Resting State Analysis and the Open MEG Archive (OMEGA)

Technical and Ethical aspects

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3rd MEG@McGill Comprehensive Training — 7th November, 2016

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

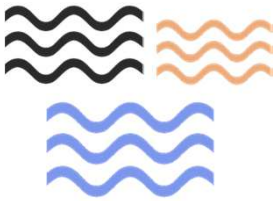
The Open MEG Archive

Guiomar Niso

November, 2016

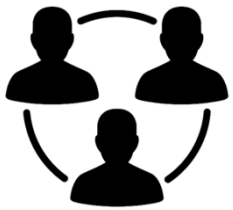
OMEGA: The Open MEG Archive

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



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

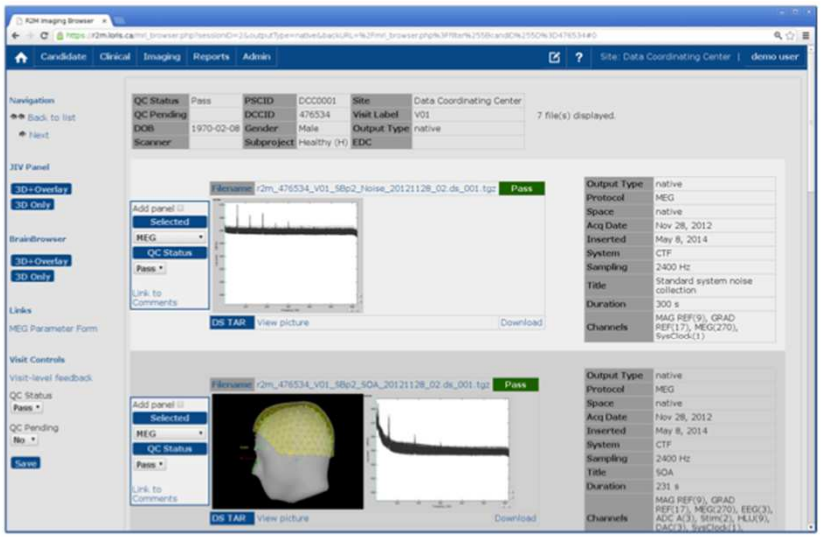
Contains data in **raw and processed** forms, including source image volumes



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)

Contents lists available at ScienceDirect

NeuroImage

journal homepage: www.elsevier.com/locate/ynimg

OMEGA: The Open MEG Archive

Guiomar Niso [a,1], Christine Rogers [a,1], Jeremy T. Moreau [a], Li-Yuan Chen [a], Cecile Madjar [b], Samir Das [a], Elizabeth Bock [a], François Tadel [a], Alan Evans [a], Pierre Jolicoeur [c], Sylvain Baillet [a,*]

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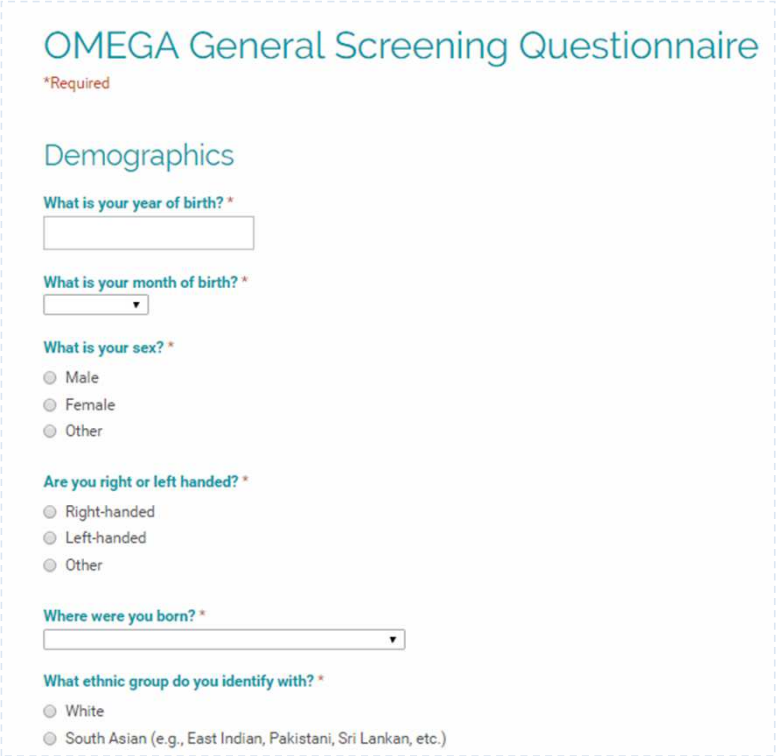
General Screening Questionnaire

- 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



OMEGA General Screening Questionnaire

*Required

Demographics

What is your year of birth? *

What is your month of birth? *

What is your sex? *

- Male
- Female
- Other

Are you right or left handed? *

- Right-handed
- Left-handed
- Other

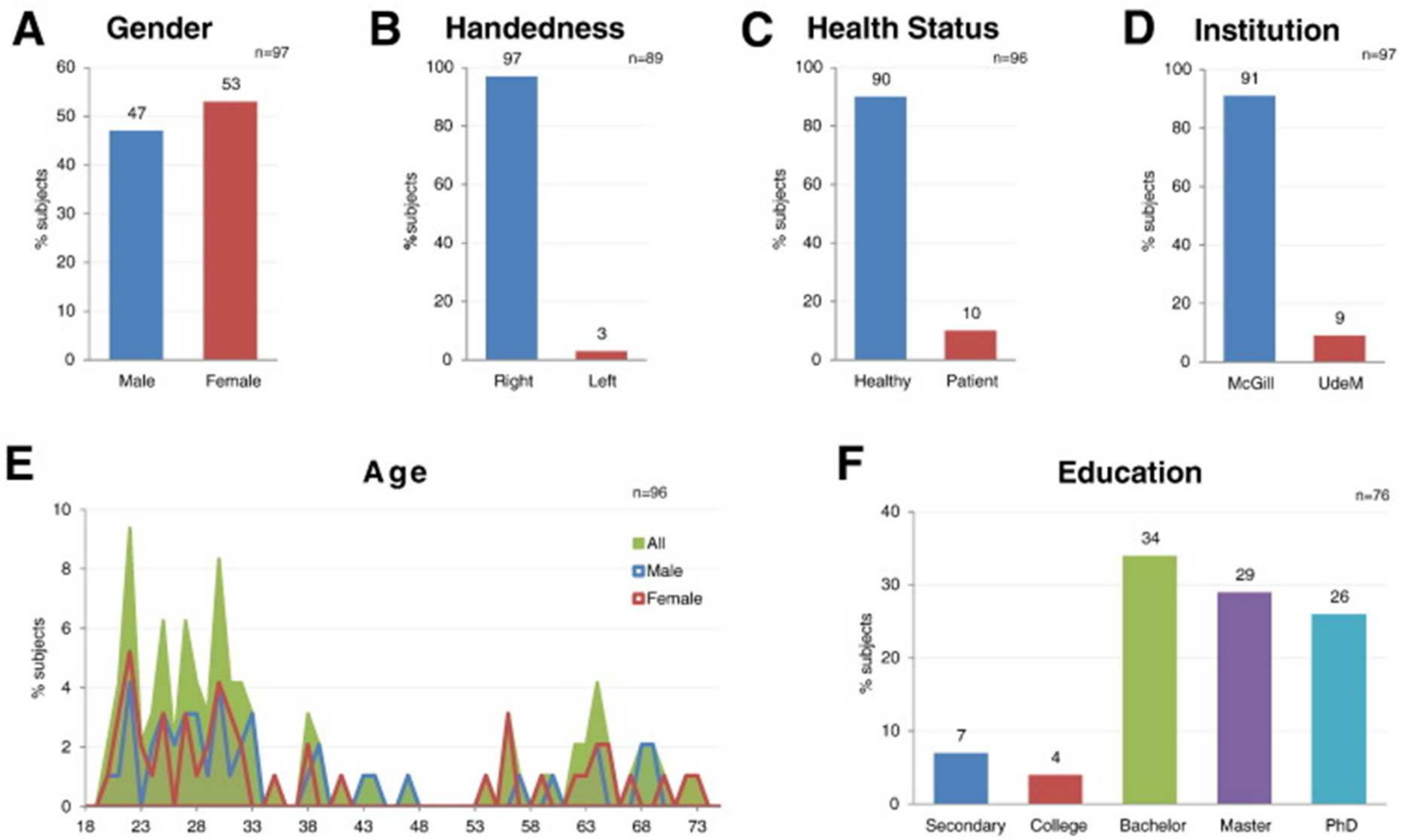
Where were you born? *

What ethnic group do you identify with? *

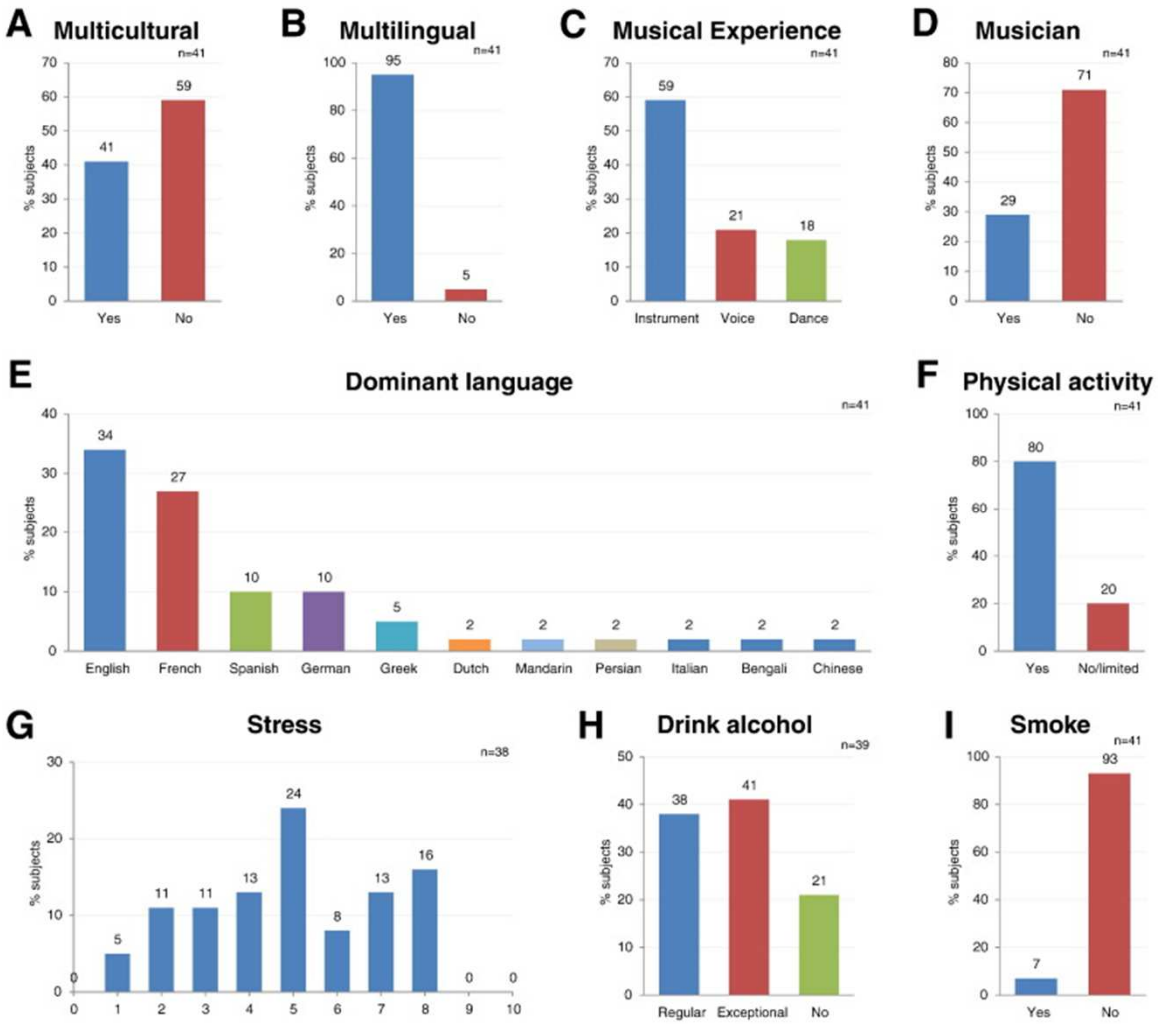
- White
- South Asian (e.g., East Indian, Pakistani, Sri Lankan, etc.)

- Current status → Retrospective Questionnaire

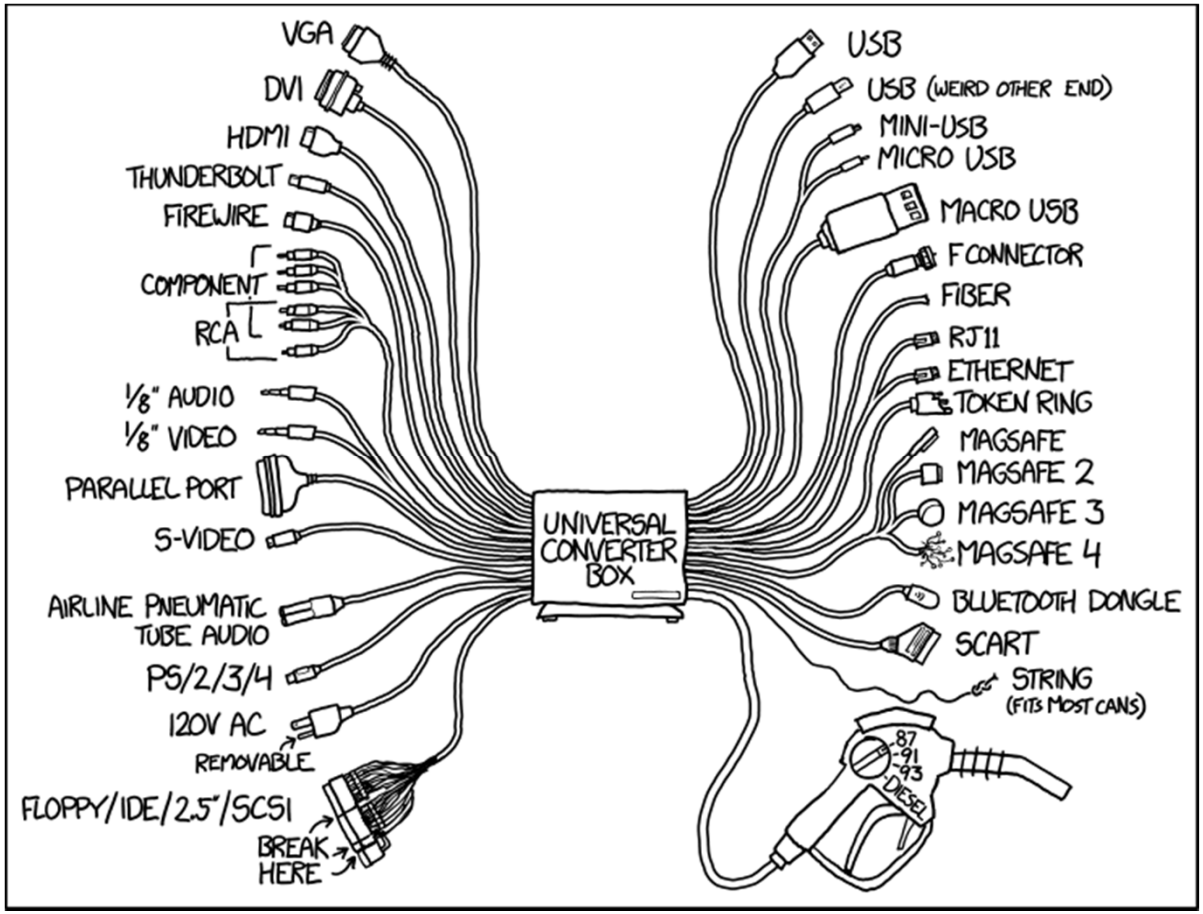
General demographic info participants in OMEGA



Cultural and lifestyle participants in OMEGA



MEG formats

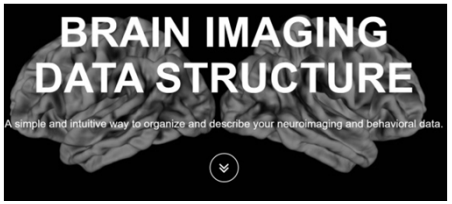


- There's NO **dicom** format in MEG
- Each system has its own proprietary format

WE NEED A

STANDARD

MEG file repository standardization



Niso et al., Biomag2016

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.

Default

- 20160514
  - sub-0001_noise_20160514.ds
  - sub-0001_resting_20160514_01.ds
  - sub-0001_resting_20160514_02.ds
  - sub-0002_noise_20160514.ds
  - sub-0002_resting_20160514_01.ds
  - sub-0002_auditory_20160514_01.ds
  - sub-0002_motor_20160514_01.ds
  - sub-0003_noise_20160514.ds
  - sub-0003_resting_20160514_01.ds
  - sub-0003_auditory_20160514_01.ds
  - sessionLog_20160514_01.txt
  - Pictures
    - p1020267.jpg
    - p1020268.jpg
    - p1020269.jpg
    - p1020270.jpg
    - p1020271.jpg
    - p1020272.jpg
- 20160518
  - sub-0001_noise_20160518.ds
  - sub-0001_resting_20160518_01.ds
  - sub-0001_motor_20160518_02.ds
  - sub-0003_noise_20160518.ds
  - sub-0003_resting_20160518_01.ds
  - sub-0003_resting_20160518_02.ds
  - sessionLog_20160518_01.txt
  - Pictures

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
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      - sub-0001_digit.pos
      - sub-0001_fiducials.tsv
      - sub-0001_task-rest_run-01_channels.tsv
      - sub-0001_task-rest_run-02_channels.tsv
  - ses-002
  - ses-003
- sub-0002
- sub-0003
- participants.tsv
- dataset_description.json

Description of the optional sidecar JSON file:

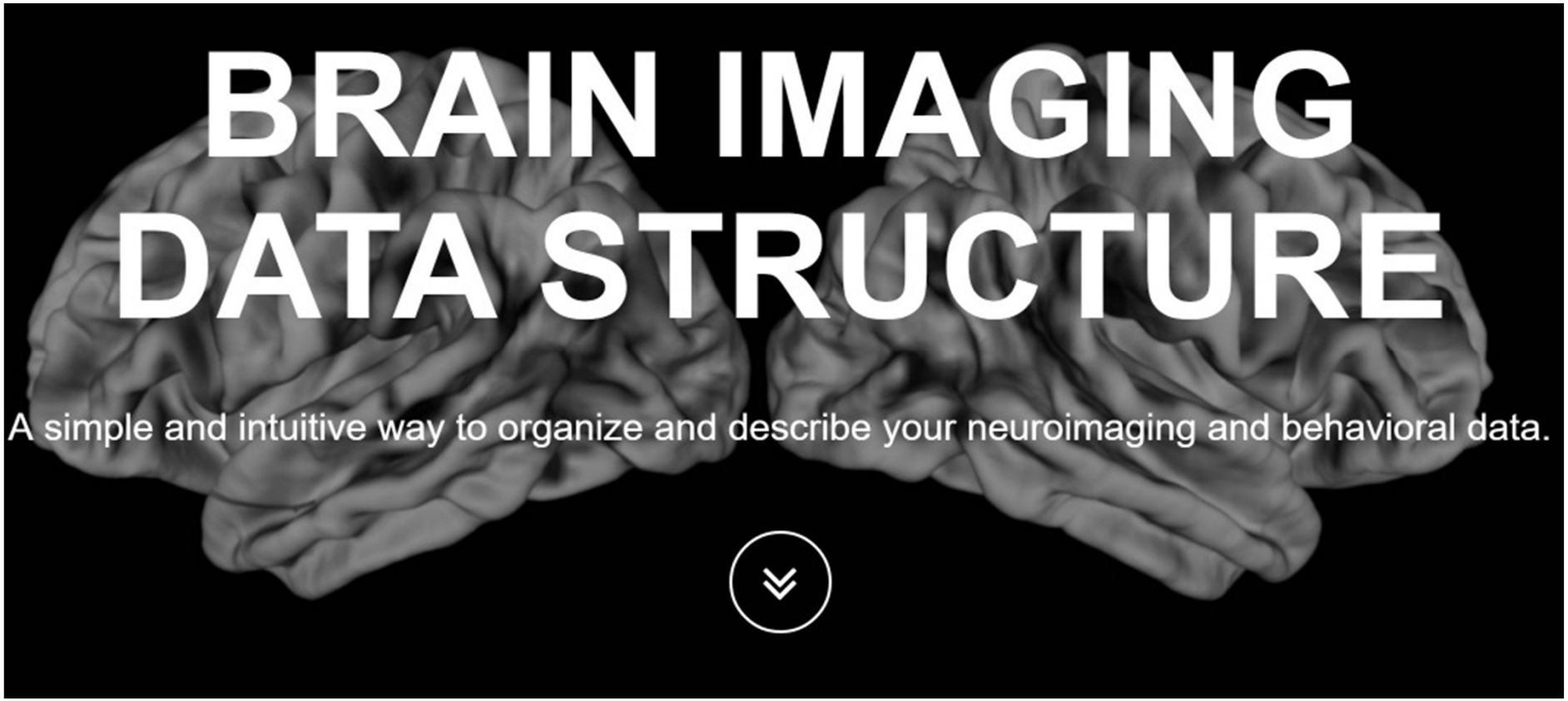
Required fields:

- **TaskName**: Name of the task (for resting state use the "rest" prefix). No two tasks should have the same name. Task label is derived from this field by removing all non alphanumeric ([a-zA-Z0-9]) characters.
- **SamplingFrequency**: Sampling frequency (in Hz) of the recording (e.g. 2400Hz)
- **Manufacturer**: Manufacturer of the MEG system (e.g. "CTF")
- **ManufacturerModelName**: Manufacturer's designation of the MEG scanner model (e.g. "CTF-275")
- **MEGChannelCount**: Number of MEG channels included in the recording (e.g. 275)
- **MEGREFChannelCount**: Number of MEG reference channels included in the recording (e.g. 23)
- **EEGChannelCount**: Number of EEG channels included in the recording (e.g. 21)
- **EOGChannelCount**: Number of EOG channels included in the recording (e.g. 2)
- **ECGChannelCount**: Number of ECG channels included in the recording (e.g. 1)
- **EMGChannelCount**: Number of EMG channels included in the recording (e.g. 2)

Other recommended metadata:

- **PowerLineFrequency**: Frequency (in Hz) of the power grid where the MEG scanner is installed (i.e. 50 or 60)
- **EEGMontage**: Montage of the EEG electrodes. Either the name of a standardised montage (e.g. "10-20") or a list of standardised electrode positions (e.g. ["Cz", "Pz"])
- **EEGReference**: Description of the type of EEG reference used (e.g. "mastoid", "average", or "longitudinal bipolar")
- **MEGPosition**: Position of the subject in the MEG scanner (e.g. "upright" or "supine")
- **OnlineFilters**: List of non-reversible filters applied at the time of acquisition (e.g. ["0.3 Hz high-pass", "anti-aliasing filter"])
- **SoftwareFilters**: List of software filters applied or ideally key:value pairs of pre-applied software filters and their parameter values (e.g. {"SSS": {"frame": "head", "badlimit": 7}})
- **GradientOrder**: Order of the gradient compensation. Set to "0" if not applied
- **AssociatedAnatomicalMRI**: Relative path to the anatomical MRI to be used with the MEG recording (e.g. "../anat/sub-01_T1w.nii.gz")
- **RecordingStart**: Date and time at which the recording began (e.g. "2009-06-15T13:45:30")
- **RecordingDuration**: Length of the recording in seconds (e.g. 3600)
- **RecordingType**: "continuous", "epoched" or "averaged"
- **EpochLength**: Duration of individual epochs in seconds (e.g. 1). If recording was continuous, set value to 0.
- **TriggerChannels**: Collection of key: value pairs associating channel names with a brief description (e.g. {"STI101": "Button responses of the subject"})
- **MiscChannels**: Collection of key: value pairs associating channel names with a brief description (e.g. {"UADC001": "Envelope of audio signal sent to the subject"})
- **BadChannels**: List of bad (i.e. excessively noisy or broken) channels throughout the whole recording (e.g. ["MLT45", "MRP51"])
- **DeviceSoftwareVersion**: Manufacturer's designation of the acquisition software.
- **TaskInstructions**: Text of the instructions given to participants before the scan. This is especially important in context resting state recordings and distinguishing between eyes open and eyes closed paradigms
- **TaskDescription**: Longer description of the task
- **RestingState**: Boolean value indicating whether the subject was recorded during resting state / spontaneous activity or performing a task. A value of "true" indicates that it is a resting state recording
- **EyesClosed**: Boolean value indicating whether the subject was instructed to keep his or her eyes for the duration of the recording. A value of "true" indicates that the eyes were closed
- **ContinuousHeadLocalization**: Boolean (true or false) value indicating whether continuous head localisation was performed or not
- **HLCFrequency**: List of frequencies used by the head localisation coils that track the subject's head position in the MEG helmet (e.g. [293, 307, 314, 321])
- **MaxMovement**: Maximum head movement (in mm) during the recording as measured by the head localisation coils (e.g. 4.8).
- **SubjectArtefact**: Boolean value indicating whether the subject had any non-removable implant generating significant artefactual noise in the recording
- **SubjectArtefactDescription**: Freeform description of the cause of the observed subject artefact (e.g. "Vagus Nerve Stimulator")
- **DigitizedLandmarks**: Boolean value indicating whether anatomical landmark points are contained within this recording
- **DigitizedHeadPoints**: Boolean value indicating whether head points outlining the scalp surface are contained within this recording

BIDS: Brain Imaging Data Structure



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

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neurospeed neuro McGill

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      - sub-0001_task-rest_run-02_channels.tsv
  - ses-002
  - ses-003
- **sub-0002**
- **sub-0003**
- participants.tsv
- dataset_description.json

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
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            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 a 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

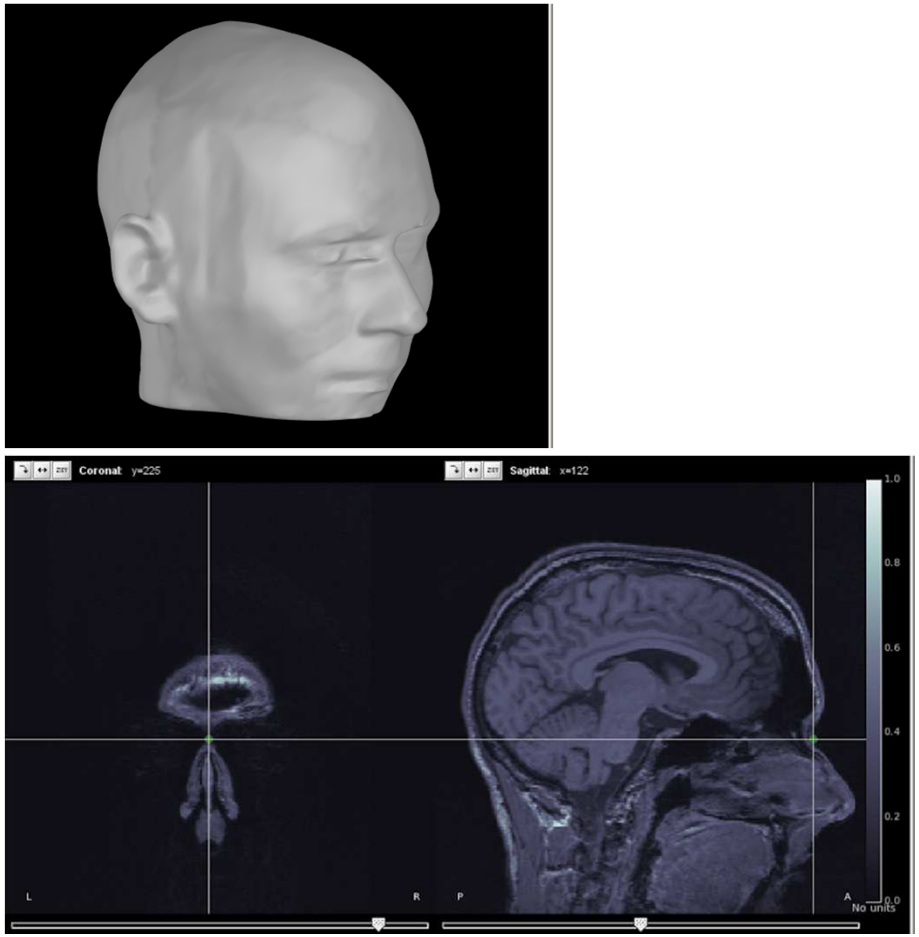
MRI

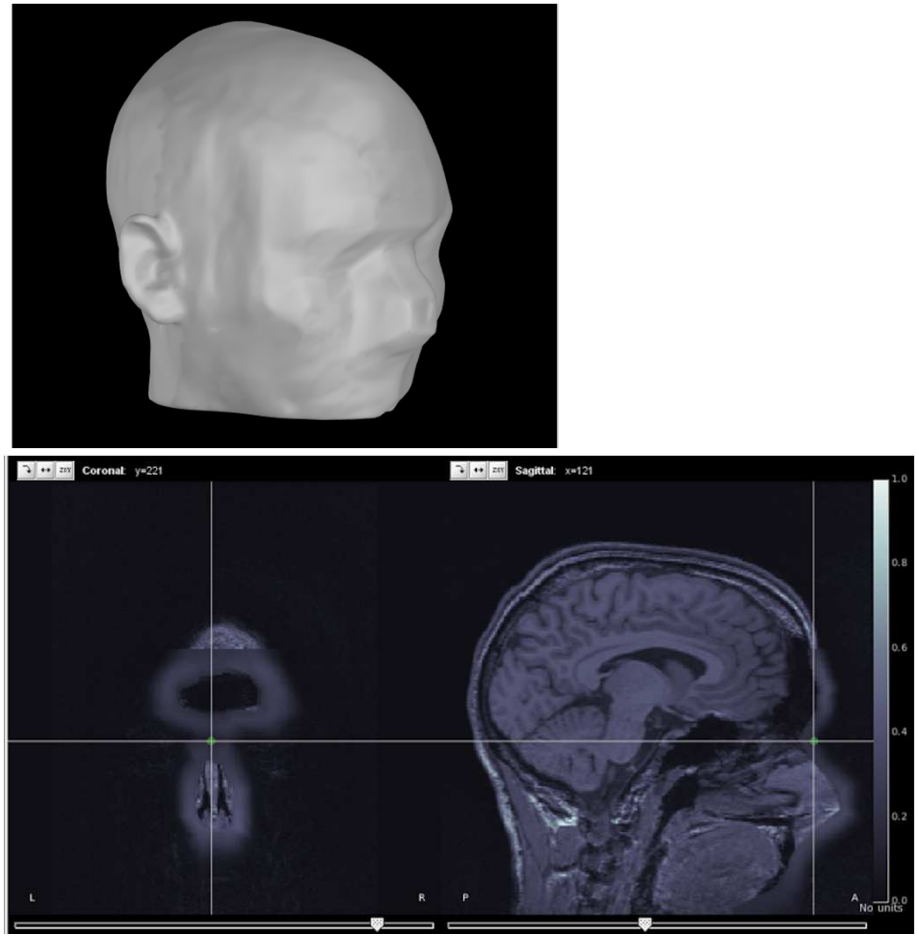
- Dicom raw files are defaced using Face Masking software (Mikhail Milchenko, Neuroinformatics Research Group at the Washington University School of Medicine).

- 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

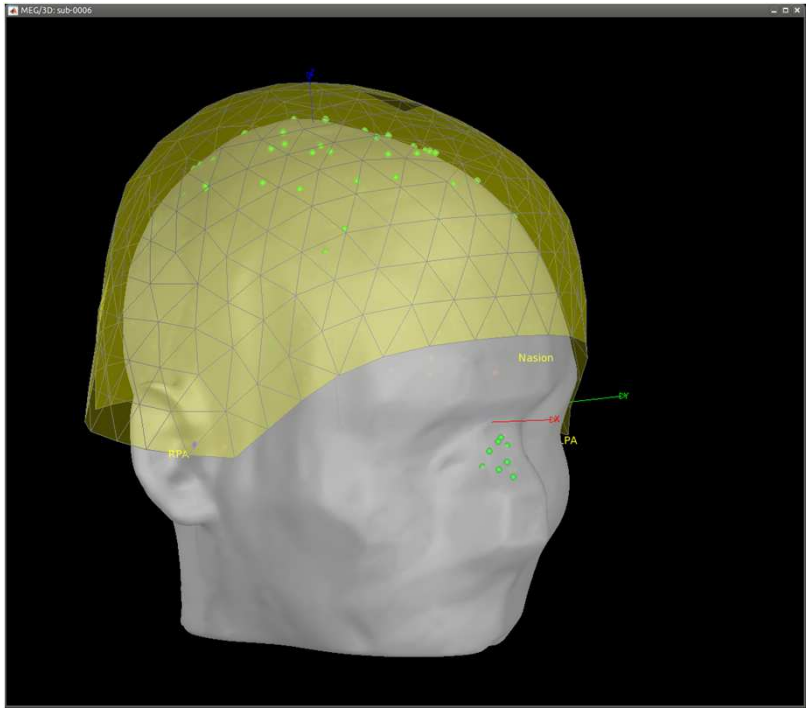
ANATOMY

- 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



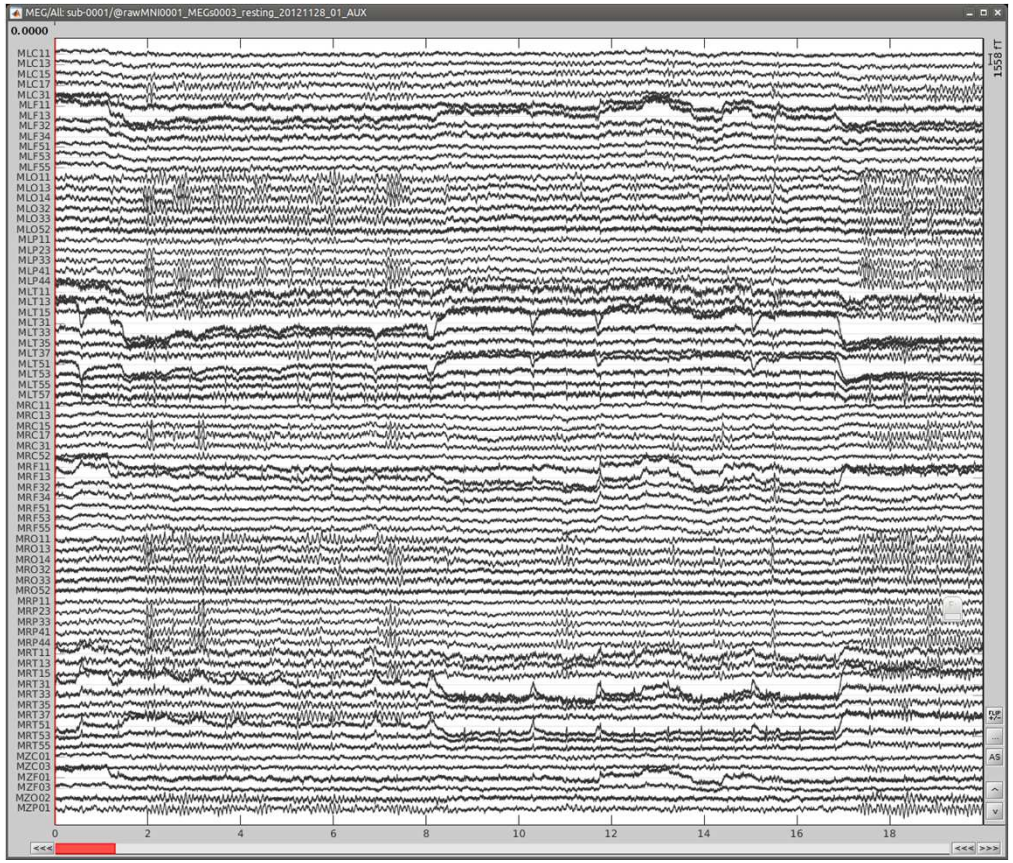
RAW MEG

- **2) Quality control: PSD on sensors (before filtering)**
  - PSD in sensors (all freqs)
  - Welch
  - win_length = 4seconds, win_overlap = 50%

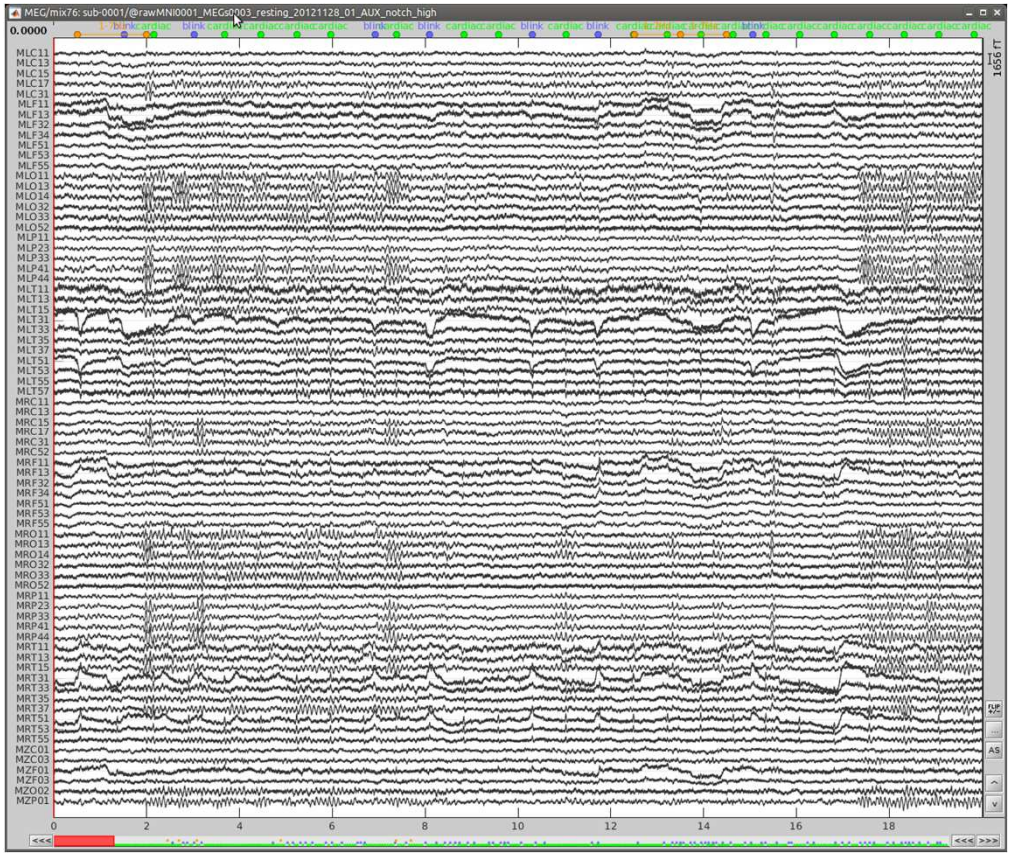
- **3) FILTER: Notch filter + High pass (0.3 Hz)**
  - Notch filter (60Hz and harmonics) check from file (both noise and resting)
  - 60, 120, 180, 240, 300, 360, 420, 480, 540, 600
  - MEG, EEG
  - High pass (0.3Hz), mirror signal

RAW MEG

Raw MEG



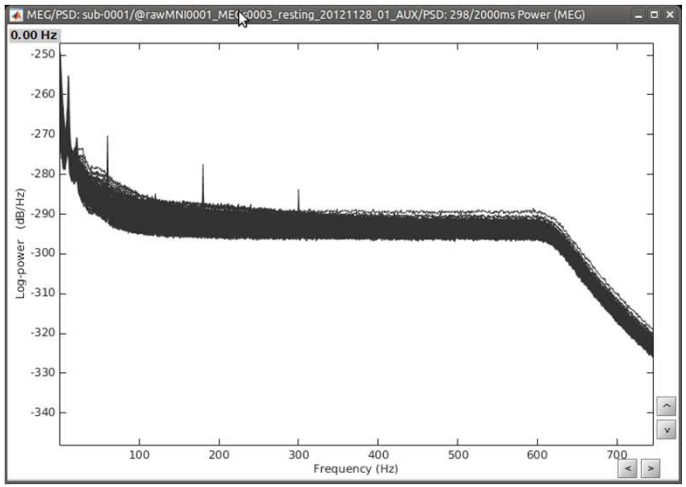
FILTER: Notch + High pass (0.3 Hz)



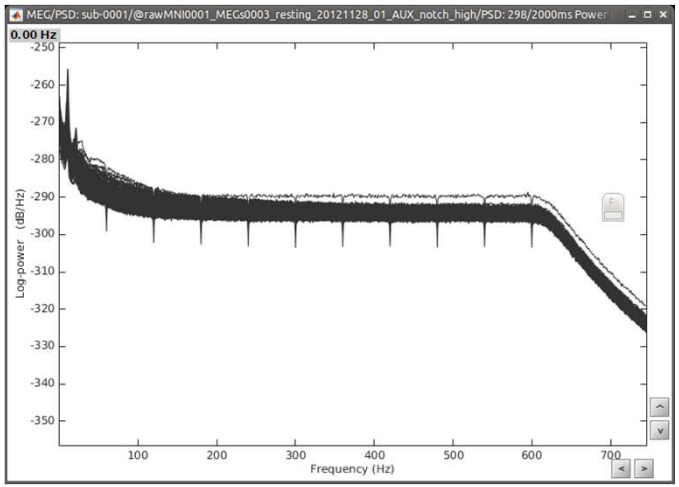
RAW MEG

- **4) Quality control: PSD on sensors (after filtering)**
  - PSD in sensors (all freqs)

Raw MEG

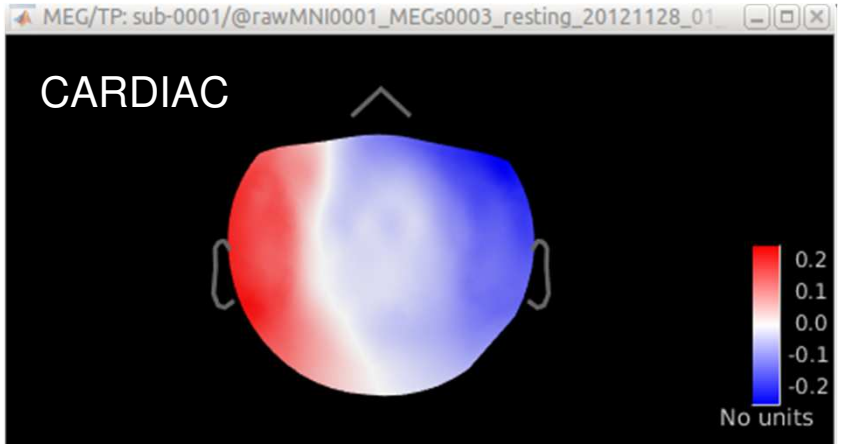


FILTER: Notch + High pass (0.3 Hz)



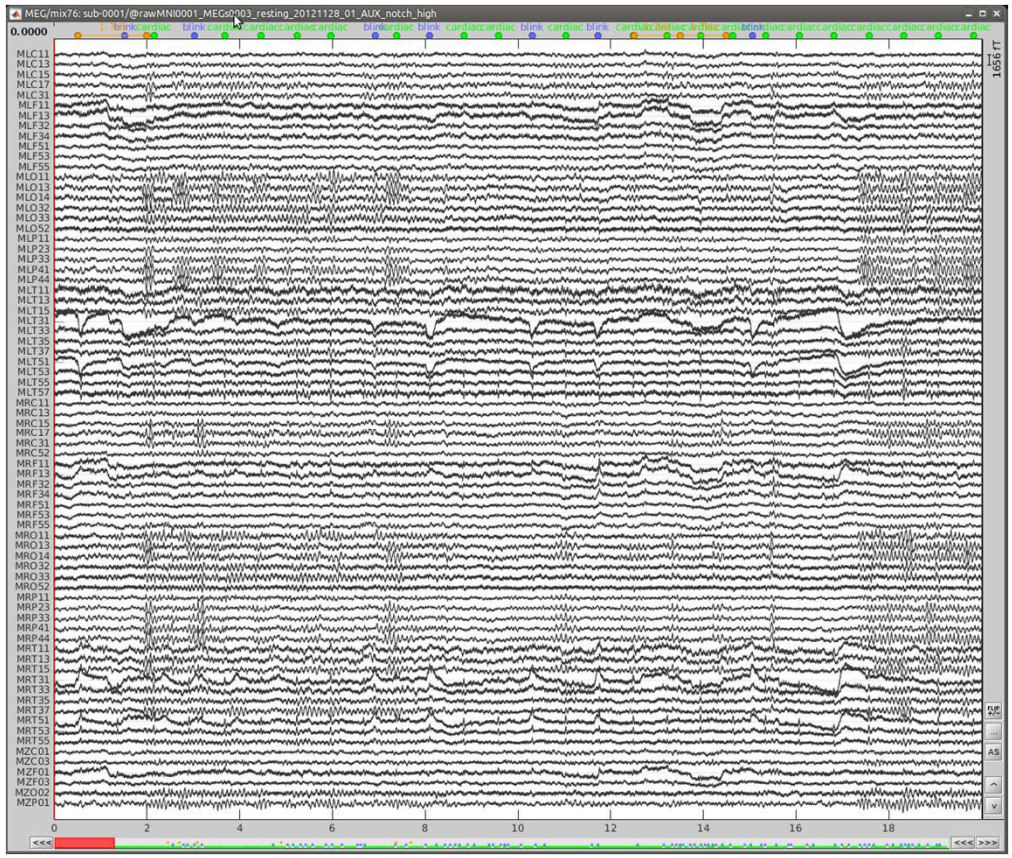
RAW MEG

- **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

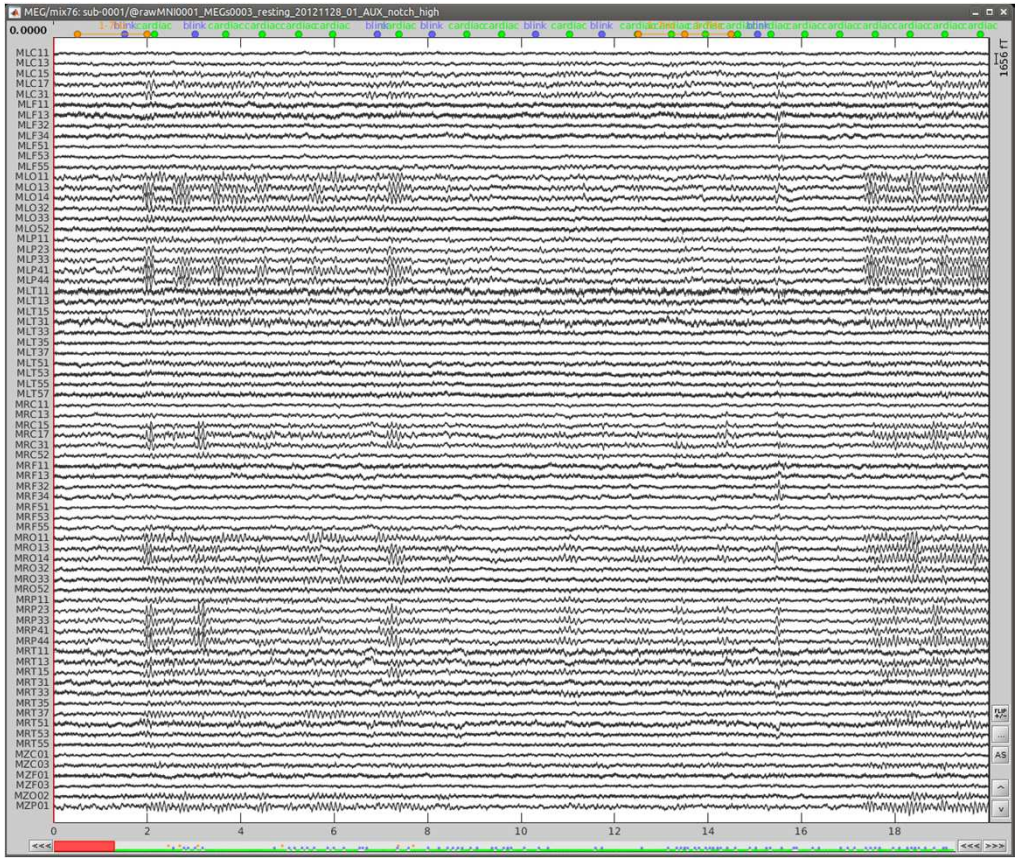


RAW MEG

FILTER: Notch + High pass (0.3 Hz)



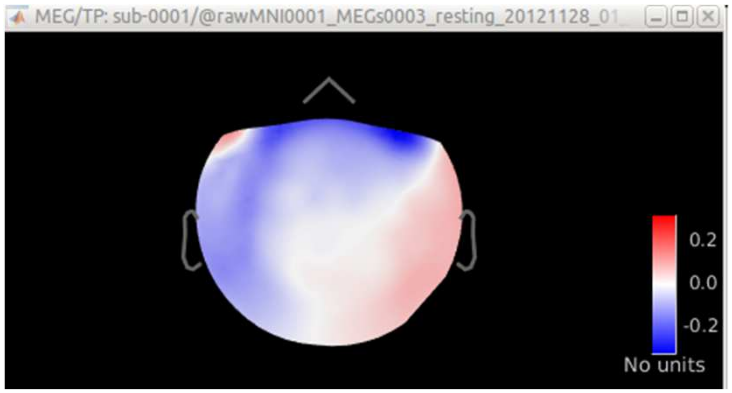
SSP blinks and cardiac



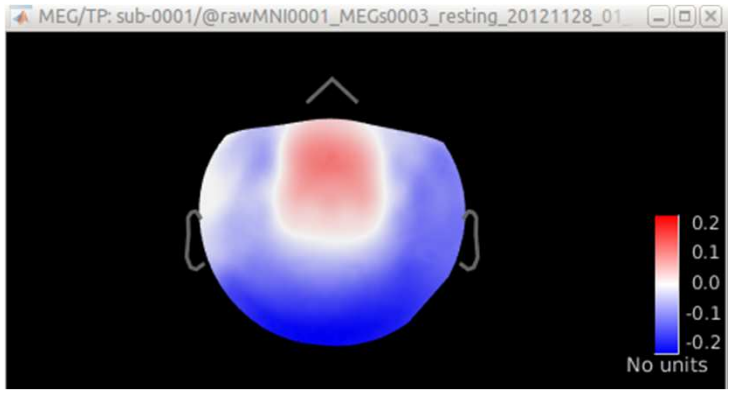
RAW MEG

- **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

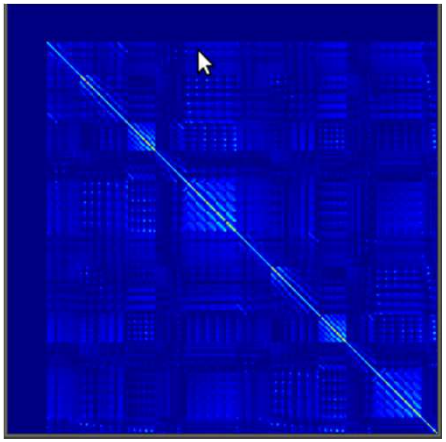


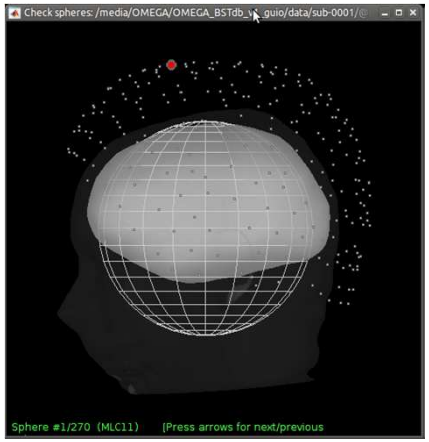
- **8) SSP for high frequencies (muscle) 40-400Hz**
  - To remove muscle artifacts throughout the recordings (usually around the neck)
  - Detect generic SSP:
  - No event name
  - Frequencies: 40-400Hz
  - PCA, no need for a window since they are extended events

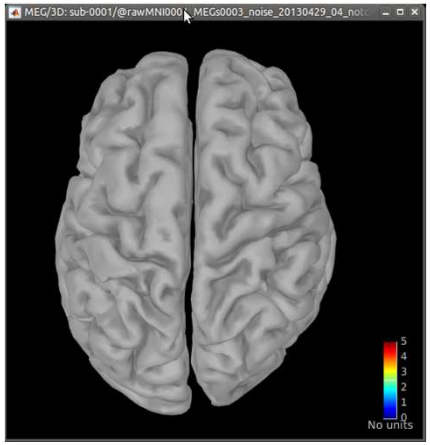


MEG ANALYSIS

- **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)





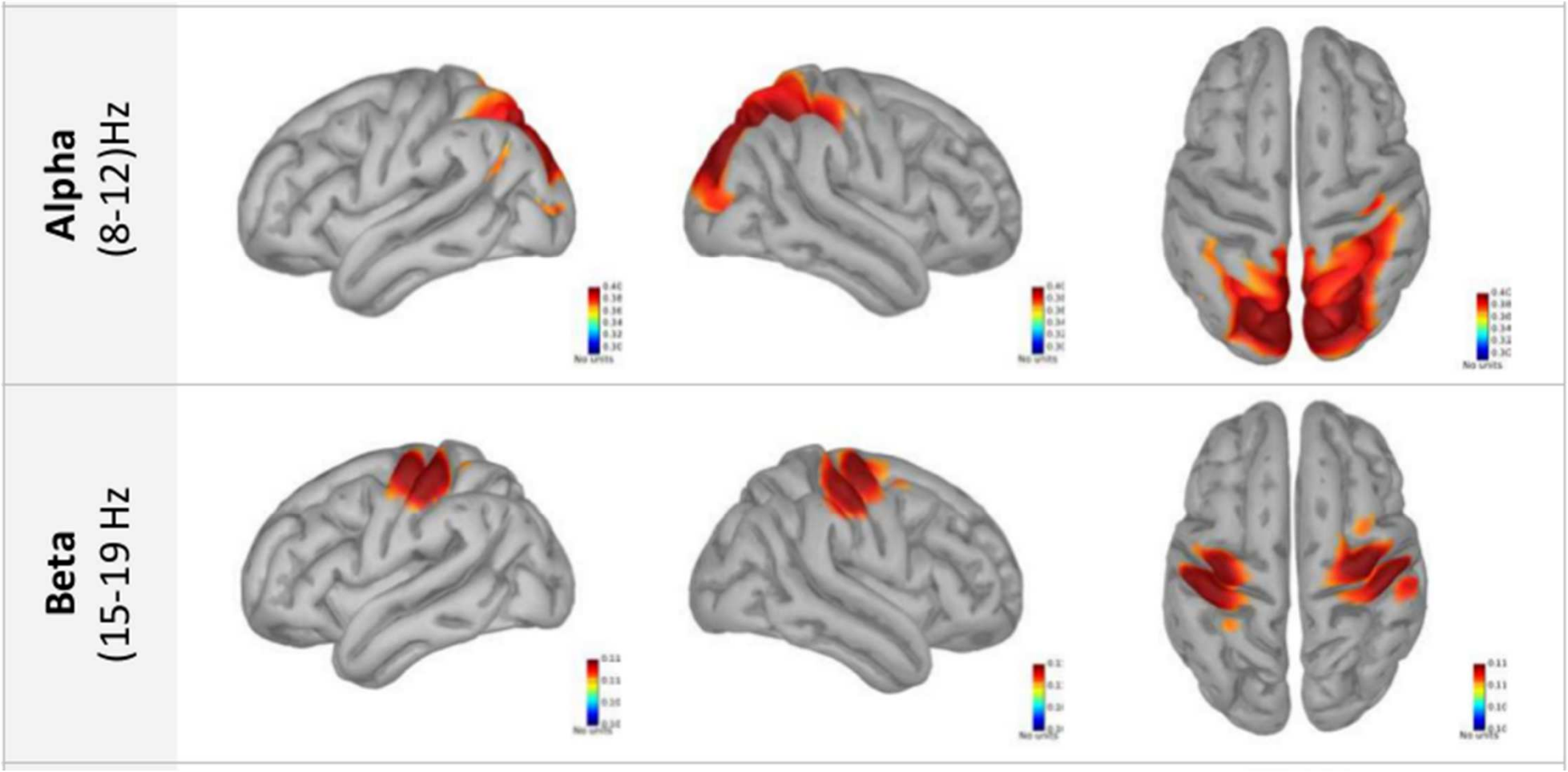


MEG ANALYSIS

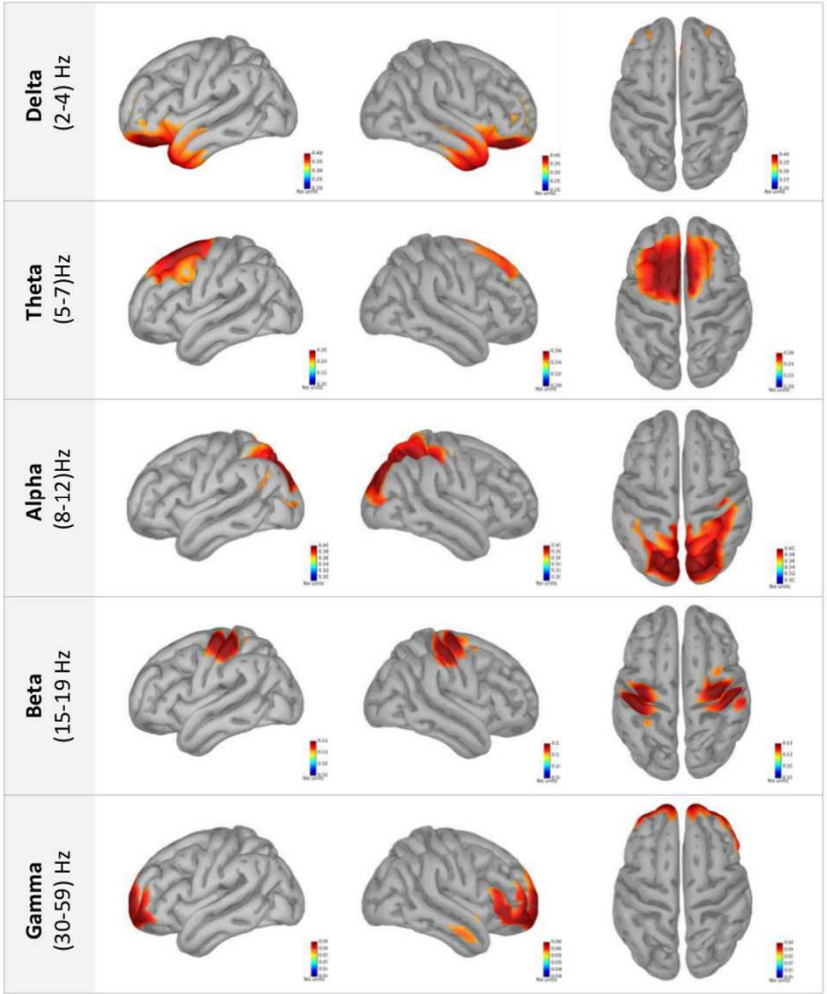
- **Power Spectral Density (PSD)**
  - win_length = 4s, win_overlap = 50%
  - Total and Relative (dividing by the sum of total PSD)
  - Average over trials
    - Frequency bands:
    - delta=2, 4 Hz
    - theta=5, 7 Hz
    - alpha=8, 12 Hz
    - beta=15, 29 Hz
    - gamma1=30, 59 Hz
    - gamma2=60,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

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

MEG ANALYSIS

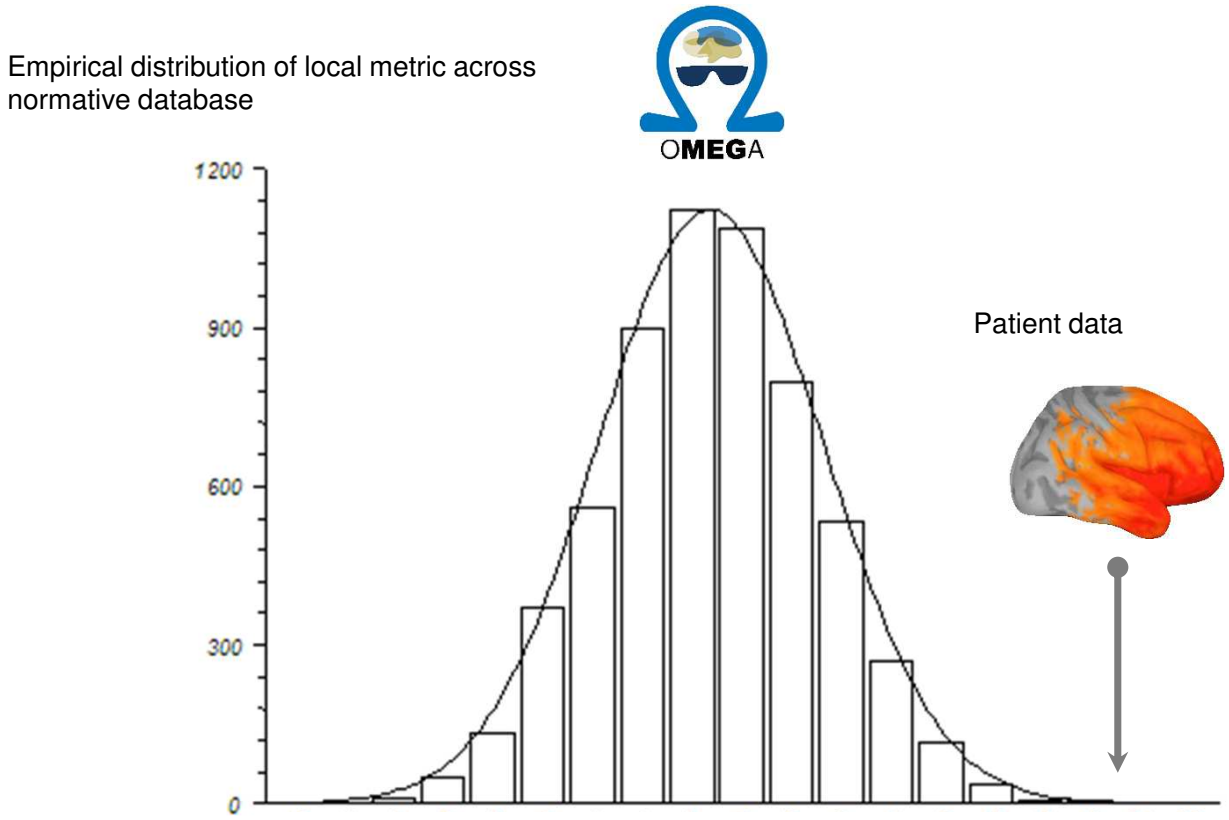


Relative PSD of ongoing cortical activity in OMEGA



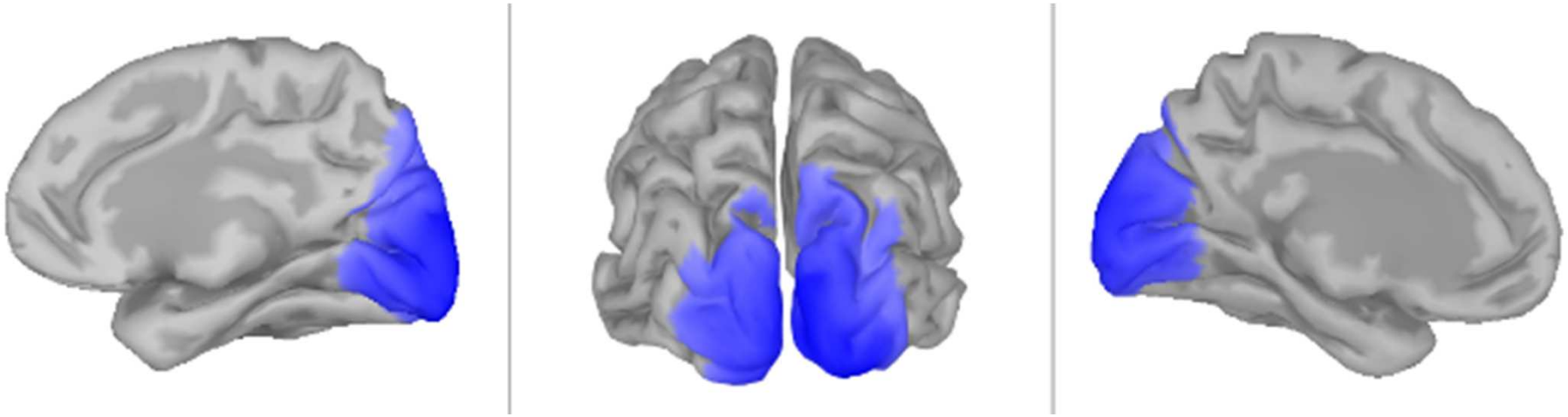
OMEGA: The Open MEG Archive

- Assessing the likelihood of individual oscillatory expressions as normal variants



Example: blind

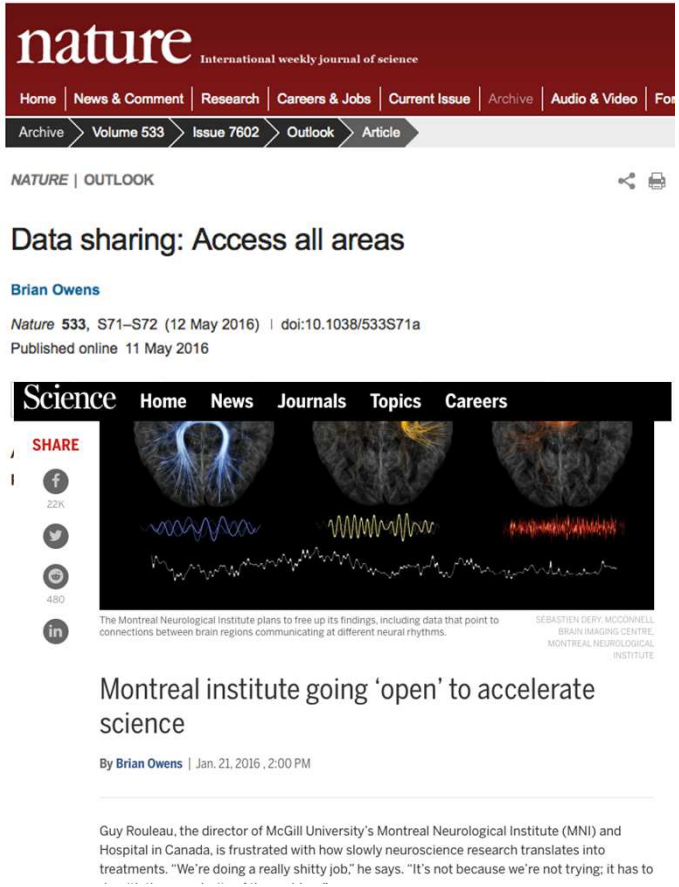
- PSD difference between healthy population in OMEGA (resting state with eyes closed) and BLIND group (**ALPHA band**)
- Data collected in University of Copenhagen, Denmark



(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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Data sharing: Access all areas

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Nature **533**, S71–S72 (12 May 2016) | doi:10.1038/533S71a

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The Montreal Neurological Institute plans to free up its findings, including data that point to connections between brain regions communicating at different neural rhythms.

SEBASTIEN DERY, MCCONNELL BRAIN IMAGING CENTRE, MONTREAL NEUROLOGICAL INSTITUTE

Montreal institute going 'open' to accelerate science

By Brian Owens | Jan. 21, 2016 , 2:00 PM

Guy Rouleau, the director of McGill University's Montreal Neurological Institute (MNI) and Hospital in Canada, is frustrated with how slowly neuroscience research translates into treatments. "We're doing a really shitty job," he says. "It's not because we're not trying; it has to

Resting State Analysis and the Open MEG Archive (OMEGA)

Technical and Ethical aspects

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3rd MEG@McGill Comprehensive Training — 7th November, 2016