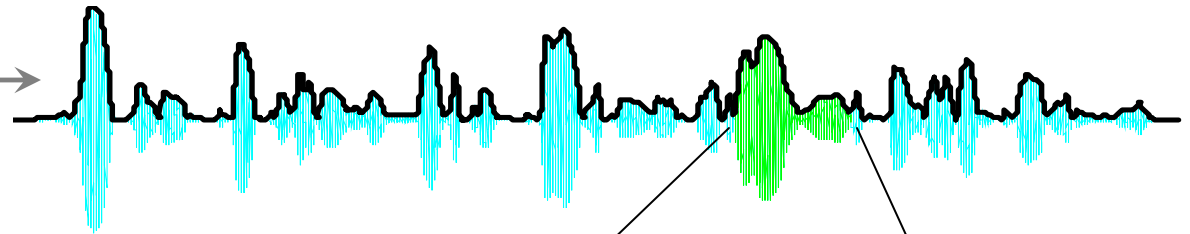


# Complex Modulations in Speech

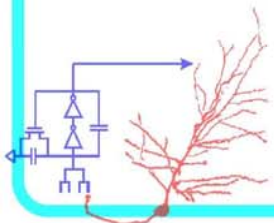
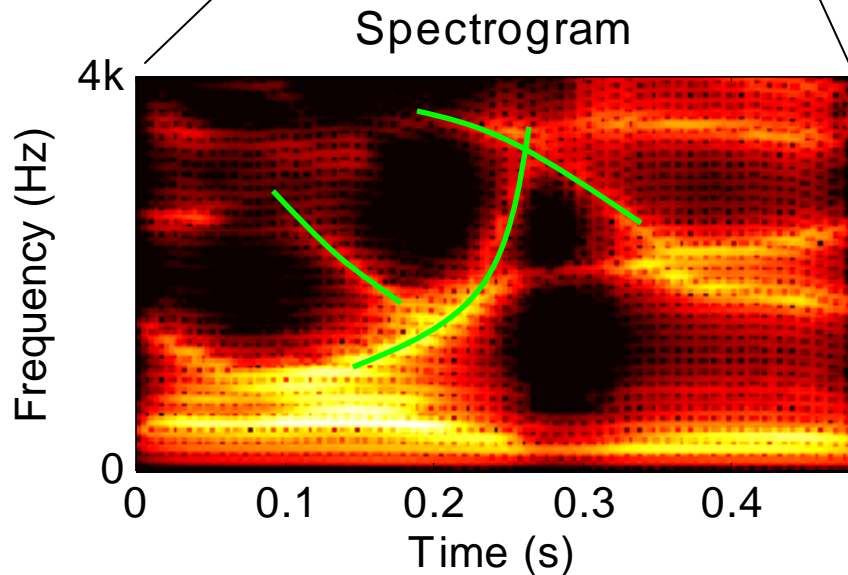


# Complex Modulations in Speech

Envelope



Fine structure

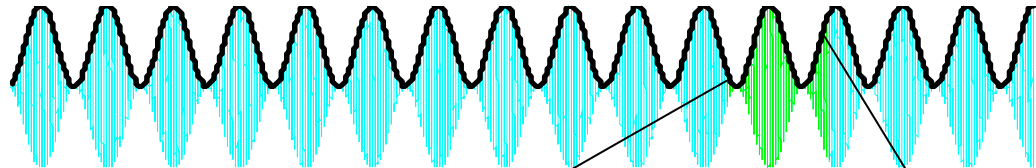


# Our Stimuli

Envelope



AM rate: 3.1 Hz

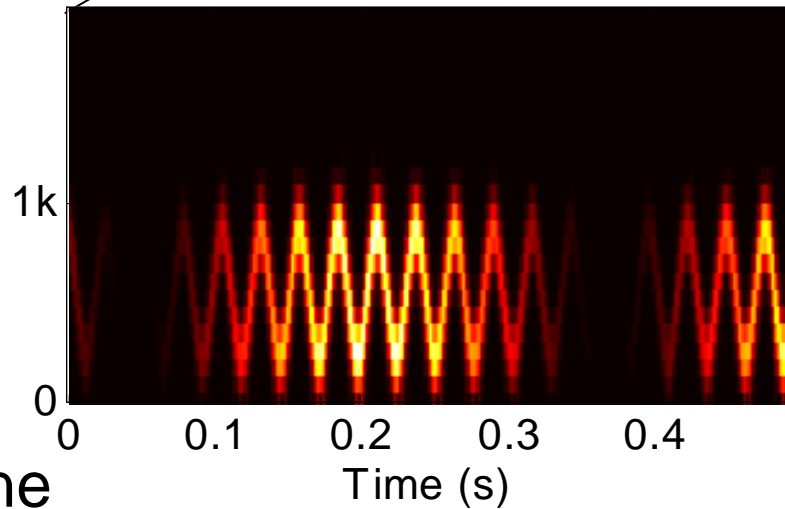


Fine structure



FM rate: 37.7 Hz

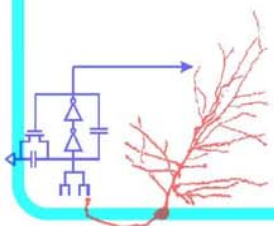
Frequency (Hz)



Carrier: 550 Hz pure tone

AM rate: 0.3, 0.7, 1.7, 3.1, 4.9, 9.9, 13.8 Hz

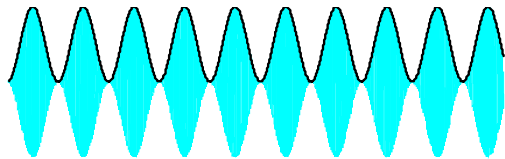
FM rate: 37.7 Hz



# MEG Response to Temporal Modulations

**Acoustic Stimulus**

AM at 3 Hz



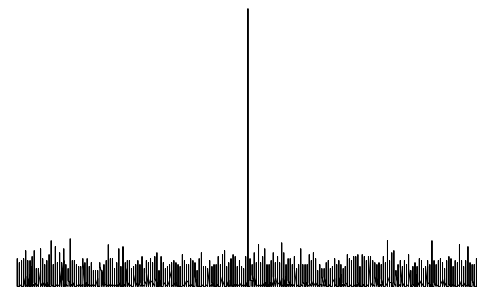
**Cartoon Neural Response  
Measured by MEG**

3 Hz phase locked oscillation

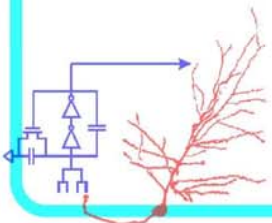


Fourier Transform

Power spectrum of MEG response



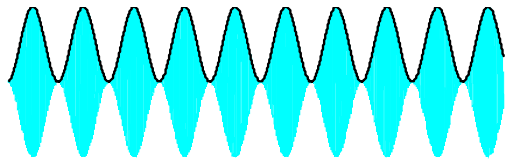
1 Hz      3 Hz      5 Hz



# MEG Response to Temporal Modulations

**Acoustic Stimulus**

AM at 3 Hz



**Cartoon Neural Response  
Measured by MEG**

3 Hz phase locked oscillation

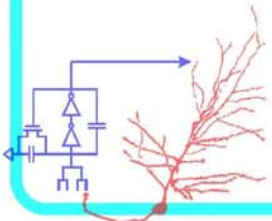


Fourier Transform

Power spectrum of MEG response

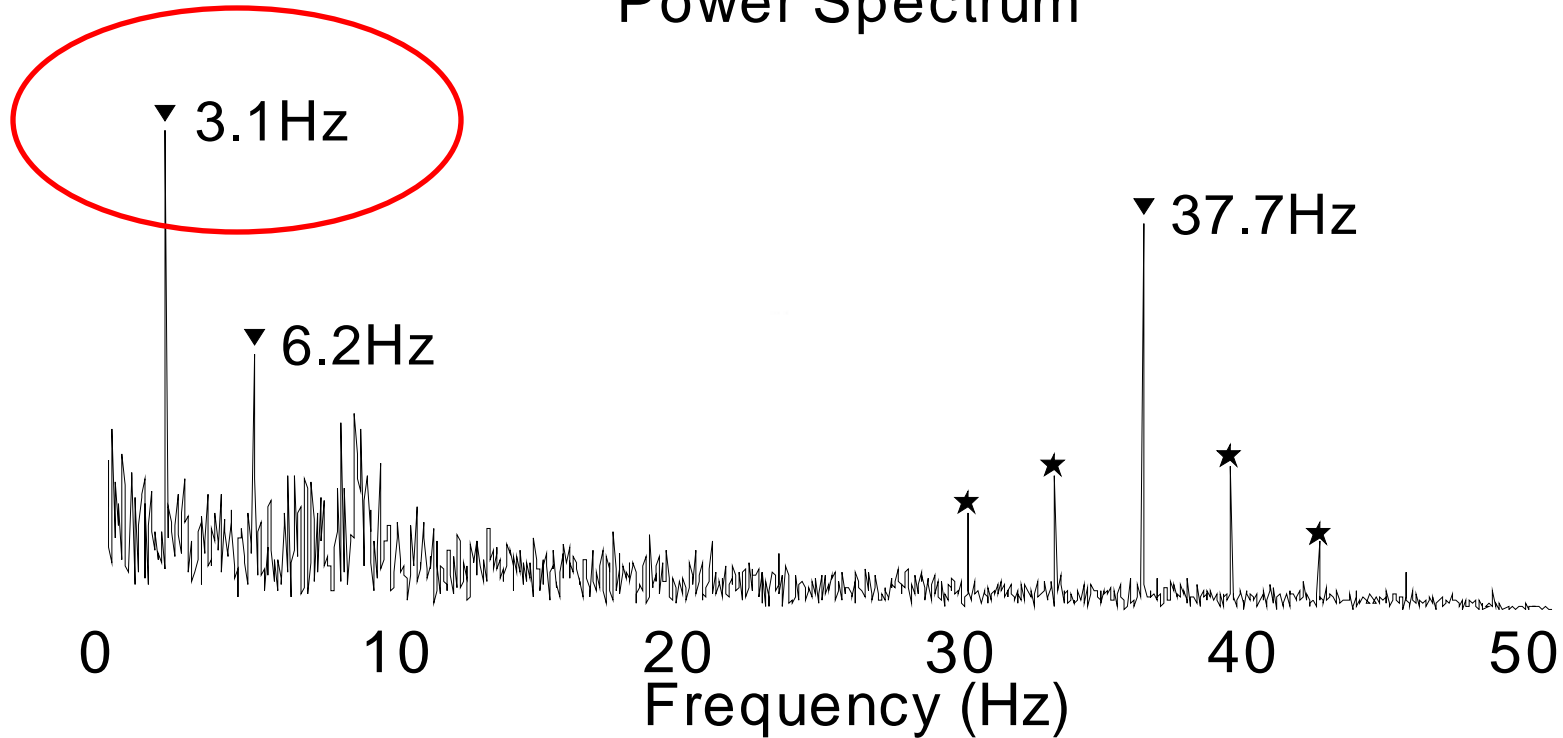


1 Hz 3 Hz 5 Hz

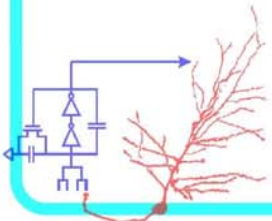


# Neural response to our stimuli

## Power Spectrum

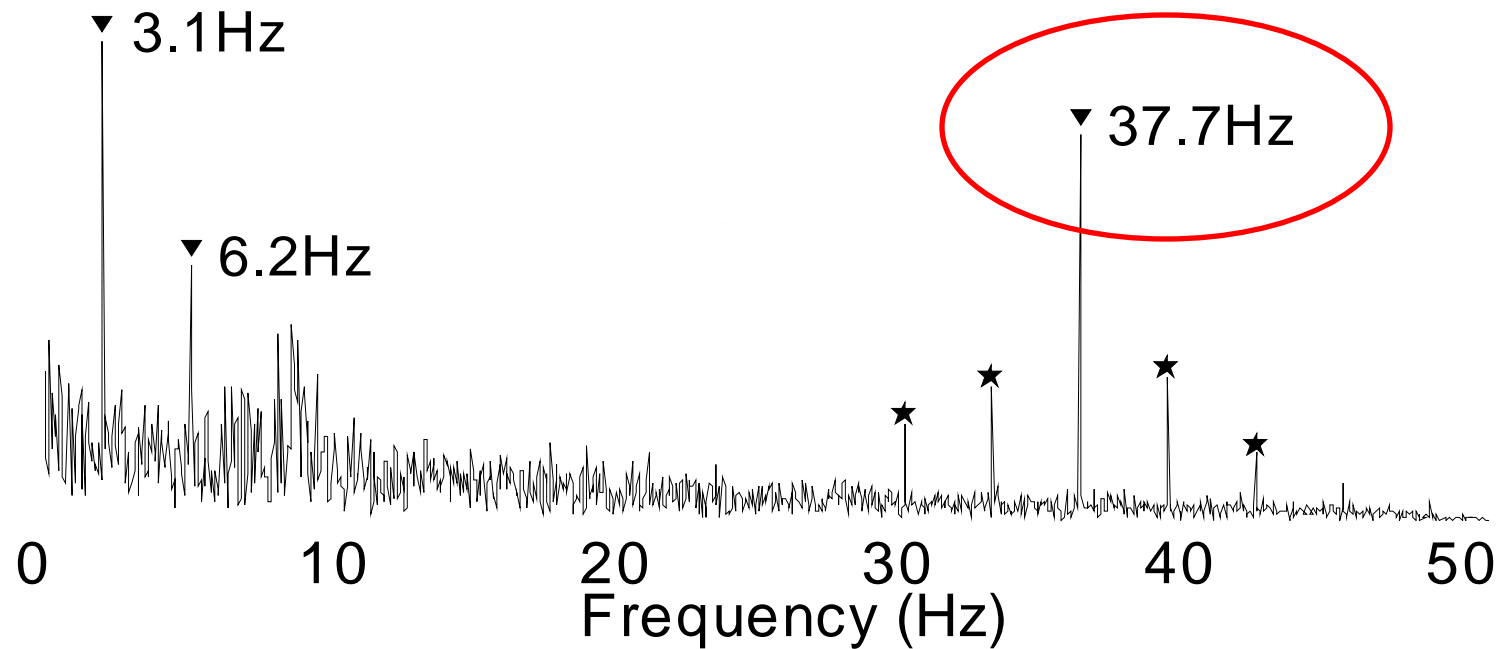


AM rate = 3.1 Hz, FM rate = 37.7 Hz

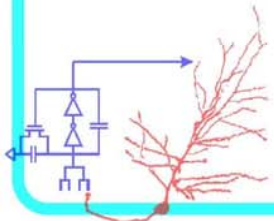


# Neural response to our stimuli

## Power Spectrum



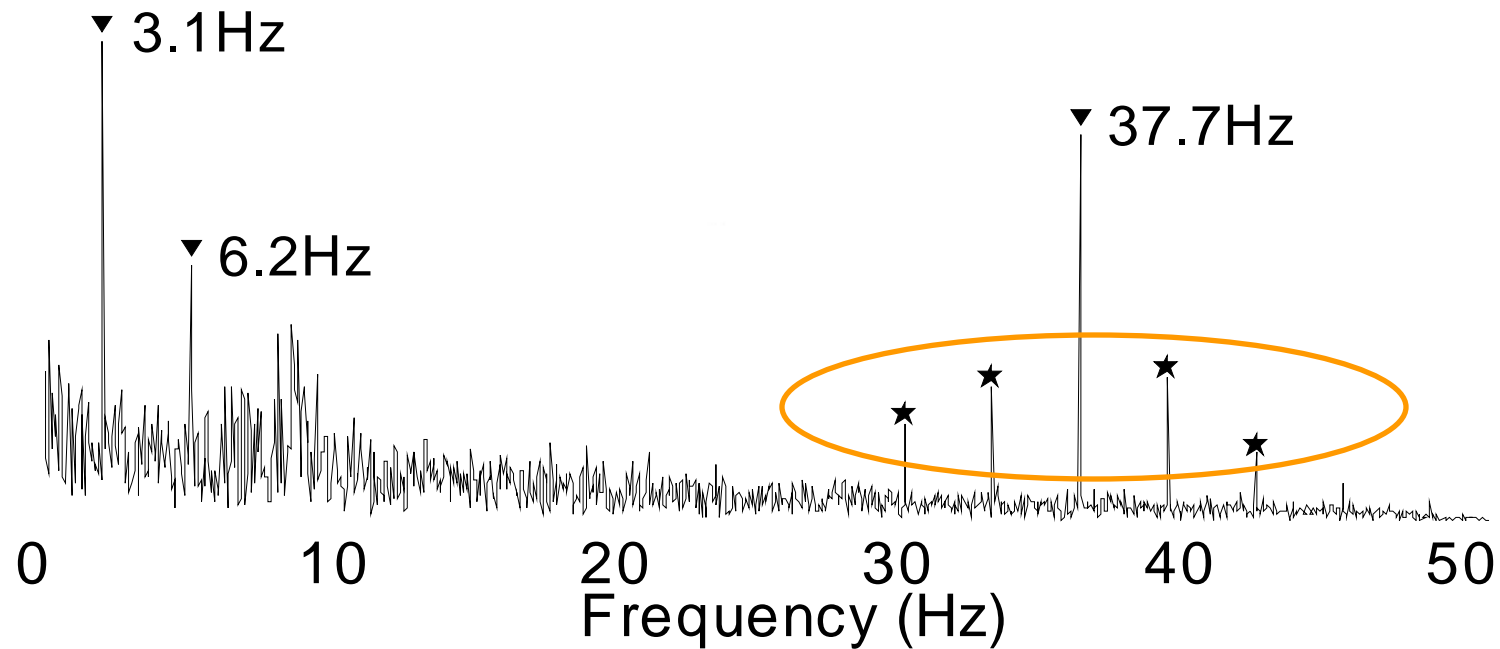
AM rate = 3.1 Hz, FM rate = 37.7 Hz



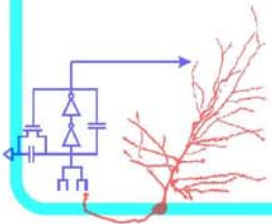


# Neural response to our stimuli

## Power Spectrum



AM rate = 3.1 Hz, FM rate = 37.7 Hz

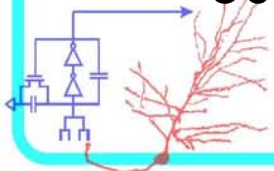
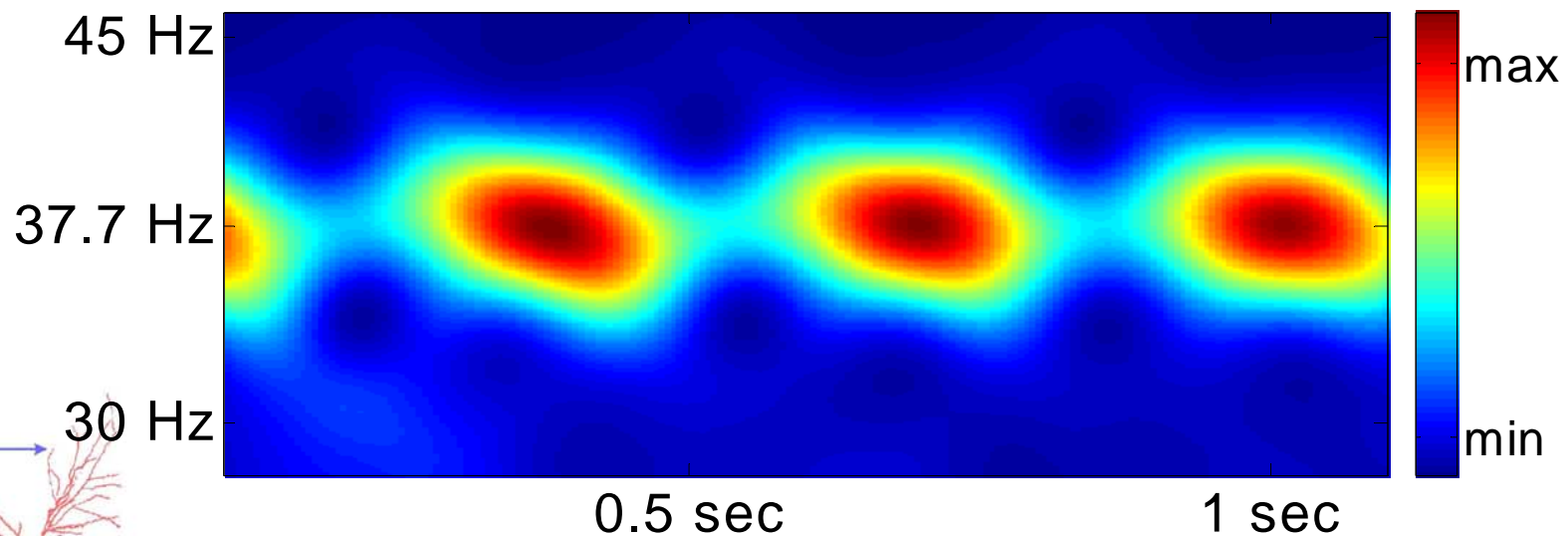


# Interactions between Neural Responses

- The power or phase of the neural response at the FM rate is fluctuating with fundamental frequency at the stimulus AM rate.

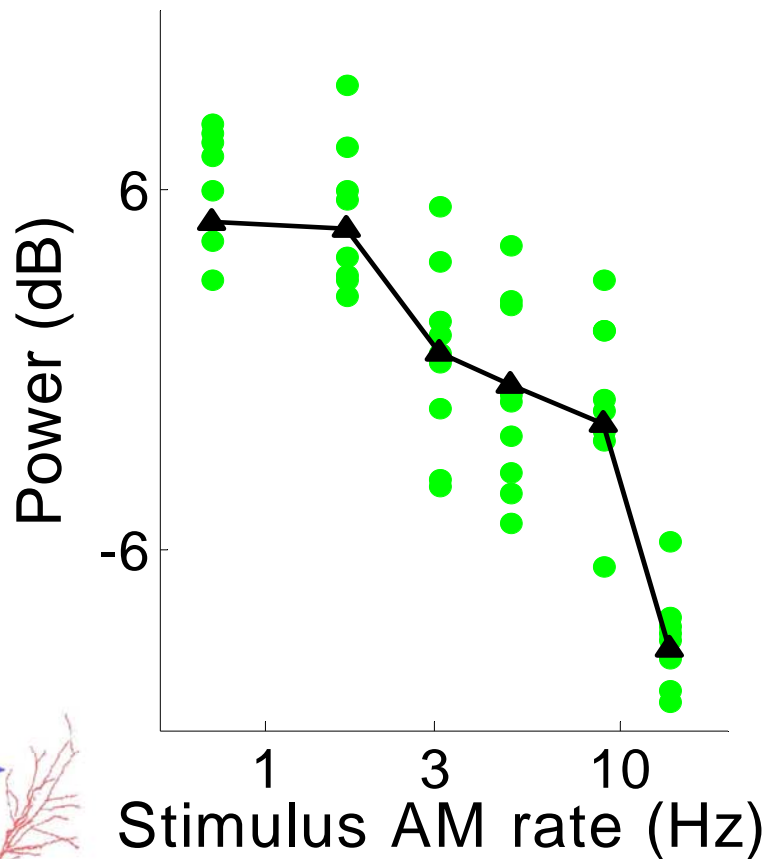
AM rate = 3.1 Hz, FM rate = 37.7 Hz

## Spectrogram

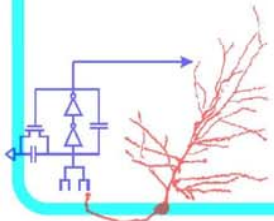
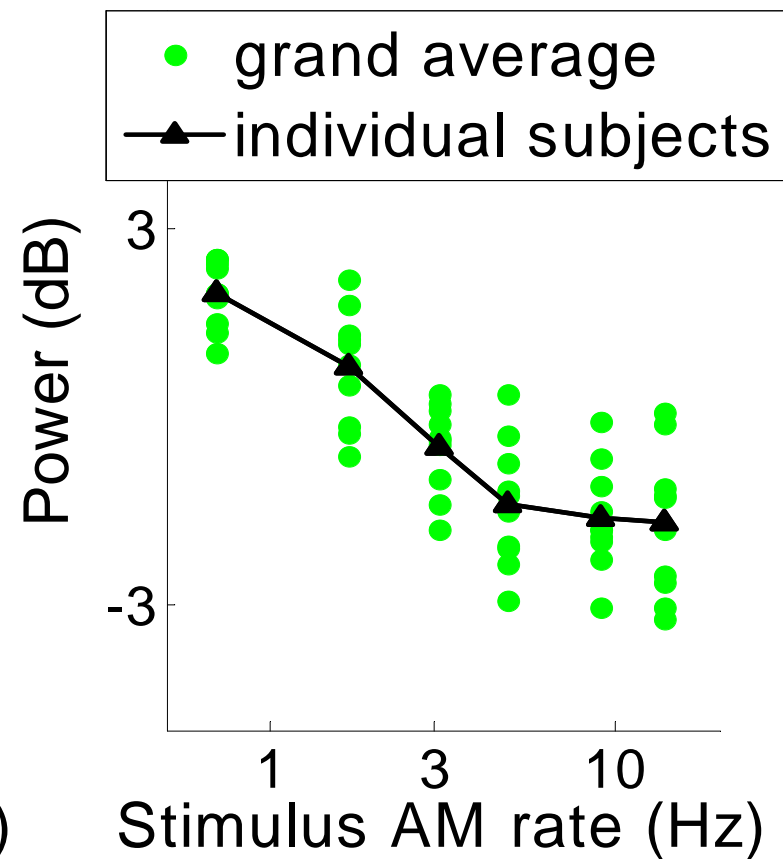


# Power of responses to AM

Response at AM rate

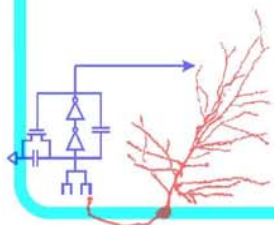


Response at FM rate



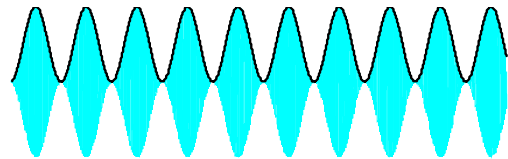
# Neural representations of Complex Modulations

- Both slow ( $<15$  Hz) and fast ( $\sim 40$  Hz) temporal modulations are represented by phase locked neural responses.
- Slow modulations are represented by not only the neural response at its own modulation rate but also by the temporal dynamics of the neural responses to faster modulations.

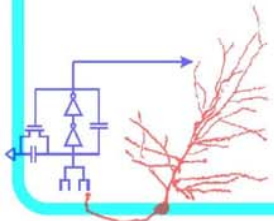


# From AM to Speech

AM Stimulus

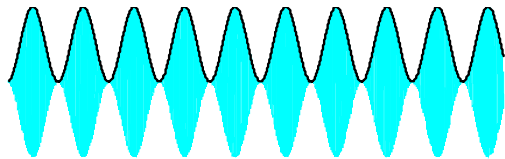


Neural Representation  
Measured by MEG



# From AM to Speech

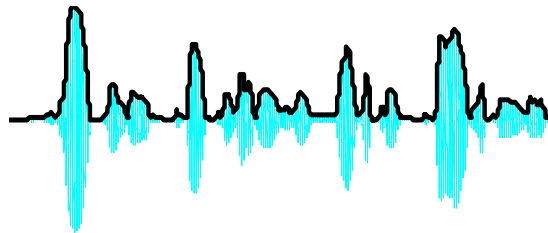
AM Stimulus



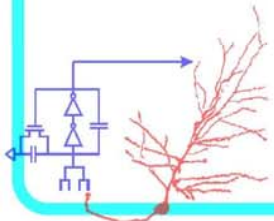
Neural Representation  
Measured by MEG



Speech

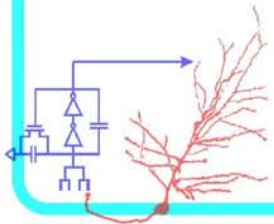
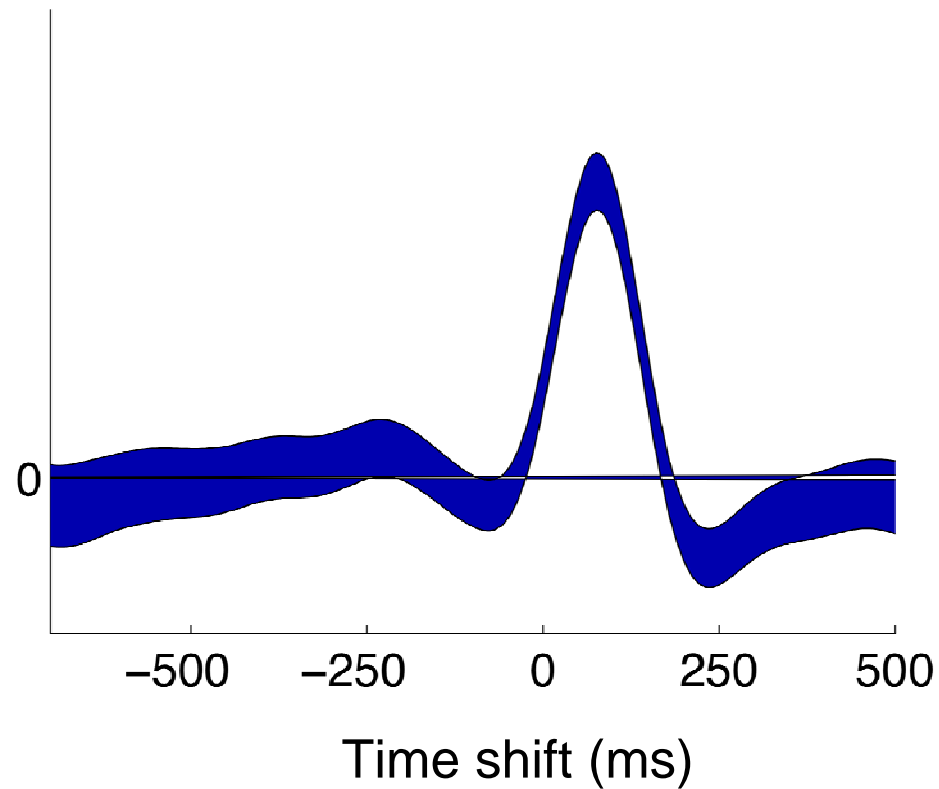


?



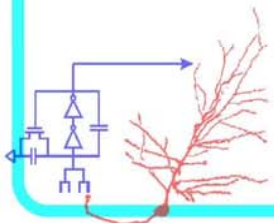
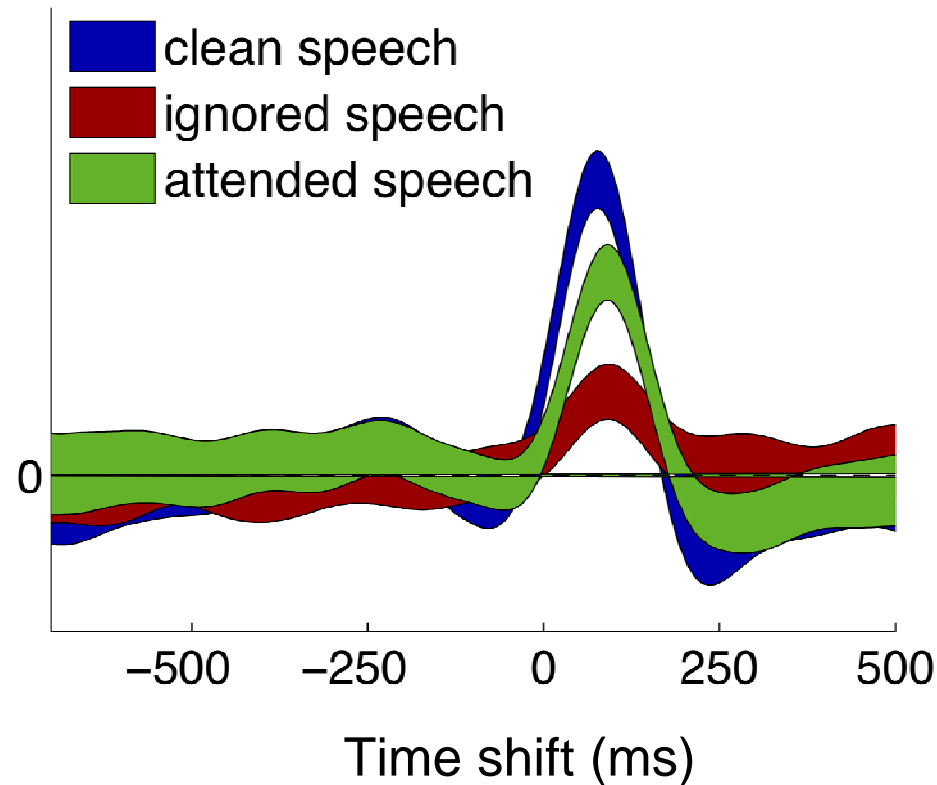
# MEG response to speech

Correlation between MEG response  
and speech envelope



# MEG response to speech

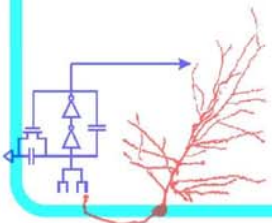
Correlation between MEG response  
and speech envelope





# Summary

- 1. The neural representation of slow temporal modulations is phase locked and measurable using MEG.
- 2. The neural representation of slow temporal modulations is highly modulated by attention.



# Thank you!

