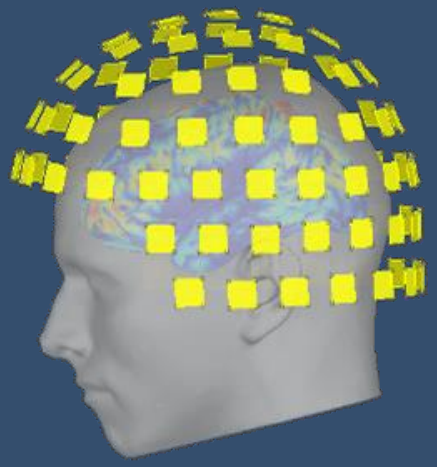
SEEG analysis using

Brainstorm

http://neuroimage.usc.edu/brainstorm



USC UNIVERSITY OF SOUTHERN CALIFORNIA

Cleveland Clinic

McGill

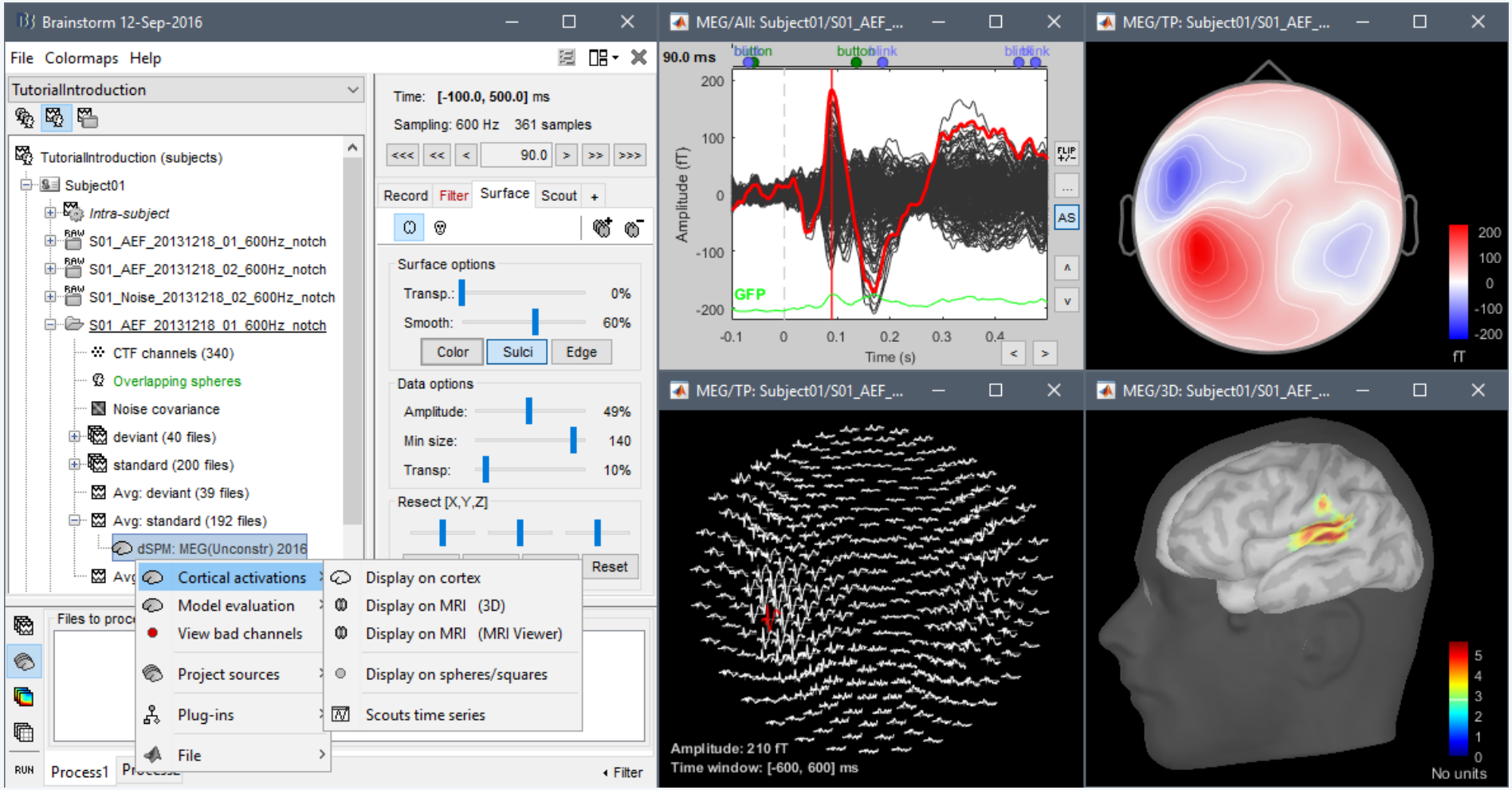
neuro

Paris - July 2018

Francois Tadel

Anne-Sophie Dubarry

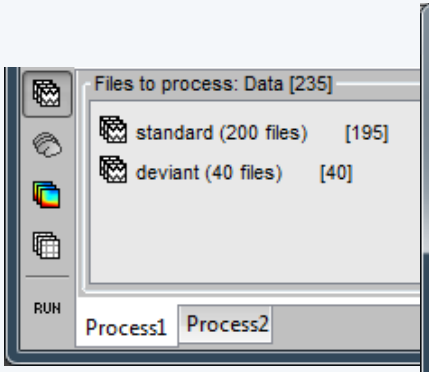
Graphic interface

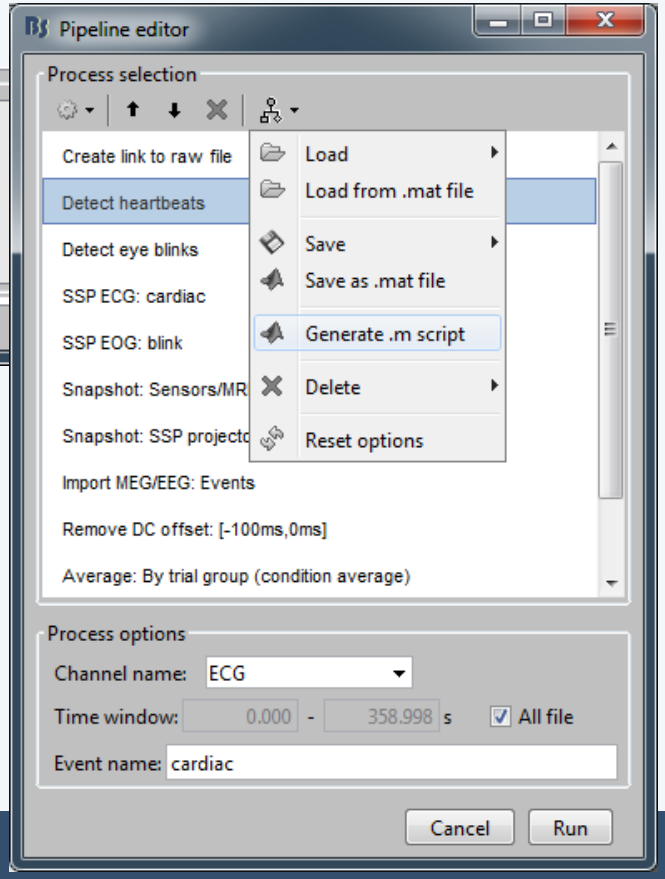


Brainstorm

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);
```

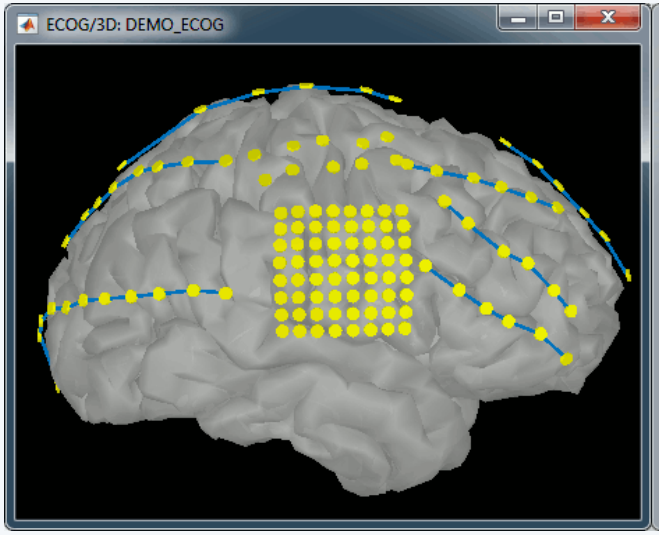
- Free and open-source application
- Matlab & Java: Platform-independent
- Designed for Matlab
- Stand-alone version available
- Interface-based: click, drag, drop
- No programming experience required
- Daily updates of the software
- Supports most common file formats



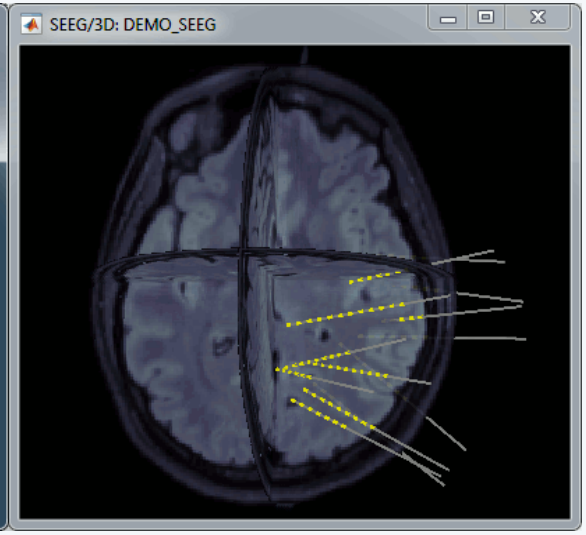


Multi-modal imaging

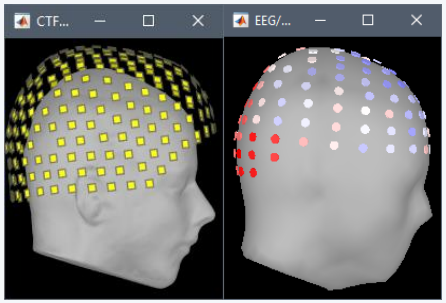
ECoG



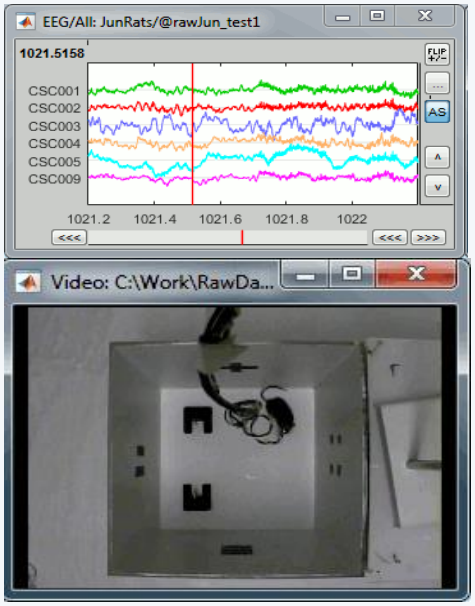
Depth electrodes



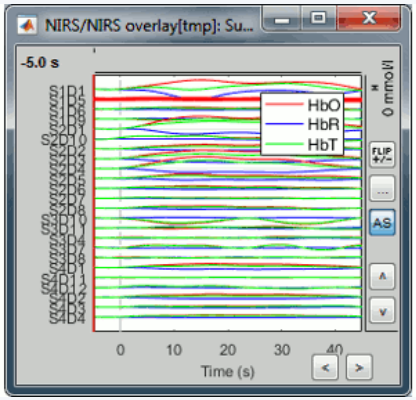
MEG/EEG

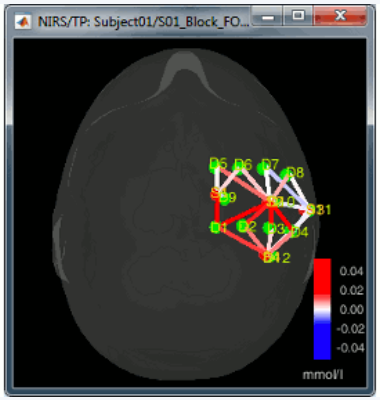


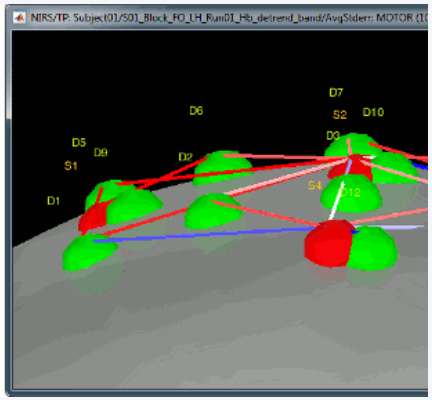
Electrophysiology



fNIRS







Brainstorm

Single subject

Anatomy
Link recordings
MRI registration

Importing

PSD
Filters
Bad channels
Artifacts
Correction
Bad segments

Pre-processing

Markers
Epoching
Averaging
Sources
Time-frequency

Analysis of the experimental data

Loop:
all acquisition runs
all subjects

Import

Anatomy
Link recordings
MRI registration

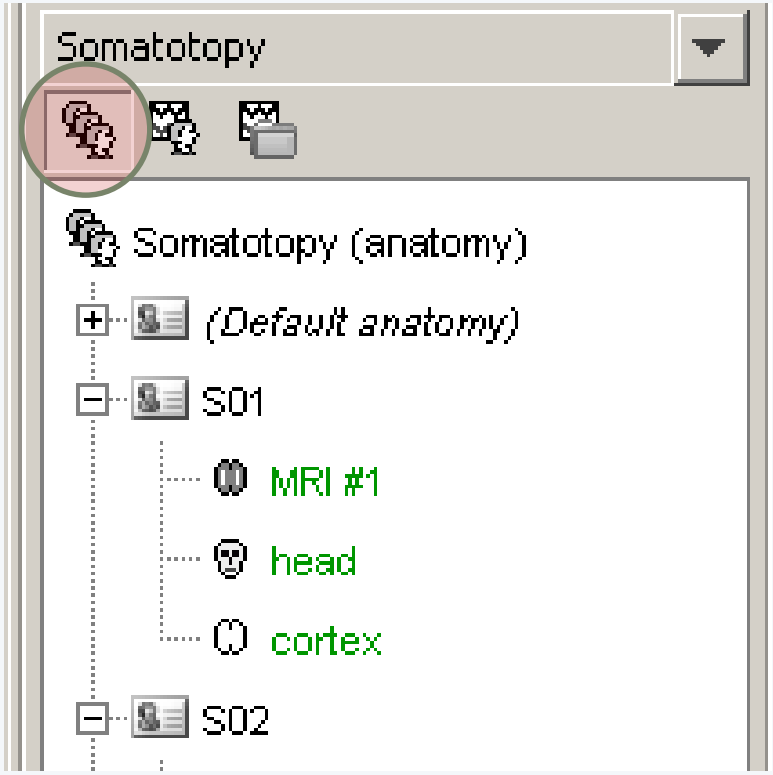
PSD
Filters
Bad channels
Artifacts
Correction
Bad segments

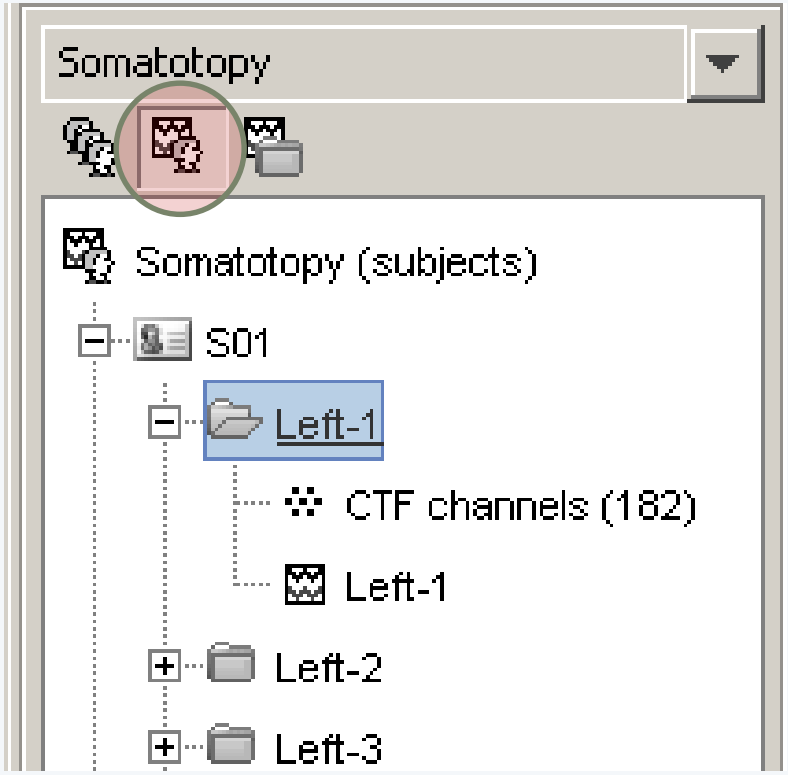
Markers
Epoching
Averaging
Sources
Time-frequency

- One-click import of the T1 segmentation: FreeSurfer, BrainSuite, BrainVISA, CIVET
- Import and place fiducials in the MRI (N,L,R)

Brainstorm

Database



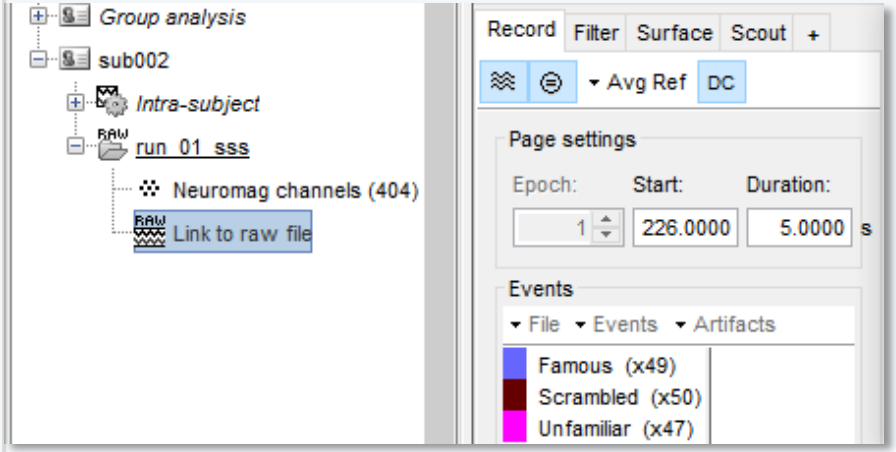


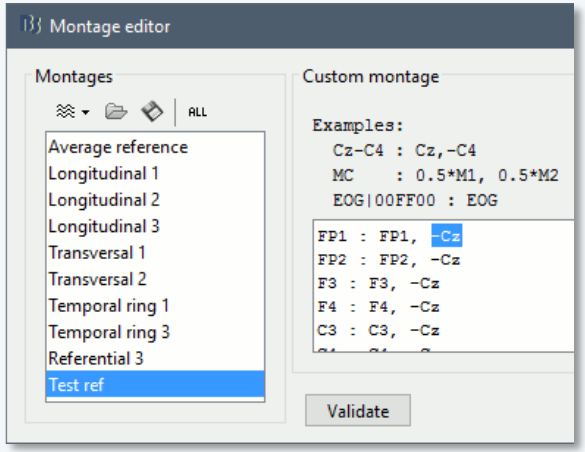
- Three levels:
  - Protocol
  - Subject
  - Condition

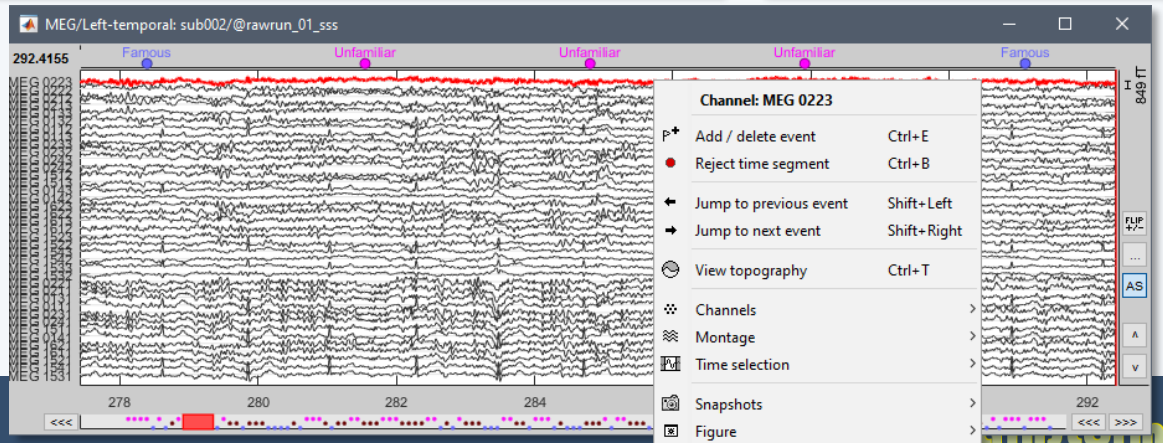
- Popup menus
- All files saved in Matlab .mat
- Same architecture on the disk

Import

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







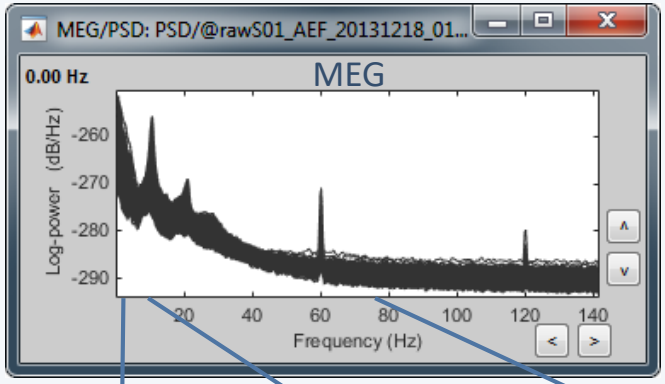
Quality control

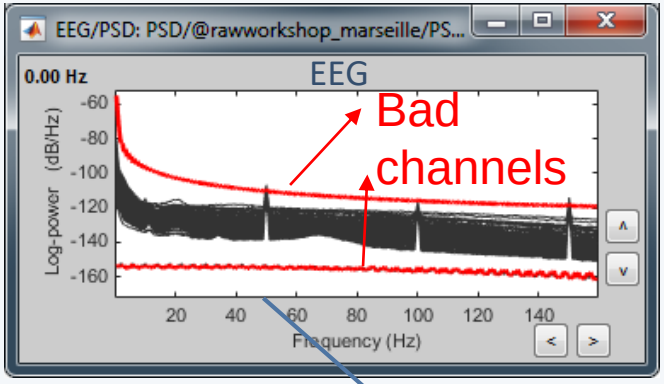
Anatomy
Link recordings
MRI registration

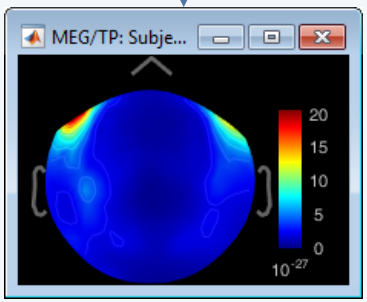
PSD
Filters
Bad channels
Artifacts
Correction
Bad segments

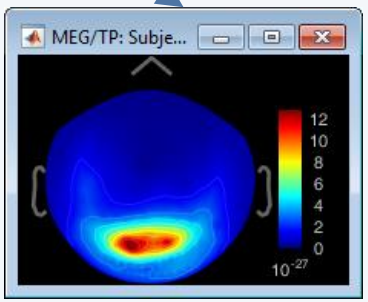
Markers
Epoching
Averaging
Sources
Time-frequency

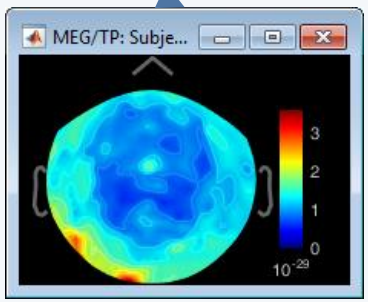
- Power spectrum density for quality control

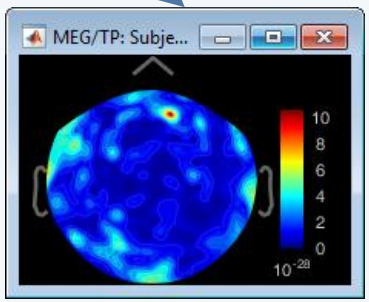












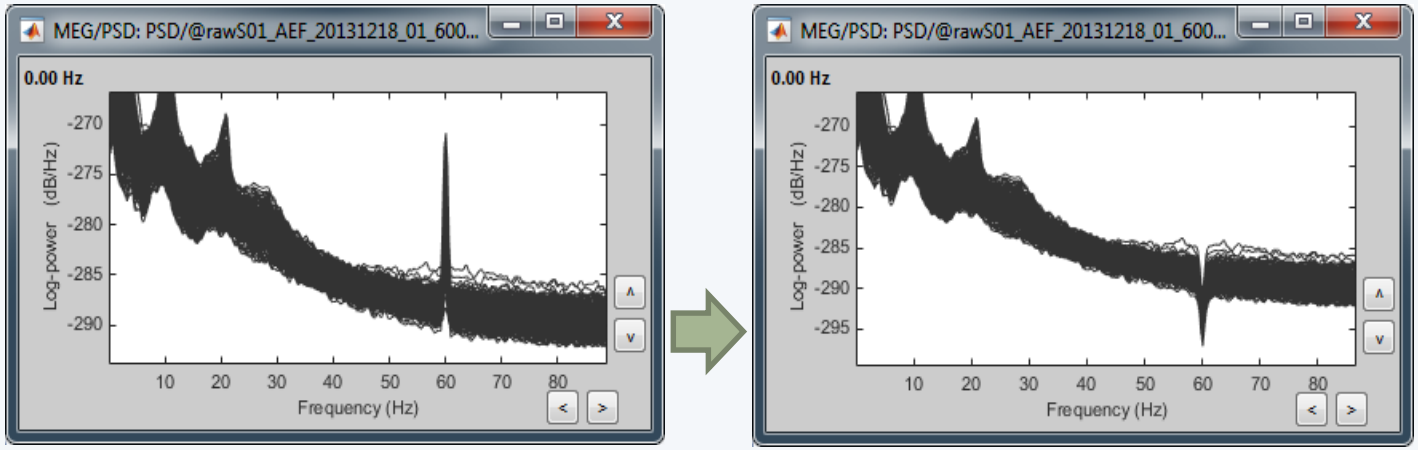
< 3Hz: Eyes | 10Hz: Alpha | > 40Hz: Muscle | 50/60Hz

Brainstorm

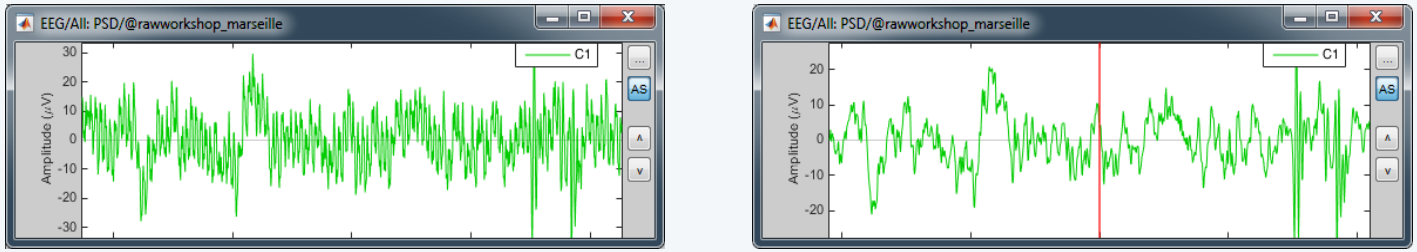
Pre-processing

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

PSD

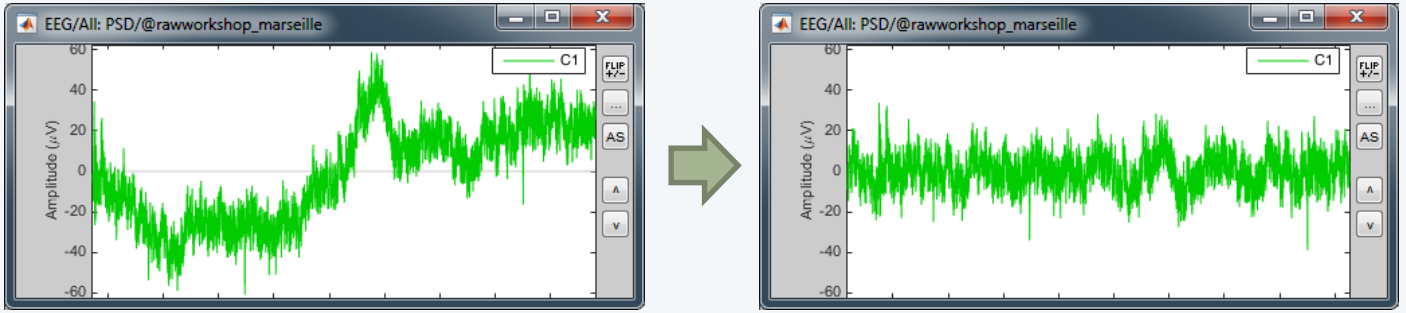


Signal

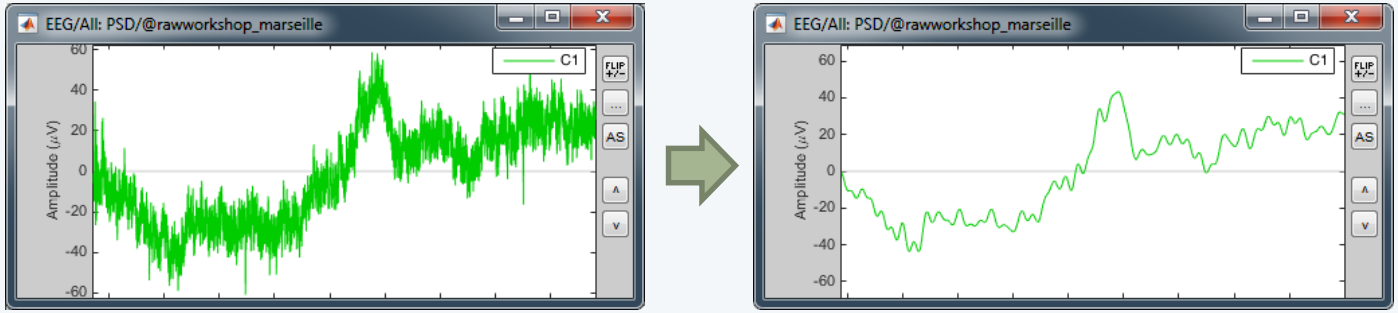


Pre-processing

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

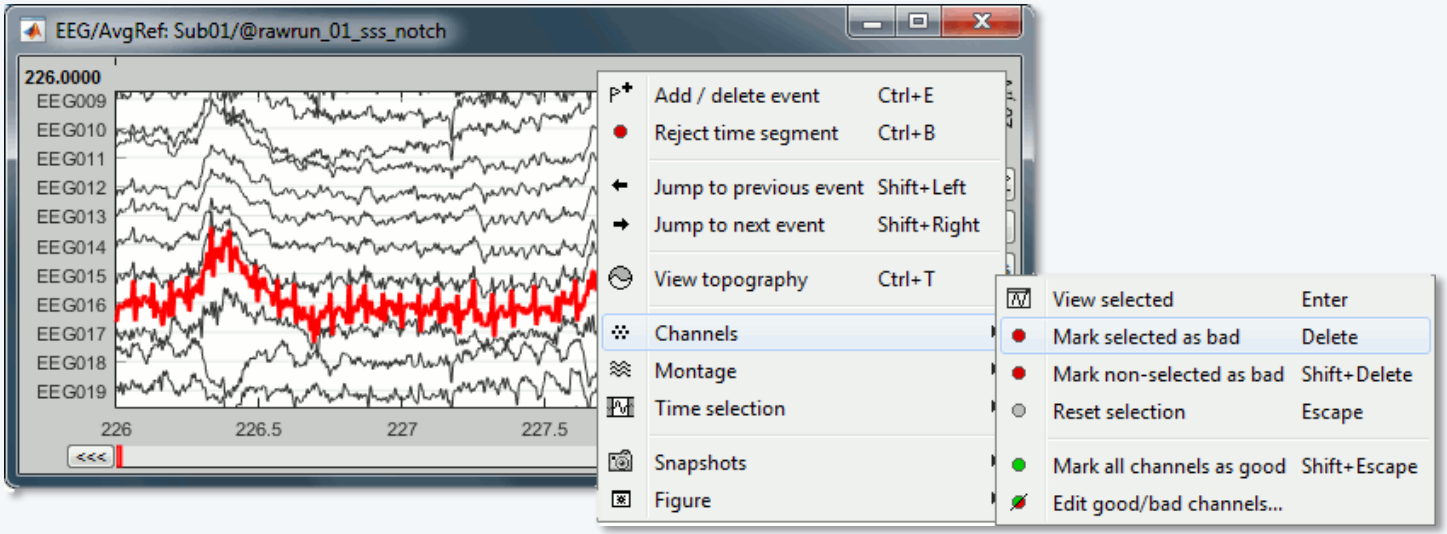


- Low-pass filter: Remove high-frequencies



Pre-processing

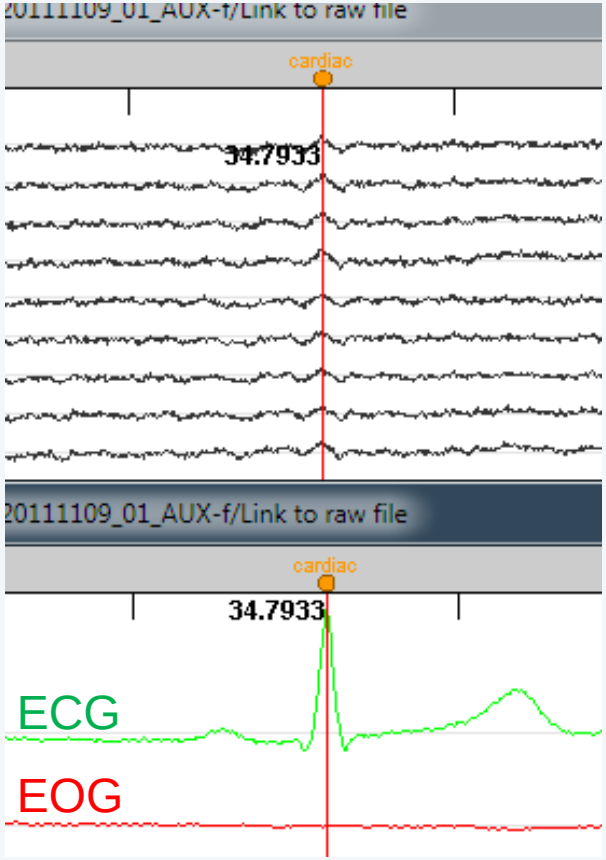
- Manual inspection of the recordings
- Interactive selection of bad channels
- Re-reference the EEG if necessary (Average ref)

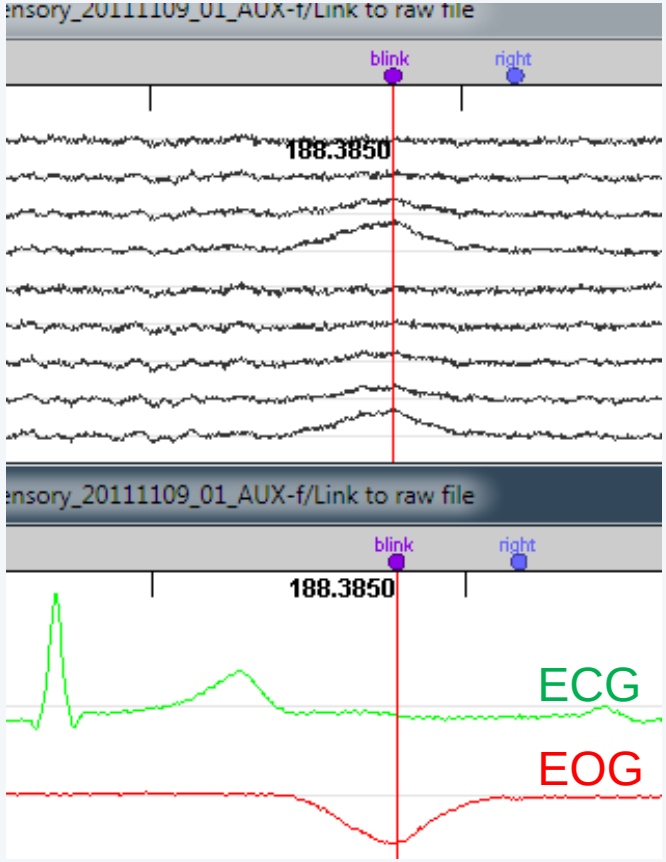


Brainstorm

Pre-processing

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

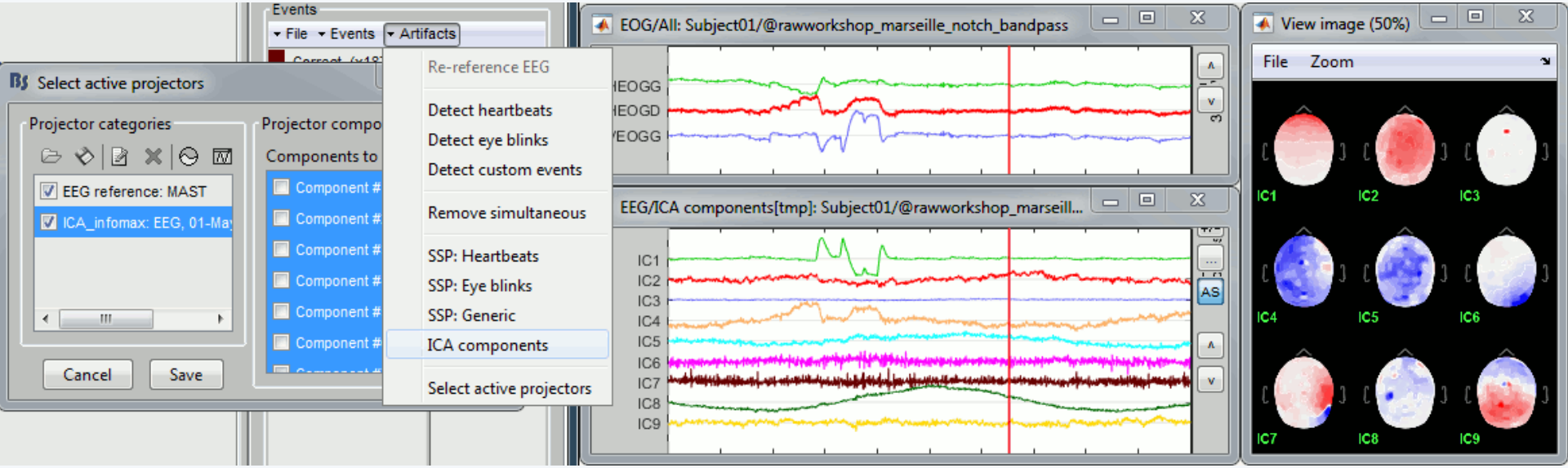




Brainstorm

Pre-processing

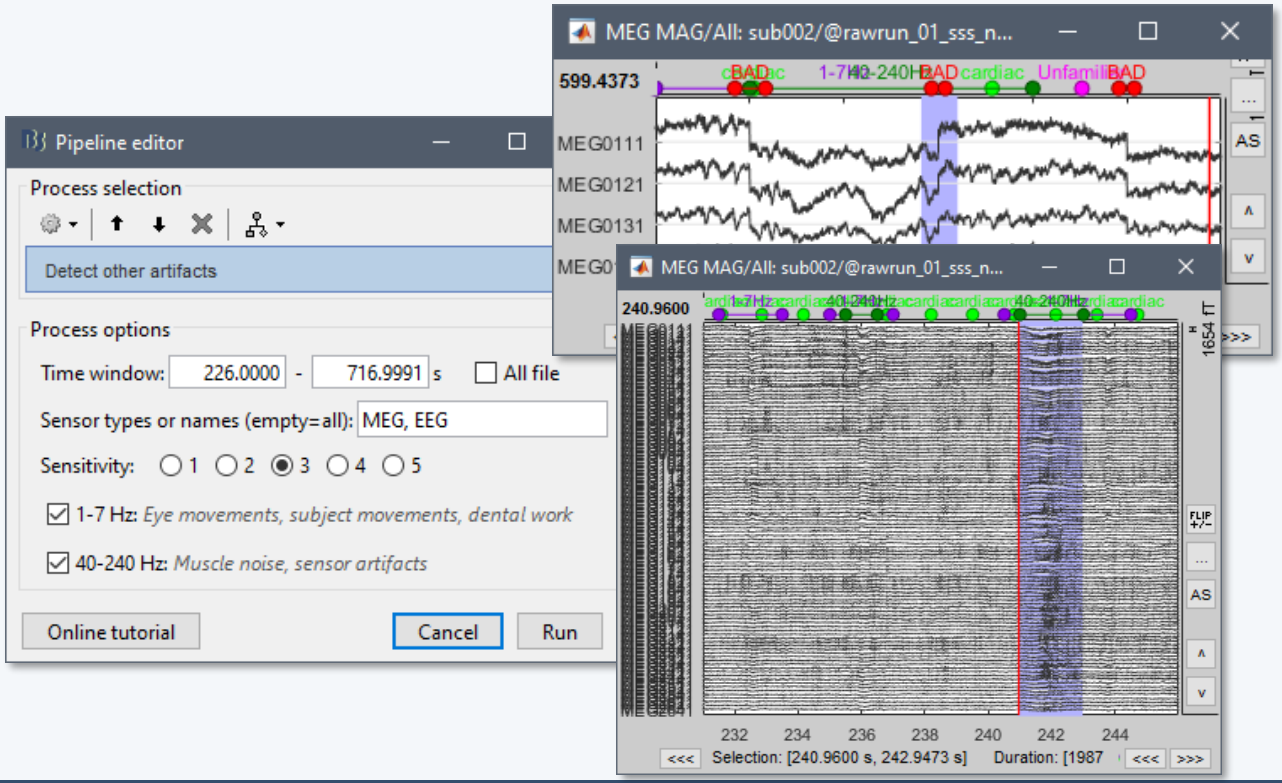
- Independent component analysis (ICA):
  - Popular in the EEG literature
  - Alternative to SSP for low number of sensors
  - Already implemented: Infomax and JADE (EEGLAB)



Brainstorm

Pre-processing

- Automatic detection of artifacts (RMS-based)
- Manual screening of all the recordings is advised (scroll all the sensors by pages of 10-20s)
- Exclude: Blinks, movements, SQUID jumps



Brainstorm

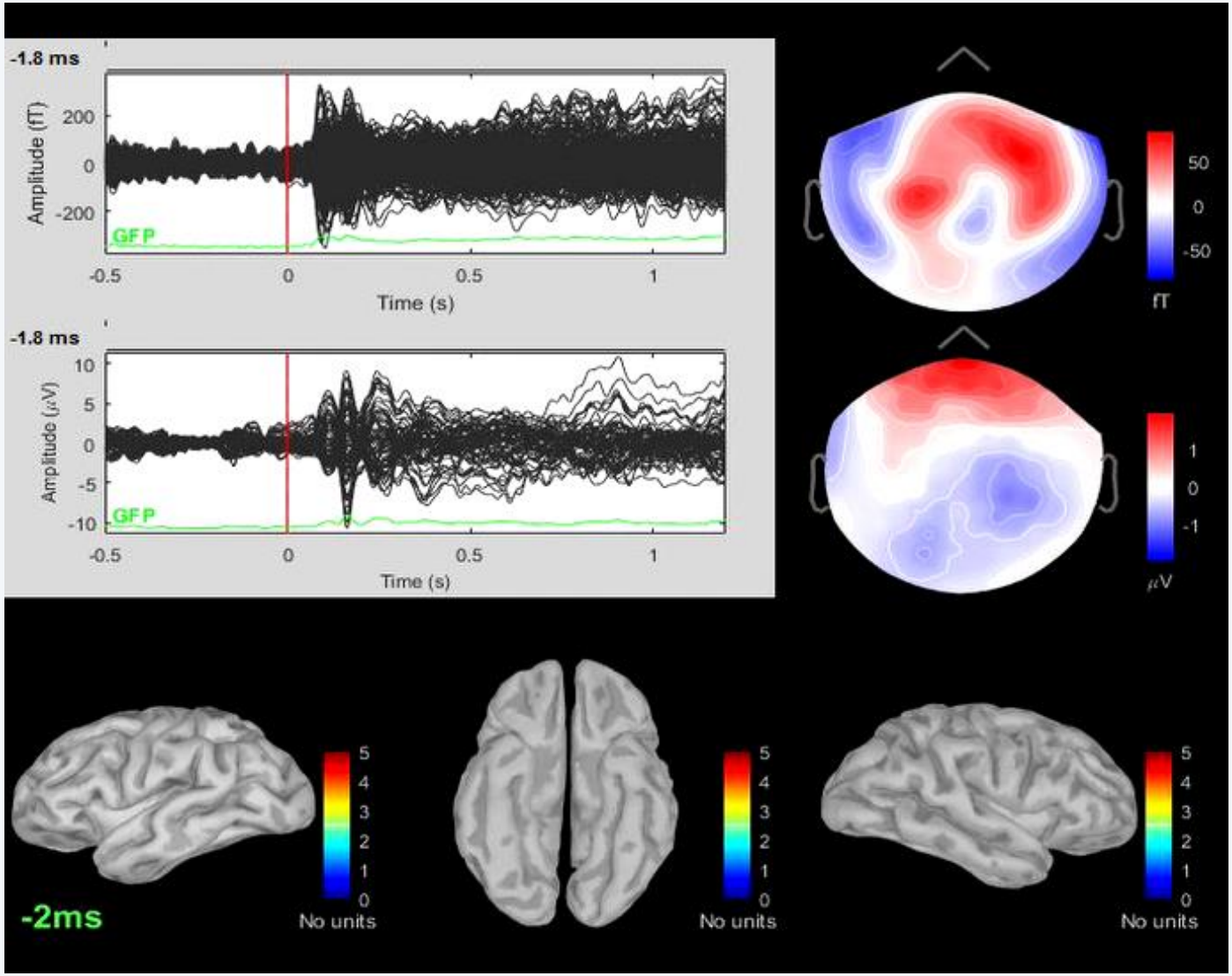
Single subject

Anatomy
Link recordings
MRI registration

PSD
Filters
Bad channels
Artifacts
Correction
Bad segments

Markers
Epoching
Averaging
Sources
Time-frequency

Famous faces



Brainstorm

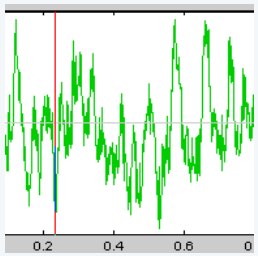
Single subject

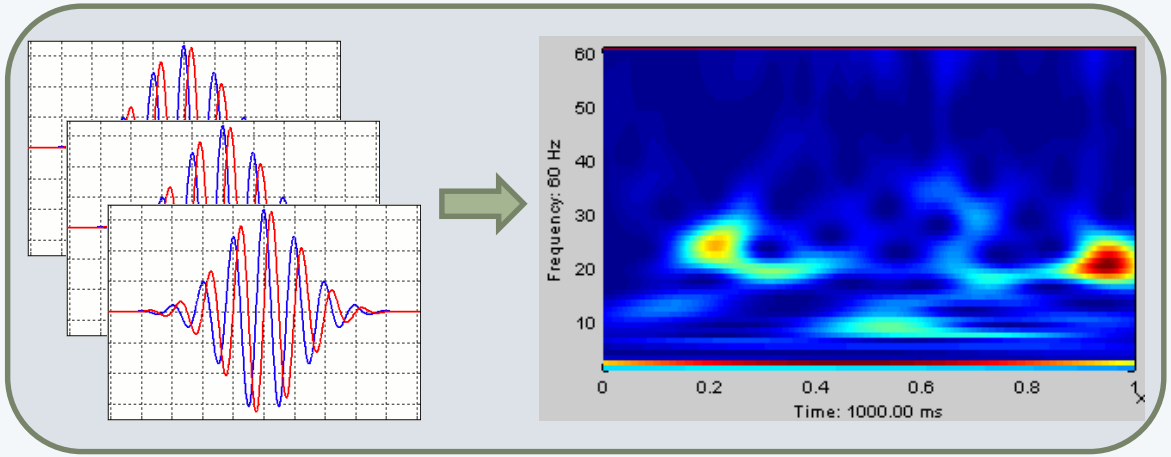
Anatomy
Link recordings
MRI registration

PSD
Filters
Bad channels
Artifacts
Correction
Bad segments

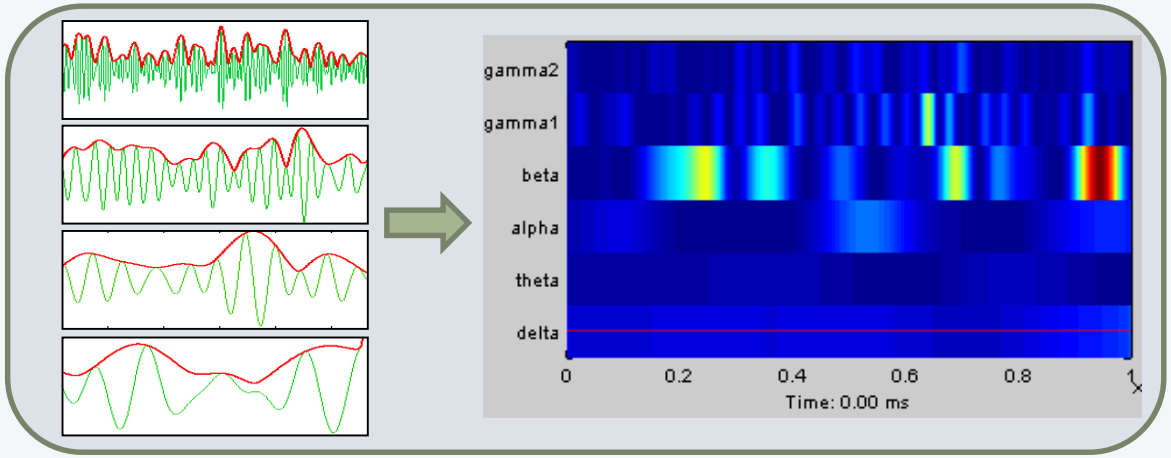
Markers
Epoching
Averaging
Sources
Time-frequency

Morlet wavelets





Hilbert transform + band-pass filter



Brainstorm

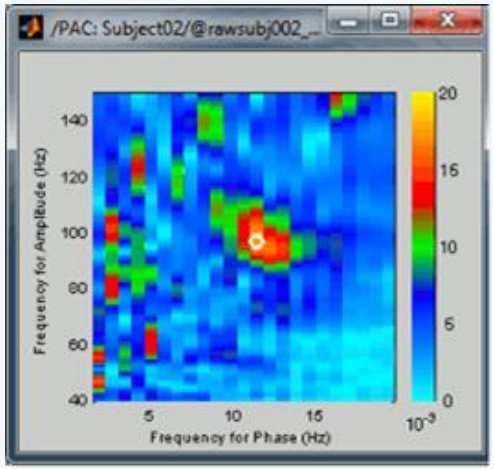
Single subject

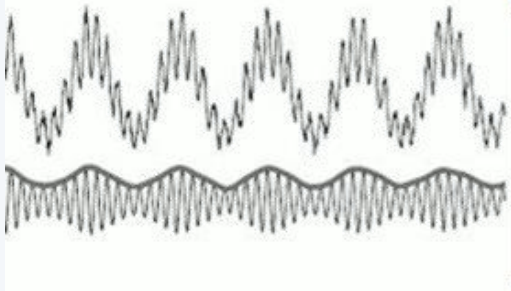
Anatomy
Link recordings
MRI registration

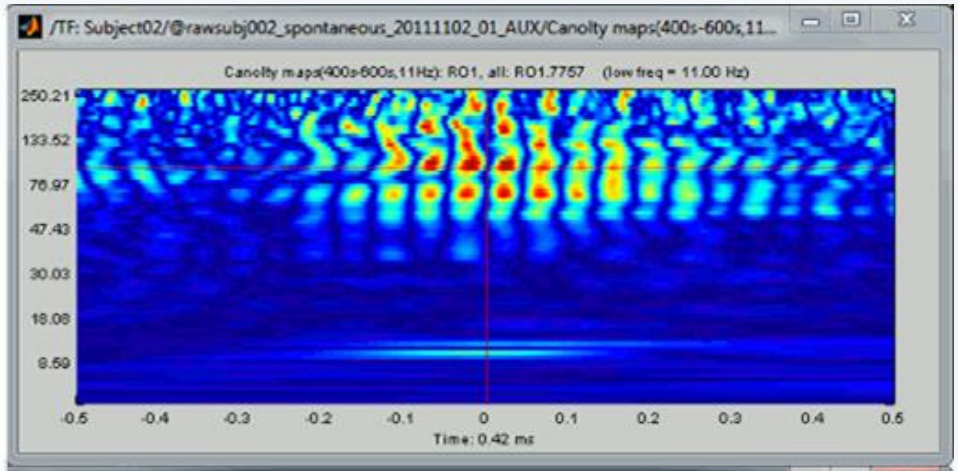
PSD
Filters
Bad channels
Artifacts
Correction
Bad segments

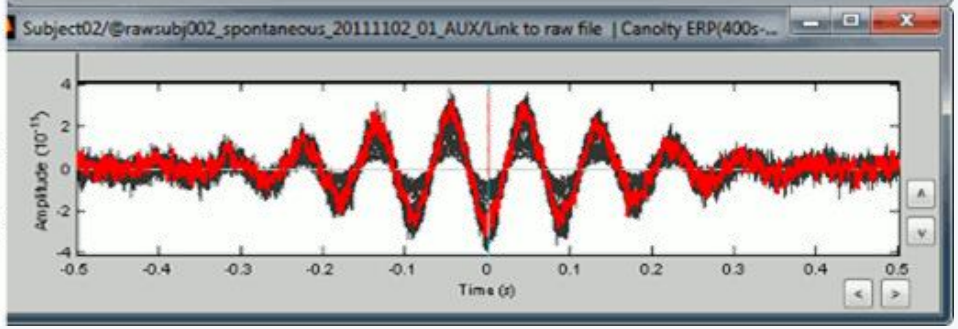
Markers
Epoching
Averaging
Sources
Time-frequency
Other measures

- Phase-amplitude coupling









Brainstorm

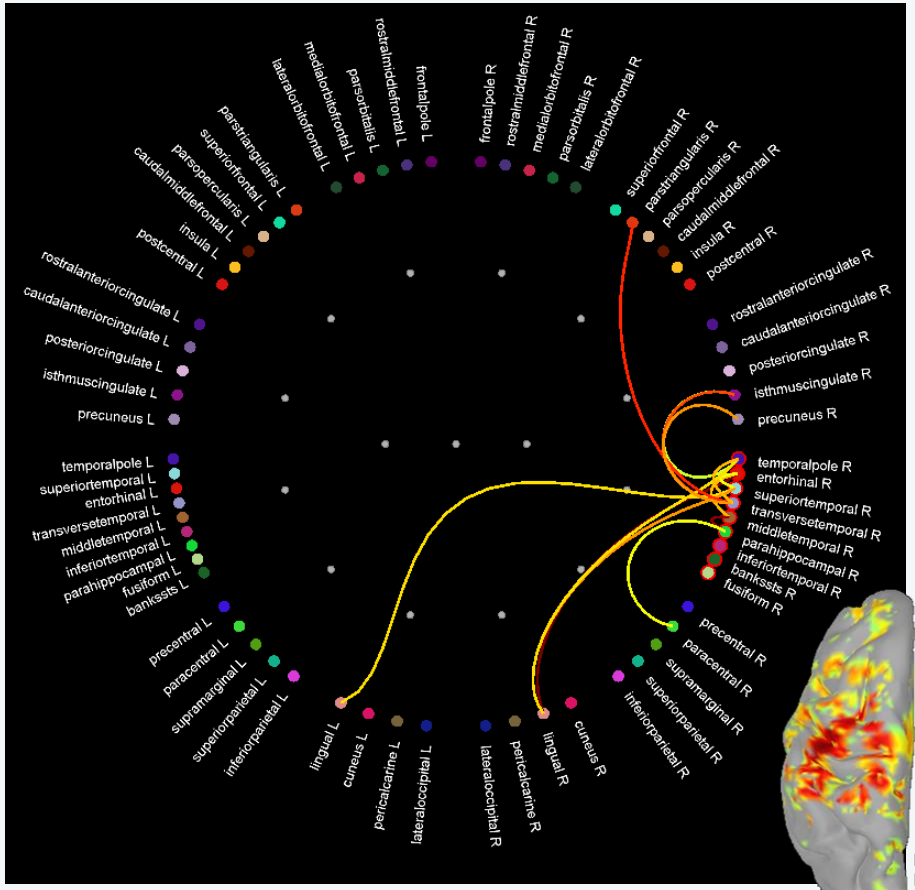
Single subject

Anatomy
Link recordings
MRI registration

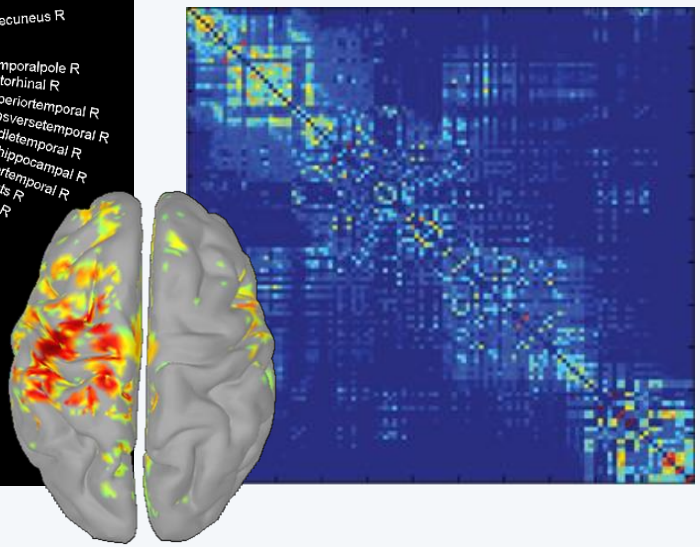
PSD
Filters
Bad channels
Artifacts
Correction
Bad segments

Markers
Epoching
Averaging
Sources
Time-frequency
Other measures

- Connectivity measures



- Correlation
- Coherence
- Phase locking value
- Granger causality



Brainstorm

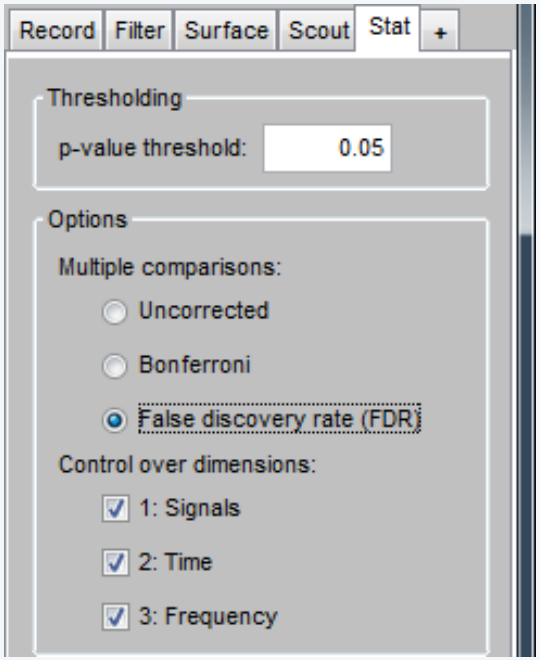
Group analysis

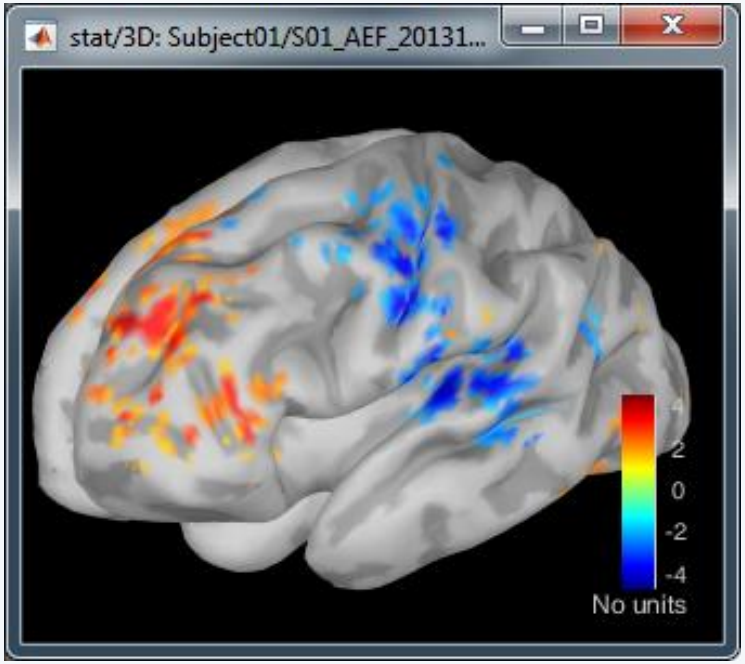
Subject averages
Low-pass
Normalize
Project

Group averages
Group statistics

Quality control
Workflow

- Contrasts between subjects or conditions
- Parametric or non-parametric t-test
- Cluster-based non-parametric tests
- Export to: **SPM**, R, Excel, SPSS, Matlab…





Brainstorm

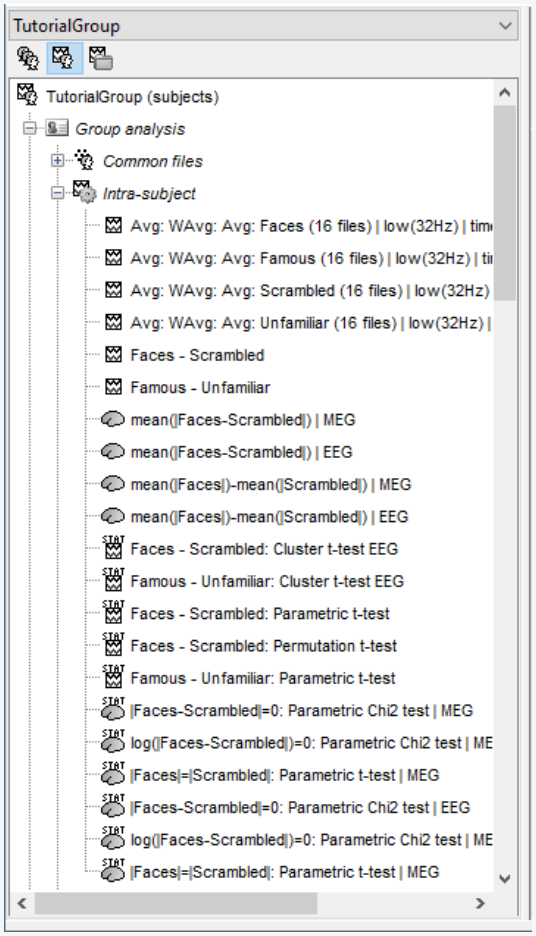
Group analysis

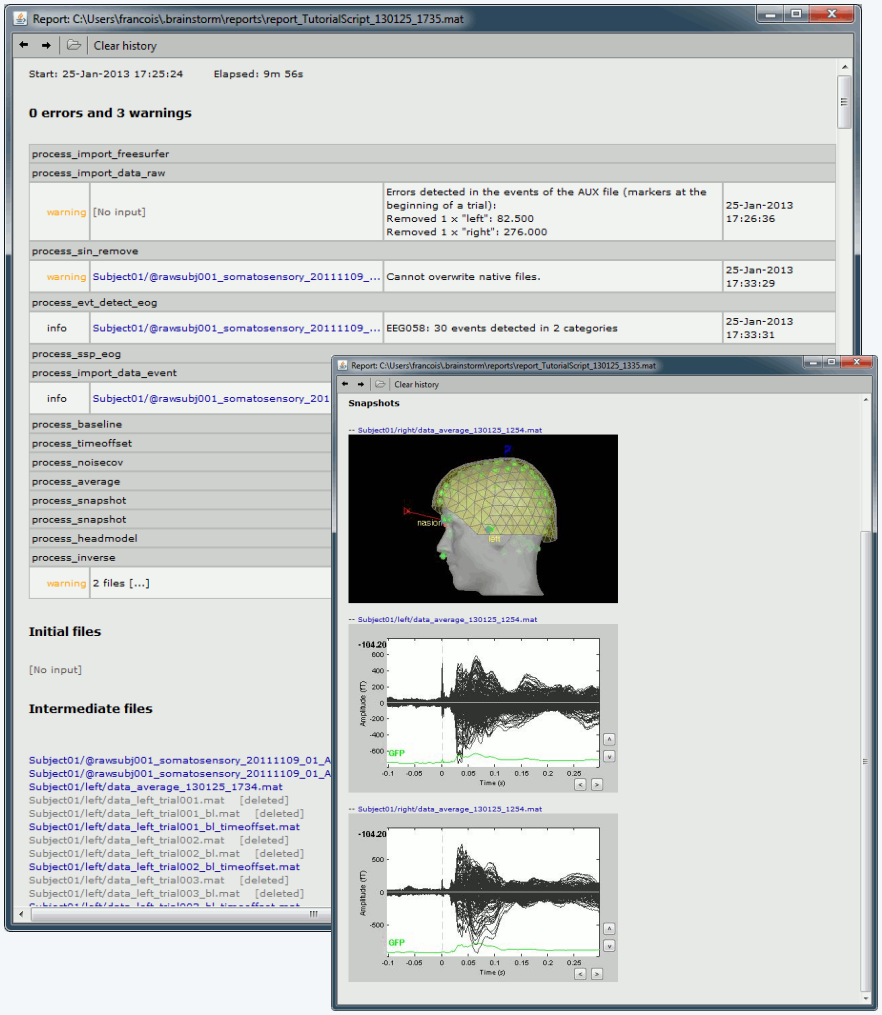
Subject averages
Low-pass
Normalize
Project

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 plugin:
  - Well documented API
  - Lots of example (200 functions written as plugins)
- Examples of recent external contributions:
  - MVPA decoding (Oliva, MIT)
  - Microstate segmentation (Cacioppo, UChicago)
  - Eyetracker/EEG synchronization (Uni Freiburg)

User community

- 19,900 users registered on the website

Find users next to you

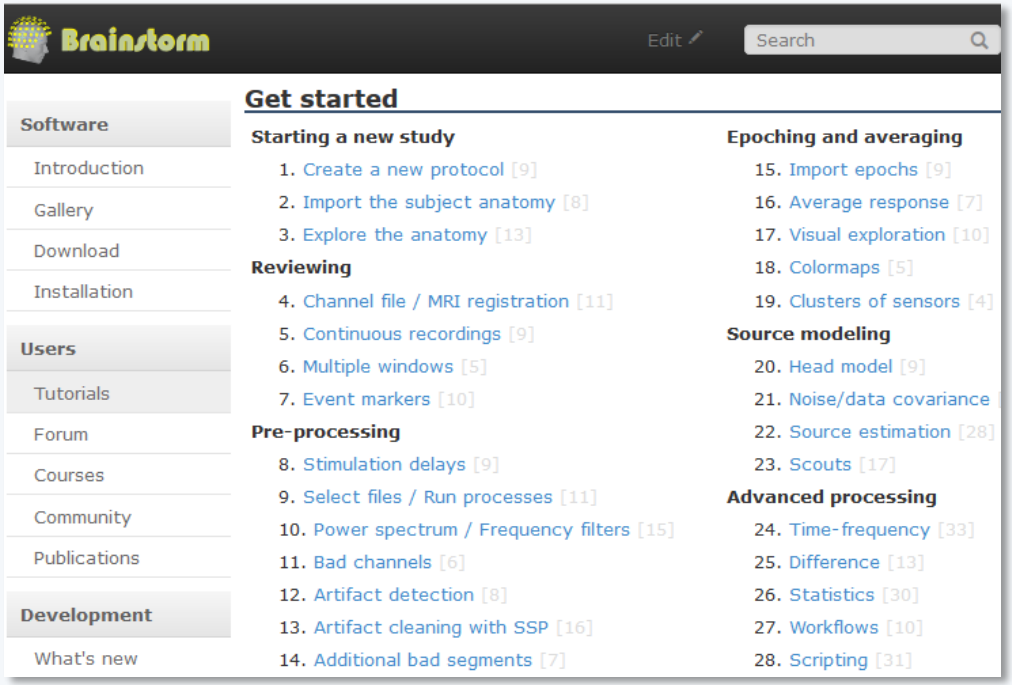
Location: montreal

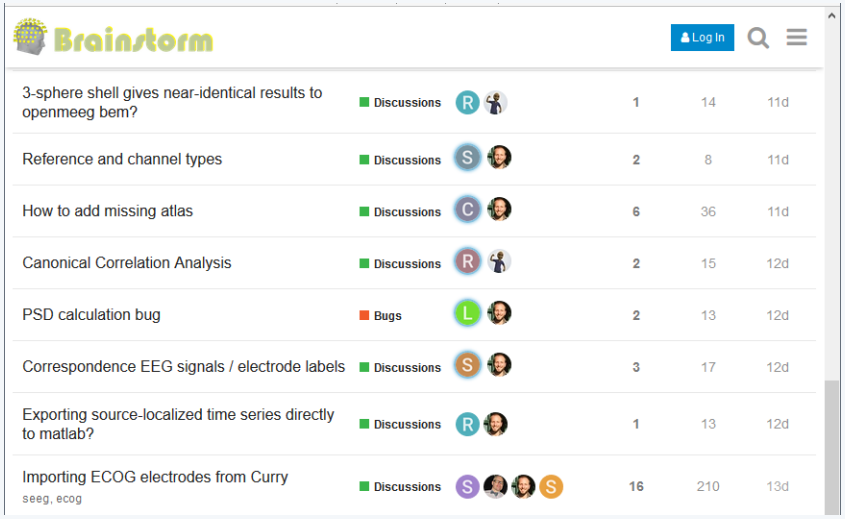
josieannebertrand	UQAM, Montreal	EEG	post-doc	2013
timothynest	Montreal, McGill	MEG, fNIRs	research	2013
Clara Moreau	Montreal	MEG	stagiare	2013

Brainstorm

User support

- Online tutorials: 30-hour self-training program
- Active user forum: 300 posts/month
- Daily updates: 800 downloads/month





Brainstorm

Contributors

Investigators


Sylvain Baillet
MNI


Richard Leahy
USC


John Mosher
Cleveland Clinic

Geeks


François Tadel
Univ Grenoble-Alpes


Martin Cousineau
MNI

And...

Matti Hamalainen
Antoine Ducorps
Denis Schwartz
…

MEG @ McGill


Elizabeth Bock
MEG engineer


Soheila Samiee
PhD student


Jeremy Moreau
PhD student


Peter Donhauser
PhD student


K. Nasiotis
PhD student

Key collaborators


Dimitrios Pantazis
MIT


Guiomar Niso
Politécnica Madrid


Anand Joshi
USC


Hossein Shahabi
USC


Esther Florin
Univ Hosp Cologne


Anne-Sophie Dubarry
Aix-Marseille Univ

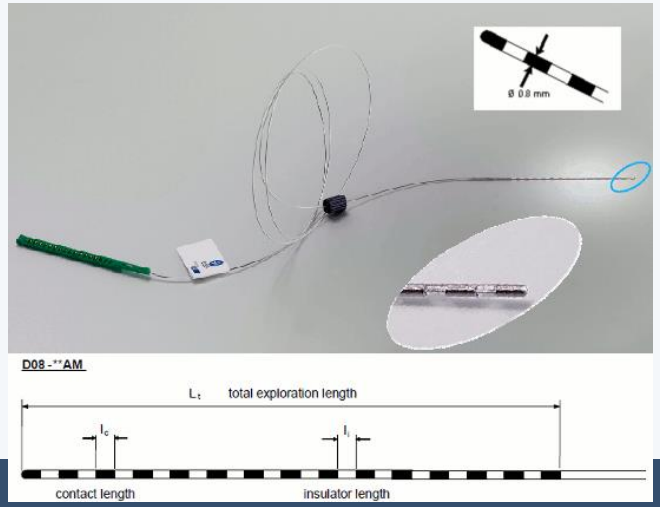
Sample data

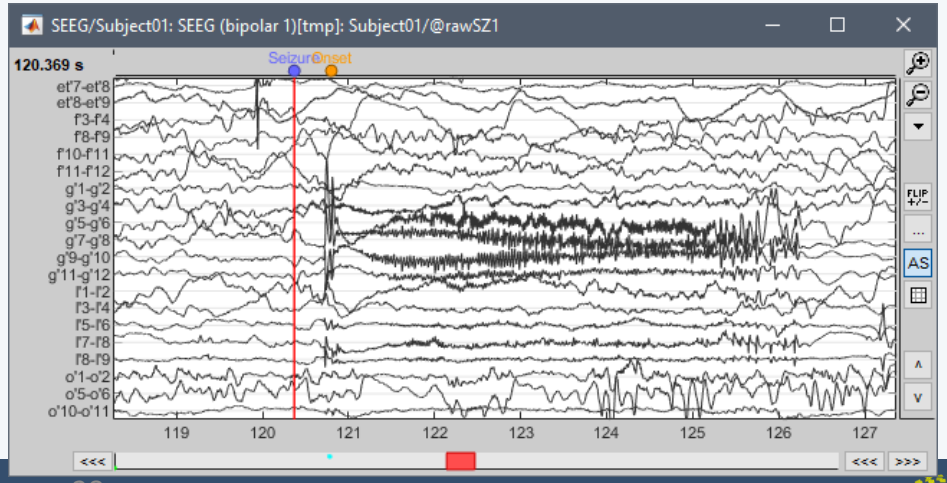
TODAY

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 short seizure (no propagation)



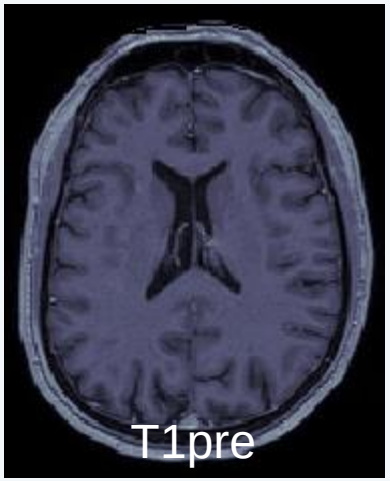


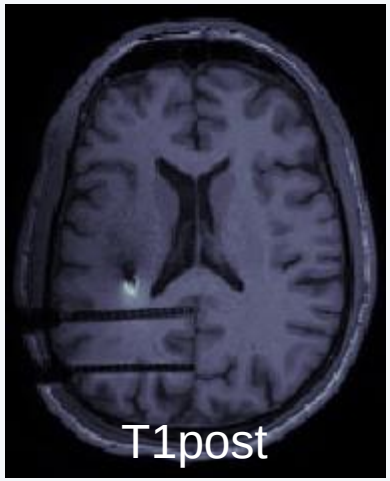
Brainstorm

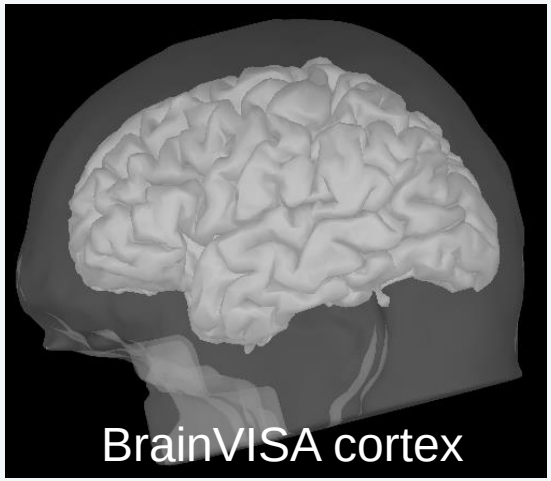
Sample data

Patient anatomy:

- T1 MRI pre-implantation, processed with BrainVISA 4.5
- T1 MRI post-implantation
  - Registered on the pre-implantation image with SPM
  - Used to get 3D positions for the SEEG contacts
- Volumes were de-identified with FreeSurfer's mri_deface

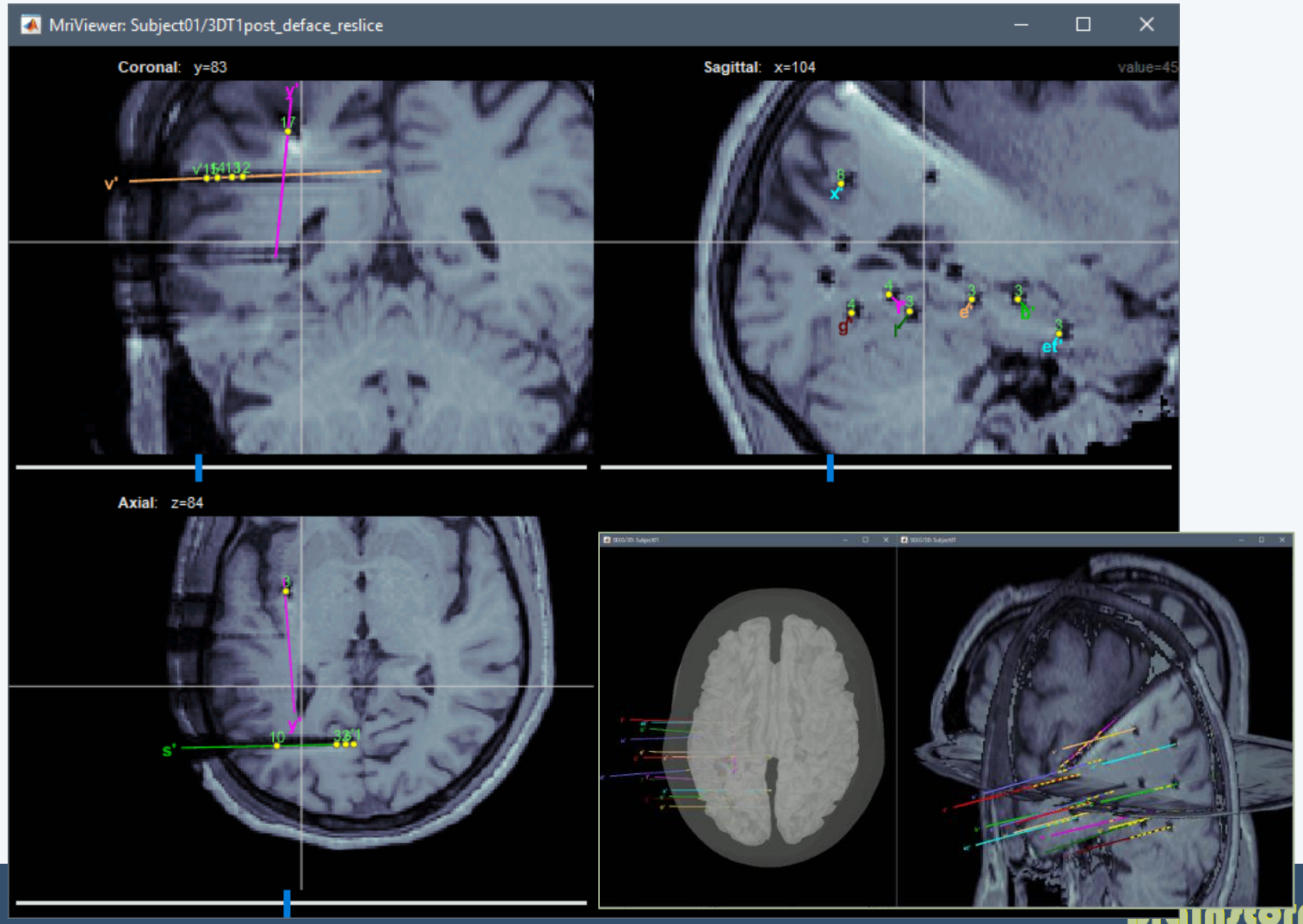






Sample data

SEEG electrodes marked in the T1post:



Sample data

Epileptogenicity maps:

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