# Poeppel Lab @ NYU

## Brain basis of language, speech, hearing

OPINION

### The cortical organization of speech processing

*Gregory Hickok and David Poeppel*

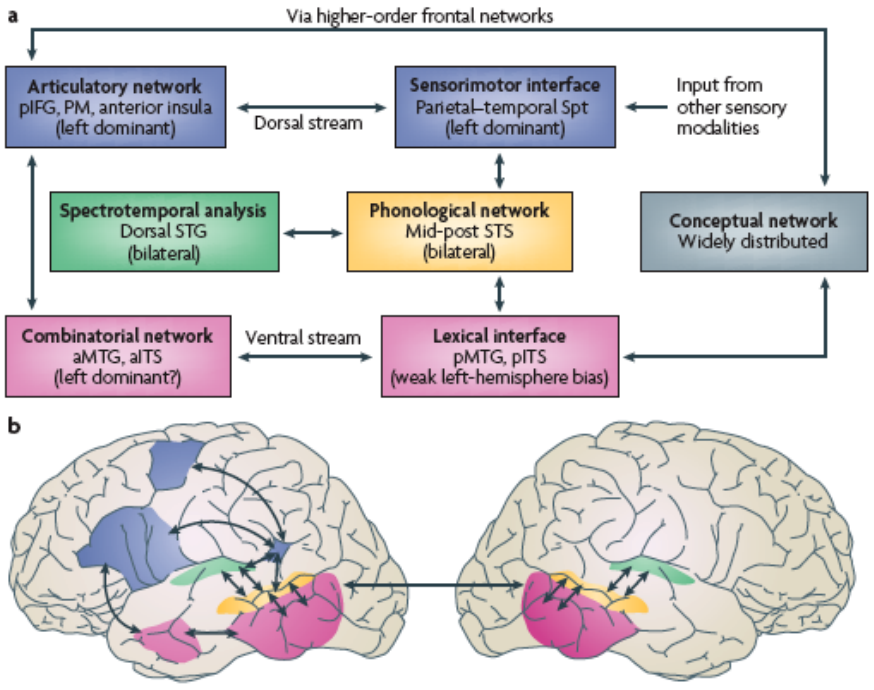



Figure 1 | **The dual-stream model of the functional anatomy of language. a** | Schematic diagram

***Nature Reviews Neuroscience 2007***

### A cortical network for semantics: (de)constructing the N400

*Ellen F. Lau*, Colin Phillips*‡ and David Poeppel*‡§‖*

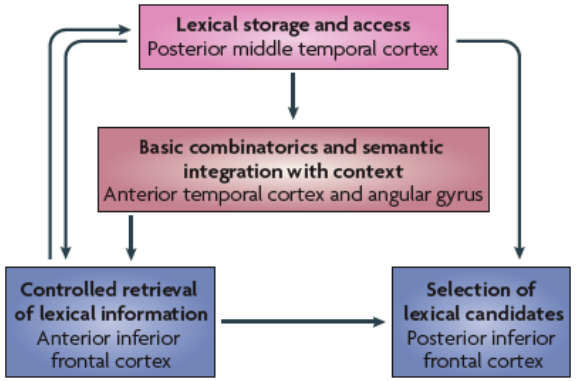



Figure 2 | **Schematic model for semantic processing.**

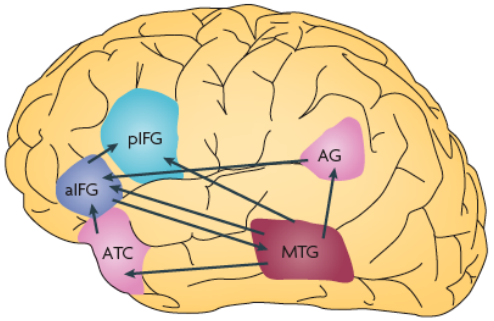


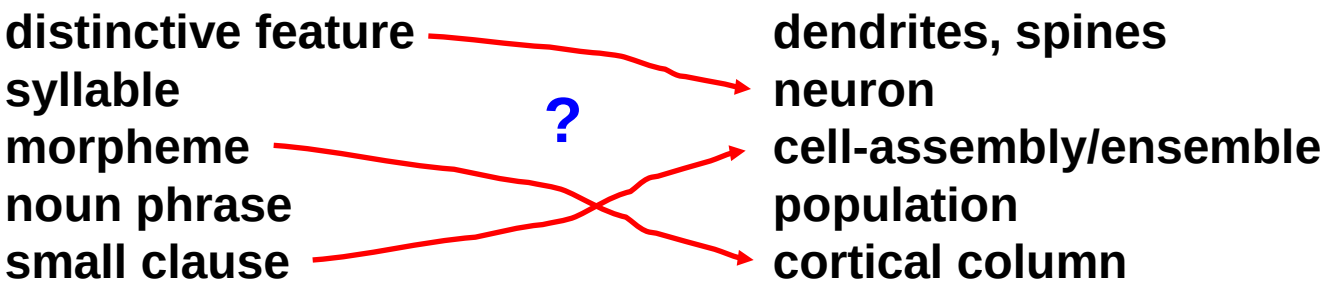

Figure 5 | **A functional neuroanatomic model for semantic processing of words in context.** Lexical

***Nature Reviews Neuroscience 2008***

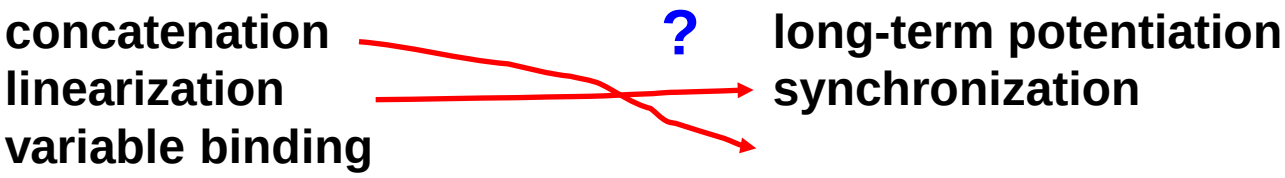
# Challenges for interdisciplinarity and unification

**Linguistics** **Neuroscience**

***Fundamental elements of representation***




***Fundamental operations on primitives***



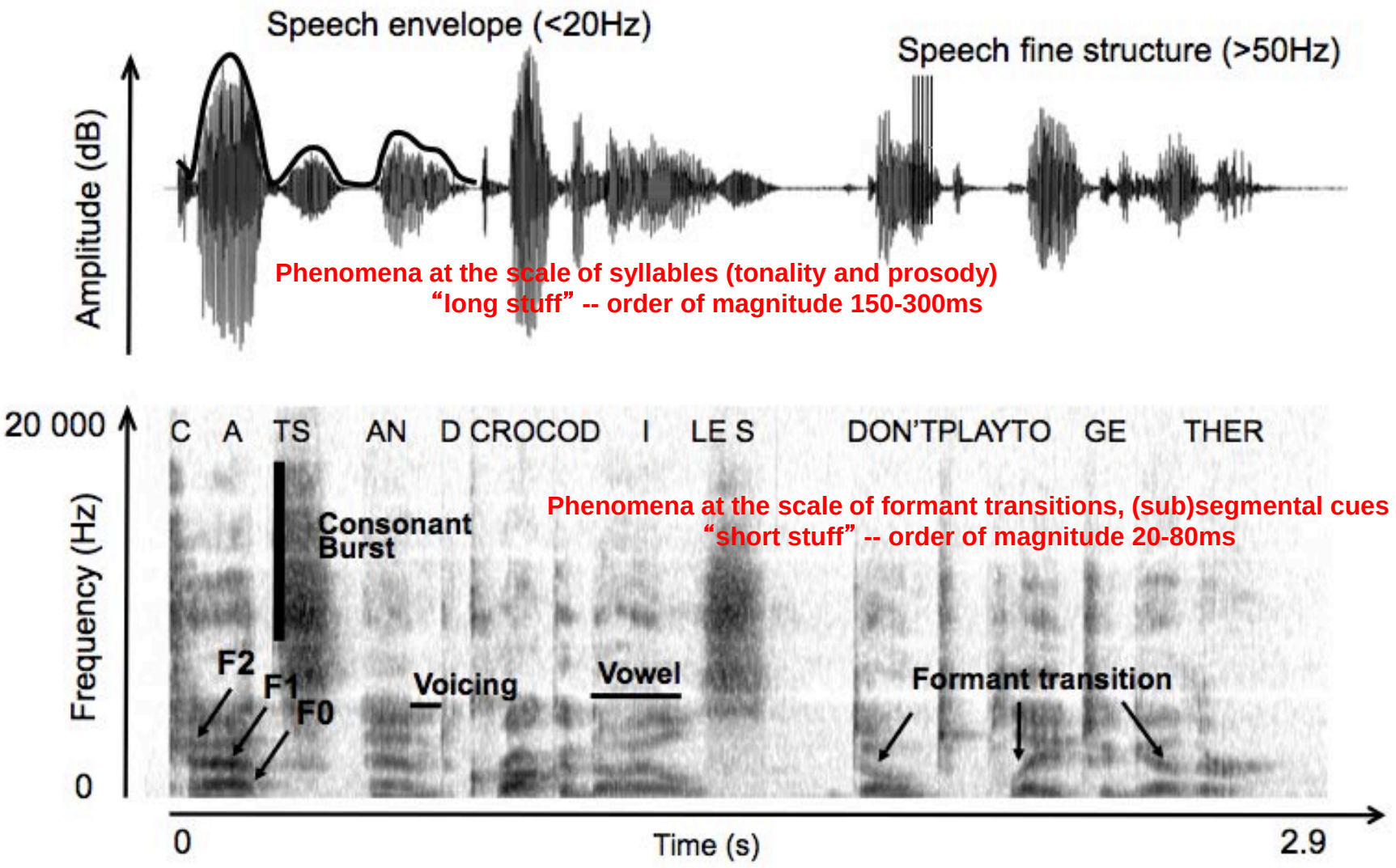

**There is an absence of 'linking hypotheses' by which we explore how brain mechanisms form the basis for linguistic computation.**

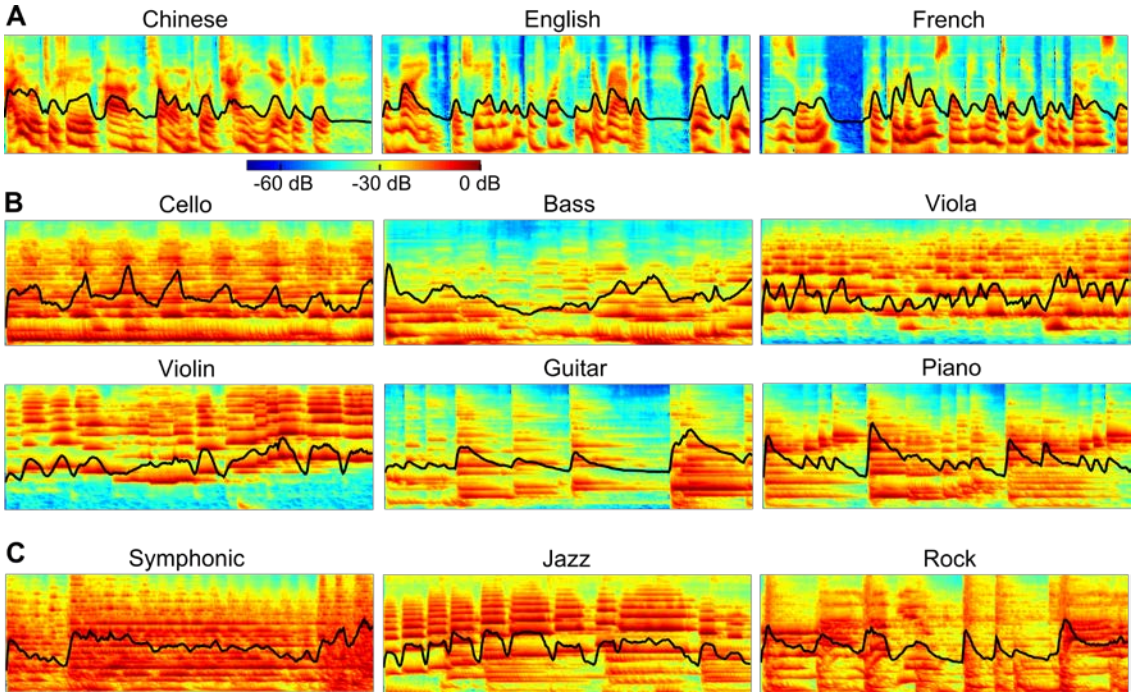
**Why?**

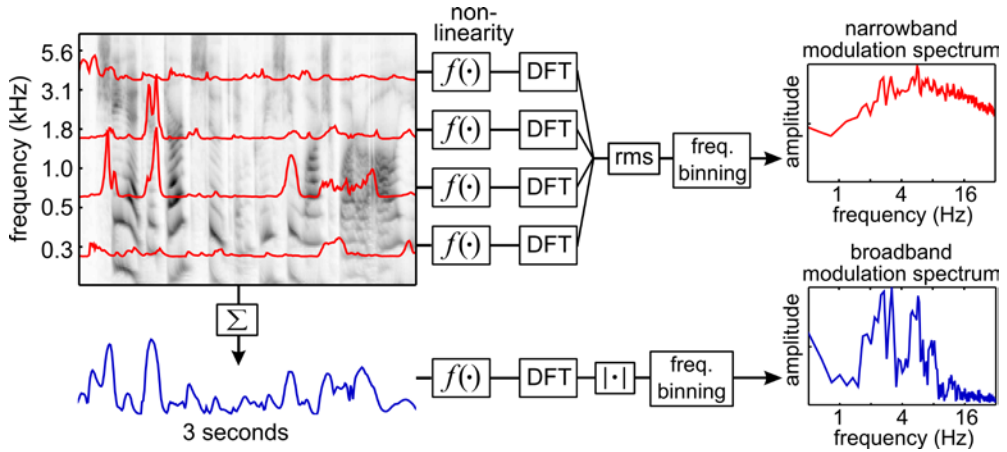
- **The granularity mismatch problem (practical)**
- **The ontological incommensurability problem (principled)**

***Poeppel & Embick, 2005; Poeppel 2012; Embick & Poeppel 2014***

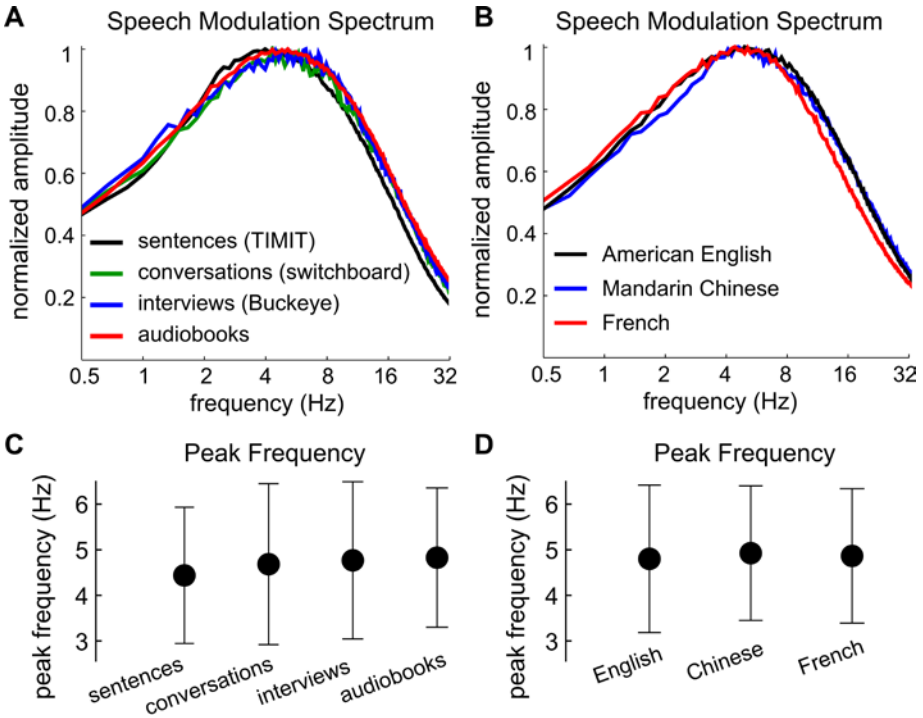
# Acoustic and articulatory phonetic phenomena occur on different time scales

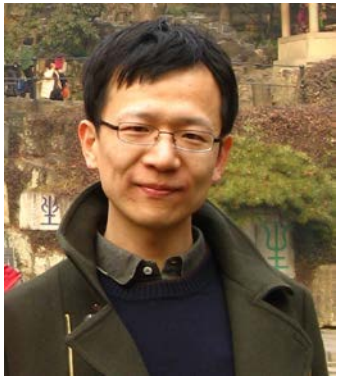



A
Chinese
English
French
-60 dB
-30 dB
0 dB
B
Cello
Bass
Viola
Violin
Guitar
Piano
C
Symphonic
Jazz
Rock

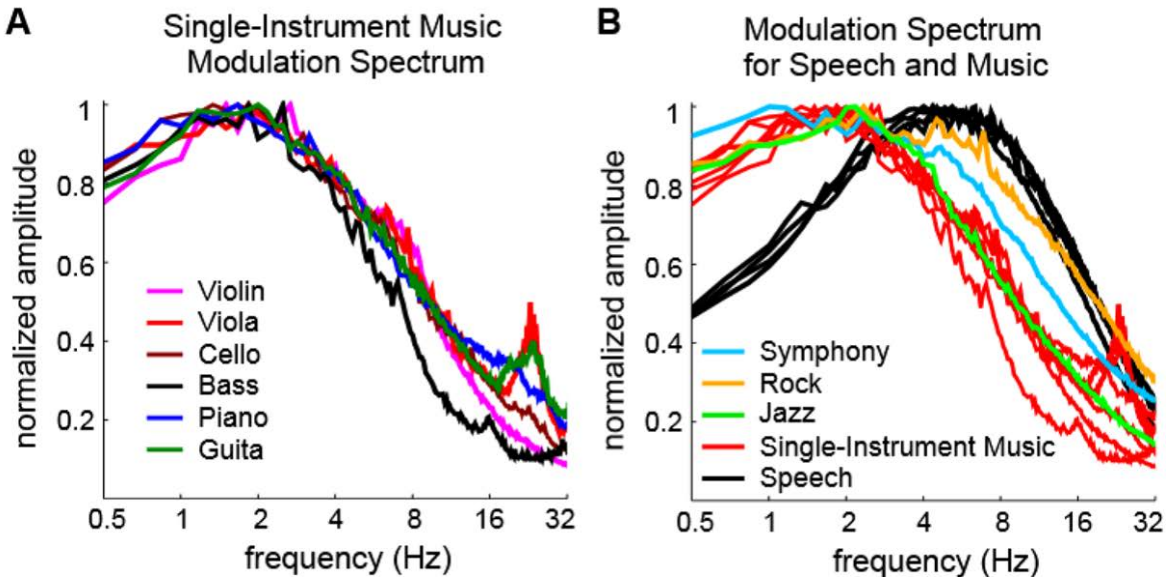

non-
linearity
frequency (kHz)
5.6
3.1
1.8
1.0
0.5
0.3
f(·)
DFT
rms
freq.
binning
narrowband
modulation spectrum
amplitude
1
4
16
frequency (Hz)
Σ
3 seconds
|·|
broadband
modulation spectrum

5 Hz - 200 ms

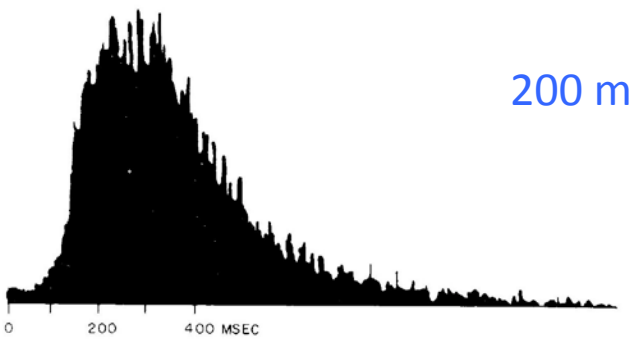


Nai Ding



# Syllable duration across languages -- The syllable as computational primitive?




200 ms – 5 Hz

Figure 1 Histogram of the intervals between some 10 000 successive jaw openings in running speech (reading).

Ohala 1972

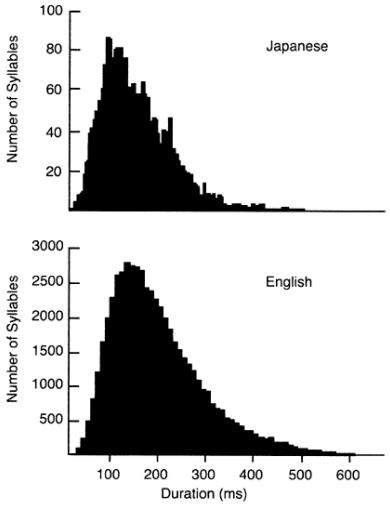



Fig. 1 Statistical distribution of syllable duration for spontaneous material in Japanese and American English. Adapted from [1].

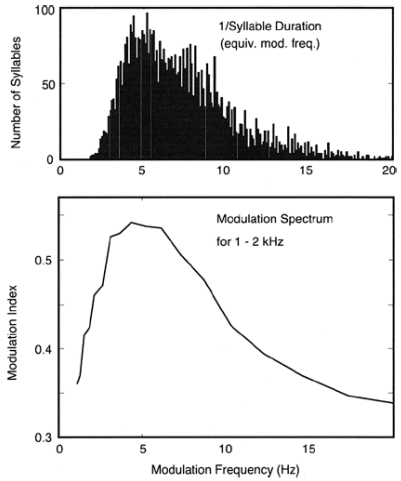
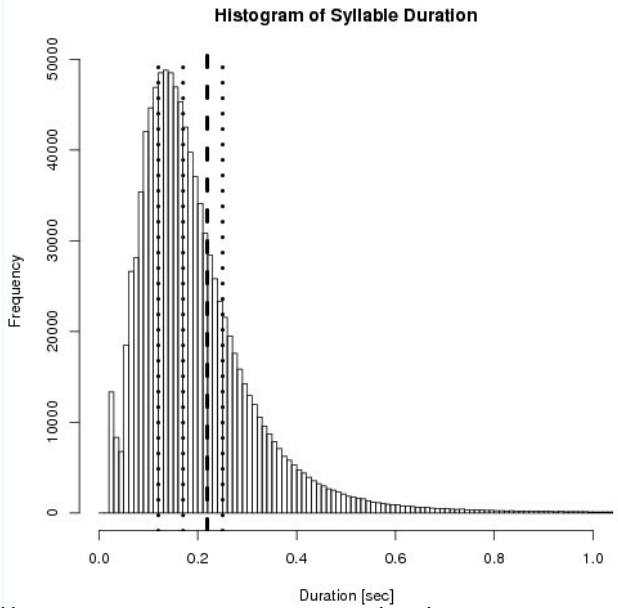



Fig. 2 The relation between the distribution of syllable duration (transformed into modulation frequency) and the modulation spectrum of the same Japanese material as shown in Fig. 1, computed for the octave region between 1 and 2 kHz. Adapted from [1].

Greenberg & Arai 2004




http://www.phonetik.uni-muenchen.de/Bas/BasPHONSTATeng.html

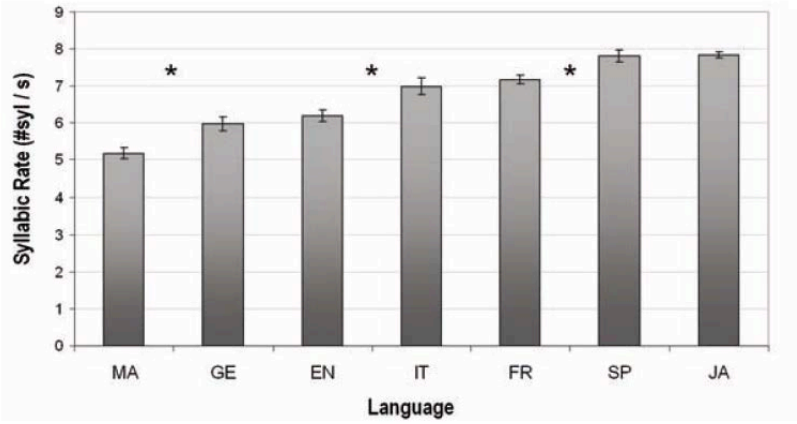



FIGURE 1. Speech rate measured in terms of the number of syllables per second (mean values and 95% confidence intervals). Stars indicate significant differences between the homogeneous subsets revealed by post-hoc analysis.

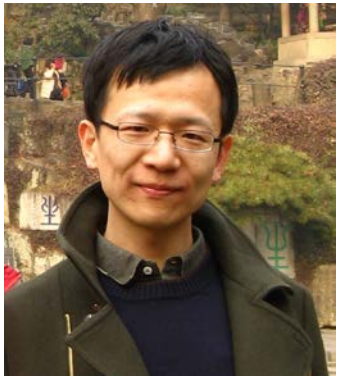
Pellegrino et al. 2011


Le Medecin guarissant Phantasie
Purgeant aussi Par drogues la folie.

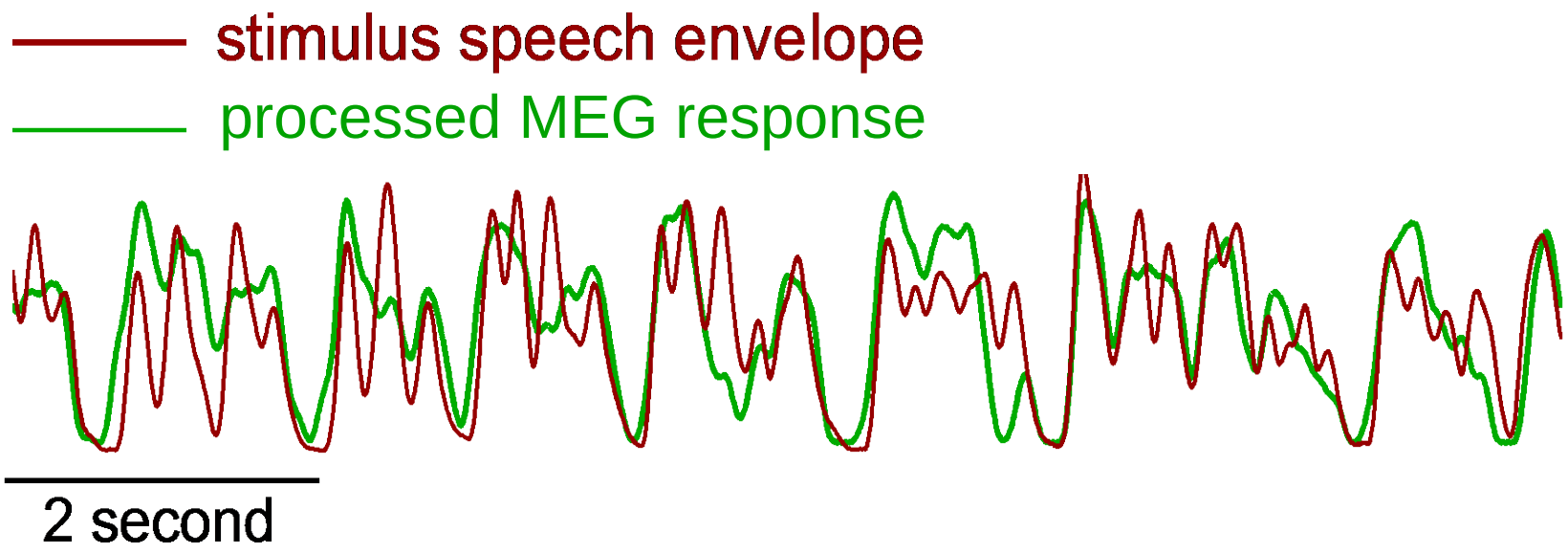
Keith Doelling

Neural entrainment is seen in both the theta and delta bands during spoken language comprehension.

=> Auditory cortical activity is entrained to the syllabic rhythm.



Nai Ding




5 Hz - 200 ms => Neural oscillations parse speech into syllable size chunks. Surfing the waves

***e.g. Luo & Poeppel, Neuron 2007; Ding & Simon, PNAS 2012; J Neuroscience 2013; Doelling et al. 2014***

Mingzhou Ding

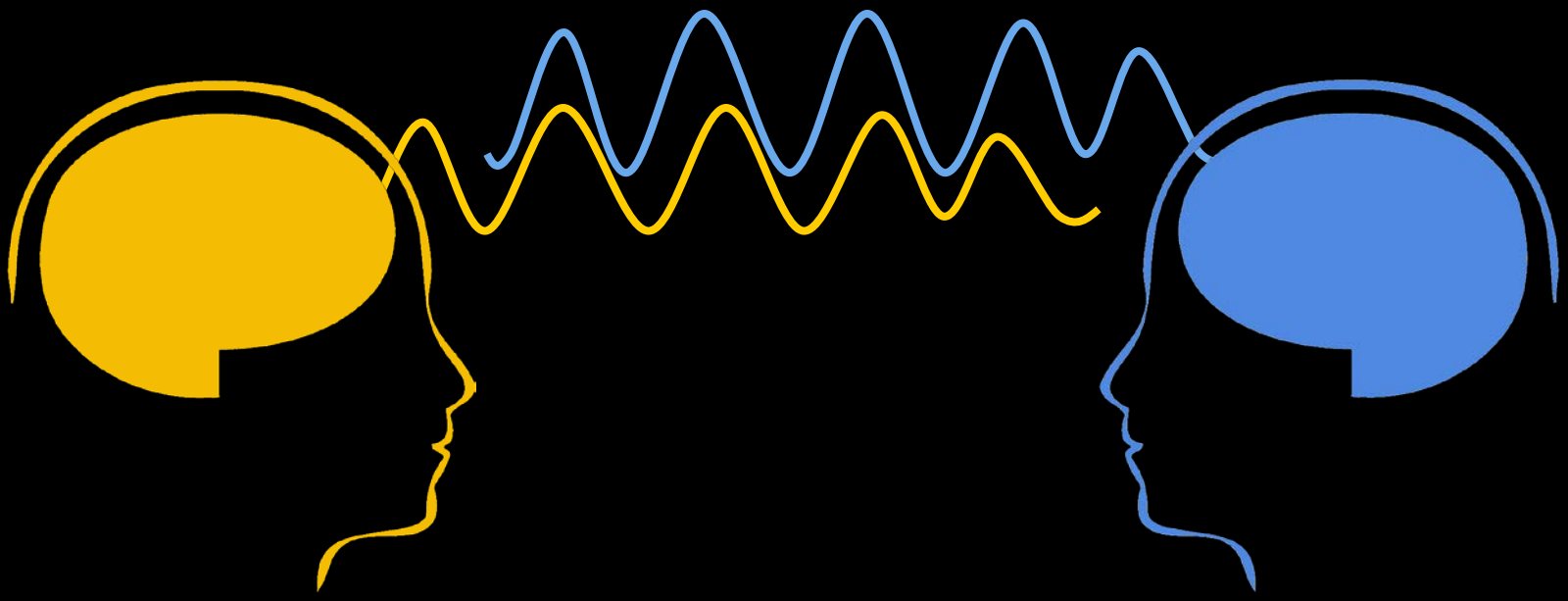
# Crowd-sourcing neuroscience: Neural oscillations and human social dynamics

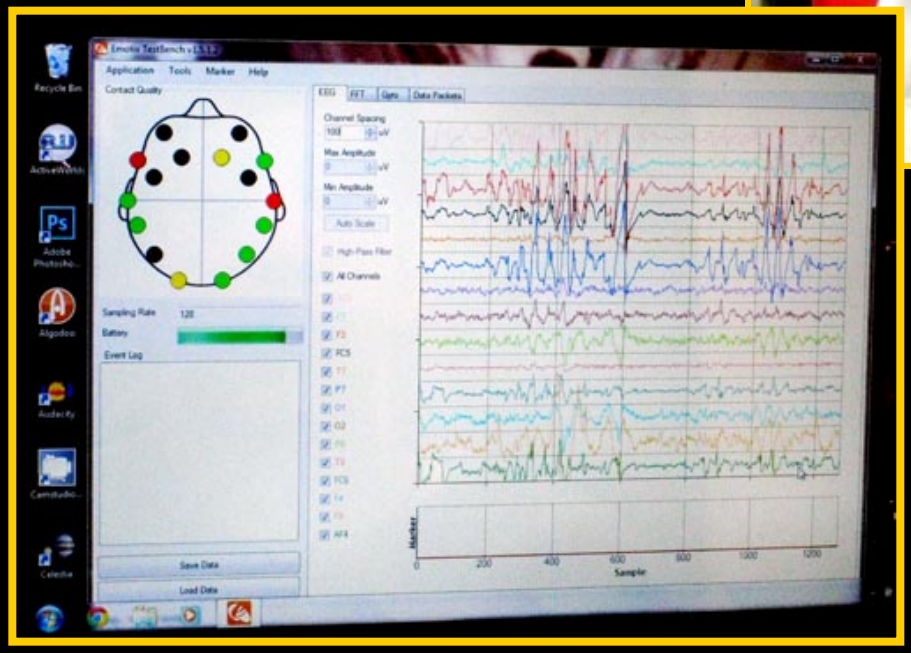
NSF INSPIRE
NYU & University of Florida
(David Poeppel Lab and Mingzhou Ding Lab)

# Goals of this project

- Expand the amount and scope of data testing these models
- Expand the research to groups, not just single participants of pairs
- Expand the research into the educational domain

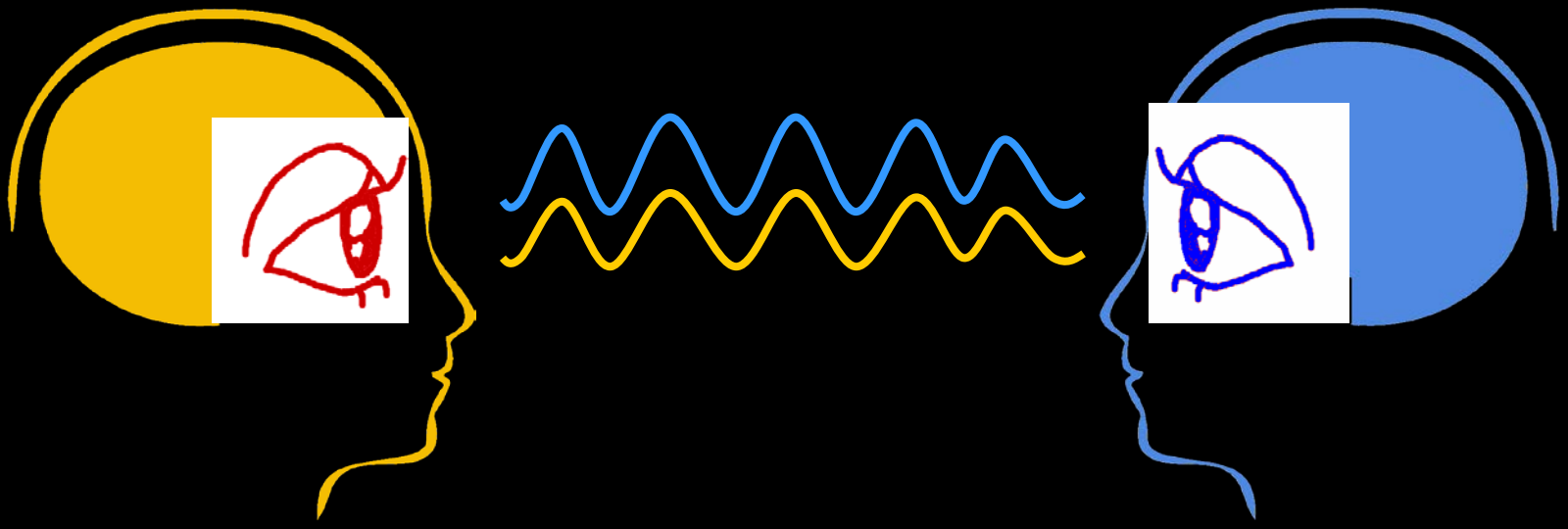
# “ON THE SAME WAVELENGTH”



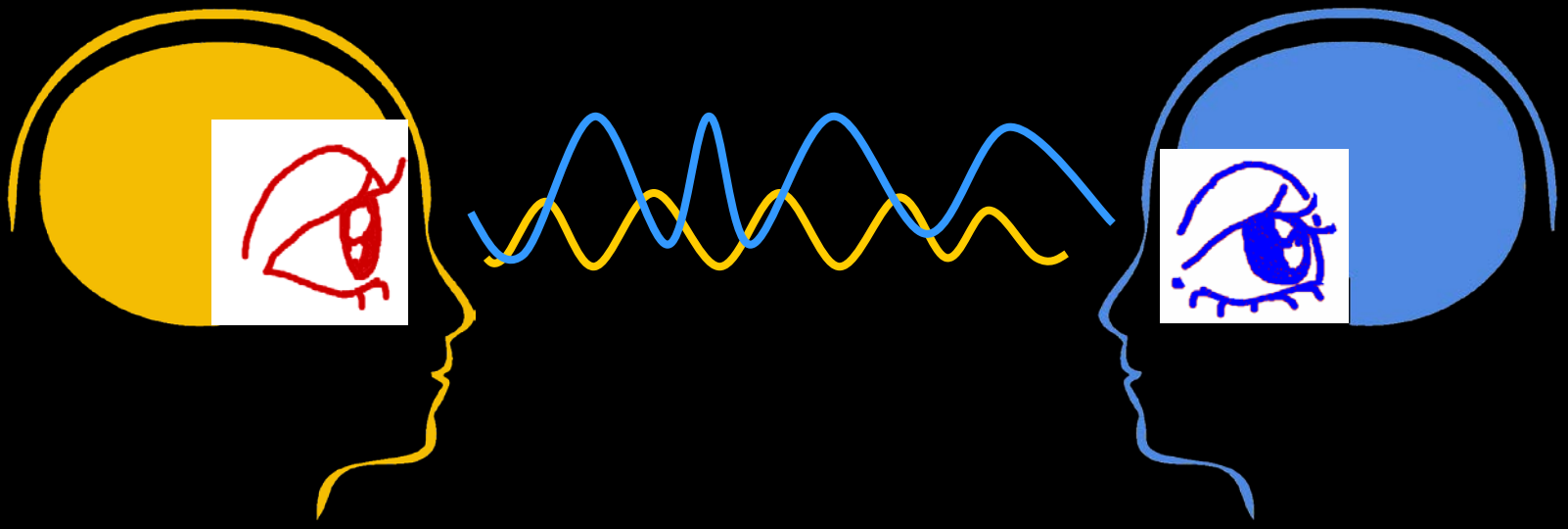



IMAGES BY ELLEN PEARLMAN

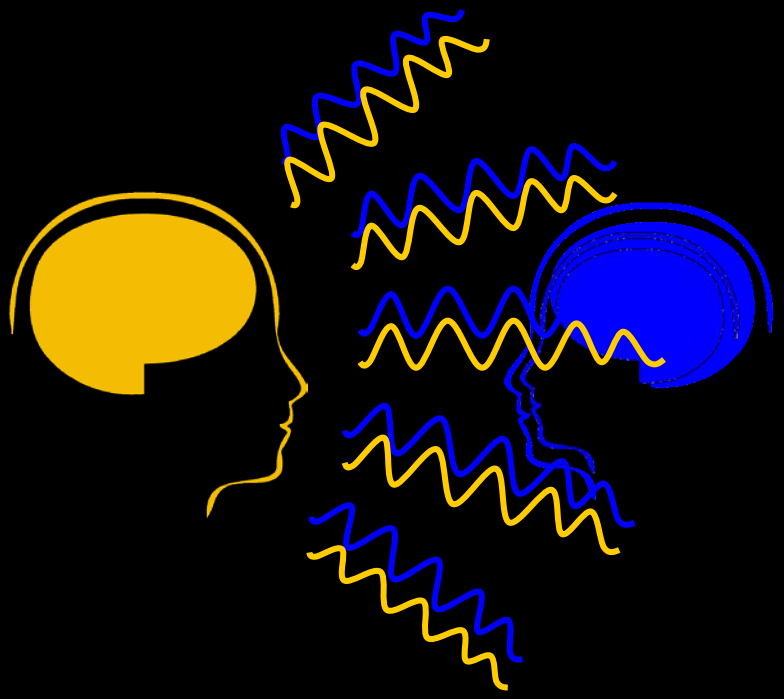
# SUCCESSFUL INTERACTION?



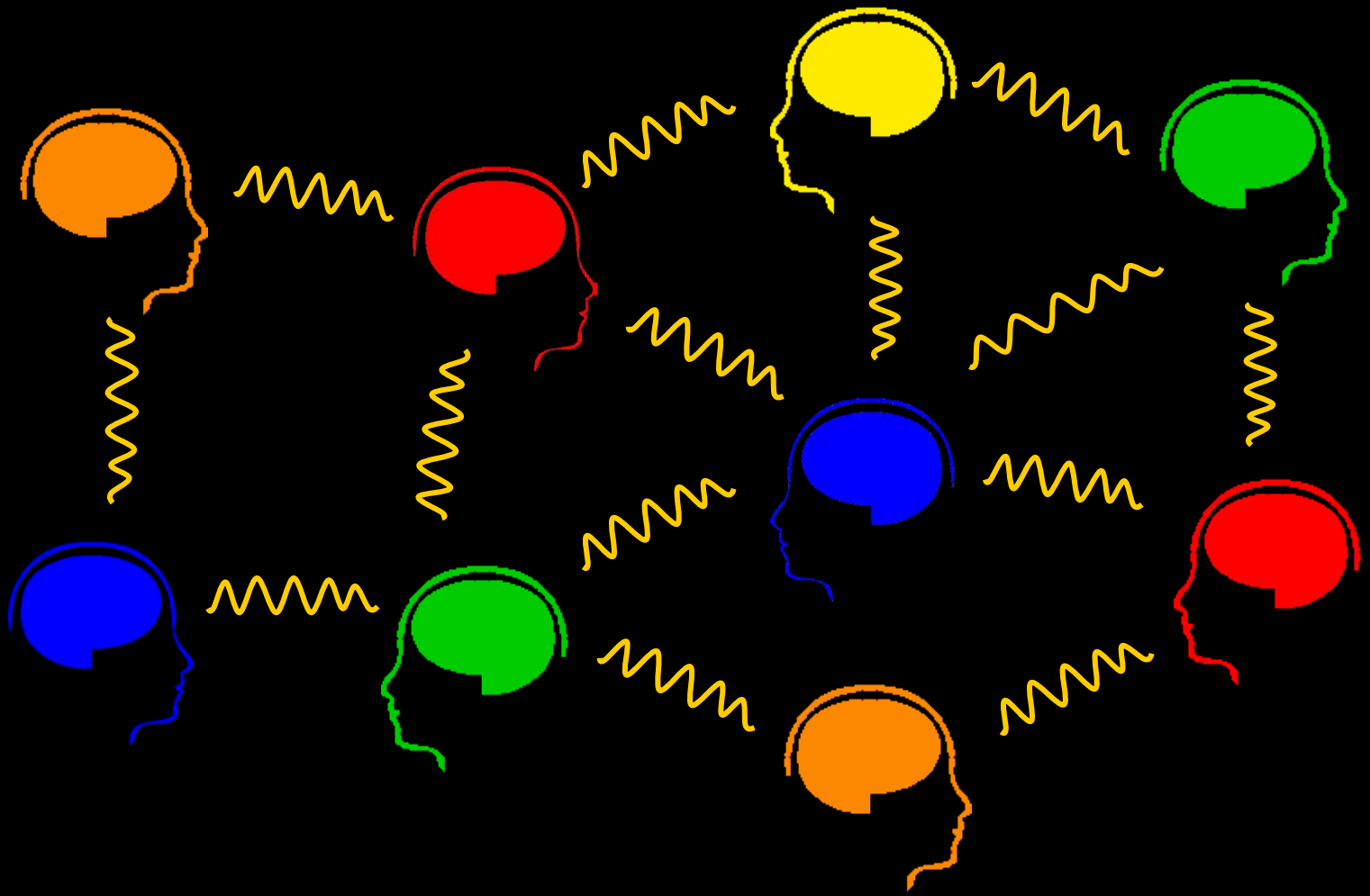
# UNSUCCESSFUL INTERACTION?



PAIRS →
GROUPS



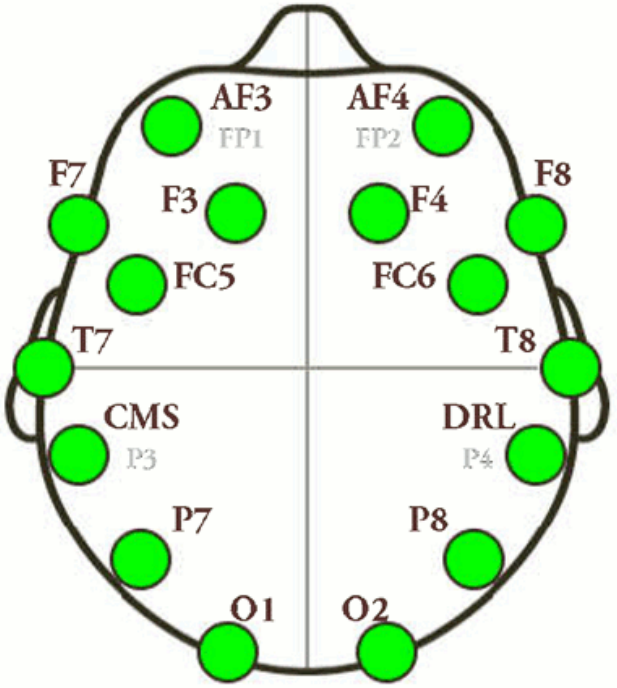
CLASSROOM
INTERACTIONS?



CLASSROOM
INTERACTIONS?

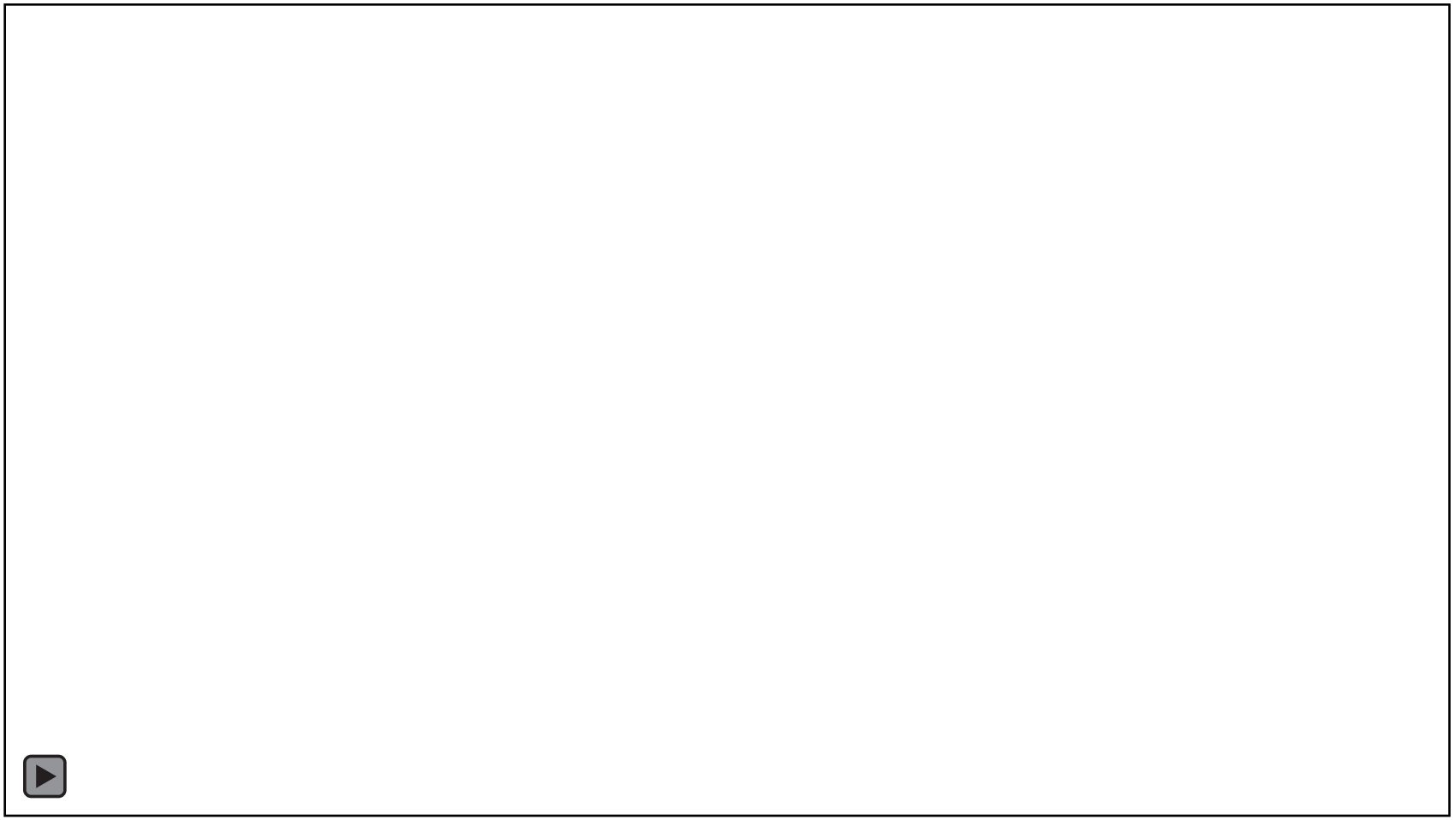
# Emotiv Headset

Emotiv headset




Electrode locations

# Students at work in experiment



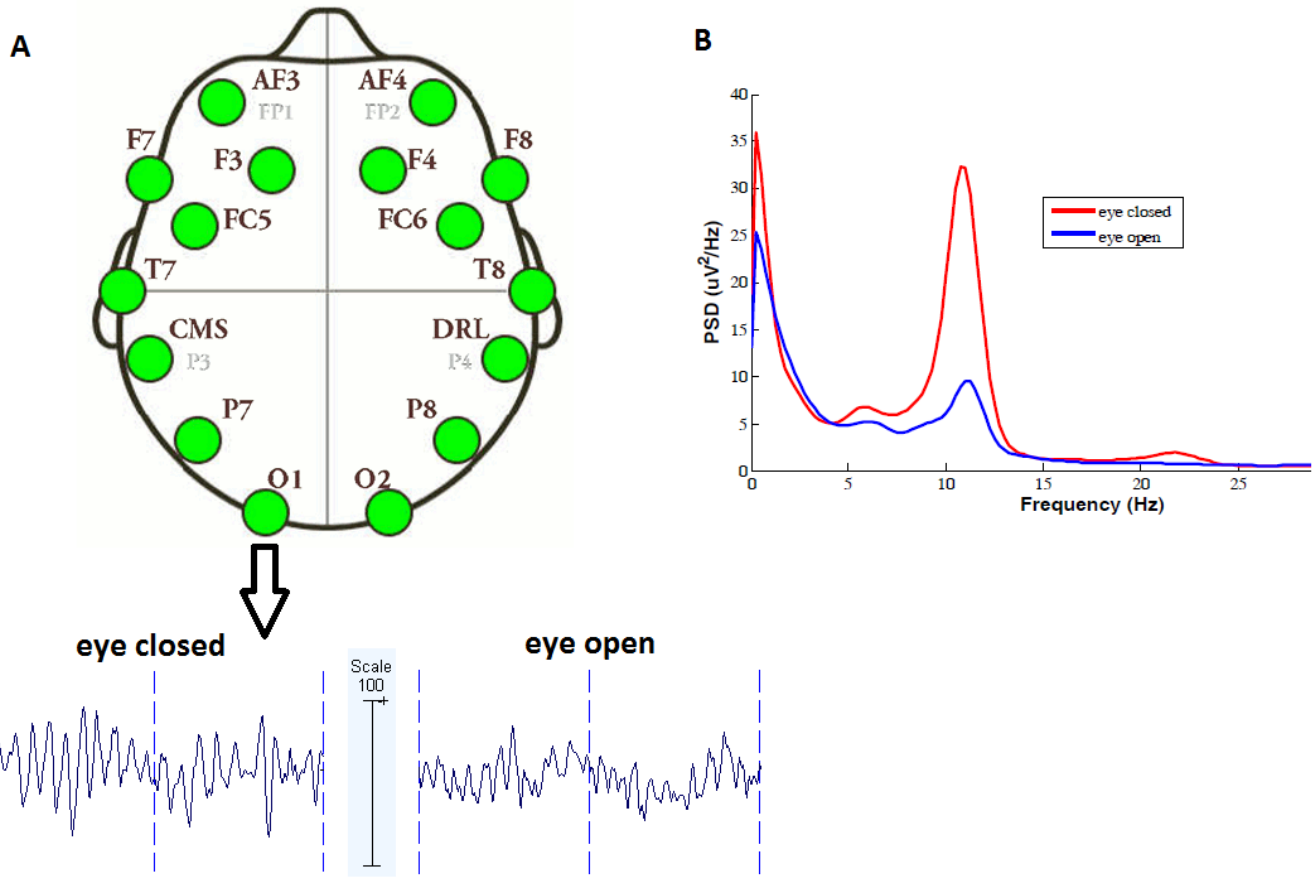
# Each class period

- Baseline
  - Facing wall (2 min)
  - Facing group / eye-contact in pairs (2 min; alternate)
  - Tones oddball (or other stimulus baseline)
- Teaching
  - Teacher reads aloud (no visual support; 3 min)
  - Video (2 min)
  - Teacher lectures (with visual support; 5 min)
  - Group Discussion (5 min)
- Baseline
  - Facing group / eye-contact in pairs (2 min; alternate)
  - Facing wall (2 min)

# Timeline

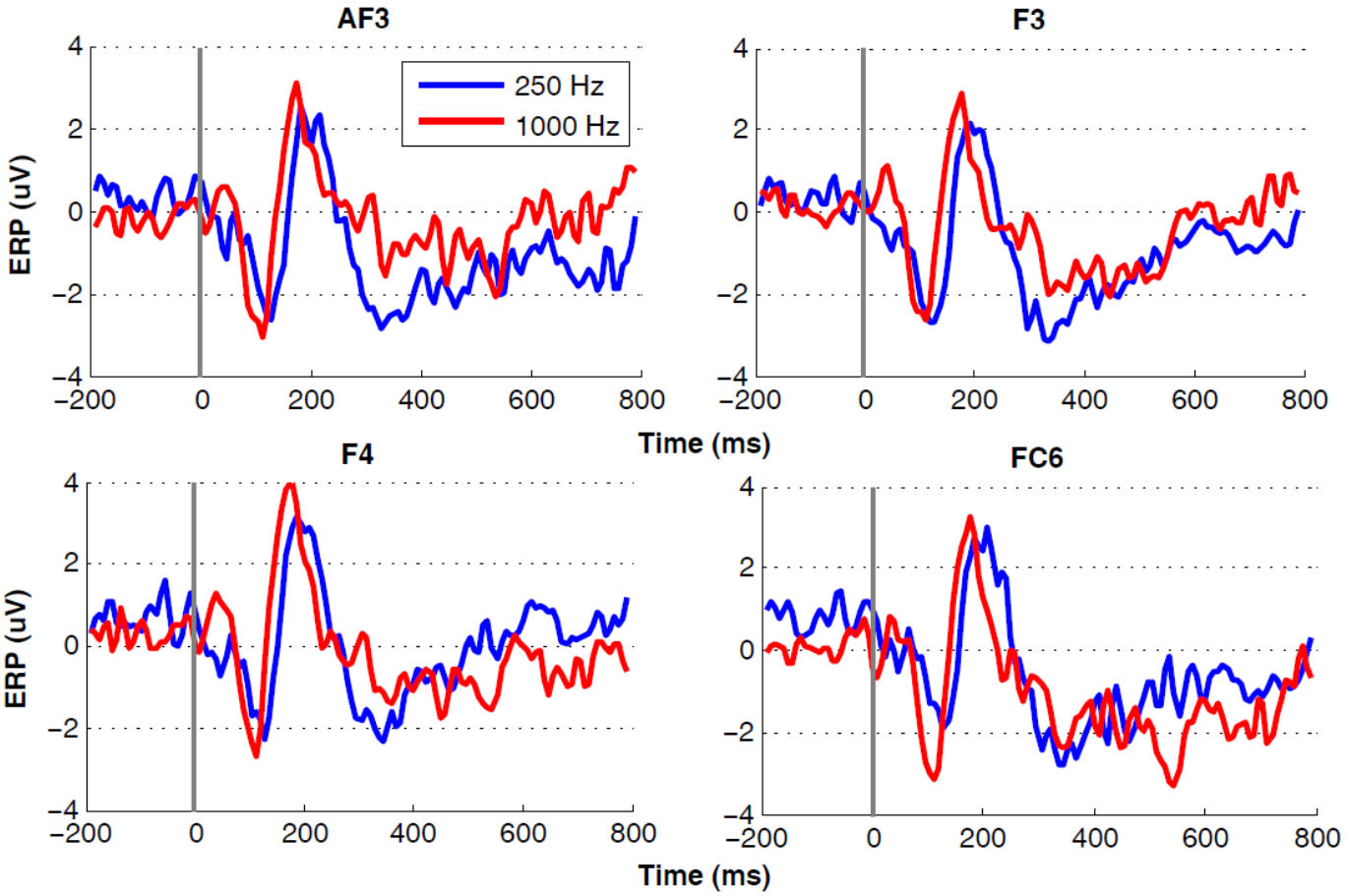
- September
  - Neuroscience crash-course
- October – December
  - Recording sessions / baseline testing
- December on
  - Data analysis
- Spring 2015
  - Student-initiated projects
  - Expected: some students will be involved in data analysis / write-up of project

# Alpha Rhythm: Eye-open Versus Eyes-closed

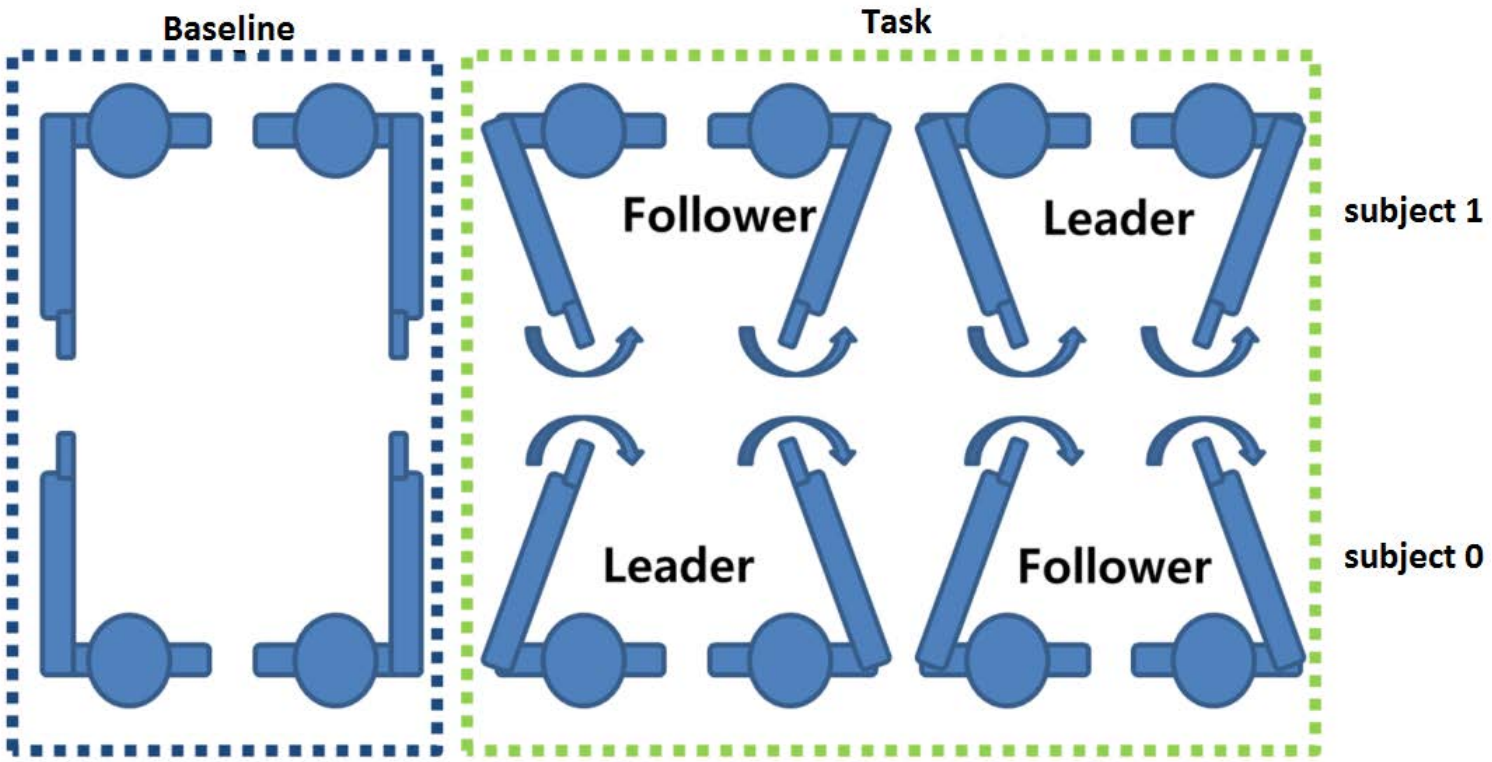


# Event-related Potential to Tones

- Testing that set-up works, equipment works, brains work.
- ERP results were averaged across subjects. Some frontal channels gave good N1-P2.



# Synchronized Figure-movement




- Baseline: two subjects sat face-to-face with index fingers held stationary and directed at each other.
- Task: one served as a leader whose finger movements were tracked and mimicked by the follower.

# Methods

*Amplitude Envelope Correlation (AEC)*

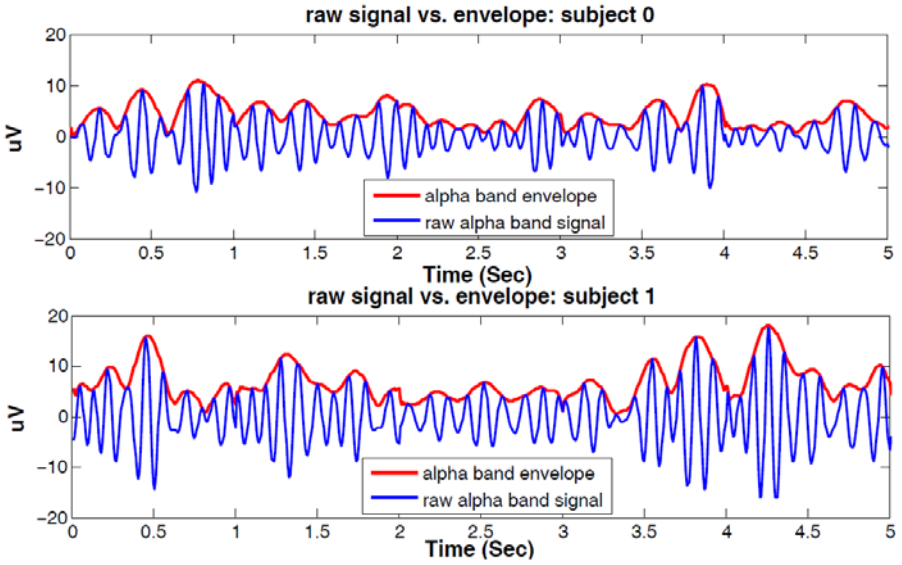
- Hilbert transform was performed on filtered EEG signals (8 to 12 Hz) to extract amplitude envelope.
- AEC was defined as the cross correlation function of the amplitude envelopes from two channels.

*Coherence (COH)*

- Coherence is the Fourier-based method of connectivity that was used to estimate inter-brain connectivity in this study.

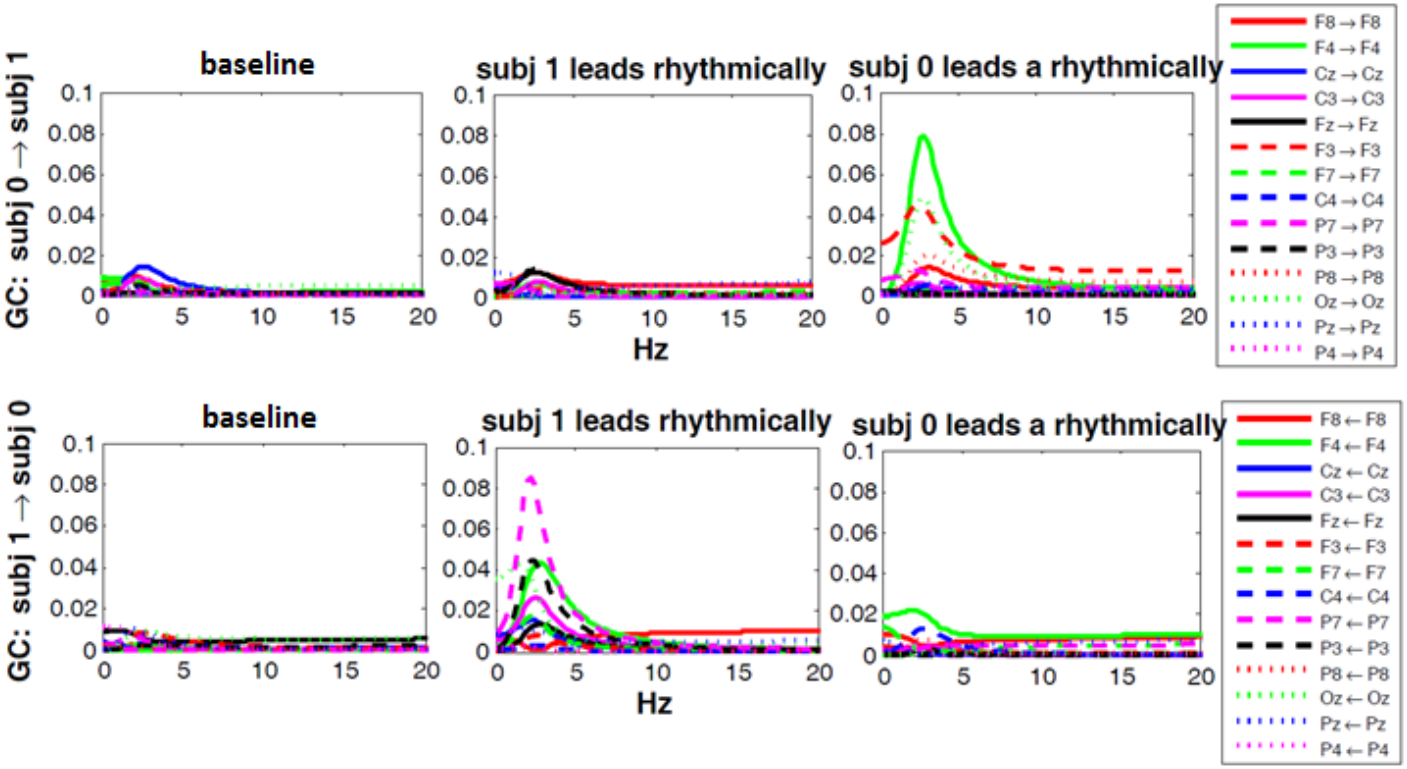
*Granger Causality*

- Given two time series $X_1(t)$ and $X_2(t), X_2(t)$ is said to Granger-cause $X_1(t)$ if knowing the past of $X_2(t)$ improves the prediction of $X_1(t)$ .
- $X_2$ may Granger-cause $X_1(t)$ without $X_1(t)$ Granger-cause $X_2(t)$, then the predominant directionality would be from $X_2$ to $X_1$ $(X_1 \leftarrow X_2)$ .




Amplitude envelopes of alpha band filtered signals at Oz

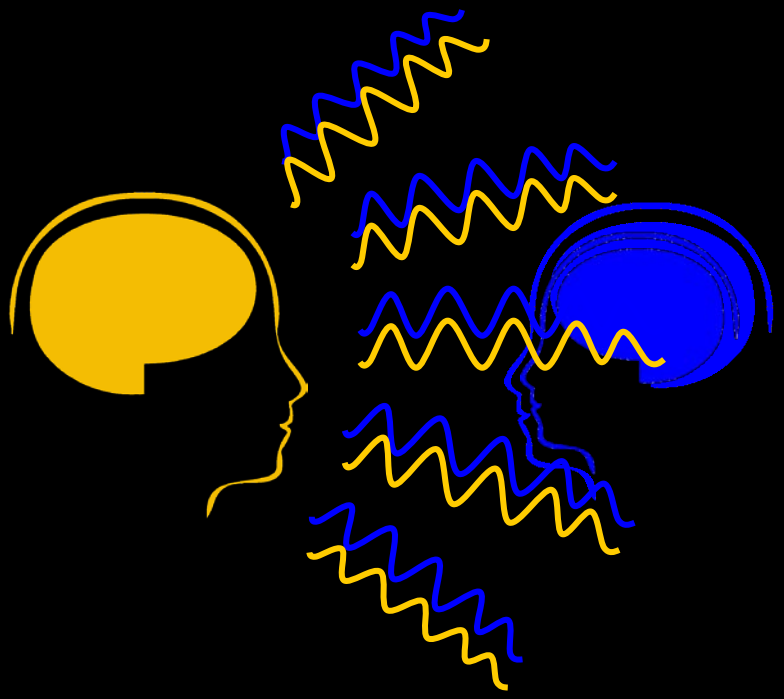
# Finger-moving results




Inter-brain Granger Causality based on amplitude envelopes for three conditions.

Conclusion: Leader→follower is larger. GC based on amplitude envelopes of bandpass-filtered signals is capable of identifying leader and follower in this case. And the electrodes that show this effect are mainly located in frontal-parietal area.

PAIRS →
GROUPS



CLASSROOM
INTERACTIONS?

# Why are we excited about this?

The work reveals principled connections between:

- physics (acoustics, modulation spectrum)
- linguistics (syllable as computational primitive)
- neuroscience (oscillations entrain to speech)
- social neuroscience (crowd-sourcing and education)

We aim to articulate detailed linking hypotheses between the empirical and theoretical approaches (*theoretically well motivated, computationally explicit, biologically plausible*)

# How does the BRAIN initiative relate?

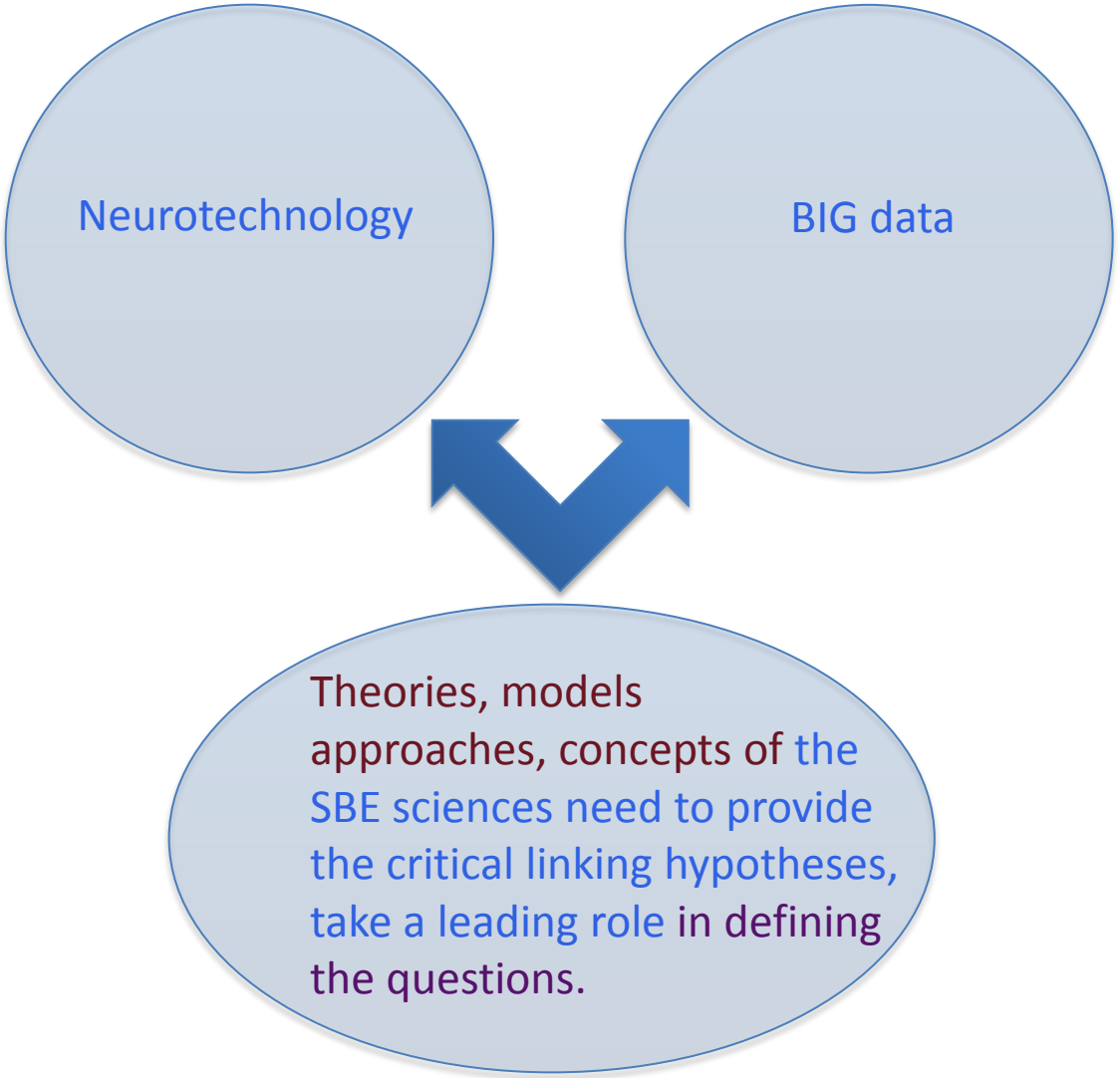
The main conceptual building blocks – to date – are:

Neurotechnology BIG data

The conceit of the (laudable, exciting, to-be-supported) initiative is that new technologies, paired with the ability to analyze ever-larger bodies of data, will 'break' problems, more or less by 'overwhelming' them with our biggest weapons.

*What is not as well developed – but should be – concerns what the initiative is actually about, in terms of its endgame: an understanding (i.e. mature theories) of behavior, perception, cognition, action, decision, memory, social engagement, ...*
*What will really help is to embrace the SBE sciences, or even promote them more 'muscularly' to highlight relevance of BRAIN*

# How does the BRAIN initiative relate?



# How does the BRAIN initiative relate?