ECoG-Motor-Imagery

Raclette2-meet2

Title: Does Imagery share similar neural mechanisms with the actual movement?

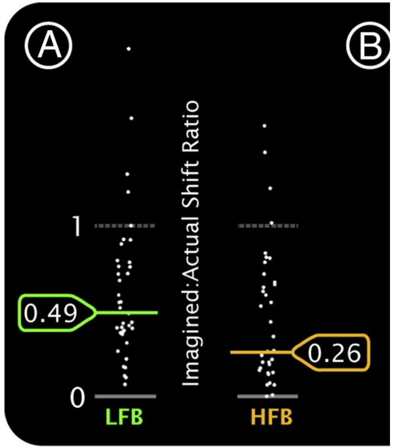
Imagined motor movement ("Imagery") plays a crucial role in preparing actual movements and learning of complex motor skills. Miller et al (2010) have shown that the spatial distribution of activities in the primary motor area for imagery and actual movements does not overlap in high frequency (76-100Hz), but in low frequency band (8-32Hz). However, the neural substrates and neural representations of imagery still remain largely unknown.

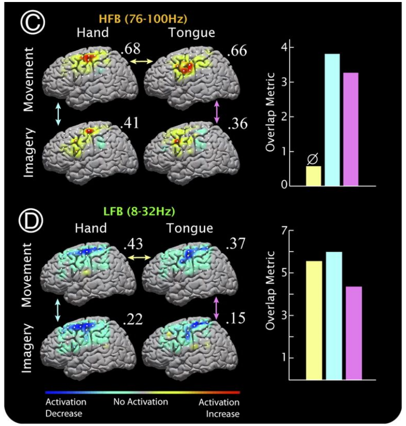
The present study examined whether imagery shares similar mechanisms with actual movement at different levels. With electrocorticography (ECoG) dataset in seven human subjects during actual movement and kinesthetic imagery of the same motion type (hand & tongue), we investigated the channel-level mechanisms by looking at the differences between actual movement and imagery in the power of specific frequency bands (i.e. alpha/beta/gamma). Furthermore, we investigated the population-level mechanism by performing the multivariate classification and the neural trajectory analysis. Specifically, we trained the classifier on actual movement/imagery and tested it on imagery/actual movement to see whether the decoding can be generalized to each other. Also, using t-SNE, we examined whether the imagery and actual movement activated in the same sequence at the neural subspace.
Our results (may) suggest that in addition to common neural substrates shared by imagery and actual movements, there also exists imagery-specific neural substrates at both the channel level and the population level.

Keyword: electrocorticography (ECoG) | time frequency analysis | multivariate classification | neural trajectory analysis

Background

1. which **brain area(s)** does motor imagery recruit, compared to actual movement?
   - a large fronto-parietal network and motor-related area, but primary motor area (M1/precentral gyrus) does not show persistent activities (ref 2, BOLD signal meta-analysis)
2. do motor imagery and actual movement have **common neural correlates**, or do they have **distinct** neural correlates
   - they were similar in low frequency bands (alpha/beta, ref 3, 5, 6 & original), but differ in high frequency bands (original)
   - also, the coupling between the phase of alpha (8–12 Hz) and the amplitude of high gamma (70–120 Hz) and this PAC decreases during motor imagery (ref 14)
3. do different **motion types** have common neural correlates, or do they have distinct neural correlates?
   - they were similar in low frequency bands, but may differ in high frequency bands (original)





Our project

1. Our group project wants to examine whether sensorimotor cortex represents motion types similarly in actual movement and imagery
   - hypothesis 1: no, they have distinct representations of motion types
   - hypothesis 2: yes, they share similar representations though differ in the power

2. specifically, we want to ask two questions:
   - 1) do actual movement and imagery differ in activation sequence/dynamics;
   - 2) do actual movement and imagery differ in representation code

1) time-frequency analysis (single channel mechanism)
2) population analysis (population level mechanism)
   a) raw broadband signal
   b) specific band signal (trajectory?)

Data Set

Table S1. Patient descriptions and characteristics

Patient	Age	Sex	Hand	Grid location	Seizure focus
1	18	F	R	L Frontal	L Frontal
2	23	M	R	L Frontotemporal	L Temporal
3	41	M	L	L Frontotemporal	L Temporal
4	38	M	R	R Frontal	R Frontal
5	48	M`	R	R Temporal-parietal-occipital	R Temporal-occipital
6	31	F	R	R Frontotemporal	R Insula
7	12	M	R	L Frontotemporal	R Temporal
8	32	M	R	R Frontotemporal	L Temporal

"Simple motor and imagery tasks were studied in eight patients (two females, and the age range is 12–48;" (Miller et al., 2010, p. 4434)

Behaviour Tasks

A series of three experiments were performed:

- interval-timed active motor movement (3s interval)
    - repetitive movements of the hand (synchronous flexion and extension of all fingers ≈1 Hz)
    - the tongue (opening of mouth with protrusion and retraction of the tongue also at 1 Hz)
    - shoulder (shrug at 1Hz)
    - simple vocalization (saying the word “move”).
- interval-timed motor imagery
    - Kinesthetic imagery
    - Imagining making identical movement rather than executing the movement.
- cursor-to-target movement task to provide feedback on motor imagery

Signal Preprocessing

- Sample rate is always 1000Hz, and the ECoG data has been notch-filtered at 60, 120, 180, 240 and 250Hz
- followed by z-scoring across time
- PCA to denoise

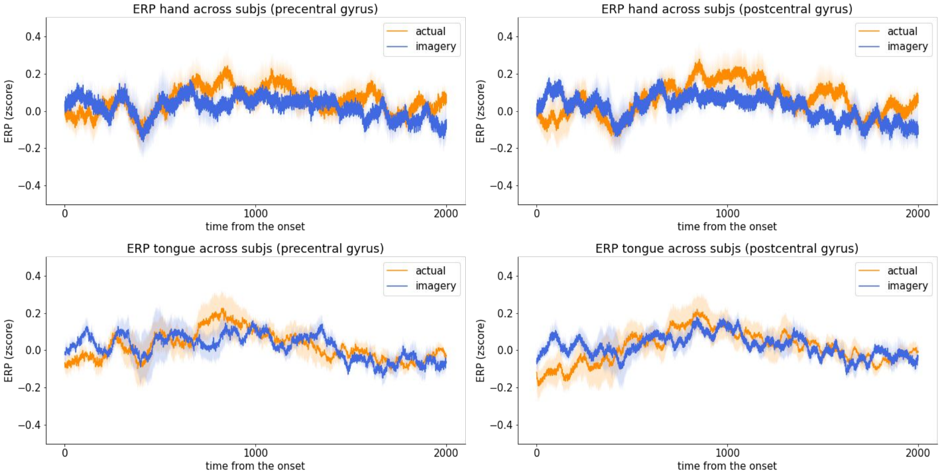
Analysis Pipeline : Data Preprocessing

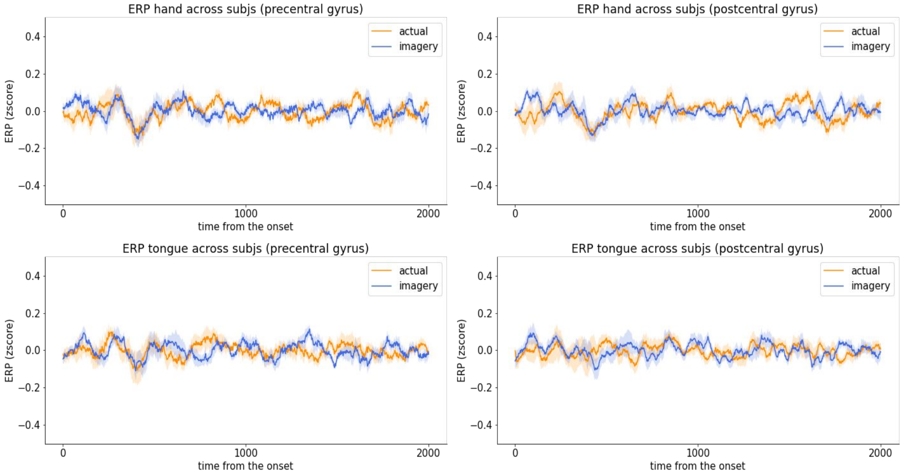
Data Preprocessing Methods Considered:

- Resampling (?)
- Baseline Correction
- Normalization
- Averaging
- **Filtering**
  - DC Noise Filter (0-5Hz)
  - Other Noise/Artifact Filter (?)
  - Ultra-high Frequency Filter (?) (>100Hz)

- Other?

Analysis Pipeline : ERP Analysis





Unfiltered ERP

Filtered (1-200 Hz) ERP

Analysis Pipeline : Time-Frequency Analysis

Time-Frequency Analysis to Analyze Activation in LFB & HFB

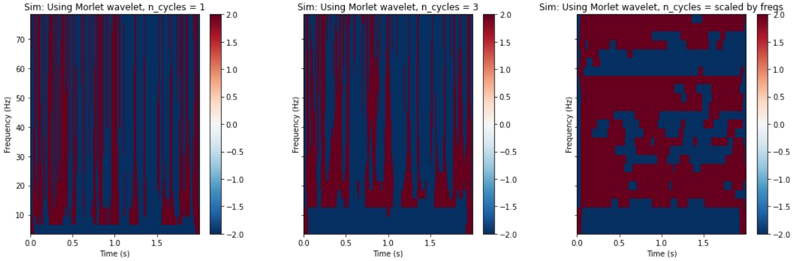
Methods Considered:

- STFT
- Wavelet Convolution (Morlet, etc)

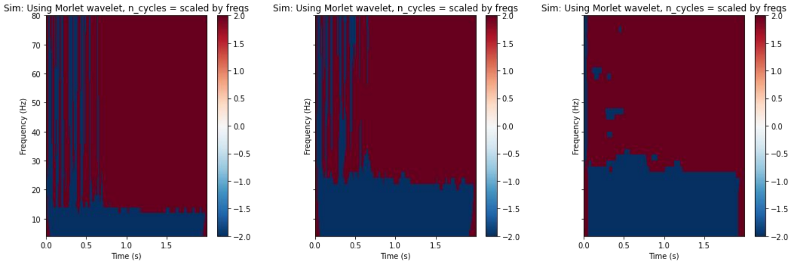
Other Things to Consider:

- Parameters (bins, cycles, wavelet type)
- Preprocessing (highly tied with TF analysis result)

Preliminary TF Exploration (messy!) -------------->



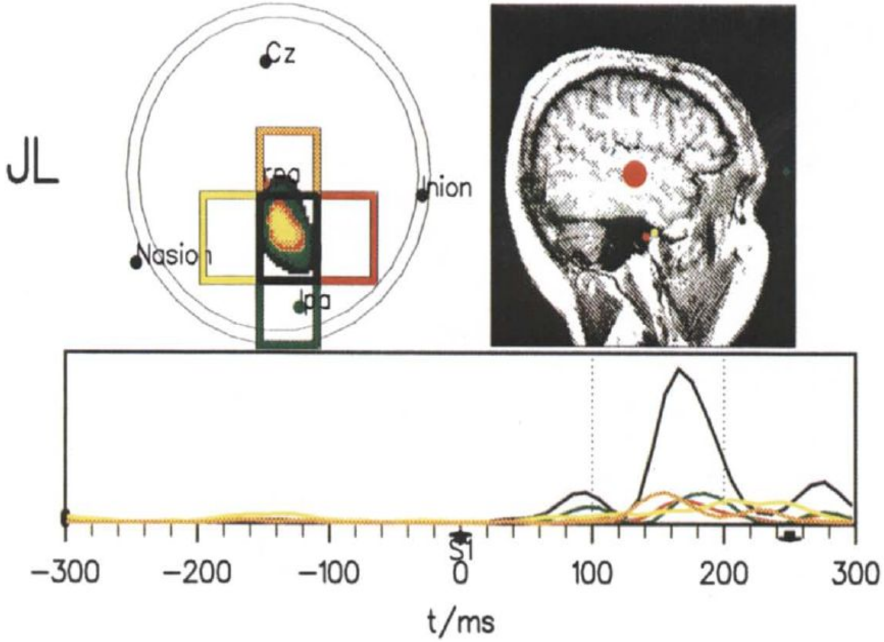
Subject 0 Channel-20, <u>tongue</u> real movement



Subject 0 Channel-20, <u>hand</u> real movement

Analysis Pipeline: Activation sequence/dynamics

- choose ROI, color-code with activation region

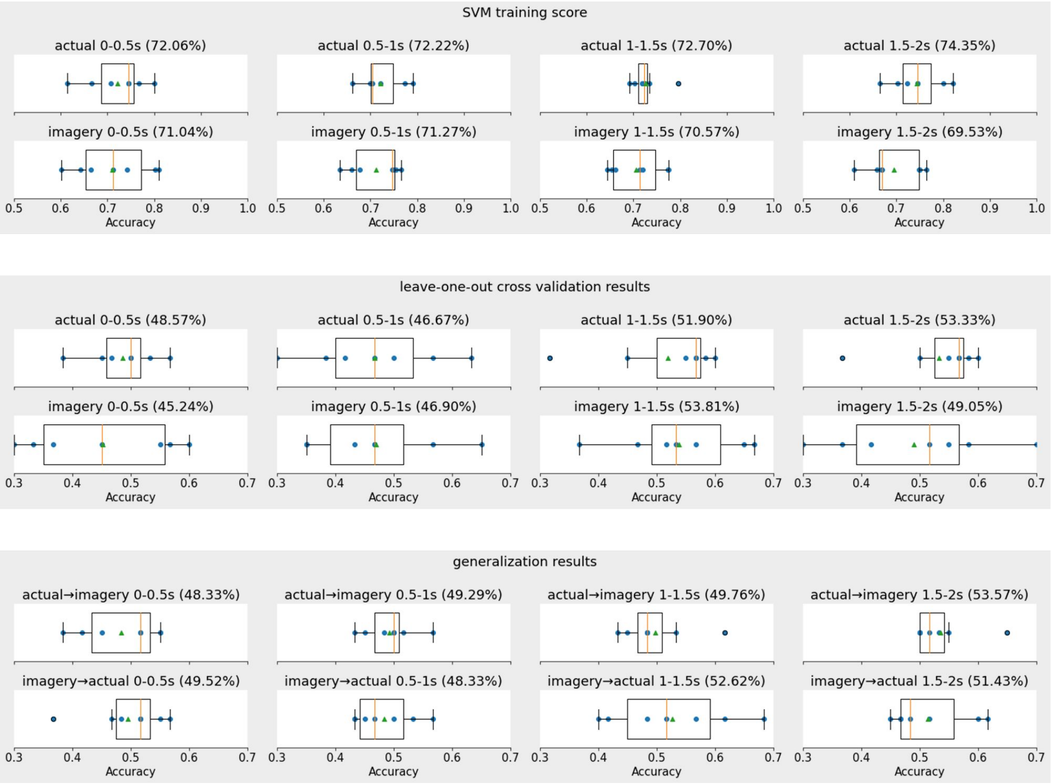


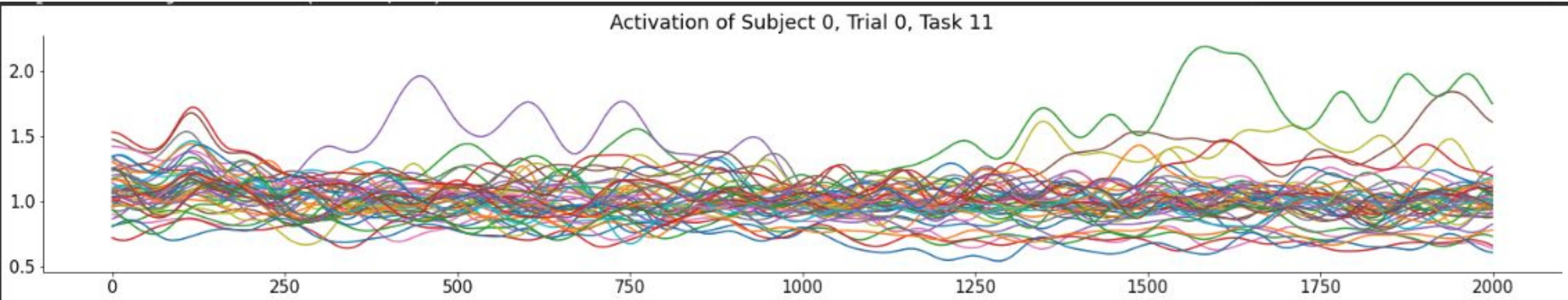
A.A. Ioannides, et al, 1994

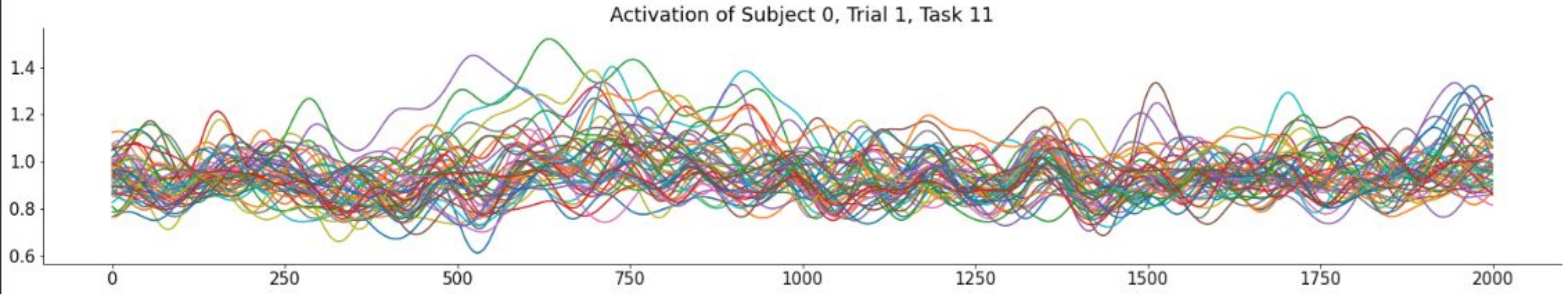
Do actual movement and imagery differ in representation code (classifier)?

- train and test a classifier in actual movement
- then generalize it to imagery data to see whether the classifier can still decode movement types.

overfitting!

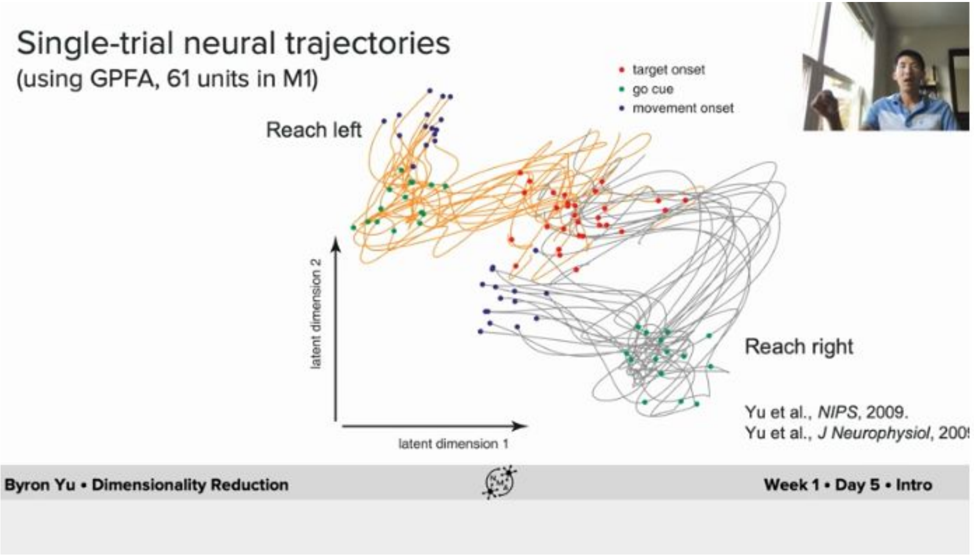



Activation of Subject 0, Trial 0, Task 11
0.5
1.0
1.5
2.0
0
250
500
750
1000
1250
1500
1750
2000


Activation of Subject 0, Trial 1, Task 11
0.6
0.8
1.0
1.2
1.4
0
250
500
750
1000
1250
1500
1750
2000

Analysis Pipeline: Activation sequence/dynamics

- dimensionality reduction (PCA) to find activation trajectory



Yu et al., NIPS. 2009