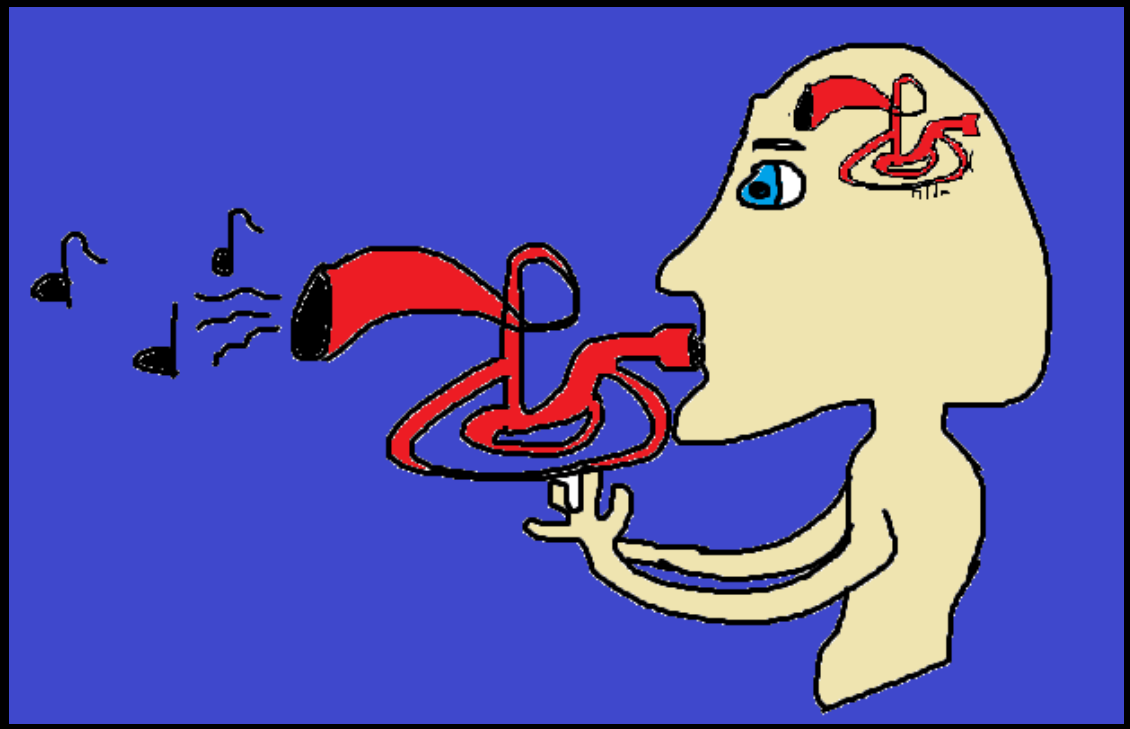
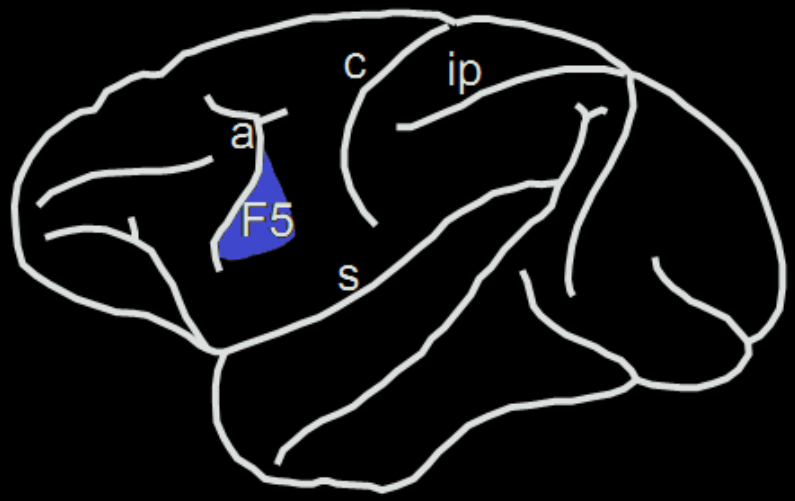
Audiomotor Mirroring



Matt Schalles

What is Mirroring?

Hearing Sounds, Understanding Actions: Action Representation in Mirror Neurons

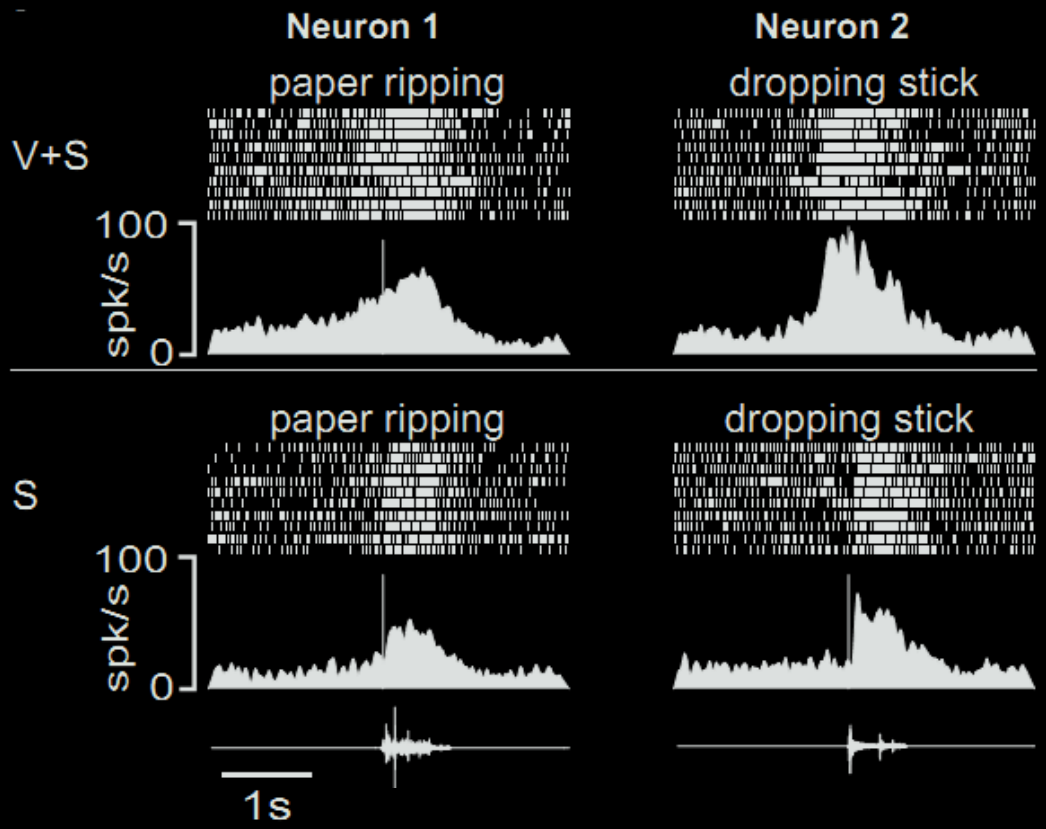


Kohler et al. 2002

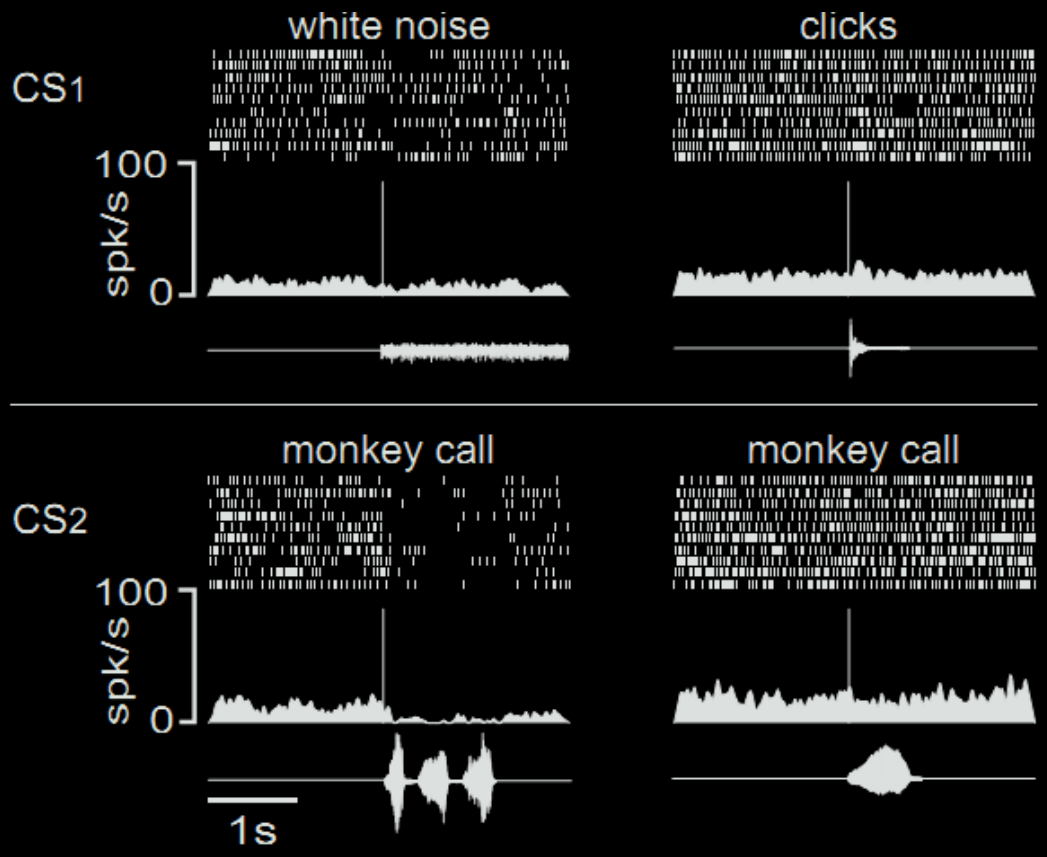
Acoustically Triggered Premotor Neurons

Action	Number of neurons
Peanut breaking	27
Paper ripping	21
Plastic crumpling	5
Metal hitting metal	3
Paper shaking	3
Dry food manipulating	2
Stick dropping	2
Total	63

Acoustically Triggered Premotor Neurons



Acoustically Triggered Premotor Neurons

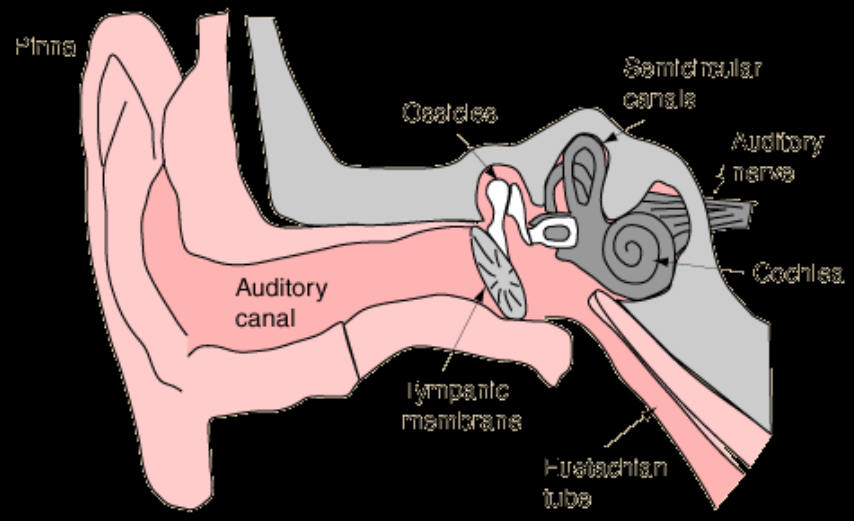


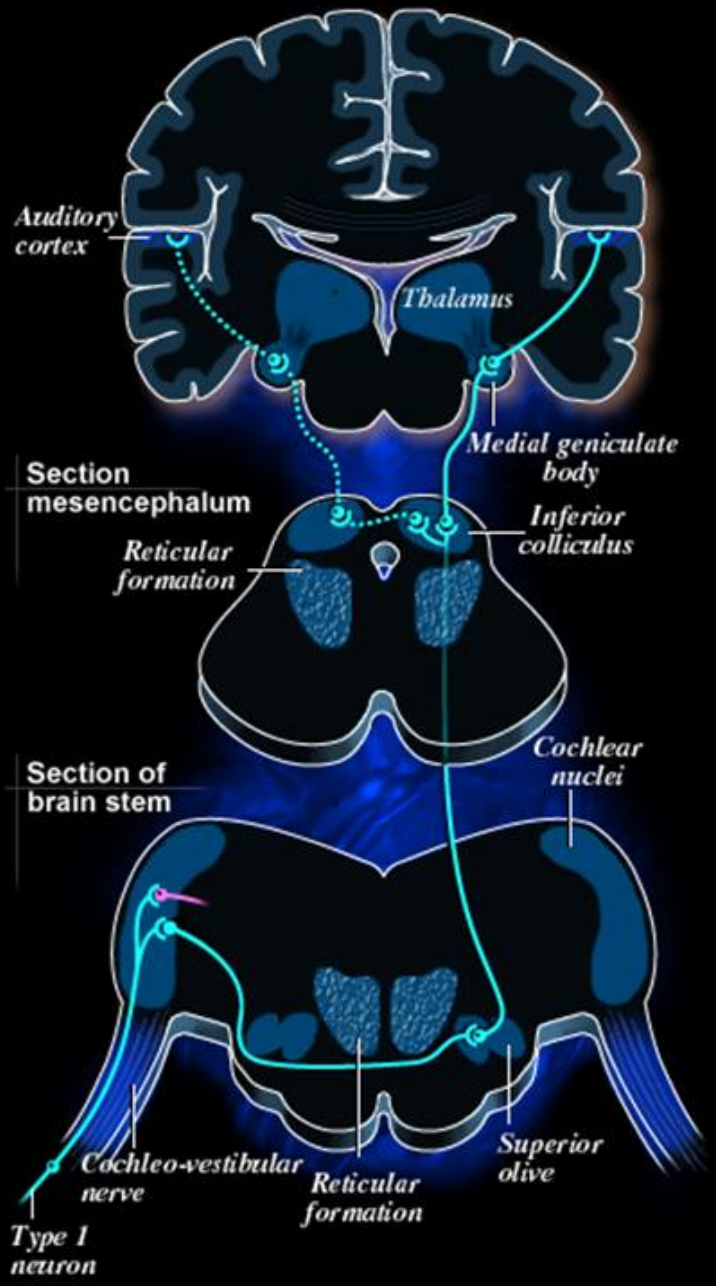
Is audiomotor mirroring:

- Anatomically Feasible?
- Seen in humans?

What are sounds?

How ear Works

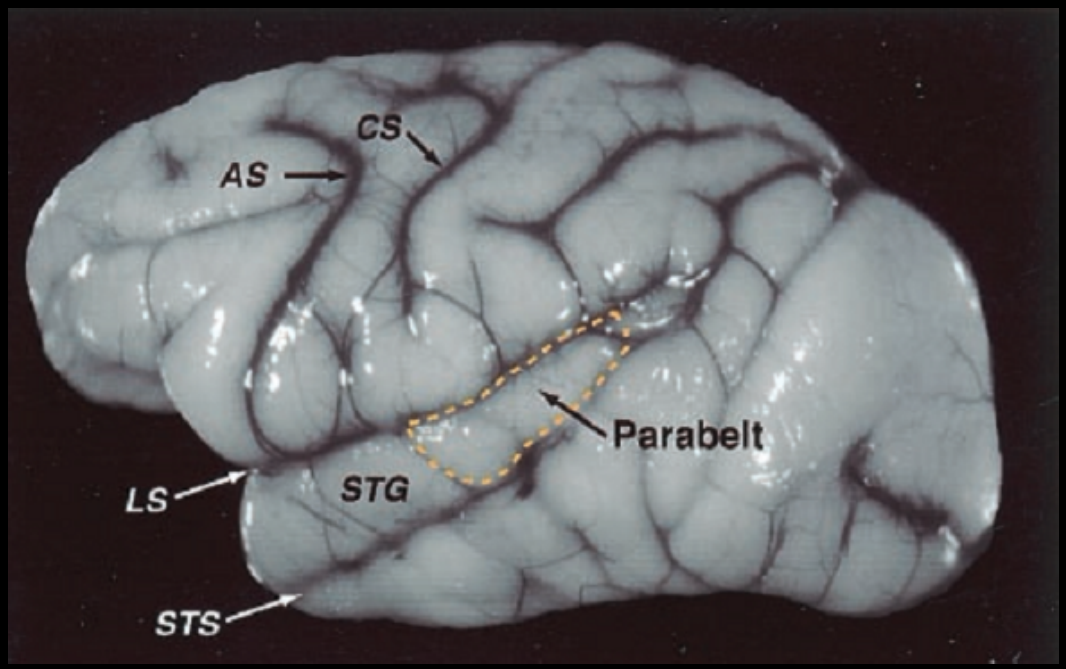




The Auditory Pathway

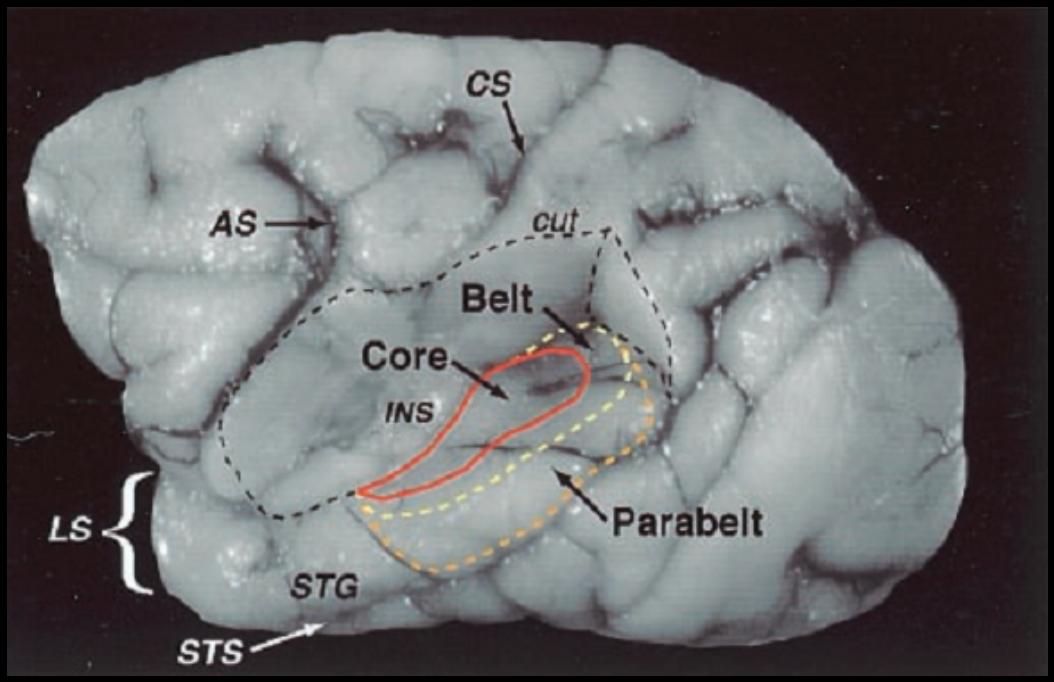
1. Cochlea
2. Cochlear nerve
3. Cochlear nucleus
4. Superior olivary complex
5. Lateral lemnscus
6. Inferior colliculus
7. Medial geniculate body
8. cortex

Auditory Cortex



Kaas & Hackett, 2000

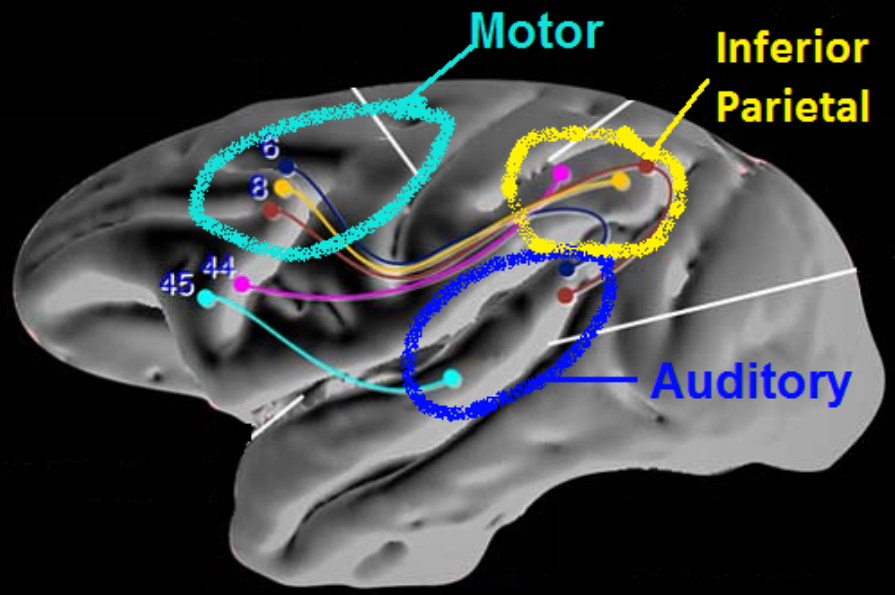
Auditory Cortex



Kaas & Hackett, 2000

Auditory-Motor Connections

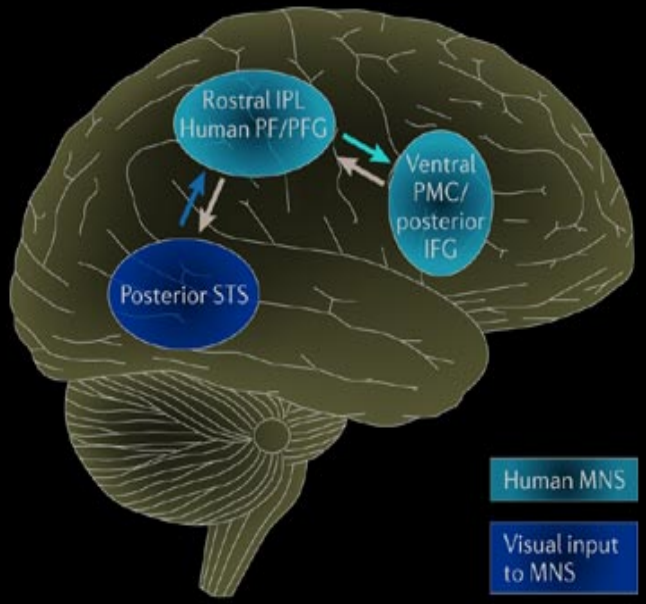
Macaque

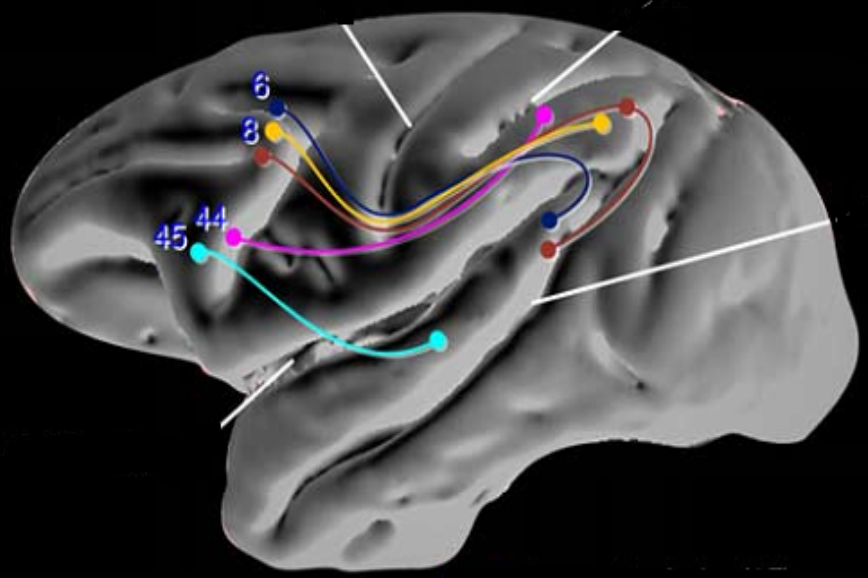


Frey, Campball, Pike & Petrides, 2008

(labels added for emphasis)

Auditory Mirror System?

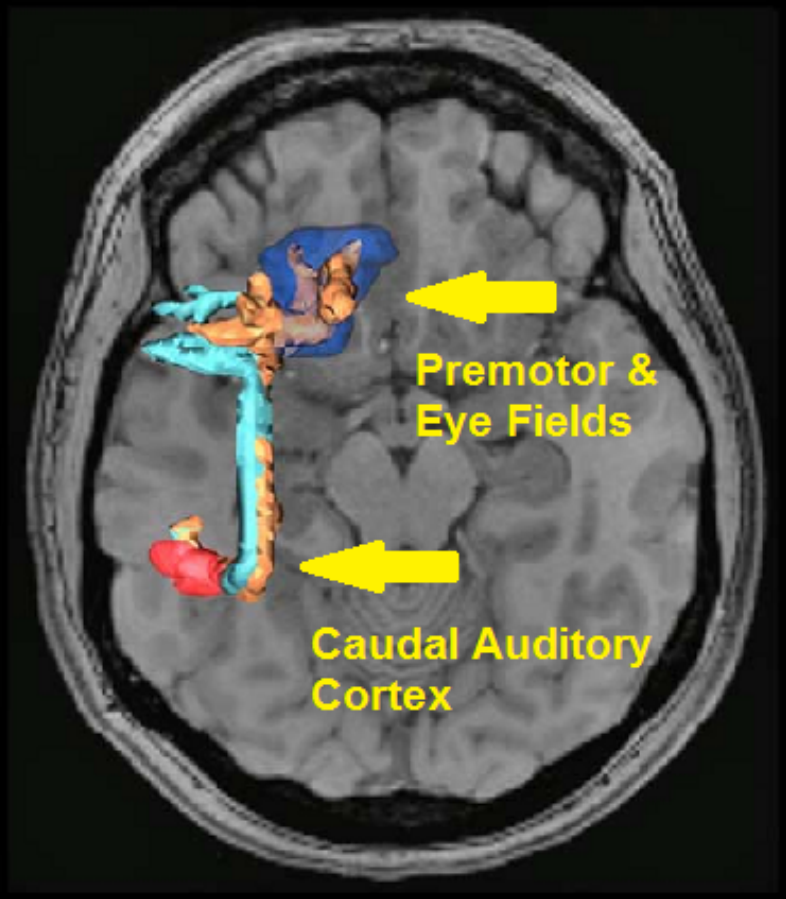




Iacoboni & Dapretto, 2006

Auditory-Motor Connections

Human

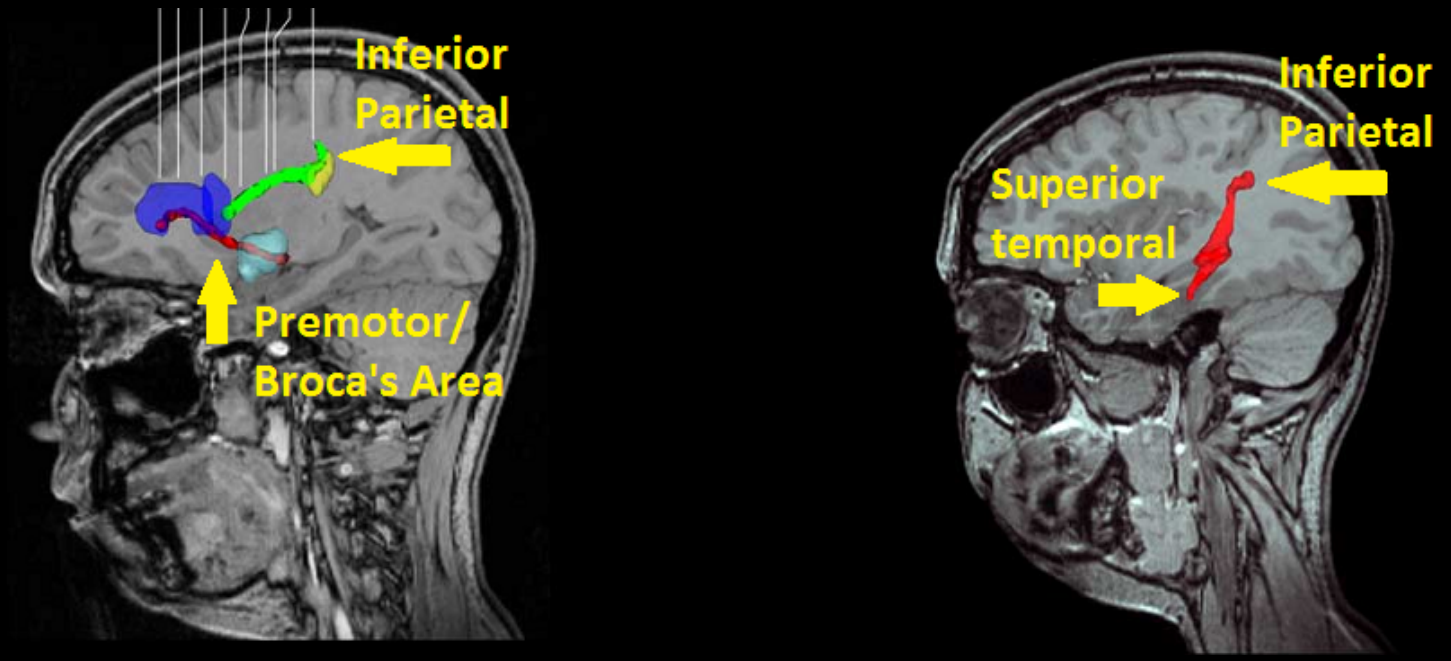


Frey, Campball, Pike & Petrides, 2008

(labels added for emphasis)

Auditory-Motor Connections

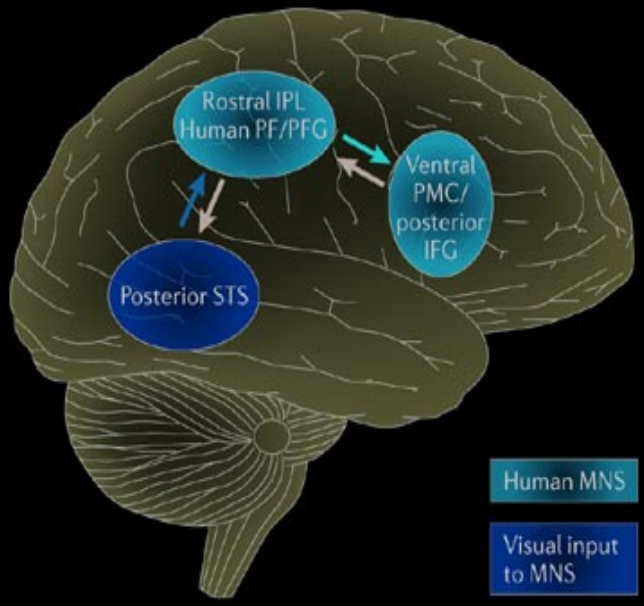
Human

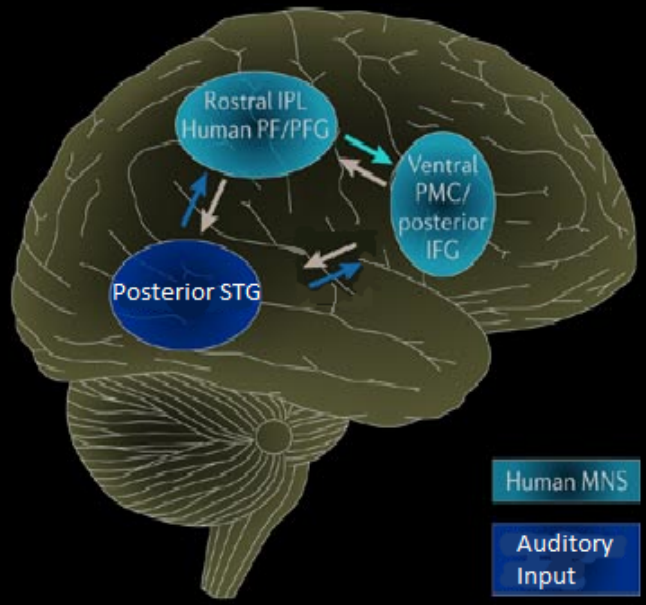


Frey, Campball, Pike & Petrides, 2008

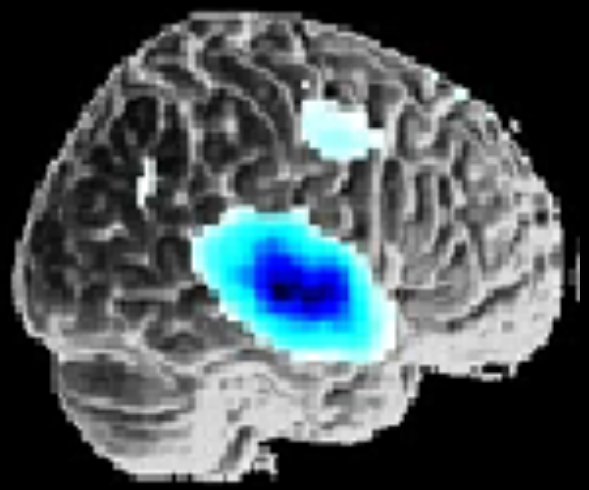
(labels added for emphasis)

Audiomotor Mirror System?





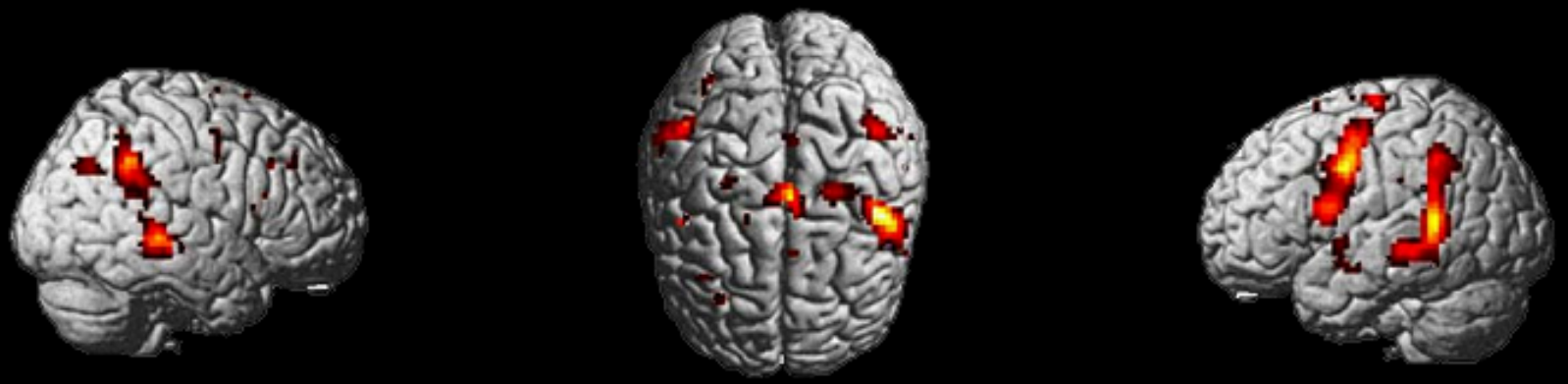
Functional Connections between Auditory and Motor Systems



Shared networks for auditory and motor processing in professional pianists

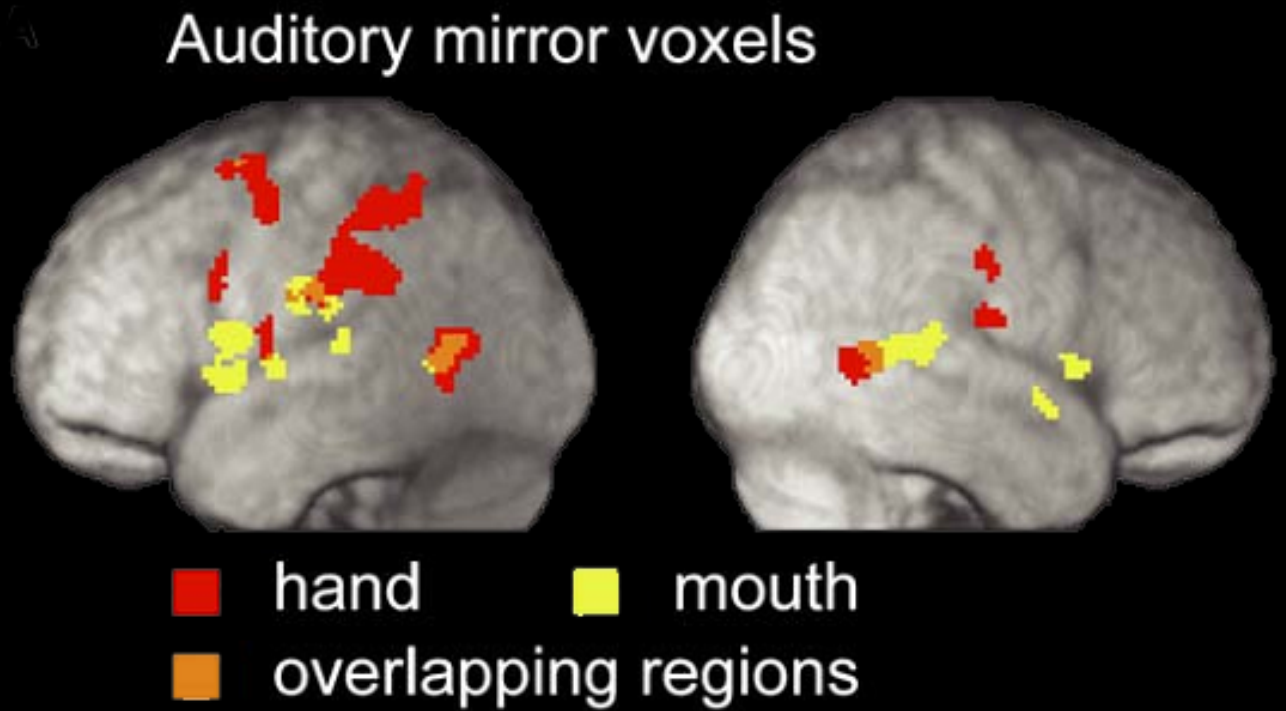
Bangert et al. 2005

Pianists > Non Pianists
Areas co-active for silent play & listening



Bangert et al. 2005

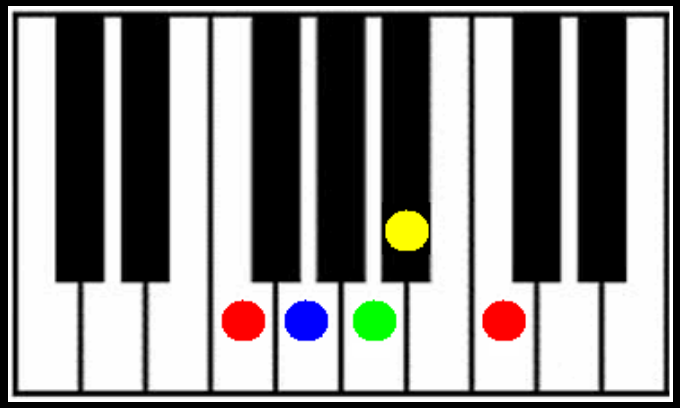
Somatotopic Auditory Mirror System in Humans

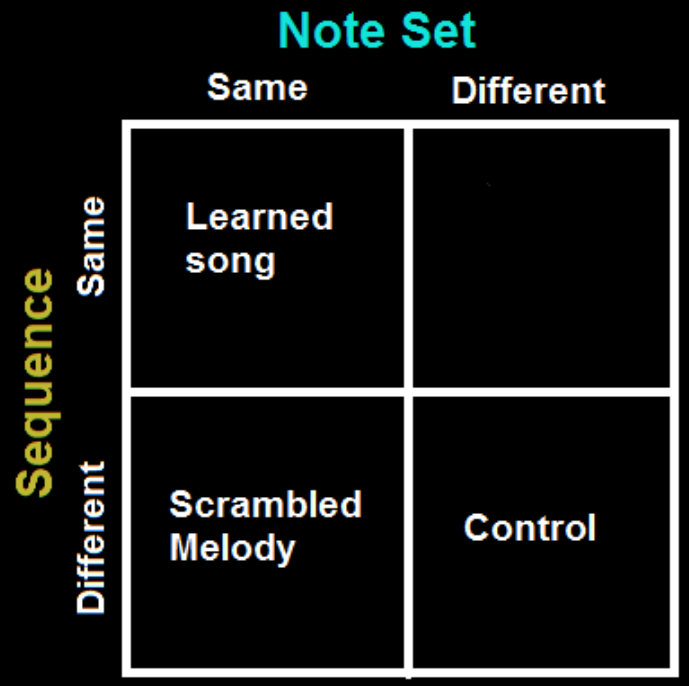


Gazzola et al. 2006

Listening to Newly Acquired Actions

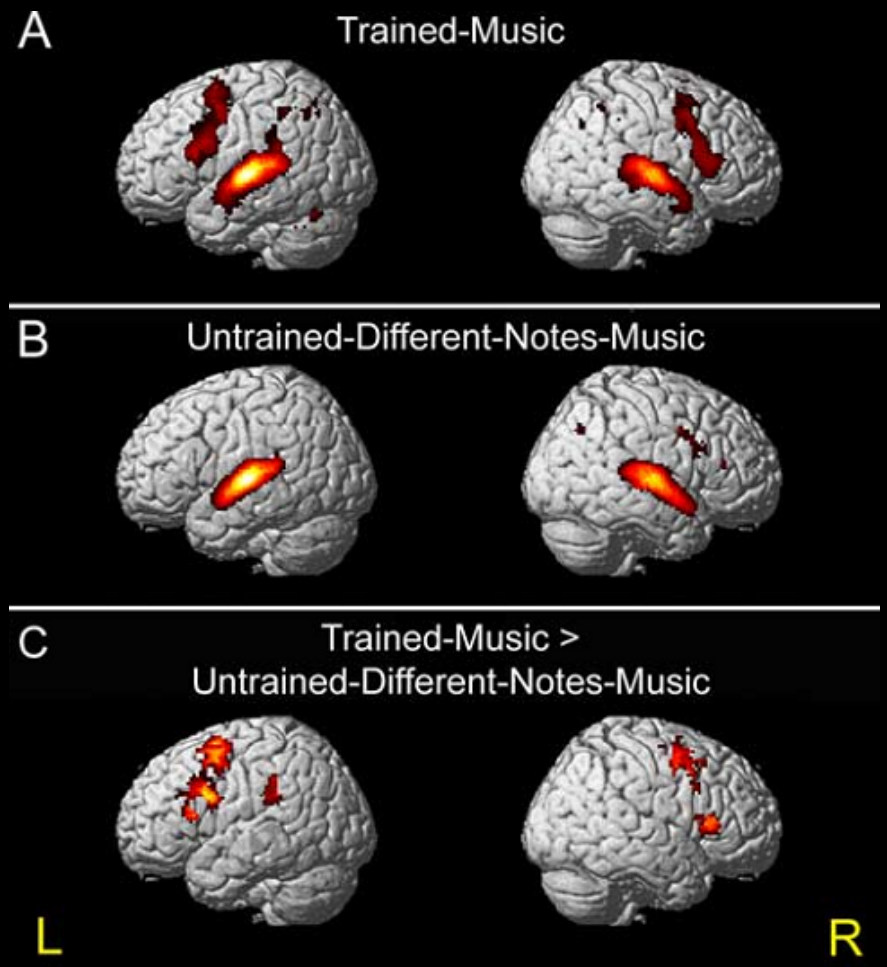
- 5 days practicing simple piano melody
- Piano naïve subjects
- Learned by ear
- fMRI post test





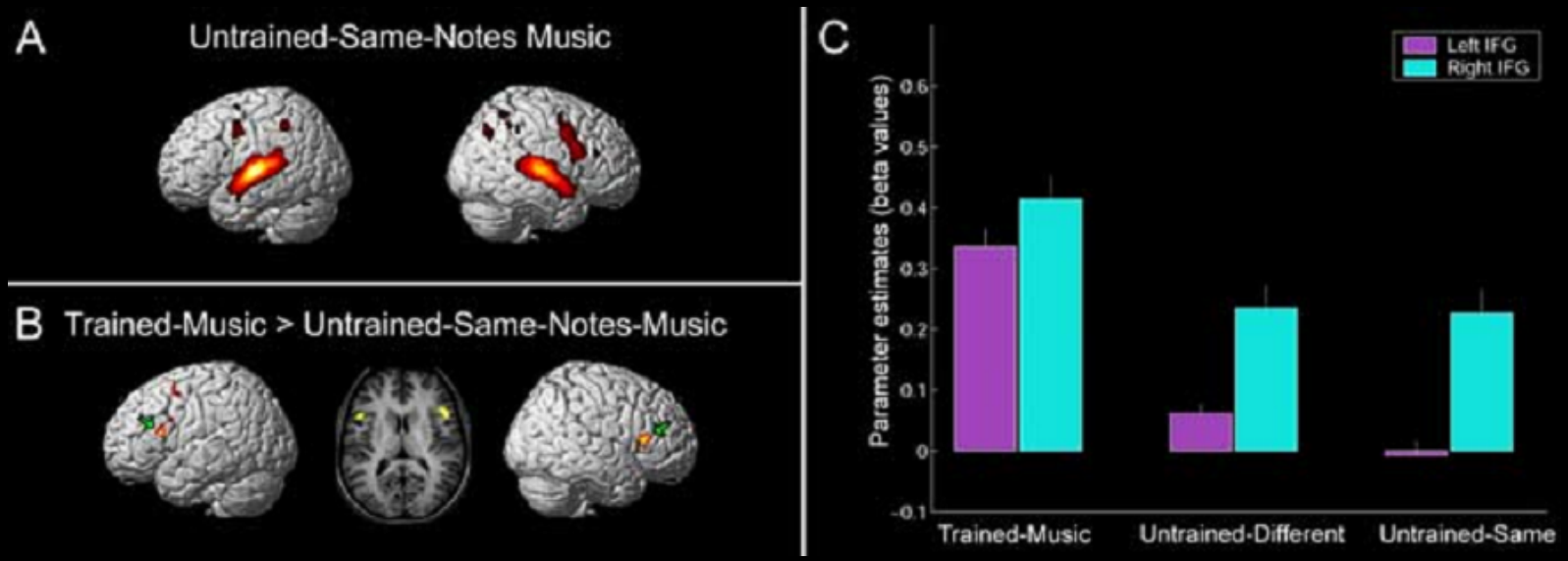
Lahav, Saltzman & Schlaug, 2007

Listening to Newly Acquired Actions



Lahav, Saltzman & Schlaug, 2007

Listening to Newly Acquired Actions



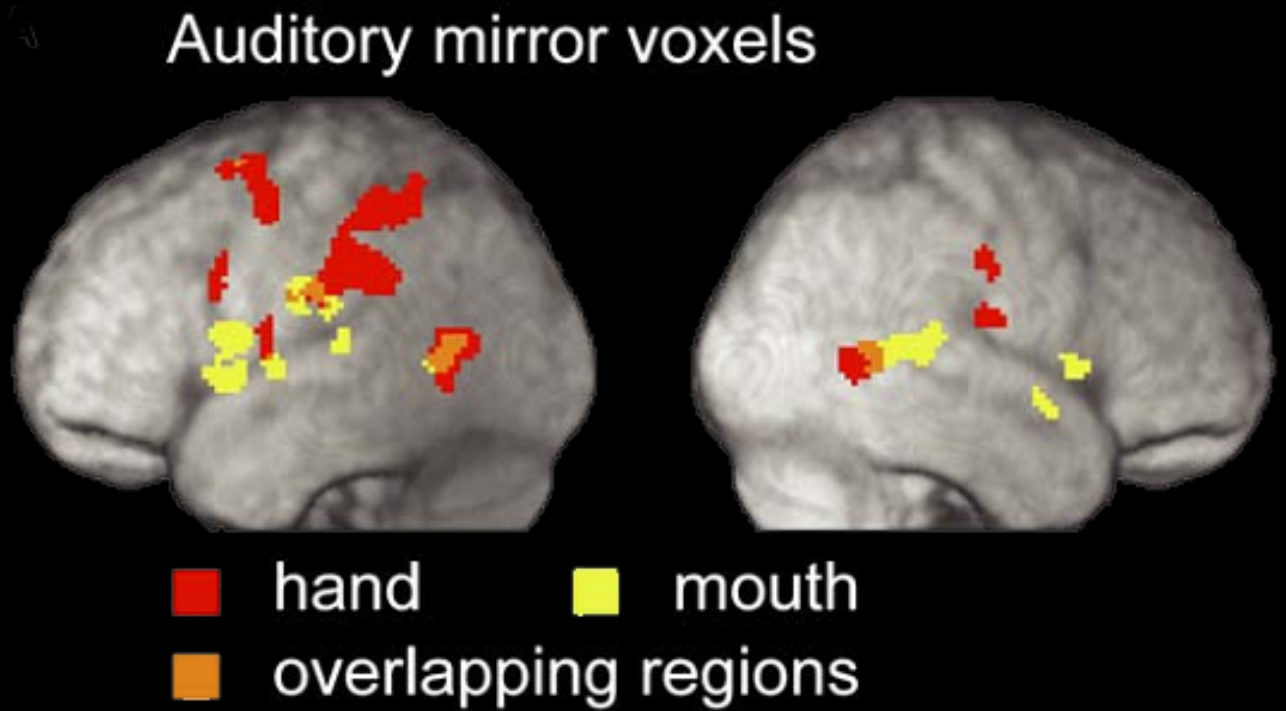
Lahav, Saltzman & Schlaug, 2007

Somatotopic Auditory Mirror System in Humans

Sound Category	Examples Used
Mouth action sounds (MouthSnd)	Crunching a candy with the teeth Kissing Gurgling Crunching potato chips Finishing a can of soft-drink with a straw
Hand action sounds (HandSnd)	Ripping a sheet of paper Unrolling an adhesive tape Opening a zipper Opening a soft-drink can Crushing a soft-drink can

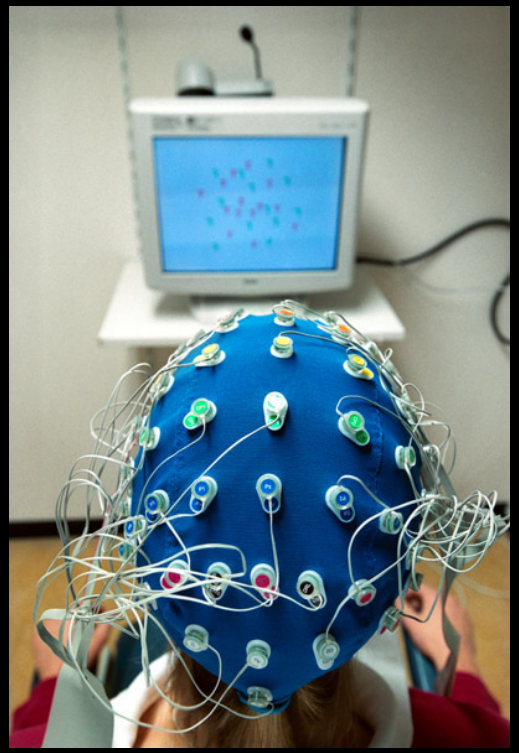
Gazzola et al. 2006

Somatotopic Auditory Mirror System in Humans



Gazzola et al. 2006

Temporal Resolution



milleseconds

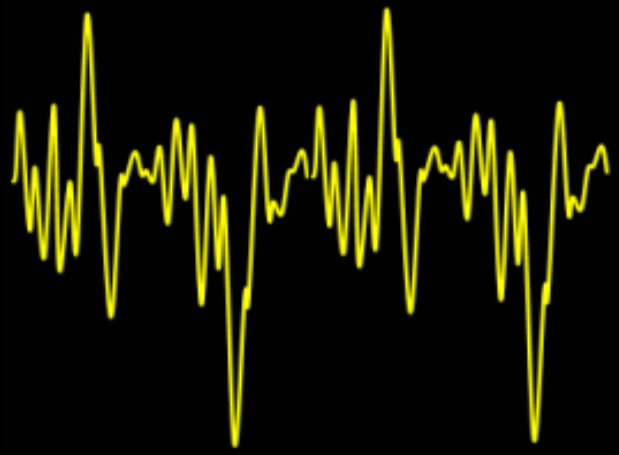
seconds

What does fine temporal resolution get us?

- Time locking of neural responses to sounds or actions

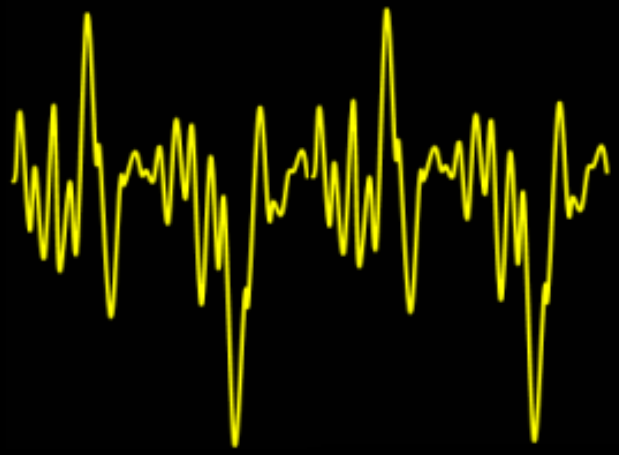
EEG Analysis

Complex waveform

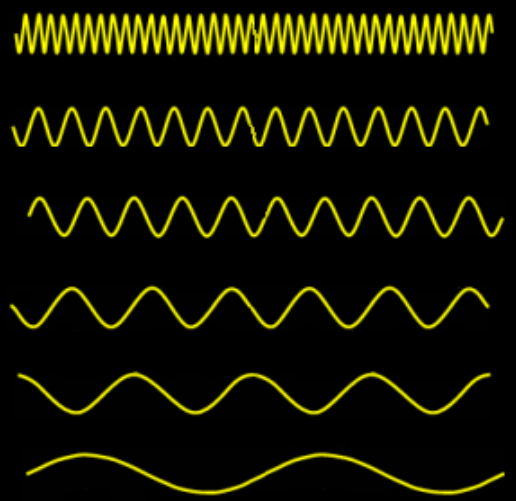


EEG Analysis

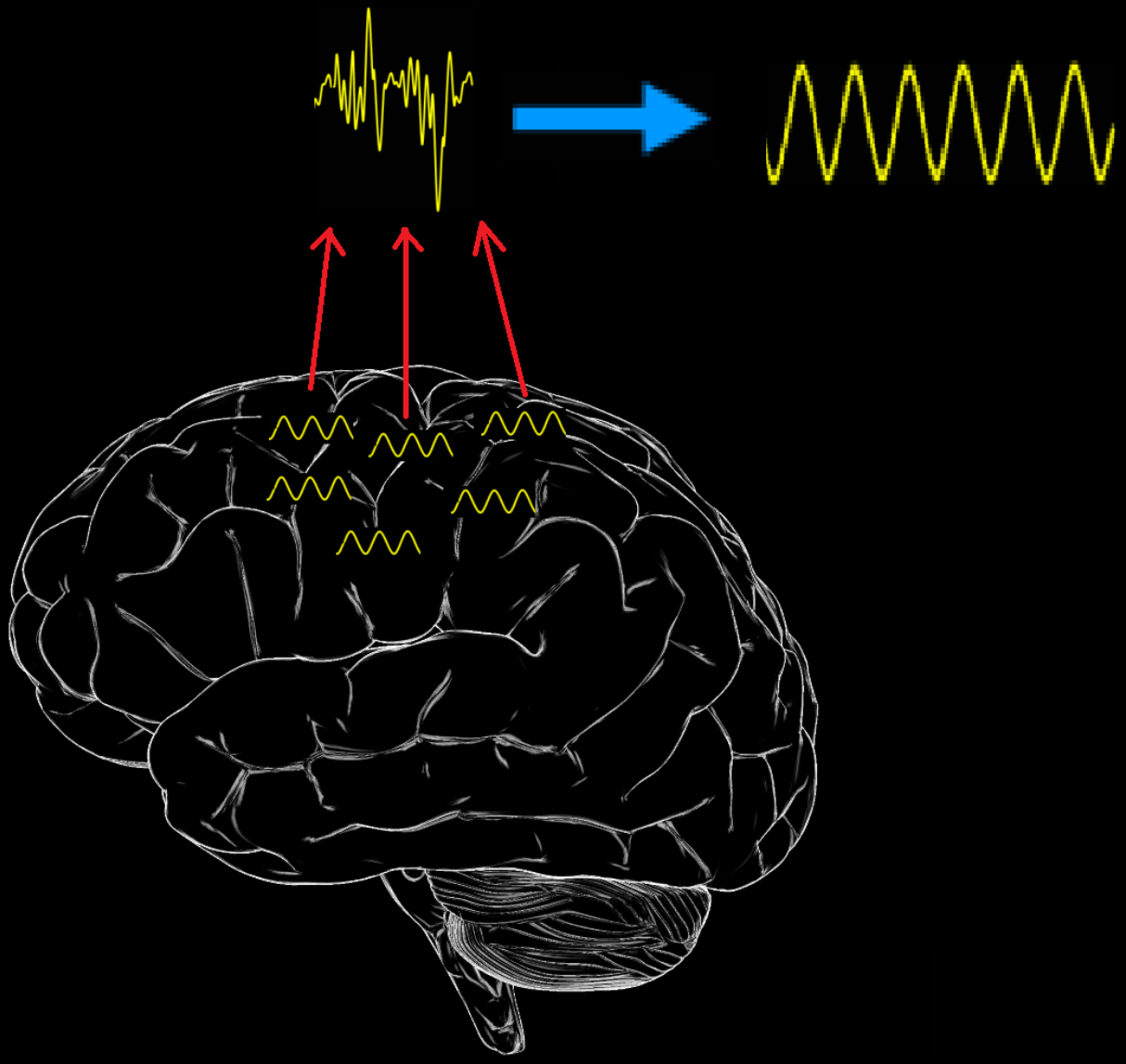
Complex waveform



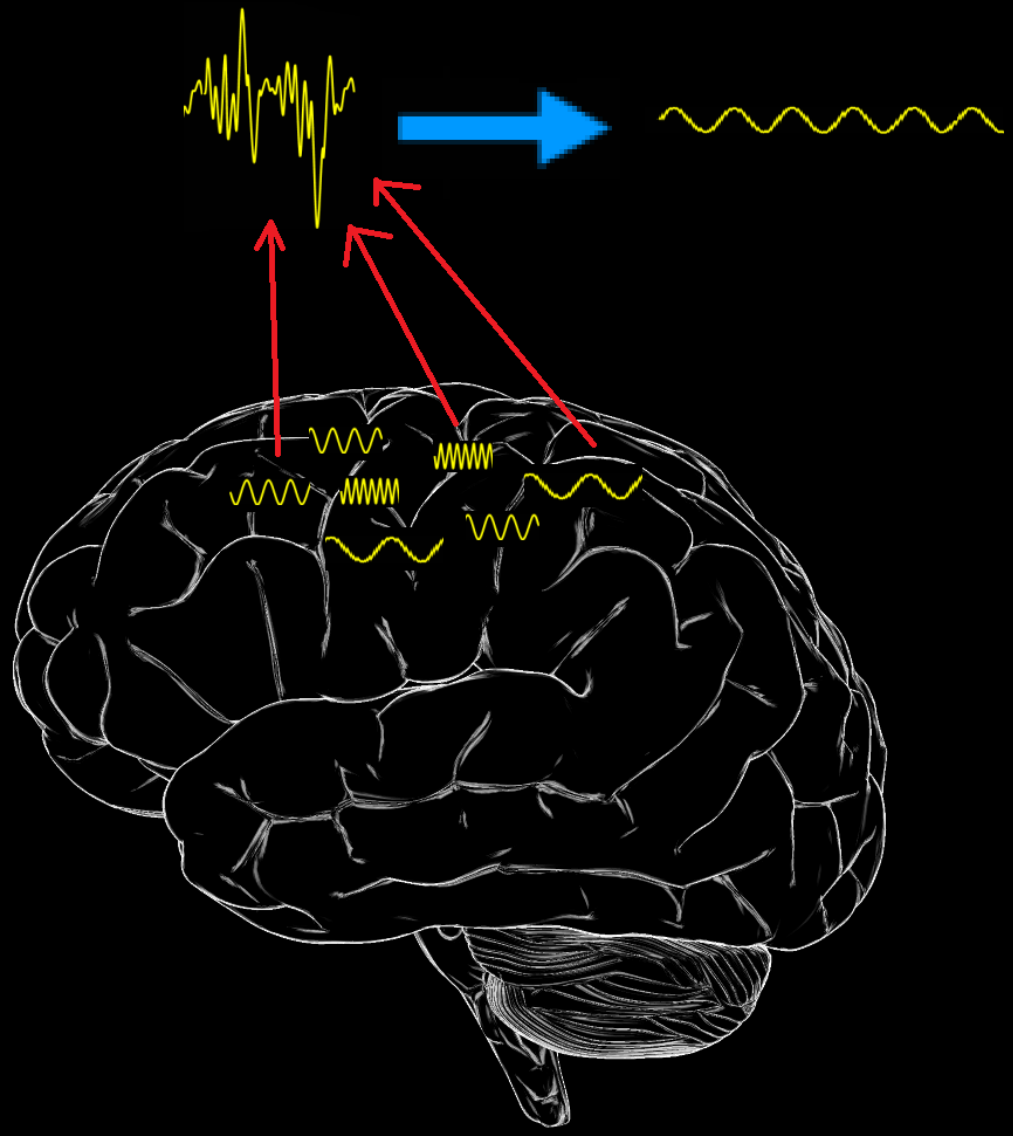
Sum of sine waves



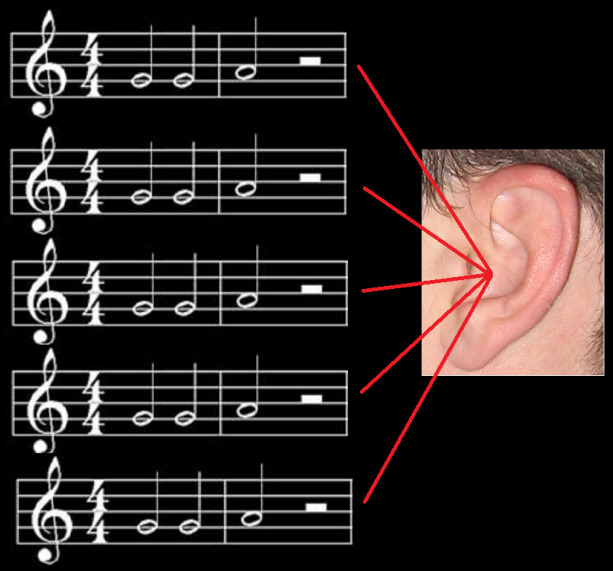
Event Related Desynchronization

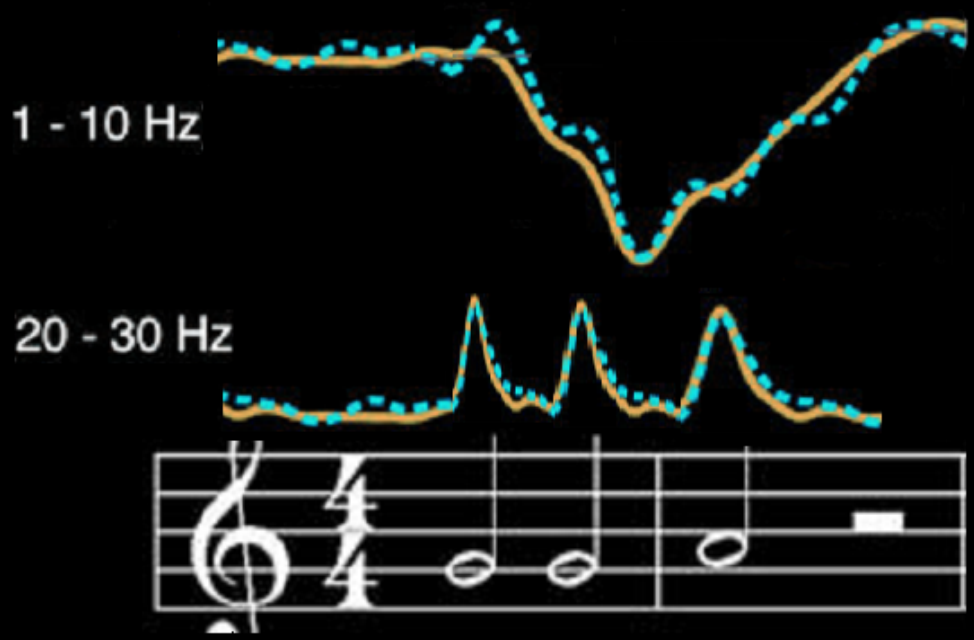


Event Related Desynchronization



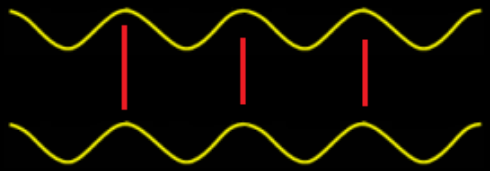
Time Averaging & Event Dynamics



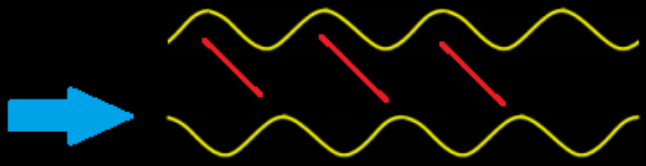


Coherence & Phase

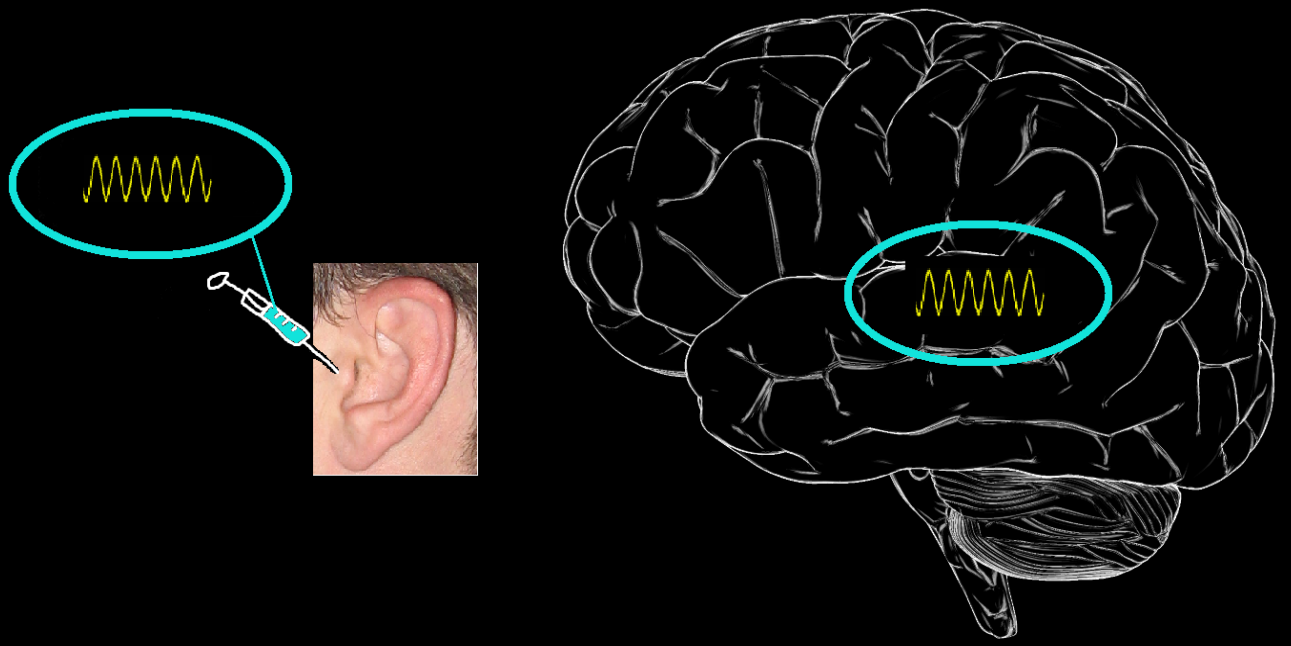
- Phase locked



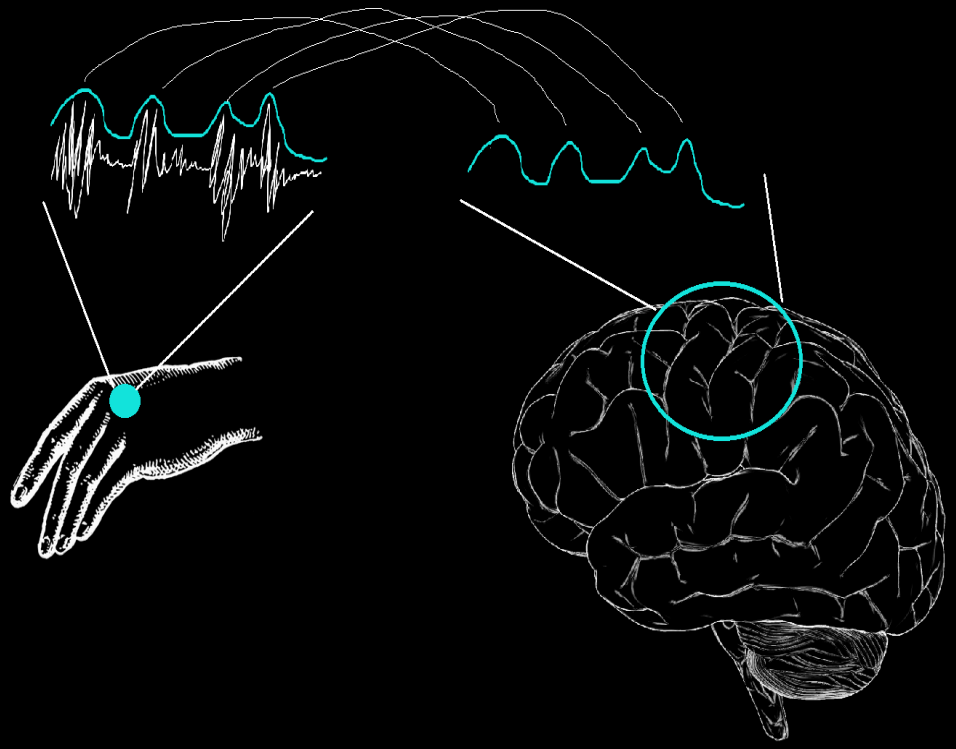
- Phase shifted



Identifying Auditory Components



Identifying Motor Components



What Frequencies of Interest for Audiomotor processing?

Cortical regions that communicate with 10 & 20 Hz signals

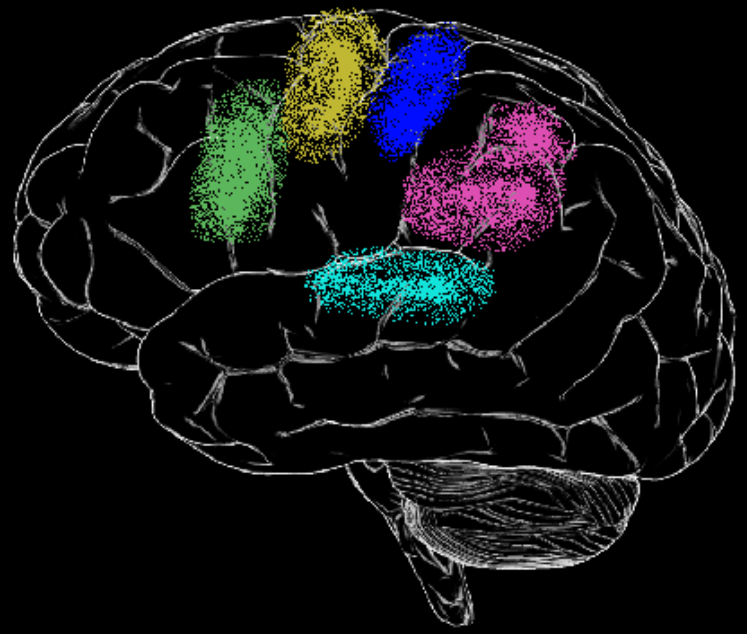
Premotor

Auditory

Primary Motor

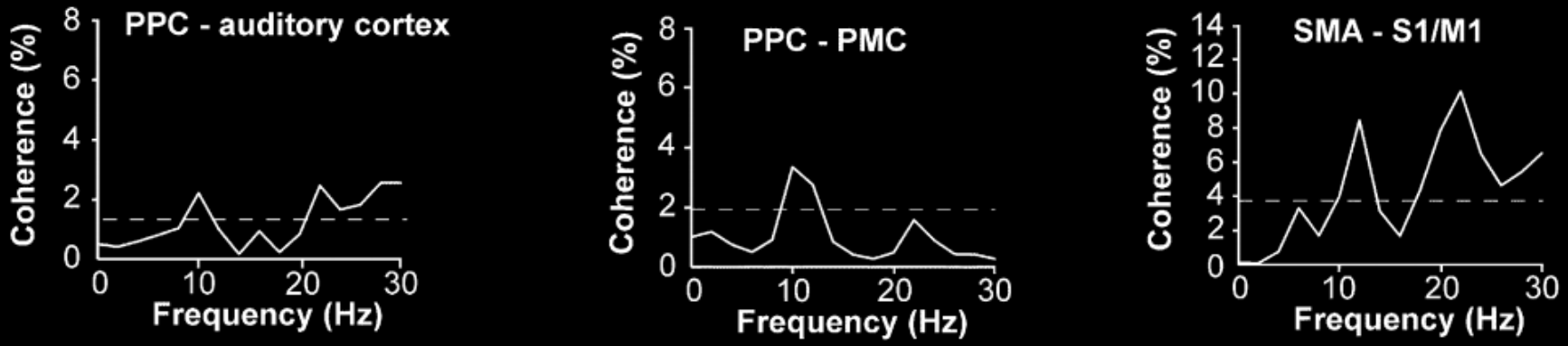
Primary Somatosensory

Inferior/Posterior Parietal



Pollok, Gross, Muller, Aschersleben & Schnitzler (2005)

Audiomotor Coherence



Pollok, Gross, Muller, Aschersleben & Schnitzler (2005)

Actor's and observer's primary motor cortices stabilize similarly after seen or heard motor actions

- Caetano, Jousmaki & Hari, 2007

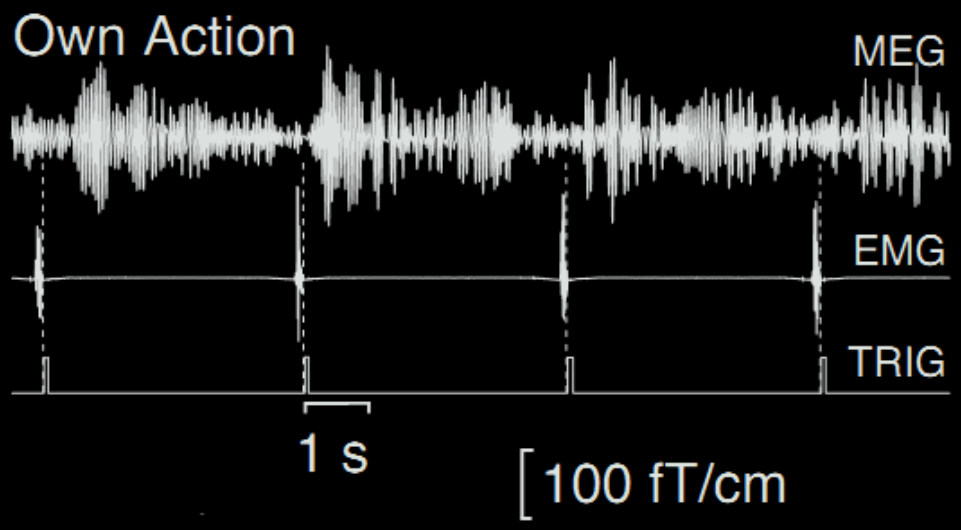
Data Acquisition

- MEG
- Additional waveforms
  - Tapped surface
  - EMG
- Filtered to extract 10 & 20 Hz peaks

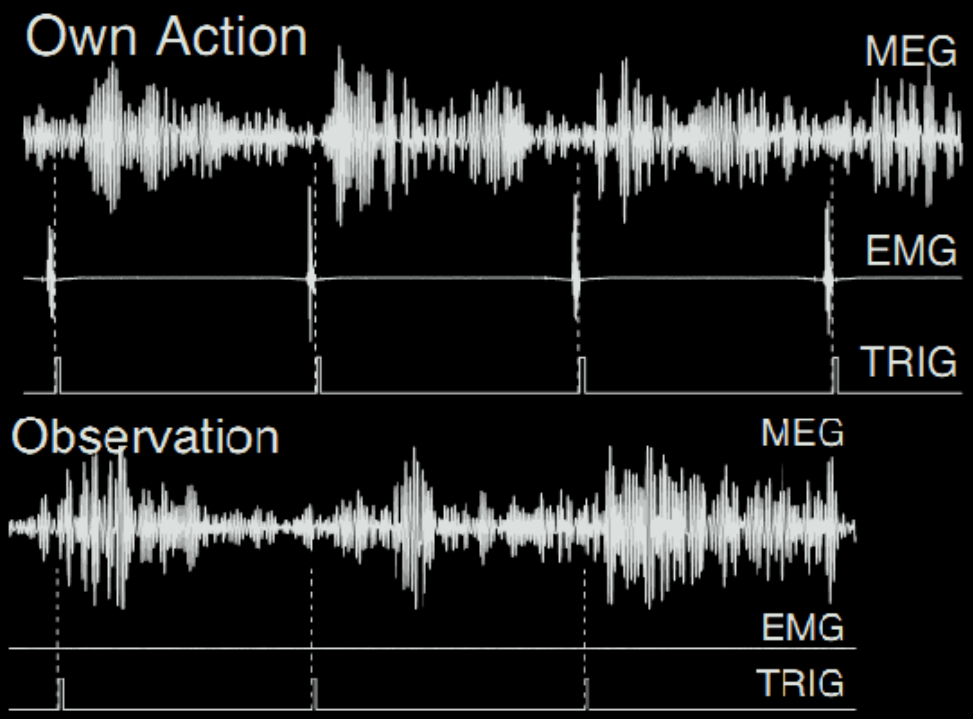
Why the interest in 10 & 20 Hz peaks?

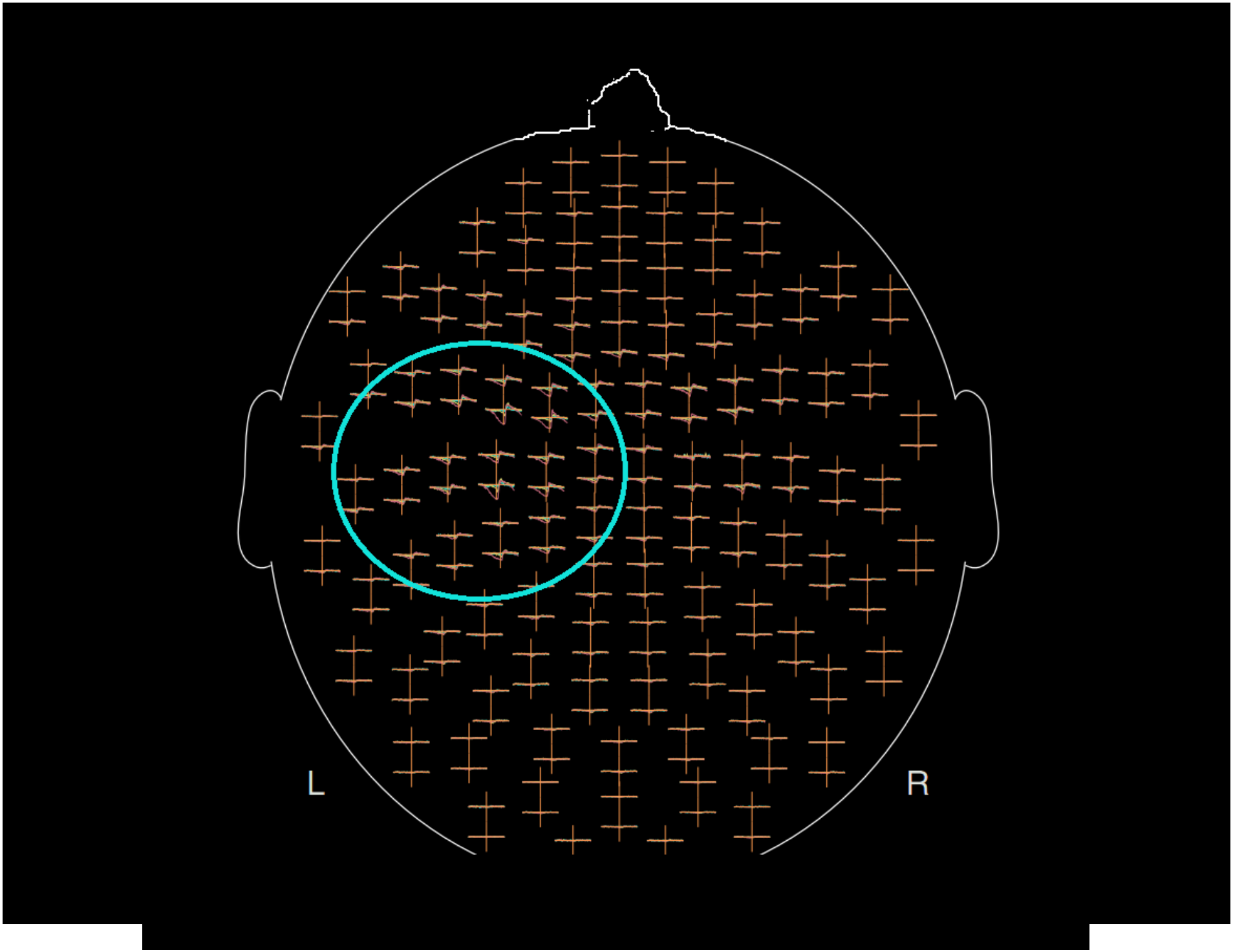
- Somatosensory contributions
- Motor processing

20 Hz Activity

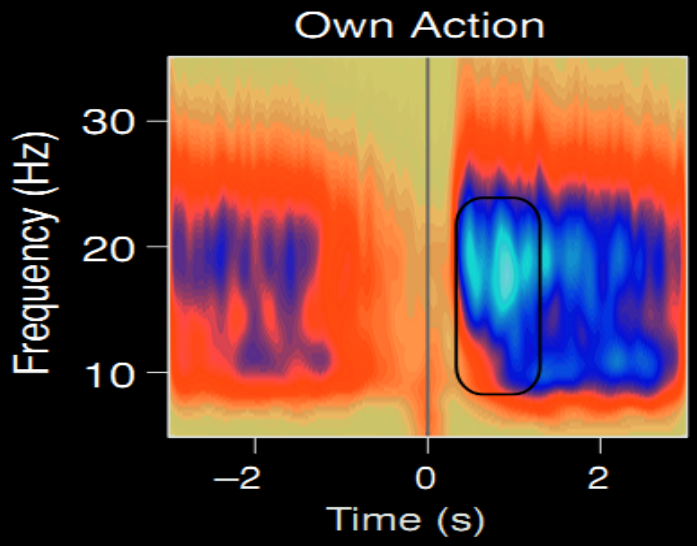


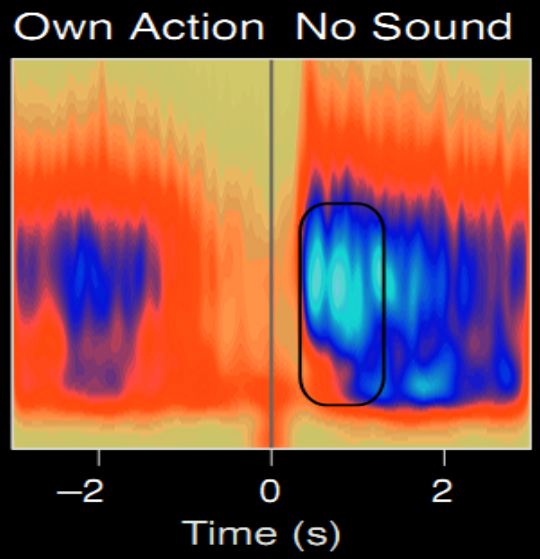
20 Hz Activity



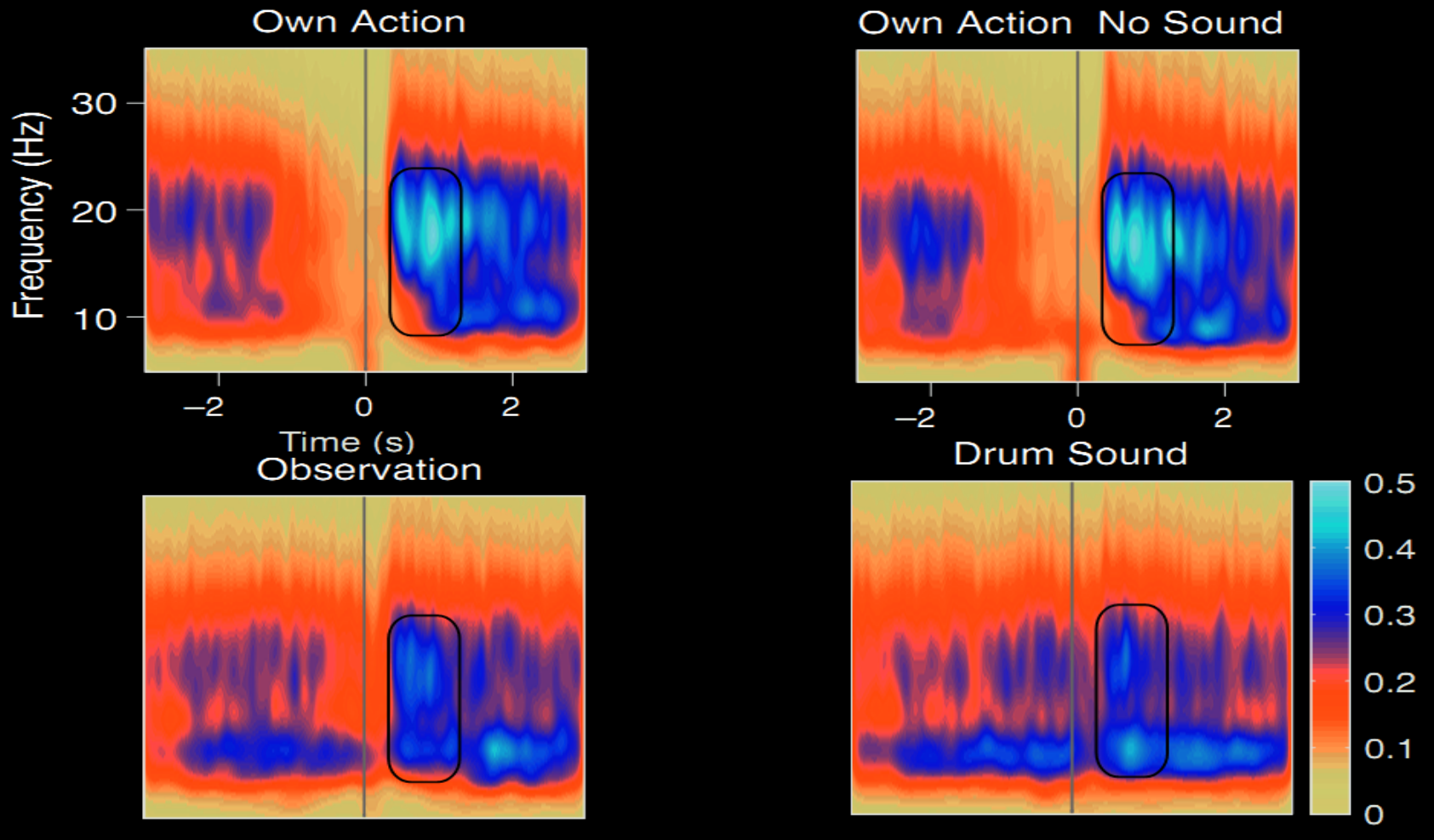

L
R

Time x Frequency





Time x Frequency



Implications?

- 1st vs 3rd person

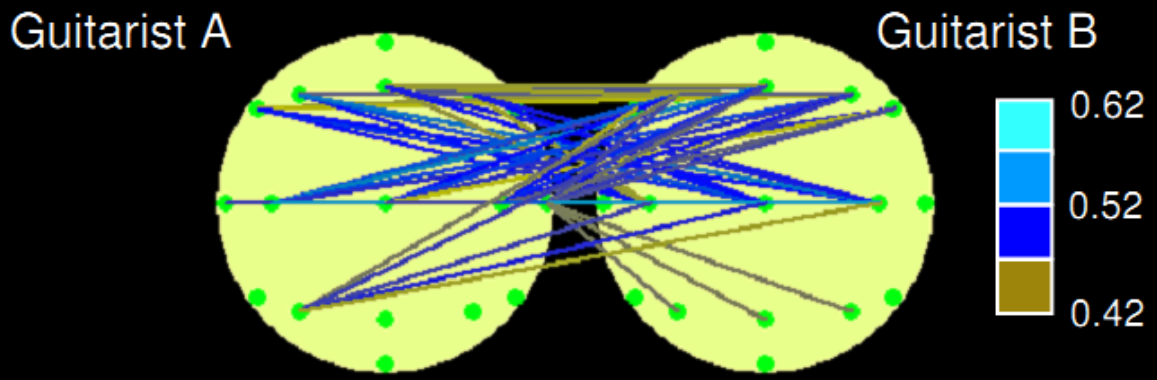
Is mirroring related to social coordination?

- What would evidence for this look like?

Brains swinging in concert: cortical phase synchronization while playing guitar

- Lindenberger, Li, Gruber, & Mueller

2009

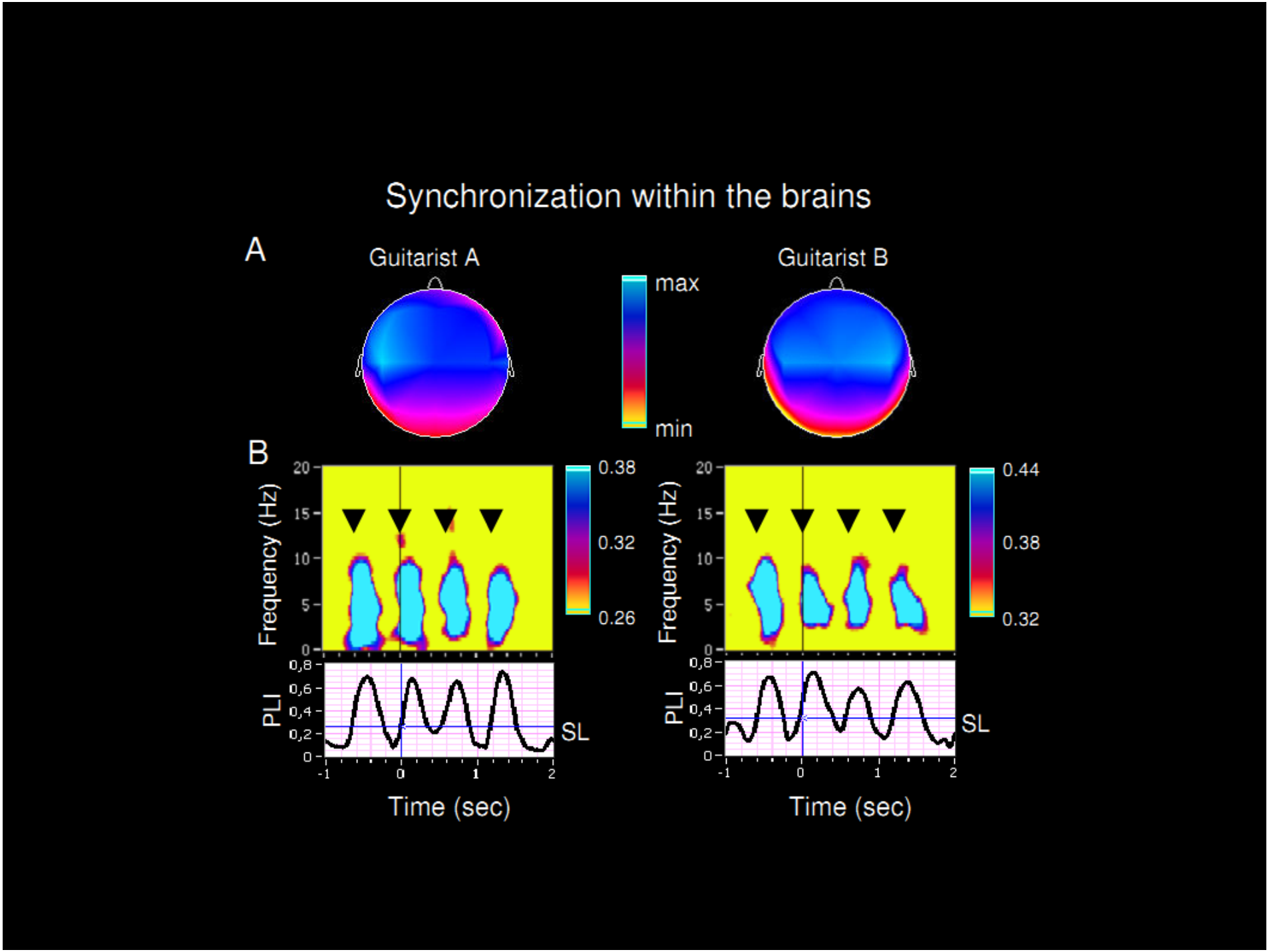


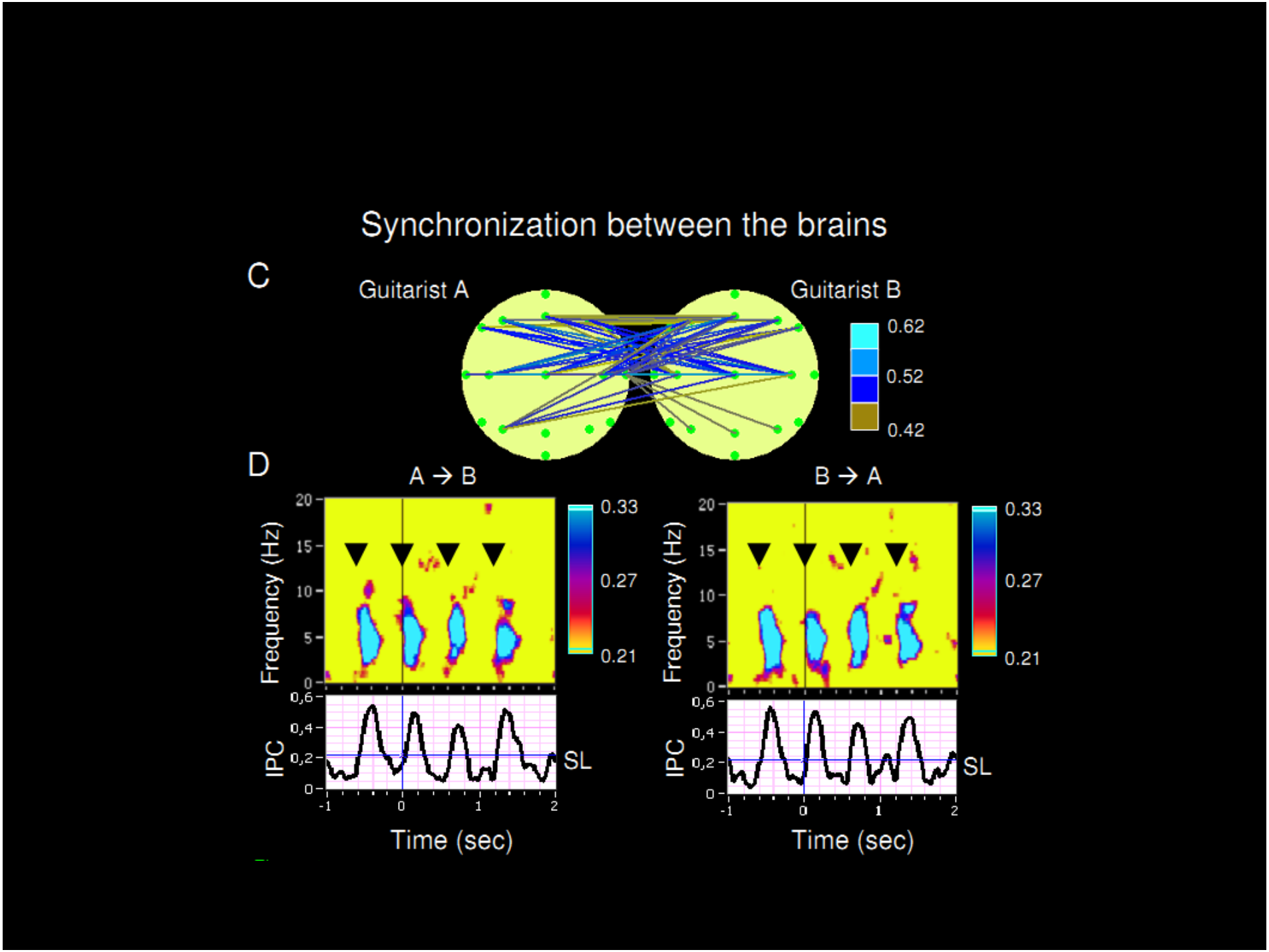
The Task

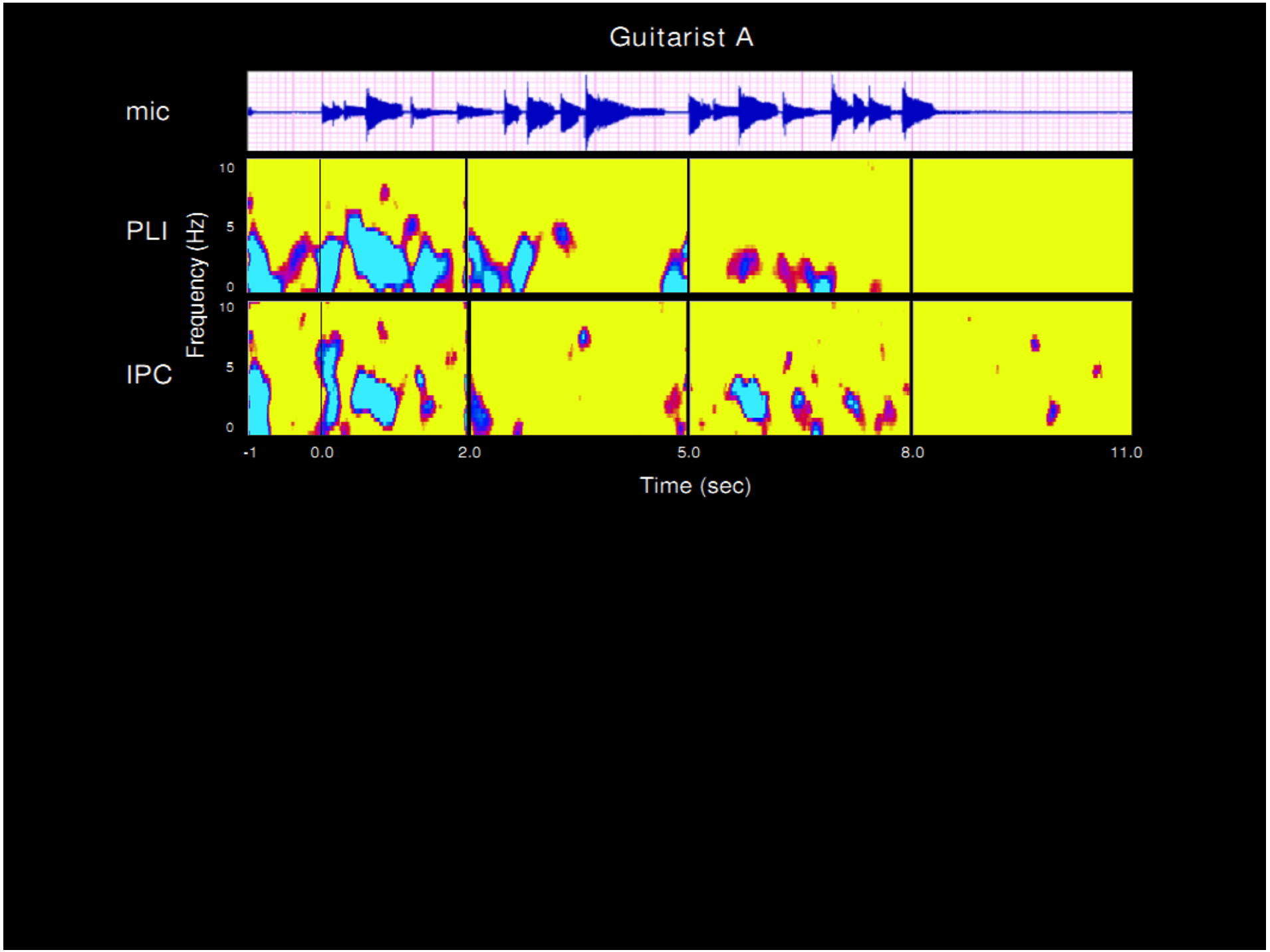
- Cue video

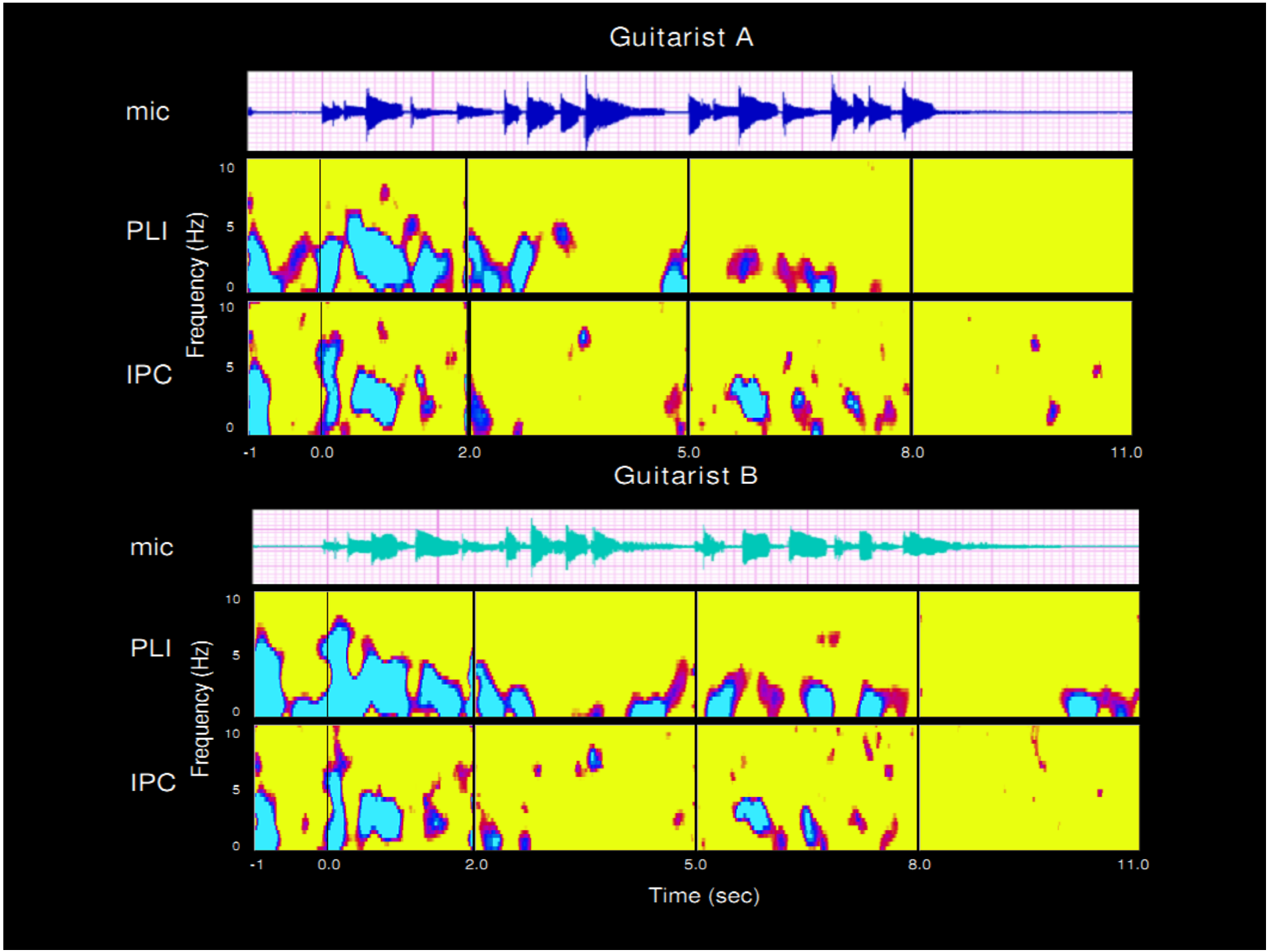
Comparing Brains

- Interbrain Phase Coherence (IPC)
  - Consistency of phase changes between *brains*
- Phase-Locking Index (PLI)
  - Consistency of phase between *trials*


Synchronization within the brains
A
Guitarist A
max
min
Guitarist B
B
Frequency (Hz)
20
15
10
5
0
0.38
0.32
0.26
PLI
0,8
0,6
0,4
0,2
0
SL
-1
0
1
2
Time (sec)
Frequency (Hz)
0.44
0.38
0.32
PLI
SL
Time (sec)


Synchronization between the brains
C
Guitarist A
Guitarist B
0.62
0.52
0.42
D
A → B
B → A
Frequency (Hz)
20
15
10
5
0
0.33
0.27
0.21
IPC
0,6
0,4
0,2
0
SL
-1
0
1
2
Time (sec)


Guitarist A
mic
PLI
IPC
Frequency (Hz)
10
5
0
10
5
0
-1
0.0
2.0
5.0
8.0
11.0
Time (sec)


Guitarist A
mic
PLI
IPC
Frequency (Hz)
10
5
0
-1
0.0
2.0
5.0
8.0
11.0
Guitarist B
mic
PLI
IPC
Frequency (Hz)
Time (sec)

“We conjecture that neural networks supporting social cognition and theory of mind abilities might support interbrain couplings during coordinated voluntary actions”

“If two subjects share the same sensory inputs and produce similar motor outputs.....

...then inter-brain synchronizations might arise because of similar neural responses to the same sensory inputs and motor outputs...

...without reflecting neural processes of social interaction”