BrainHack School

Exploring Stroke-Related Brain Connectivity Patterns from fNIRS data

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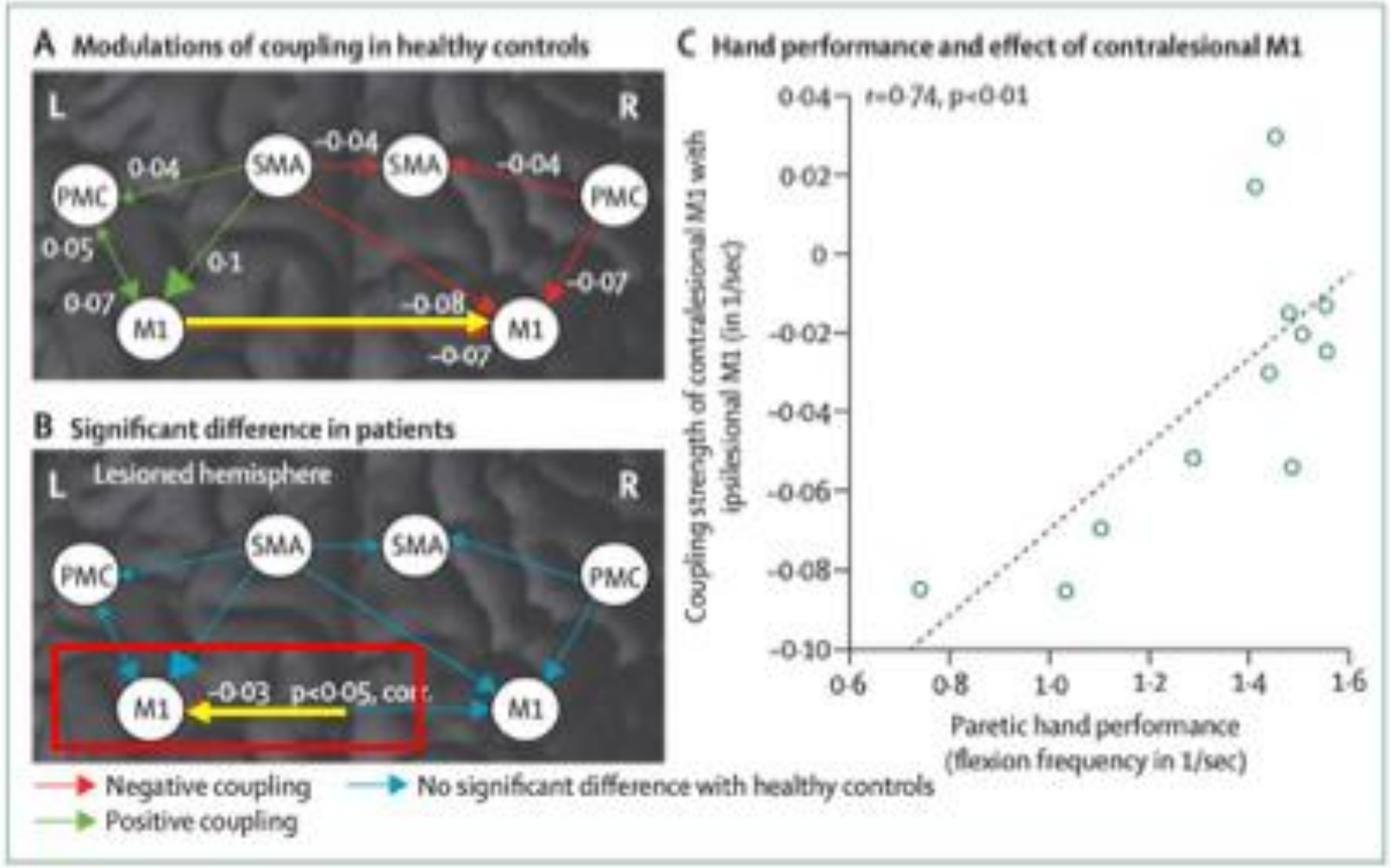
Background



Grefkes, C., & Fink, G. R. (2014). Connectivity-based approaches in stroke and recovery of function. *The Lancet. Neurology*, *13*(2), 206–216. https://doi.org/10.1016/S1474-4422(13)70264-3

Goals (previous)

MNE-python

1. **Preprocess the fNIRS data**

2. **Visualize the data and explore the Functional connectivity**

Machine learning

3. ~~**Network Deviation Score (NDS)**~~

   - NDS = 1−confidence of being “normal”
   - A personalized score based on how much a subject’s functional connectivity pattern deviates from the healthy network model.

Data

1. **Dataset status:** Internal use only (not published)
2. **Collection period**: 2024/08 – 2025/05
3. **Subjects:** total 17 participants, 218 trails
    - Stroke patients (SP): 10
    - Healthy adults (SH): 7
4. **Experiment design**
    - Each session includes pre/post stimulation fNIRS recordings
    - Tasks: 2-minute rest + repeated handgrip (3 blocks per side)

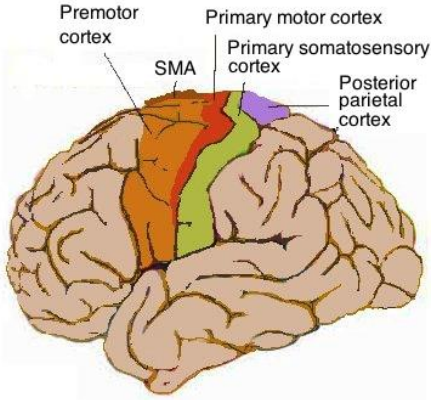
Demographic Characteristics of Participants

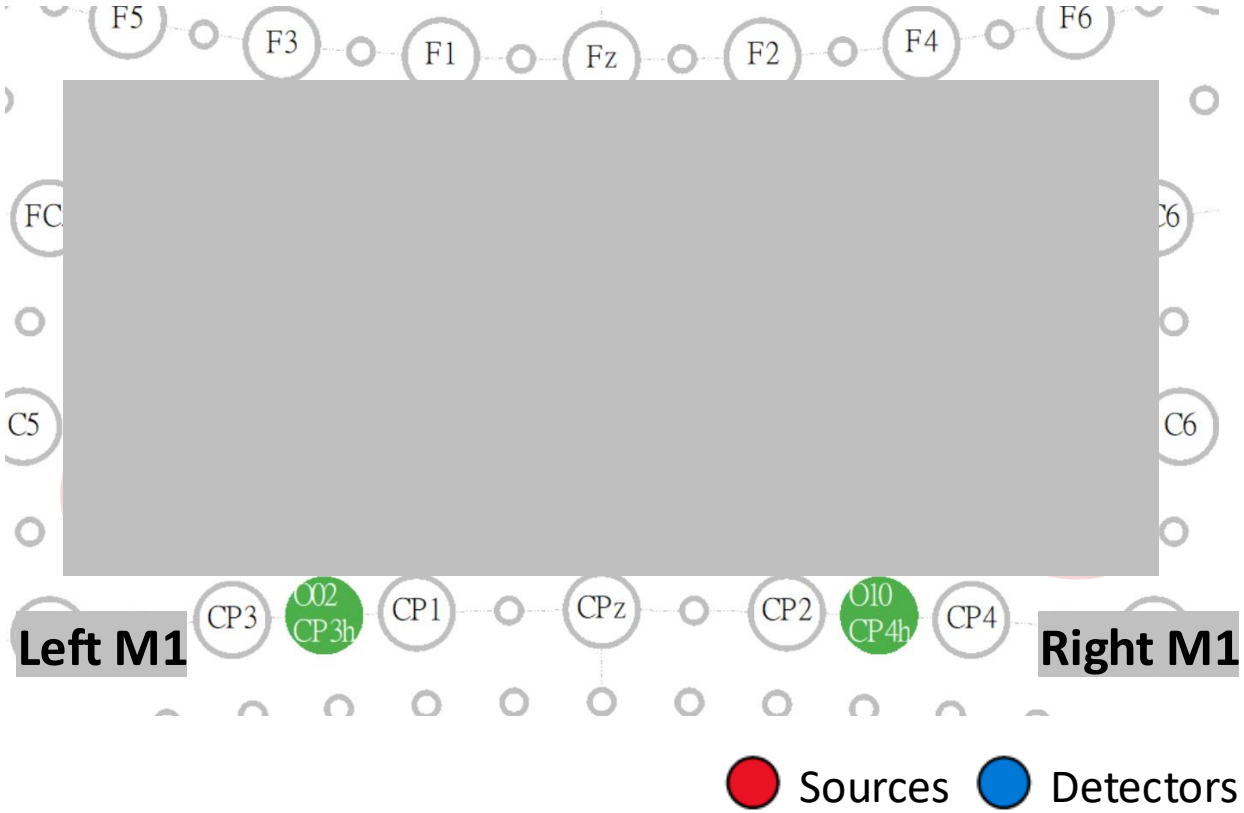
Table 1.

Variable	Category	Stroke (n = 14)	Healthy (n = 10)	Total (N = 24)
Sex	Male	9 (64.3%)	4 (40.0%)	13 (54.2%)
	Female	5 (35.7%)	6 (60.0%)	11 (45.8%)
Age (years)	—	59.1 ± 9.9	31.0 ± 11.9	47.9 ± 17.4
Education level	High school or below (≤3)	1 (7.1%)	1 (10.0%)	2 (8.3%)
	College/University (4–5)	11 (78.6%)	7 (70.0%)	18 (75.0%)
	Graduate school (6)	2 (14.3%)	2 (20.0%)	4 (16.7%)
Stroke Type	Ischemic	9 (64.3%)	—	9 (37.5%)
	Hemorrhagic	5 (35.7%)	—	5 (20.8%)
Affected Hemisphere	Left	9 (64.3%)	—	9 (37.5%)
	Right	5 (35.7%)	—	5 (20.8%)

Montage

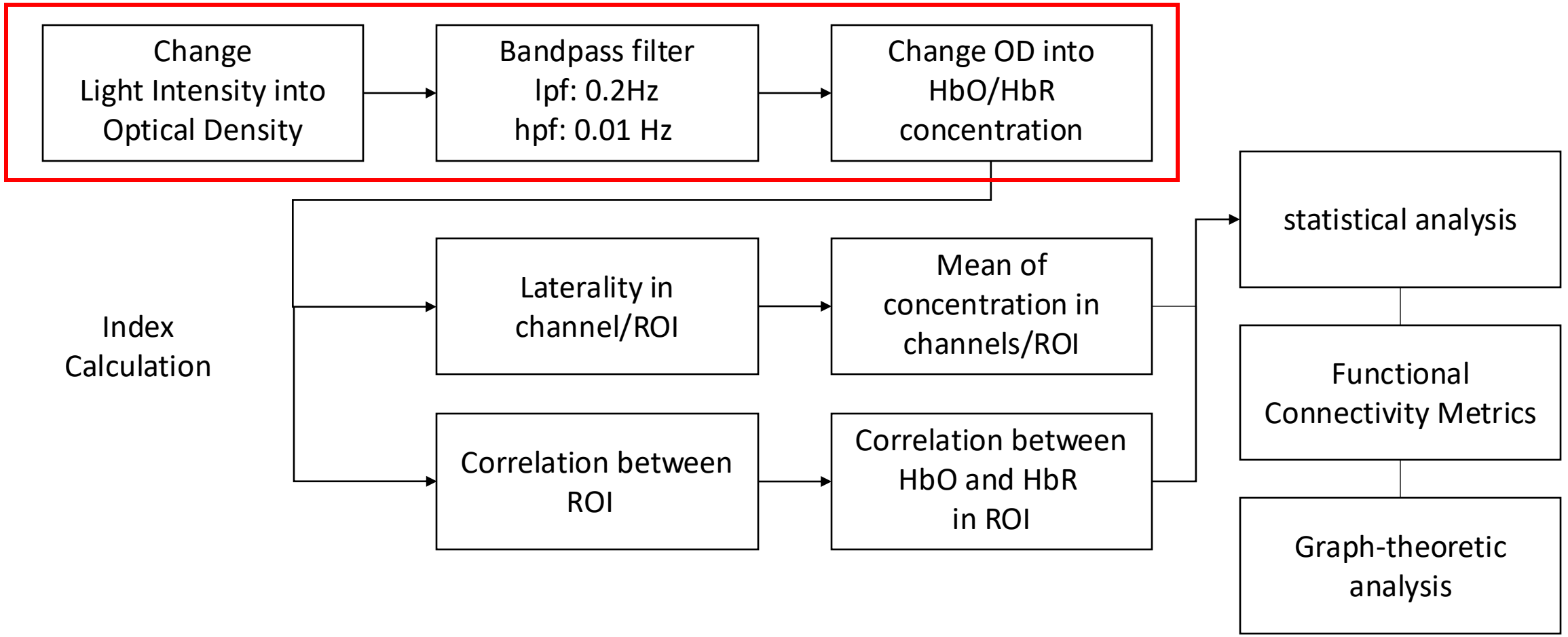
- Based on 10–10 EEG layout
- 8 sources & 8 detectors → **22 channels**





Methods

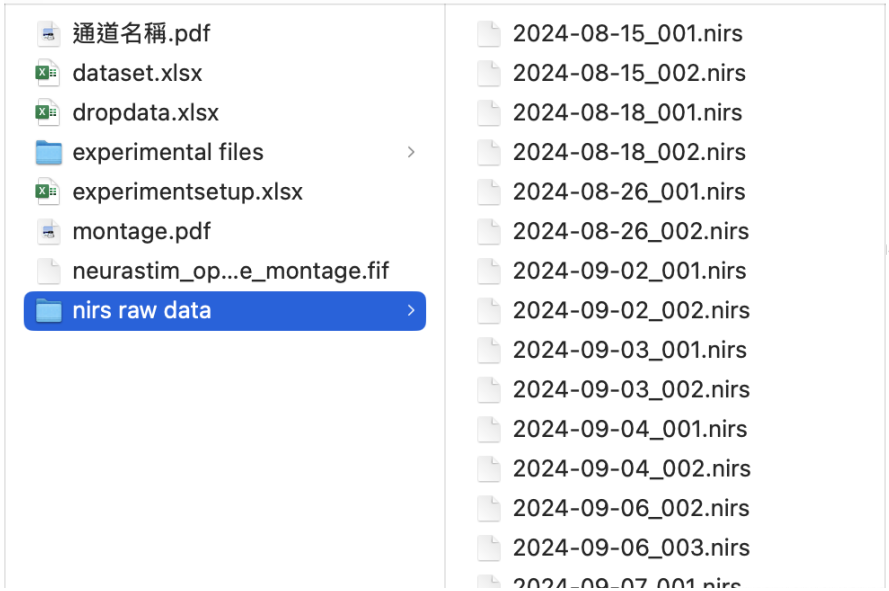
Preprocessing



Raw data ⟶ BIDS-Structure

```
.
├── dataset.xlsx
├── dropdata.xlsx
├── experimental files
│   ├── SH-001
│   ├── SH-002
│   ├── SH-003
│   ├── SH-004
│   ├── SH-005
│   ├── SH-006
│   ├── SH-007
│   ├── SH-008
│   ├── SP-001
│   ├── SP-002
│   ├── SP-003
│   ├── SP-004
│   ├── SP-005
```

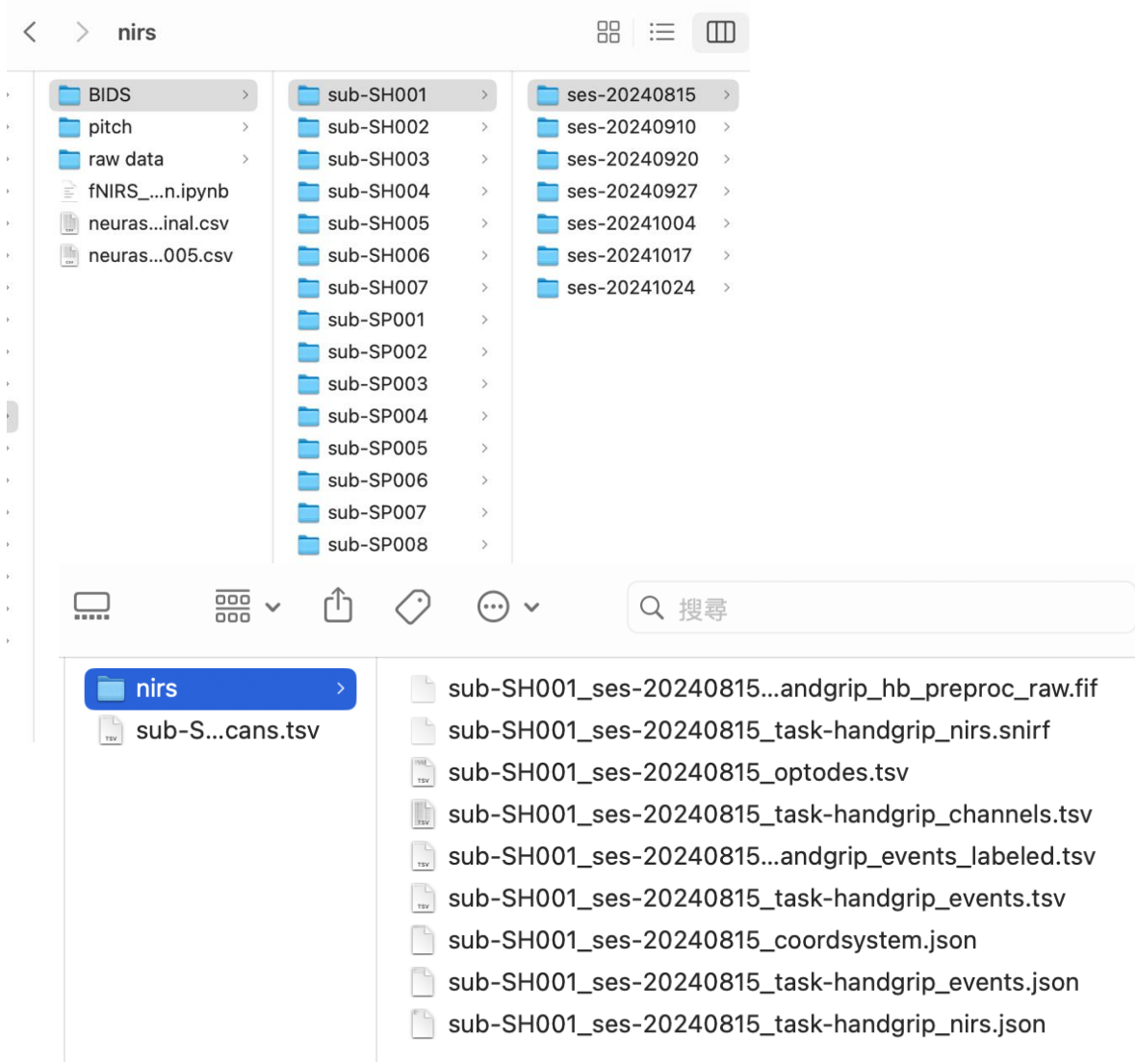
```
/Users/yvonne/Desktop/Neurastim_data/experimen
├── NSP2
│   ├── 2024-08-15_SH-001-1_post
│   │   ├── 2024-08-15_002.nirs
│   │   ├── 2024-08-15_002.snirf
│   │   ├── 2024-08-15_002.wl1
│   │   ├── 2024-08-15_002.wl2
│   │   ├── 2024-08-15_002.zip
│   │   ├── 2024-08-15_002_calibration.json
│   │   ├── 2024-08-15_002_config.hdr
│   │   ├── 2024-08-15_002_config.json
│   │   ├── 2024-08-15_002_description.json
│   │   ├── 2024-08-15_002_lsl.tri
│   │   ├── 2024-08-15_002_probeInfo.mat
│   │   └── digpts.txt
│   ├── 2024-08-15_SH-001-1_pre
│   │   ├── 2024-08-15_001.nirs
```



.json

.json

at



Channels

Type of wavelength

Signal Quality

name	type	source	detector	wavelength_nominal	unit		status	status_description	
S1_D1	760	NIRSCWAMPLITUDE	S1	D1	760.0	V	0.0	10.172939979654121	good	n/a
S1_D2	760	NIRSCWAMPLITUDE	S1	D2	760.0	V	0.0	10.172939979654121	good	n/a
S8_D8	850	NIRSCWAMPLITUDE	S8	D8	850.0	V	0.0	10.172939979654121	good	n/a

Optodes Position

name	type	x	y	z	
S1	source	-0.073145287237532	0.0042141877021233	0.044368788208521	
S2	source	-			
S3	source	-			
S4	source	-			
S5	source	0			
S6	source	0			
S7	source	0			
S8	source	0			
D1	detector				2
D2	detector				5
D3	detector				9
D4	detector				1
D5	detector				1
D6	detector				2
D7	detector				6
D8	detector				7

Data Preprocessing

1. Convert to Optical Density

- Long-transform light intensity to prepare for concentration estimation

 # optical_density (raw)

2. Band-Pass Filtering

- Removes low-frequency drifts and high-frequency noise (e.g., heartbeat, muscle)
- Frequency range: **0.01–0.2 Hz**
- Method: Butterworth filter (IIR, 4th order)

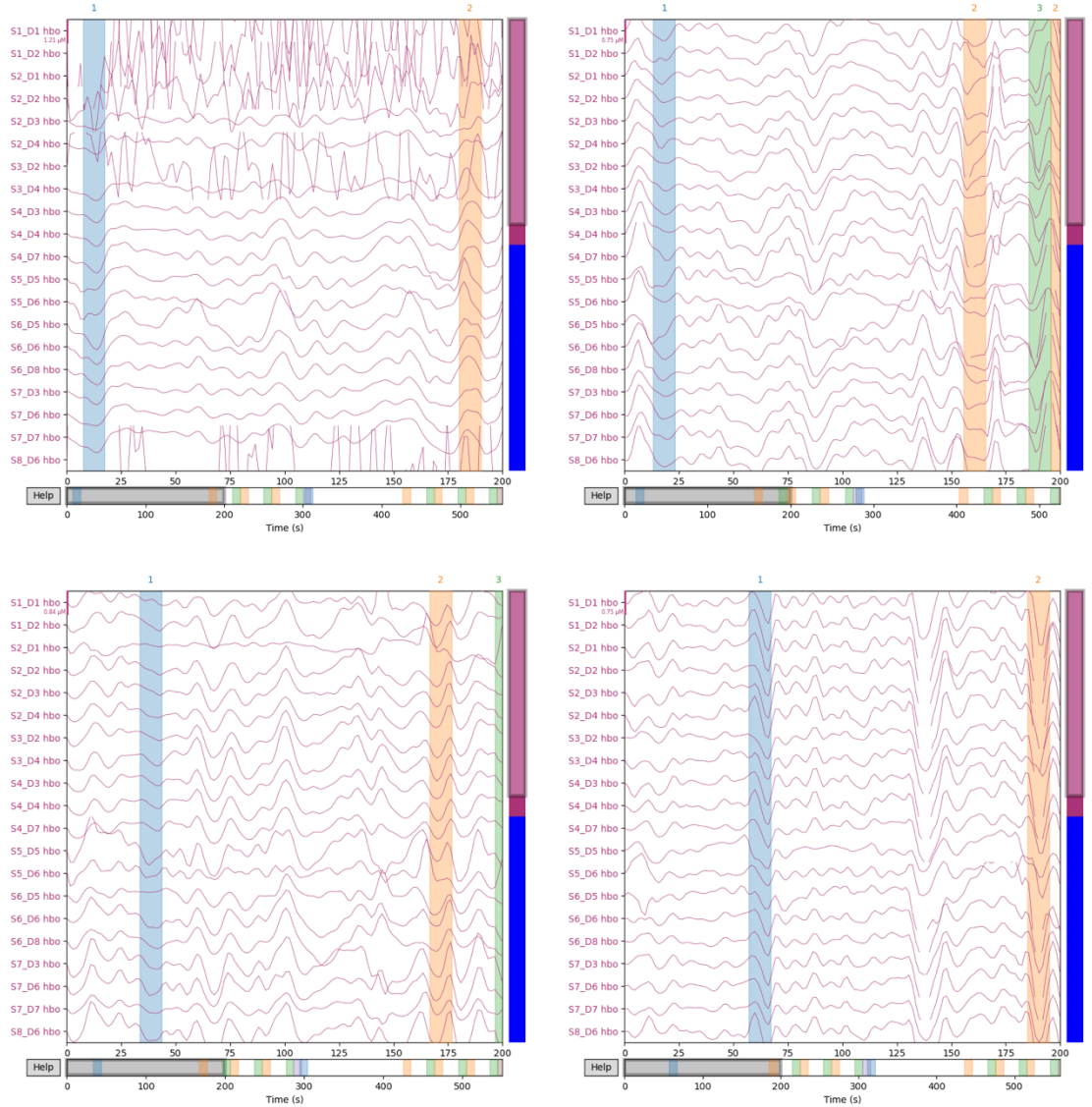
 # filter(0.01, 0.2, method="iir", iir_params==dict(order=4, ftype="butter"), verbose=False)

3.Compute Δ[HbO] and Δ[HbR]

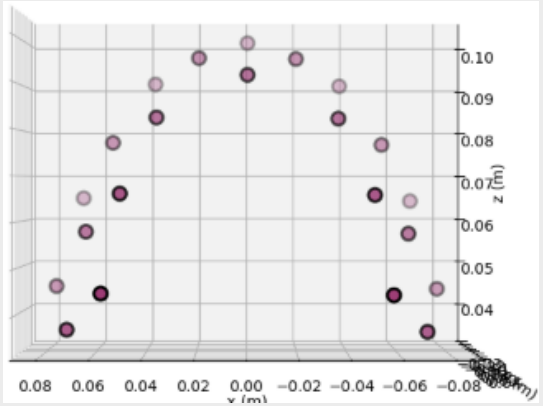
 # beer_lambert_law(od)

Data Preprocessing_Visualization

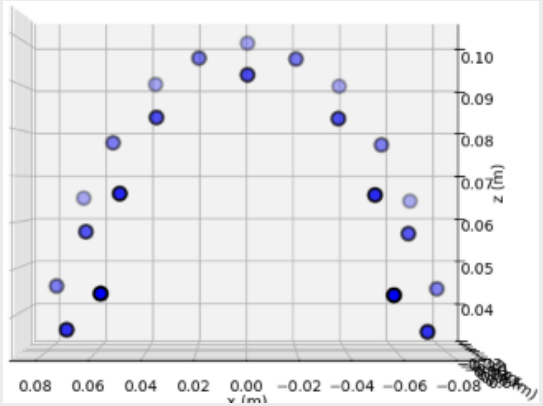
- Displays time-series changes in oxygenated hemoglobin (HbO) across channels
- Useful for quality control and detecting motion artifacts or bad channels



Confirms correct spatial arrangement of optodes



HbO optode positions



HbR optode positions

ERP analyzes

1. Add Event Labels

```
event_labels = [
    "rest1", "onset1", "task1",
    "onset2", "task2", "onset3", "task3",
    "ch_hand", "rest2",
    "onset4", "task4", "onset5", "task5", "onset6", "task6"
```

2. Data by Condition

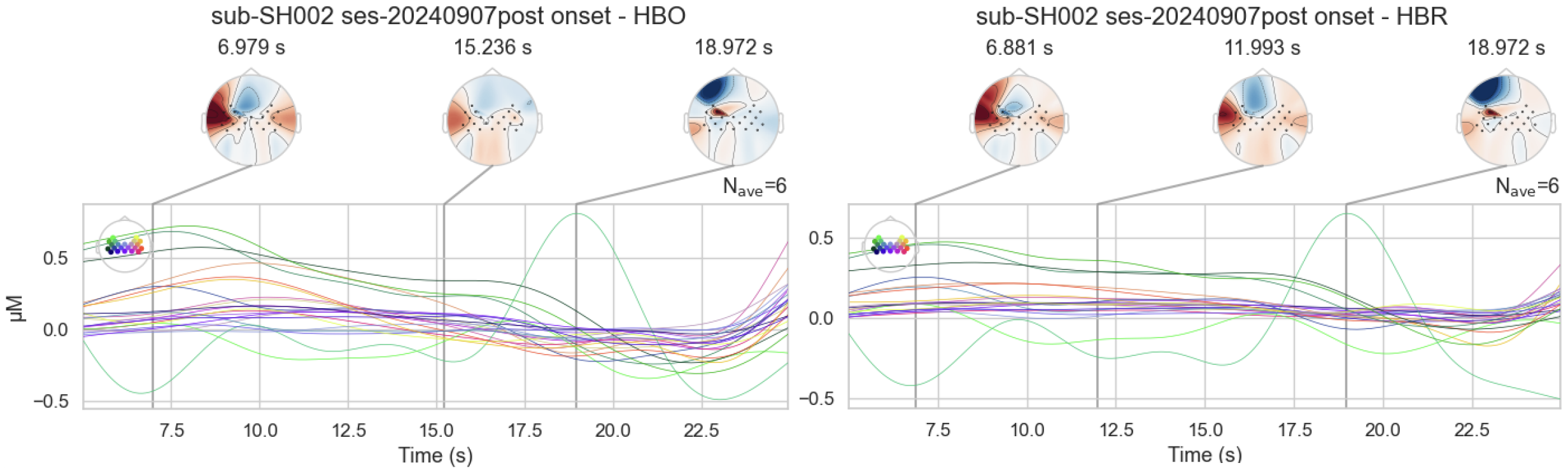
- Define time windows: **Task**: 0–10s; **Onset**: 5–25s; **Rest**: 0–30s
- Epochs created for both HbO and HbR
- Ratio computed as HbO / HbR

3. ERP Analysis

- Average across epochs (Evoked)
- Extract ERP Features (Mean, Peak, AUC…)

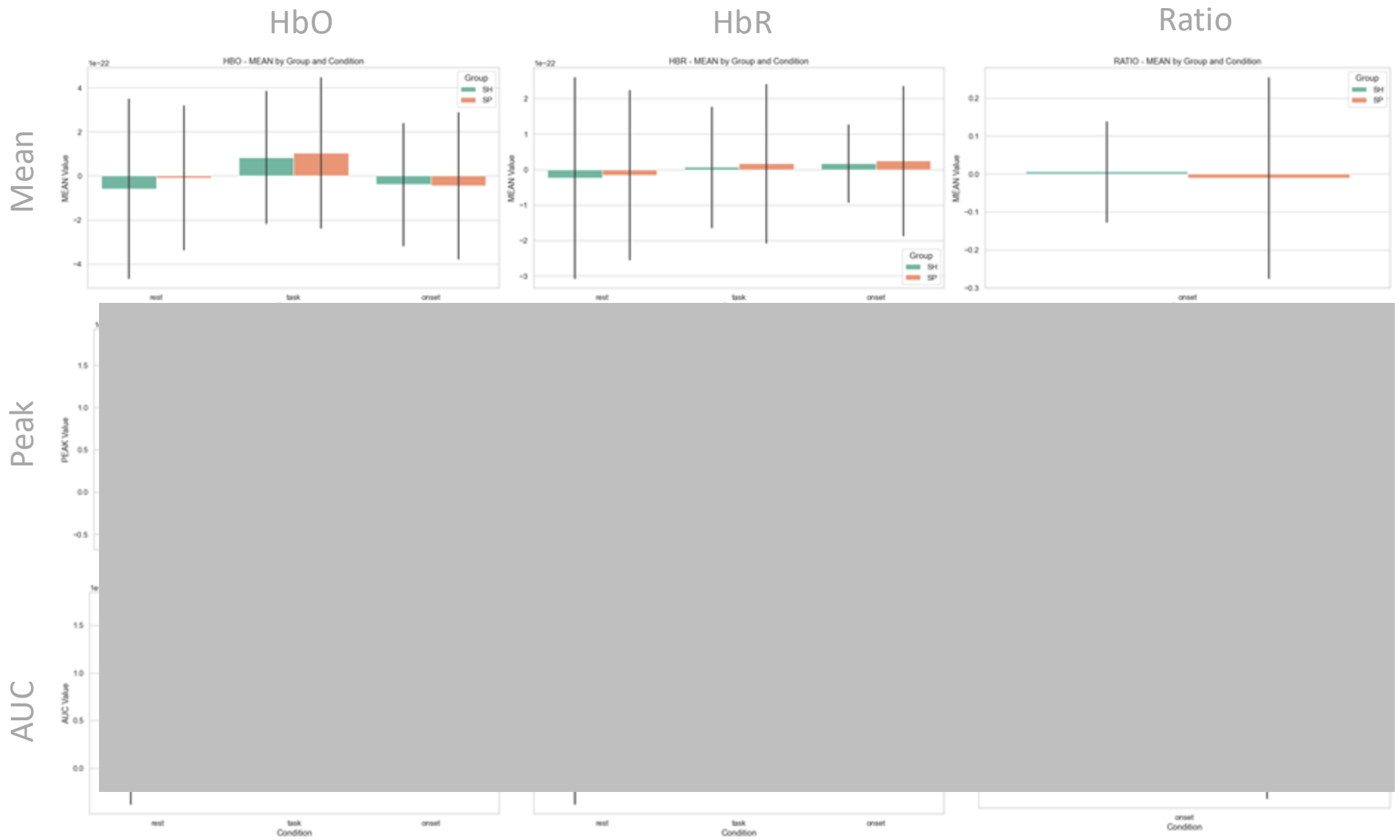
ERP analyzes_ Visualization

- Displays brain spatial distribution at specific time points
- Red = ↑ activation, Blue = ↓ decrease
- Applicable to HbO, HbR, or HbO/HbR ratio data



 # joint plot

ERP features_ Visualization



Functional Connectivity

1. Compute Correlation-Based FC

- Concatenate all epochs across time to form a (n_channels × total_time) array.
- Use Pearson correlation (np.corrcoef) to compute channel-wise connectivity.

2. Classify Connection Type

- Classify each channel pair into one of four regions

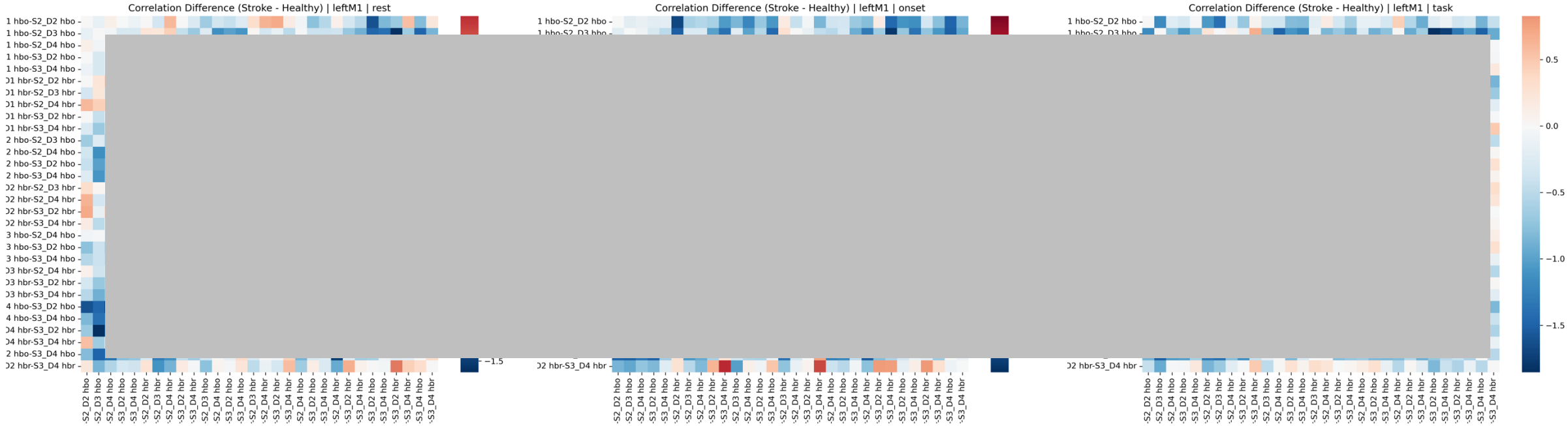
  LeftM1; RightM1; Interhemispheric (leftM1-right M1); Other (non-M1)

3. Statistical and Network-Level Analyses

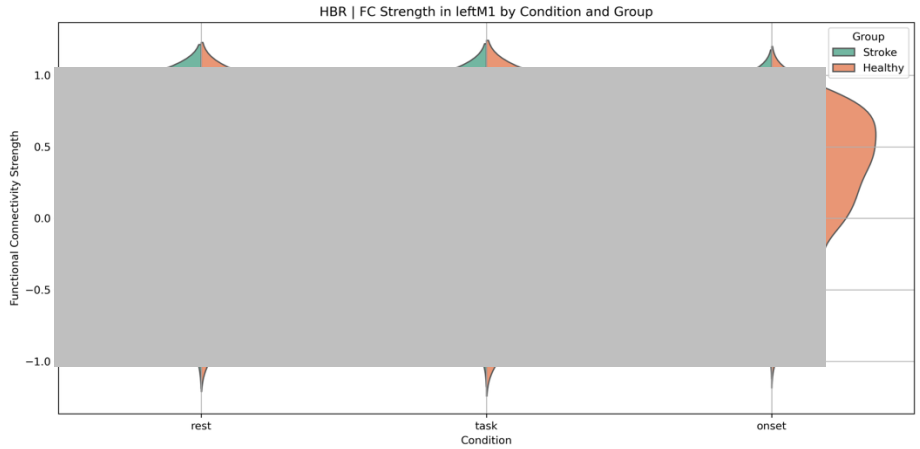
- Healthy Subjects(SH) vs Stroke patients(SP)
- Statistical analysis, graph-theoretic analysis, functional connectivity metrices…etc

Result 1

Left M1

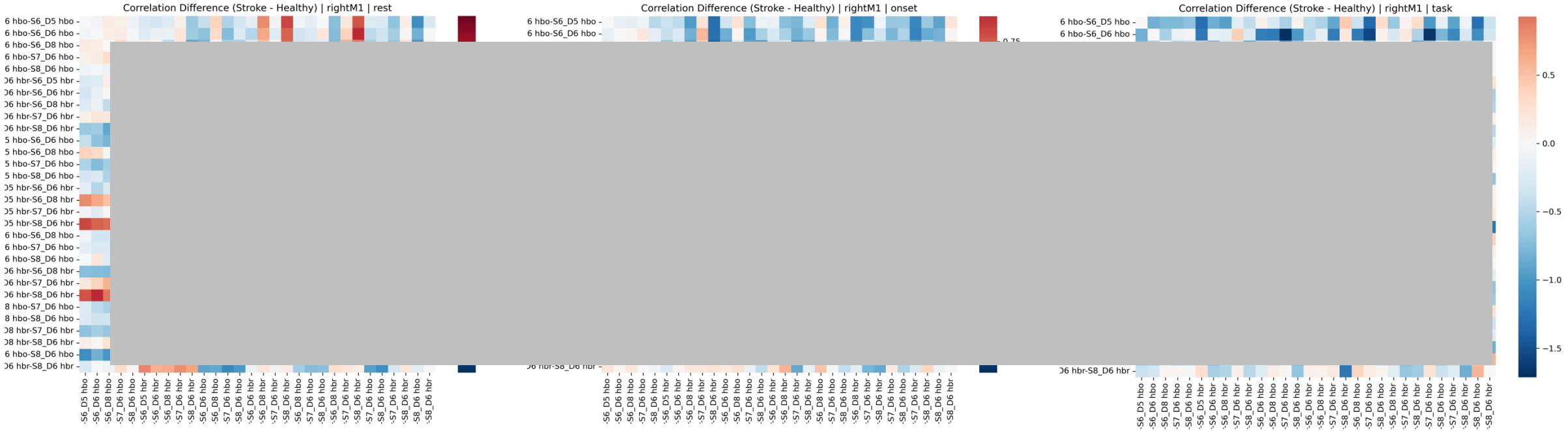


signal_type	region_pair	condition	t_statistic	p_value	cohen_d	p_adj	effect_size_label
hbo	leftM1	rest	-6.774	1.50e-11	-0.245	0.00000	small
							negligible
							small
							negligible
							negligible
							small

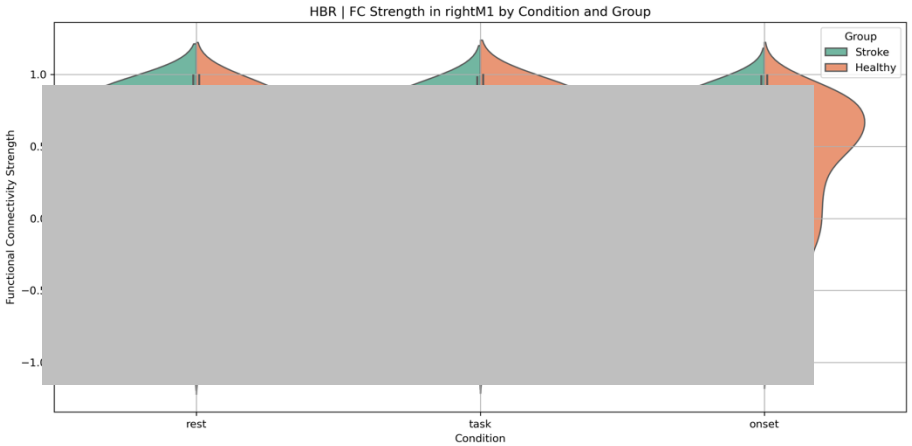


Result 2

Right M1

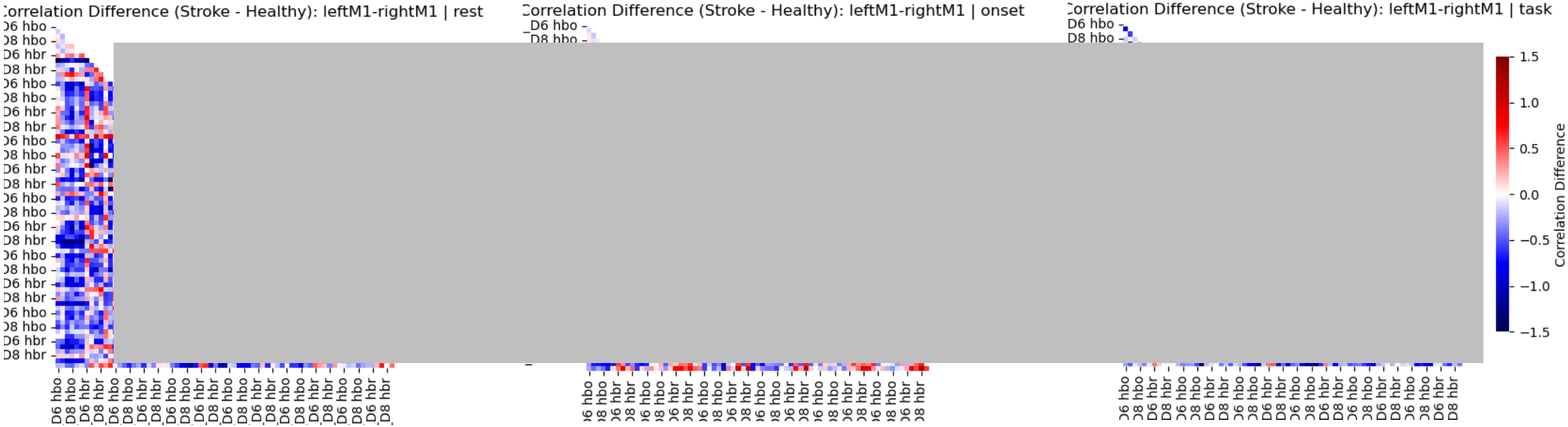


signal_type	region_pair	condition	t_statistic	p_value	cohen_d	p_adj	effect_size_label
hbo	rightM1	rest	-9.089	1.80e-19	-0.326	0.00000	small
							negligible
							small
							negligible
							negligible
							negligible

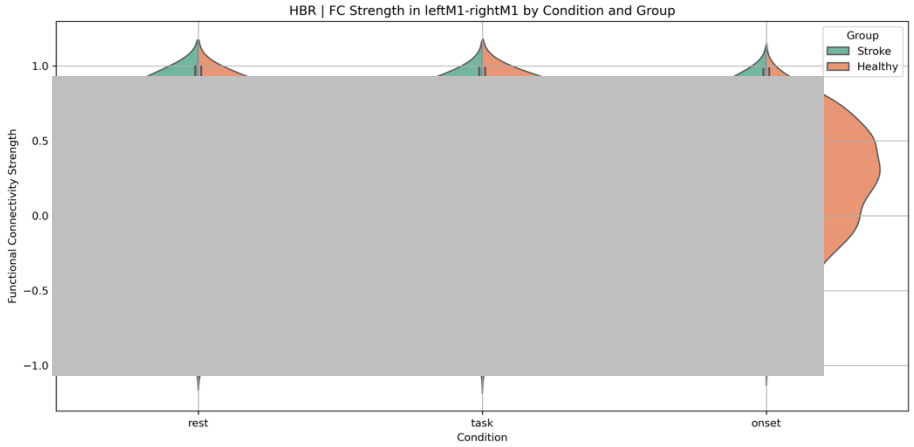


Result 3

Left M1 - RightM1



signal_type	region_pair	condition	t_statistic	p_value	cohen_d	p_adj	effect_size_label
hbo	leftM1-rightM1	rest	-13.012	2.83e-38	-0.303	0.0000	small
							negligible
							small
							negligible
							negligible
hbr	leftM1-rightM1	onset	-11.139	1.40e-28	-0.265	0.0000	small



Discussion

1. Interhemispheric inhibition theory

- Stroke patients showed reduced functional connectivity:

  Within left and right M1

  Between left and right M1 (interhemispheric)

- Effects most evident during rest and movement

2. fNIRS-based connectivity

Limitations

1. Preprocessing took more time than expected (e.g., filtering, epoch labeling, ….)

   ⟶ Did not complete the third part: **machine learning**

2. Use **more precise time windows** for epoching

3. Consider **stroke duration** and **lesion severity** as covariates

4. Increase **sample size** for better statistical power and subgroup analysis

Thanks for Listening

Any Questions

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