Plan Overview

A Data Management Plan created using DMPonline

Title: Causal Discovery of Non-Stationary Causal Graphical Models: Applications in Brain Effective Connectivity

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Template: UoB short template

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Project abstract:

Functional Near-Infrared Spectroscopy (fNIRS) provides a non-invasive, portable, and affordable method for monitoring brain activity by measuring cortical hemodynamic changes. While fNIRS is increasingly used in neurorehabilitation, traditional analytical methods often assume stationary causal relationships, failing to account for the dynamic nature of neural interactions during learning and recovery. Because brain connectivity is inherently non-stationary, meaning interactions between variables evolve over time, accurately modeling these shifts is critical for understanding the progression of effective connectivity.

This research will develop a framework for the Causal Discovery of Non-Stationary Causal Graphical Models to represent the evolution of brain connectivity. The study follows a longitudinal design where participants engage with Gesture Therapy (GT), a videogame-based rehabilitation platform designed to stimulate motor function, while their neural activity is recorded using an ****fNIRS system. Data will be collected from healthy participants aged 18 to 70 across multiple sessions to capture the dynamics of the learning process.

The objective is to apply these causal discovery techniques to identify patterns of effective connectivity that change as participants familiarize themselves with the motor tasks. By integrating behavioral data from pressure sensors with neurofisiological signals, this project aims to provide a robust framework for analyzing dynamic brain networks. This approach will ultimately facilitate the development of more adaptive and personalized neurorehabilitation interventions.

ID: 195711

Start date: 23-02-2026

End date: 24-08-2026

Last modified: 23-01-2026

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Causal Discovery of Non-Stationary Causal Graphical Models: Applications in Brain Effective Connectivity

Data description

What types of data will be used or created?

The research will generate and utilize several types of multi-modal data:

- Demographics: Textual and numeric data (age, gender, and health status) collected via surveys to define inclusion criteria and match corresponding brain atlases.
- Neuroimaging Signals: Primary cortical hemodynamic data (oxygenated and de-oxygenated hemoglobin) captured as numeric time-series using a NIRx fNIRS system.
- Behavioral and Kinematic Data: Numeric data from pressure sensors and movement metrics recorded through the Gesture Therapy (GT) platform to track motor learning.
- Derived Data: Processed neurofisiological signals, statistical dataframes, and causal graphical models (graphs) representing dynamic brain connectivity.
- Documentation: Textual files including signed consent forms and experimental metadata.

Data Formats and Rationale:
The project prioritizes open and standard formats to facilitate long-term re-use and interoperability:

- .snirf: Chosen as the primary open standard for neuroimaging data; it ensures that experimental metadata is embedded and shared according to community standards.
- .csv / .json / .txt: Utilized for behavioral metrics, derived statistics, and metadata to ensure files are non-proprietary and easily readable by various analysis platforms.
- pdf: Standard format for participant documentation and consent records.
- .jpg / .png: Used for photographic records of optode registration to verify spatial placement.

Collection, Re-use, and Protection:

Methods: Data will be collected through a longitudinal experimental design consisting of three sessions per participant. No existing research datasets will be re-used, though standardized anatomical brain atlases will be utilized for spatial registration.

Protection Measures: All data will be pseudonymized at the source using unique alphanumeric codes to ensure participant identity remains confidential. The master list linking names to codes will be stored separately from experimental data in an encrypted file with strictly limited access.

How will the data be structured and documented?

The data will be organized in a hierarchical folder structure adhering to the fNIRS-BIDS (Brain Imaging Data Structure) standard to ensure consistency and interoperability across the research team. Following best practices for clarity, the folder hierarchy will be kept to a maximum depth of three to four levels, with separate top-level directories for data and documentation.

File Naming and Organization:

- Files will be named using the BIDS (Brain Imaging Data Structure) naming convention.
- To maintain cross-platform compatibility, file names will exclude spaces or special characters, using underscores or hyphens as separators.

Documentation and Metadata:

- Neuroimaging signals will be stored in the .snirf format, which includes embedded technical metadata.
- Experimental metadata will be documented according to the fNIRS-BIDS standard using sidecar JSON files.
- A project-specific data dictionary will be maintained to define all variables, including behavioral metrics from Gesture Therapy (GT) pressure sensors and parameters for the CausalMorph algorithms.
- Each major directory will include a README.md file in plain text format to describe folder contents and data collection protocols.

Versioning and Quality Control:

- A formal version control strategy will distinguish between major "milestone" versions (e.g.,v1-0, v2-0) and minor iterative

revisions (e.g.,v1-1).
- A version history table will be maintained for all primary datasets and code, tracking the date, author, and summary of changes.
- Once a dataset is finalized for publication, a master copy will be set to read-only within the secure institutional repository to prevent accidental modification or deletion.

Data storage and archiving

How will your data be stored and backed up?

The University of Birmingham provides a Research Data Store (RDS); access to the RDS is restricted to project members. Backup copies of data are taken on a daily basis and data is stored in separate buildings from the live data. The RDS has a backup and retention policy on how it looks after the data including archiving of primary data here: Backup and Retention Policy

Is any of the data of (ethically or commercially) sensitive nature? If so, how do you ensure the data are protected accordingly?

To ensure anonymity, all personal identifiers will be removed from the dataset before sharing.

Where will your data be archived in the long term?

Data will be shared through the University of Birmingham's eData repository (https://edata.bham.ac.uk/) which makes the datasets discoverable through search engines like Google. Publications will include a data access statement, linking to the dataset deposited in the University of Birmingham's data repository, where the data can be accessed by anyone, and access conditions will be provided if the data cannot be shared openly.

Data sharing

Which data will you share, and under which conditions? How will you make the data available to others?

Data will be shared through the University of Birmingham's eData repository (https://edata.bham.ac.uk/) which makes the datasets discoverable through search engines like Google. However, the data is planned to be shared with collaborators from Instituto Nacional de Astrofísica, Óptica y Electrónica, Mexico.

In order to be able to shared and move the data across both countries we will cover the requirements from GDPR law.