BHS Project Pitch

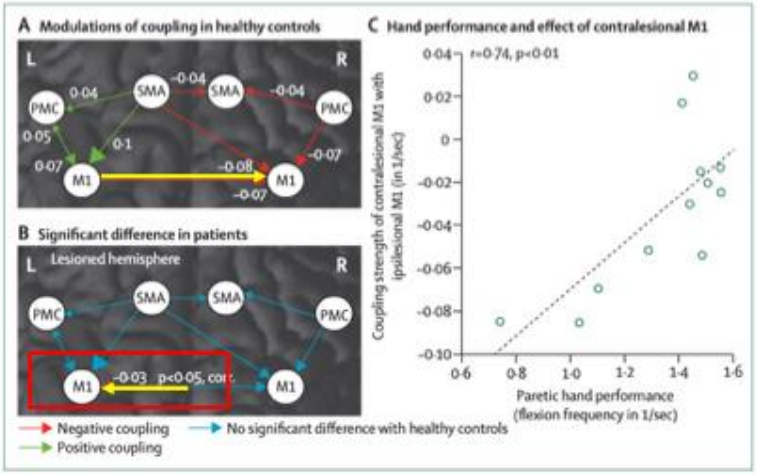
Decoding Stroke-related Brain Network Disruption from fNIRS: A Functional Connectivity and Graph Theory Approach

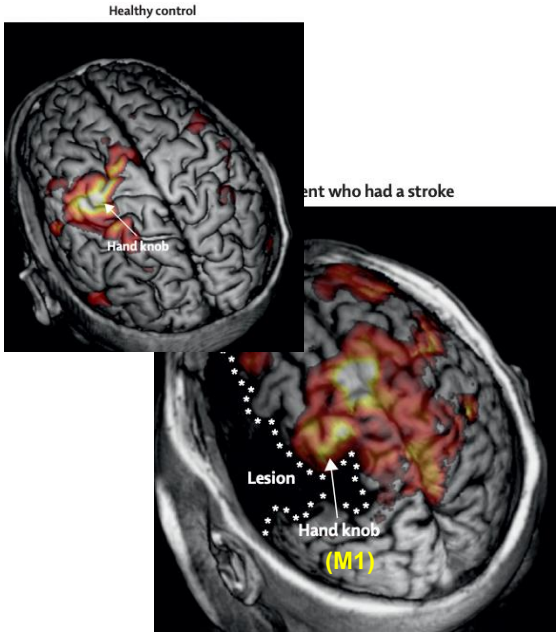
Presented by Pai-Yi Hsu
National Taiwan University

Background

Stroke & Brain Connectivity

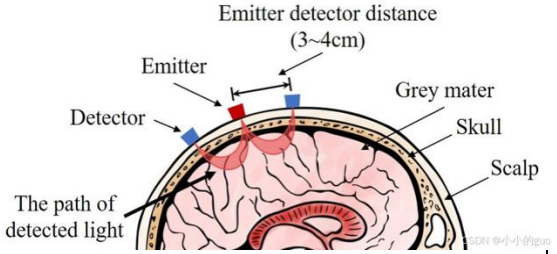
- Interhemispheric Inhibition (IHI)
- Primary motor cortex (M1) or Premotor cortex (PMC)





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

Background



fNIRS for Monitoring Motor Network Dynamics

- Portable, non-invasive, and suitable for clinical populations
- Captures task-evoked hemodynamic responses from motor-related cortical areas

	⭐ fNIRS	EEG	fMRI
Signal Type	Optical (HbO / HbR)	Electrical (postsynaptic potentials)	BOLD signal
Temporal Resolution	Moderate (~100 ms)	Excellent (~1 ms)	❌ Poor (~1–2 s)
Spatial Resolution	Moderate (~1–3 cm)	❌ Low (~cm, dep. on density)	✅ High (millimeter scale)
Portability	✅ High	✅ High	❌ Not portable
Suitability for Patients	✅ Ideal for stroke, pediatric...	✅ Suitable for most populations	❌ Less suitable for certain groups
Typical Applications	Motor, language, cognition, rehabilitation monitoring	Cognitive tasks, epilepsy, BCI, attention	Brain mapping, resting-state networks, diagnostic imaging

Can be used bedside or in real-time rehabilitation settings

How Abnormal Is the Brain Network?

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.

Clinical Relevance

- Identifies mild vs. severe disruption
- Works even without behavioral output (e.g., severely impaired patients)
- Can support personalized neurostimulation strategies in the future

This project builds on concepts from functional brain network analysis, translating them into the fNIRS domain to explore its potential for clinical neuro-assessment.

Research Questions & Objectives

RQ

- Can we distinguish stroke from healthy individuals using fNIRS-derived functional connectivity features?
- Can we quantify each subject's deviation from healthy brain network patterns using the Network Deviation Score (NDS)?
- Do patients with greater deviation show more impaired motor-related cortical function?

Objectives

- Apply EEG/fMRI-inspired network analysis to fNIRS data
- Develop a classification model to differentiate stroke vs. healthy brains

Construct a subject-level NDS to represent individualized network disruption

Explore the relationship between NDS and clinical markers (e.g., stroke duration, severity..etc)

This project builds on concepts from functional brain network analysis, translating them into the fNIRS domain to explore its potential for clinical neuro-assessment.

Dataset

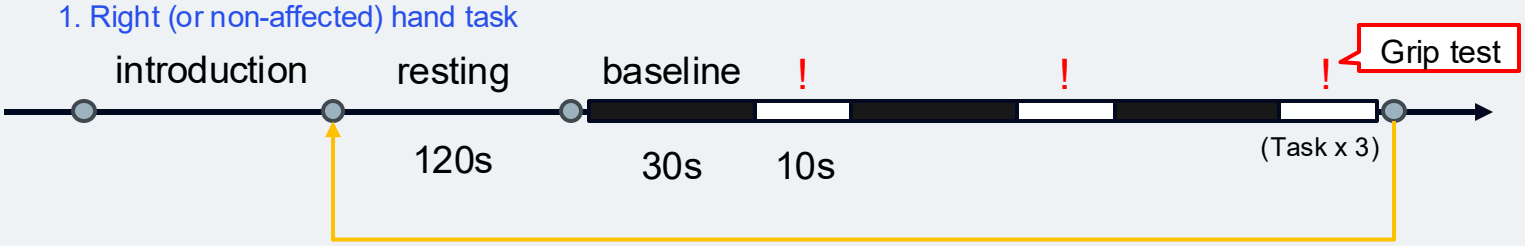
SP/SH database (from my lab)

- 10 stroke patients / 7 healthy subjects
- fNIRS data format: SNIRF (organized with NIRS-BIDS)

	Healthy Subjects	Stroke Patients
Number of participants	7	10
Sessions per participant	7	6
Recordings per session	2 (pre- and post-stimulation)	
Total fNIRS recordings	$7 \times 7 \times 2 = \mathbf{98}$	$10 \times 6 \times 2 = \mathbf{120}$

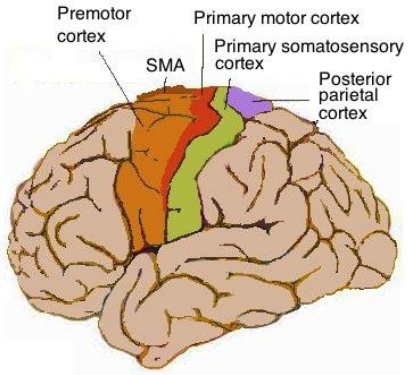
Experimental Design

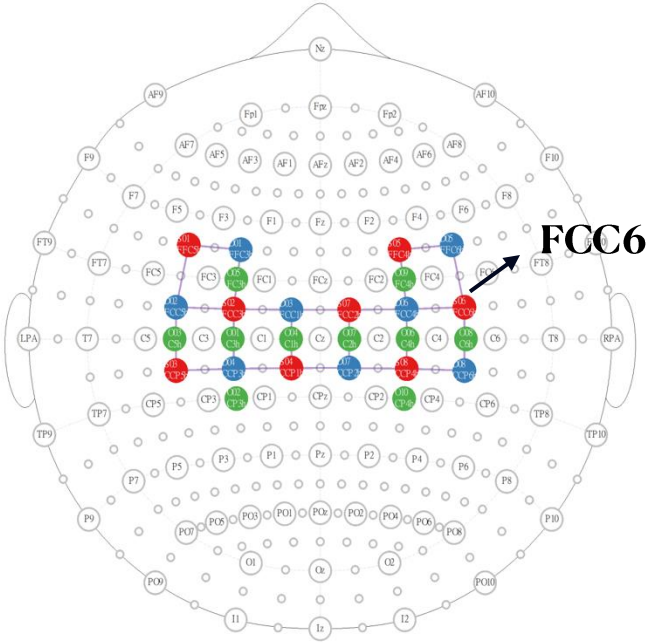
fNIRS functional task HD-tES fNIRS functional task



Montage Configuration

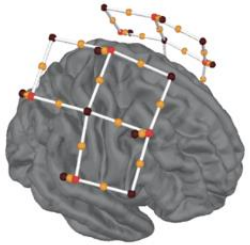
- Based on 10–10 EEG layout
- 8 sources (🔴 red), 8 detectors (🔵 blue) → **22 channels**
- tES electrodes (🟢 green)





Methods

Step 1	Step 2	Step 3
Preprocessing	**Feature Extraction**	**Modeling**
• Convert raw.snirf data to HbO/HbR • Apply filtering, motion correction, epoching	• Compute functional connectivity (FC) matrices • Extract graph theory metrics and HbO features	• Train classifiers to distinguish stroke vs. healthy • Compute Network Deviation Score (NDS) using healthy baseline



Step 1 : Preprocessing

MNE-NIRS (Python)

Processes

- Convert raw intensity to HbO/HbR
- Bandpass filtering & motion artifact correction
- Epoching based on task events (grip onset)
- Baseline correction (e.g., -5 to 0 s pre-task)

Luke, R., Oostenveld, R., Cockx, H., Niso, G., Shader, M. J., Orihuela-Espina, F., Innes-Brown, H., Tucker, S., Boas, D., Yücel, M. A., Gau, R., Salo, T., Appelhoff, S., Markiewicz, C. J., McAlpine, D., BIDS Maintainers, & Pollonini, L. (2025). NIRS-BIDS: Brain Imaging Data Structure Extended to Near-Infrared Spectroscopy. *Scientific data*, *12*(1), 159.

Step 2 : Feature Extraction

Functional connectivity (FC)

- Pearson correlation between channels (HbO)
- Separate FC matrices for each session (pre/post)

Graph theory metrics

- Global efficiency, modularity, interhemispheric connectivity, node degree

Channel-wise statistics

- Mean/slope of HbO for each task epoch

Step 3 : Modeling & Classification

Stroke vs. Healthy classification

- Input: FC features or graph metrics
- Model: SVM, Random Forest, XGBoost
- Validation: Stratified K-fold, LOSO

Network Deviation Score (NDS)

- Train model using Healthy group (pre vs. post)
- Test Stroke group → compute NDS = 1 − confidence
- Visualize NDS distribution across subjects

Expected Results

- Identify disrupted functional connectivity patterns in stroke patients using fNIRS
- Quantify individual brain network abnormality via Network Deviation Score (NDS)
- Detect group-level differences in graph metrics (e.g., efficiency, modularity)

Provide a foundation for personalized neuromodulation planning based on brain network profiles

Thanks For Listening

Q & A