# MEG and EEG analysis using

# Brainstorm

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

USC UNIVERSITY OF SOUTHERN CALIFORNIA

Cleveland Clinic

McGill

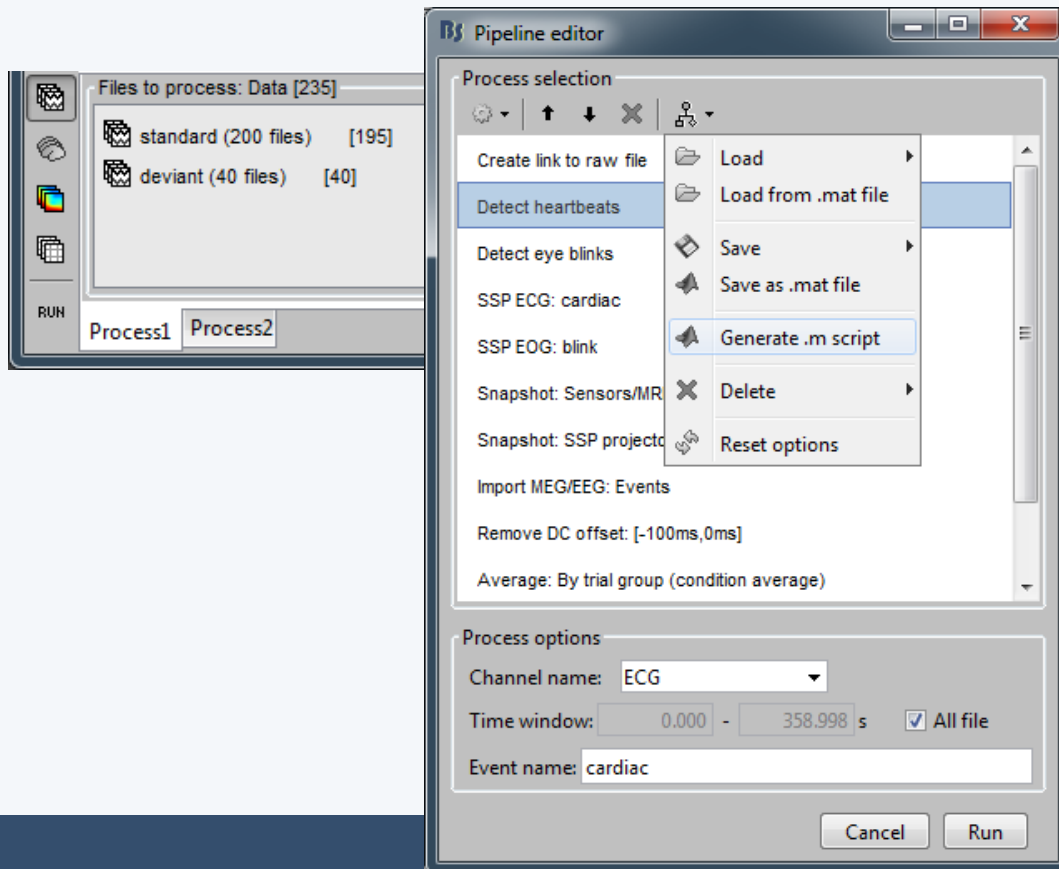neuro
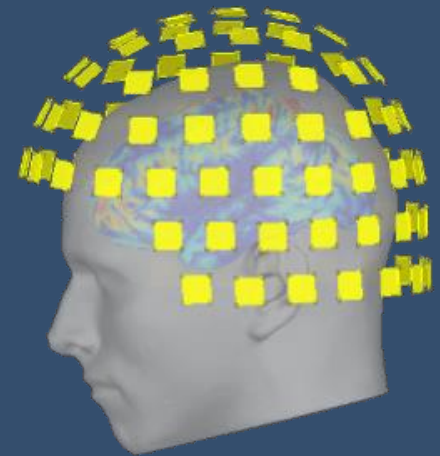
**PracticalMEEG 2019**

Francois Tadel

# Graphic interface
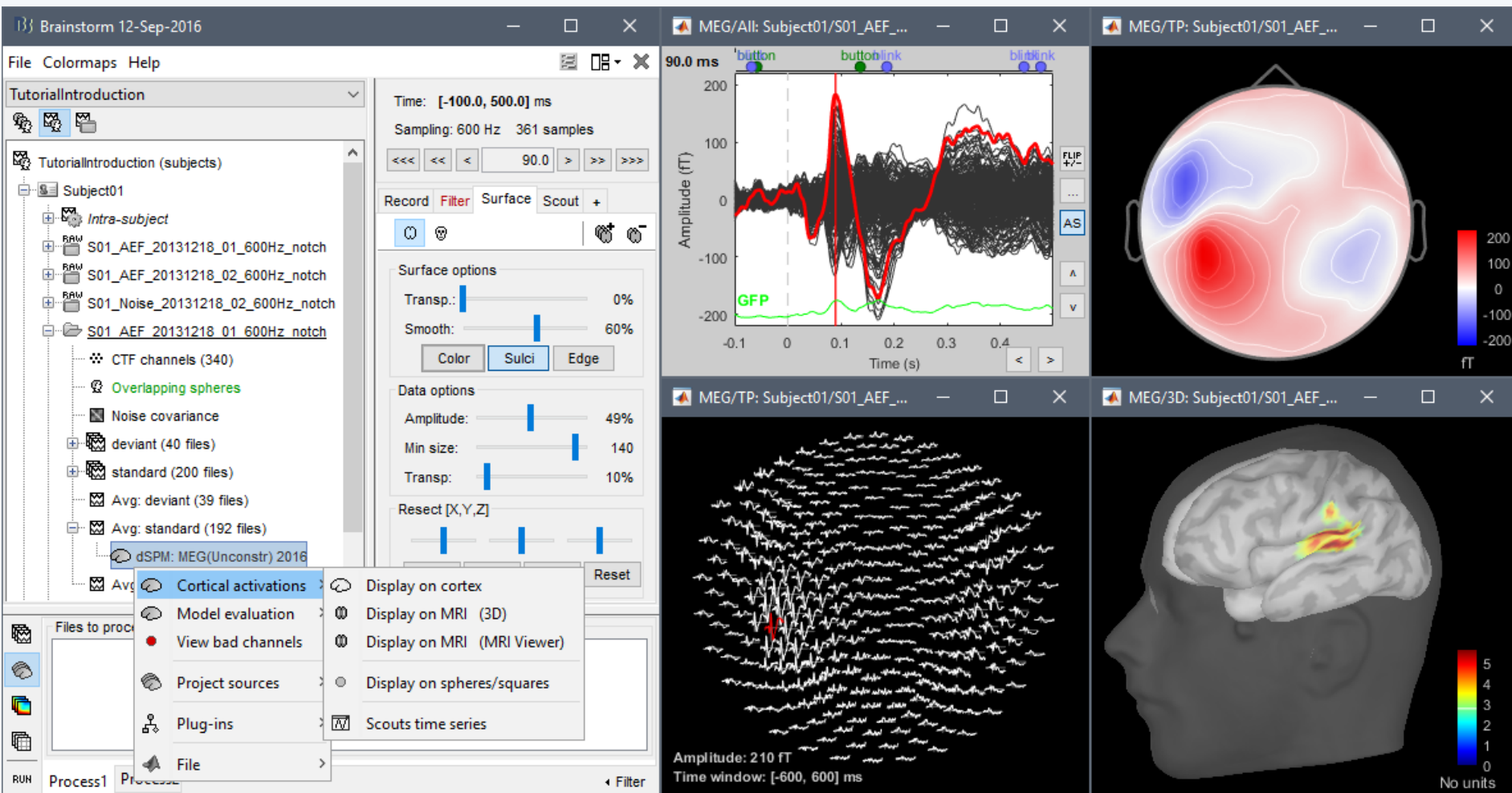
# Scripting environment

- Rapid selection of files and processes to apply

- Automatic generation of Matlab scripts

- Plug-in structure: easy to add custom processes
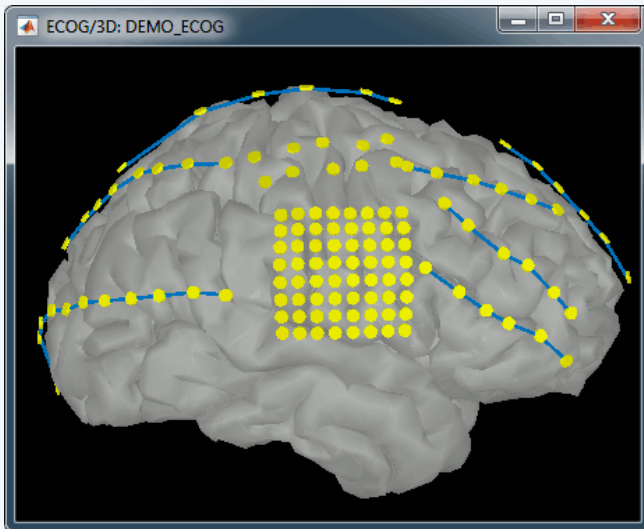
# Brainstorm

- 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
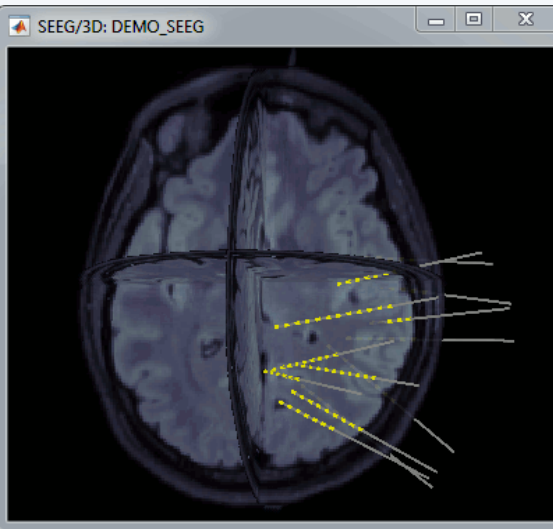
- Supports most common file formats
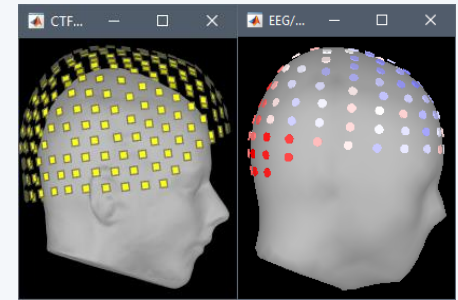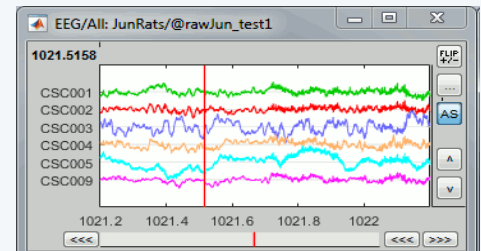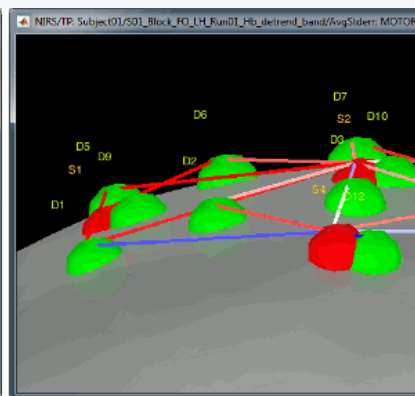
Brainstorm

# Multi-modal imaging

## ECoG



## Depth electrodes



## MEG/EEG



## Electrophysiology



## fNIRS

Brainstorm
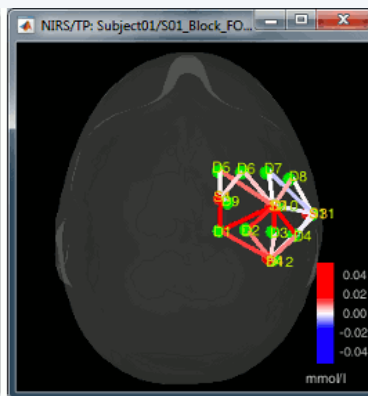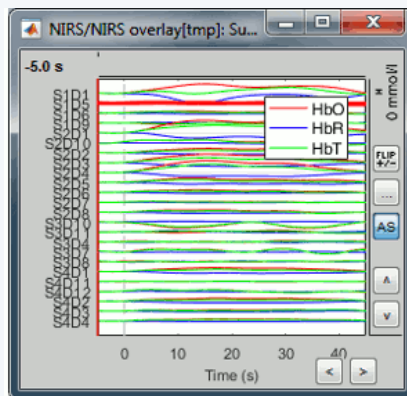
# Workflow



Anatomy

Sensors

EEG/MEG

Analysis

Averages
Contrasts
Group analysis
Time-frequency
Connectivity
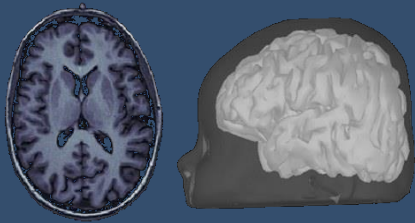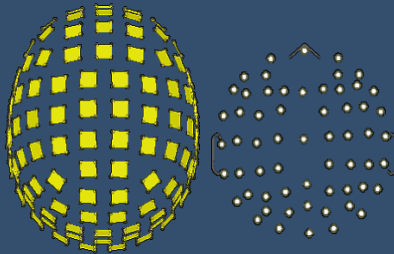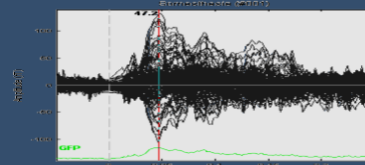
Co-registration

Source estimation

Brainstorm

# Import

Link recordings
MRI registration

PSD
Filters
Bad channels
Artifacts
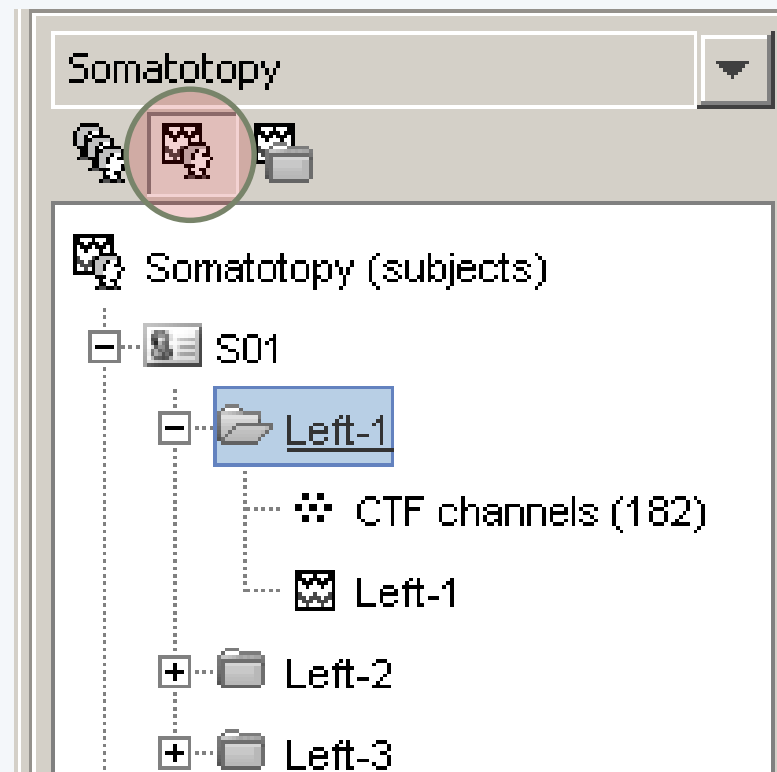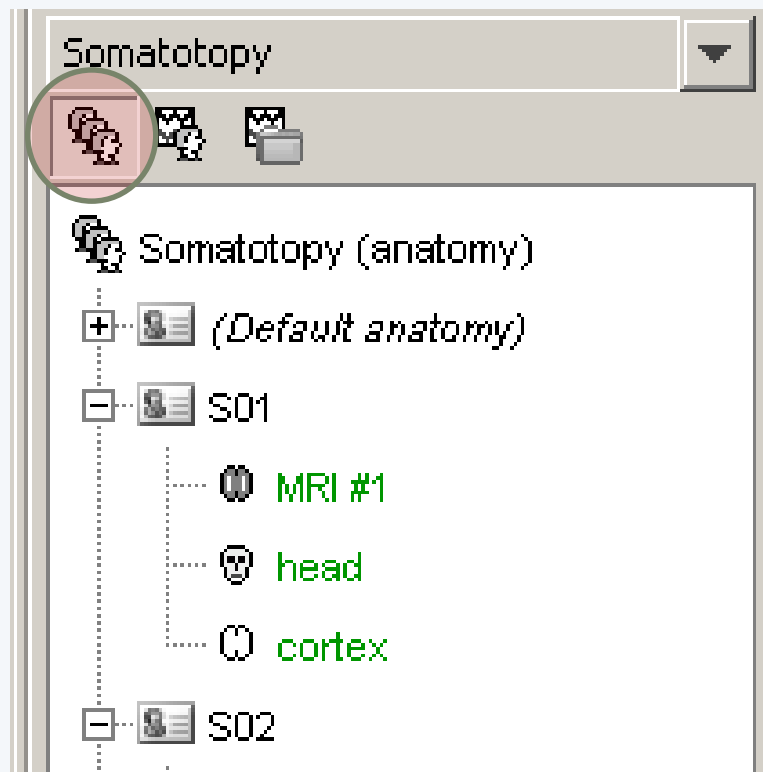Correction
Bad segments

Markers
Epoching
Averaging
Sources
Time-frequency

- One-click import of the T1 segmentation: FreeSurfer, BrainSuite, BrainVISA, CAT, 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

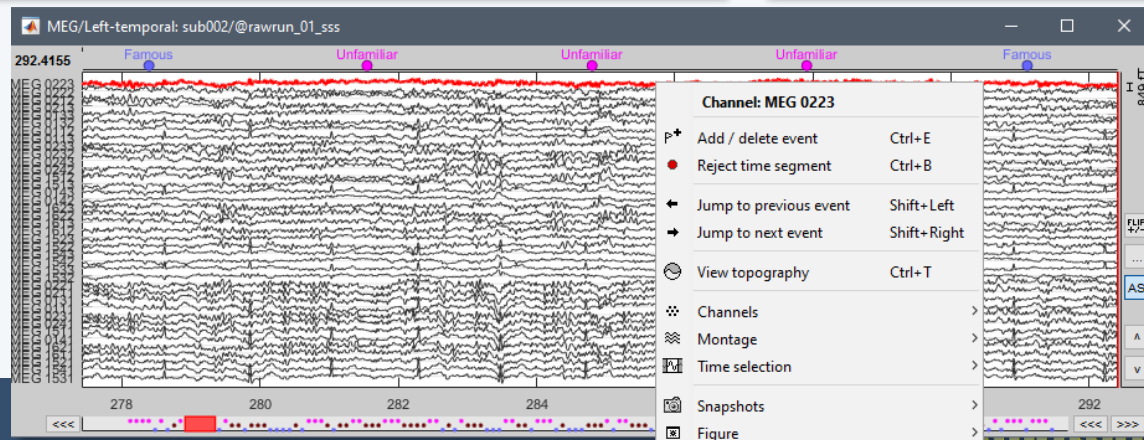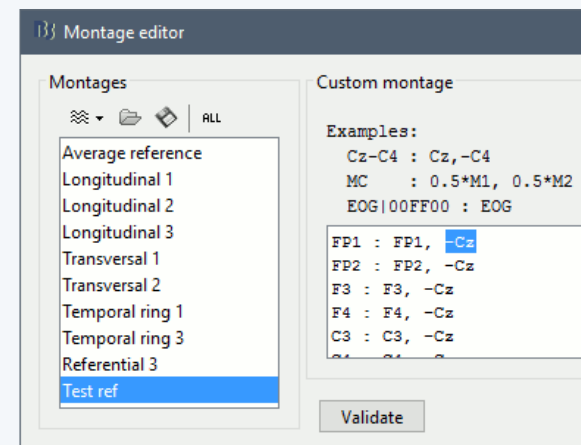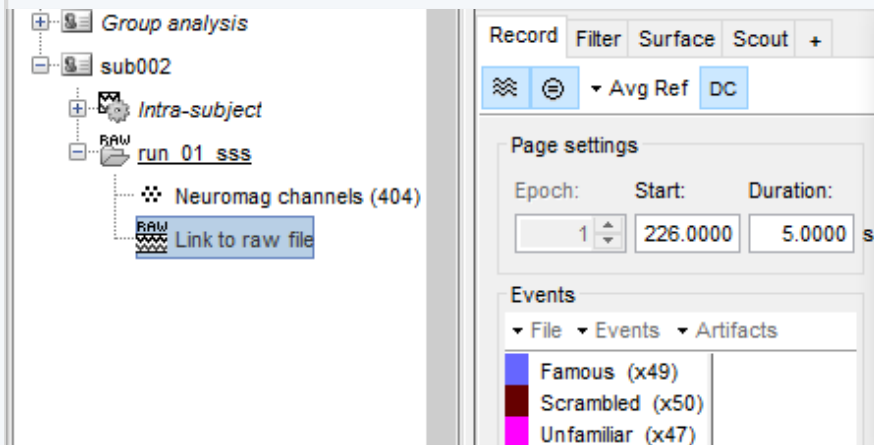Brainstorm

# Import

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

# Co-registration MEG / MRI (2)

Anatomy
Link recordings
**MRI registration**

PSD
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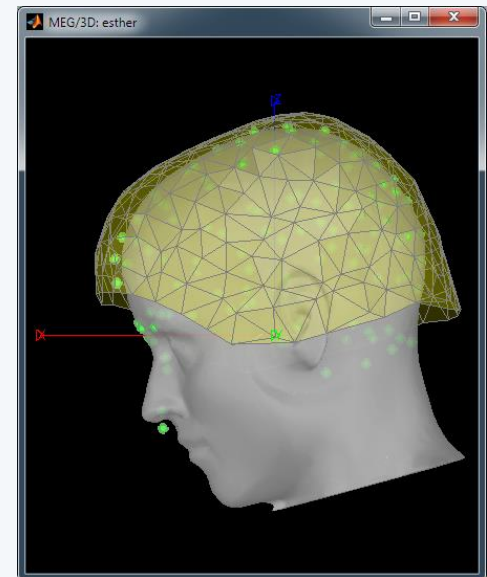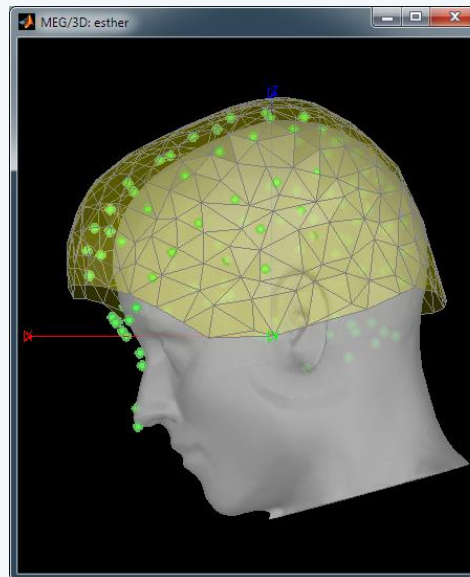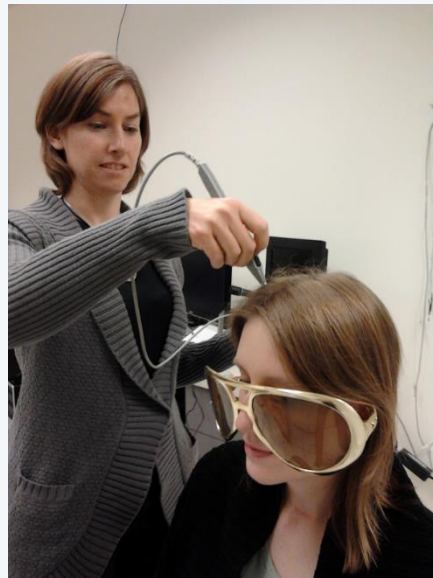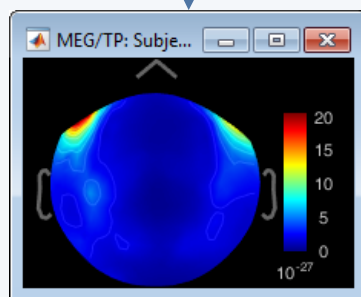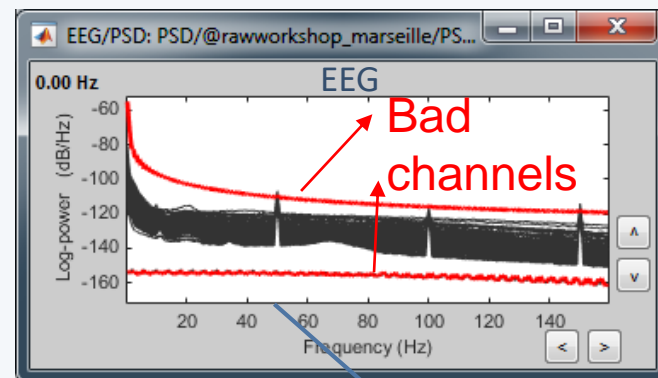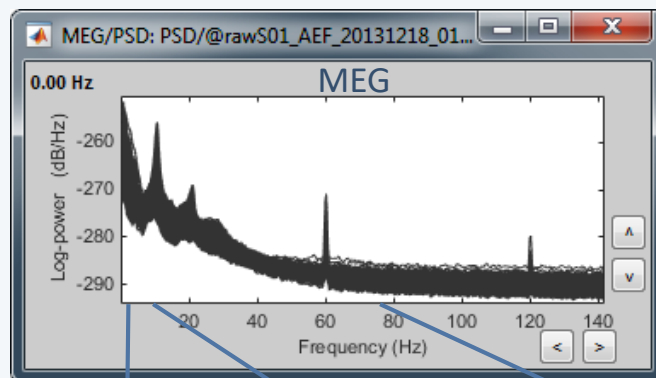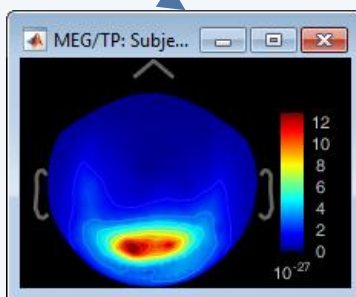Correction
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- Automatic adjustment based on head shape: Fitting Polhemus points on the MRI head surface

- Final registration must be checked manually

- Polhemus driver included in Brainstorm



**Brainstorm**
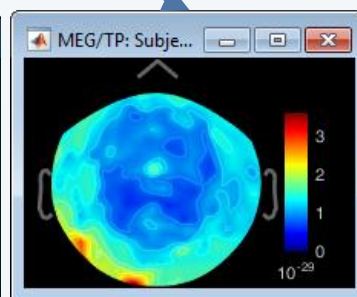
# Quality control

- Power spectrum density for quality control



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

# Pre-processing

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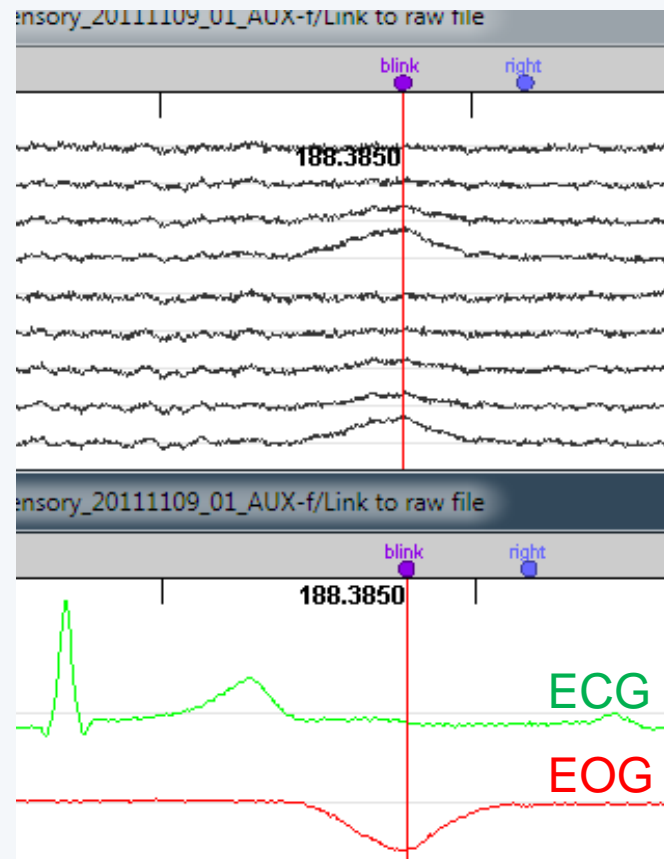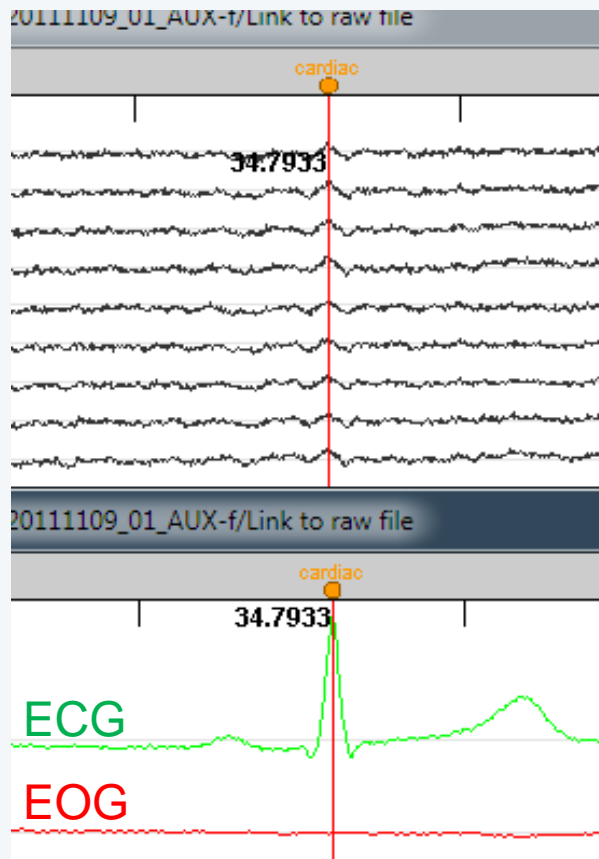


**Brainstorm**

# 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

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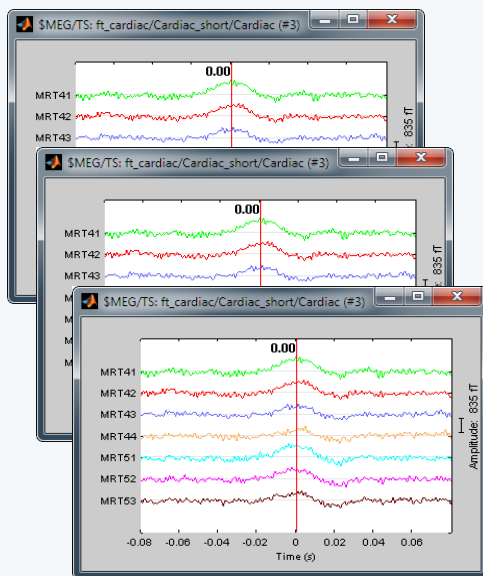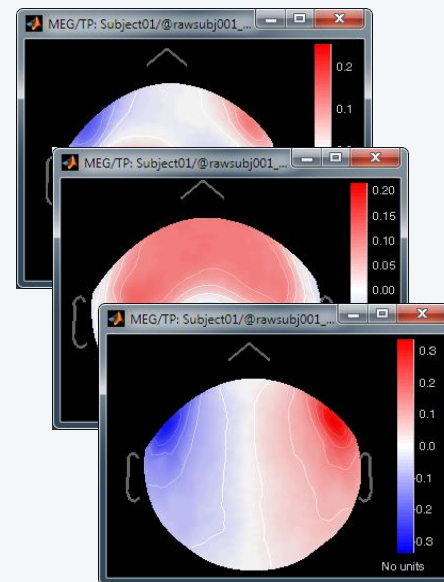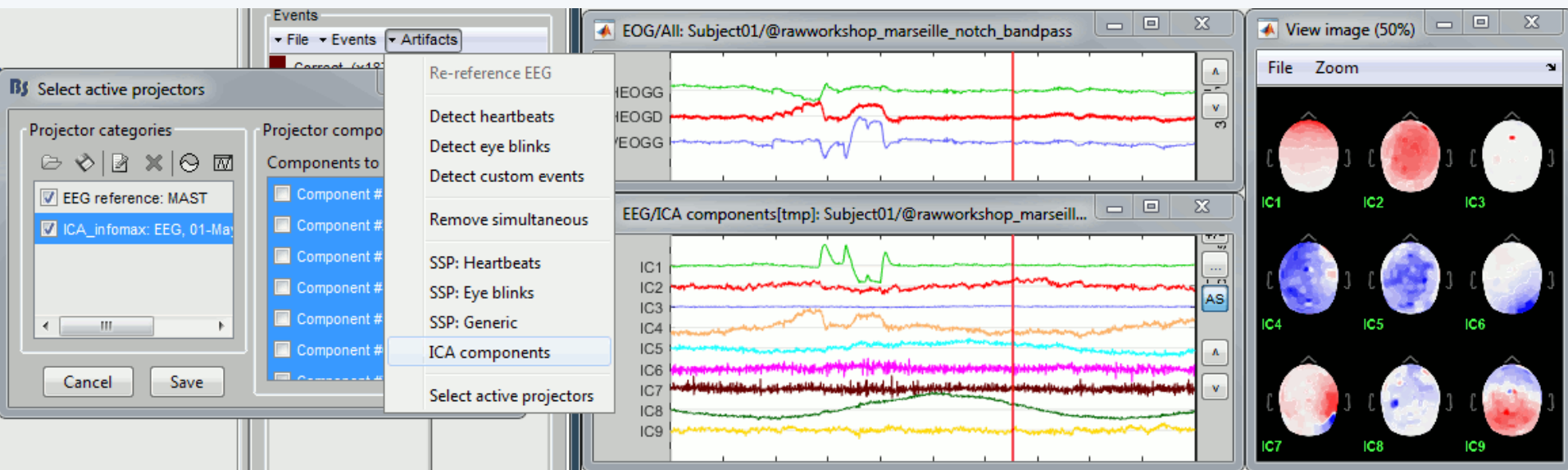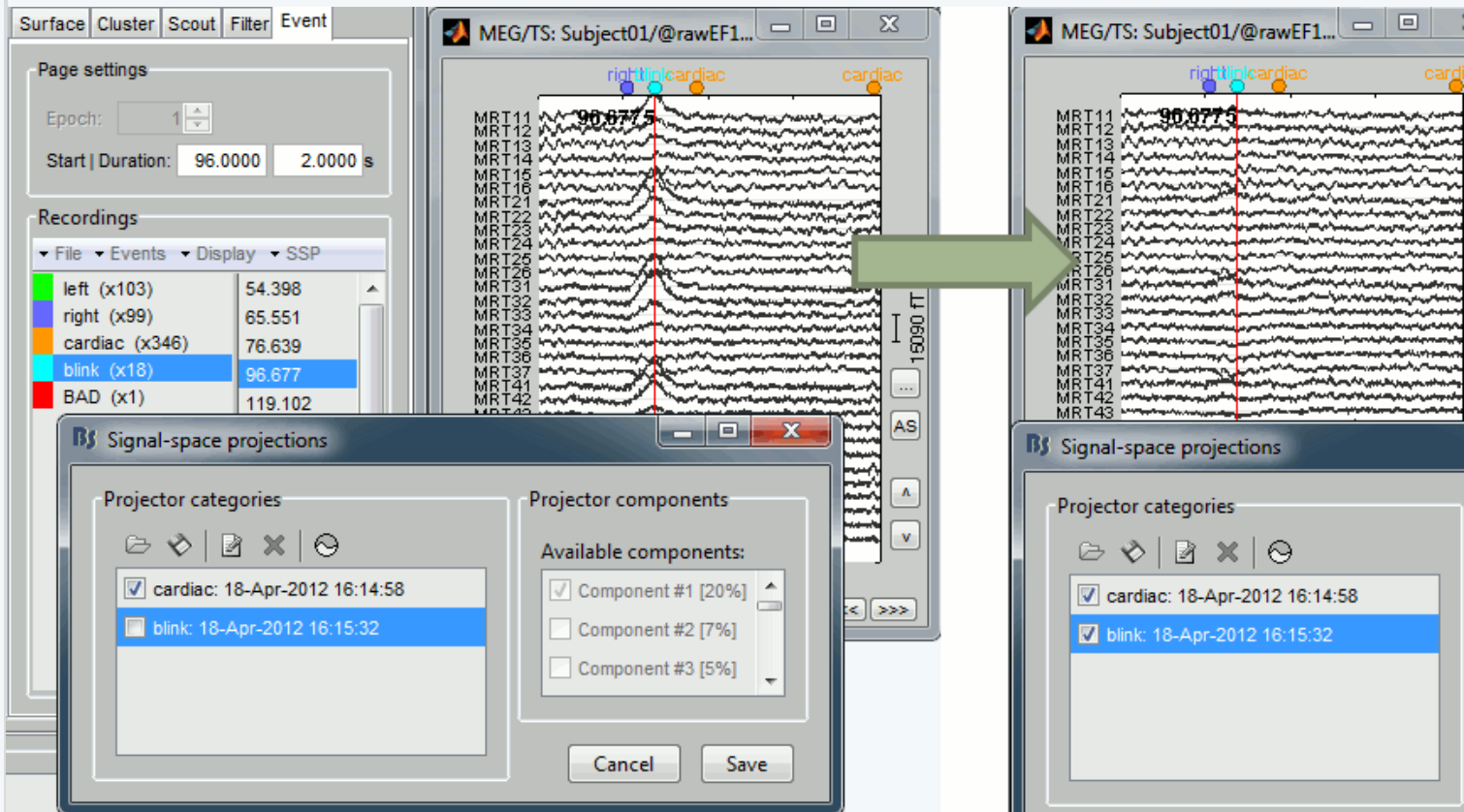  - Already implemented: Infomax and JADE (EEGLAB)

Brainstorm

Anatomy
Link recordings
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Artifacts
**Correction**
Bad segments

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Sources
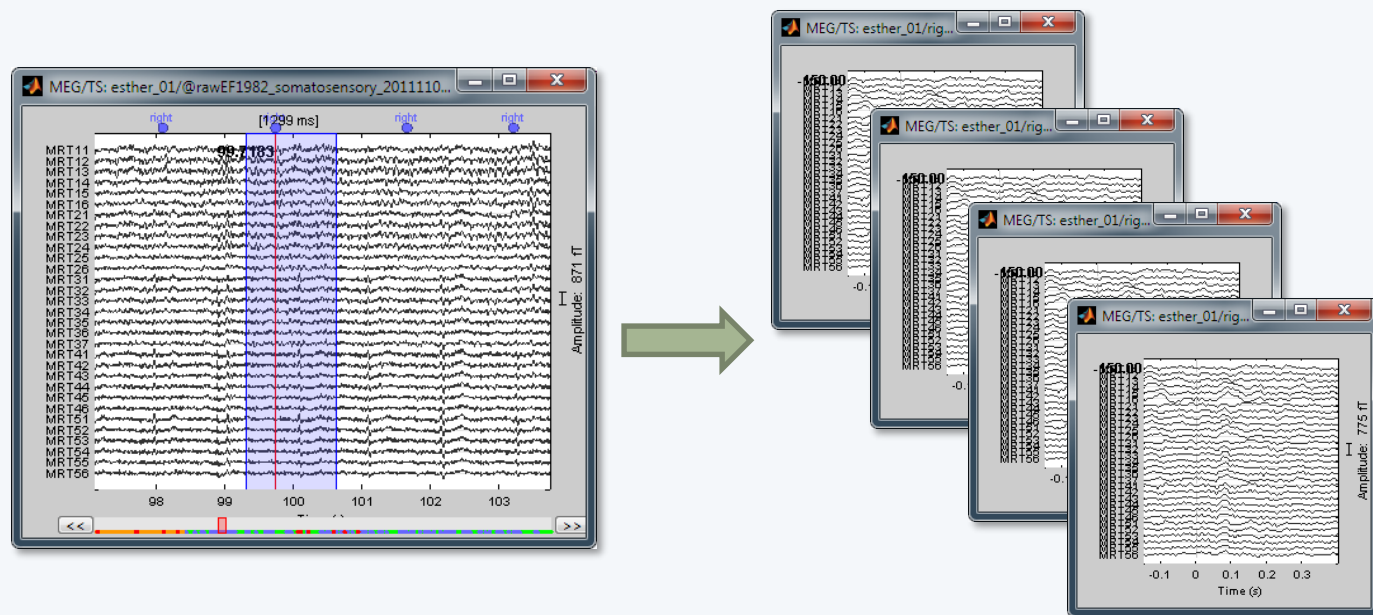Time-frequency

- ## Example: Blink

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- 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

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Epoching
**Averaging**
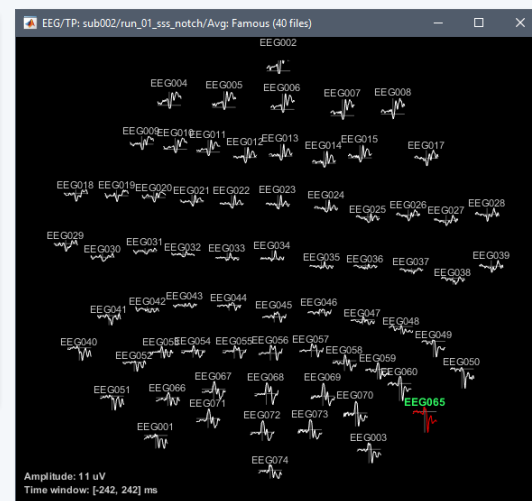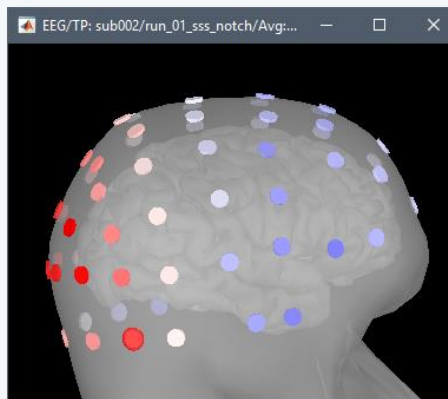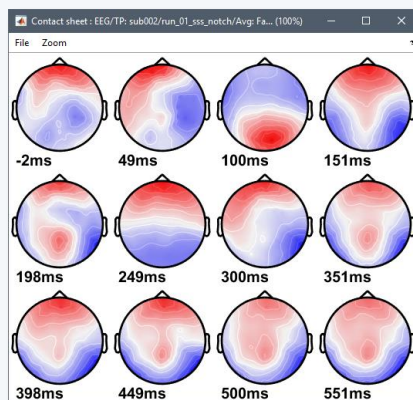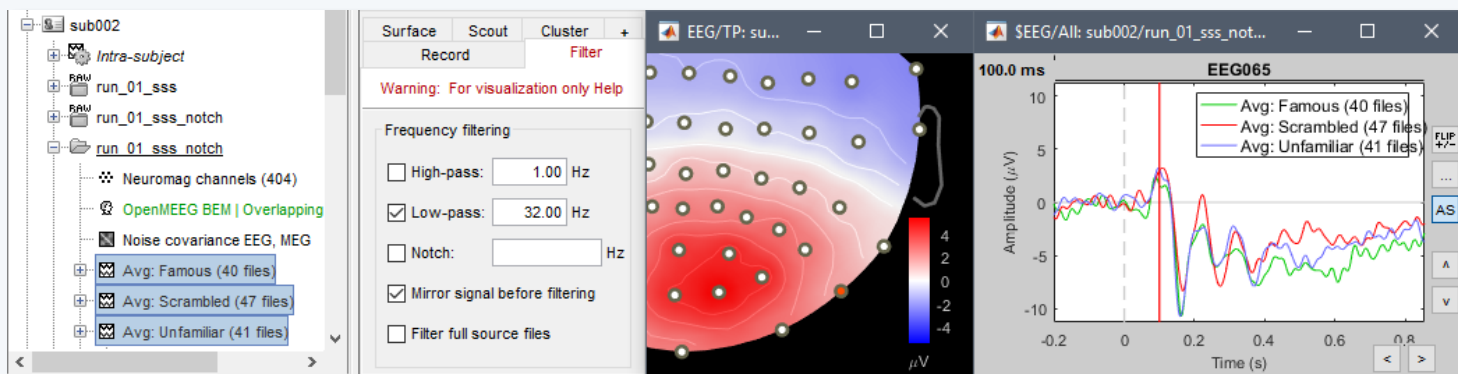Sources
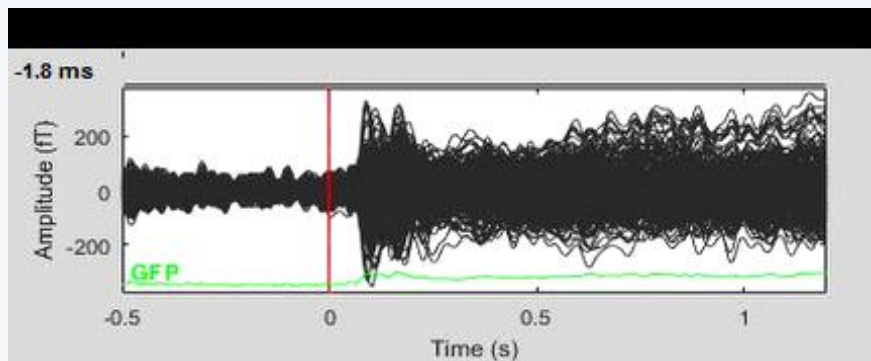Time-frequency

- ## EEG ERP:  Famous faces
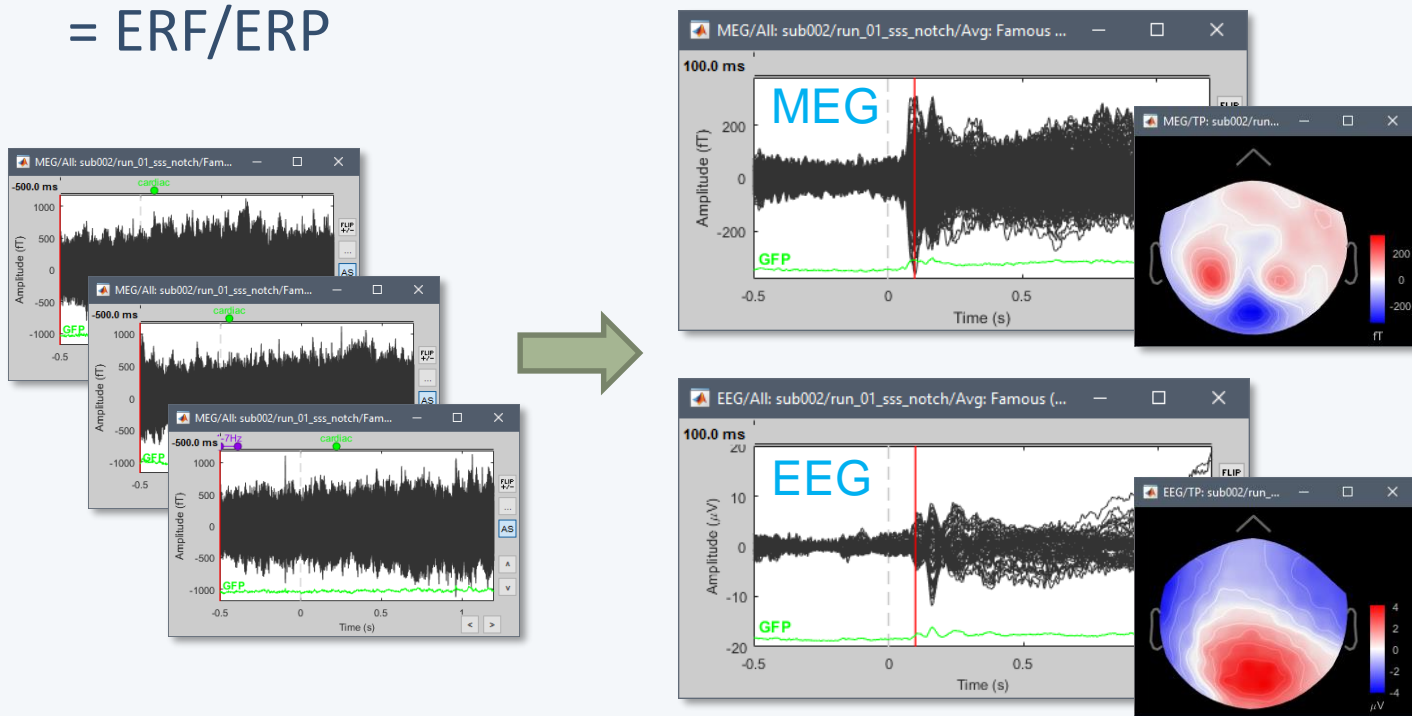
# Single subject
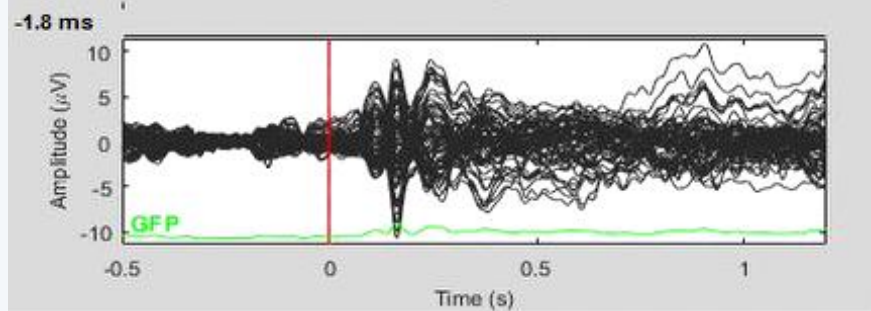
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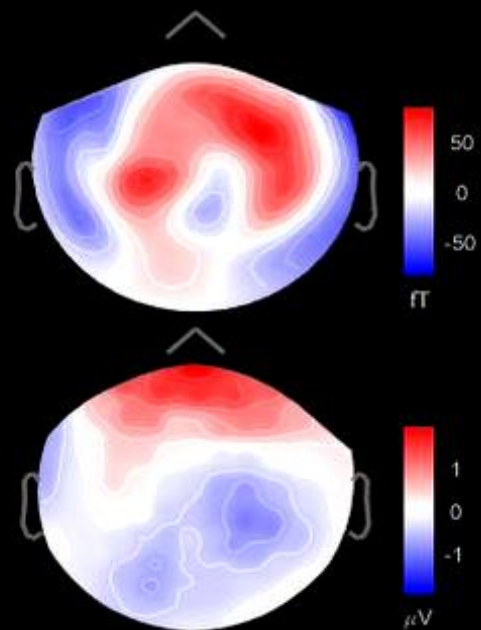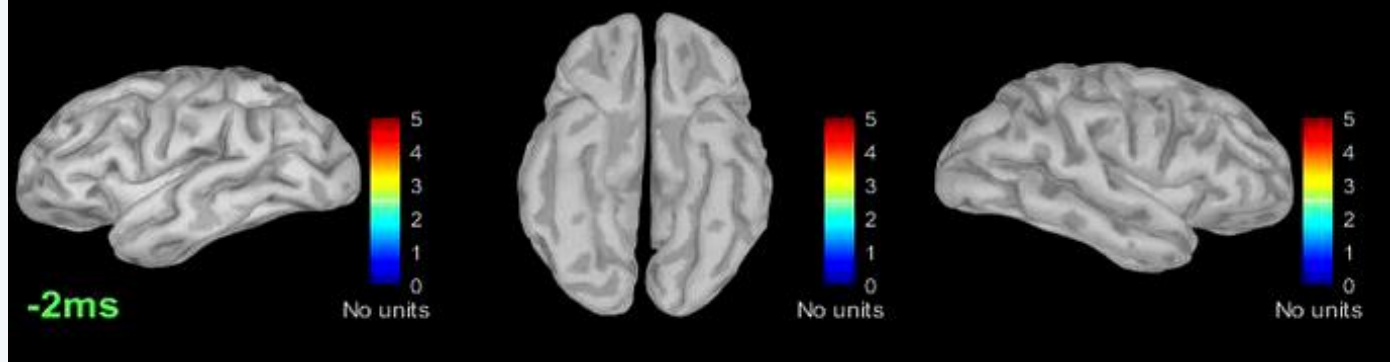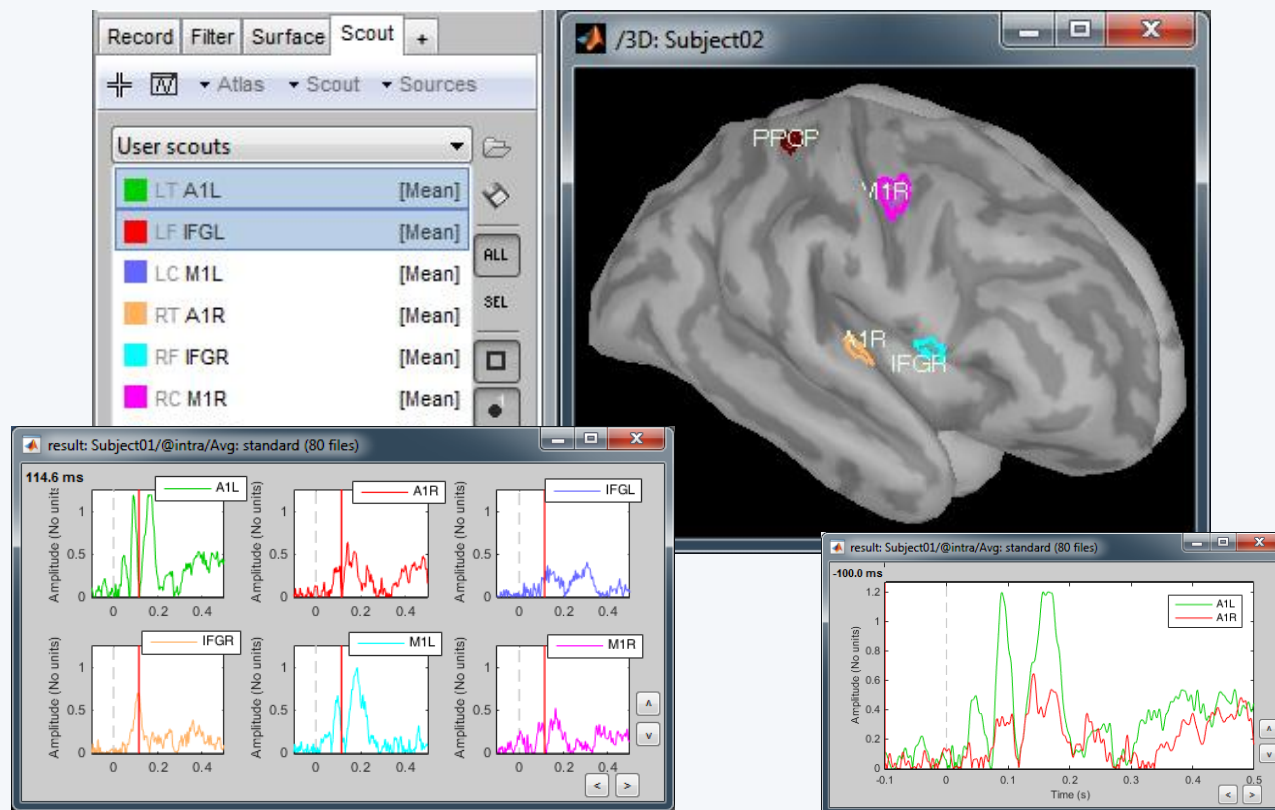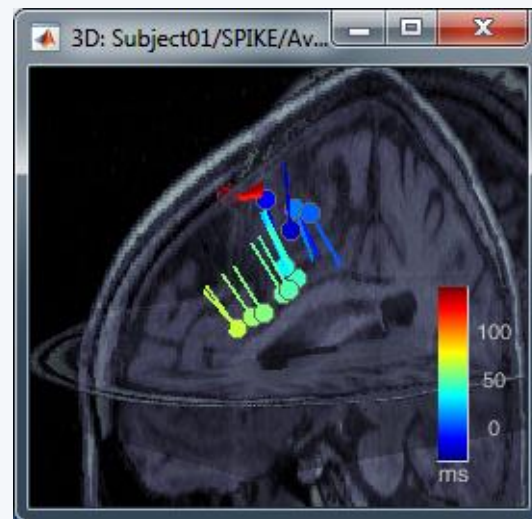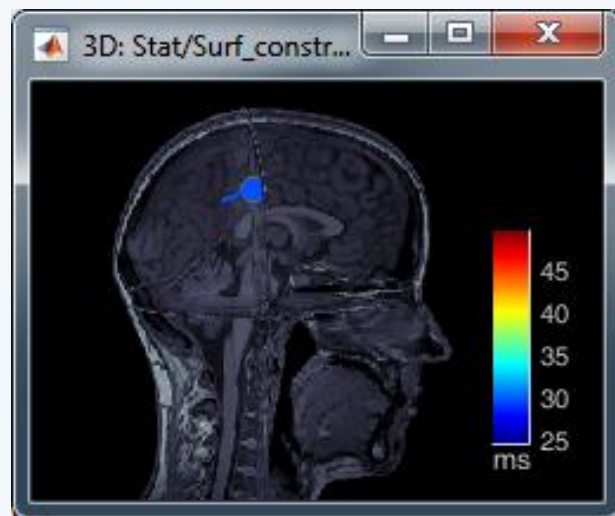Averaging
**Sources**
Time-frequency

Famous faces

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

# Single subject

- ## Dipole scanning
  Compute a distributed source model, then find the most significant dipole at each time sample.

- ## Dipole fitting (FieldTrip)
  Non-linear search of the dipoles that minimizes the residuals (data explained - recordings)

Brainstorm

# Single subject
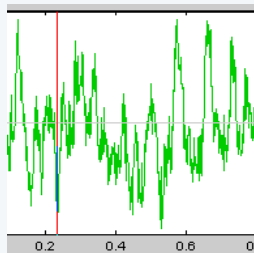
## Morlet wavelets
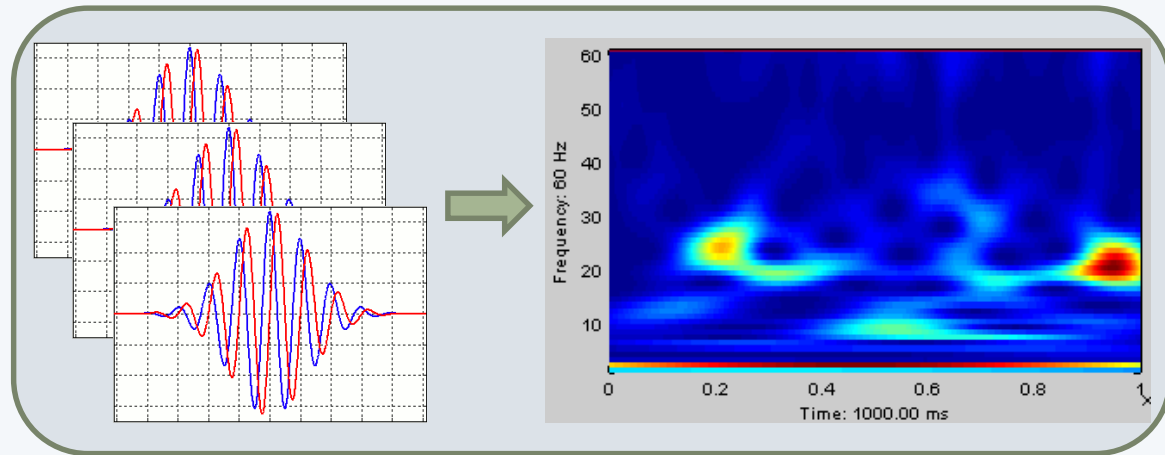


## Hilbert transform + band-pass filter
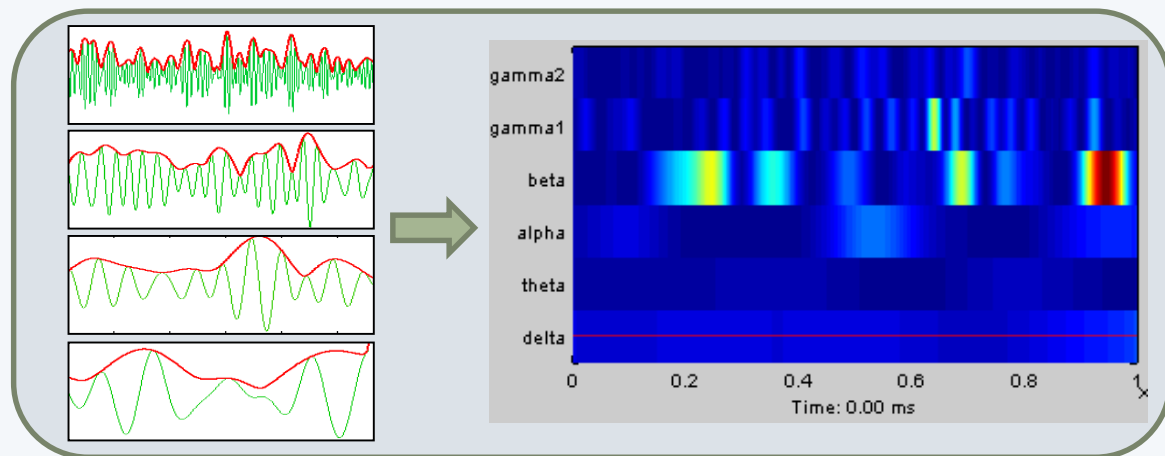
**Brainstorm**

# Group analysis
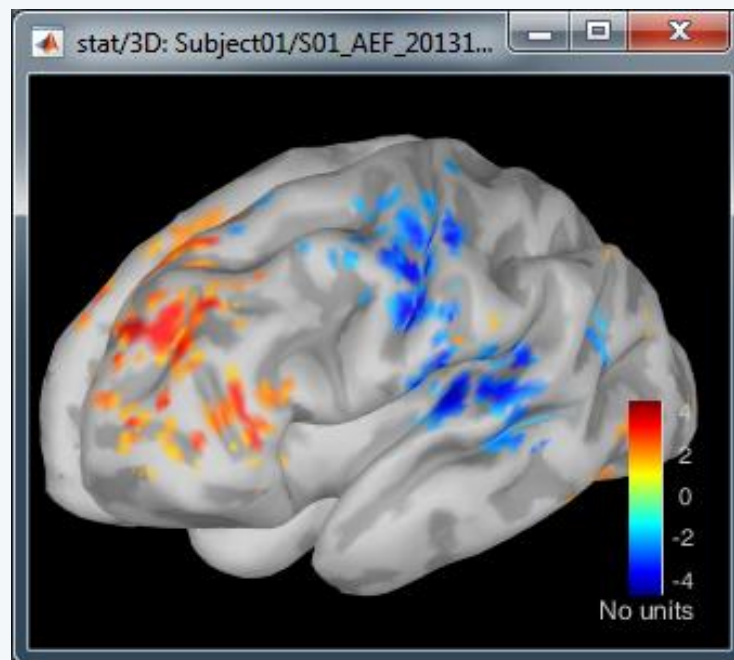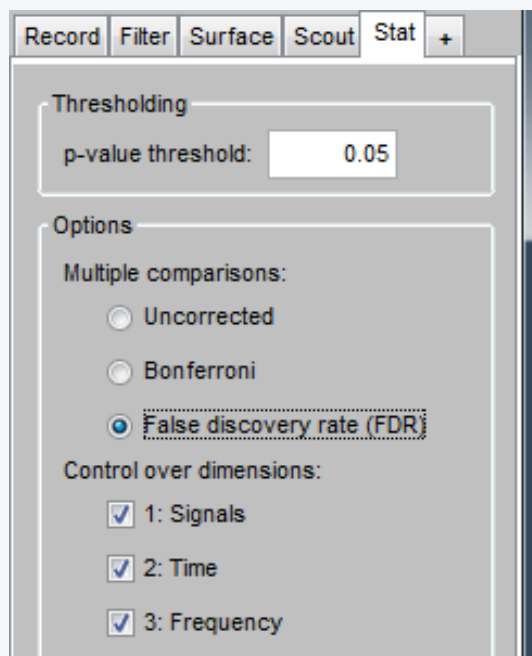
Subject averages
Low-pass
Normalize
Project

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
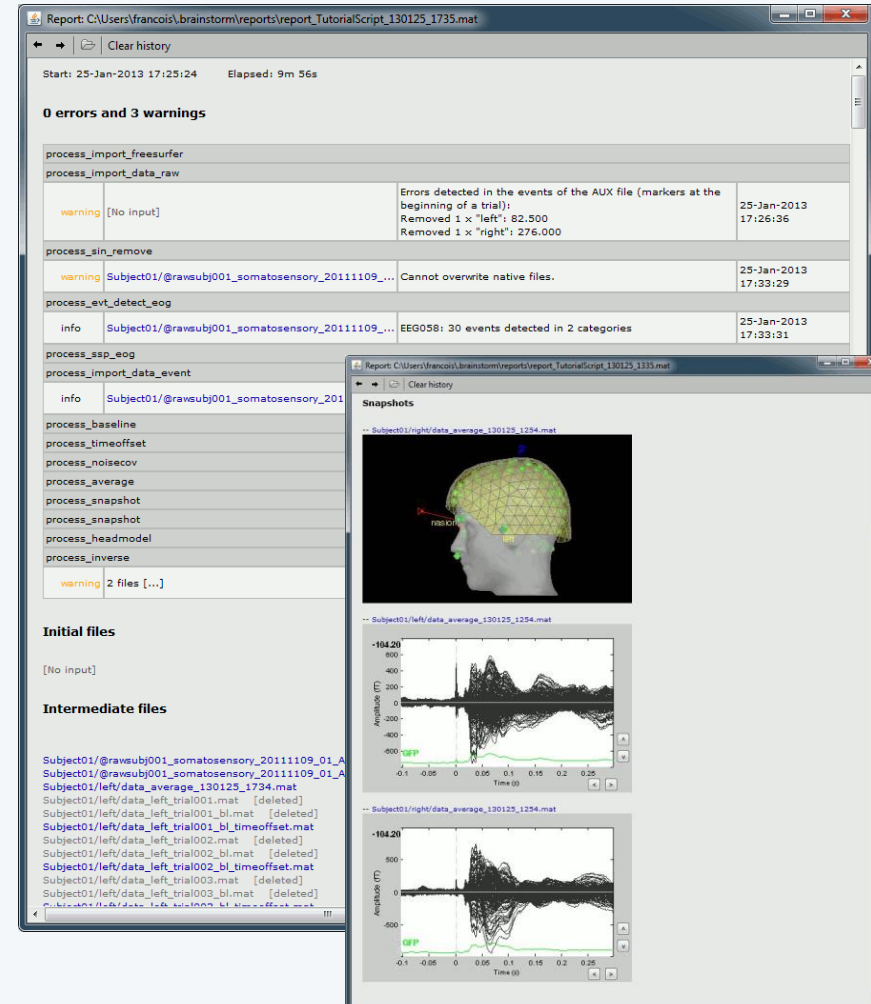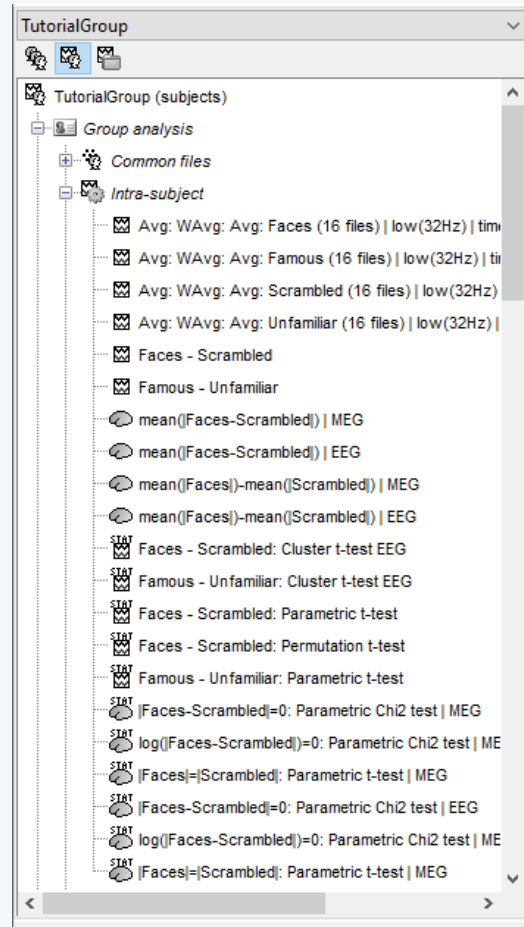
Subject averages
Low-pass
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Group averages
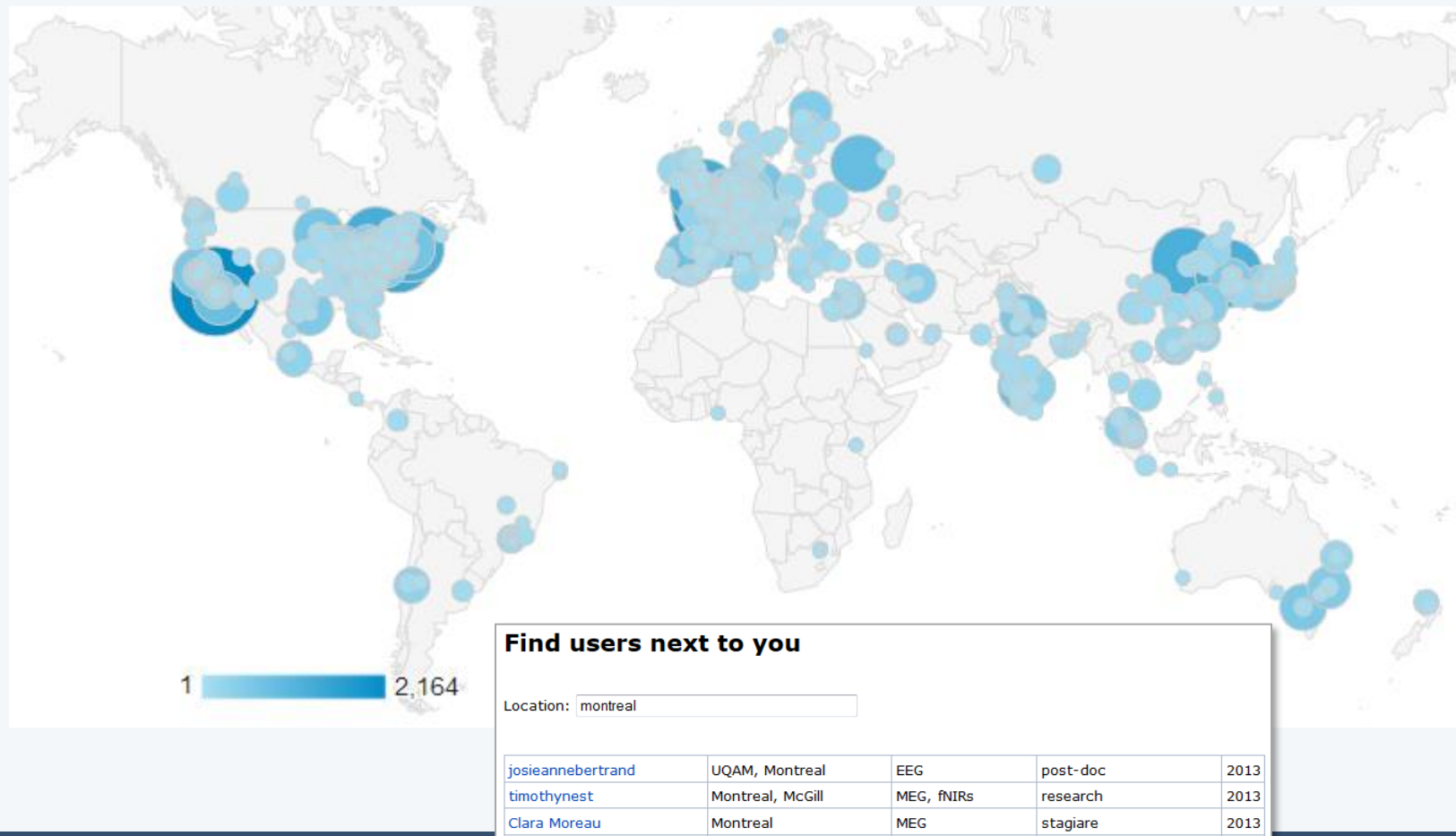Group statistics

**Quality control**
Workflow

- Execution reports with snapshots saved in HTML

**Brainstorm**

# User community

- 24,000 users registered on the website
  230 publications using Brainstorm per year

# User support

- Online tutorials:    30-hour self-training program

- Active user forum:   400 posts/month

- Daily updates:       1400 downloads/month

# Contributors

**Investigators**

Sylvain Baillet
*MNI*

Richard Leahy
*USC*

John Mosher
*Cleveland Clinic*

Dimitrios Pantazis
*MIT*

**Geeks**

François Tadel
*Software, Grenoble*

Martin Cousineau
*Software, MNI*

Marc Lalancette
*MEG manager, MNI*

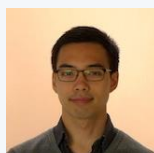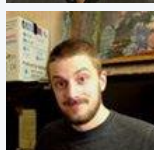**MEG @ McGill**

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*PhD student*

Jeremy Moreau
*PhD student*

Peter Donhauser
*PhD student*

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Anand Joshi
*Res Assist Professor*

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*Research assistant*

Takfarinas Medani
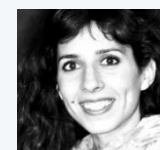*Research assistant*

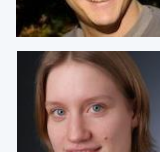**Key collaborators**

Elizabeth Bock
*MEGIN, Chicago*

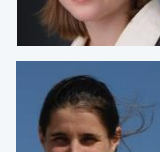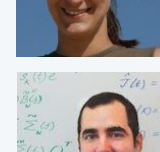Guiomar Niso
*Politécnica Madrid*

Guiomar Niso
*Politécnica Madrid*

Alexandre Gramfort
*Telecom / Neurospin*

Esther Florin
*Univ Hosp Cologne*

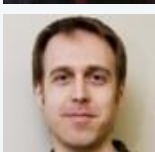Anne-Sophie Dubarry
*Aix-Marseille Univ*

Rey Ramirez
*UW*

**Brainstorm**

## Visual recognition task
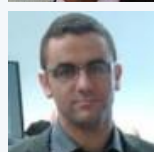
- Faces presentation: Famous / Unfamiliar / Scrambled

- 1 participant / 1 run / 50 trials per condition

- 400-600ms fixation cross, 800-1000 stim, 1700ms ISI
  Total 10min per run

- Elekta-Neuromag VectorView system (MEG+EEG)
  102 magnetometers, 204 gradiometers, 70 electrodes

- Recorded at 1100Hz

- Individual MRI, anonymized, processed with FreeSurfer 5.3

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