Resting State Analysis and the Open MEG Archive (OMEGA)

Technical and Ethical aspects

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OMEGA: The Open MEG Archive

- There is presently a scarcity of fully open resources in magnetoencephalography (MEG).
- A collaborative effort led by the McConnell Brain Imaging Centre of the Montreal Neurological Institute and the Université de Montréal.

The Open MEG Archive (OMEGA, mcgill.ca/bic/resources/omega) is a continuously expanding repository of multimodal data with a primary focus on MEG, in addition to storing anatomical MRI volumes, demographic participant data and questionnaires, and eventually other forms of electrophysiological data such as EEG.
OMEGA: The Open MEG Archive

- A “Bank” of brain imaging data
  - Magnetoencephalography (MEG)
  - Structural Magnetic Resonance Imaging (MRI)
  - Behavioral tests scores
- from healthy and patient volunteers

- Establish standard levels of brain activity in the population of healthy participants, in relation to standard factors (age, gender, standardized behavioral tests scores, etc.)
- Reveal new markers of abnormal brain activity in patients from the same population subgroup affected by neurological and mental health conditions.
OMEGA: The Open MEG Archive

First open data repository fully dedicated to MEG ... and the world largest!

Contains data in raw and processed forms, including source image volumes

Current focus on resting-state, but task data can also be contributed

OMEGA will continue to expand, with contributions from the scientific community
OMEGA: The Open MEG Archive

OMEGA offers both the technological framework for multi-site MEG data aggregation built on the LORIS data platform (Das et al. 2012), and serves as one of the largest freely available resting-state and eventually task-related MEG datasets presently available.
OMEGA: The Open MEG Archive

- OMEGA repository currently houses:
  - Resting-state MEG
  - T1-weighted anatomical MRI data (primarily for optimal source imaging)
  - 97 participants at one or more timepoints (total of 140 sessions)
  - Total volume of ~400GB
  - Over 230 user requests since May 2015

(Niso et al. 2015)
General Screening Questionnaire

- Demographics
- Language
- General Health
- Alcohol and Smoking
- MOS Sleep Scale
- Edinburgh Handedness Inventory – Short Form
- PDQ-5 (memory, attention, and concentration)
- PHQ-4
- PSS-4
- Karolinska Sleepiness Scale
- Music Screening

Current status → Retrospective Questionnaire
General demographic info participants in OMEGA

A. Gender

B. Handedness

C. Health Status

D. Institution

E. Age

F. Education
Cultural and lifestyle participants in OMEGA

A Multicultural

B Multilingual

C Musical Experience

D Musician

E Dominant language

F Physical activity

G Stress

H Drink alcohol

I Smoke
MEG formats

- There’s NO **dicom** format in MEG
- Each system has its own proprietary format

WE NEED A STANDARD
MEG file repository standardization

An MEG extension to BIDS: Brain Imaging Data Structure - a solution to organize, describe and share neuroimaging data

Niso et al., Biomag2016
BIDS: Brain Imaging Data Structure

A simple and intuitive way to organize and describe your neuroimaging and behavioral data.

http://bids.neuroimaging.io/
BIDS: Brain Imaging Data Structure

- A solution to organize, describe and share neuroimaging data

- The lack of consensus surrounding neuroimaging data formats and their organisation leads to resources being wasted on rearranging data, reproducing datasets and reimplementation of processing pipelines.

- For all these reasons, the adoption of a common standard to describe the organization of multimodal neuroimaging data would be extremely beneficial to the research community (minimizing curation, reducing errors and optimizing usage of data analysis software), especially in a context that promotes and experiments with data-sharing at growing scales.
An MEG extension to BIDS

- The **Brain Imaging Data Structure (BIDS)** standard was first established for MRI and fMRI in 2015 (Gorgolewski at al. 2016). BIDS is based on simple file formats (often text-based) and folder structures that can readily expand to additional data modalities.

- Our consortium is currently working on an **extension of the BIDS for magnetoencephalography** (MEG) datasets.

- One objective is to frame the specifications of MEG-BIDS so that **analysis pipelines** designed with major analysis tools (such as Brainstorm, FieldTrip, MNE, SPM and others) can be readily applied without requiring software or pipeline redevelopments.

- Wide support across neuroimaging tools and database engines, as well as its straightforward design make BIDS particularly suited to act as an **interoperable common exchange format** for moving data across databases (e.g. OMEGA, OpenfMRI), and for facilitating data sharing.
An MEG extension to BIDS

Unprocessed MEG data
stored in the native file format of the manufacturer

The native file format is used as there is currently no widely accepted standard file format in the community, and conversion risks the loss of crucial metadata specific to manufacturers and specific MEG systems.

JSON file
with additional meta-information

Additional meta information extracted from the manufacturer specific data files in a sidecar JSON file.

Other relevant files

Other relevant files should be included alongside the MEG data.
An MEG extension to BIDS
An MEG extension to BIDS

sub-0001
  ses-001
    anat
      sub-0001_T1w.nii.gz
      sub-0001_T1w.json
    meg
      sub-0001_task-noise_meg.ds
      sub-0001_task-noise_meg.json
      sub-0001_task-rest_run-01_meg.ds
      sub-0001_task-rest_run-01_meg.json
      sub-0001_task-rest_run-02_meg.ds
      sub-0001_task-rest_run-02_meg.json
      sub-0001_acq-LPA_fidphoto.jpg
      sub-0001_acq-NAS_fidphoto.jpg
      sub-0001_acq-RPA_fidphoto.jpg
      sub-0001_digit.pos
      sub-0001_fidinfo.txt
      sub-0001_task-rest_run-01_channels.tsv
      sub-0001_task-rest_run-02_channels.tsv
An MEG extension to BIDS

- This is an ongoing effort so feedback is welcome!

- Available datasets in the proposed MEG-BIDS format:
  - OpenfMRI study ds000117: A multi-subject, multi-modal human neuroimaging dataset of 19 subjects on a MEG visual task
  - Brainstorm Auditory tutorial dataset
  - OMEGA: The Open MEG Archive fully available in 2017
MRI

- Dicom raw files are defaced using Face Masking software (Mikhail Milchenko, Neuroinformatics Research Group at the Washington University School of Medicine).

- Participants’ individual scalp and cortical surfaces were segmented from MRI volume data using Freesurfer (Fischl et al. 2012), with default parameter settings.

- Anatomical files:
  - dicom
  - dicom_defaced
  - nifti_defaced
  - freesurfer_defaced
MRI defacing
RESTING STATE Brainstorm pipeline

ANATOMY

- Create new subject

- Import anatomy folder > File format: FreeSurfer
  - Number of vertices 15000
  - Select the fiducial points:
    - NAS, LPA, RPA: Manually marked (info in fiducials.mat)
      - depend on every lab (MANUALLY)
    - AC, PC, IH: this is done automatically (MNI transformation)

(Tadel et al. 2011)
RAW MEG

1) Link to RAW MEG

- Review raw data > File format: MEG/EEG CTF
- folder at the level of the session, it will import everything inside (both noise and resting)
- Convert all the files to “continuous”: Switch epoched/continuous
- Continuous
- Refine registration using head points
2) Quality control: PSD on sensors (before filtering)

- PSD in sensors (all freqs)
- Welch
- win_length = 4 seconds, win_overlap = 50%

3) FILTER: Notch filter + High pass (0.3 Hz)

- Notch filter (60 Hz and harmonics) check from file (both noise and resting)
- 60, 120, 180, 240, 300, 360, 420, 480, 540, 600
- MEG, EEG
- High pass (0.3 Hz), mirror signal
RAW MEG

Raw MEG

FILTER: Notch + High pass (0.3 Hz)
RAW MEG

4) Quality control: PSD on sensors (after filtering)

- PSD in sensors (all freqs)

Raw MEG

FILTER: Notch + High pass (0.3 Hz)
RAW MEG

5) SSP Detect and remove blinks and cardiac

- Detect events: blinks and cardiac (only for resting)
- ECG: EEG057
- VEOG: EEG058
- Remove simultaneous:
  - cardiac / blink/ 250ms
- Compute SSP
- use previous ssp (yes)
- force 1st component
RAW MEG

FILTER: Notch + High pass (0.3 Hz)

SSP blinks and cardiac
6) Detect other artifacts

- Low (1-7Hz) and High Frequencies (40-240Hz): threshold=3

7) SSP for low frequencies (saccades) 1-7Hz

- To remove saccades (blink SSP could also show this component)
- Detect generic SSP:
  - Event: 1-7Hz
  - Frequencies: 1-7Hz
  - PCA, no need for a window since they are extended events

8) SSP for high frequencies (muscle) 40-400Hz

- To remove muscle artifacts throughout the recordings (usually around the neck)
- Detect generic SSP:
  - No event name
  - Frequencies: 40-400Hz
  - PCA, no need for a window since they are extended events
MEG ANALYSIS

- **Compute sources**
  - **Noise covariance** from noise recordings (bandpassed the same as MEG signals)
  - Copy it to other conditions
    - Checks DATE of the session (therefore, date needs to be in a fixed position)
  - Compute **head model**: cortex surface, overlapping spheres
  - Compute **sources** (only MEG sensors)
MEG ANALYSIS

Power Spectral Density (PSD)

- win_length = 4s, win_overlap = 50%
- Total and Relative (dividing by the sum of total PSD)
- Average over trials
  - Frequency bands:
    - delta=2, 4 Hz
    - theta=5, 7 Hz
    - alpha=8, 12 Hz
    - beta=15, 29 Hz
    - gamma1=30, 59 Hz
    - gamma2=60, 90 Hz

- 1) PSD on sensors (in all freqs)
- 2) PSD on sensors (in bands)
- 3) PSD on sources (in bands)
MEG ANALYSIS

<table>
<thead>
<tr>
<th>Alpha</th>
<th>Beta</th>
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<tbody>
<tr>
<td>(8-12)Hz</td>
<td>(15-19 Hz)</td>
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Relative PSD of ongoing cortical activity in OMEGA
OMEGA: The Open MEG Archive

- Assessing the likelihood of individual oscillatory expressions as normal variants

Empirical distribution of local metric across normative database
Example: blind

- PSD difference between healthy population in OMEGA (resting state with eyes closed) and BLIND group (**ALPHA band**)
- Data collected in University of Copenhagen, Denmark

(Niso, Müller, Baillet, Ptito, Kupers. In preparation)
Open Science

- Work with your **REB** (ethics board):
  - databank policy, consent forms
  - anonymized sharing
- Inform participants of **secondary use of data**
- Secure **infrastructure**: first 500TB the most difficult to get
- **Portal**: keep it simple
- Educate investigators that **sharing is good for them too!**
  - Productivity
  - Reproductibility
  - Long term value
  - Reputation
  - h-impact
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