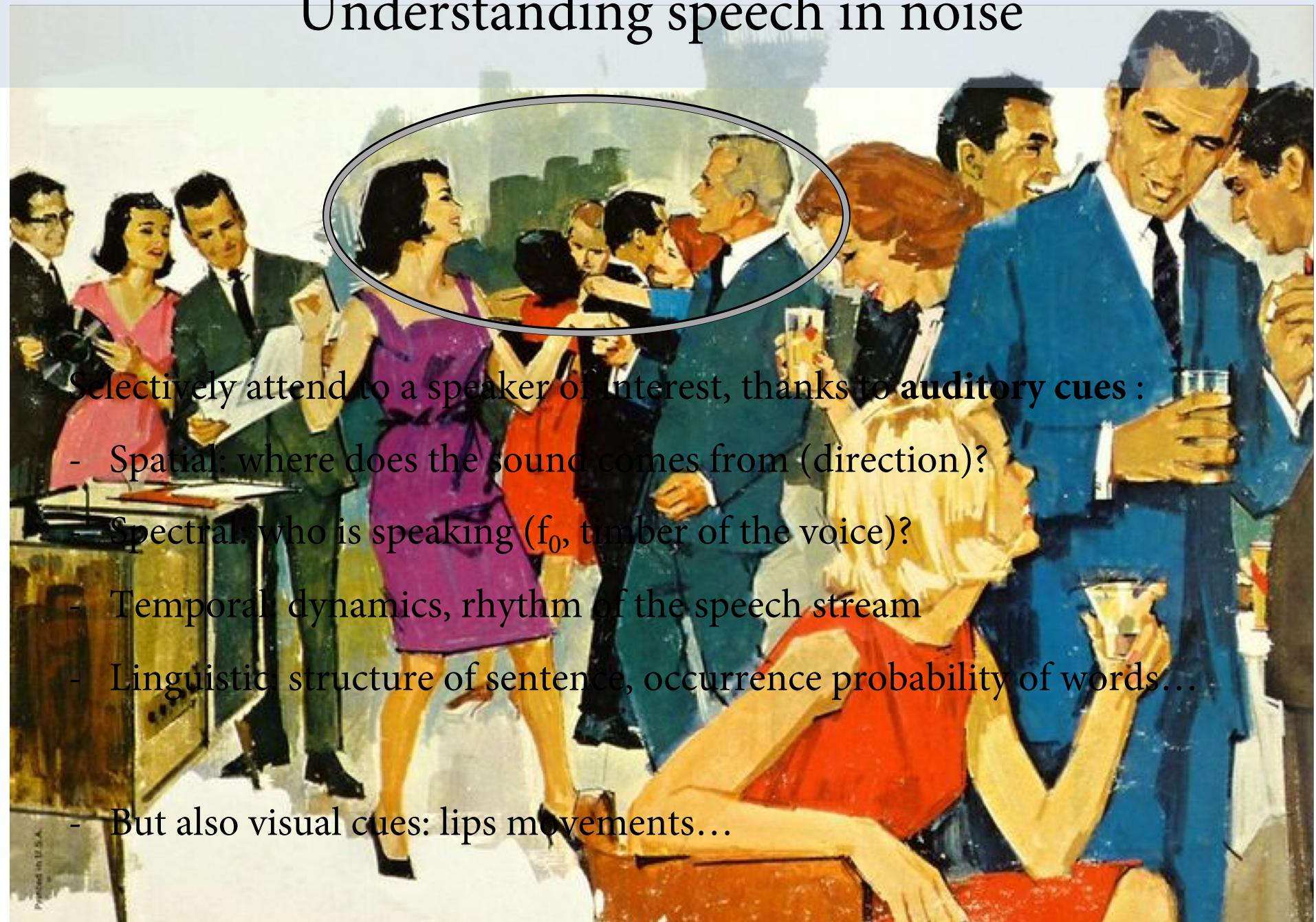


# Contribution of the motor system to auditory perception: *Temporal predictions*

Benjamin Morillon

Aix Marseille Univ., Inserm, INS, Inst. Neurosci. Syst.,  
Marseille, France

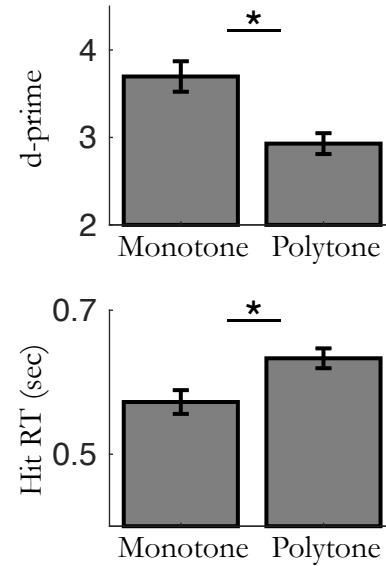
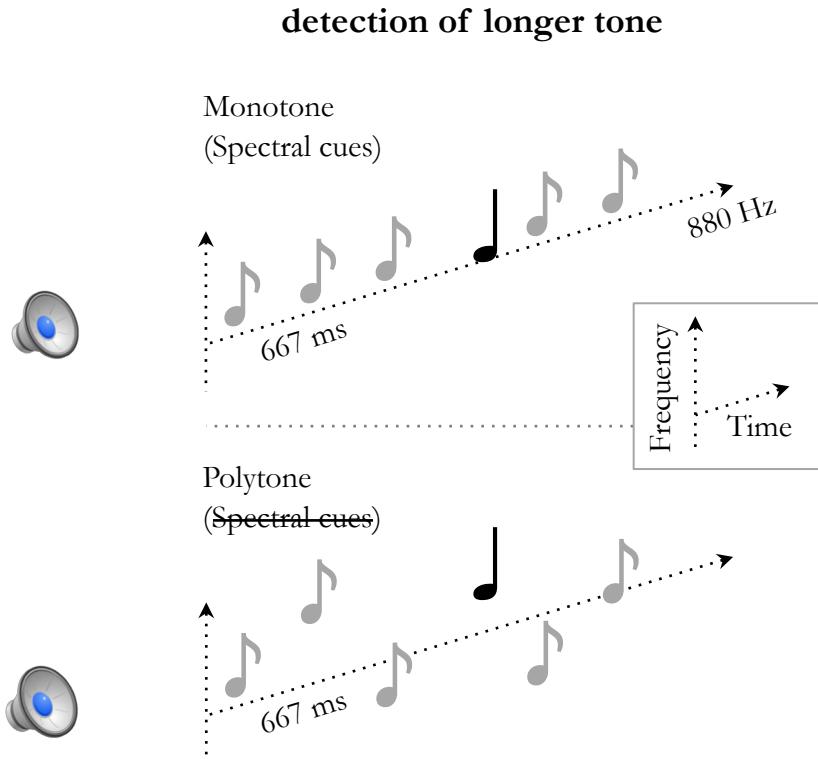
# Understanding speech in noise



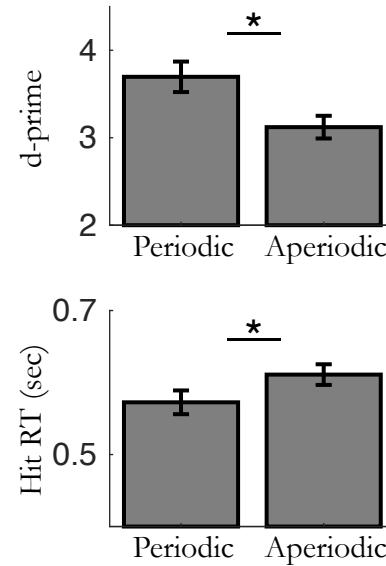
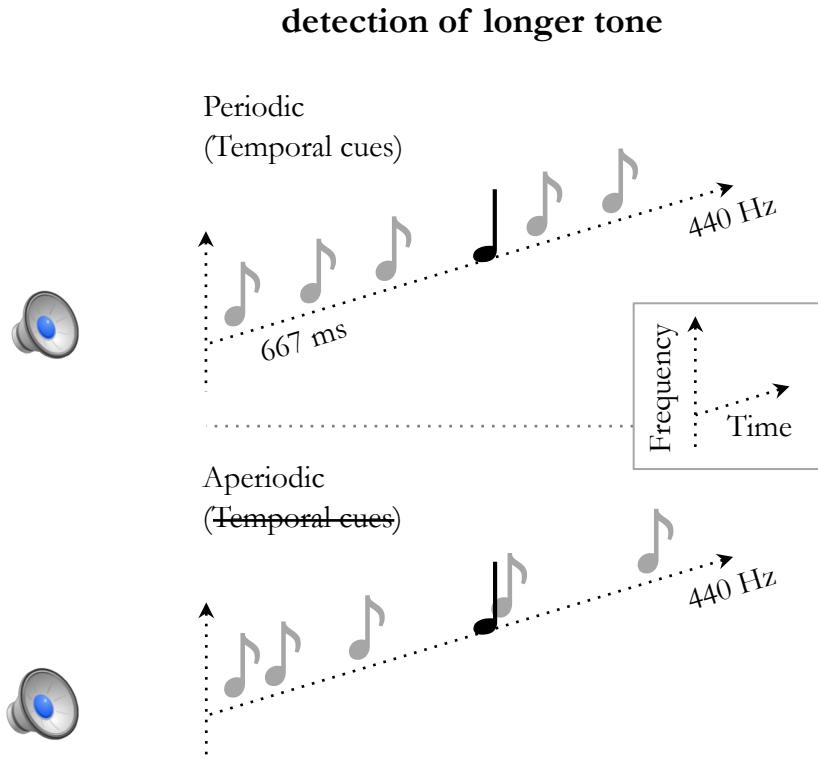
Selectively attend to a speaker of interest, thanks to **auditory cues** :

- Spatial: where does the sound comes from (direction)?
- Spectral: who is speaking ( $f_0$ , timber of the voice)?
- Temporal: dynamics, rhythm of the speech stream
- Linguistic: structure of sentence, occurrence probability of words...
- But also visual cues: lips movements...

# Perceptual benefits of spectral cues



# Perceptual benefits of temporal cues



*Implications:*

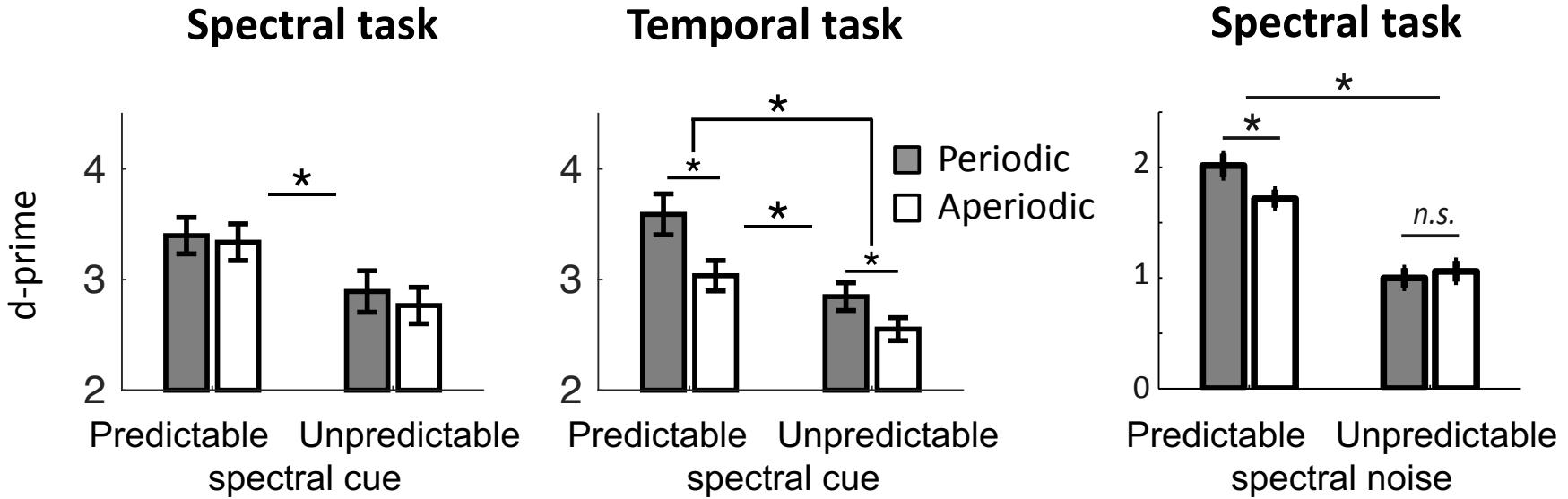
Perceive regularities in the environment (cues)

Generate internal models (predictions)

Anticipate future events

Optimize perception

# Interaction between temporal and spectral predictions



- Predictions interact and spectral priors dominate over temporal ones
- ‘Modulated’ by task-demands and prior knowledge

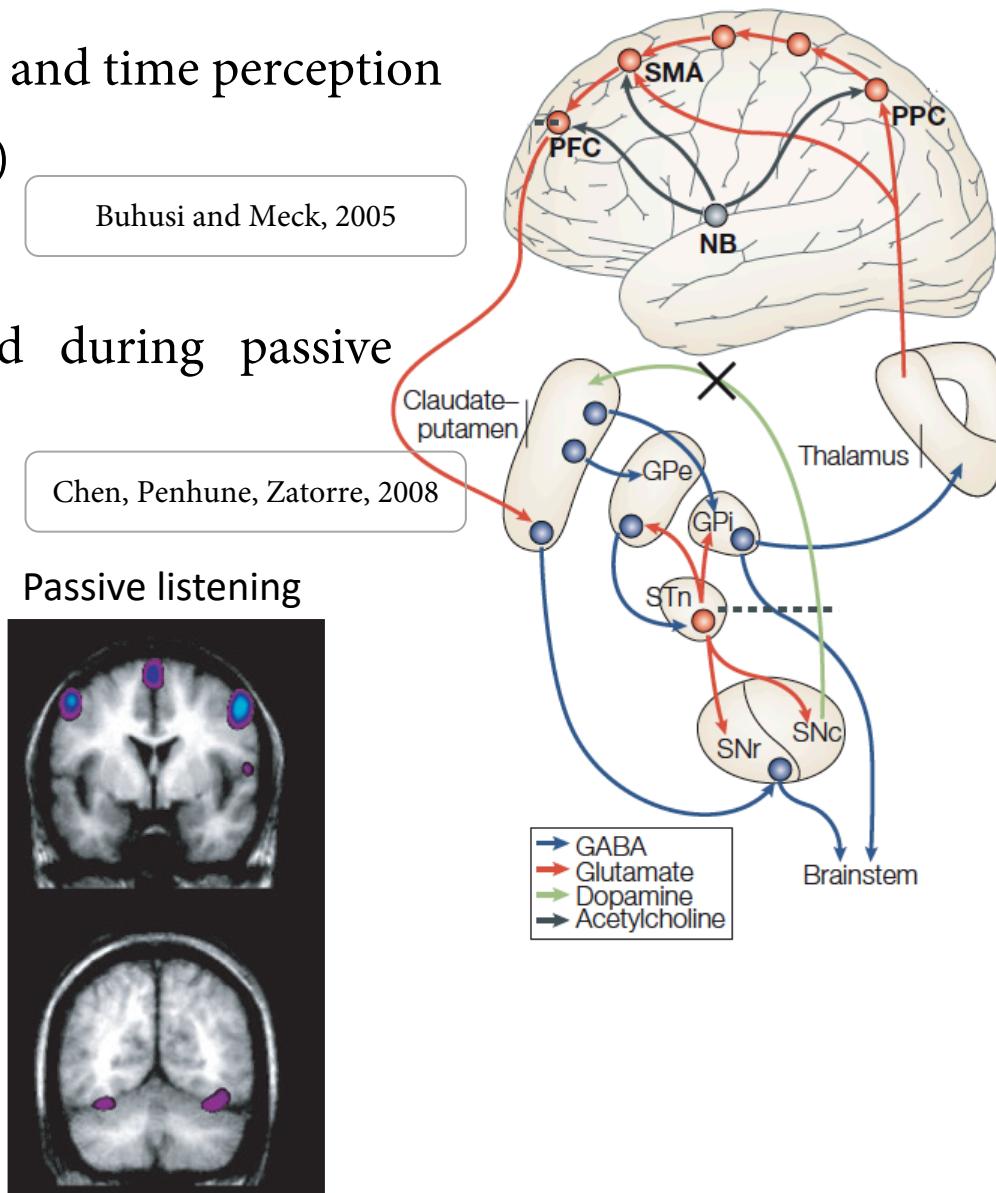
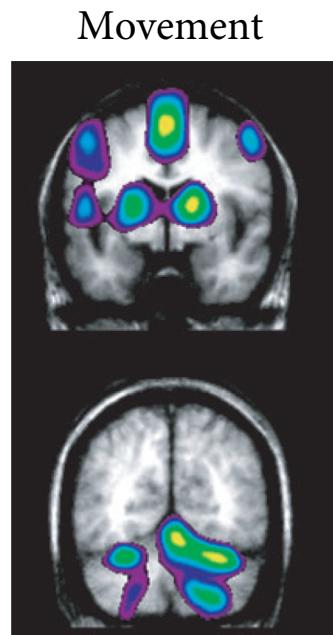
# Investigating the neural substrate of temporal predictions

# The motor system encodes temporal predictions

- ✓ The motor system supports timing and time perception in the range of seconds (~.4-2 sec)
- ✓ The motor network is recruited during passive listening of musical rhythms

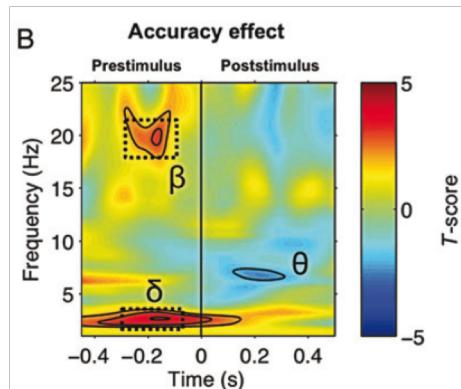
Buhusi and Meck, 2005

Chen, Penhune, Zatorre, 2008

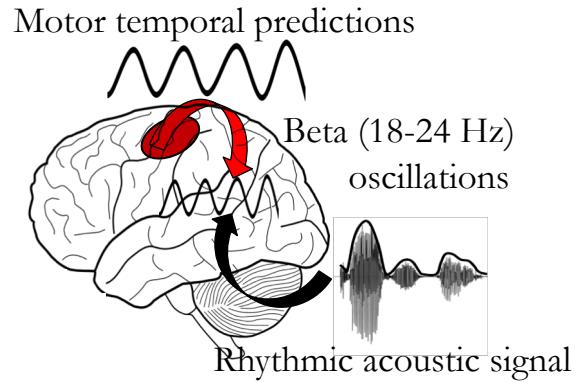


# The motor system encodes temporal predictions

- ✓ Motor origin of temporal predictions in auditory attention

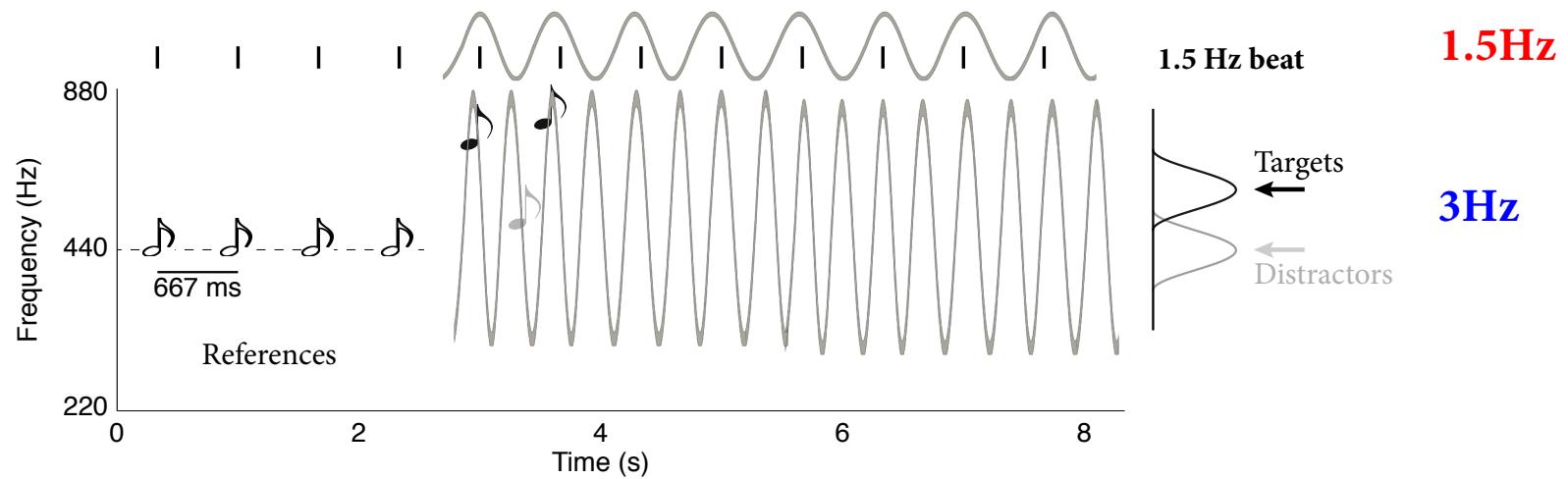
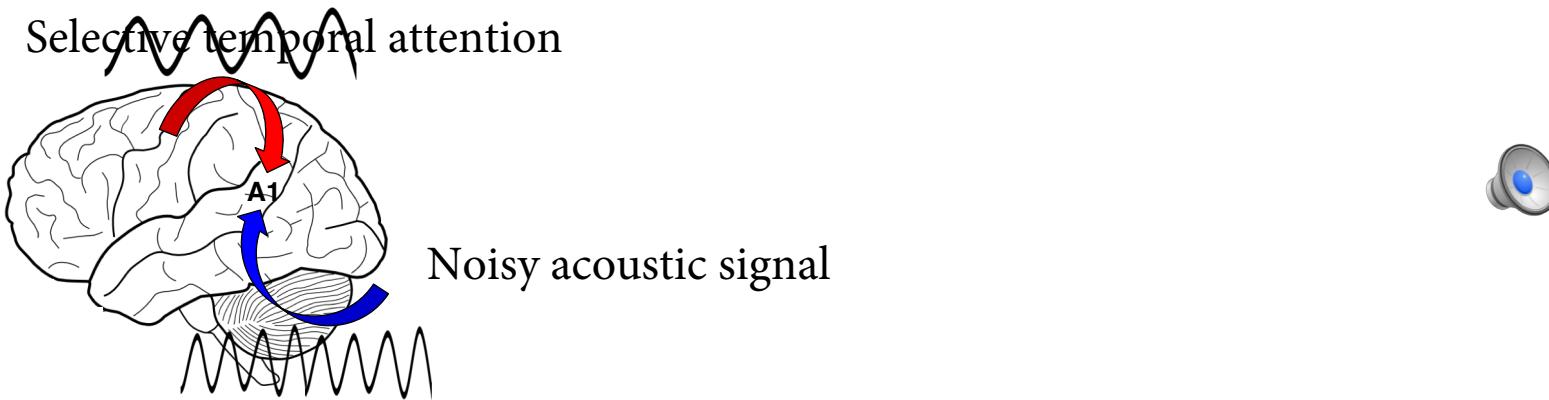


Arnal et al., 2015

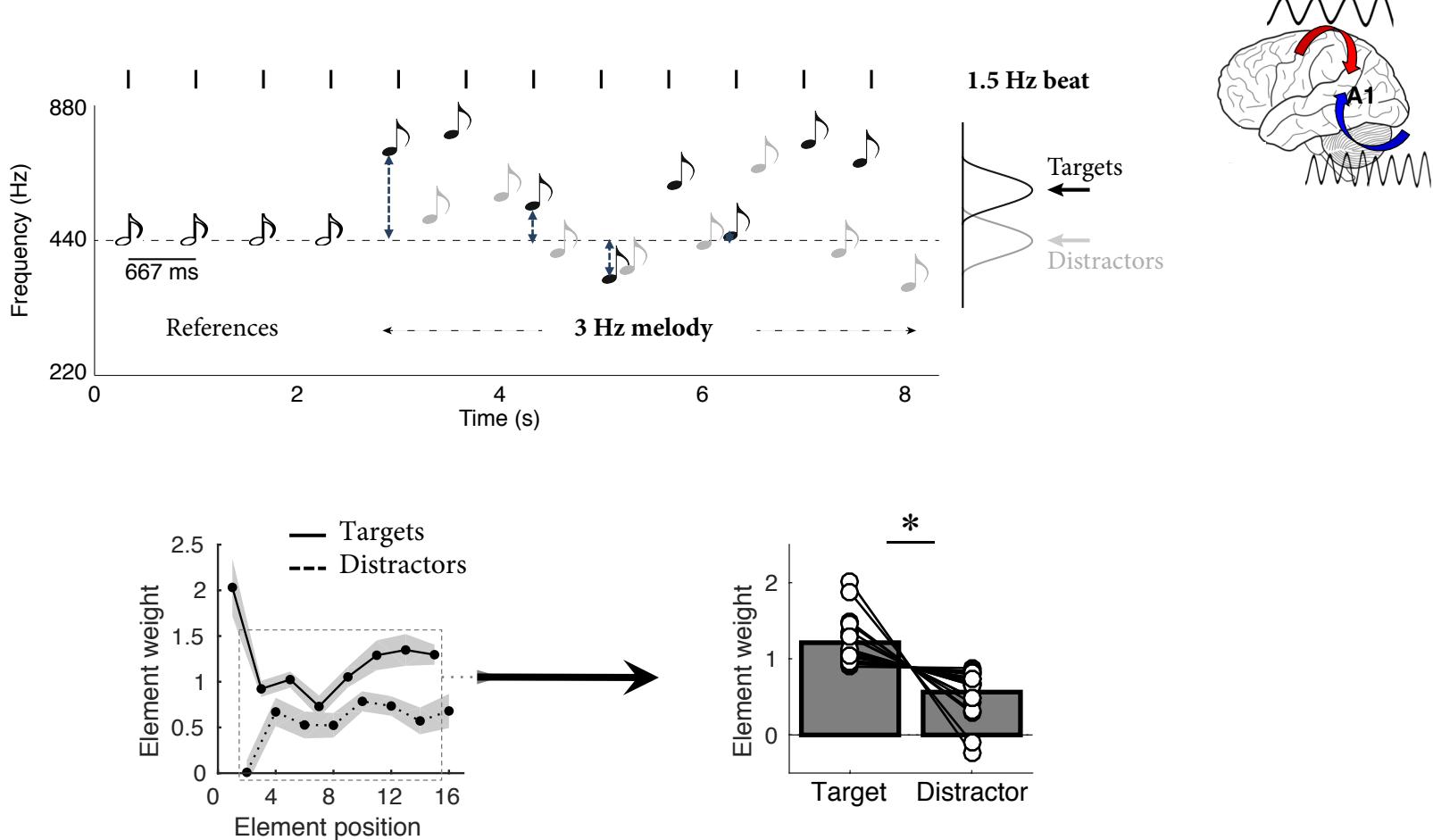


Morillon, Baillet, 2017

# Dissociating acoustic and attentional rhythms

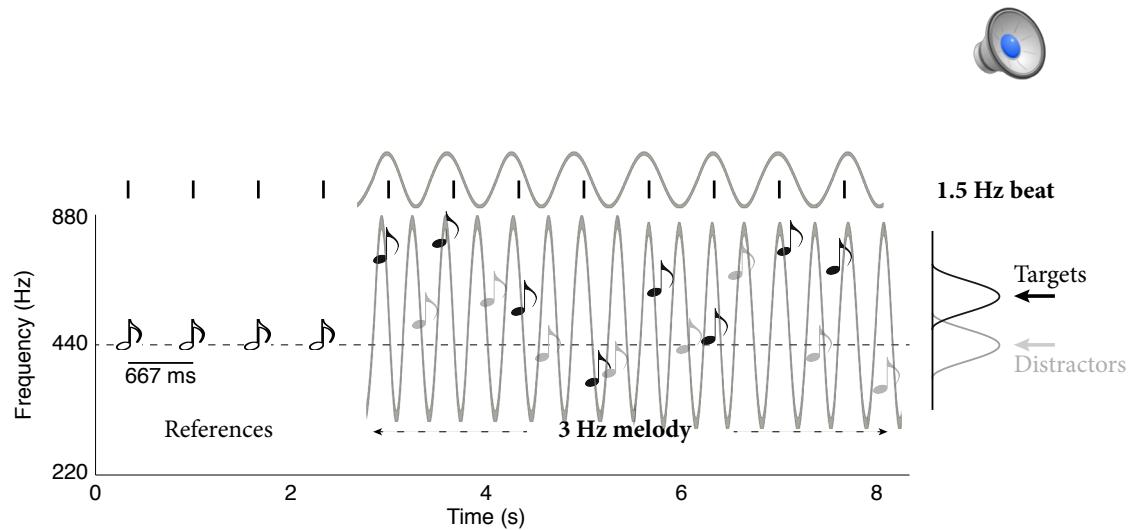
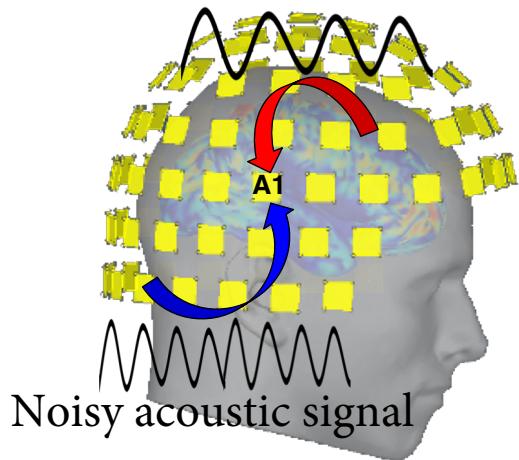


# Attention has a limited temporal precision



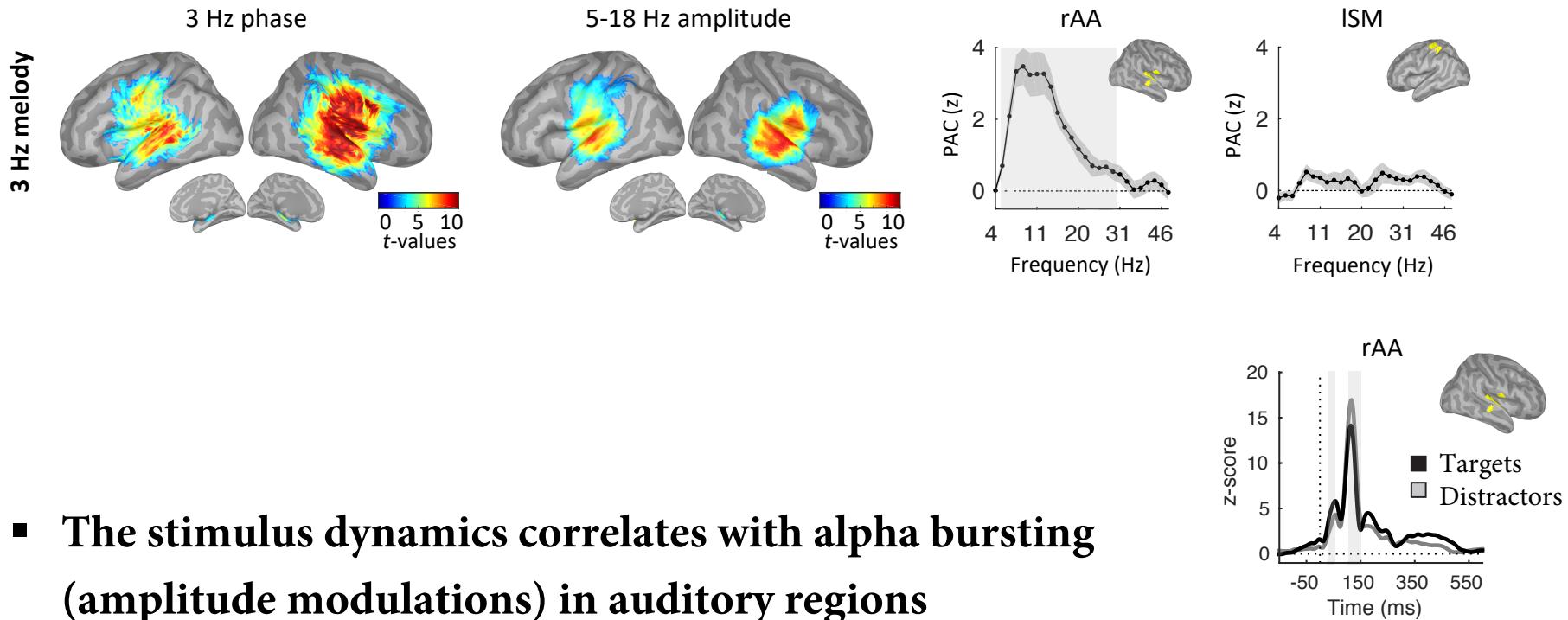
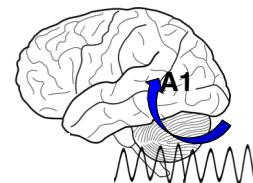
# Dissociating acoustic and attentional rhythms

Selective temporal attention



# How is stimulus dynamics encoded?

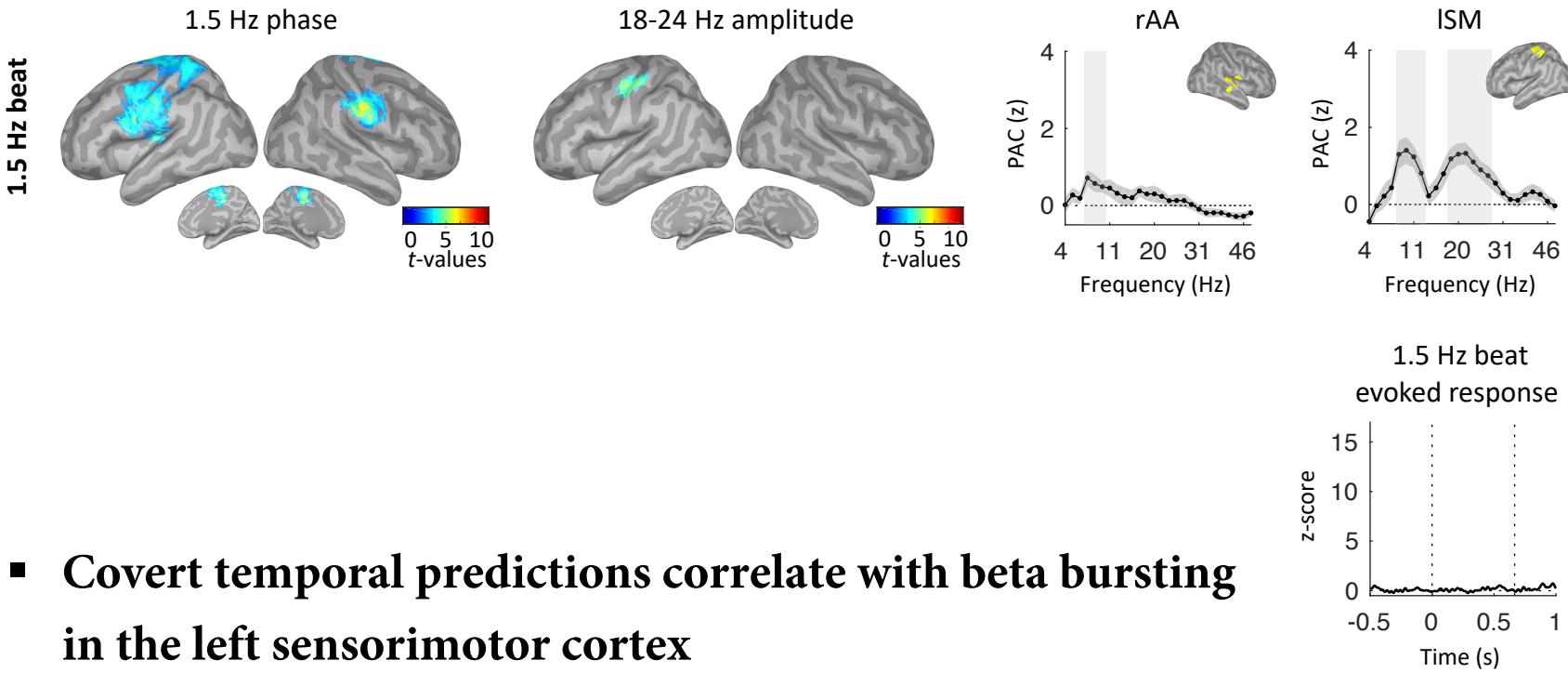
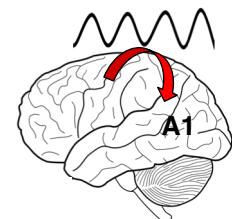
- Condition: Passive listening



- The stimulus dynamics correlates with alpha bursting (amplitude modulations) in auditory regions

# How are covert temporal predictions encoded?

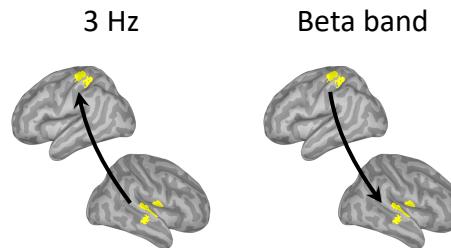
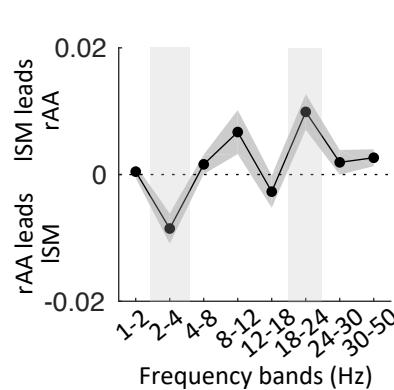
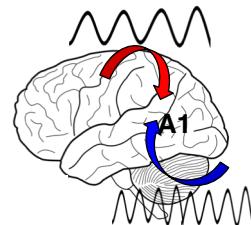
- Condition: Passive listening



- Covert temporal predictions correlate with beta bursting in the left sensorimotor cortex

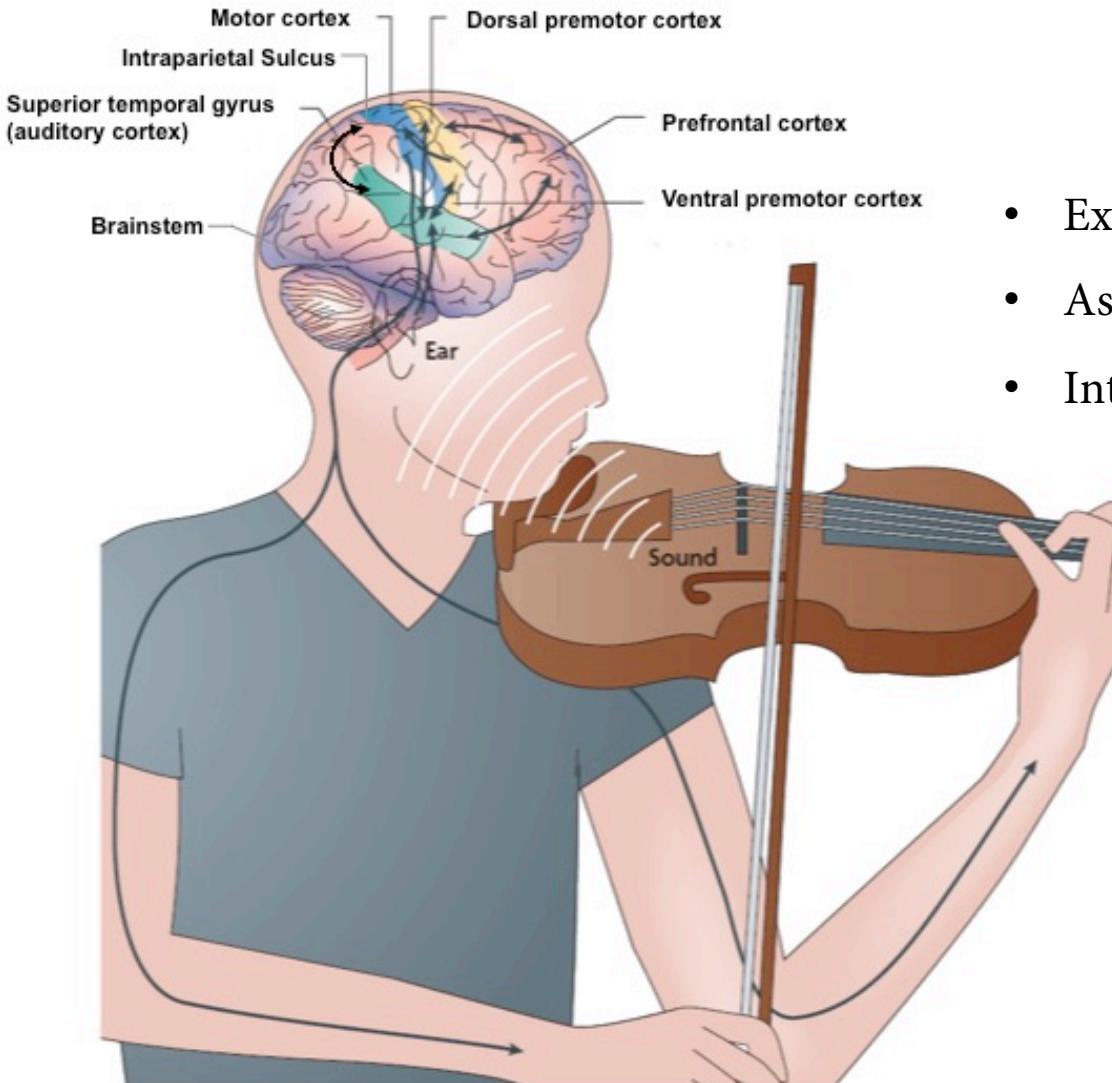
# Bottom-up and top-down directed connectivity

- Condition: Passive listening



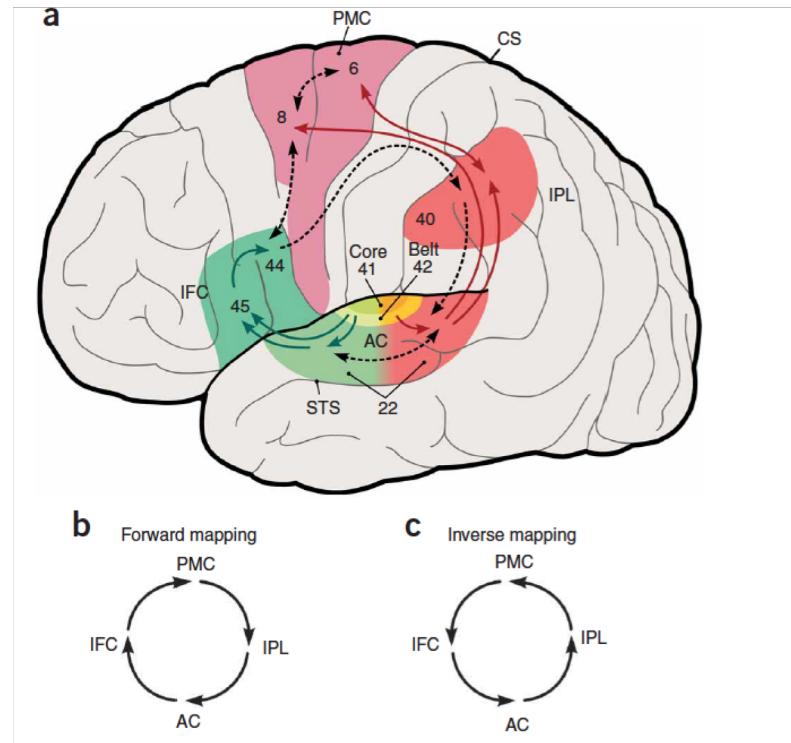
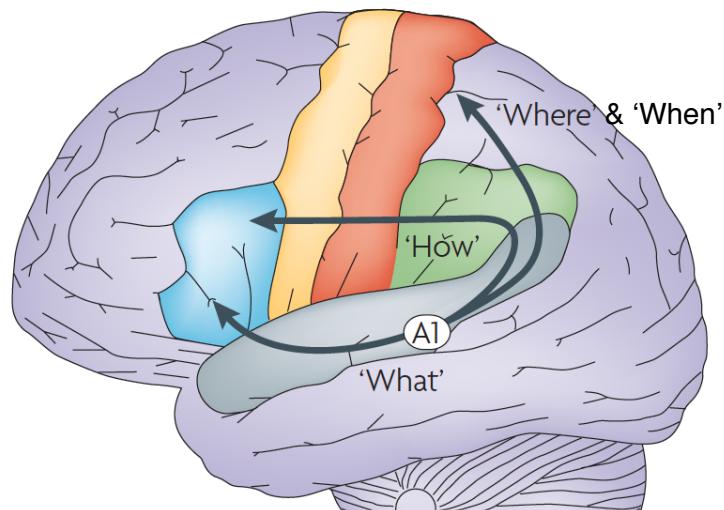
- Spectral dissociation between bottom-up (3 Hz) and top-down (Beta band) information flows

# Audio-motor interactions



- External auditory feedback
- Ascending audio-motor processing
- Internal motor feedback (descending)

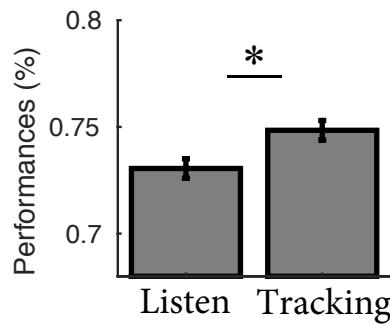
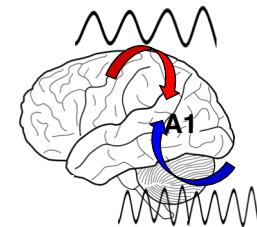
# Temporal cues are processed in the dorsal stream



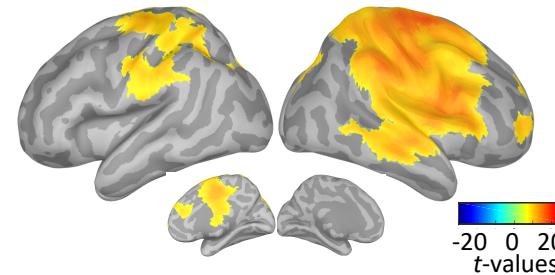
- Hypothesis: Stimulate the motor system to enhance the processing of temporal cues

# Overt motor tapping improves the temporal precision of auditory attention

- Conditions: Passive listening *vs.* overt motor tracking



Tracking-Listen contrast (1.5 Hz phase)

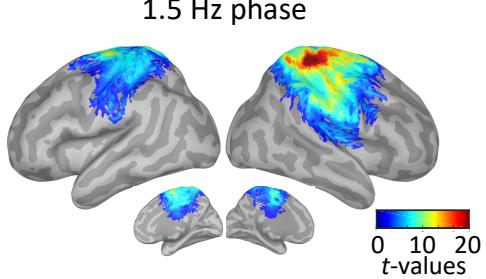


- **Overt motor tracking:**
  - improves targets|distractors segregation
  - drives rhythmic fluctuations in attention
- **Stronger and more widespread 1.5 Hz modulations during overt tracking**
- **Move to hear better**

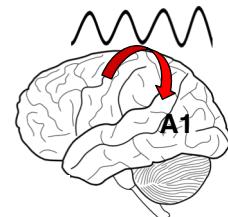
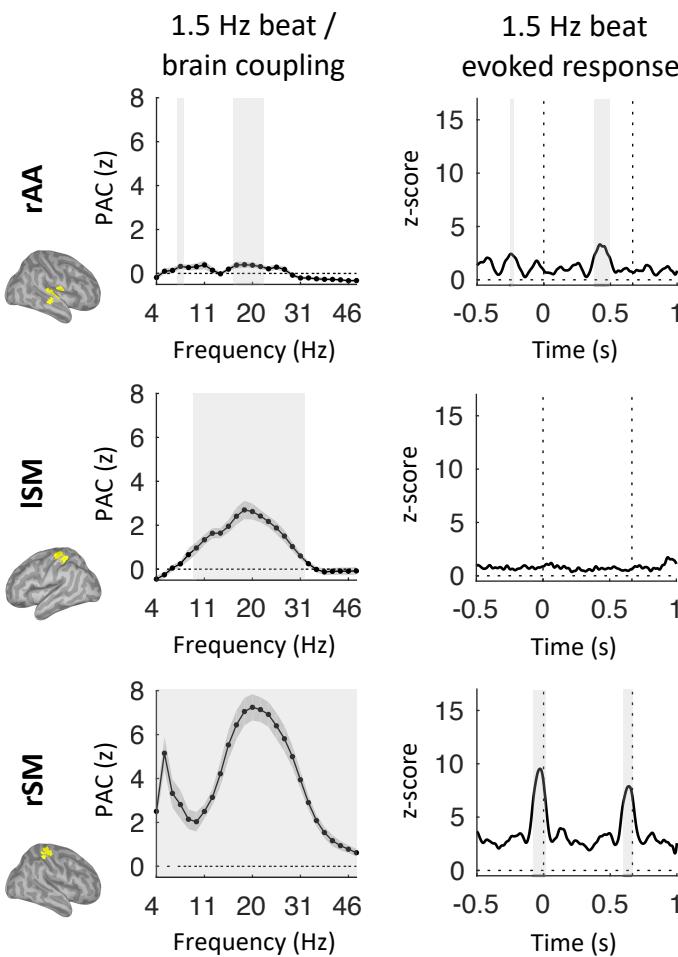
# How are overt temporal predictions encoded?

- Condition: Overt motor tracking

1.5 Hz beat



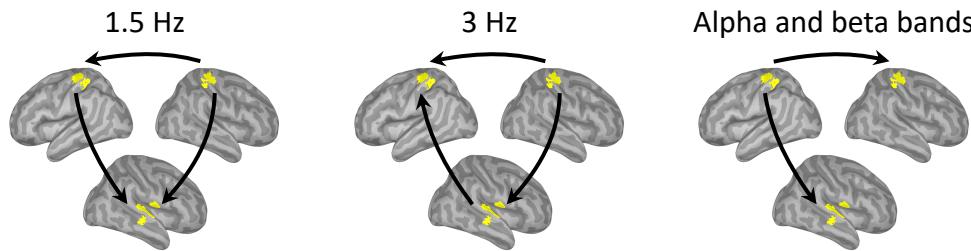
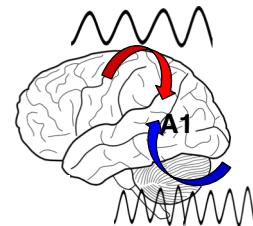
1.5 Hz phase



- Suggests that overt movements correlate with theta bursting and temporal predictions with beta bursting

# Bottom-up and top-down directed connectivity

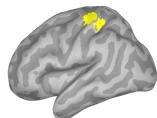
- Condition: Overt motor tracking



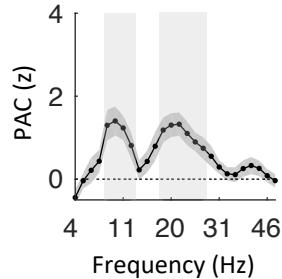
- Spectral dissociation between information flows originating from the right (low frequencies) and left (alpha and beta) sensorimotor cortices

# Common substrate across conditions

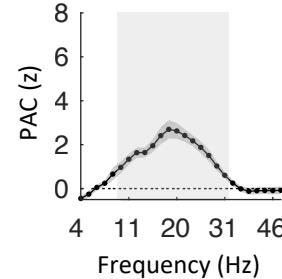
- Left sensorimotor cortex



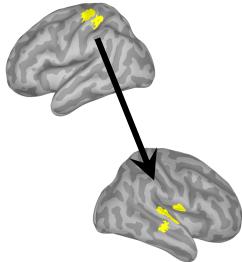
Passive listening



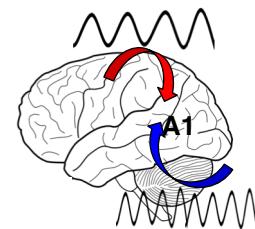
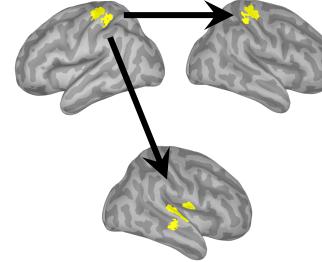
Overt motor tracking



Beta bands



(Alpha and) Beta bands



- In both *covert* and *overt* conditions, the left sensorimotor cortex represents and directs toward sensory regions temporal predictions through beta bursting (18-24 Hz)

*Implications:*

- The left somatosensory cortex encodes temporal predictions
- Mediated through beta bursting at the delta rate
- Additional and beneficial recruitment of right parieto-frontal regions during overt motor tracking

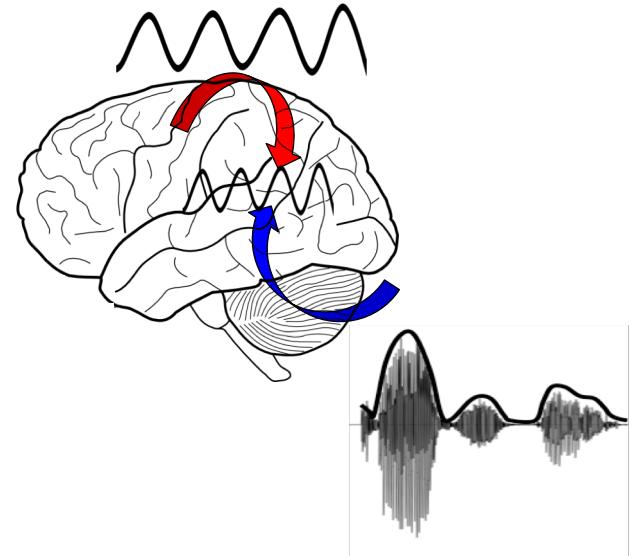
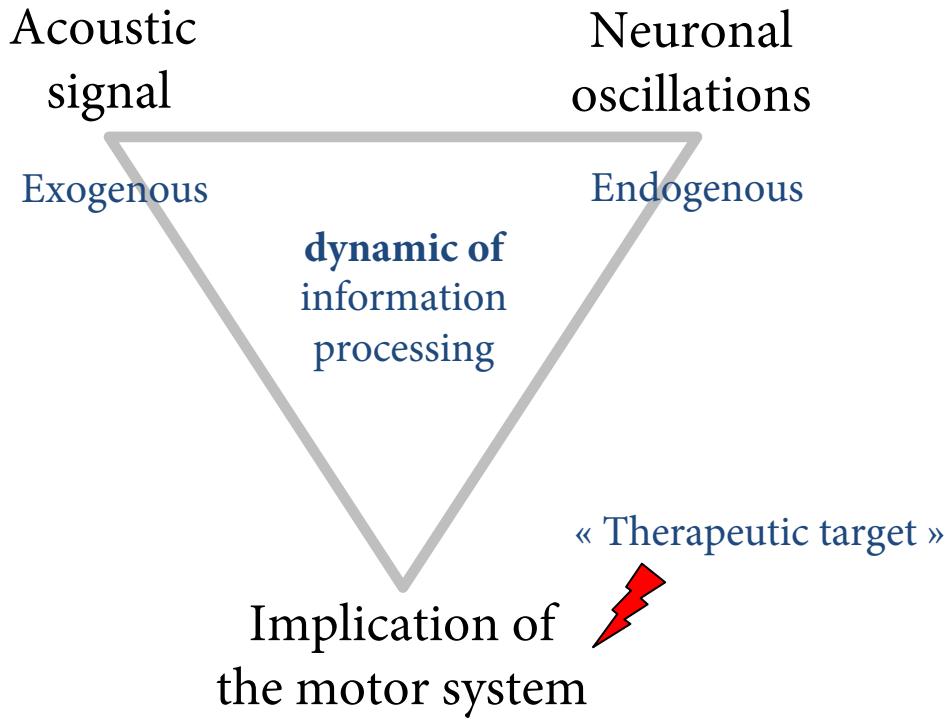
*Potential implication:*

Move during speech perception to  
better exploit temporal cues  
and thus improve perception

*Implication:*

The current results suggest that temporal structure of the auditory stream is first encoded in the SMA, and then integrated in the motor cortex.

# General Conclusion



- **The motor cortex is a constitutive part of the « auditory system »**
- **Key role of the connectivity between auditory and motor systems**
- **Move to hear better**

*Thank you for your attention*