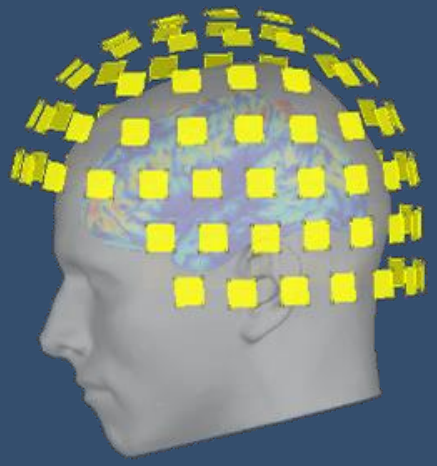
SEEG analysis using

Brainstorm

http://neuroimage.usc.edu/brainstorm



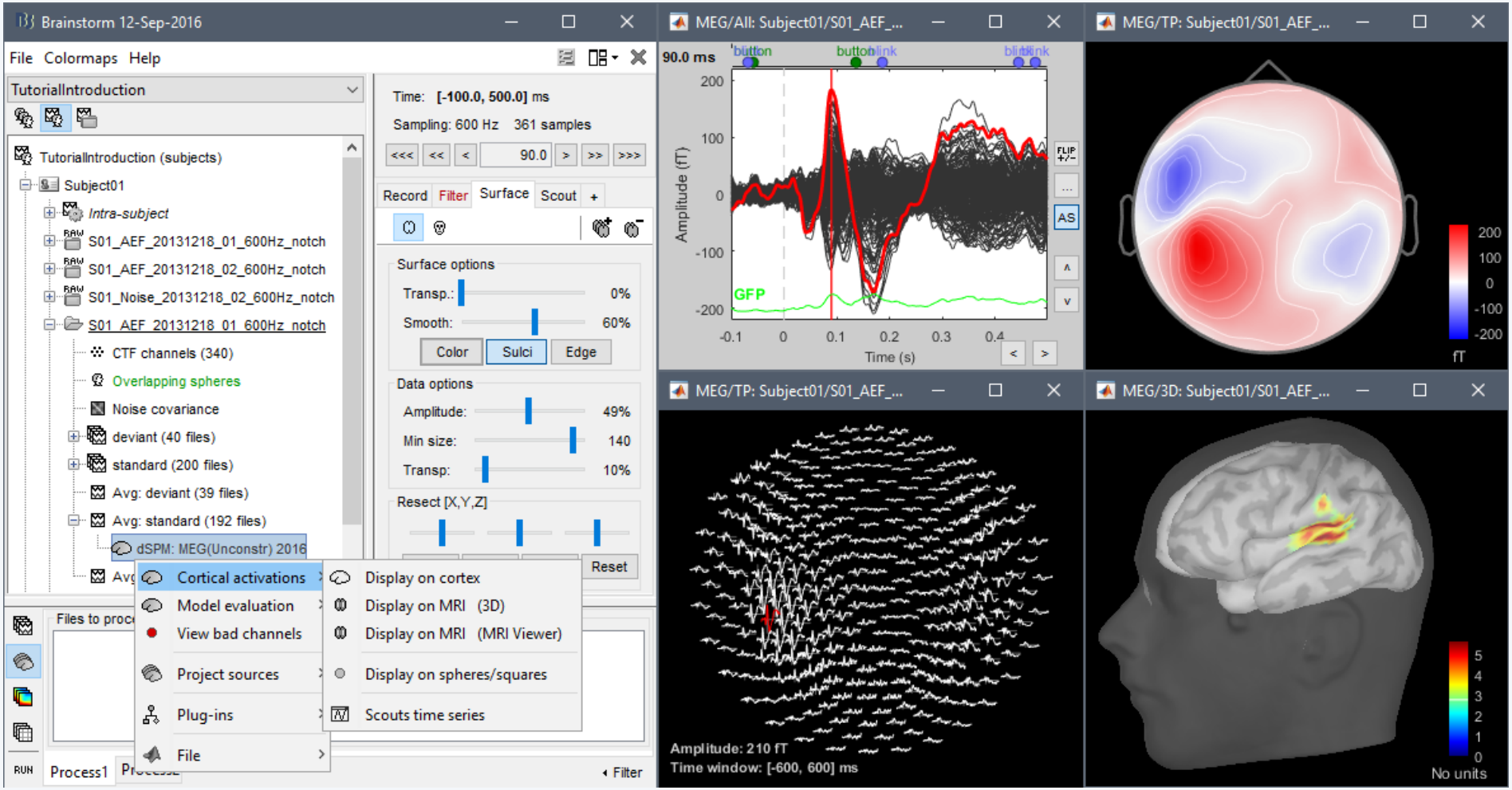
USC UNIVERSITY OF SOUTHERN CALIFORNIA

McGill neuro UTHealth

CuttingEEG 2021

Francois Tadel

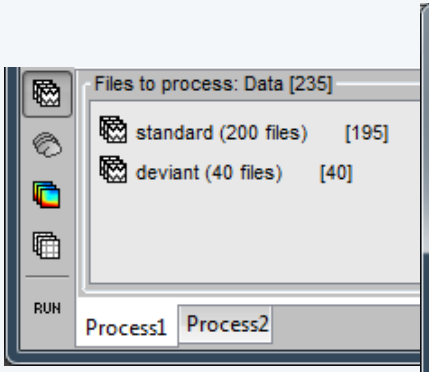
Graphic interface

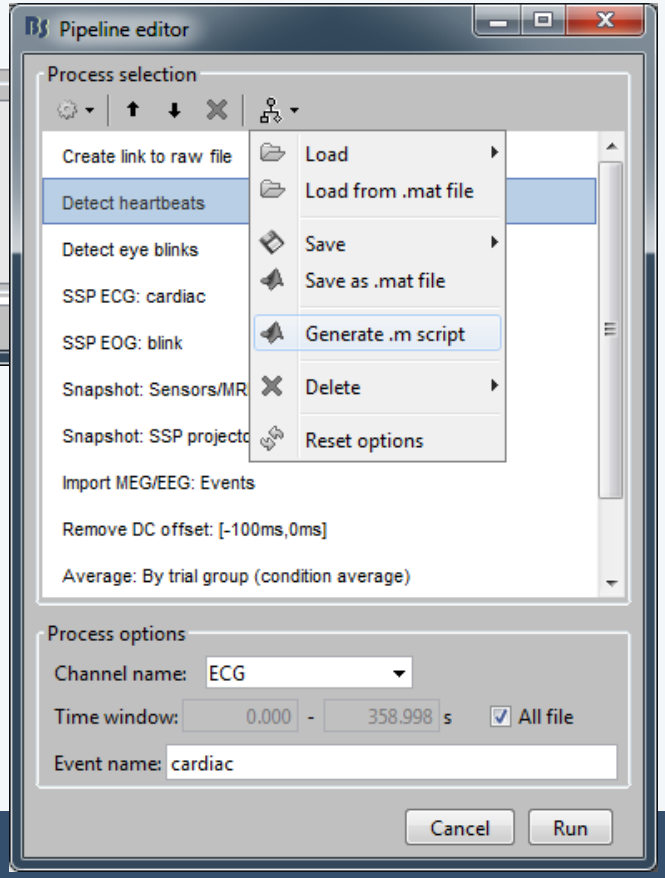


Brainstorm

Scripting environment

- Rapid selection of files and processes to apply
- Automatic generation of Matlab scripts
- Plug-in structure: easy to add custom processes






```
% Script generated by Brainstorm v3.1 (17-Dec-2010).
FileNamesA = {'Subject01\Left\data_average_101213_1558.mat', ...
              'Subject01\Right\data_average_101213_1559.mat'};
FileNamesB = [];

% Process: Detect bad trials: Peak-to-peak  MEGGRAD(0-2000)
sFiles = bst_process(...
    'CallProcess', 'process_detectbad', ...
    FileNamesA, FileNamesB, ...
    'timewindow', [-0.0998, 0.3000], ...
    'meggrad', {[0, 2000], 'fT/cm (x 0.04)', 1e-015}, ...
    'rejectmode', 2);

% Process: Remove baseline: [-100ms,-1ms]
sFiles = bst_process(...
    'CallProcess', 'process_baseline', ...
    sFiles, [], ...
    'baseline', [-0.09983, -0.00056], ...
    'overwrite', 1);

% Process: Band-pass filter: 1Hz - 80Hz
sFiles = bst_process(...
    'CallProcess', 'process_bandpass', ...
    sFiles, [], ...
    'f1', 1, ...
    'f2', 80, ...
    'overwrite', 1);

% Process: Average by condition
sFiles = bst_process(...
    'CallProcess', 'process_average', ...
    sFiles, [], ...
    'avgtype', 3, ...
    'isstd', 0);
```

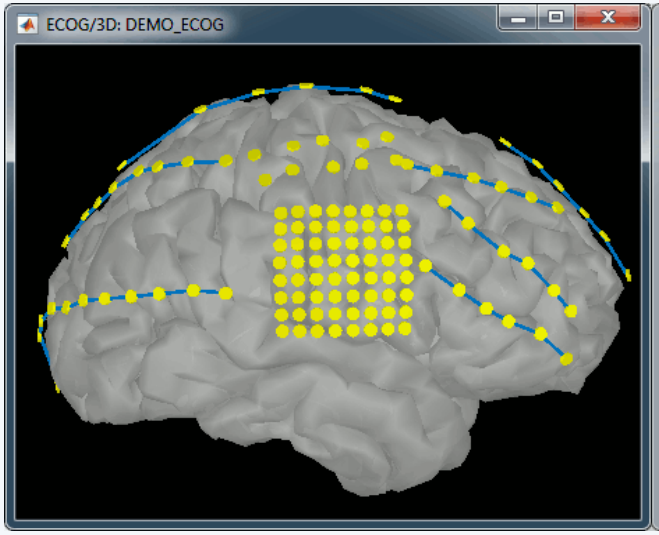
- Free and open-source application
- Matlab & Java: Platform-independent
- Designed for Matlab
- Stand-alone version available
- Interface-based: click, drag, drop
- No programming experience required
- Daily updates of the software
- Supports most common file formats



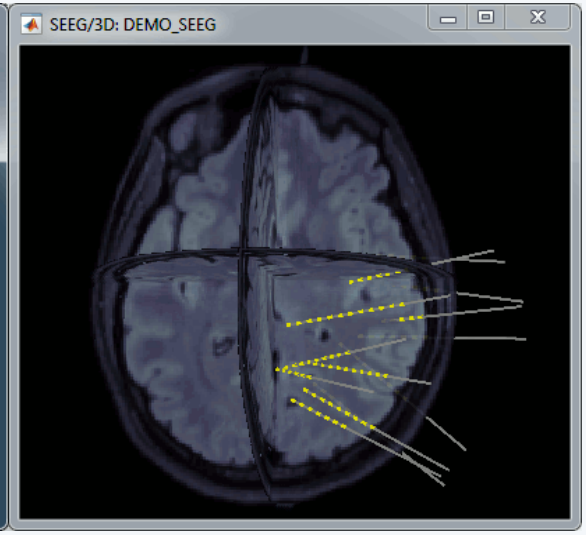


Multi-modal imaging

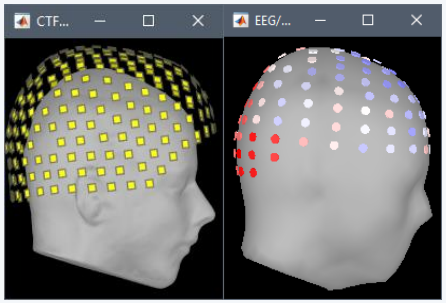
ECoG



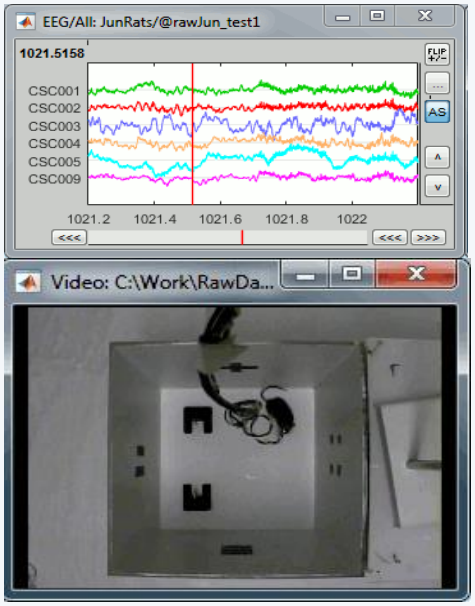
Depth electrodes



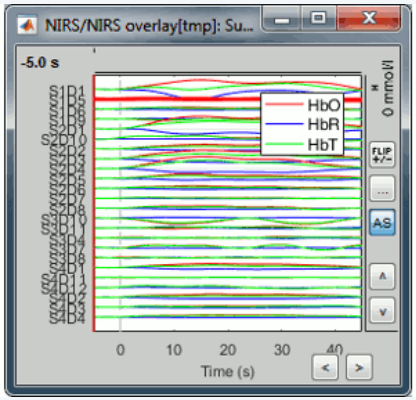
MEG/EEG

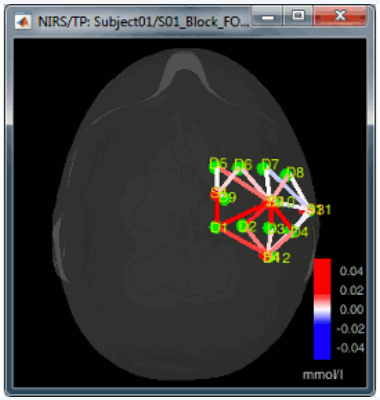


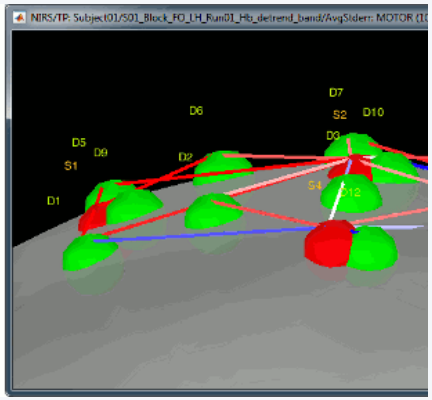
Electrophysiology



fNIRS



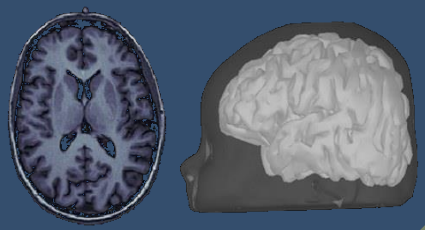




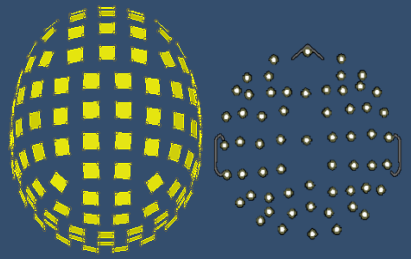
Brainstorm

Workflow

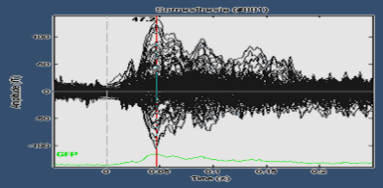
Anatomy



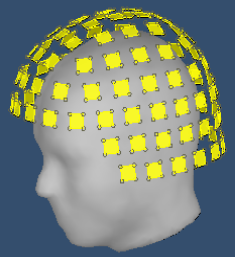
Sensors



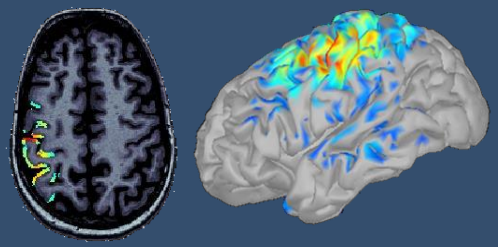
EEG/MEG



Co-registration



Source estimation



Analysis

Averages
Contrasts
Group analysis
Time-frequency
Connectivity

Import

Anatomy
Link recordings
MRI registration

PSD
Filters
Bad channels
Artifacts
Correction
Bad segments

Markers
Epoching
Averaging
Sources
Time-frequency

- One-click import of the T1 segmentation: FreeSurfer, CAT12, BrainSuite, BrainVISA, SimNIBS
- Full integration for running CAT12 and SimNIBS

Brainstorm

Import

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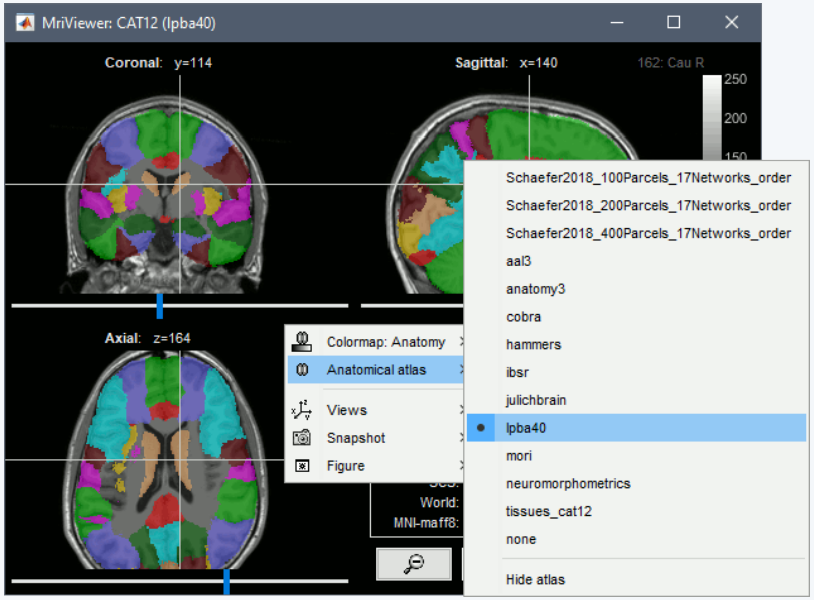
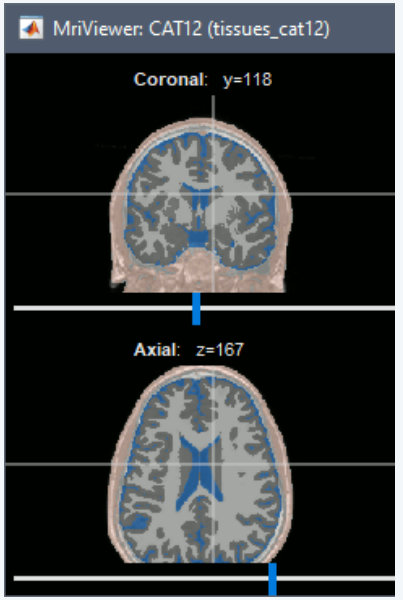
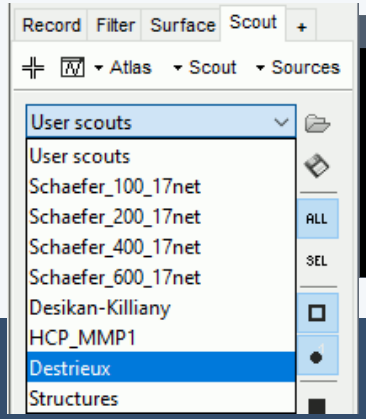
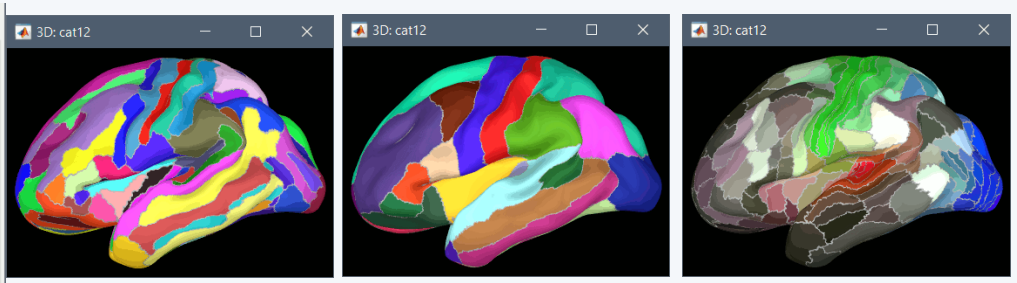
Sources
Time-frequency

- Anatomical parcellations: Volume and surface
- MNI normalization: linear and non-linear (SPM12)



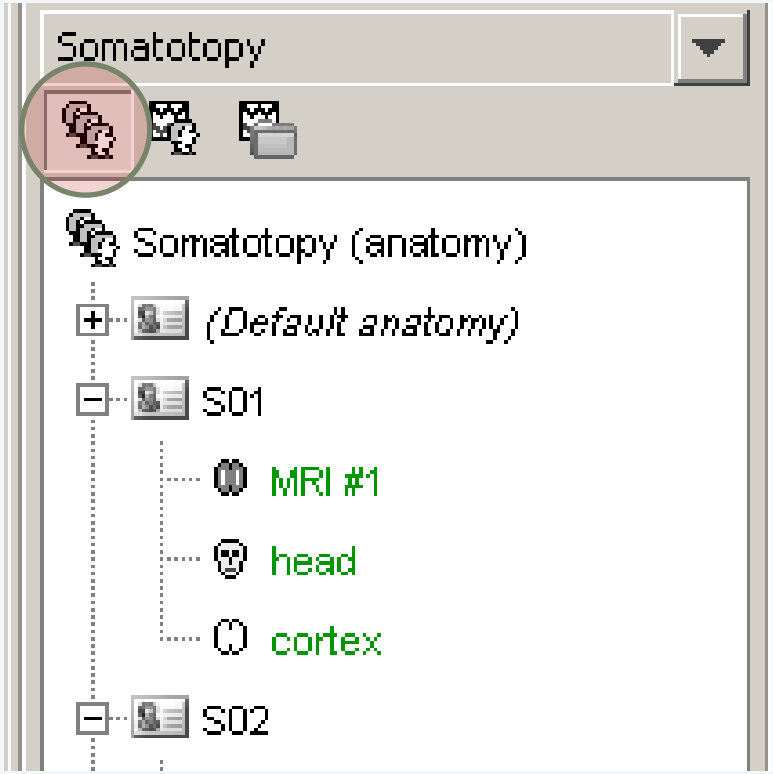


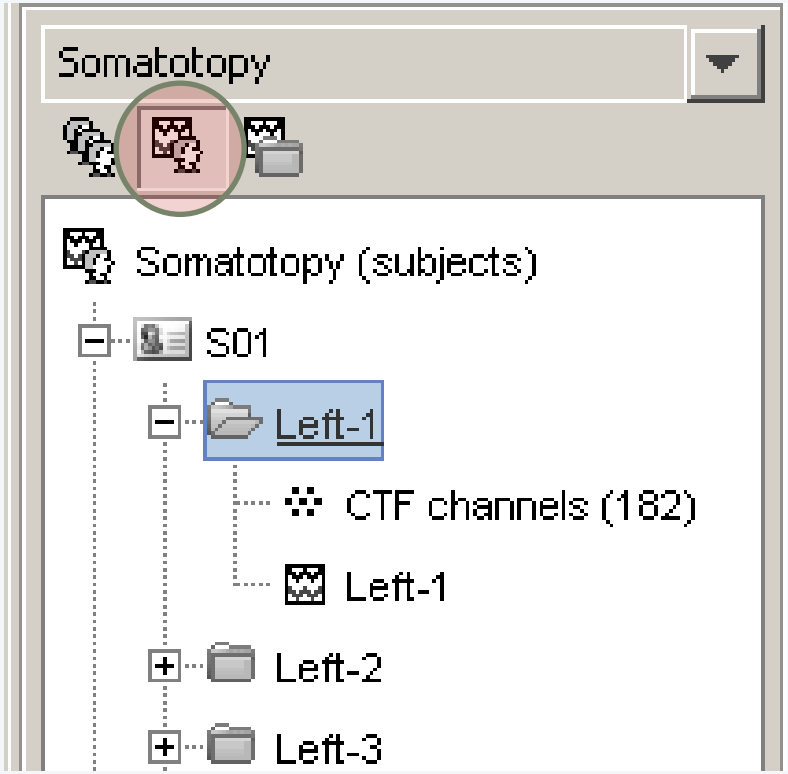




Brainstorm

Database



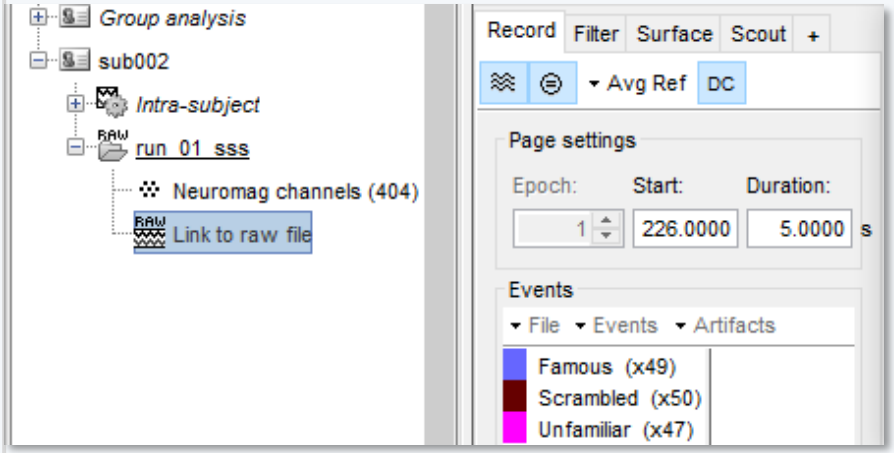


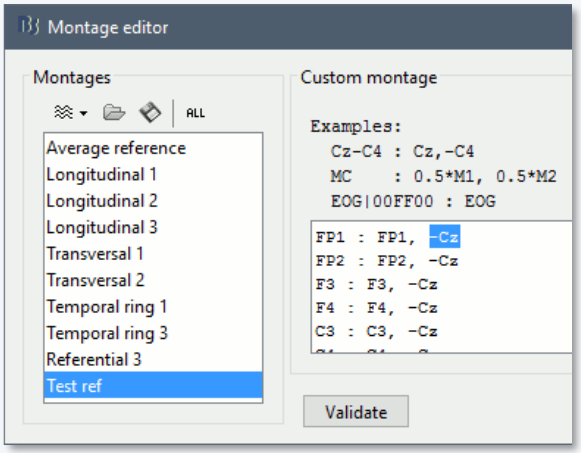
- Three levels:
  - Protocol
  - Subject
  - Condition

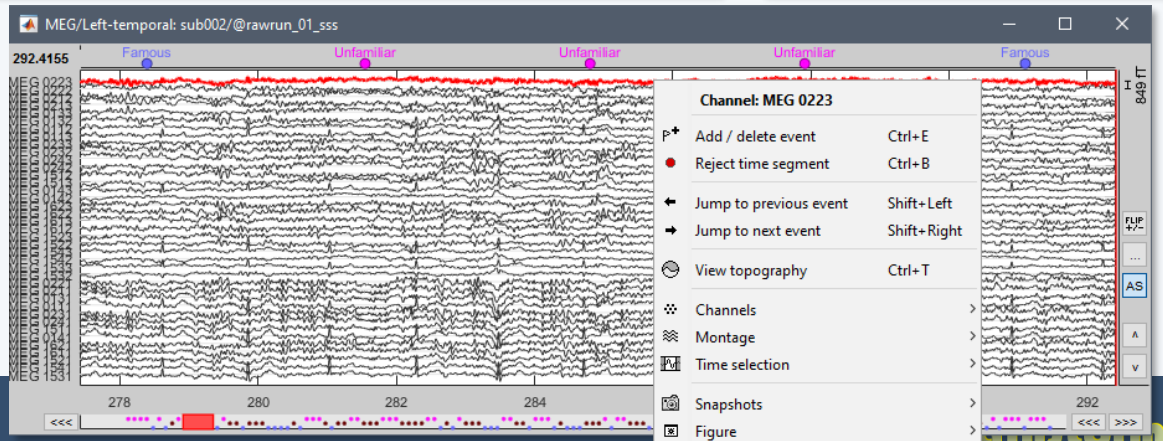
- Popup menus
- All files saved in Matlab .mat
- Same architecture on the disk

Import

- Original files linked to the database (no copy)
- Rich data viewer with flexible montage editor
- Optimized reading functions







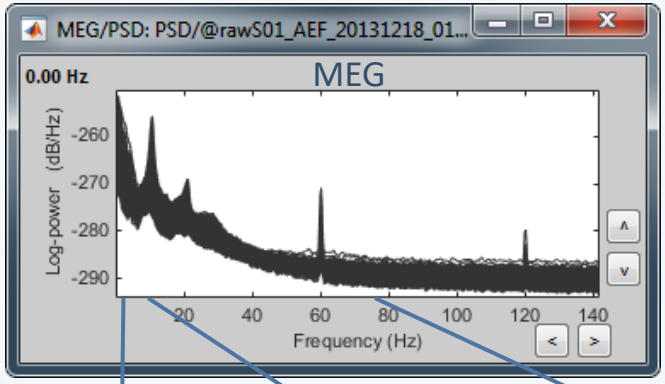
Quality control

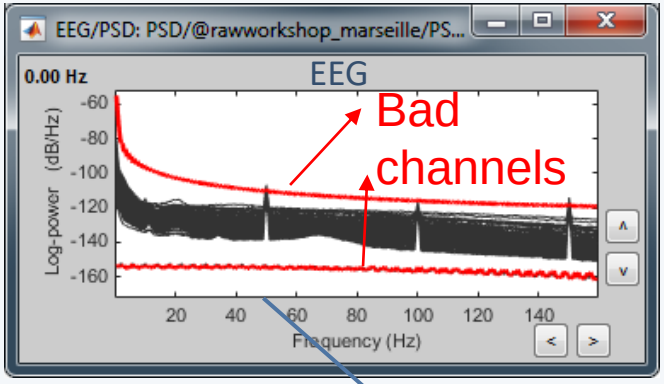
Anatomy
Link recordings
MRI registration

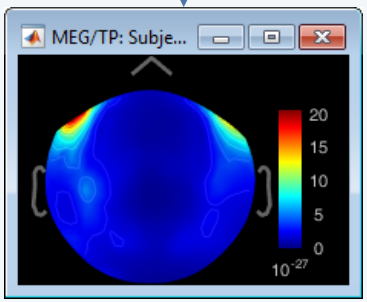
PSD
Filters
Bad channels
Artifacts
Correction
Bad segments

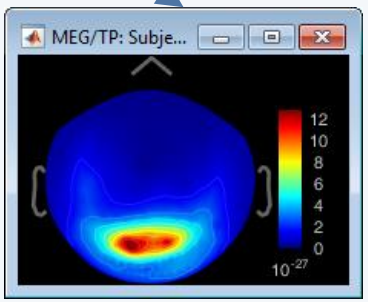
Markers
Epoching
Averaging
Sources
Time-frequency

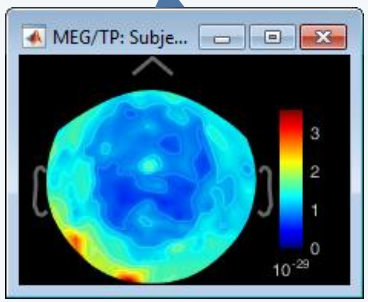
- Power spectrum density for quality control

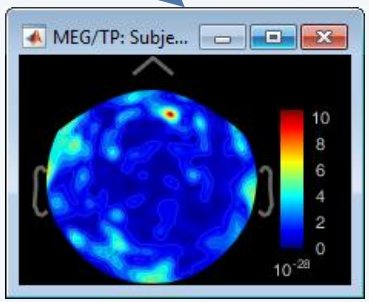












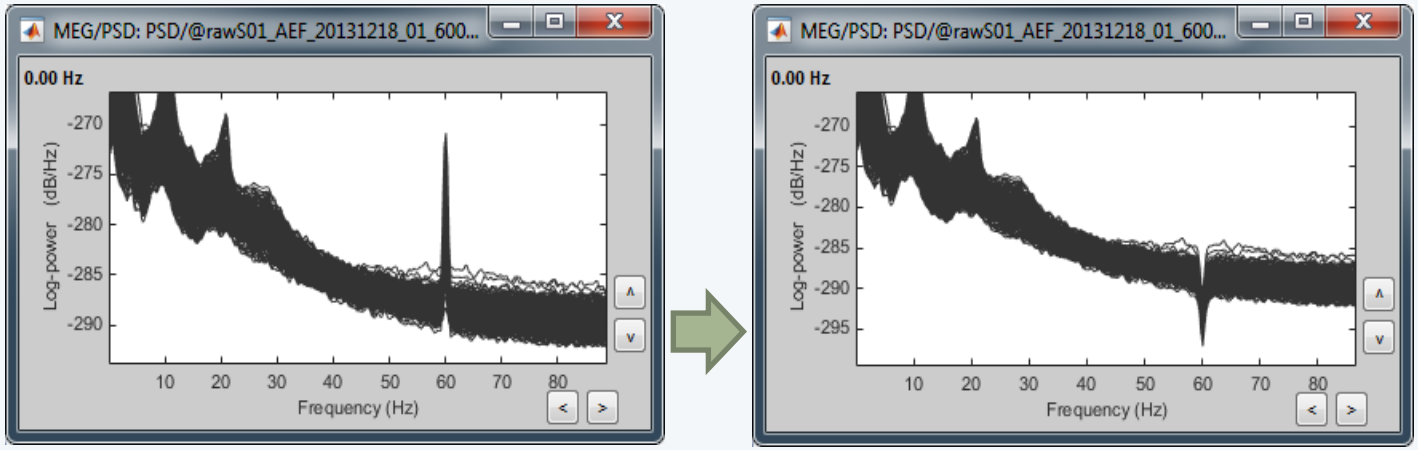
< 3Hz: Eyes | 10Hz: Alpha | > 40Hz: Muscle | 50/60Hz

Brainstorm

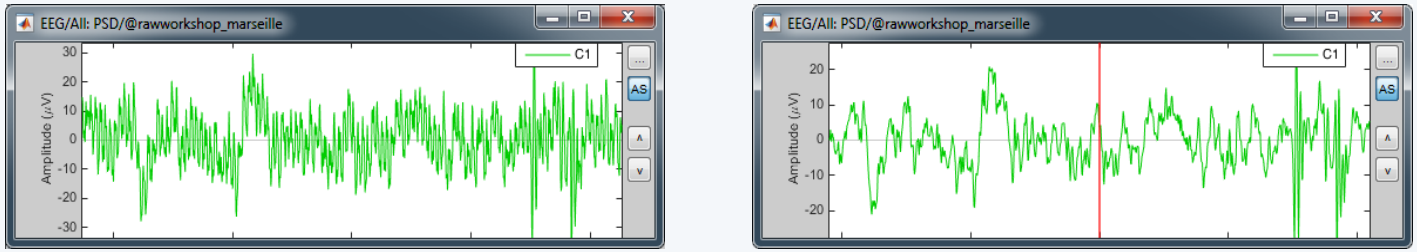
Pre-processing

- Notch filter: Removes 50Hz/60Hz power line noise (and harmonics)

PSD

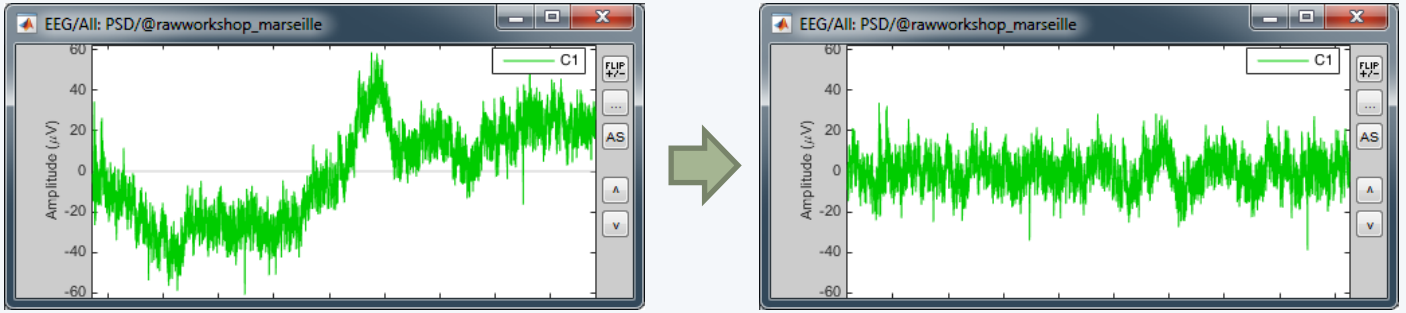


Signal

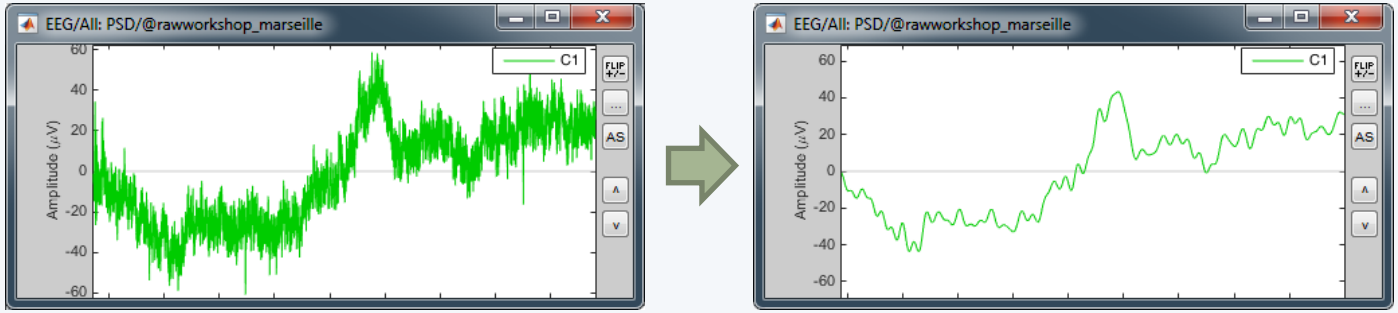


Pre-processing

- High-pass filter: Removes slow components (eye movements, breathing, sensor drifts…)

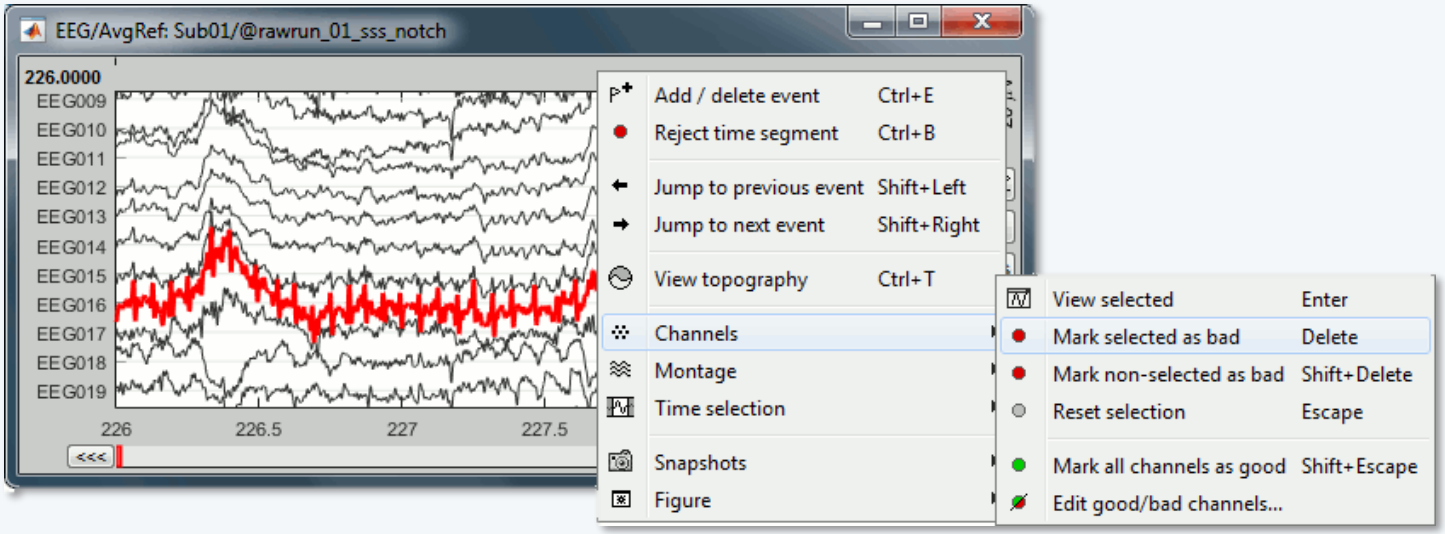


- Low-pass filter: Remove high-frequencies



Pre-processing

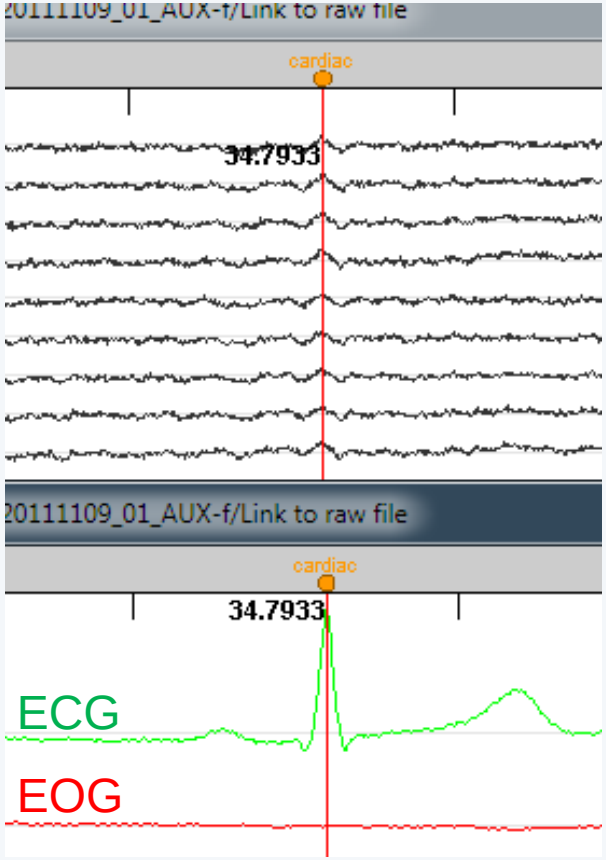
- Manual inspection of the recordings
- Interactive selection of bad channels
- Re-reference the EEG if necessary

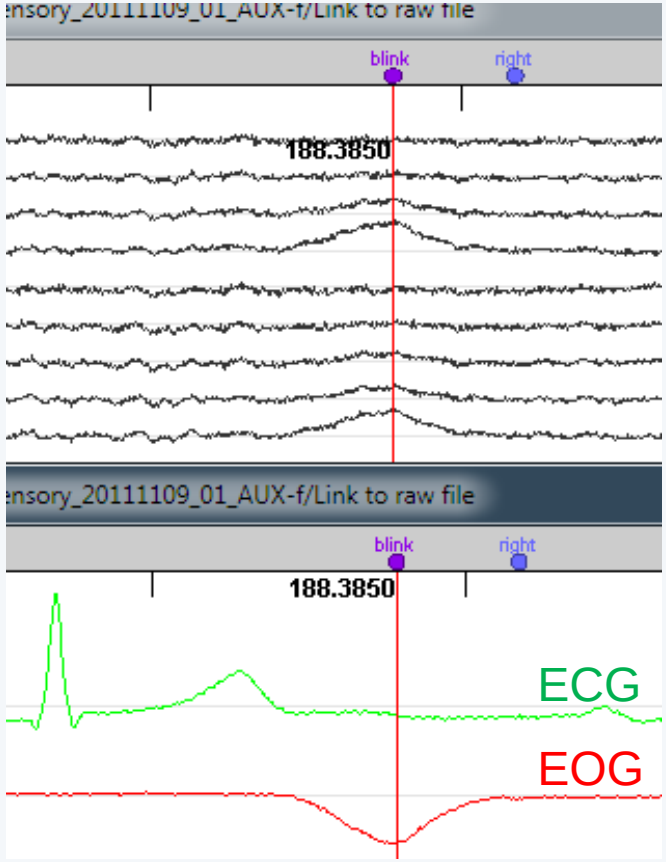


Brainstorm

Pre-processing

- Automatic detection of blinks and heartbeats (peak detection, or explicit amplitude threshold)

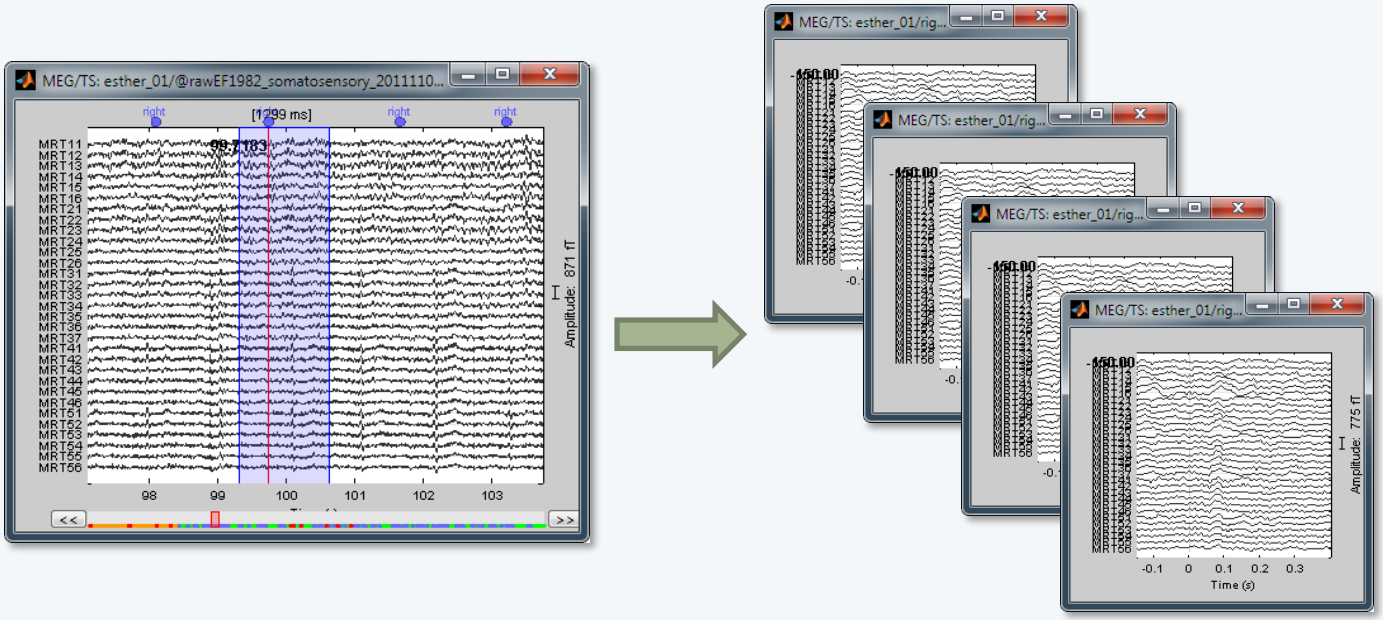




Brainstorm

Epoching

- Epochs = Trials = Short blocks of recordings around an event of interest.
- Epoching = Extracting epochs from the continuous recordings and saving them.

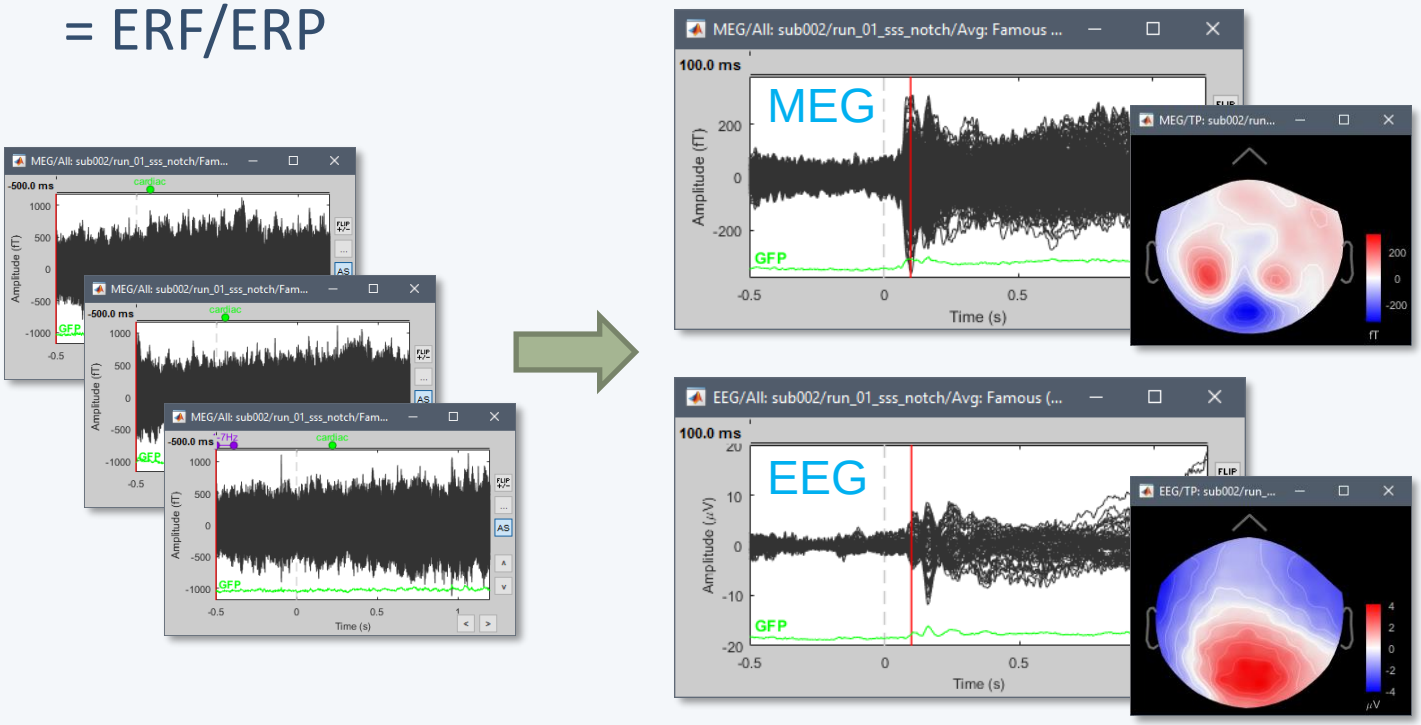


Brainstorm

Single subject

- Averaging the trials: Reveals the features of the signals that are locked in time to a given event

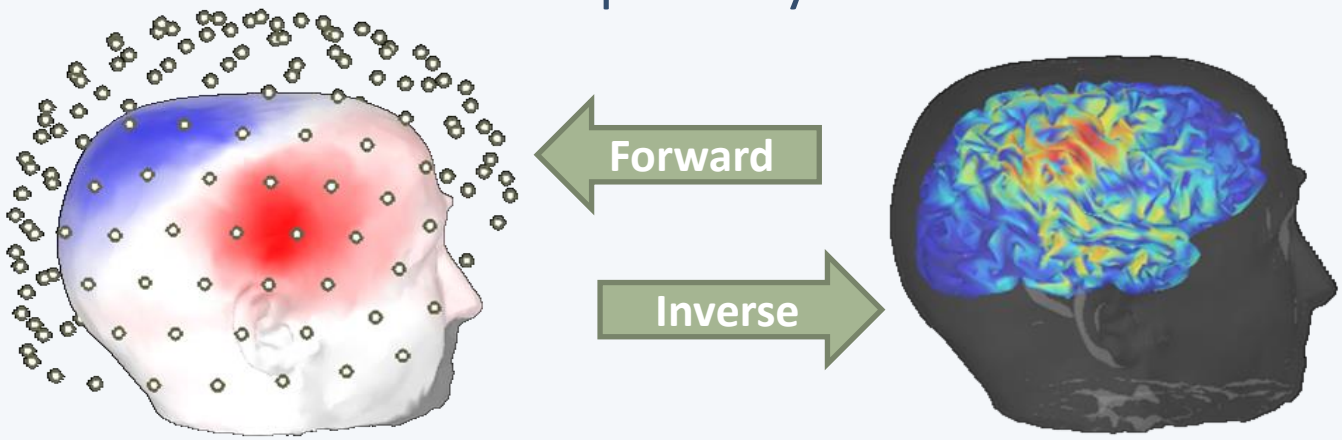
  = Event-related field / potential
  = Evoked response
  = ERF/ERP



Brainstorm

Single subject

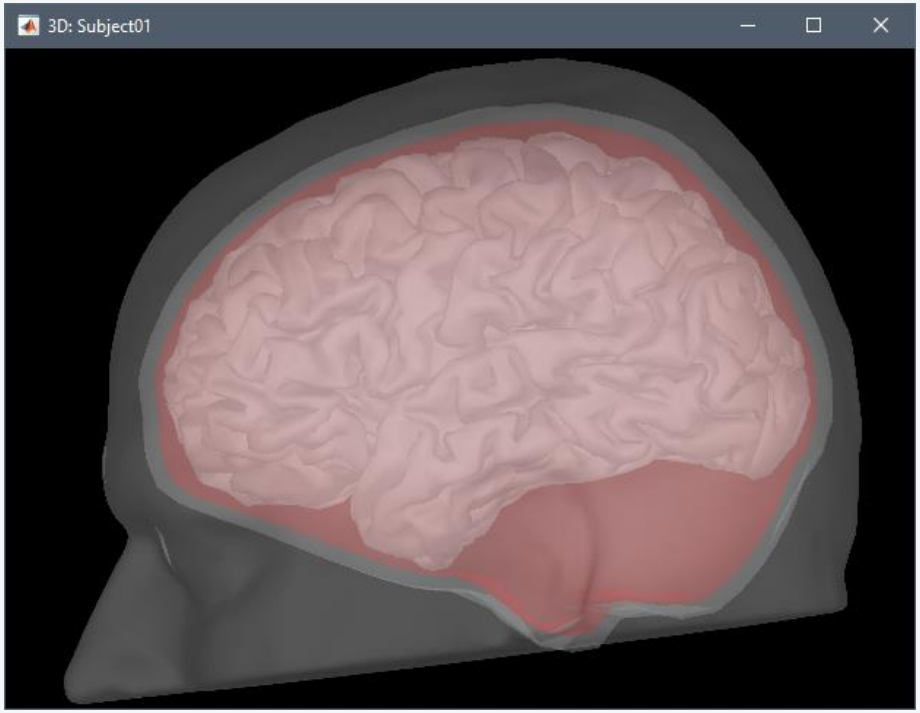
- Source space: Cortex or full head volume
- Forward model: Overlapping spheres (MEG)
  OpenMEEG BEM (EEG)
  DUNEuro FEM
- Inverse model: **Minimum norm estimates**
  Beamformers
  Separately for MEG and EEG

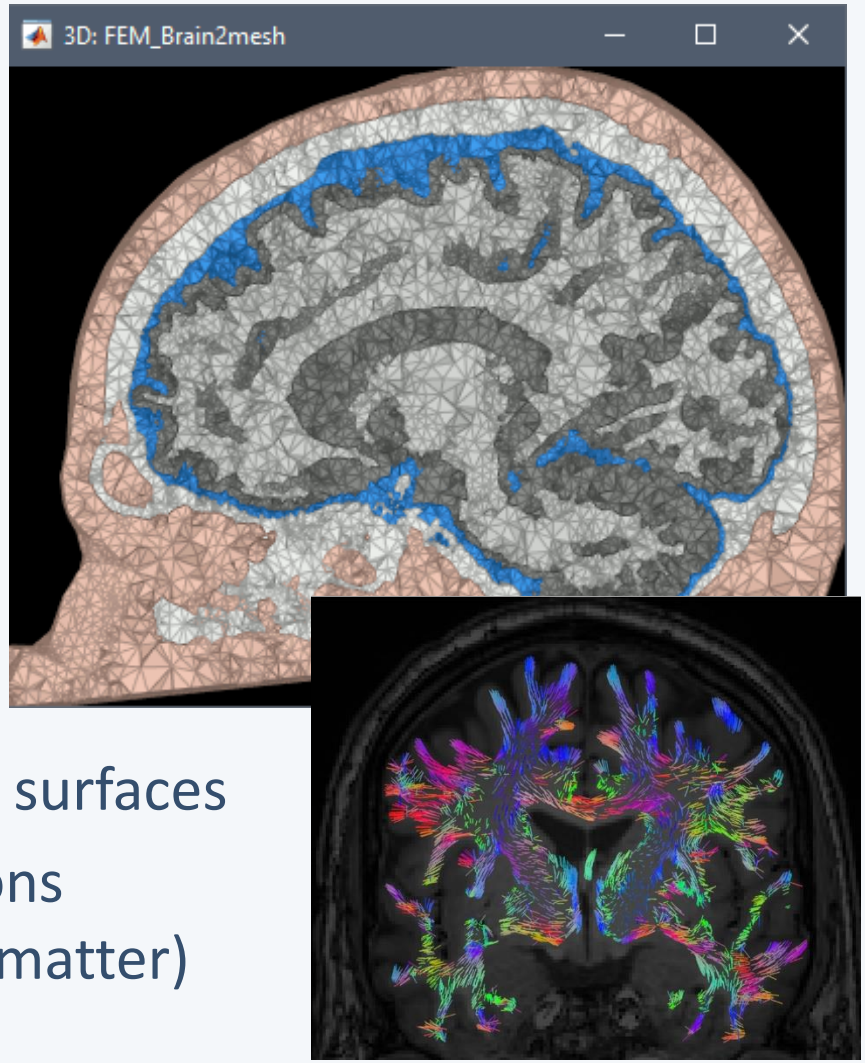


Sensor space *Source space*

Brainstorm

Forward modelling





BEM: Tissue boundaries = triangular surfaces

FEM: Volume elements = tetrahedrons
+ anisotropy from DTI (white matter)

Single subject

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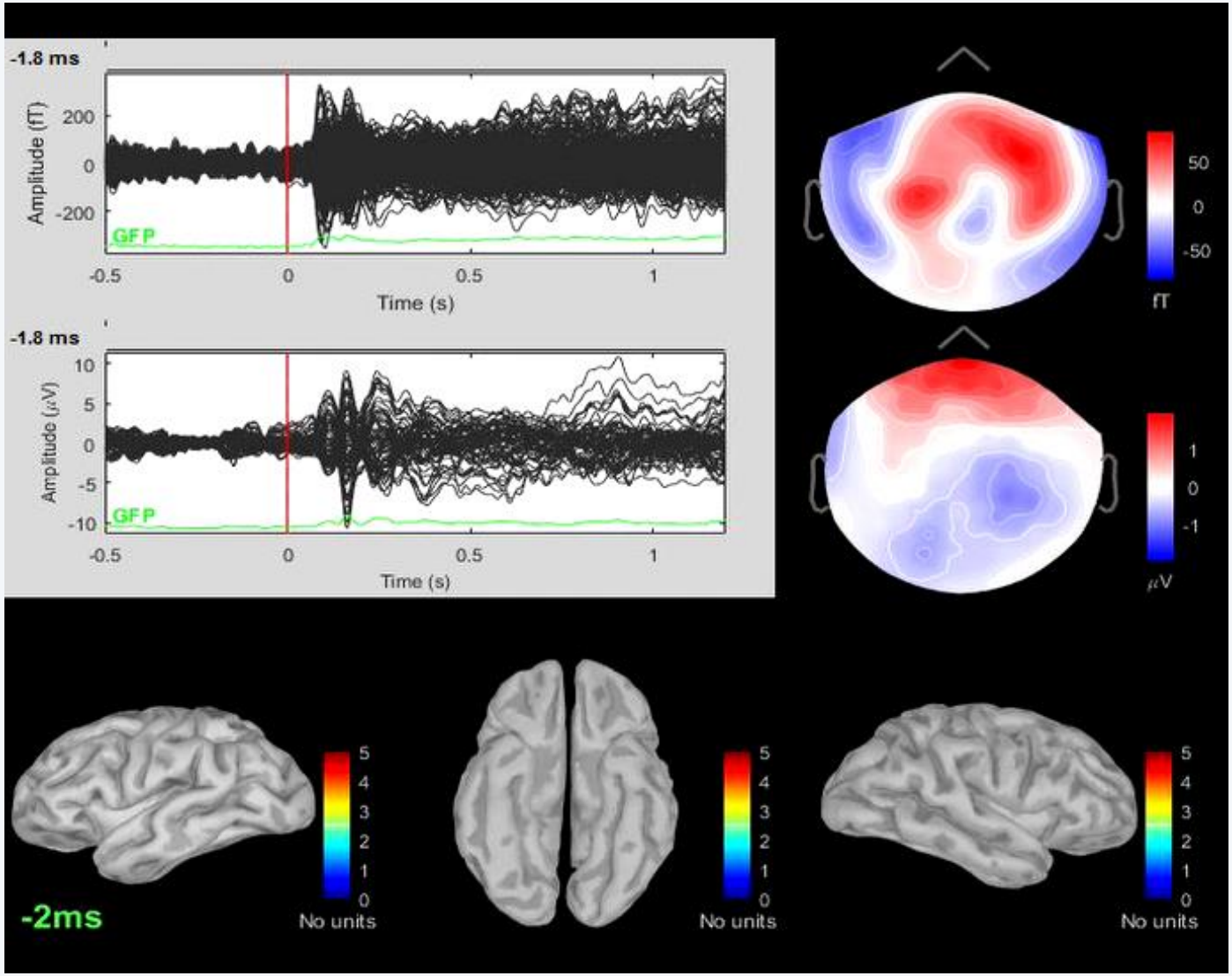
Famous faces



Brainstorm

Single subject

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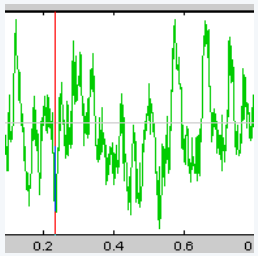
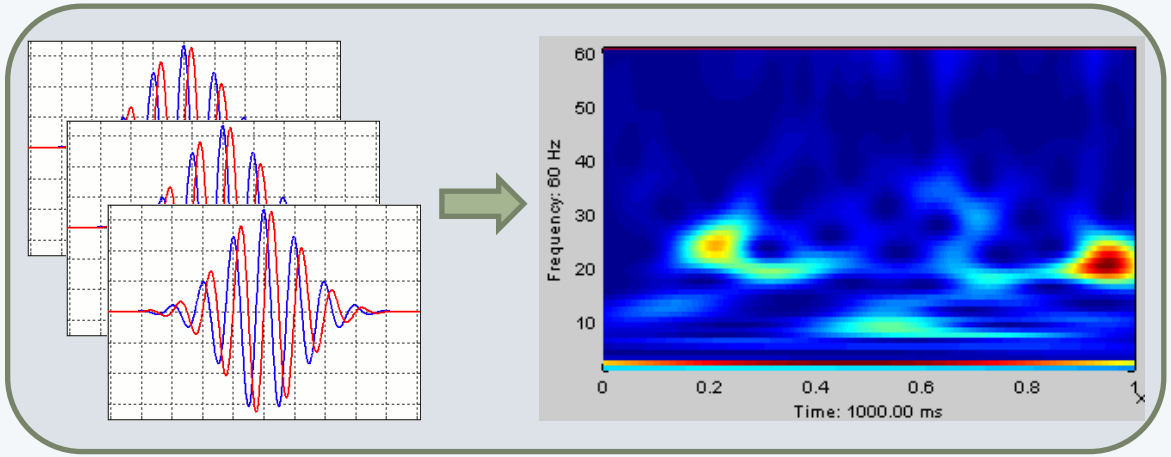
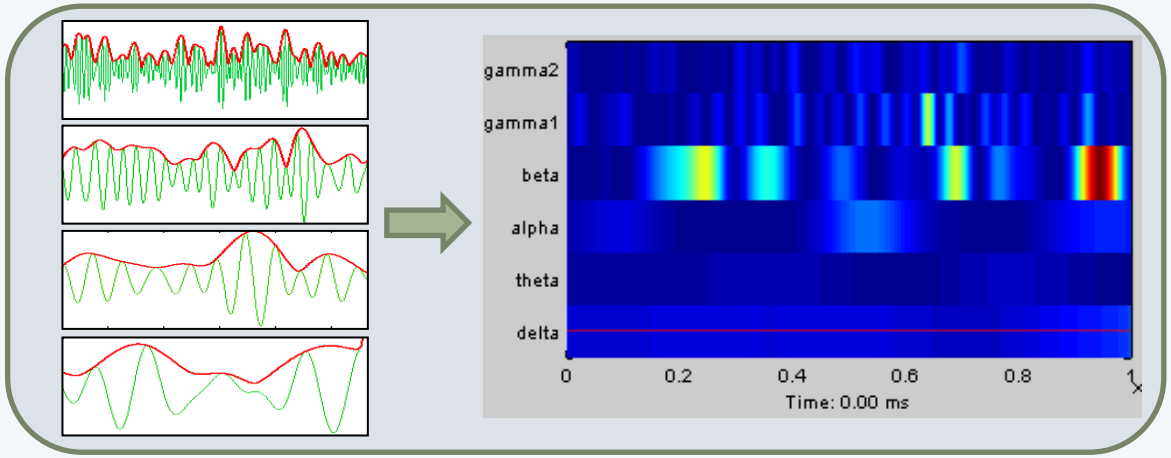
Sources
Time-frequency

Morlet wavelets





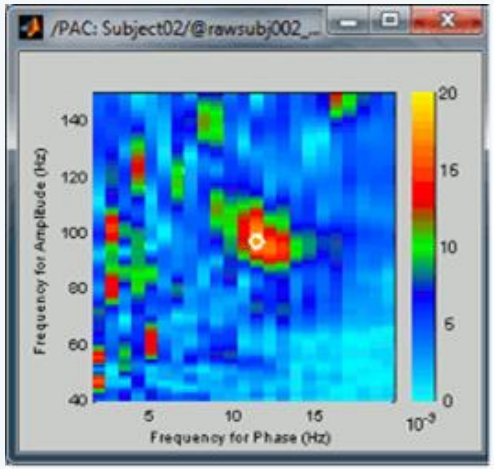
Hilbert transform + band-pass filter

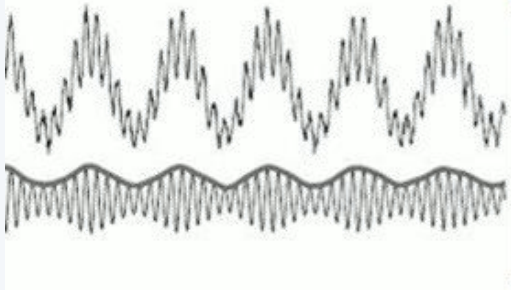


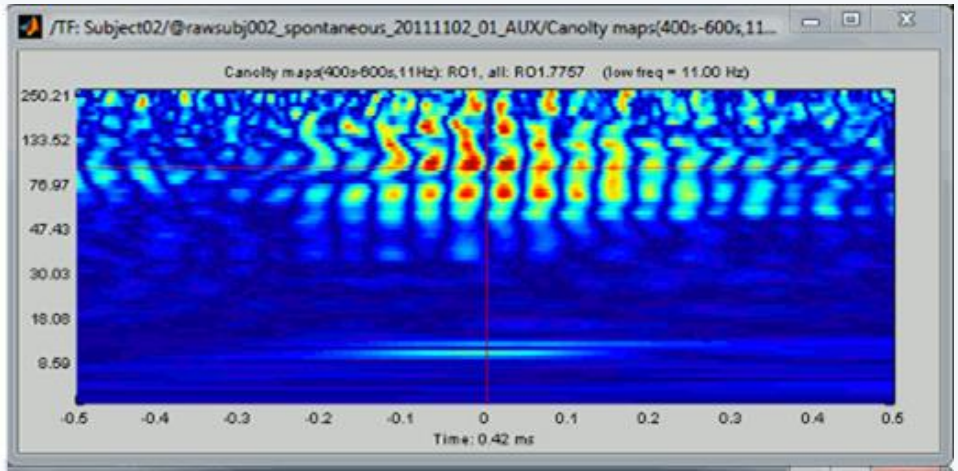
Brainstorm

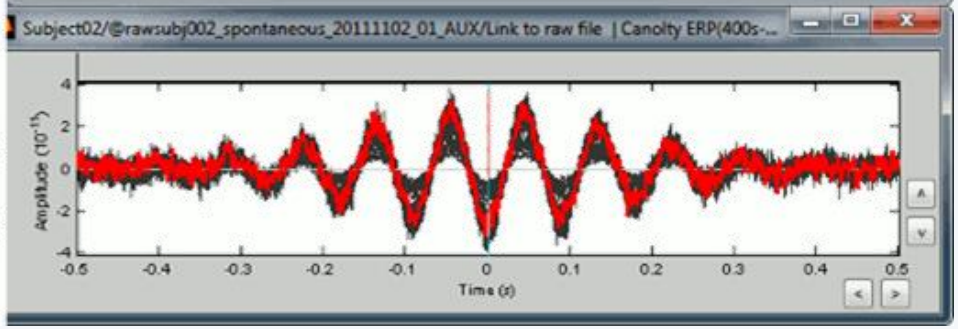
Single subject

- Phase-amplitude coupling





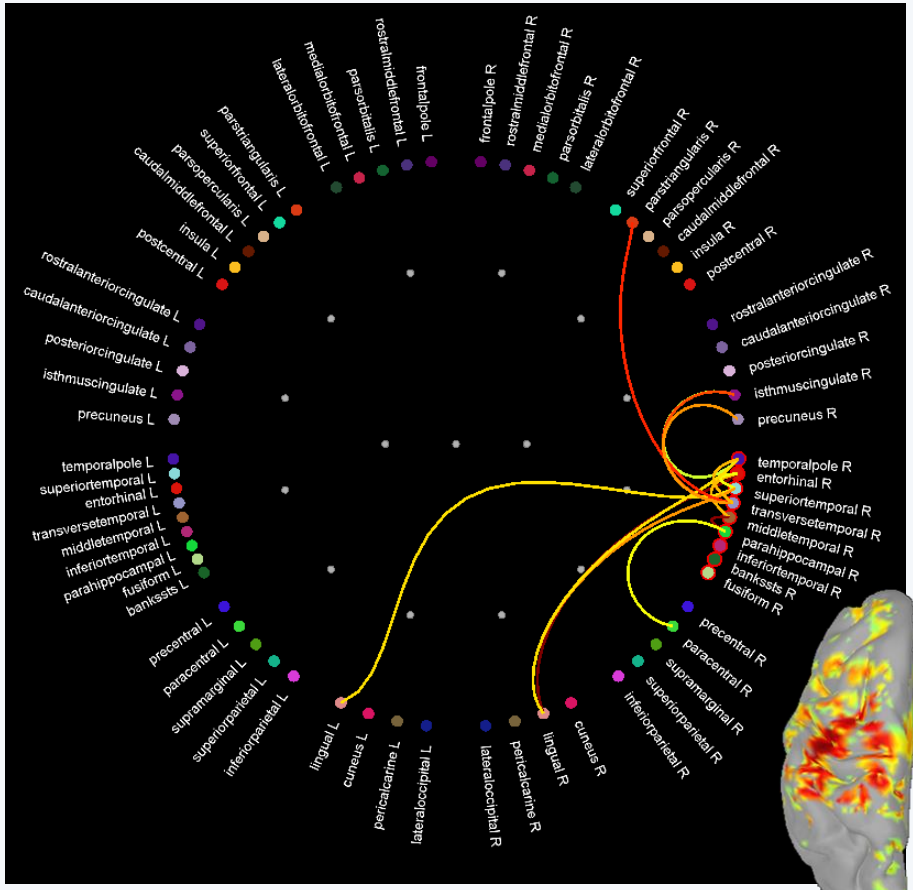




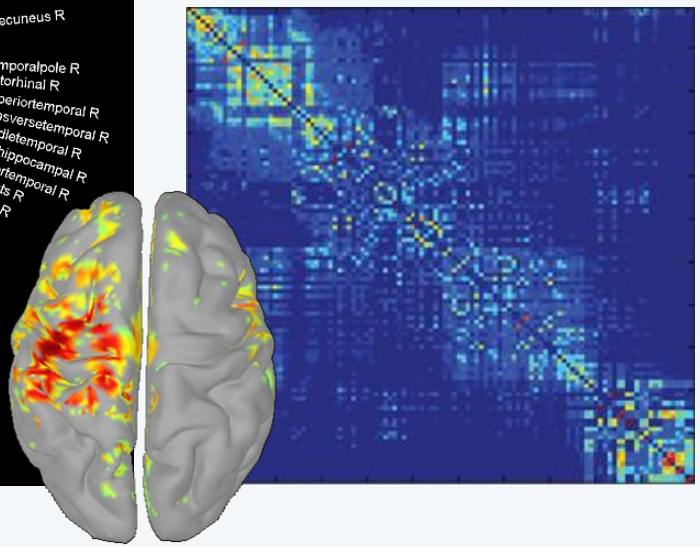
Brainstorm

Single subject

- Connectivity measures



- Correlation
- Coherence
- Phase locking value
- Granger causality
- Envelope correlation
- …



Brainstorm

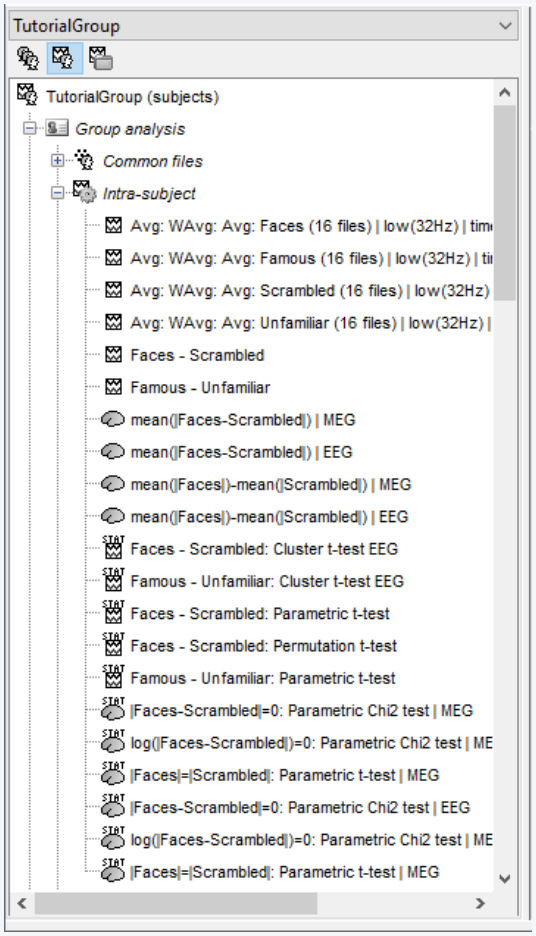
Group analysis

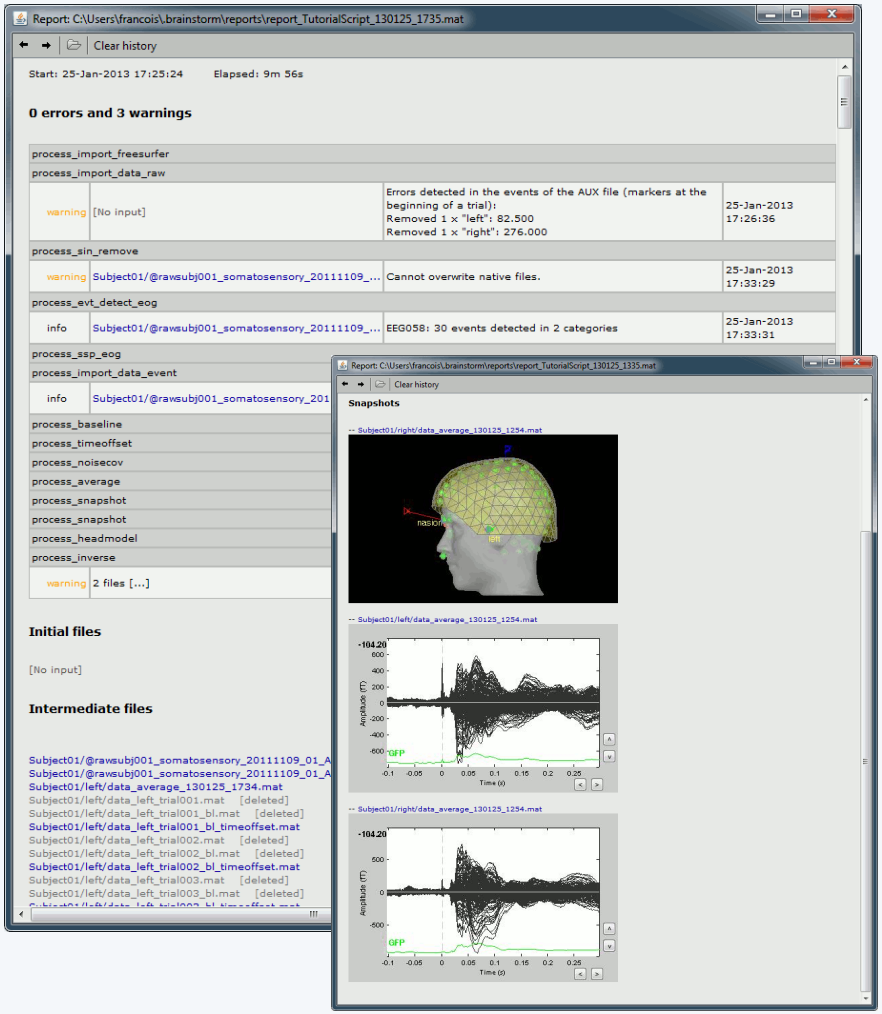
Subject averages
Low-pass
Normalize
Project

Group averages
Group statistics

Quality control
Workflow

- Execution reports with snapshots saved in HTML



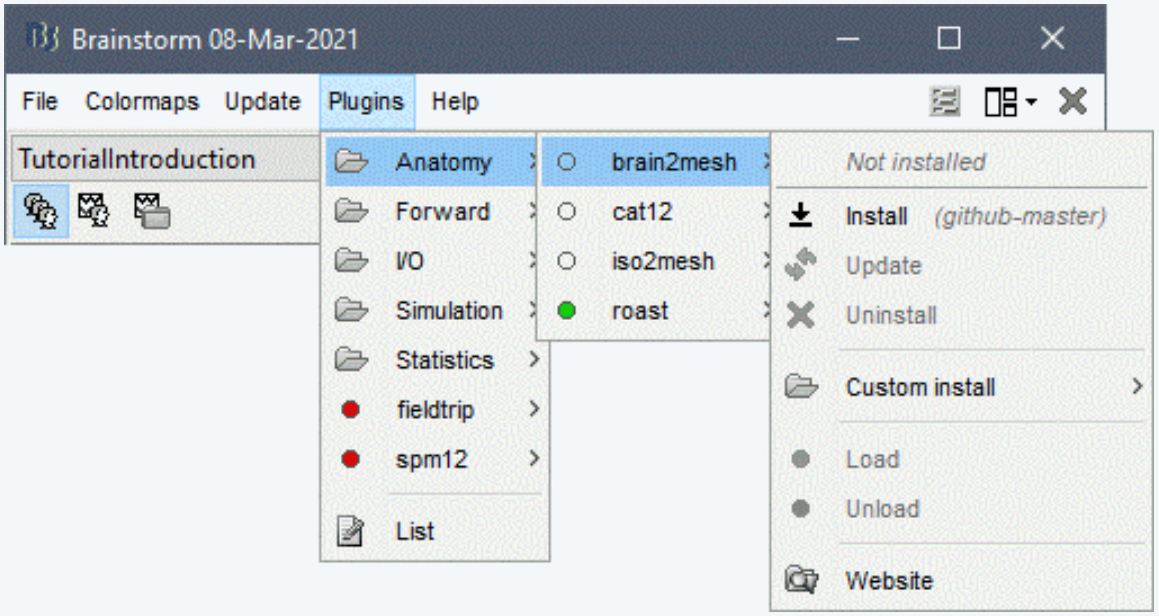


Brainstorm

Add your code to Brainstorm

- Direct manipulation of the files in Matlab
- Use the menu “Run Matlab command”
- Write a process:
  - Well documented API
  - Lots of example (230 functions written as plugins)
- Examples of recent external contributions:
  - MVPA decoding (Oliva, MIT)
  - Microstate segmentation (Cacioppo, UChicago)
  - Eyetracker/EEG synchronization (Uni Freiburg)

Plugin manager



I/O:

Philips-EGI EEG

Blackrock NeuroPort

AD Instruments SDK

Neurodata Without Borders

Tucker-Davis Technologies

Generic:

SPM12, FieldTrip

Anatomy:

CAT12, Brain2Mesh, Iso2Mesh, ROAST

Forward modeling:

OpenMEEG, DUNEuro

Simulation:

SimMEEG

Statistics:

LibSVM

fNIRS:

NIRSTORM

User community

- 32,000 users registered on the website

Find users next to you

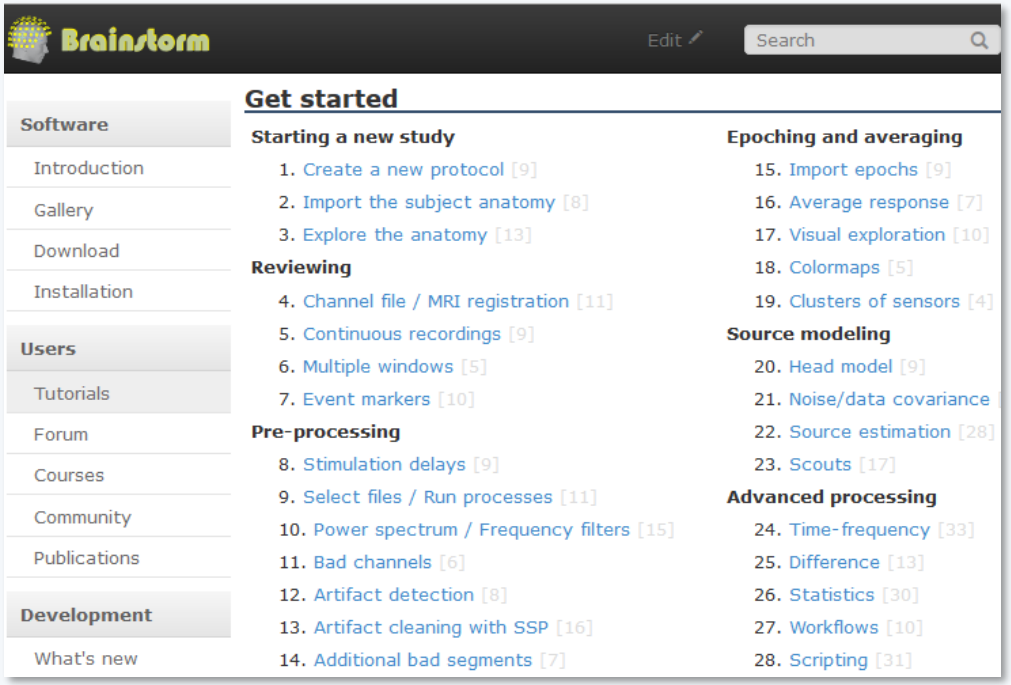
Location: montreal

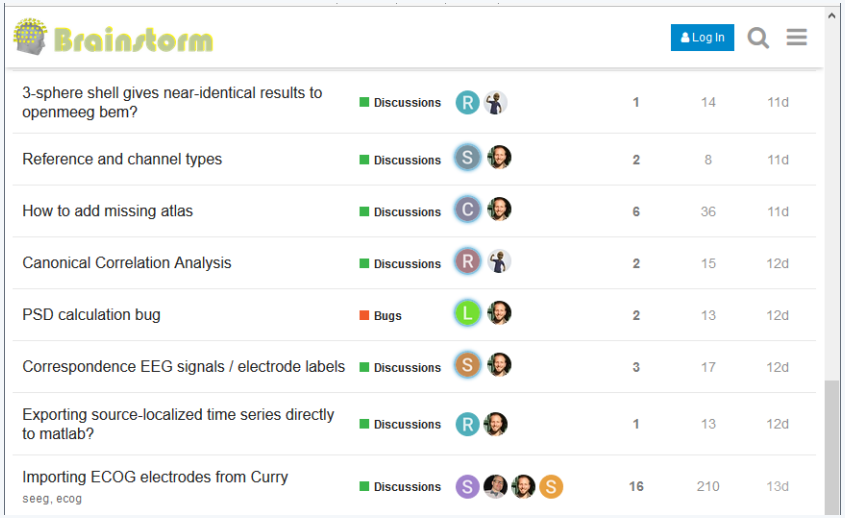
josieannebertrand	UQAM, Montreal	EEG	post-doc	2013
timothynest	Montreal, McGill	MEG, fNIRs	research	2013
Clara Moreau	Montreal	MEG	stagiare	2013

Brainstorm

User support

- Online tutorials: 30-hour self-training program
- Active user forum: 800 posts/month
- Daily updates: 1500 downloads/month





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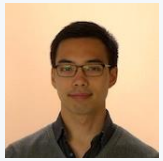
Soheila Samiee
PhD student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NIRSTORM


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Concordia


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Concordia

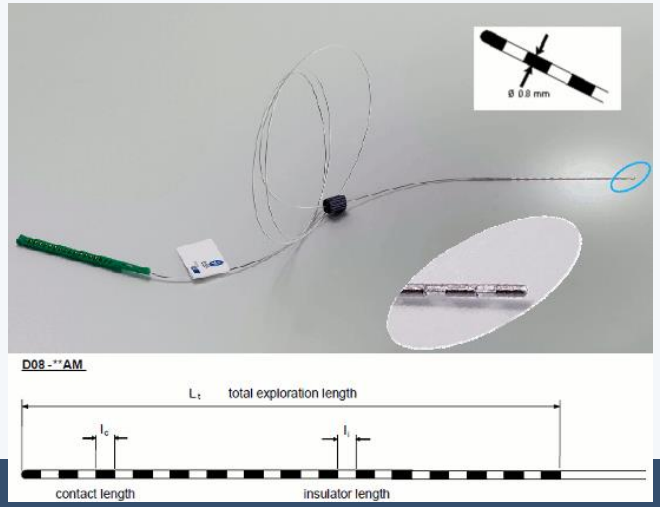
Sample data

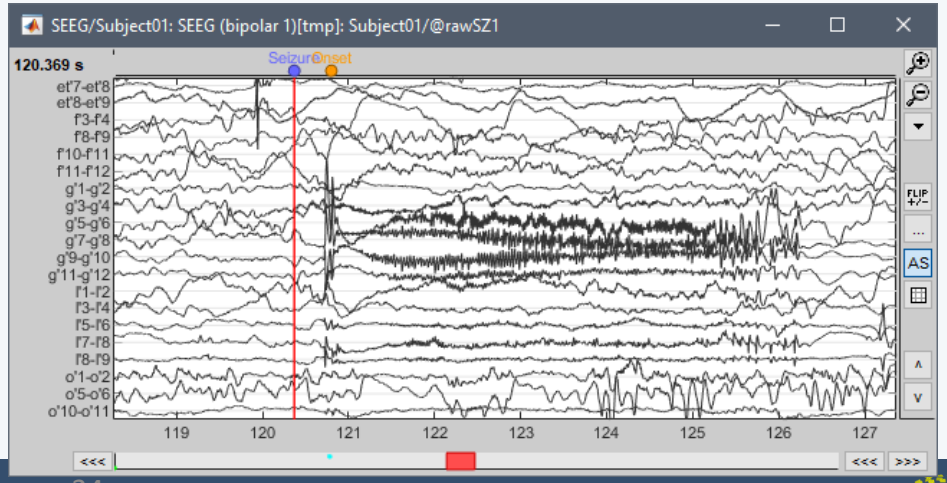
TODAY

Sample data

Epilepsy recordings:

- Patient recorded at the Grenoble University Hospital
- Focal epilepsy of the left temporo-occipital junction, MRI-negative, implanted in the surrounding areas
- Depth electrodes: DIXI D08-**AM Microdeep (8-18 contacts)
- Recorded with a Micromed system at 512Hz
- 4 minutes of recordings with one generalized seizure



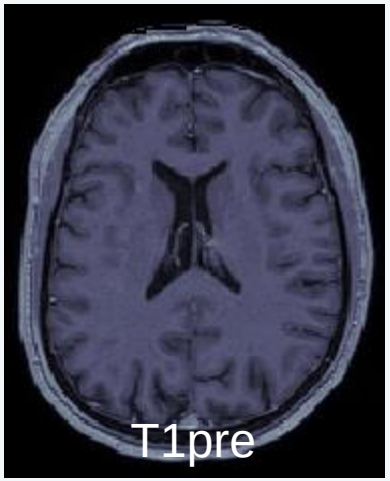


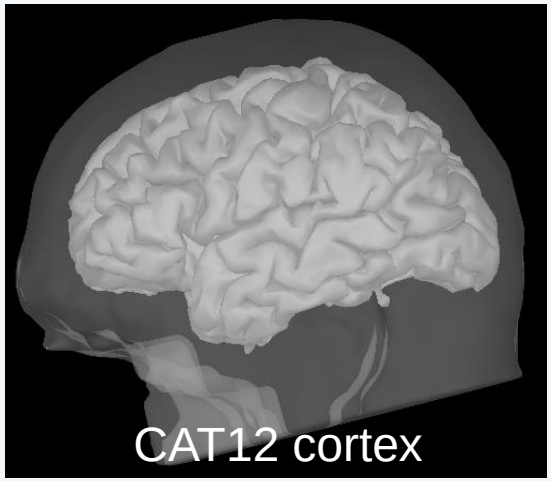
Brainstorm

Sample data

Patient anatomy:

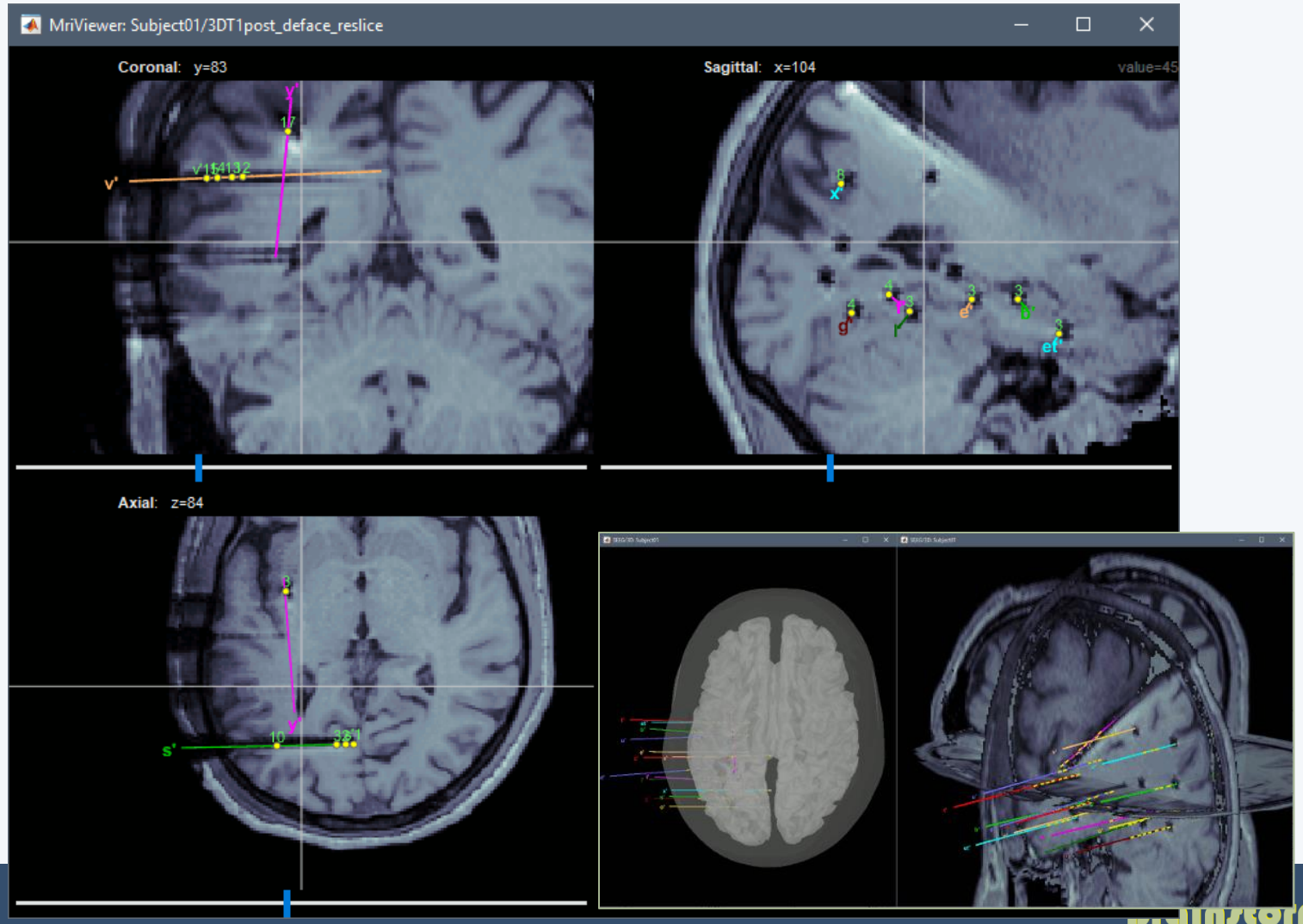
- T1 MRI pre-implantation, processed with CAT12 (r12.8)
- T1 MRI post-implantation
  - Registered on the pre-implantation image with SPM
  - Used to get 3D positions for the SEEG contacts





Sample data

SEEG electrodes marked in the T1post:

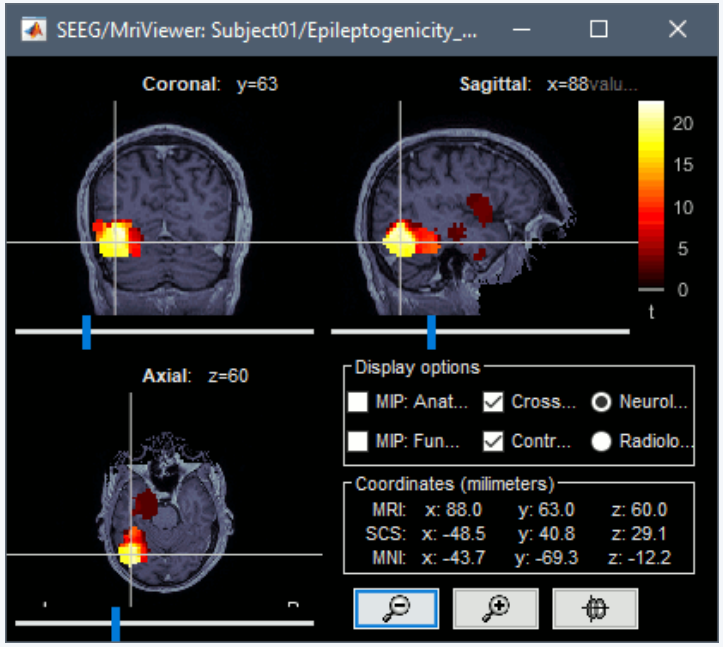


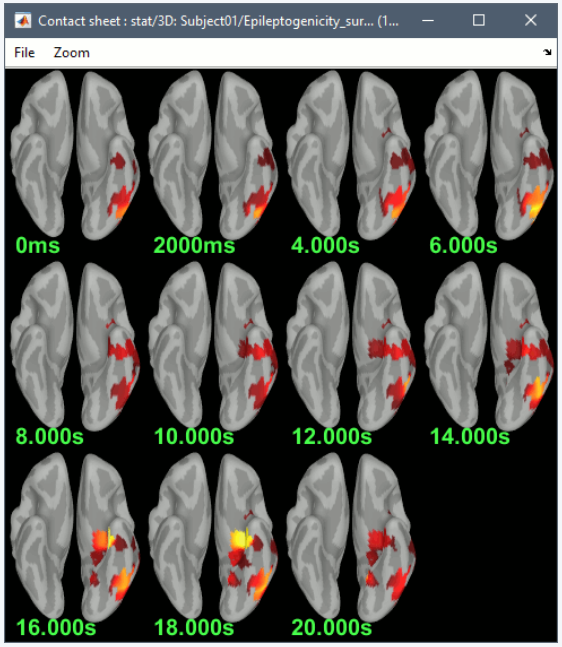
Sample data

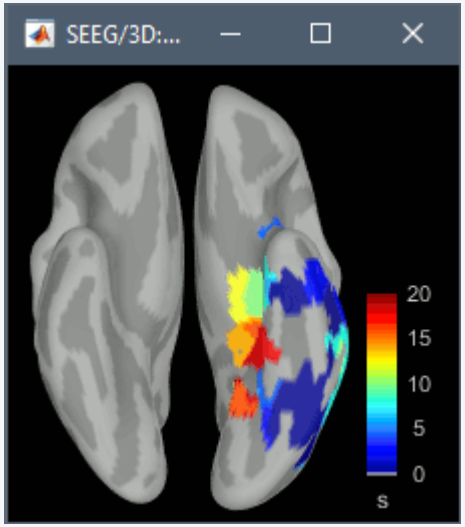
Epileptogenicity maps

David et al., Imaging the seizure onset zone with stereo-electroencephalography, Brain (2011)

- Comparison of HFO power ictal vs. baseline
- Identification of the seizure onset zone
- Estimation of the seizure propagation

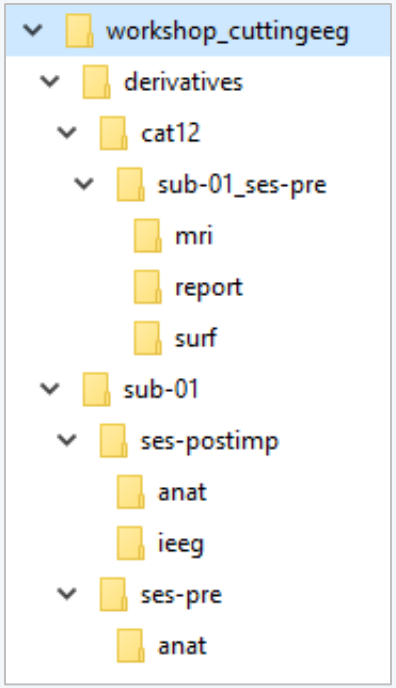


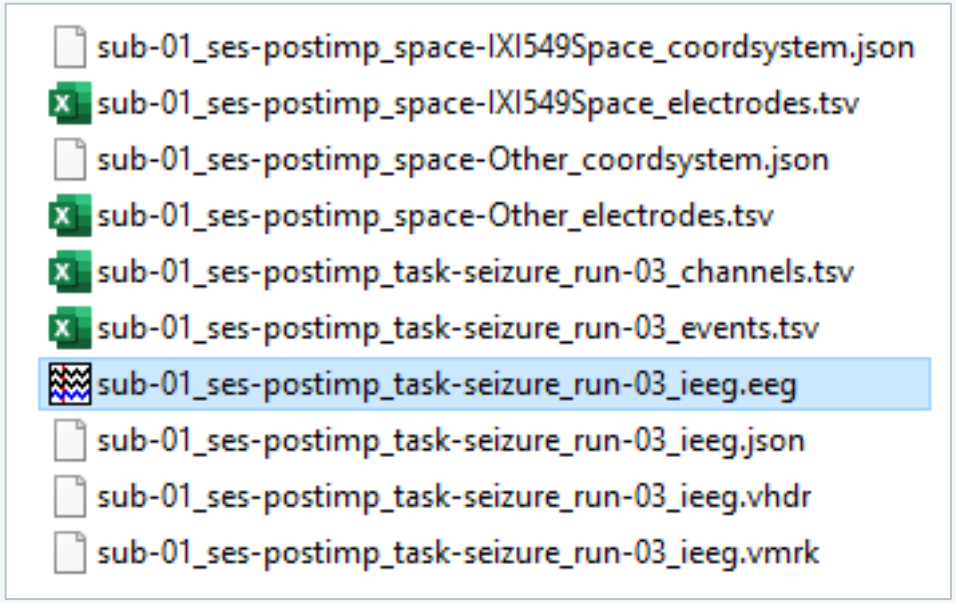




BIDS-iEEG specification

- **(Gorgolewski, 2016)**: The brain imaging data structure, a format for organizing and describing outputs of neuroimaging experiments
- **(Holdgraf, 2019)**: iEEG-BIDS, extending the Brain Imaging Data Structure specification to human intracranial electrophysiology
- https://bids.neuroimaging.io/





Brainstorm