Brainstorm Workshop los Angeles 2024

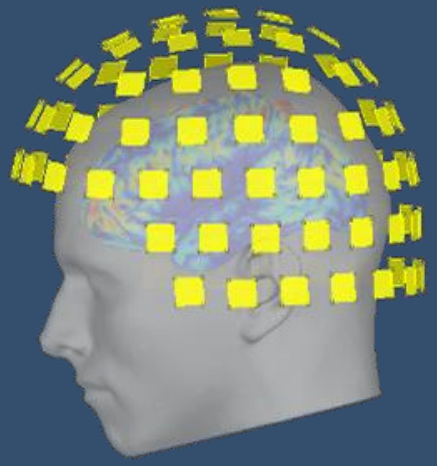
Welcome!

Brainstorm

MEG and EEG analysis using

Brainstorm

http://neuroimage.usc.edu/brainstorm



USC University of Southern California

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McGill

neuro UTHealth

December 2024

let's start with a quick poll!

Brainstorm
http://neuroimage.usc.edu/brainstorm

- **Are you currently using Brainstorm software?**
  - If Yes : Raise your hand

let's start with a quick poll!

Brainstorm
http://neuroimage.usc.edu/brainstorm

- Are you currently using Brainstorm software?
  - If Yes : Raise your hand

- **For those who aren't using it… yet, are you aware of Brainstorm and its applications?“**
  - If Yes : Raise your hand

Outline

- Brainstorm Software
- Brainstorm GUI
- Brainstorm Workflow
  - Review and Import Data
  - Data Co-registration
  - Data Analysis: Sensor and Source Level
  - Single Subject and Group level Analysis
- What's New?
- Today's Workshop

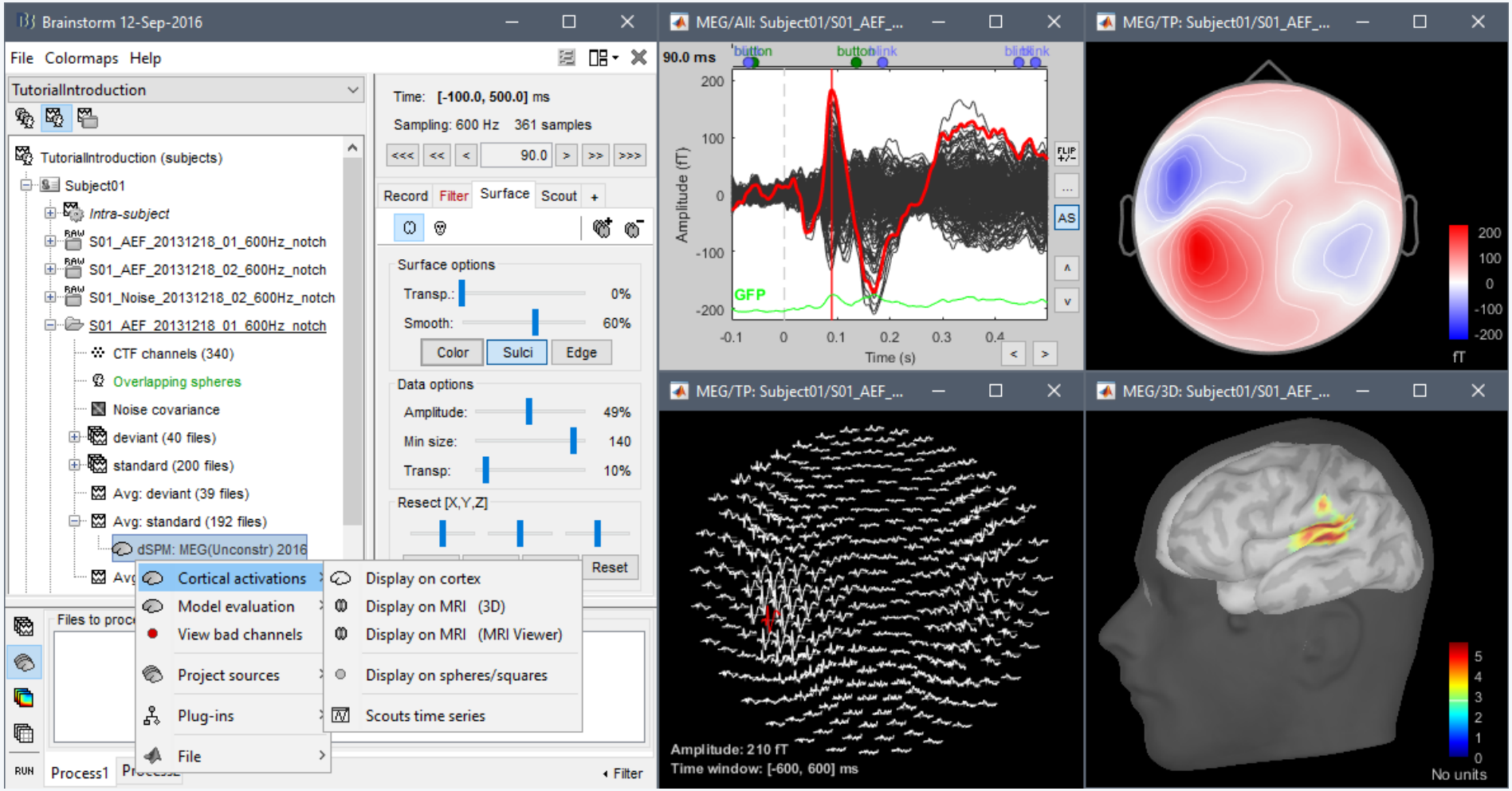
Brainstorm

- A free and open-source application (GPL)
- Matlab & Java: Platform-independent
- Stand-alone version also available
- Interface-based: **click, drag, drop**
- No Matlab experience required
- Daily updates of the software
- Supports most common file formats
- Educational resources & active users' community [Website, Forum, GitHub, …]





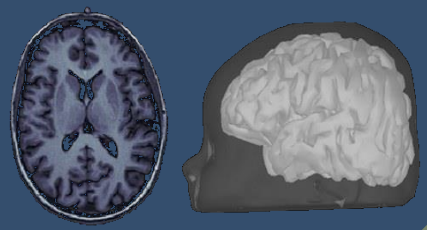
Graphic interface



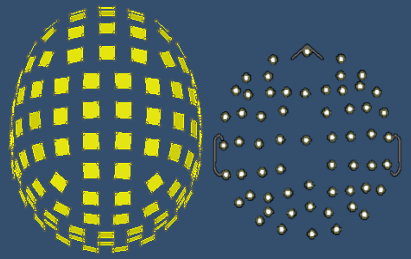
Brainstorm

Workflow

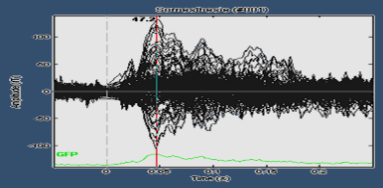
Anatomy



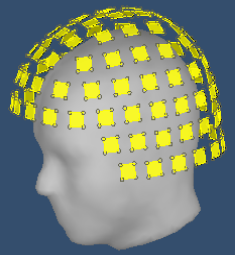
Sensors



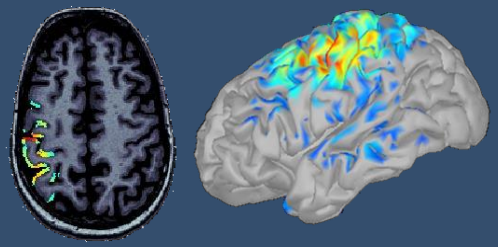
EEG/MEG



Co-registration



Source estimation



Analysis

Averages
Contrasts
Group analysis
Time-frequency
Connectivity

Single subject

Anatomy
Link recordings
MRI registration

Importing

PSD
Filters
Bad channels
Artifacts
Correction
Bad segments

Pre-processing

Events
Epoching
Averaging
Sources
Time-frequency

Analysis of the experimental data

Loop:
all acquisition runs
all subjects

Single subject

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Analysis of the experimental data

Loop:
all acquisition runs
all subjects

Similar workflow for most modalities: EEG, MEG, sEEG, fNIRS, etc.

Import

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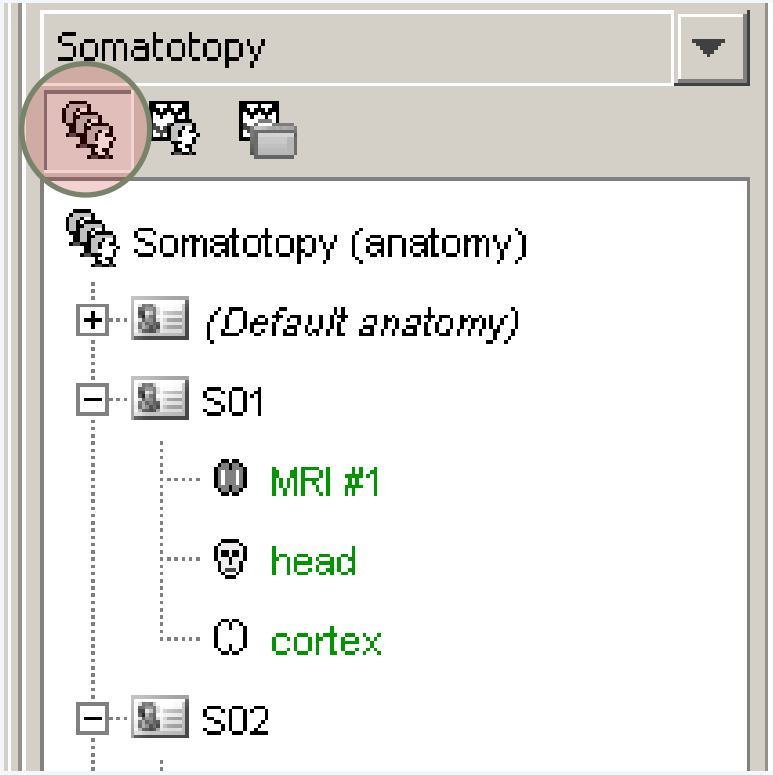
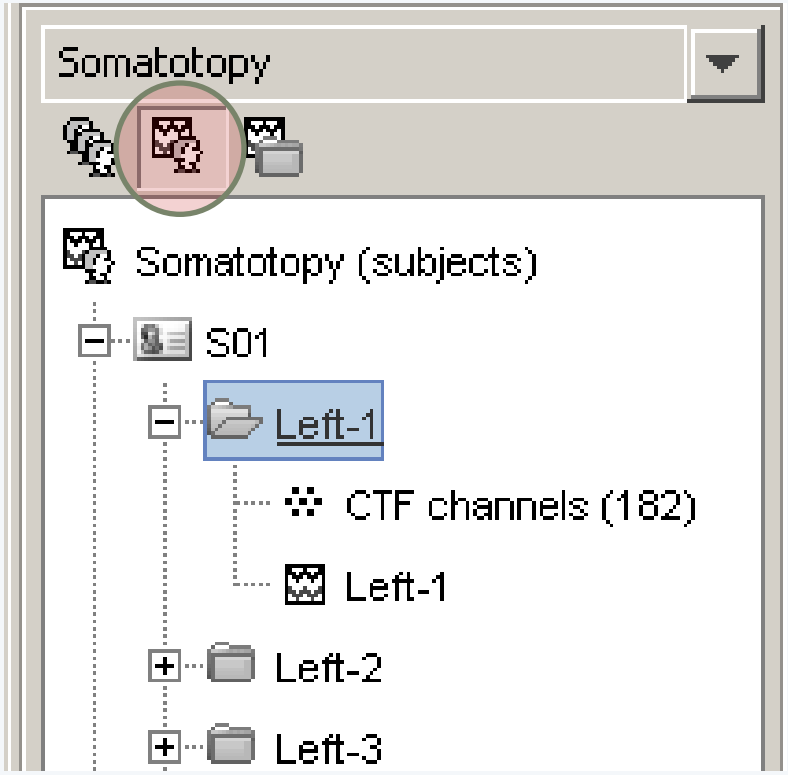
- One-click import of the T1 segmentation: FreeSurfer, BrainSuite, BrainVISA, CIVET, CAT
- Import and place fiducials in the MRI (N,L,R)

Brainstorm

Database





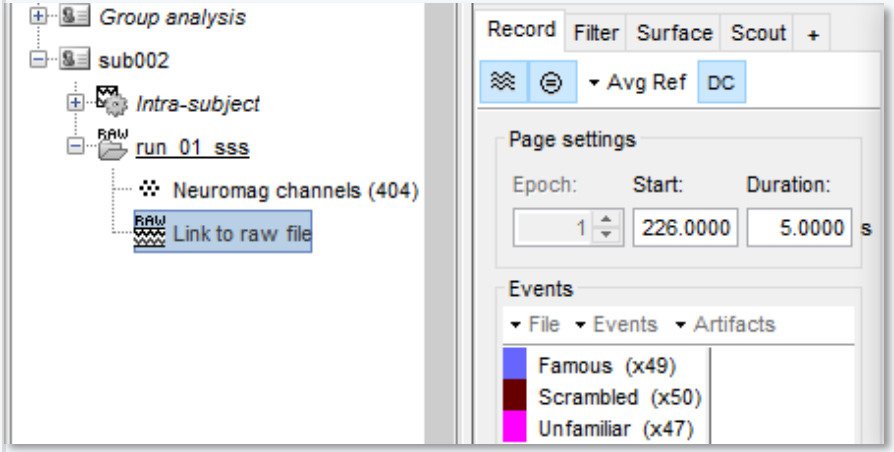
- Three levels:
  - Protocol
  - Subject
  - Condition

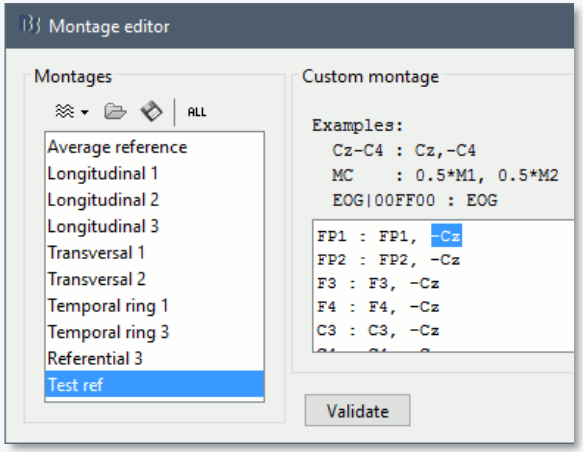
- Popup menus
- All files saved in Matlab .mat
- Same architecture on the disk

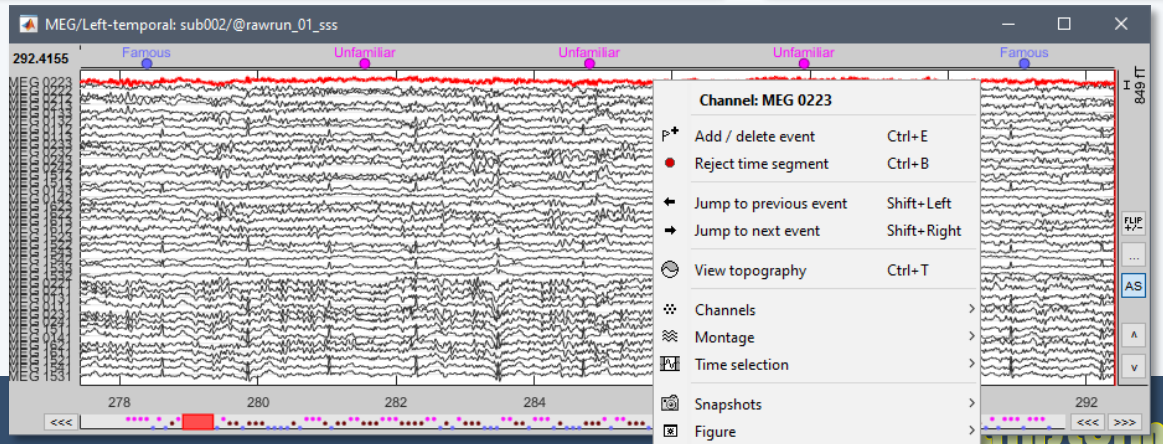
Brainstorm

Import

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

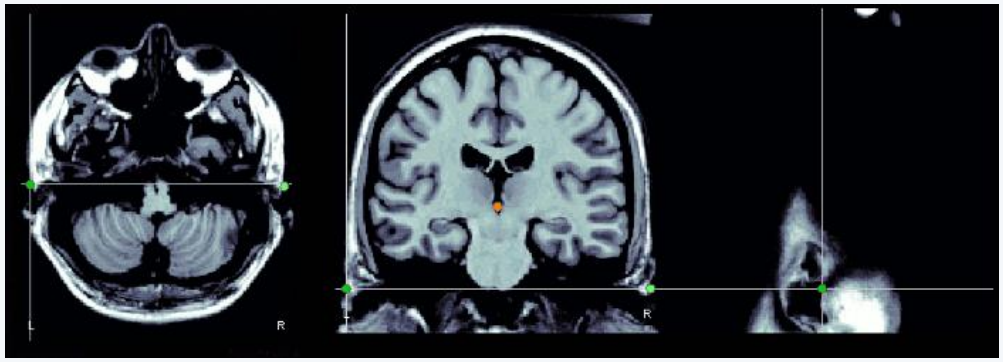






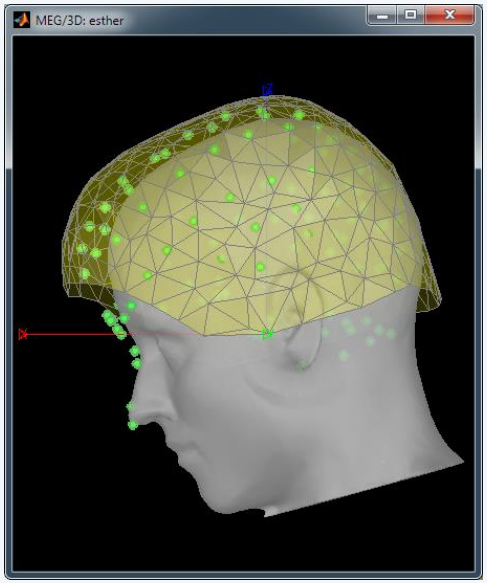
Co-registration MEEG / MRI (1)

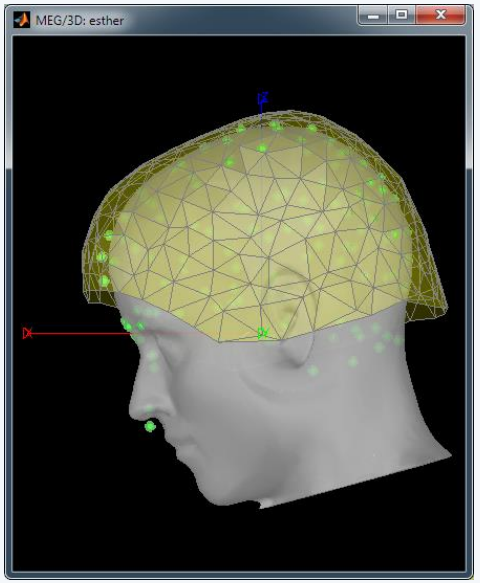
- Basic estimation based on three points:
  Nasion (NAS), Left ear (LPA), Right ear (RPA)
- MRI: Marked in the volume with the MRI Viewer
- MEEG: Obtained with a tracking system (Polhemus)



Co-registration MEEG / MRI (2)

- Automatic adjustment based on head shape: Fitting Polhemus points on the MRI head surface
- Final registration must be checked manually
- Polhemus driver included in Brainstorm





Quality control

Anatomy
Link recordings
MRI registration

PSD
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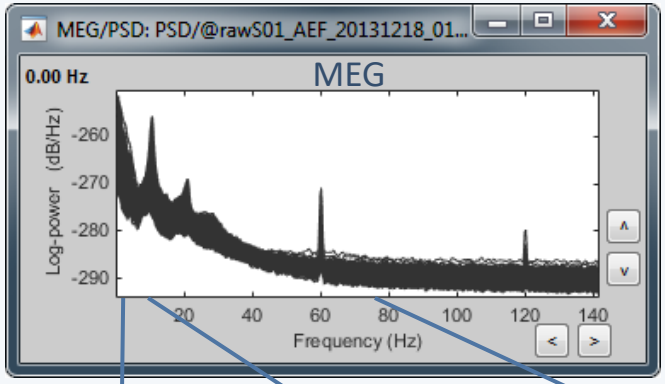
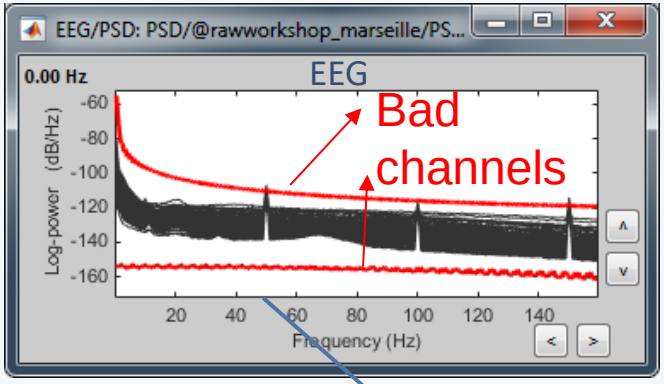
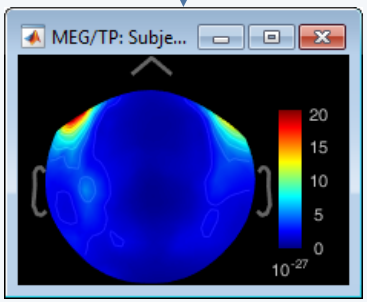
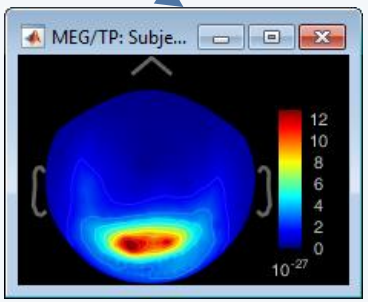
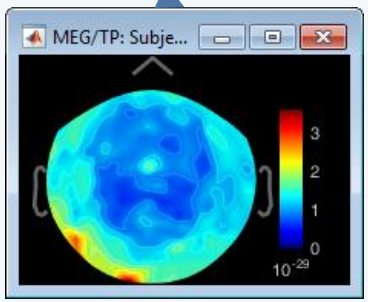
- Power spectrum density for quality control

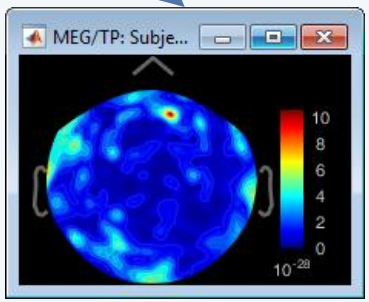












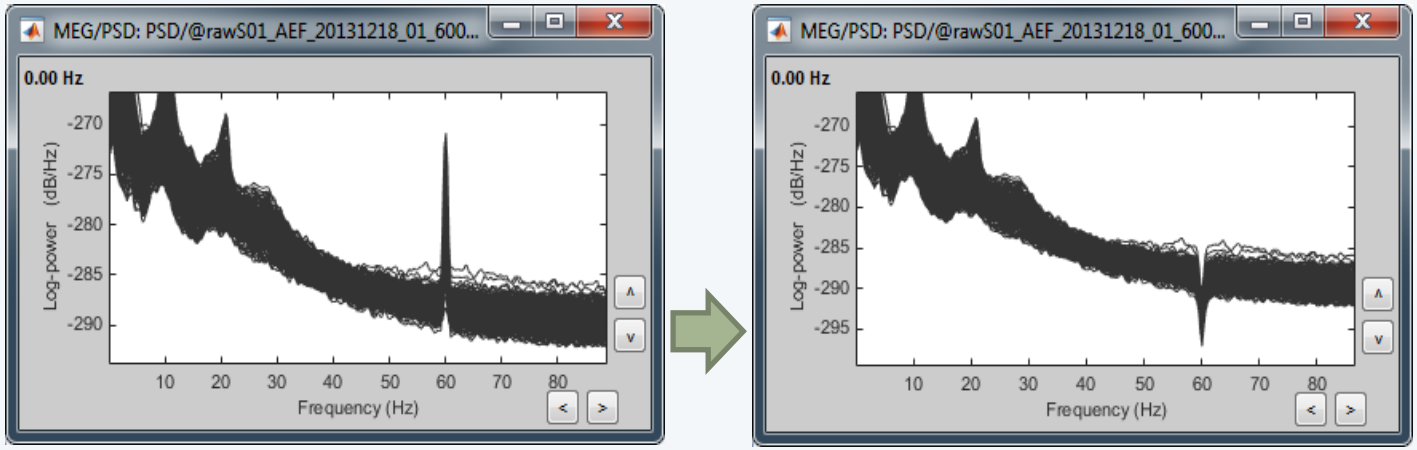
< 3Hz: Eyes | 10Hz: Alpha | > 40Hz: Muscle | 50/60Hz

Brainstorm

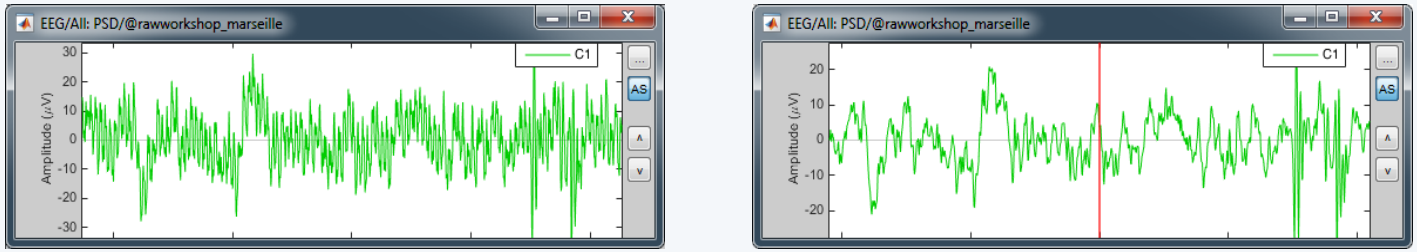
Pre-processing

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

PSD

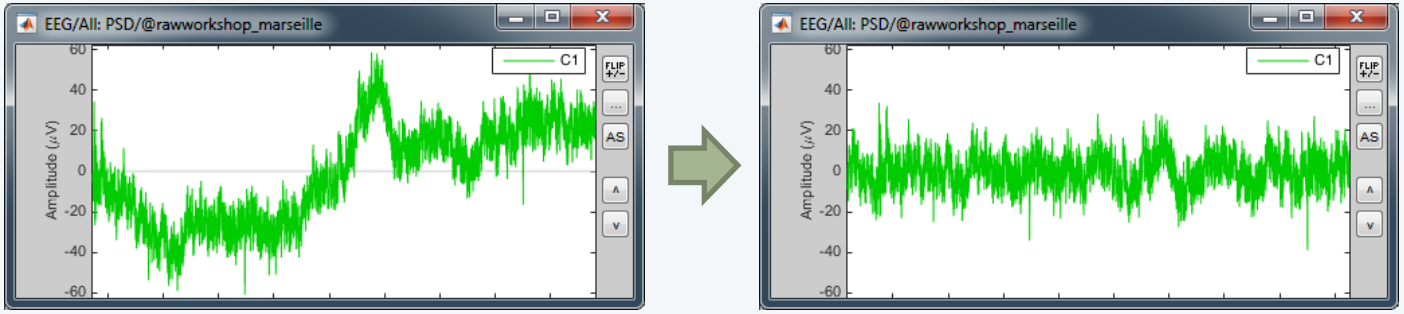


Signal

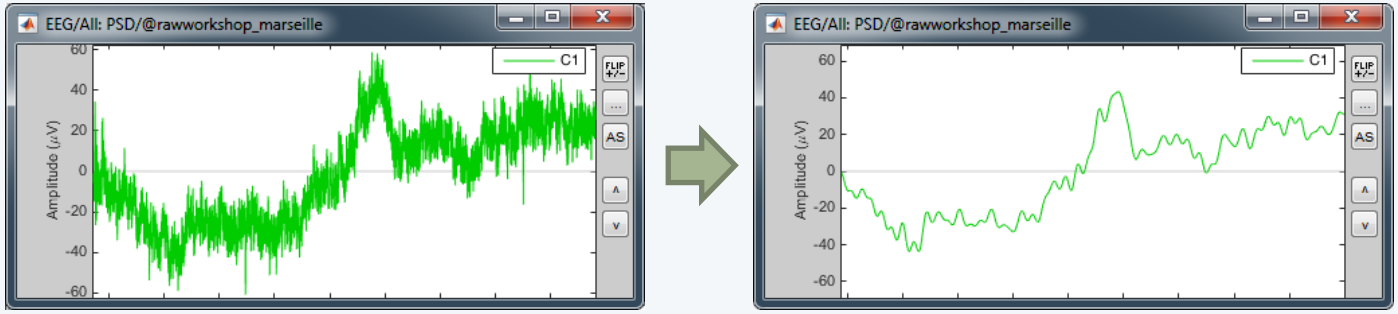


Pre-processing

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



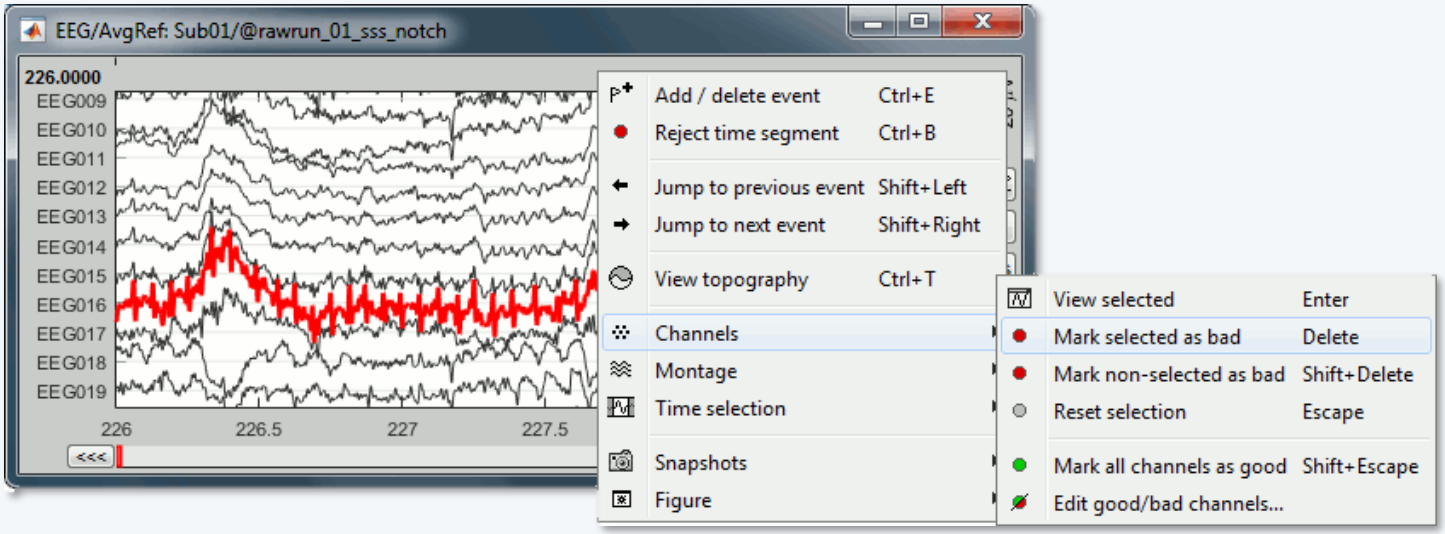
- Low-pass filter: Remove high-frequencies



Brainstorm

Pre-processing

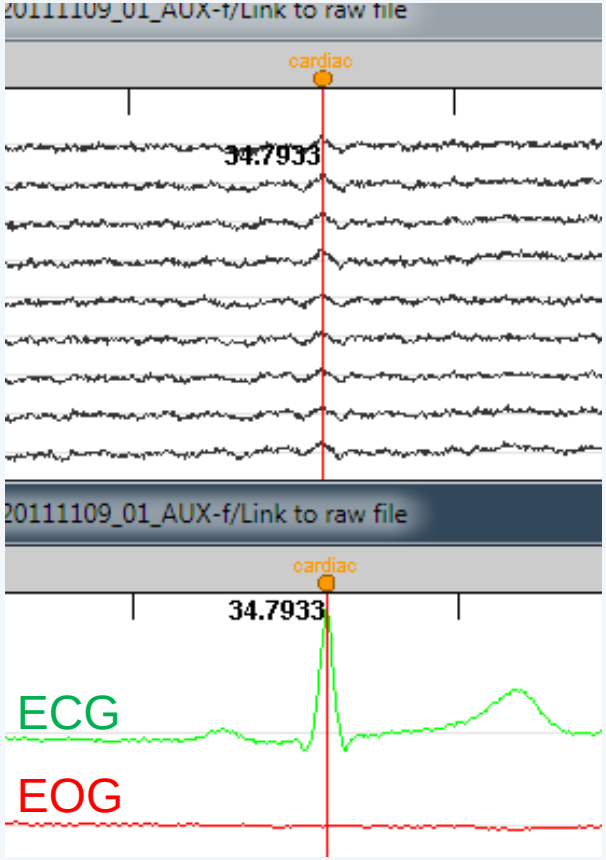
- Manual inspection of the recordings
- Interactive selection of bad channels
- Re-reference the EEG if necessary (Average ref)

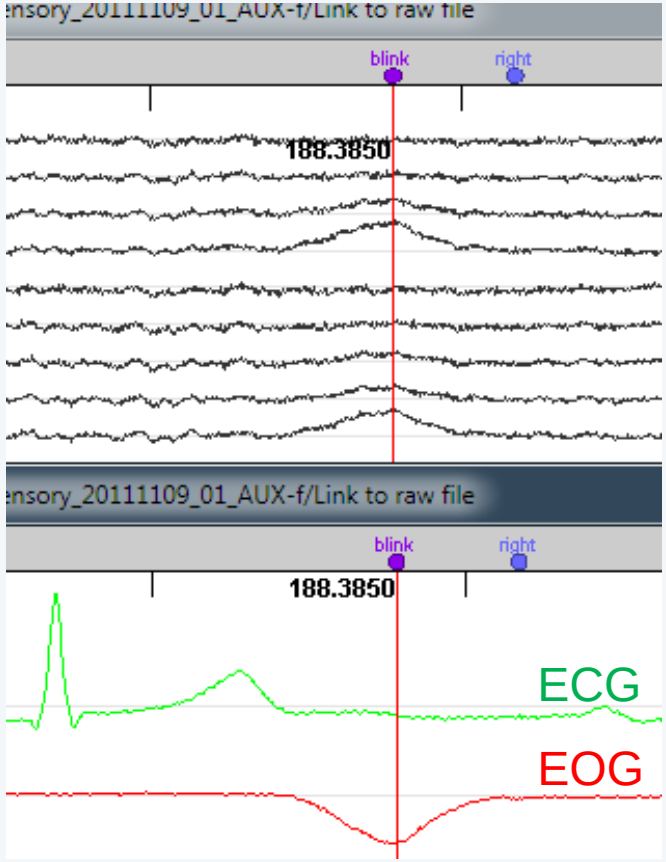


Brainstorm

Pre-processing

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





Brainstorm

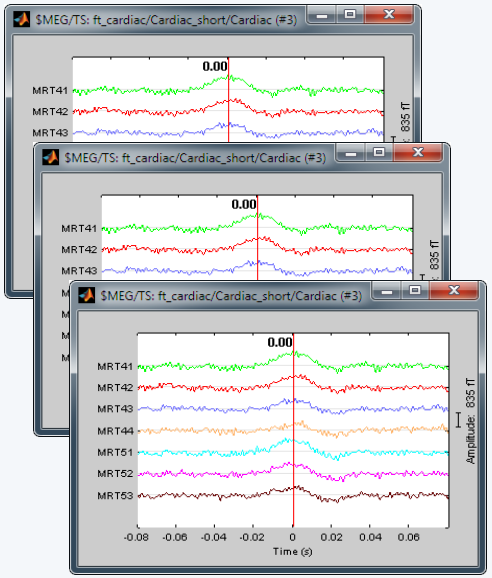
Artifact correction

- Two categories of artifacts:
  - Well defined, reproducible, short, frequent:
    - Heartbeats, eye blinks, eye movements, some stimulators
    - Unavoidable and frequent: we cannot just ignore them
    - **Can be modeled and removed from the signal efficiently**
      - **ICA, SSP**
  - All the other events that can alter the recordings:
    - Movements, building vibrations, metro nearby…
    - Too complex or not repeated enough to be modeled
    - **Safer to mark them as bad segments, and ignore them**

Pre-processing

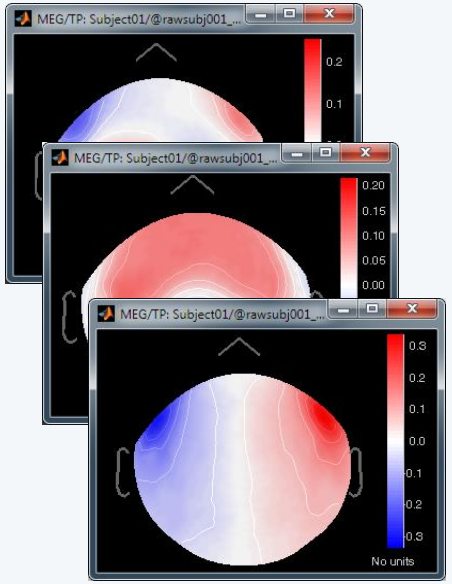
- Correction with Signal Space Projections (SSP)

Detect artifacts



PCA

Spatial components



Select components and compute a linear projector to remove their contribution from the recordings

Brainstorm

Pre-processing

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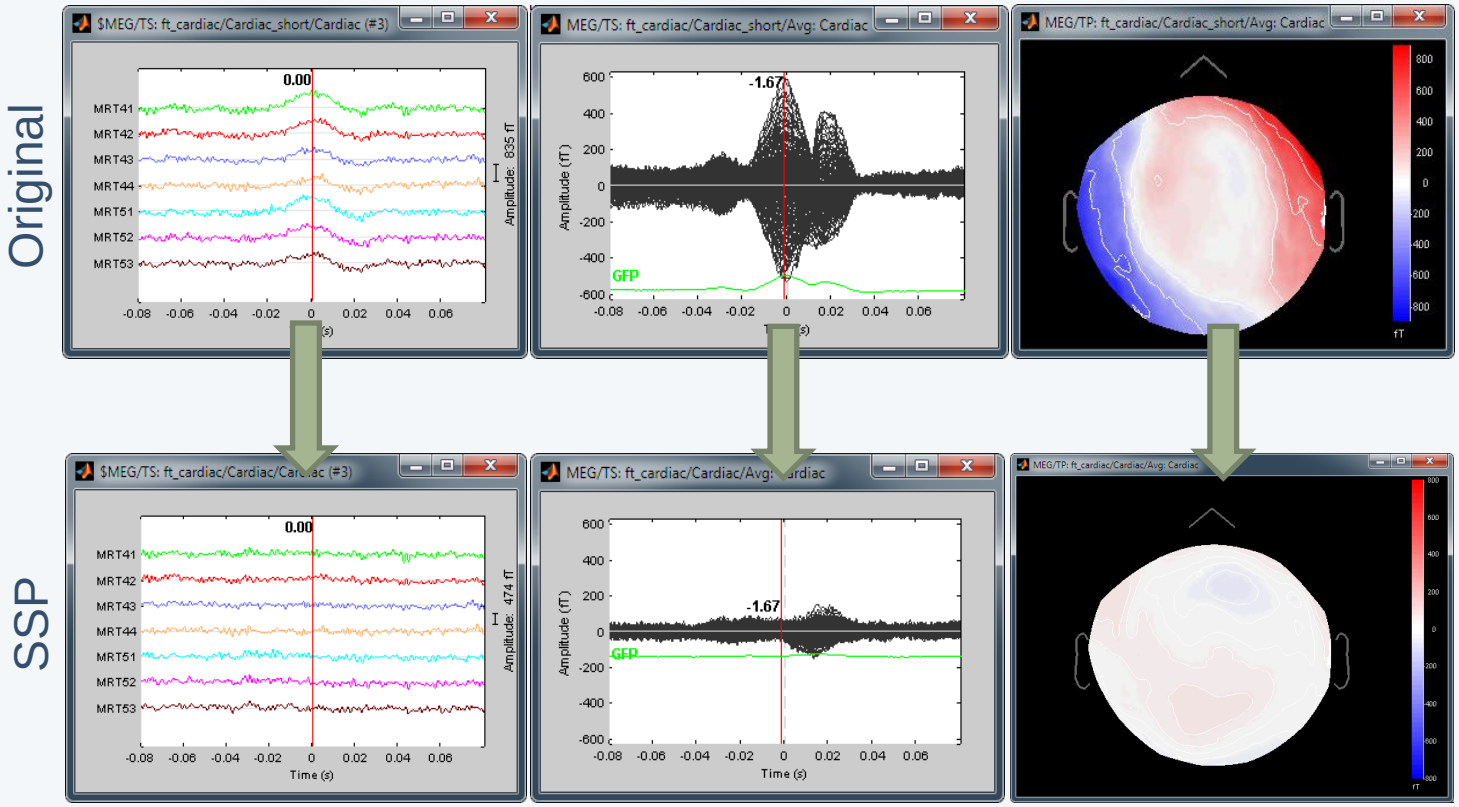
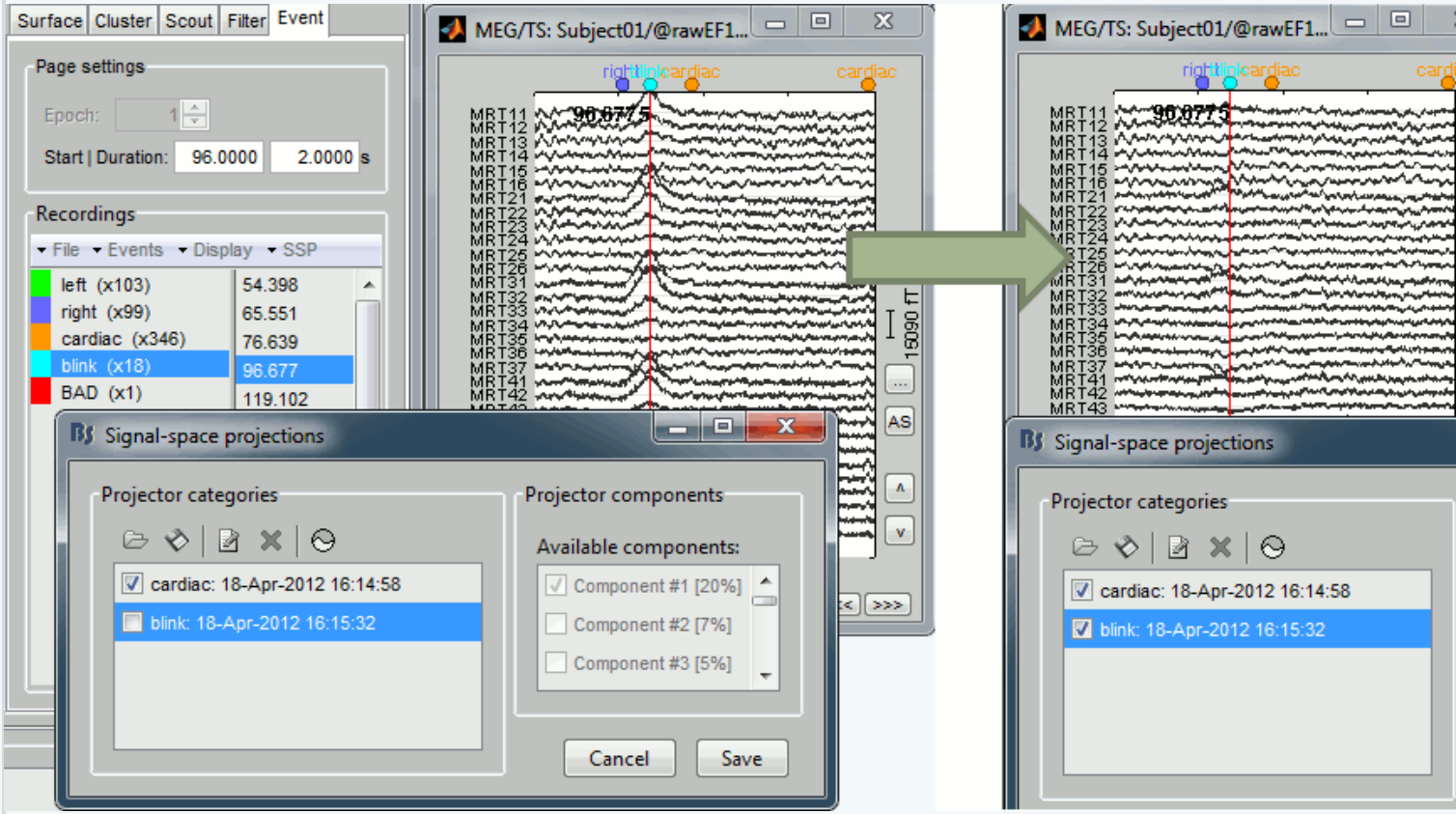
- Example: Cardiac artifact



Brainstorm

Pre-processing

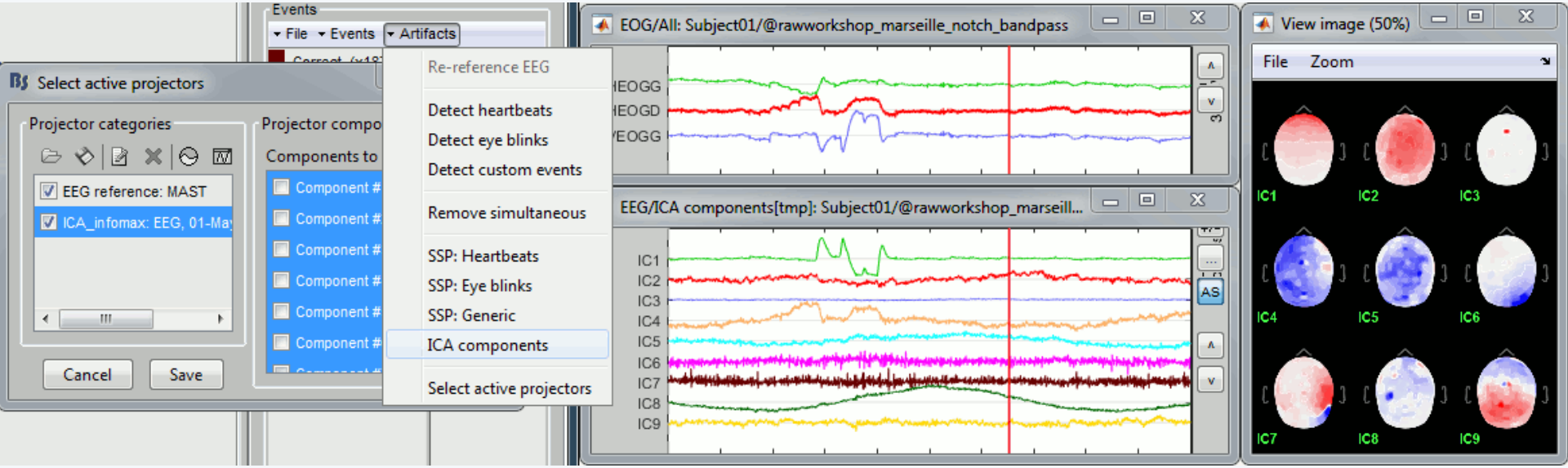
- Example: Blink



Brainstorm

Pre-processing

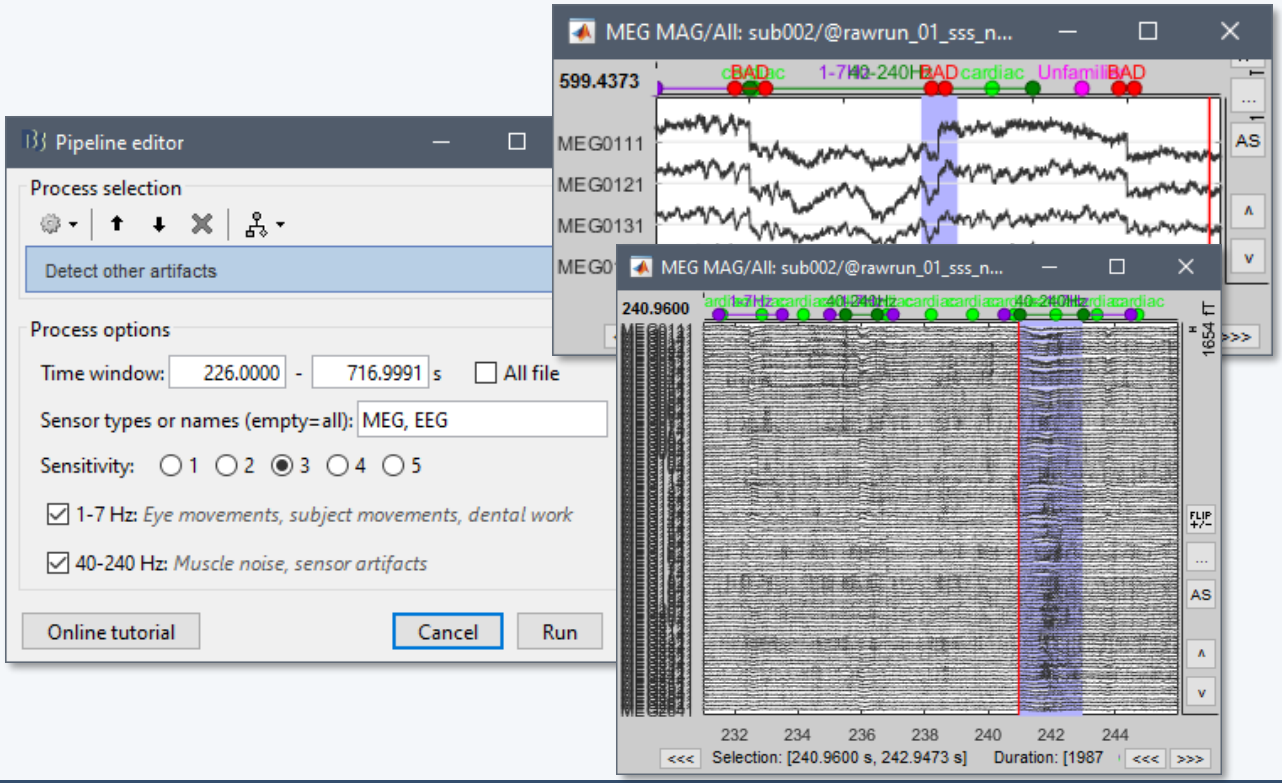
- Independent component analysis (ICA):
  - Popular in the EEG literature
  - Alternative to SSP for low number of sensors
  - Already implemented: Infomax and JADE (EEGLAB)



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

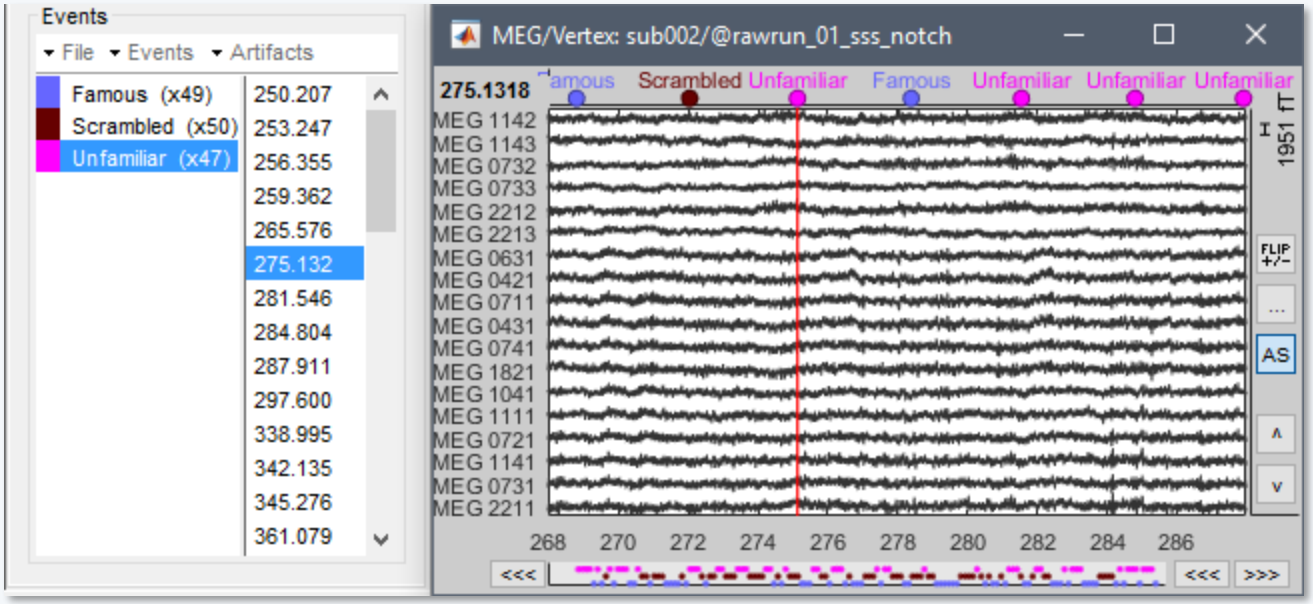


Brainstorm

Epoching

- Two types of experiments:
  - Steady-state or resting-state (ongoing activity)
  - Event-based (stimulus, response, spike…)

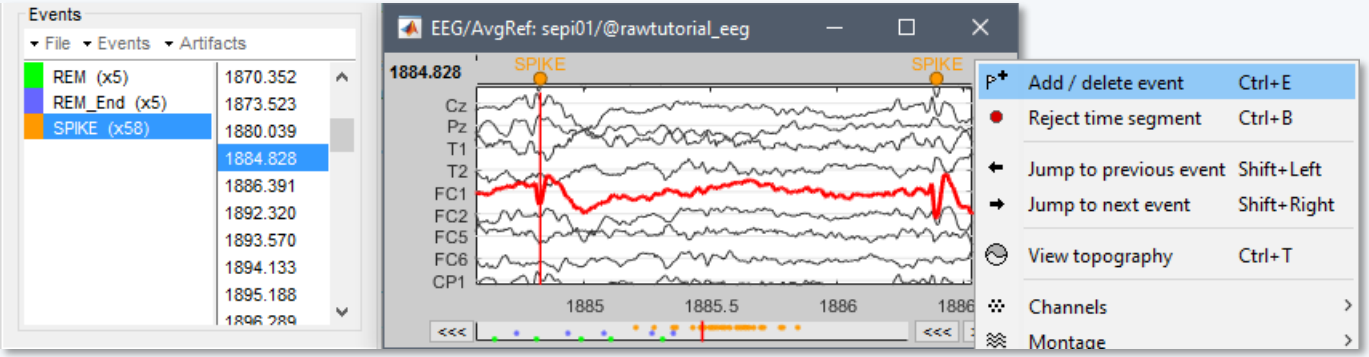
- How to get event markers in the recordings?



Brainstorm

Epoching

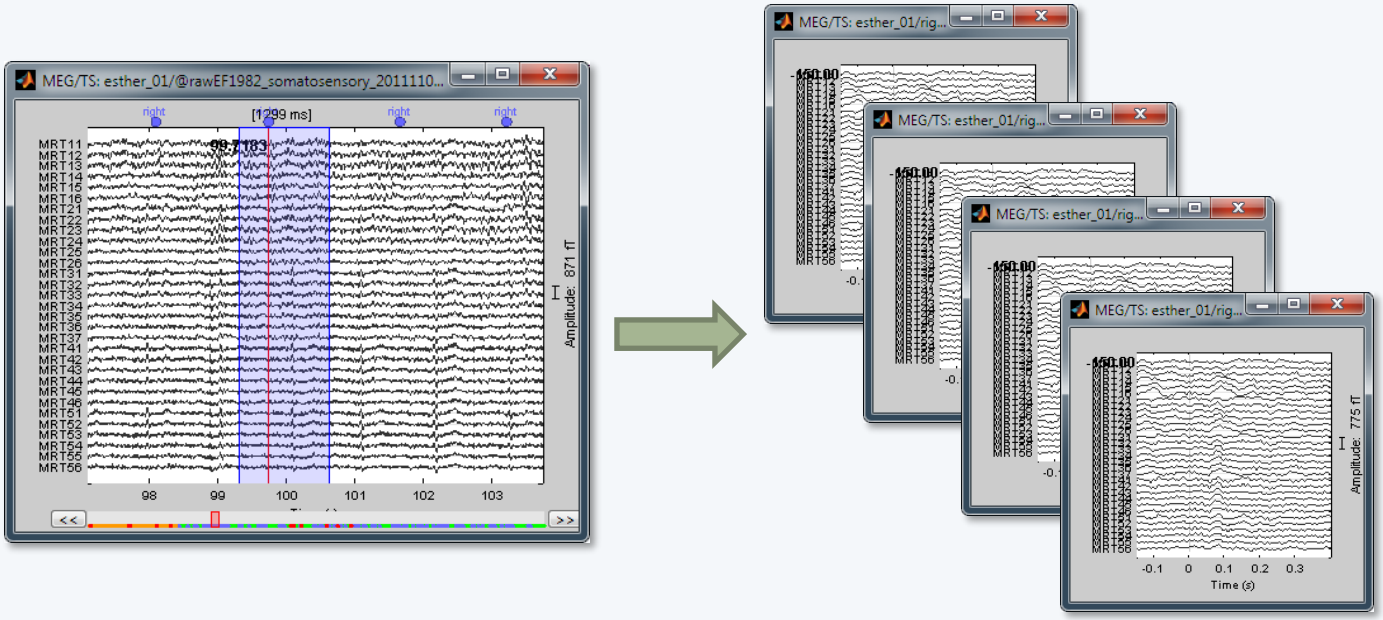
- Reading the triggers save by the presentation software (includes jittered OS delays)
- Reading information recorded on the subject side (photodiode, microphone, response box)
- Manual or automatic marking of biological or behavioral events, post-acquisition (epileptic spikes, sleep spindles, rat position in a box…)
- Optimized workflow for clinicians (keyboard and mouse shortcuts, workspace…)



Brainstorm

Epoching

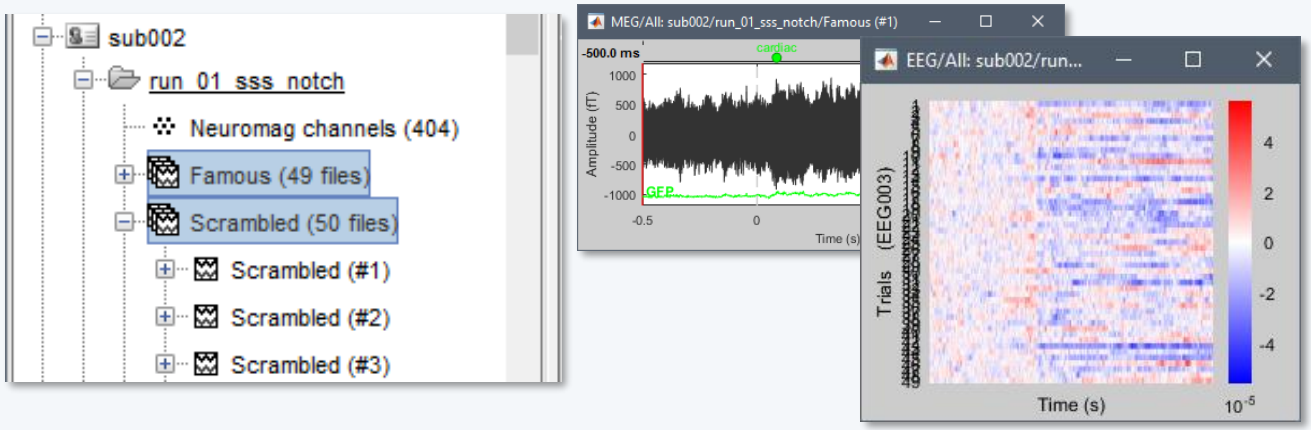
- Epochs = Trials = Short blocks of recordings around an event of interest.
- Epoching = Extracting epochs from the continuous recordings and saving them.



Brainstorm

Epoching

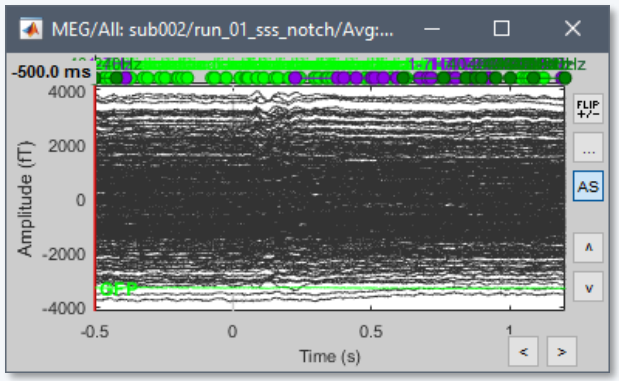
- In Brainstorm, each imported epoch is an independent file in the database.
- Accessible by event type or individually.

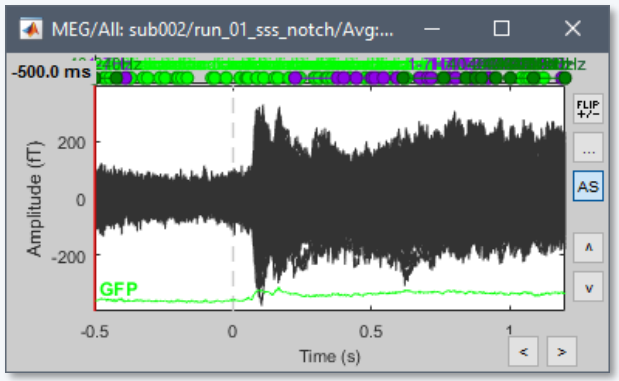


- In other programs, all the epochs from one run are saved in one single file (one file per event type, or one file with all the events).

Epoching

- Processing steps that can be applied on epochs:
  - **DC offset correction**: Subtract the average estimated over a baseline period
  - **Detrending**: Subtract a linear trend estimated over a reference period
  - **Resampling**: Decrease the sampling rate
- This dataset: DC correction, baseline=[-500,0]ms





Brainstorm

Sensor level analysis

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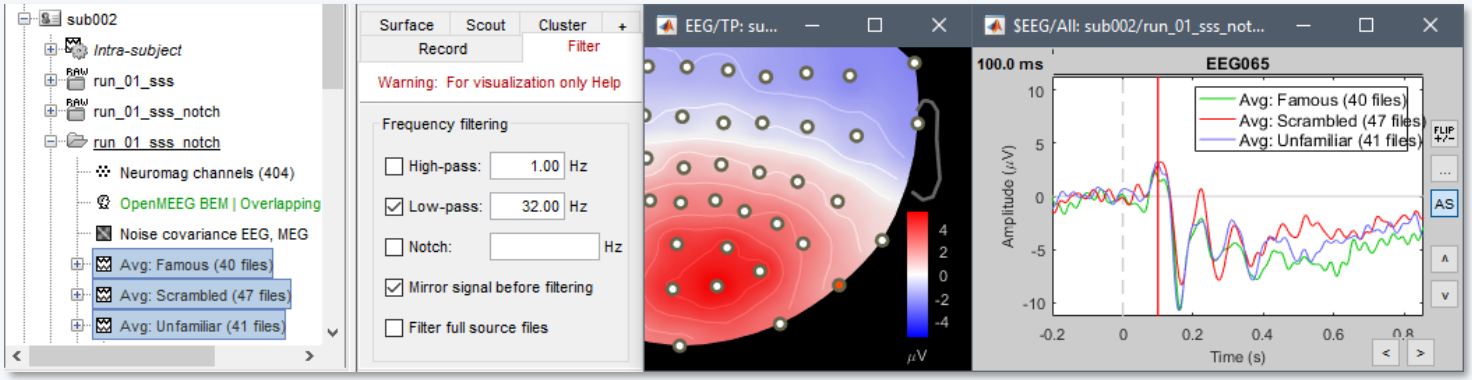
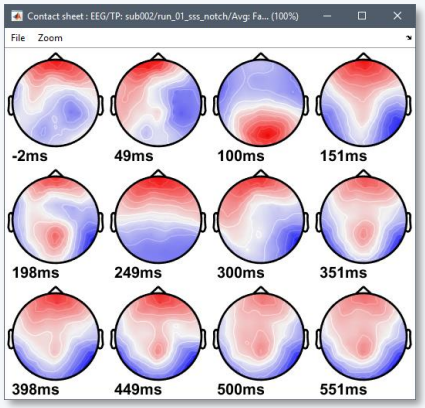
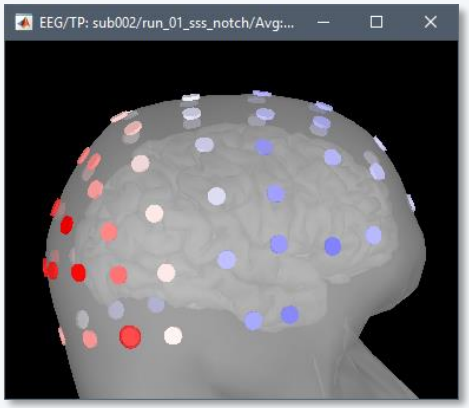
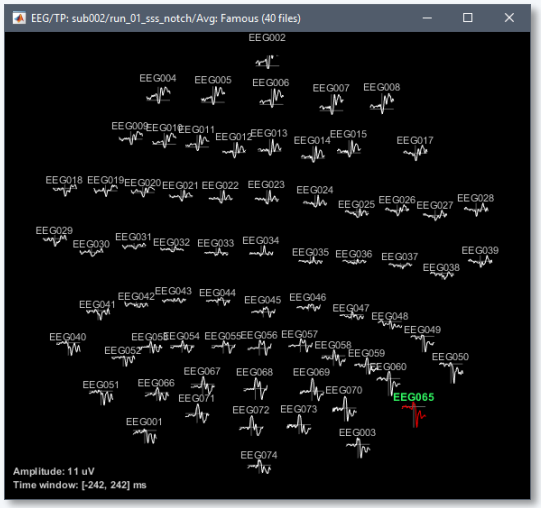
- ERP & Sensor Cluster









Brainstorm

Source Reconstruction

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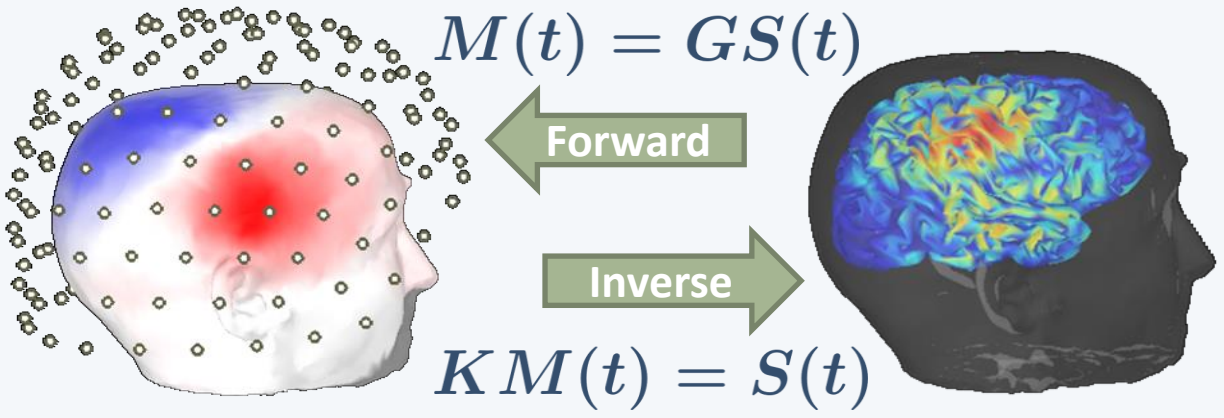
$M(t)$ Sensor space: EEG or MEG sensors

$S(t)$ Source space: Cortex or full head volume

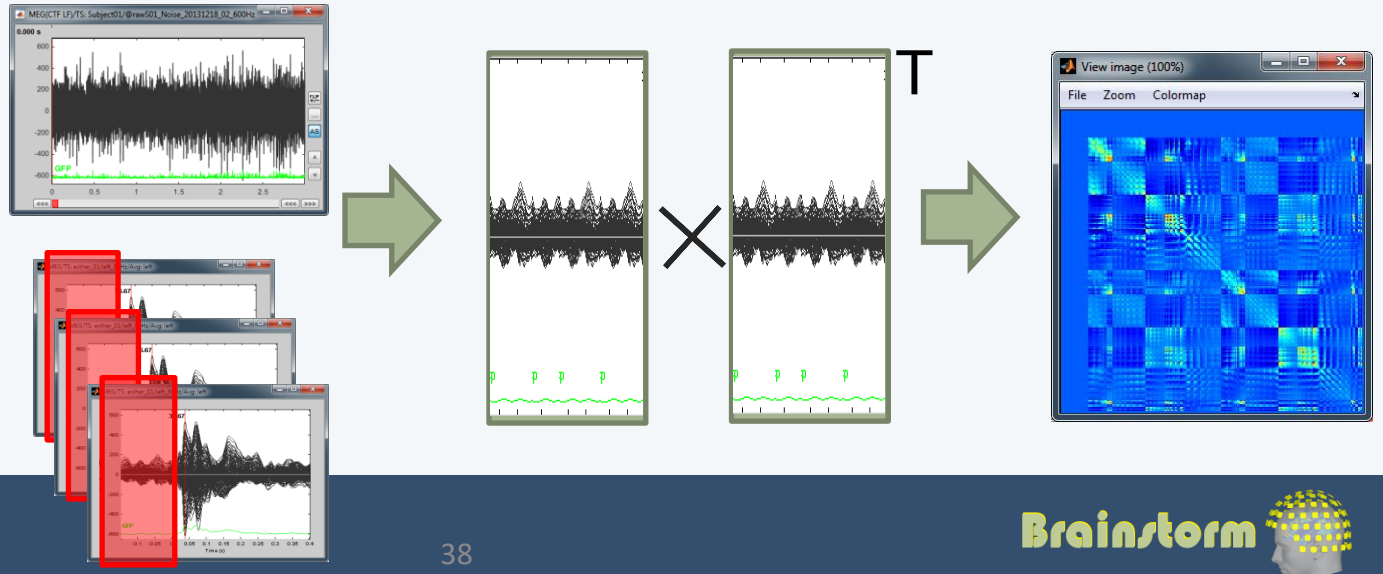
G Forward model: Overlapping spheres (MEG)
OpenMEEG BEM/DUNEuro FEM (EEG)

K Inverse model: **Minimum norm estimates**
Beamformers
Separately for MEG and EEG



Noise covariance

- The MNE model requires an estimation of the level of noise of the sensors
- Noise covariance matrix = covariance of segments that do not contain any “meaningful” data
- Empty room, pre-stim baseline, resting



Brainstorm

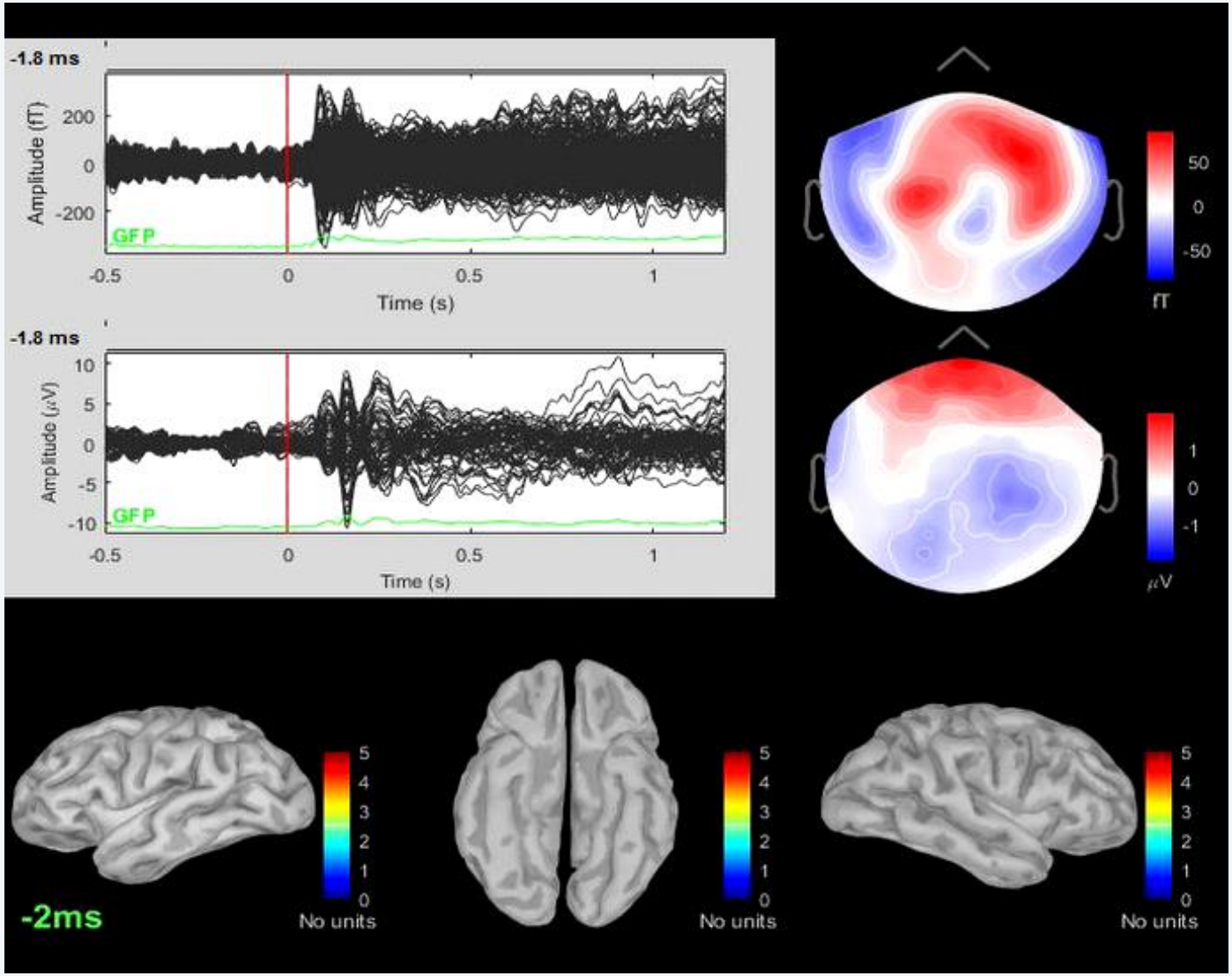
Source level analysis

Anatomy
Link recordings
MRI registration

PSD
Filters
Bad channels
Artifacts
Correction
Bad segments

Markers
Epoching
Averaging
Sources
Time-frequency

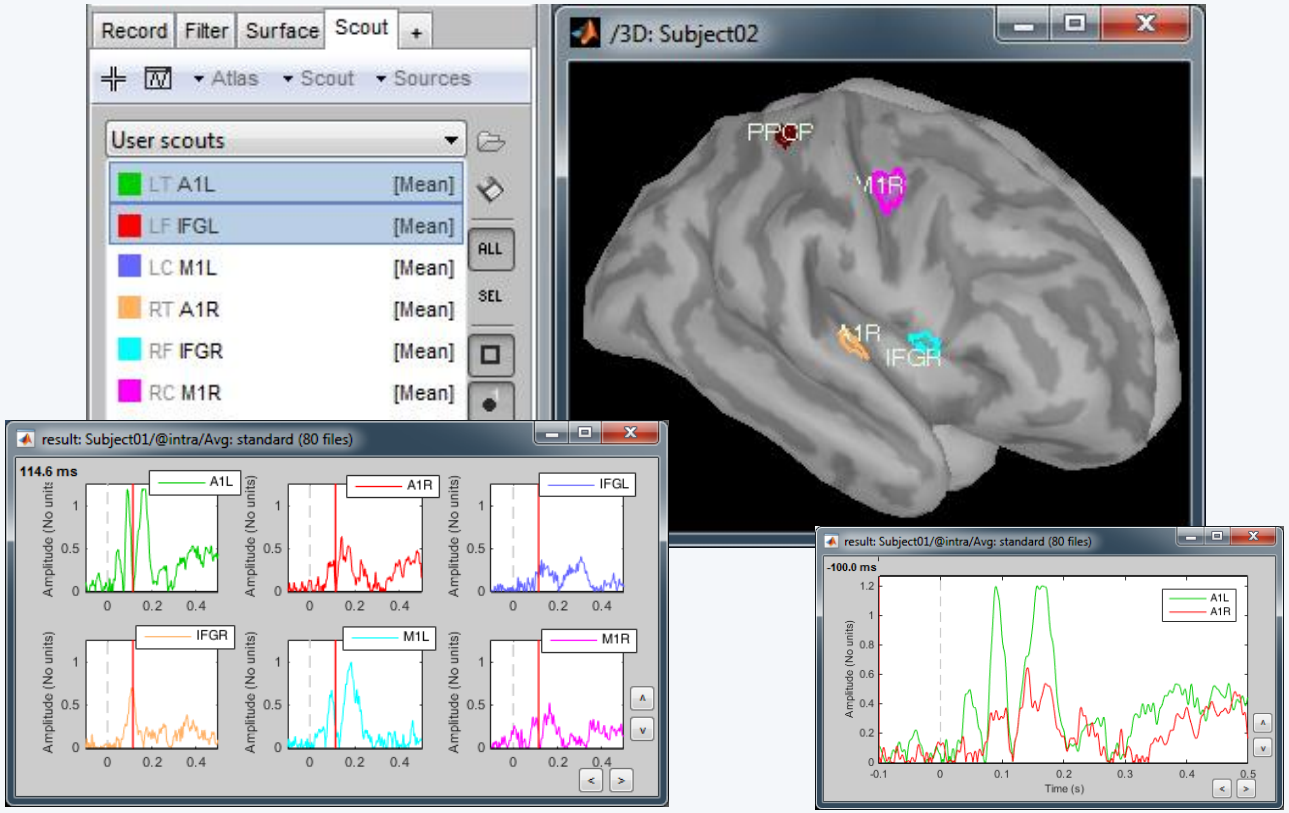
Example: Famous faces



Brainstorm

Source level analysis

- Regions of interest at cortical level (scouts)
  = Subset of a few dipoles in the brain
  = Group of vertices of the cortex surface



Brainstorm

Source level analysis

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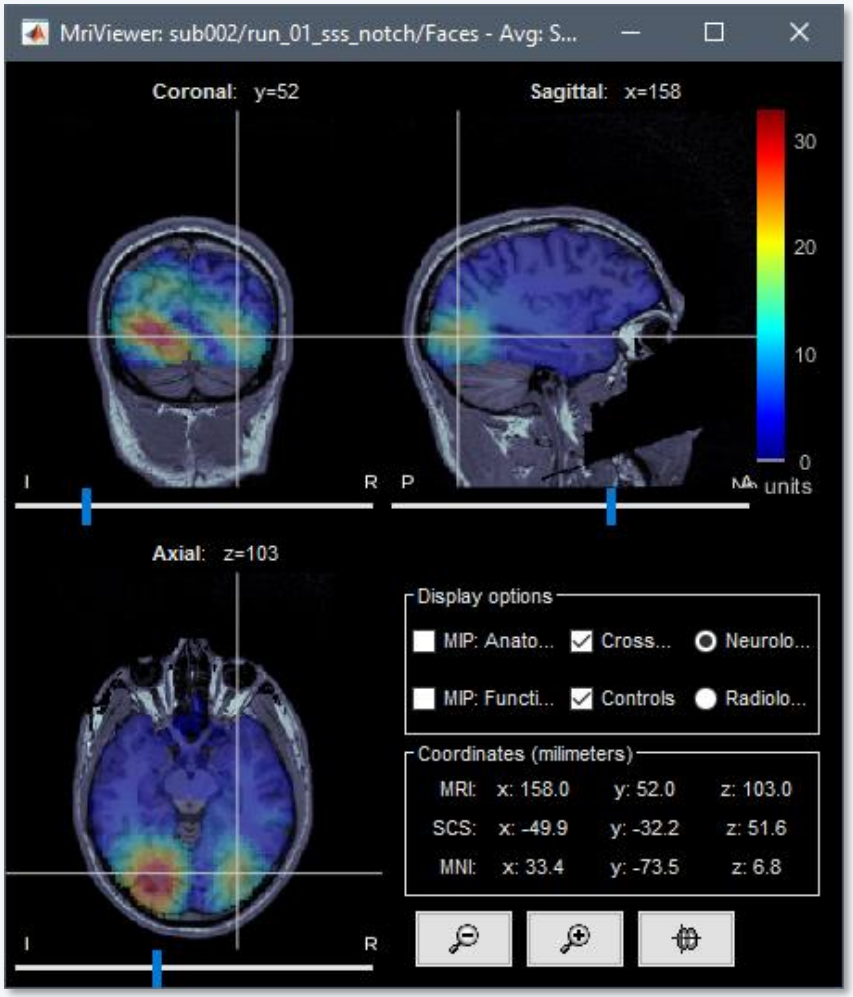
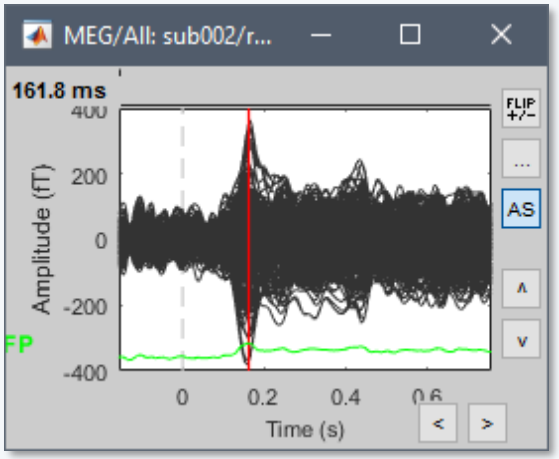
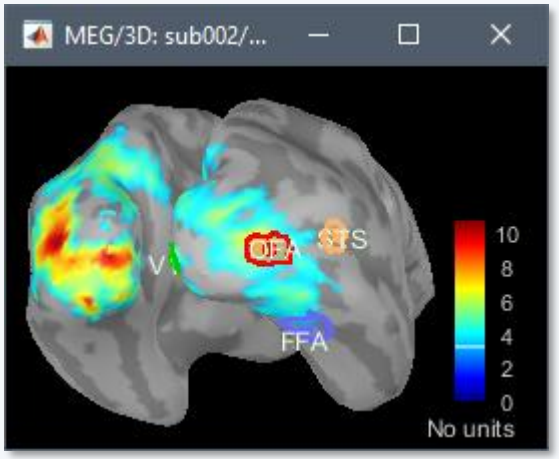
Time-frequency

- Volume Source



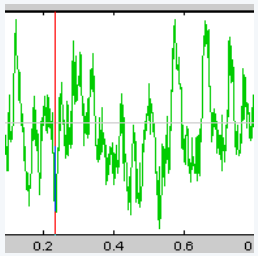


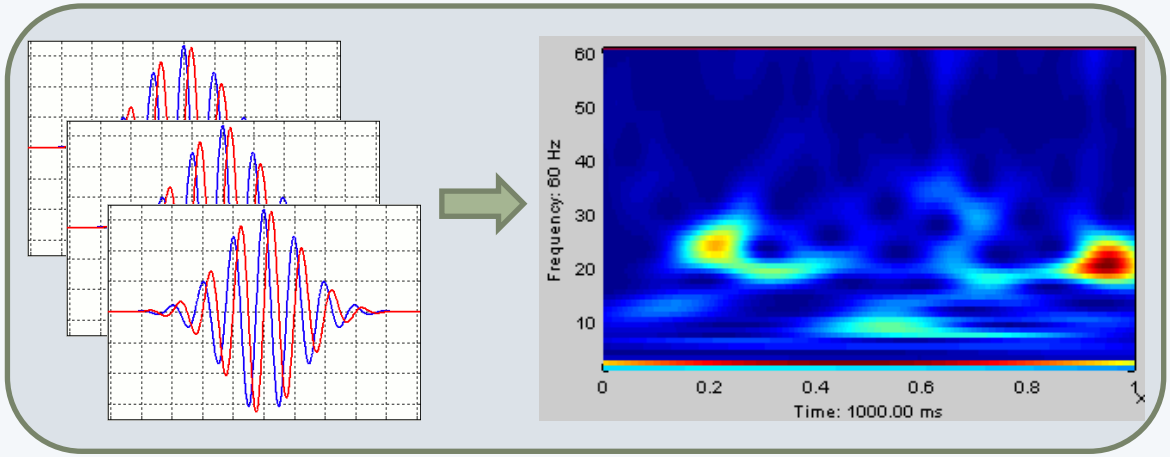


Brainstorm

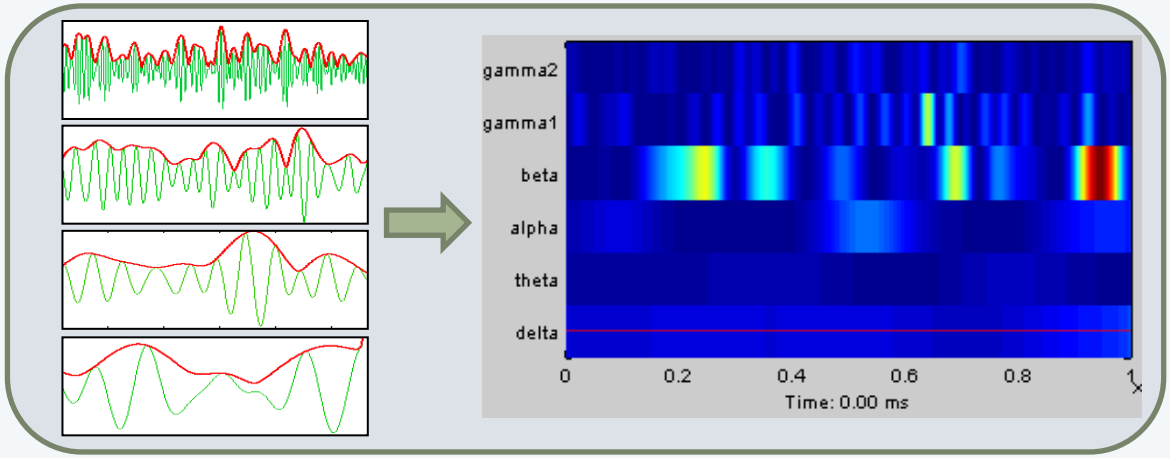
Time-frequency

Morlet wavelets



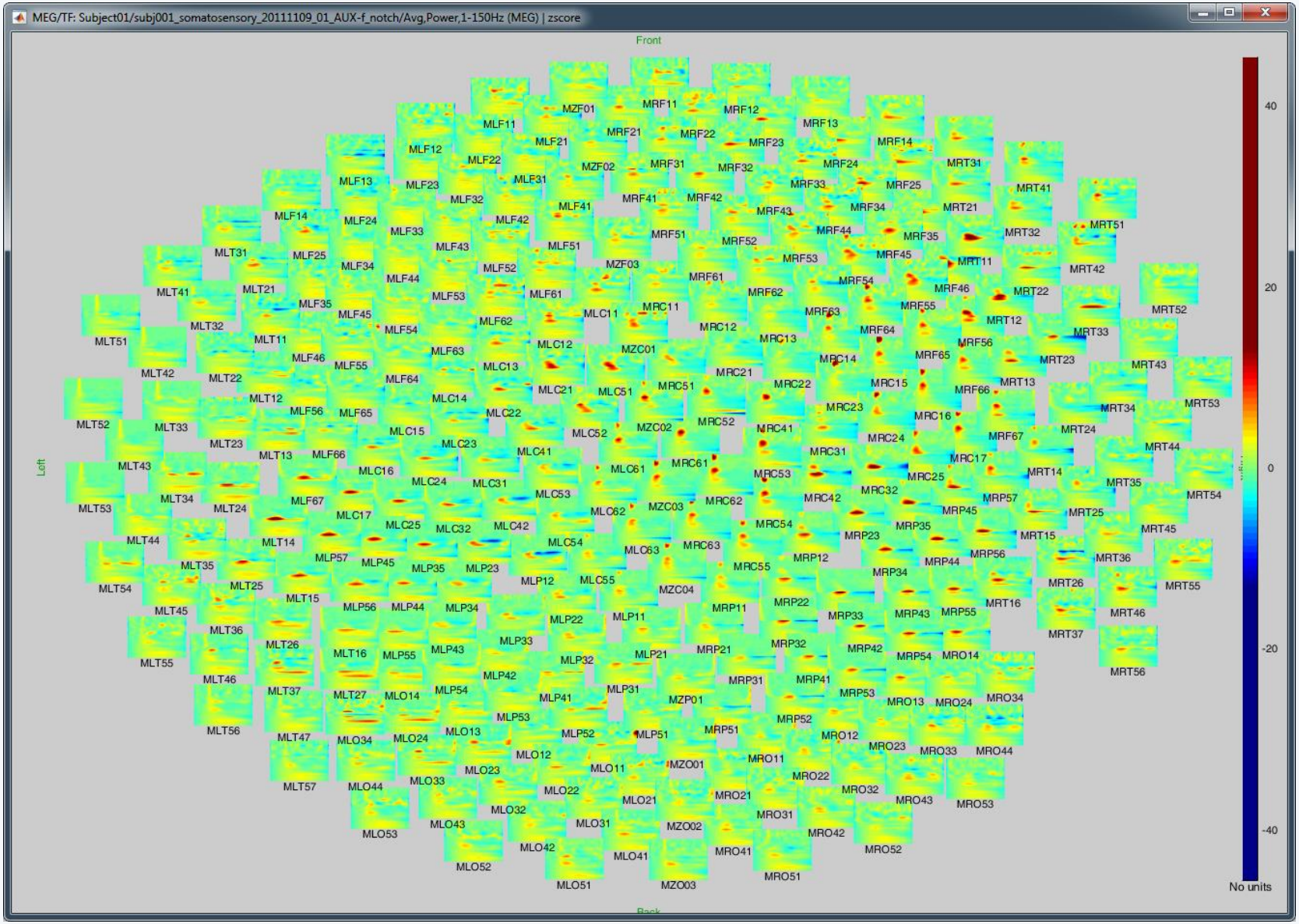


Hilbert transform + band-pass filter



Brainstorm

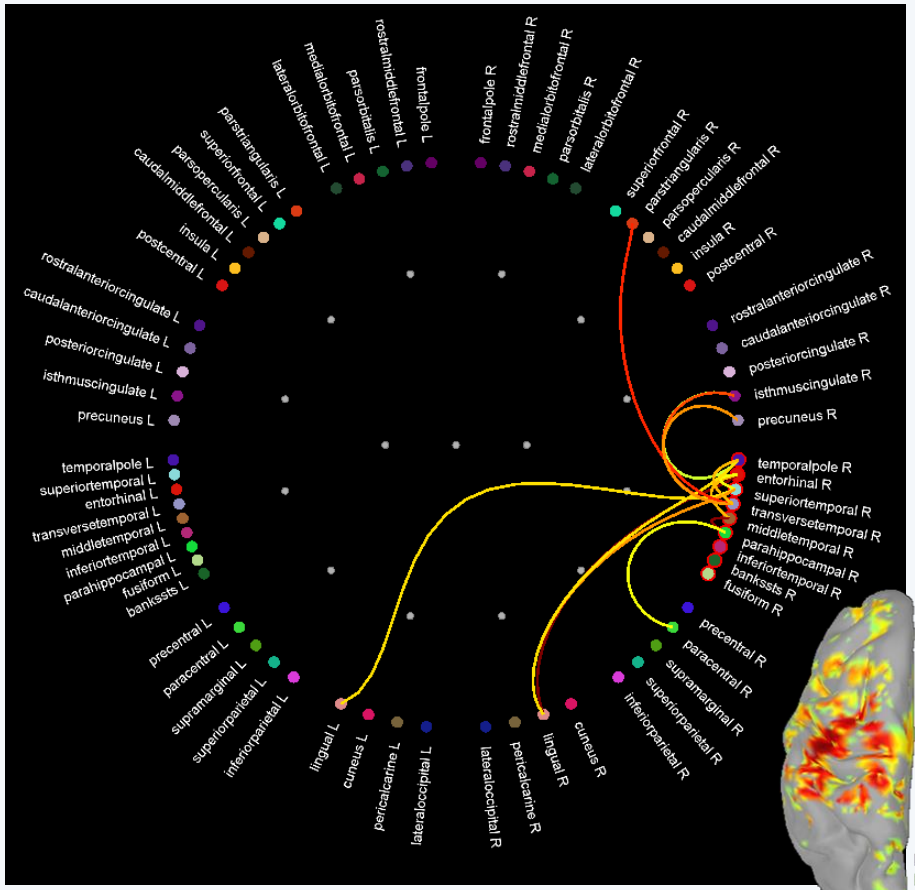
Time-frequency



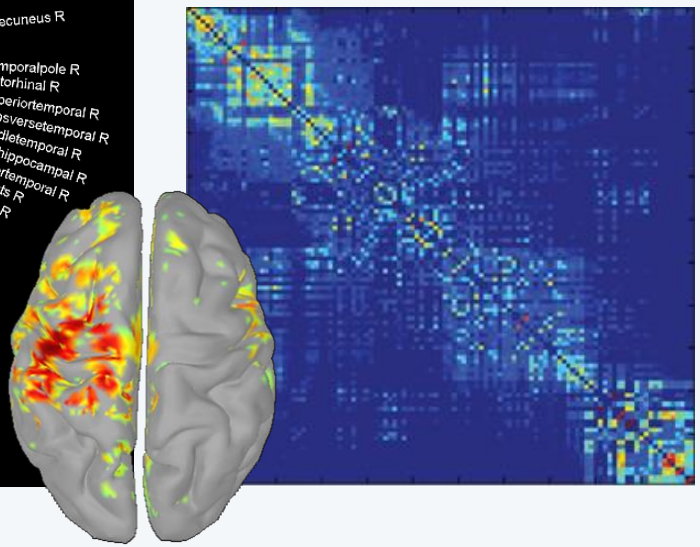
Brainstorm

Other measures

- Connectivity measures



- Correlation
- Coherence
- Phase locking value
- Granger causality



Brainstorm

Other measures

- And more …

Source modeling

- Volume source estimation
- Deep cerebral structures
- Realistic head model: BEM with OpenMEEG
- Dipoles: Scanning and displaying
- Dipoles: FieldTrip dipole fitting
- Maximum entropy on the mean (MEM)
- Other beamforming methods
- Simulations

Signal processing

- Machine learning: Decoding / MVPA
- Phase-amplitude coupling: Method
- Phase-amplitude coupling: Example
- Partial Least Squares (PLS)
- Epileptogenic Zone Fingerprint
- FOOOF: Fitting Oscillations & One-Over-F
- SPRiNT: Spectral Param. Resolved in Time

Finite Element Modeling

- Realistic head model: FEM with DUNEuro
- FEM mesh generation
- FEM tensors estimation
- FEM median nerve example

Connectivity

- Functional connectivity
- Corticomuscular coherence
- Connectivity graphs
- Virtual fibers for connectivity
- Granger causality

Brain-fingerprinting

- Brain-fingerprinting

https://neuroimage.usc.edu/brainstorm/Tutorials

Group analysis & Scripting

Anatomy
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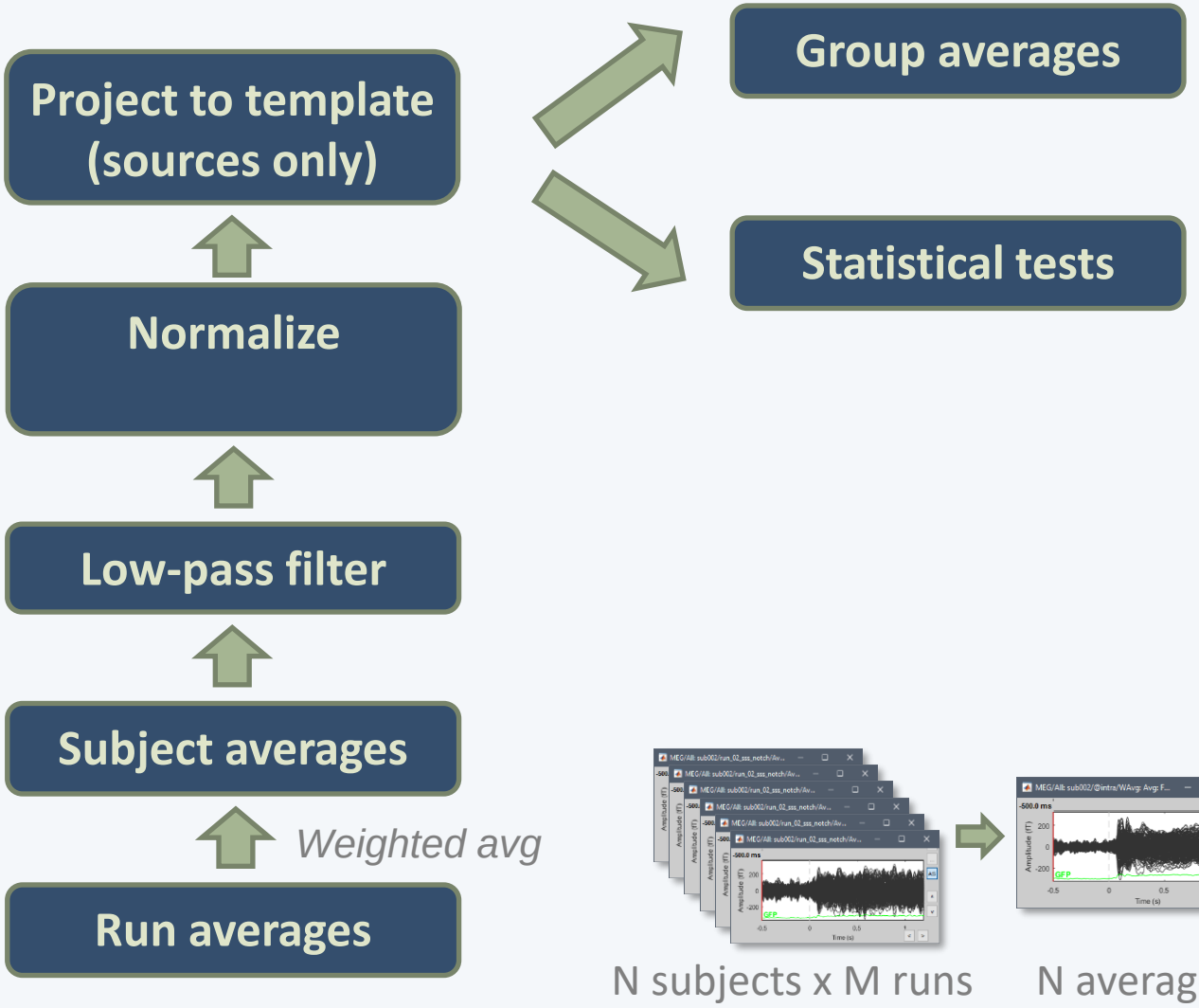


Brainstorm

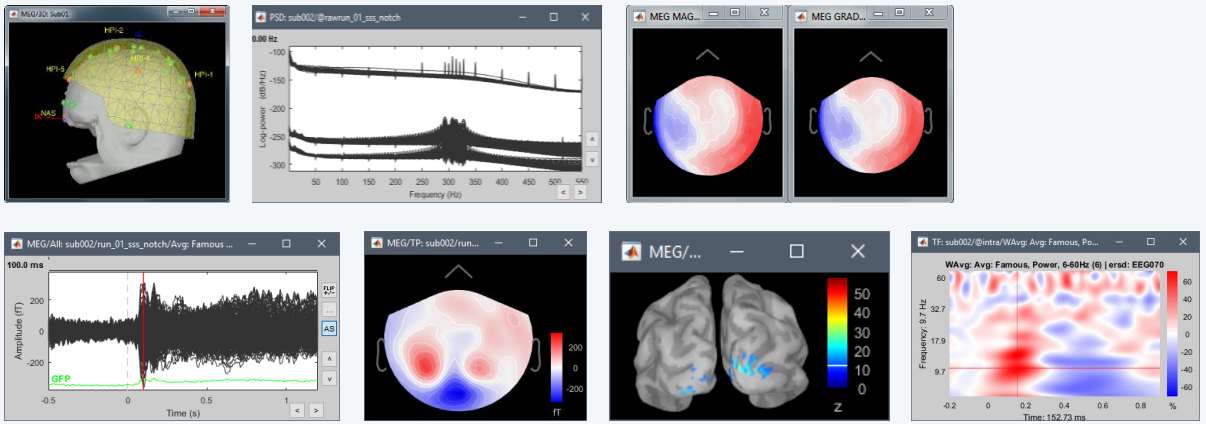
Quality control

Subject averages
Low-pass
Normalize
Project

Group averages
Group statistics

Quality control
Workflow

- When scripting the analysis, we recommend always to check visually the following items for each run separately:
  - MRI/sensors registration
  - PSD before and after filters
  - SSP and ICA component topographies
  - ERP/ERF: Sensors time series
  - ERP/ERF: Sensors topo of primary response
  - ERP/ERF: Sources of primary response
  - Any other metric of interest



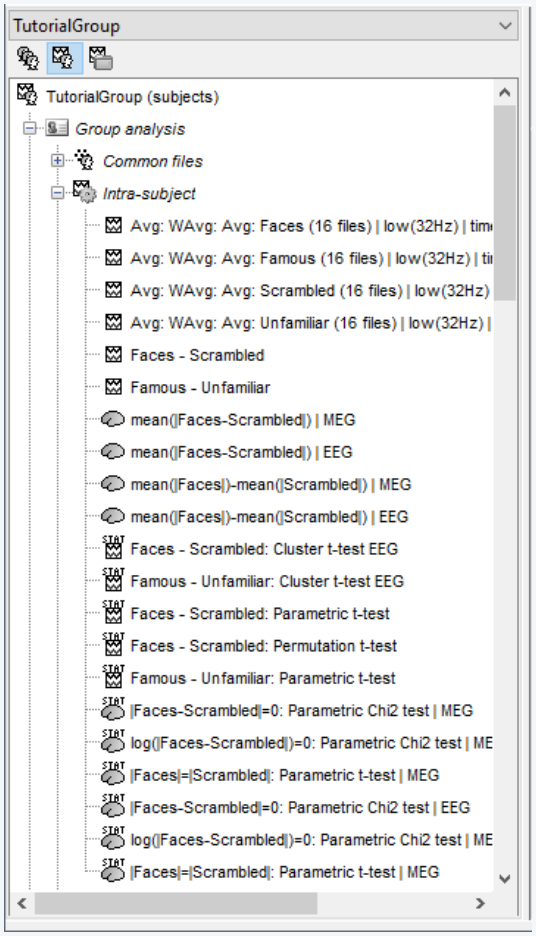
Quality control

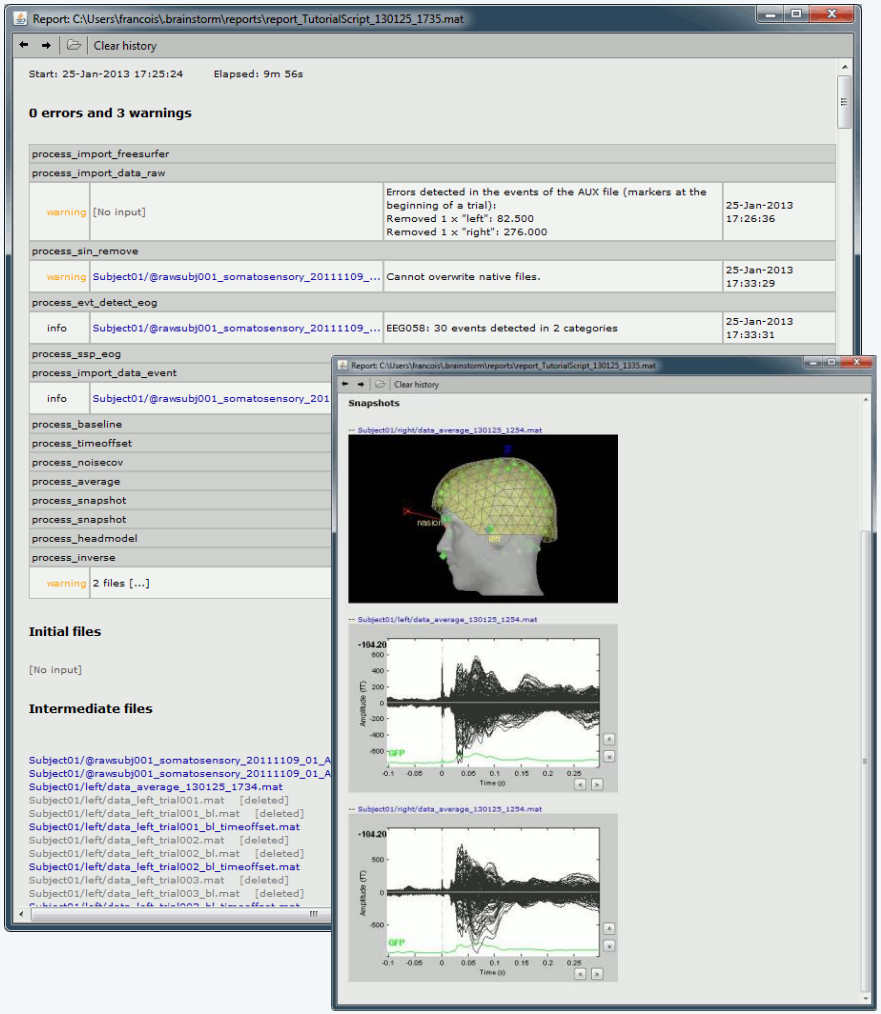
Subject averages
Low-pass
Normalize
Project

Group averages
Group statistics

Quality control
Workflow

- Execution reports with snapshots saved in HTML

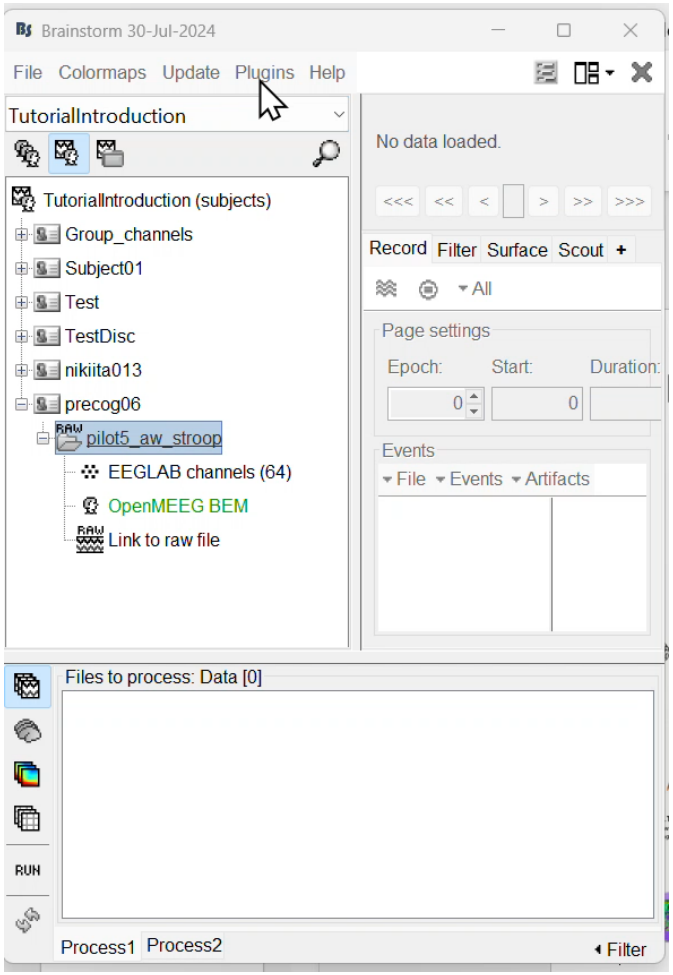


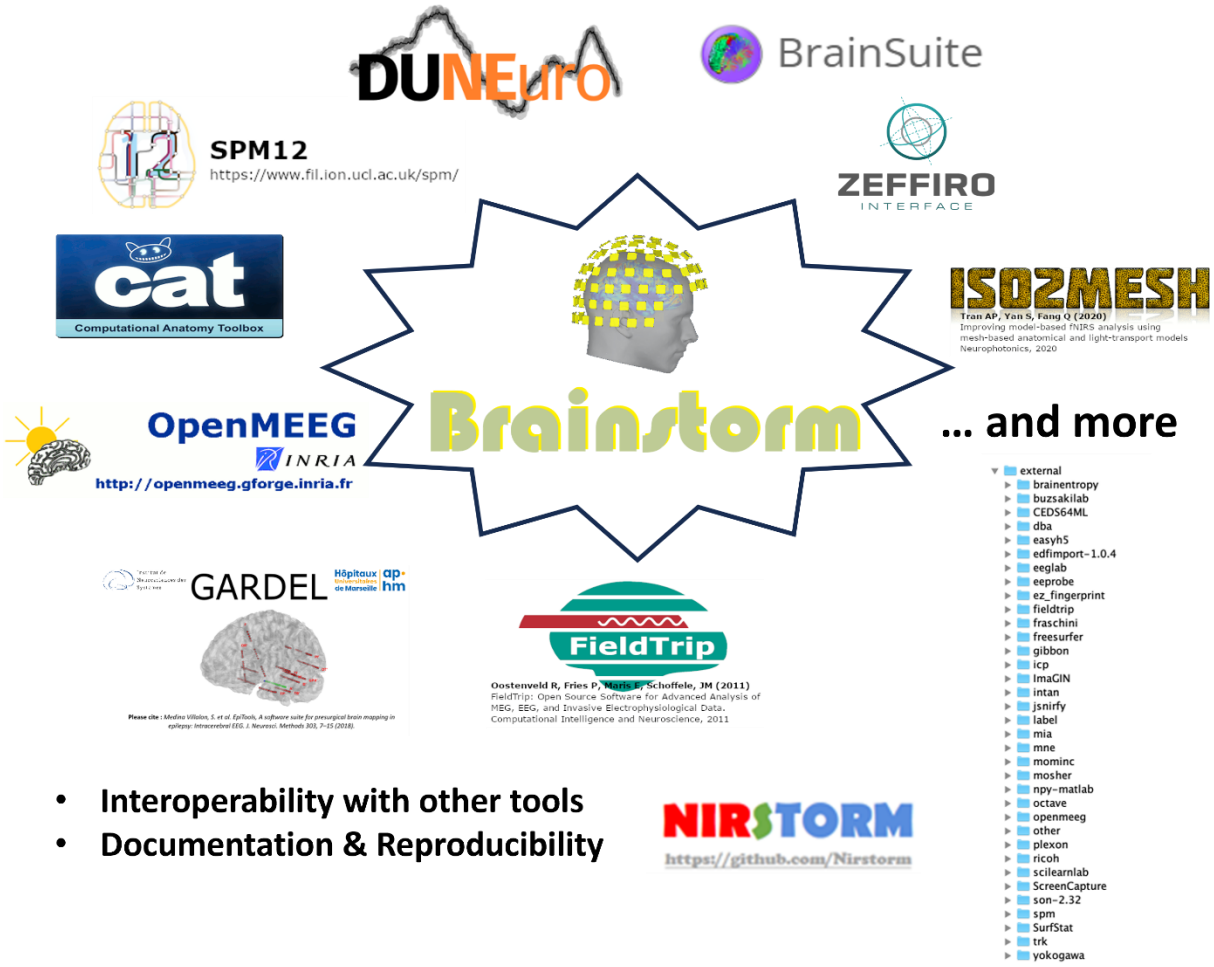


Brainstorm

What's New?

- **Brainstorm Plugin Manager: Brainstorm as a hub!**





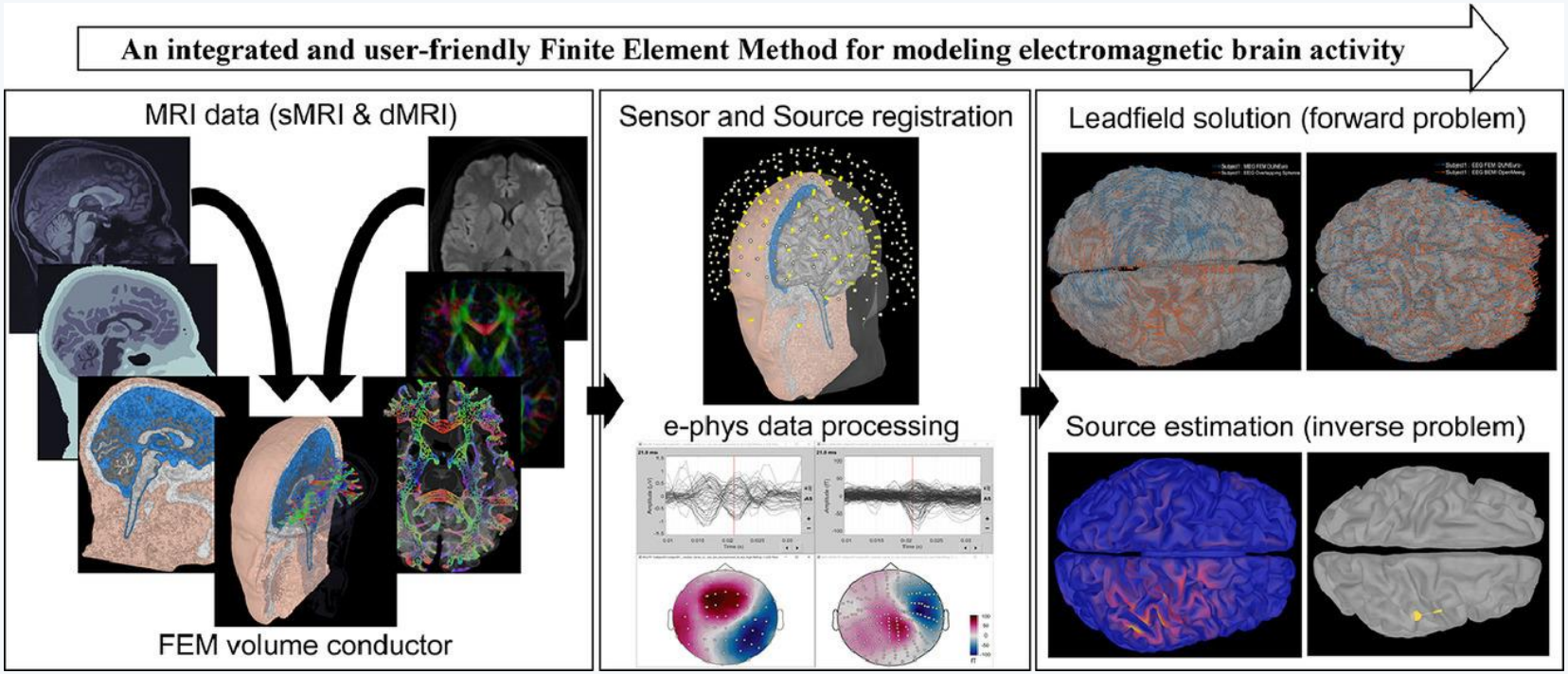
- **Interoperability with other tools**
- **Documentation & Reproducibility**

NIRSTORM
https://github.com/Nirstorm

Brainstorm

What's New?

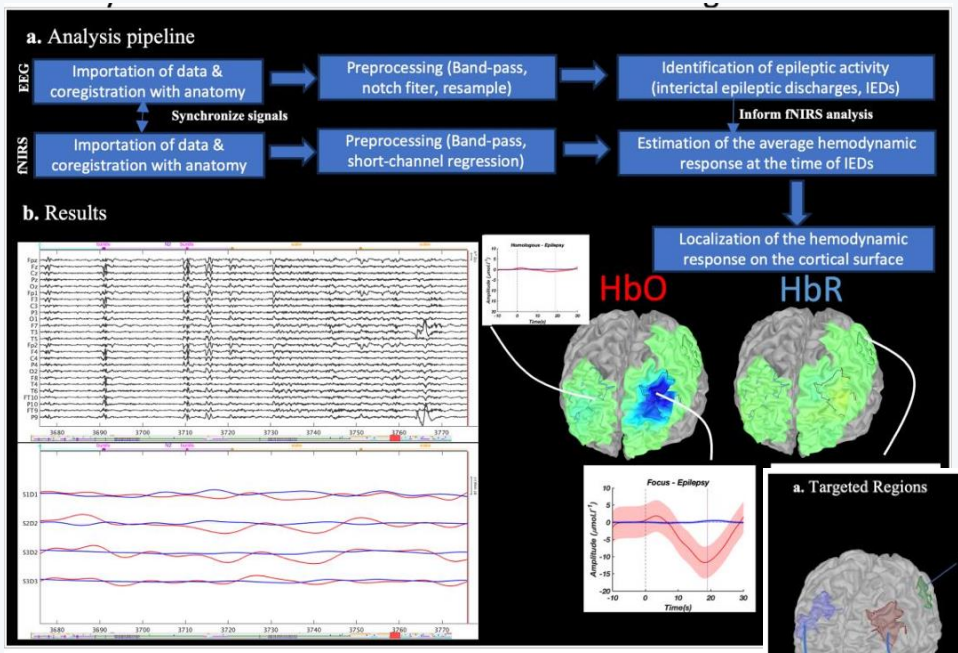
- **Brainstorm - DUNEuro: An integrated and user-friendly Finite Element Method for modeling electromagnetic brain activity**

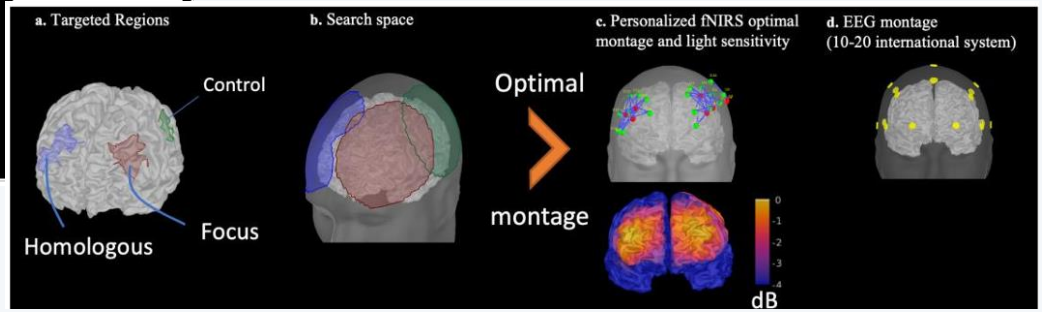


Takfarinas Medani, Juan Garcia-Prieto, Francois Tadel, Marios Antonakakis, Tim Erdbrügger, Malte Höltershinken, Wayne Mead, Sophie Schrader, Anand Joshi, Christian Engwer, Carsten H. Wolters, John C. Mosher, Richard M. Leahy
(https://doi.org/10.1016/j.neuroimage.2022.119851)

What's New?

- **NIRSTORM: a Brainstorm extension dedicated to functional Near Infrared Spectroscopy (fNIRS) data analysis, advanced 3D reconstructions, and optimal probe design**

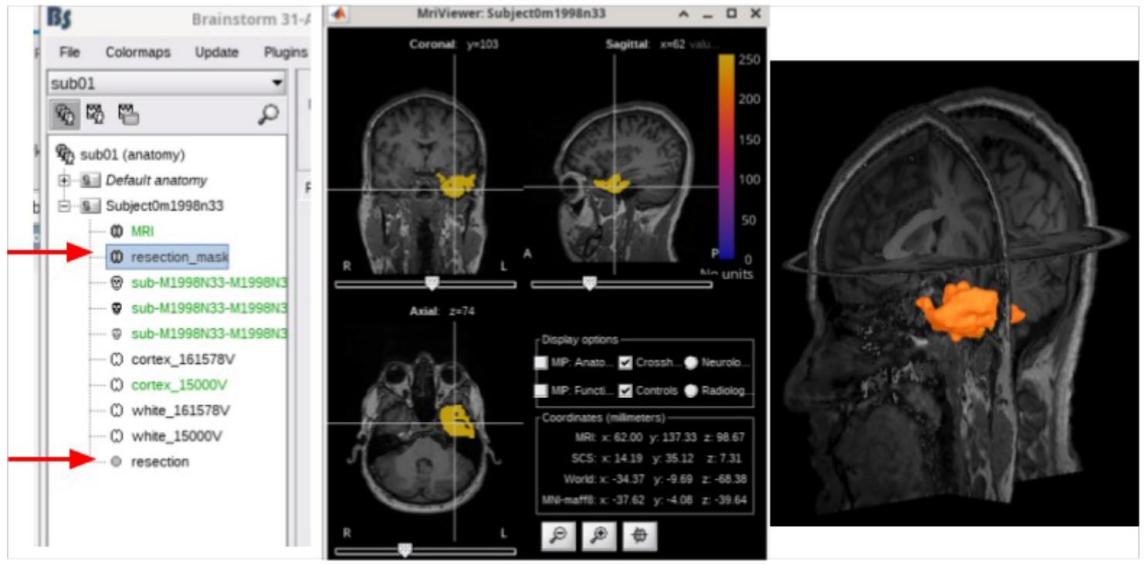




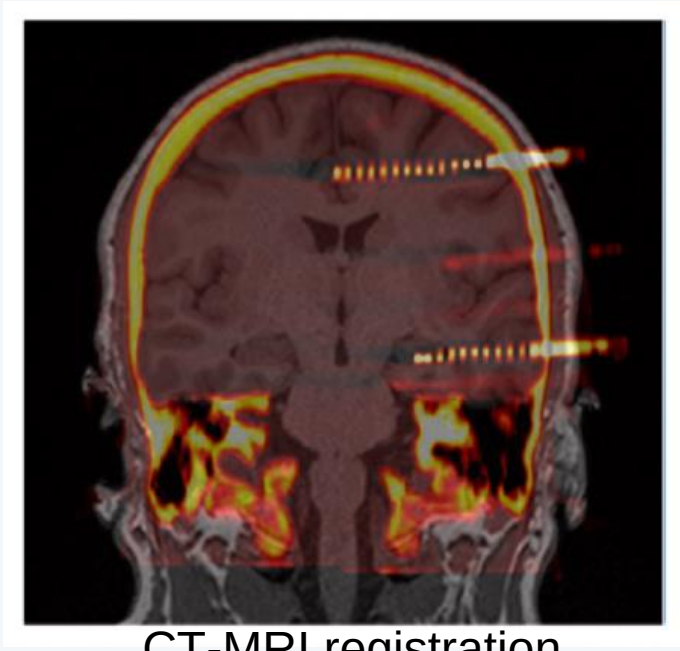
Édouard Delaire, Thomas Vincent, Zhengchen Cai, Alexis Machado, Laurent Hugueville, Denis Schwartz, Francois Tadel, Raymundo Cassani, Louis Bherer, Jean-Marc Lina, Mélanie Pélégrini-Issac, Christophe Grova (https://www.biorxiv.org/content/10.1101/2024.09.05.611463v1)

What's New?

- **CT-MRI volume co-registration and Resection labeling**



pre/post op resection volume detection

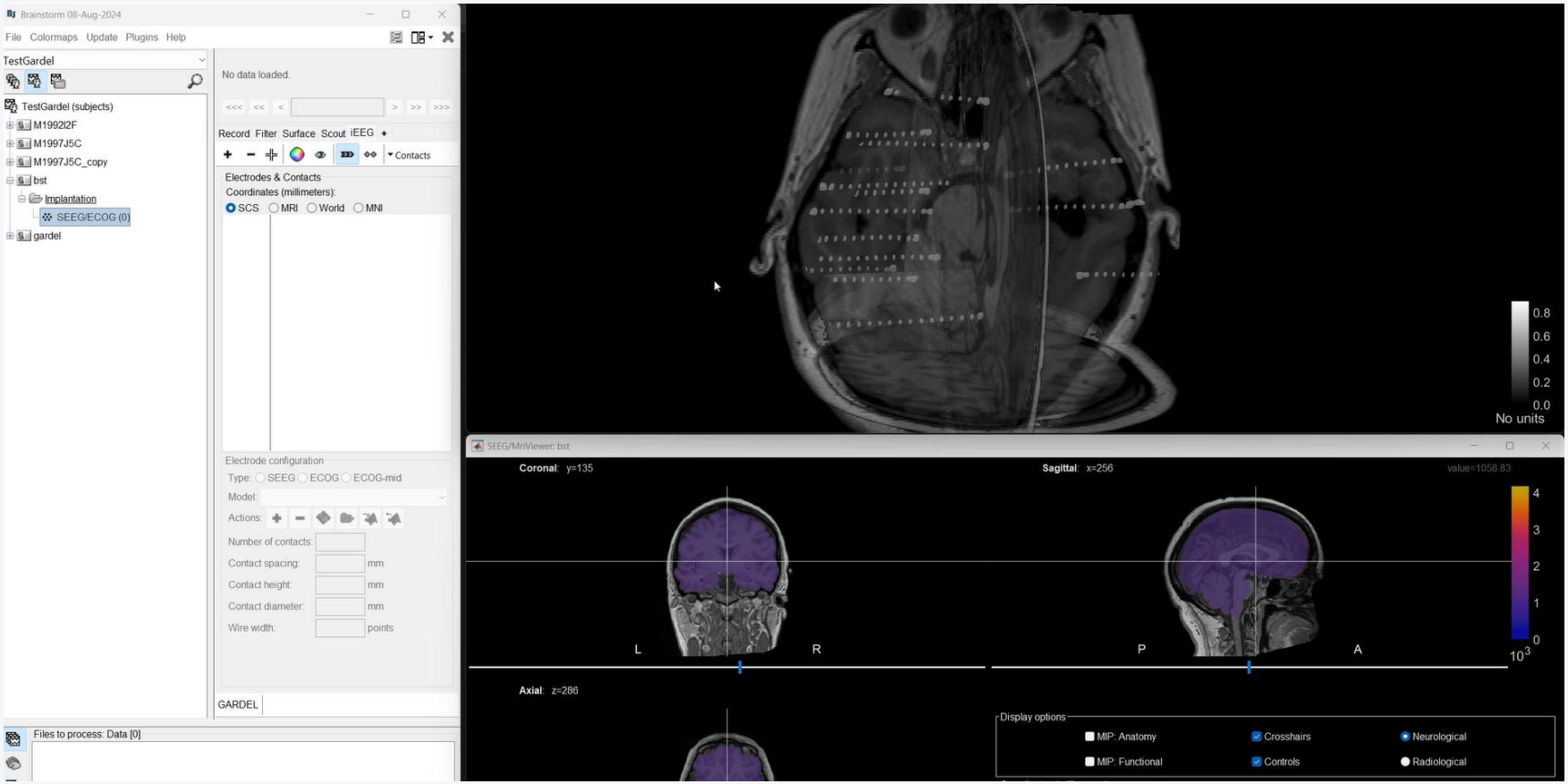


CT-MRI registration

A Joshi, Chinara, T. Medani and brainstorm team
https://neuroimage.usc.edu/brainstorm/Tutorials/SegBrainSuite?highlight=%28resection%29#Resection_labeling

What's New?

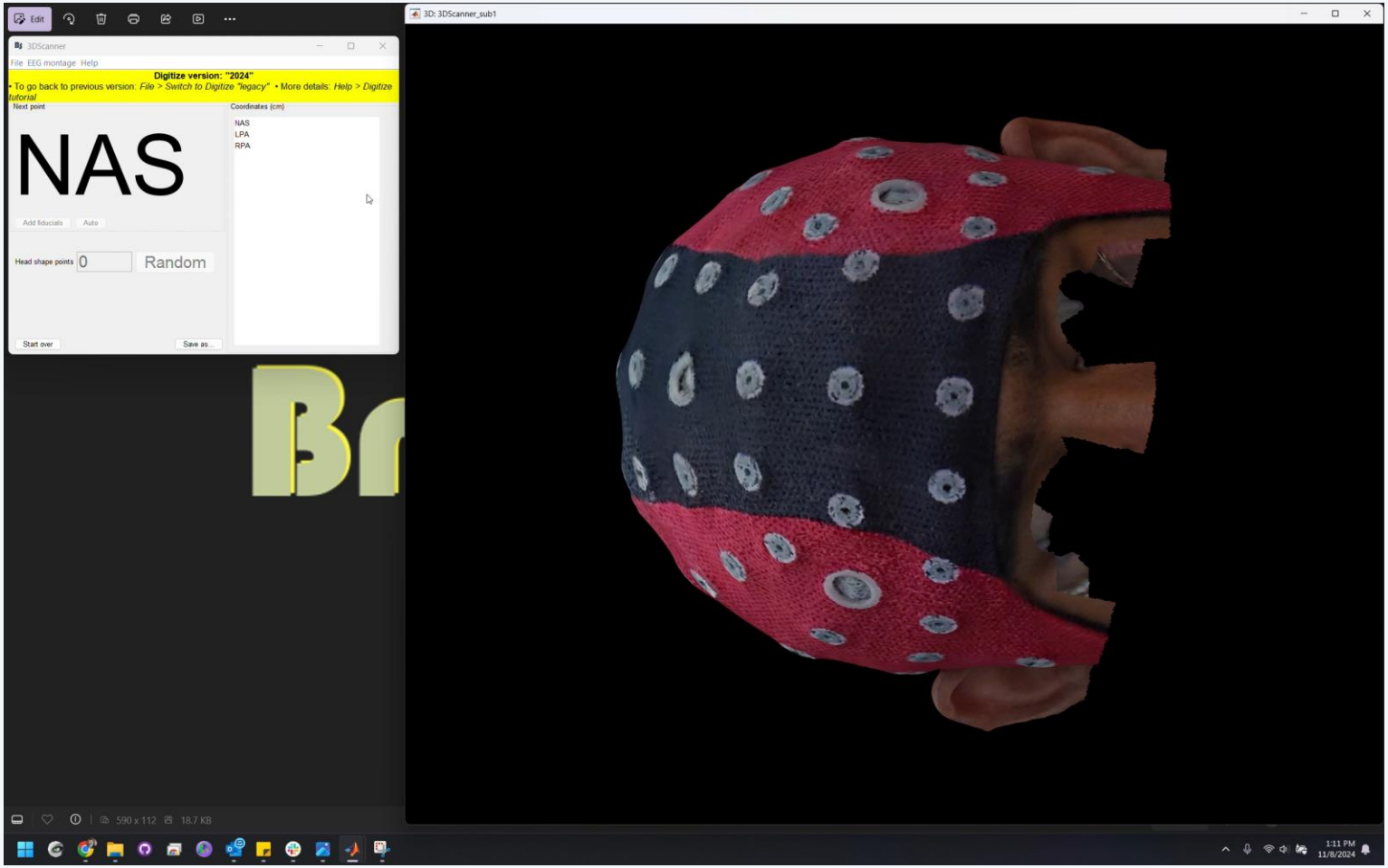
- **Automated sEEG Electrode Localization and Labeling**



Chinara, S.Medina, A Joshi, C-G Bénar , T.Medani and brainstorm team: https://neuroimage.usc.edu/brainstorm/Tutorials/IeegContactLocalization
Medina Villalon et al. EpiTools, 2018 doi: 10.1016/j.jneumeth.2018.03.018

What's New?

- **Automated EEG Electrode Localization and Labeling**

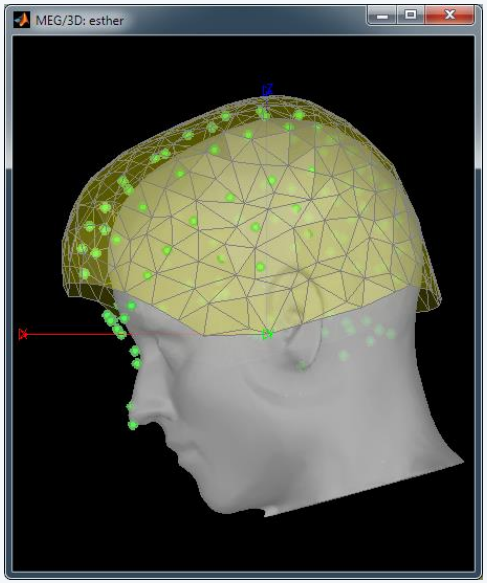


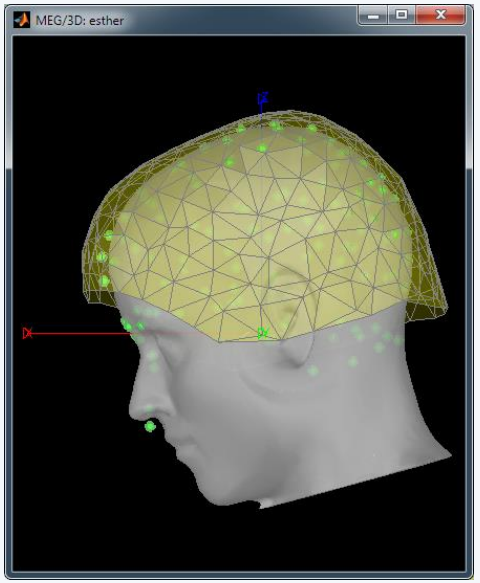
Chinara, A Joshi, Vakilna, Medani, and brainstorm team: https://neuroimage.usc.edu/brainstorm/Tutorials/TutDigitize3dScanner

Brainstorm

Co-registration MEEG / MRI (2)

- Automatic adjustment based on head shape: Fitting Polhemus points on the MRI head surface
- Final registration must be checked manually
- Polhemus driver included in Brainstorm



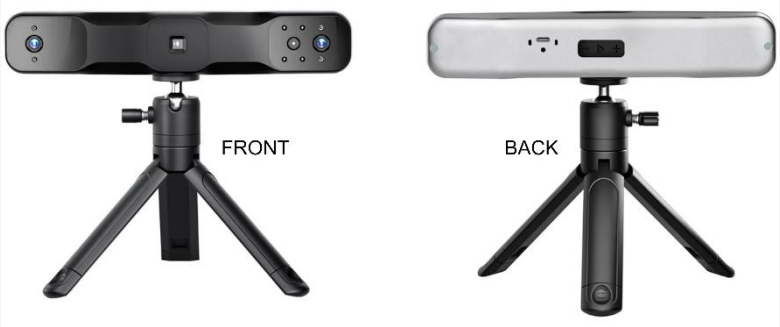


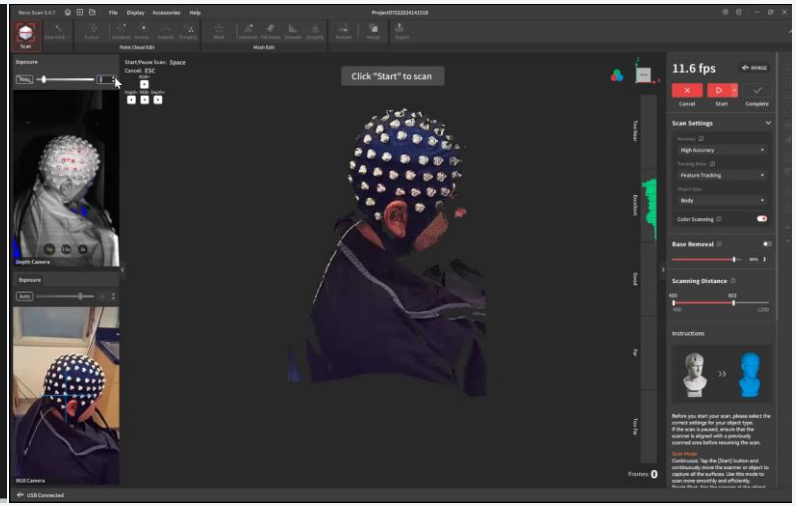
Co-registration EEG / MRI (3)

Anatomy

MRI registration

- 3D for scanning EEG scalp electrode





https://neuroimage.usc.edu/brainstorm/Tutorials/TutDigitize3dScanner

Brainstorm

What's New?

And more!!

Brainstorm

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Development
- What's new
- What's next
- About us
- Contact us
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Developers

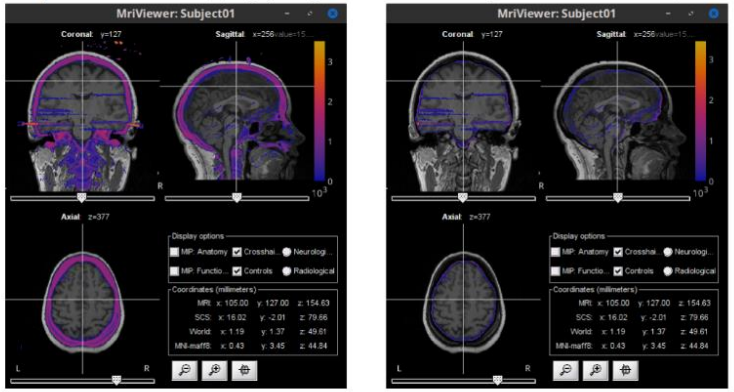
What's new

Brainstorm is in a very active development state: small or major bug fixes and improvements are issu
almost everyday. To update your version of the software easily: Install and update.
See also the full list of updates: brainstorm3/doc/updates.txt | All GitHub commits

November 2024

Anatomy

- Add NIRS template: 'Colin27_4NIRS_2024'
- Integration of skull stripping (using SPM or BrainSuite) within Brainstorm



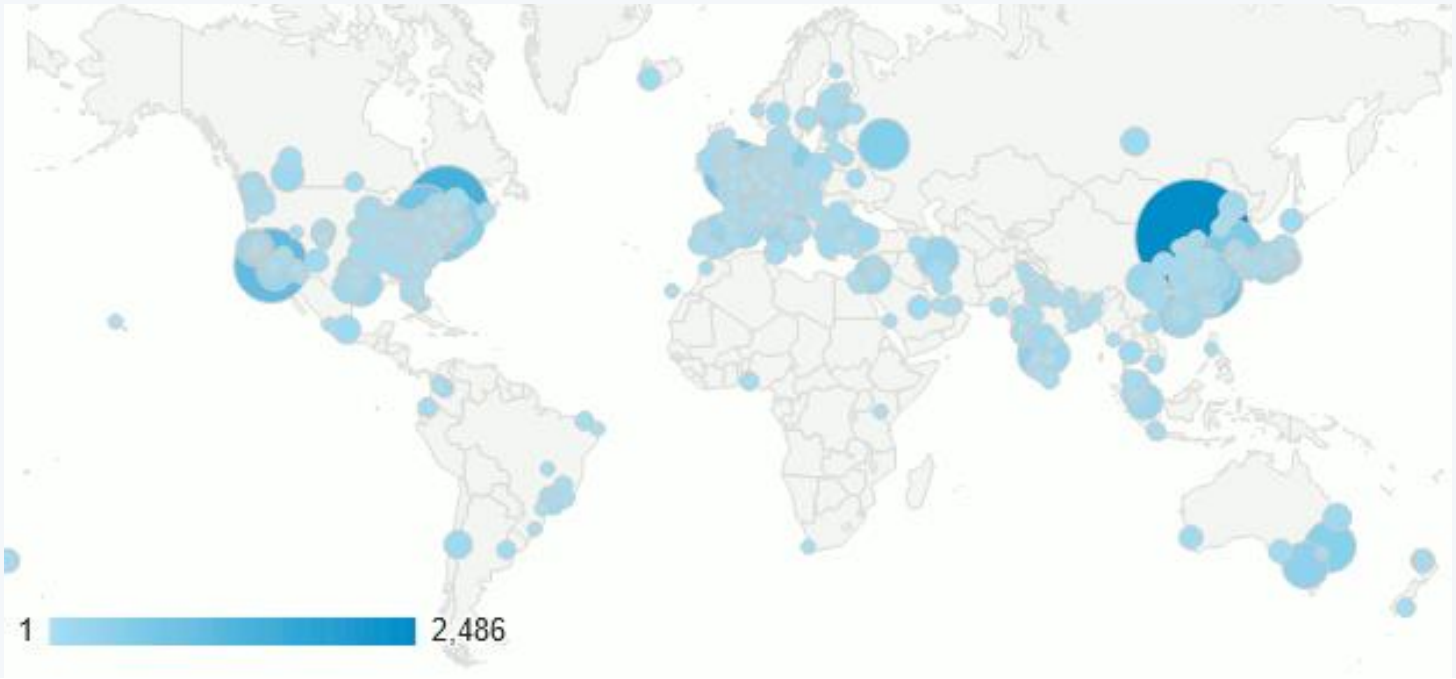
SEEG/ECOG

https://neuroimage.usc.edu/brainstorm/News

Brainstorm

User community (2024)

- >45,000+ users registered on the website



Find users next to you

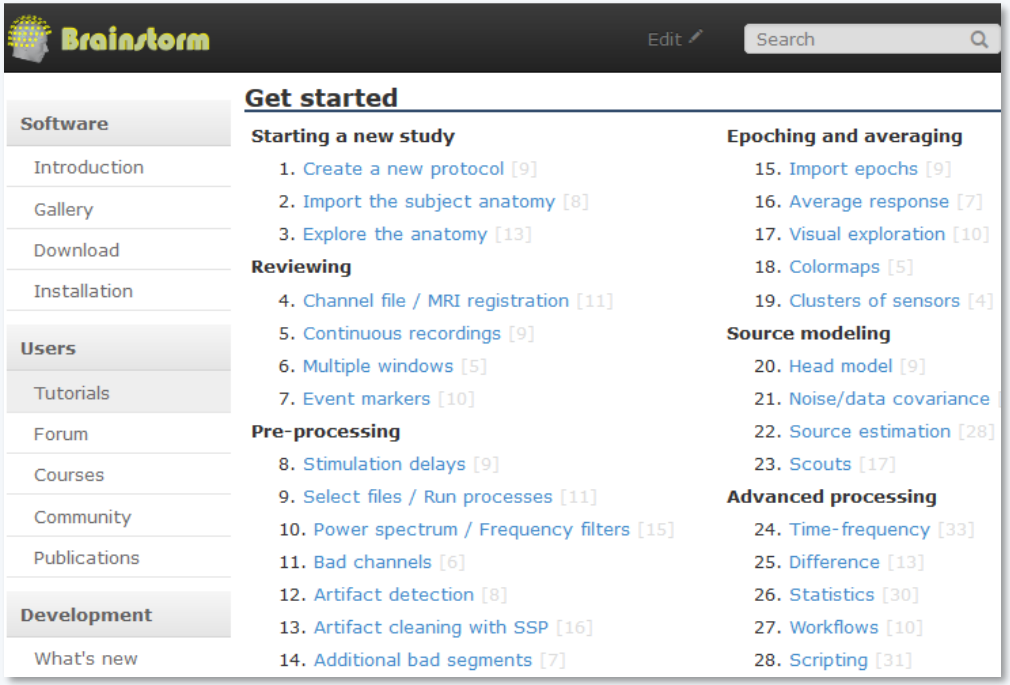
Location: montreal

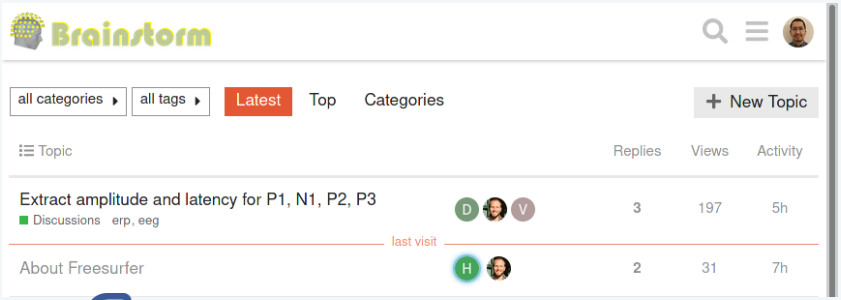
Users found: 847

Brainstorm

User support

- Online tutorials: 30-hour self-training program
- Active user forum: 150 posts/month
- Daily updates: 1500 downloads/month





@BrainstormSoftware

@brainstorm2day

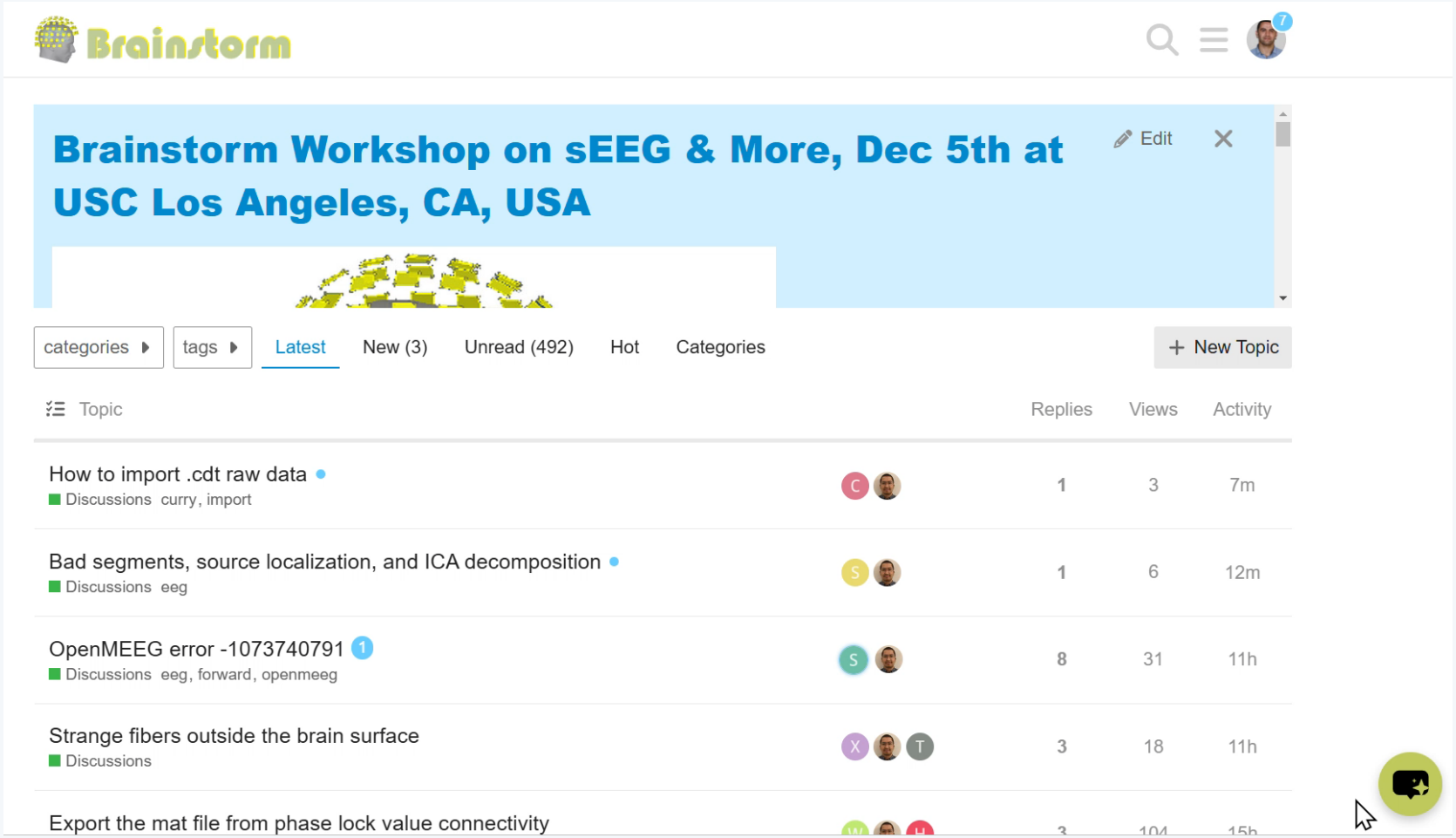
@brainstorm-tools

@ brainstorm-neuroimage

Brainstorm

User support

- Brainstorm Chabot



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McGill


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Houston, USA

NIRSTORM


Christophe Grova
Concordia


Thomas Vincent
Montreal Heart Inst.


Edouard Delaire
Concordia

Upcoming Brainstorm Events

==========

📍 Breckenridge, CO, USA

Date: March 3, 2025

Location: Breckenridge, CO

Time: 8:30 AM – 5:45 PM

Focus: Advanced training in Brainstorm's features for stereotactic EEG (sEEG) analysis.

Special Note: Part of the International Conference on Artificial Intelligence in Epilepsy and Neurological Disorders.

Early Bird Registration: Closes on December 15, 2024—take advantage of reduced rates!

Program & Registration: https://lnkd.in/dqT7w3tP

==========

📍 Hyderabad, India

Date: April 7, 2025

Location: Hyderabad, India

Time: 3:00 PM – 5:30 PM

Focus: Brainstorm overview presentation and demo on EEG and MEG analysis.

Special Note: Part of the International Conference on Acoustics, Speech, and Signal Processing (ICASSP).

Program & Registration: https://lnkd.in/diVwMDRz

==========

👩‍🏫 Host a Workshop

Looking to organize a tailored Brainstorm workshop for your lab, university, or team? Whether you need to advance your knowledge or stay at the forefront of cutting-edge methods, we're here to help!

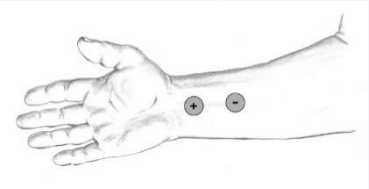
📧 DM us here or Contact us at brainstorm-l@maillist.usc.edu to discuss your needs.

Today's event!

- Agenda
  - Morning Session :
    - Hands-On Brainstorm [EEG and MEG Analysis]
  - Afternoon Session:
    - Hands-On Brainstorm [SEEG Analysis]

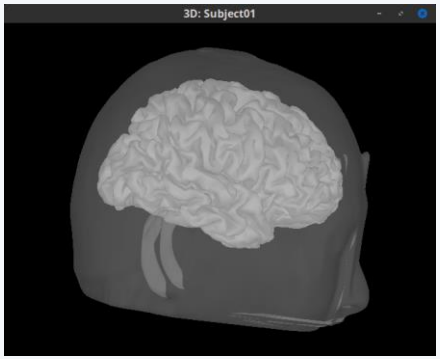
Workshop dataset

Median nerve stimulation



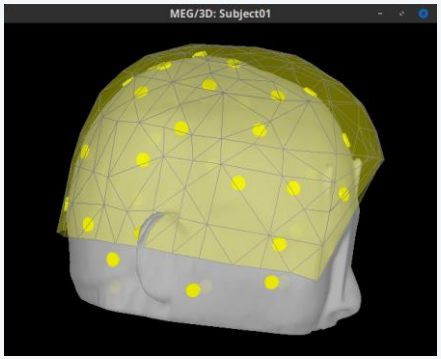
Median nerve percutaneous stimulation

- Right arm stimulation: monophasic square-wave duration 0.3 ms at 2.8 Hz
- 1 participant / 1 run / 336 stimuli

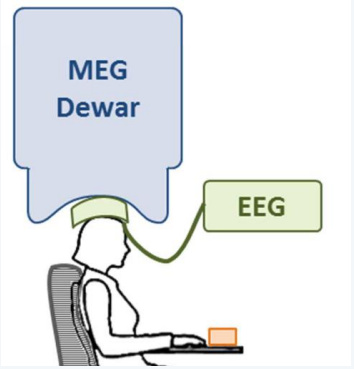


Scalp and cortical surface

- Individual MRI, processed with CAT12
- MEG: Yokogawa 160 axial gradiometers @ 2000 Hz
- EEG: Nihon Kohden 41 electrodes @ 2000 Hz



EEG electrodes and MEG helmet



Simultaneous MEG and EEG acquisition

Brainstorm

Feedback Brainstorm software & workshop

- Your feedback helps improve Brainstorm workshops and shape future sessions—share your thoughts!

https://docs.google.com/forms/d/e/1FAIpQLSdLTYBkoWfdHyKYPXKd8wpQCdWw2fvRn0bgywO4JfVv0WgT9w/viewform

Brainstorm team today

Chinmay Chinara

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Woojae Jeong

Takfarinas Medani

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John Mosher

Richard Leahy