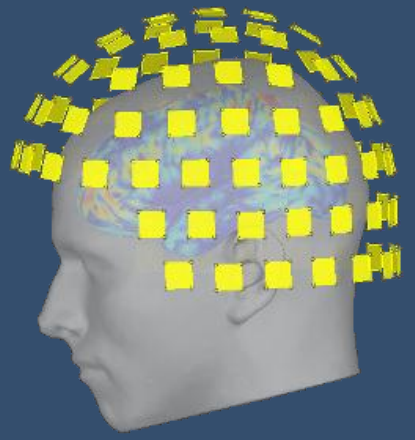
MEG and EEG analysis using

Brainstorm 3.1

http://neuroimage.usc.edu/brainstorm



USC UNIVERSITY OF SOUTHERN CALIFORNIA

Cleveland Clinic

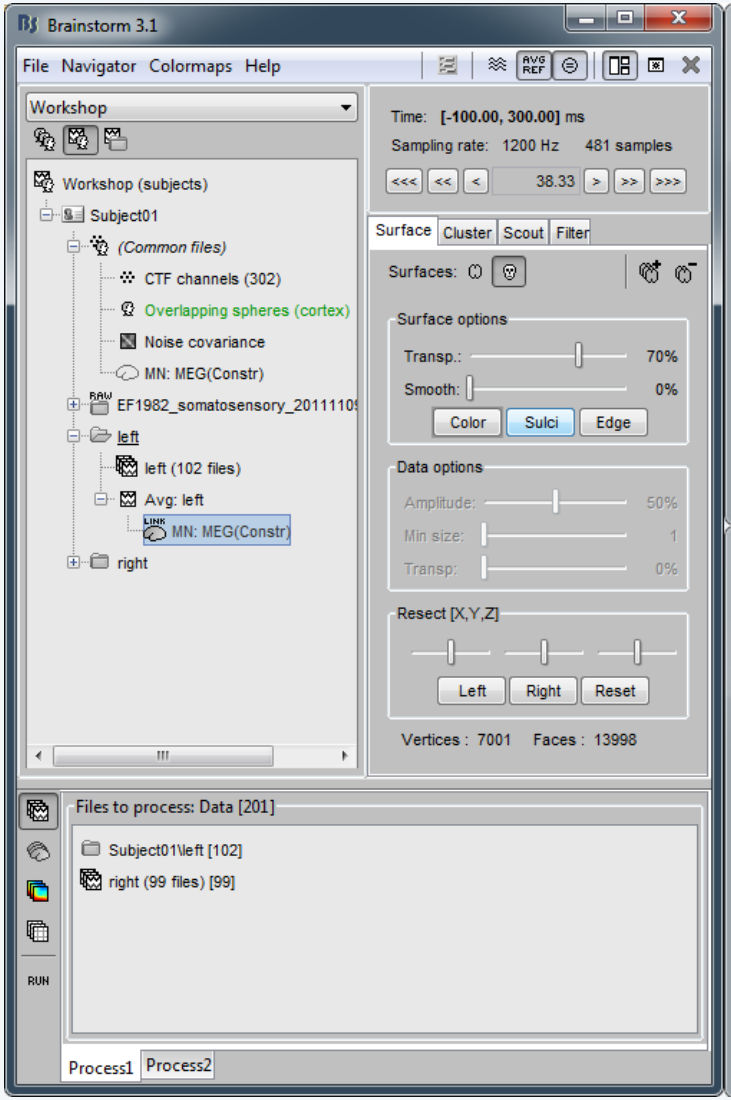
McGill

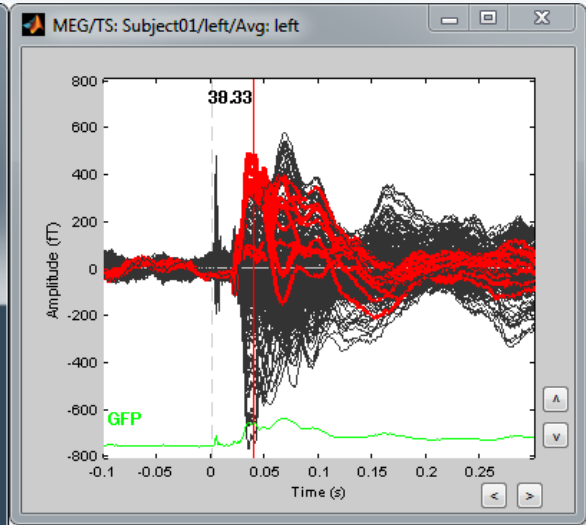
neuro

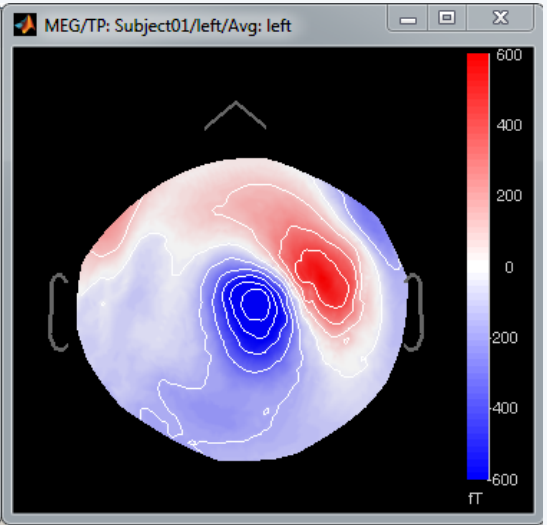
François Tadel
MIT – Boston – 04.28.2012

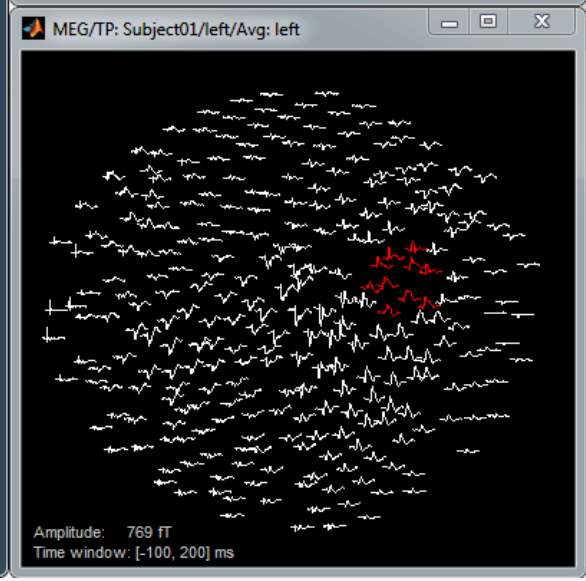
Foretaste

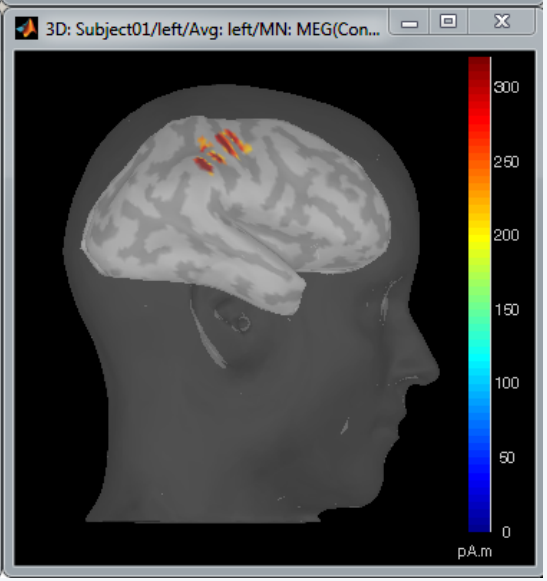
Graphic interface





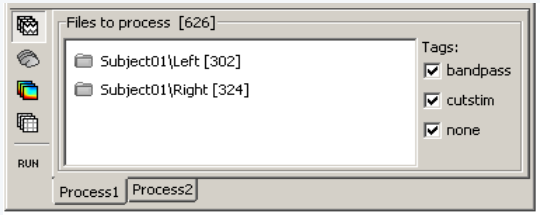


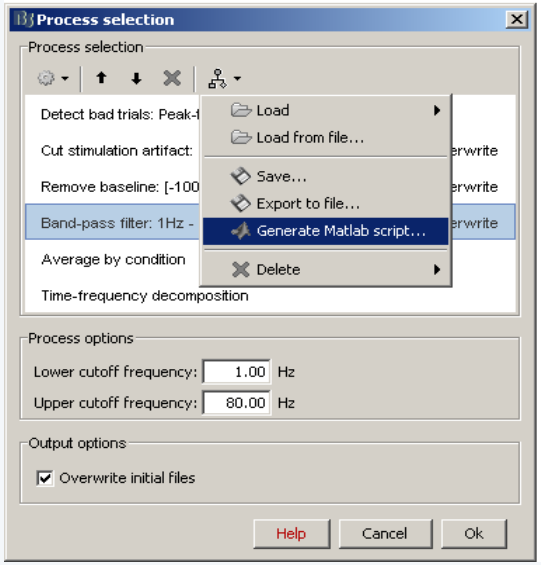




Brainstorm

- Rapid selection of files and processes to apply
- Automatic generation of Matlab scripts (everything is scriptable)
- 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);
```

Brainstorm is...

- A free and open-source application (GPL)
- Matlab & Java: Platform-independent
- Designed for Matlab environment
- Stand-alone version also available
- Interface-based: click, drag, drop
- No Matlab experience required
- Daily updates of the software

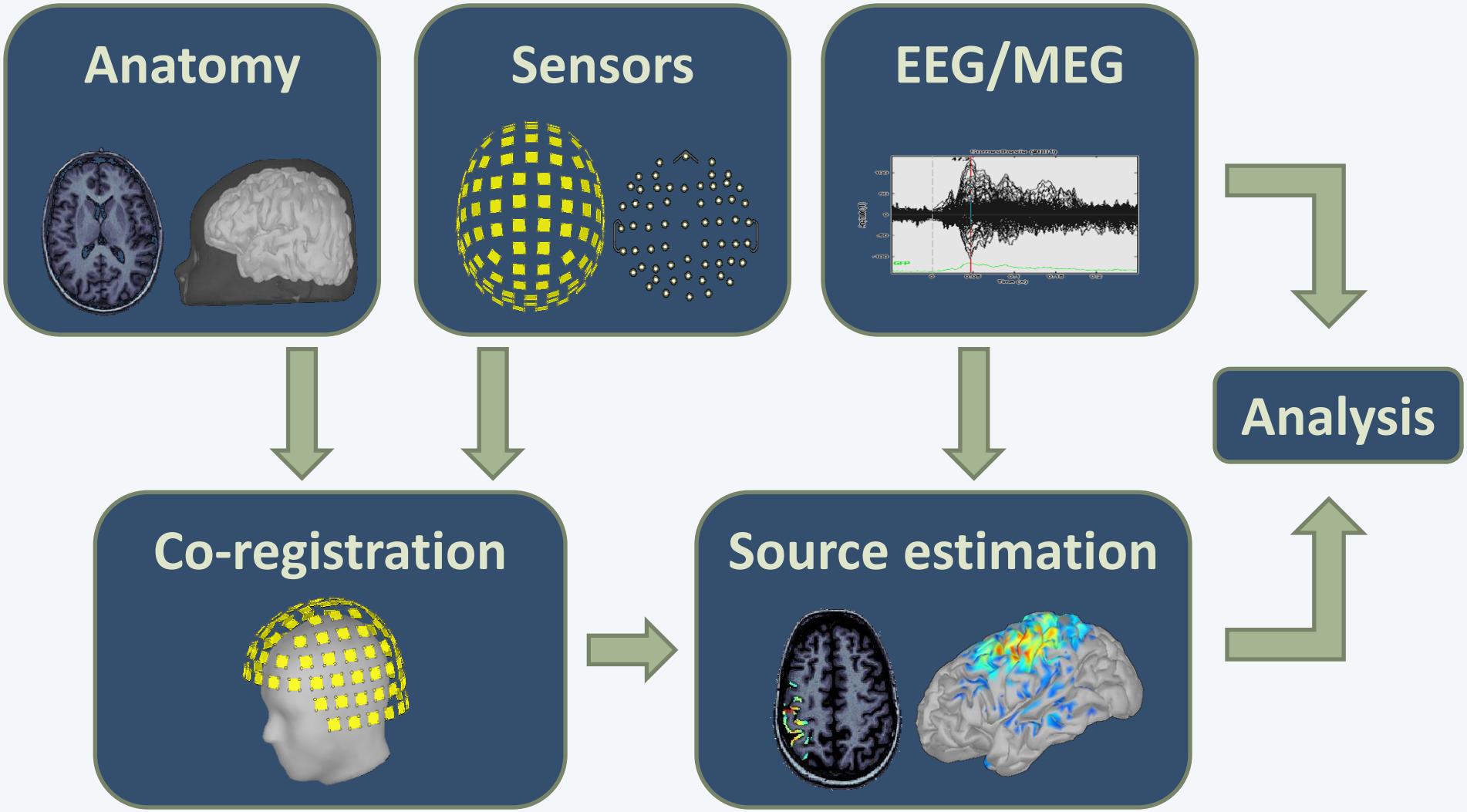




A bit of history

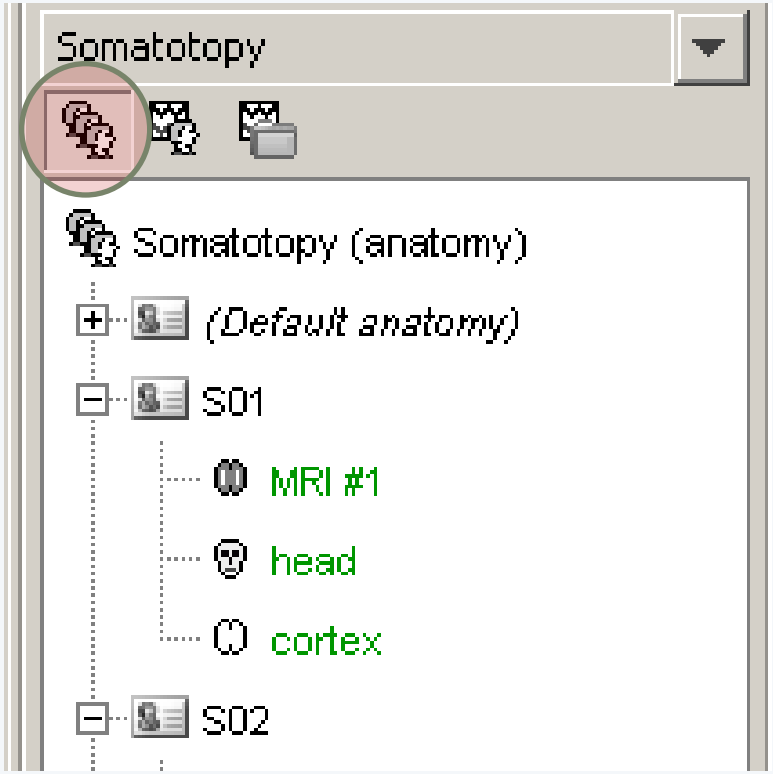
- 12 years of research and development
- Active collaboration between multiple groups:
  - University of Southern California, Los Angeles
  - La Salpetriere Hospital / CNRS, Paris
  - Neurospin / Inserm / CEA, Paris
  - Los Alamos National Lab, NM
  - Medical College of Wisconsin, Milwaukee
  - Cleveland Clinic, OH
  - Martinos Center / MGH, MA
  - McGovern Institute / MIT, MA
  - Montreal Neurological Institute / McGill, QC
- New interface released in 2009
- Over 7000 user accounts / 60 countries

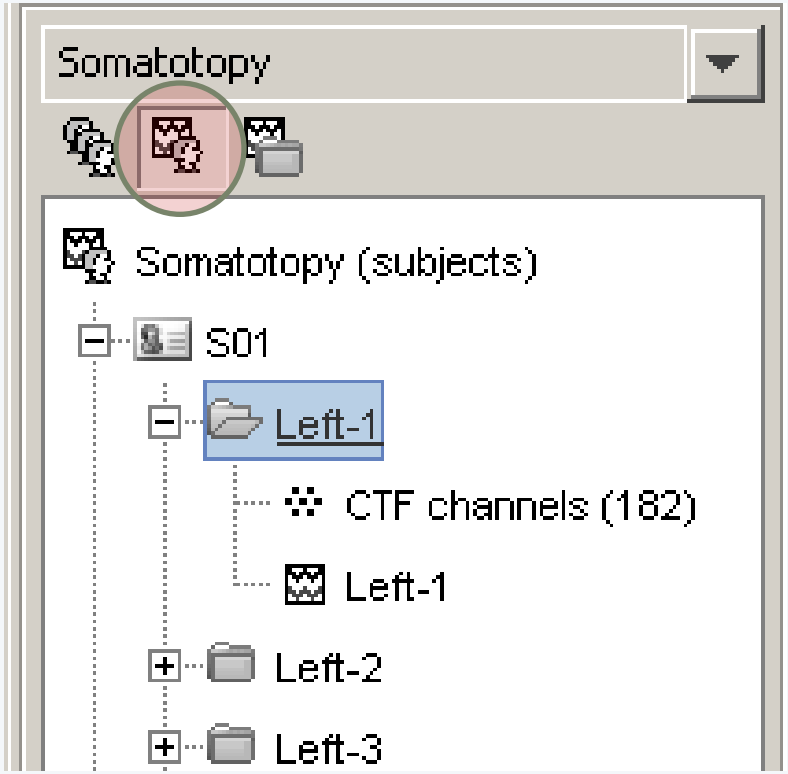
Workflow



Brainstorm

Database





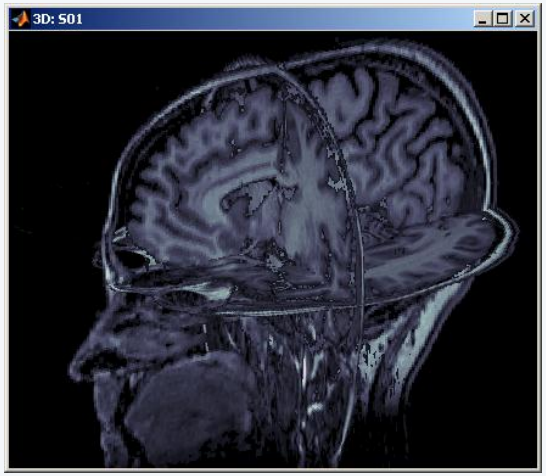
- Three levels:
  - Protocol
  - Subject
  - Condition

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

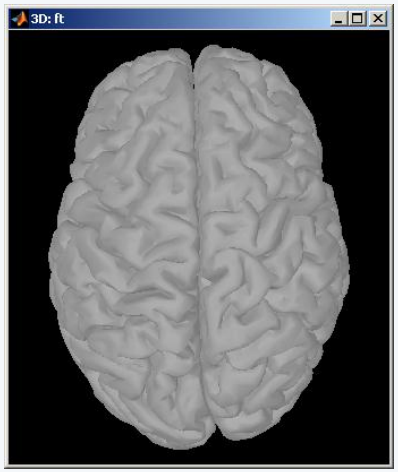
Brainstorm

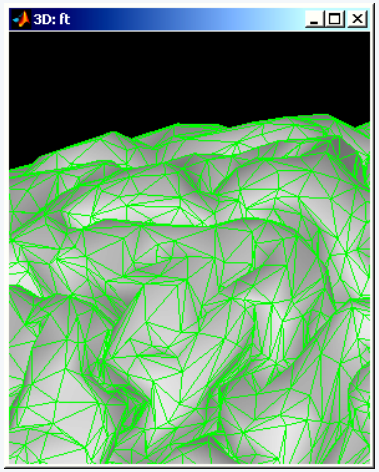
Anatomy

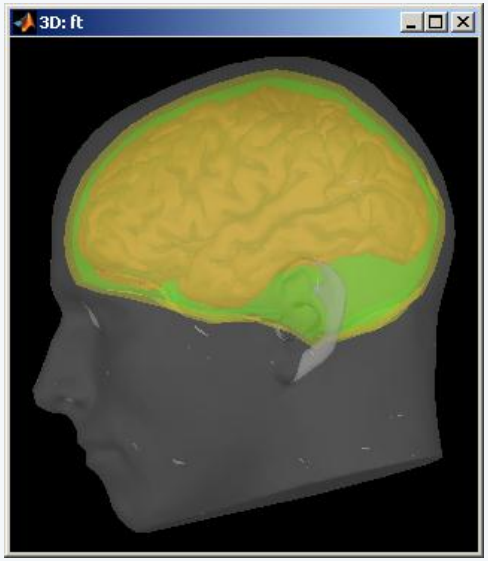
- T1-MRI volume



- Surfaces extracted with a dedicated software: BrainVISA, FreeSurfer, BrainSuite



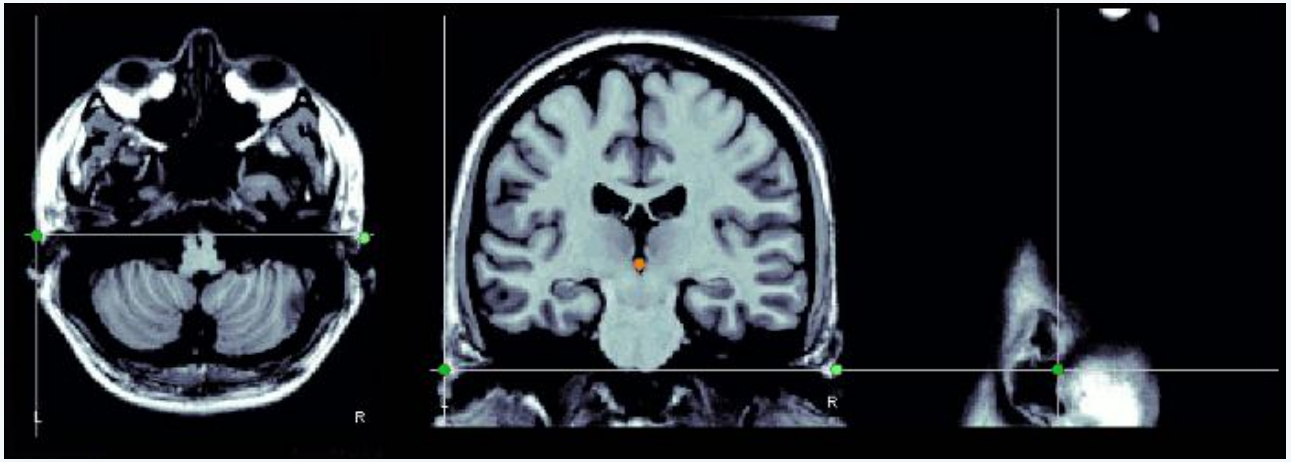




Brainstorm

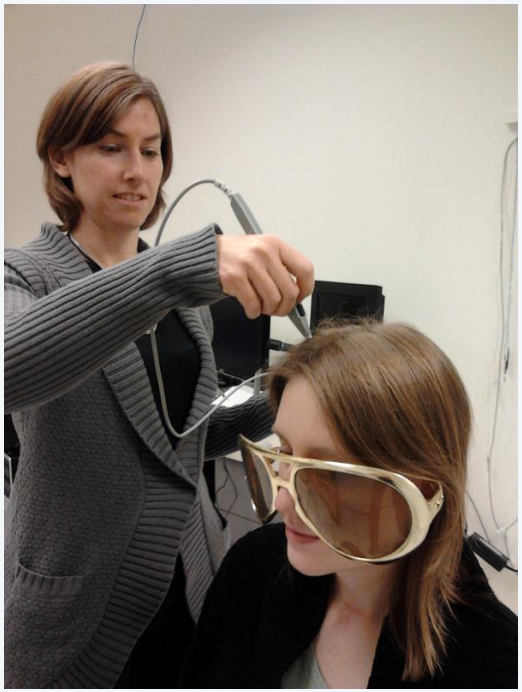
Co-registration MEG / MRI (I)

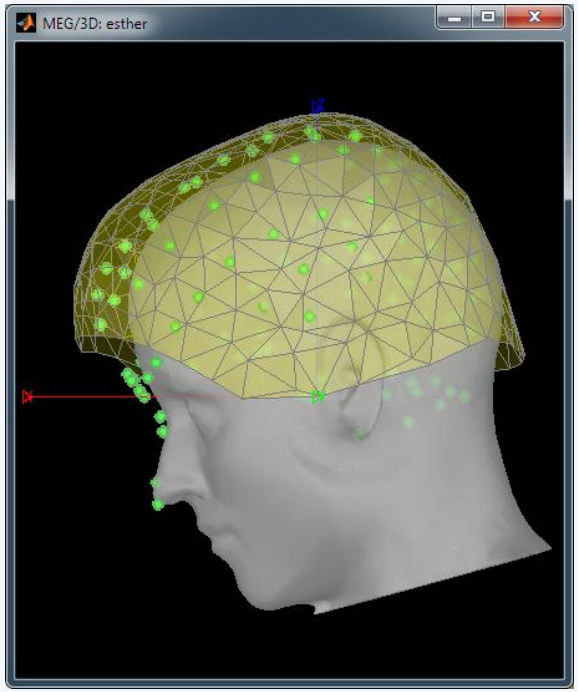
- Basic estimation based on three points (NAS,LPA,RPA)
  - MRI: Marked in the volume with the MRI Viewer
  - MEG: Obtained with a tracking system (Polhemus)

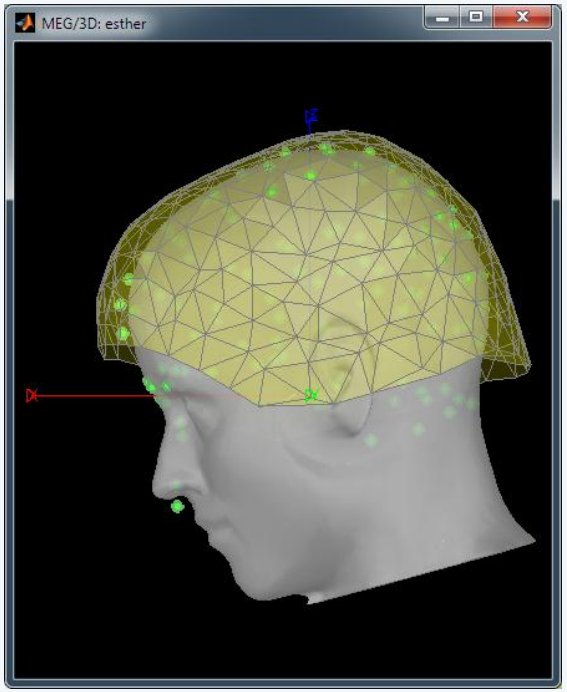


Co-registration MEG / MRI (2)

- Automatic adjustment based on head shape
  - Trying to fit the head points (digitized with the Polhemus) with the head surface (from the MRI)
- Final registration must be checked manually

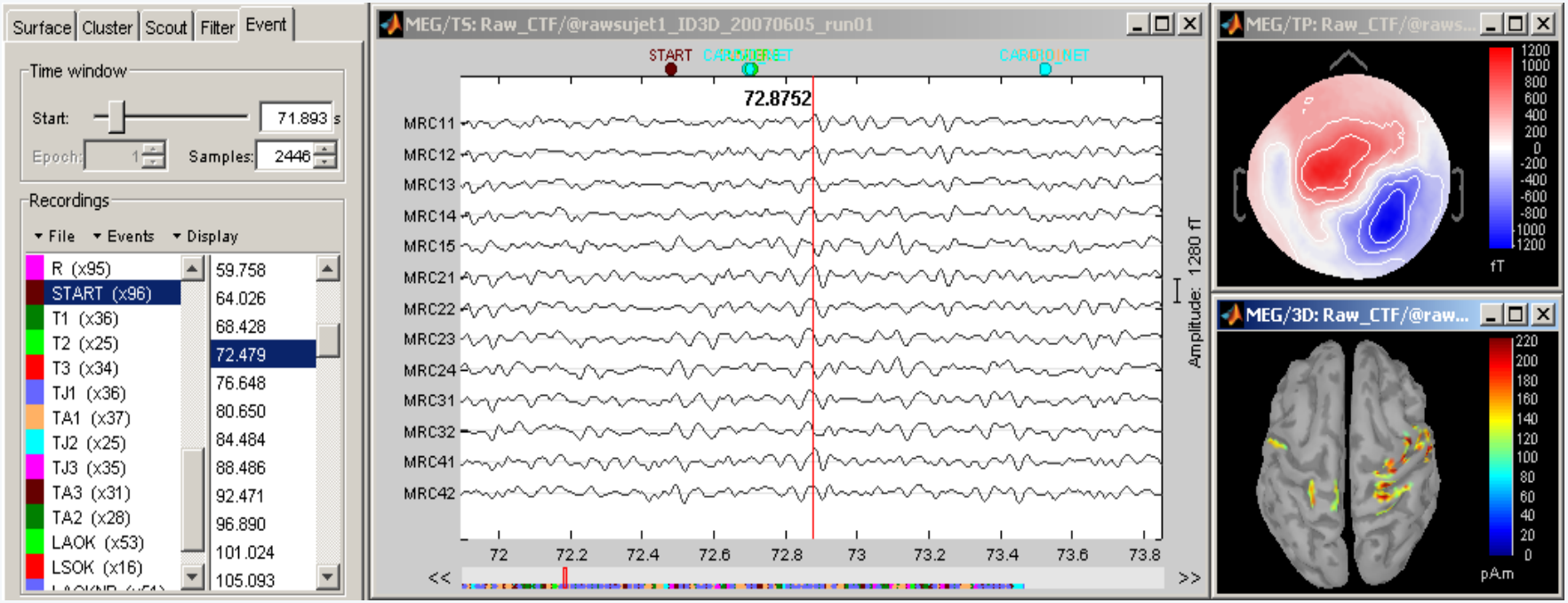






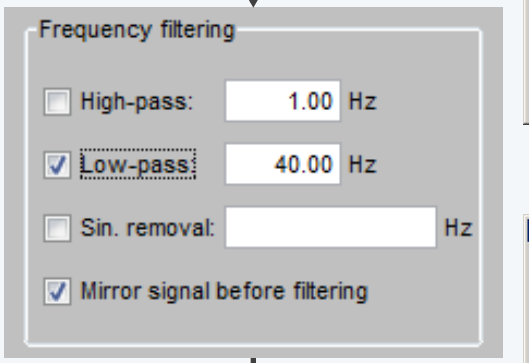
Continuous recordings

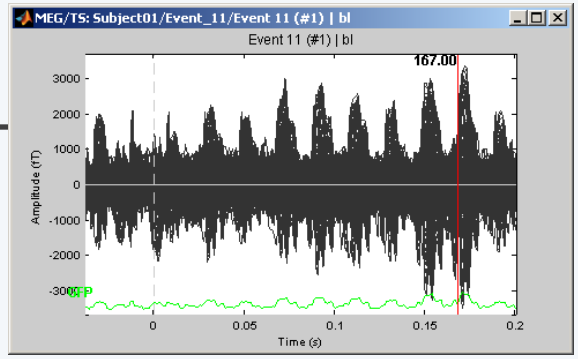
- Review continuous file
- Supports most common EEG/MEG file formats
- Edit markers, display 2D projections and sources

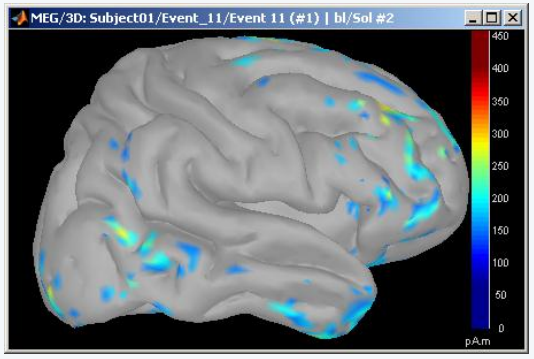


Brainstorm

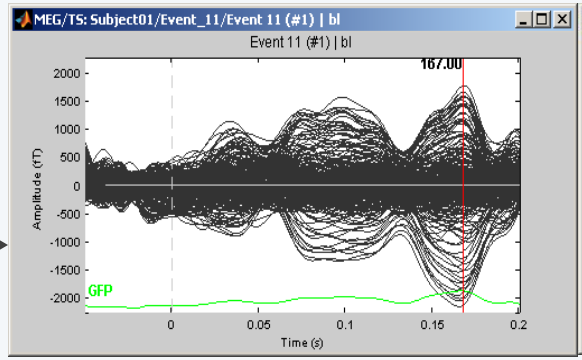
- Frequency filtering

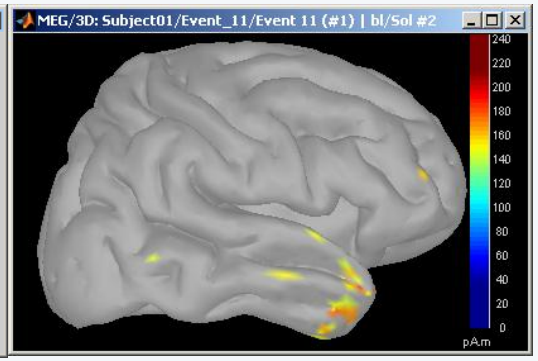






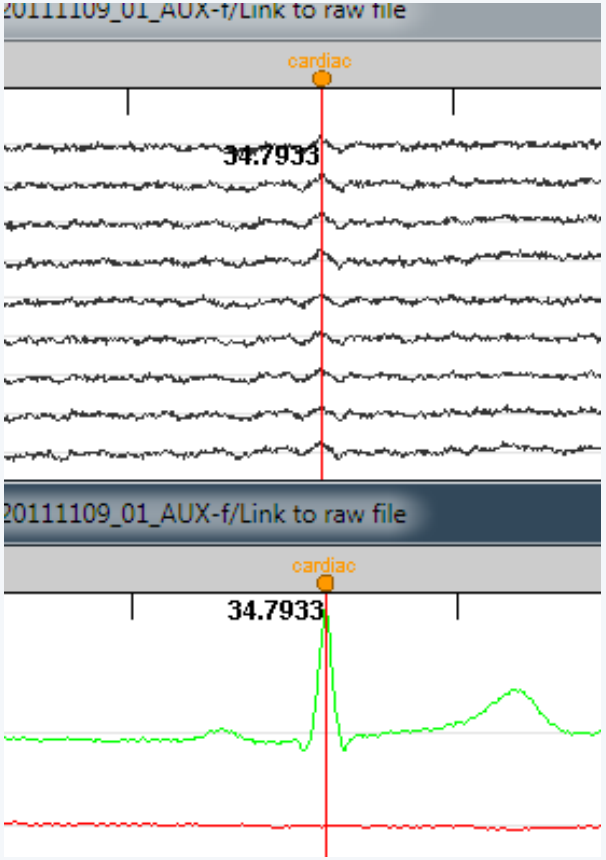
Not filtered

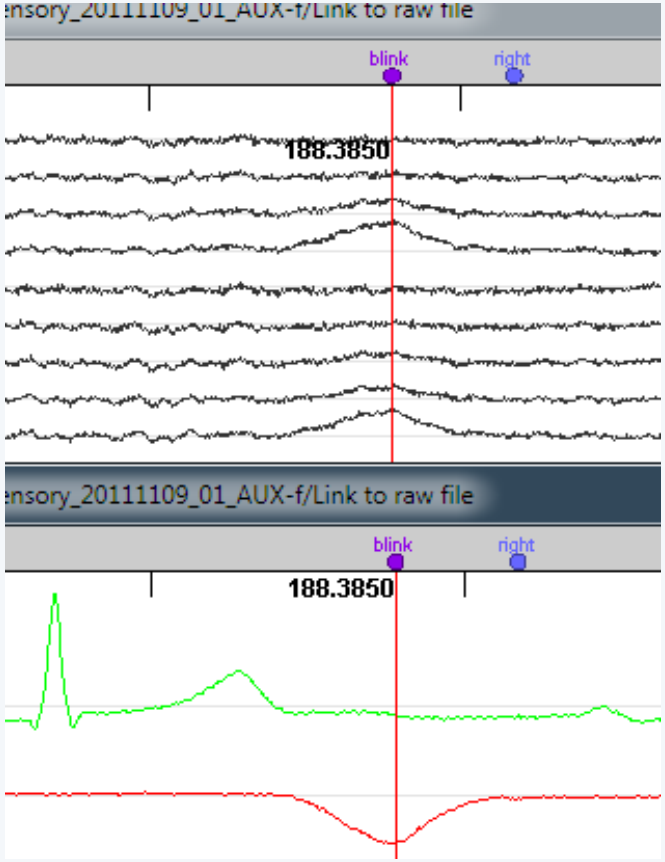




Low-pass
40Hz

- Artifact detection and removal:
  - heartbeats, eye blinks, movements, …



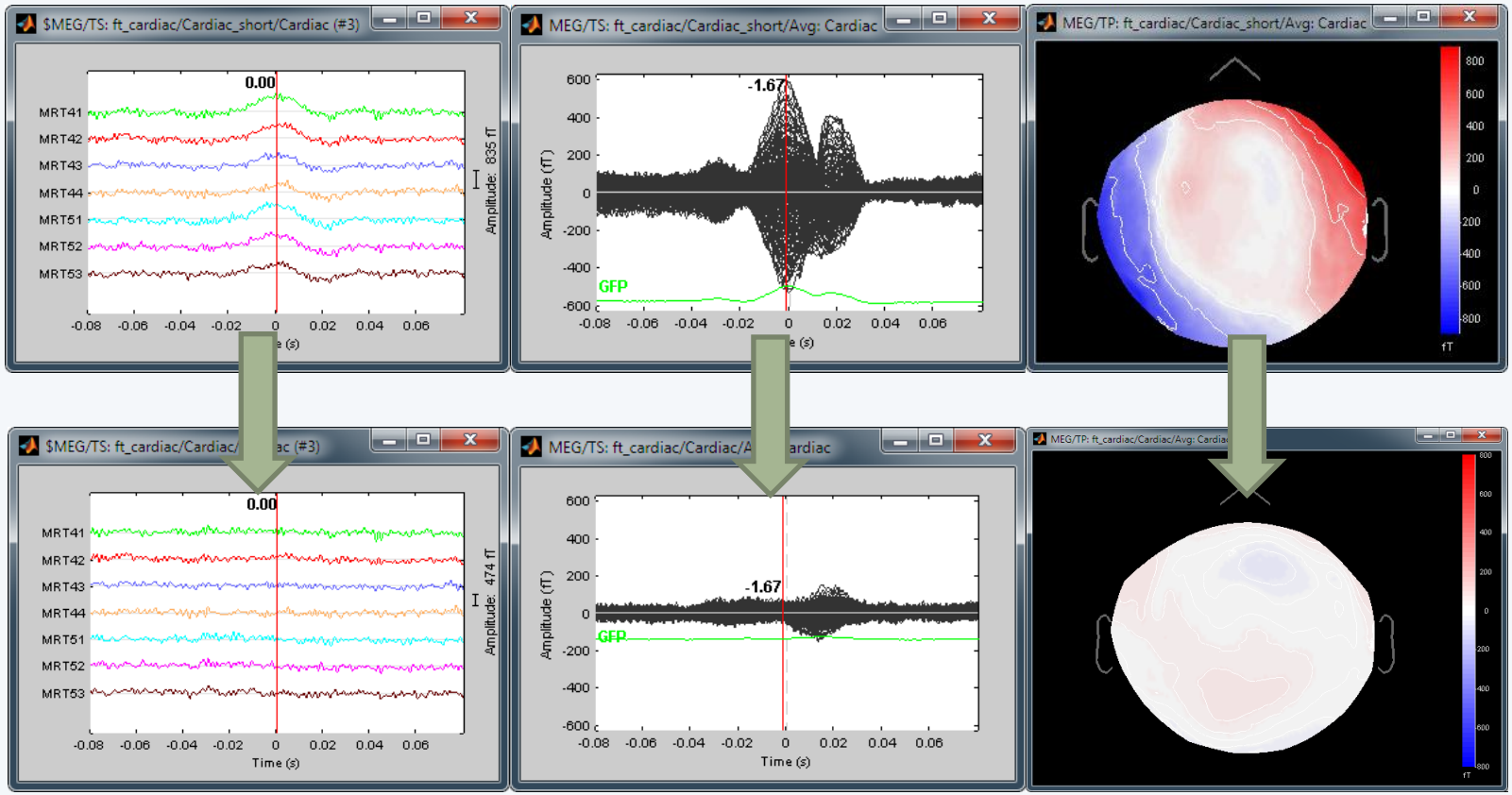


- Two categories of artifacts:
  - Well defined, reproducible, short, frequent:
    - Heartbeats, eye blinks, stimulator
    - Unavoidable and frequent: we cannot just ignore them
    - Can be modeled and removed from the signal efficiently
  - All the other events that can alter the recordings:
   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

- Example of the cardiac artifact
  => Computation of a Signal-Space Projection (SSP)

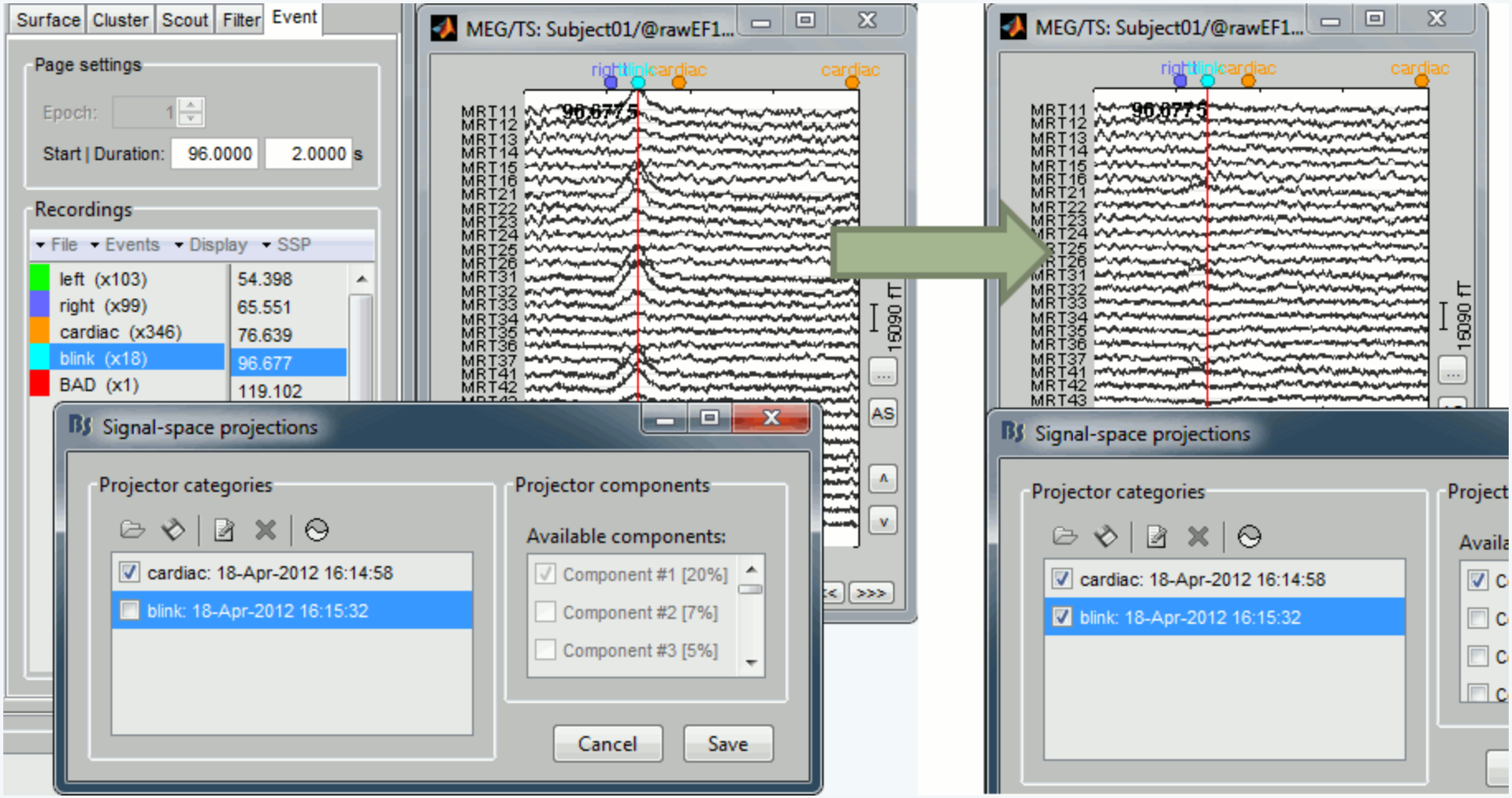
Original

SSP



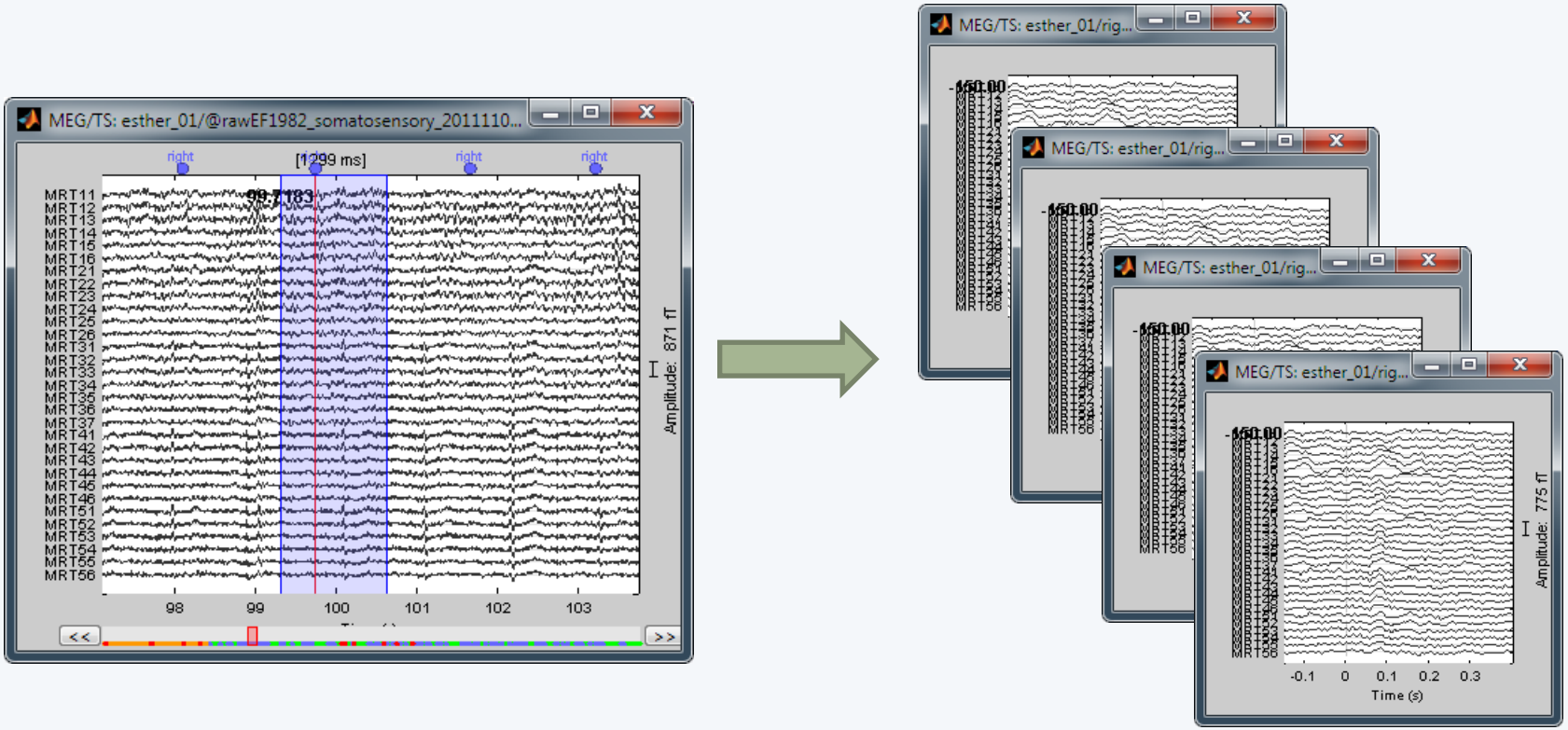
Pre-processing

Cleaning



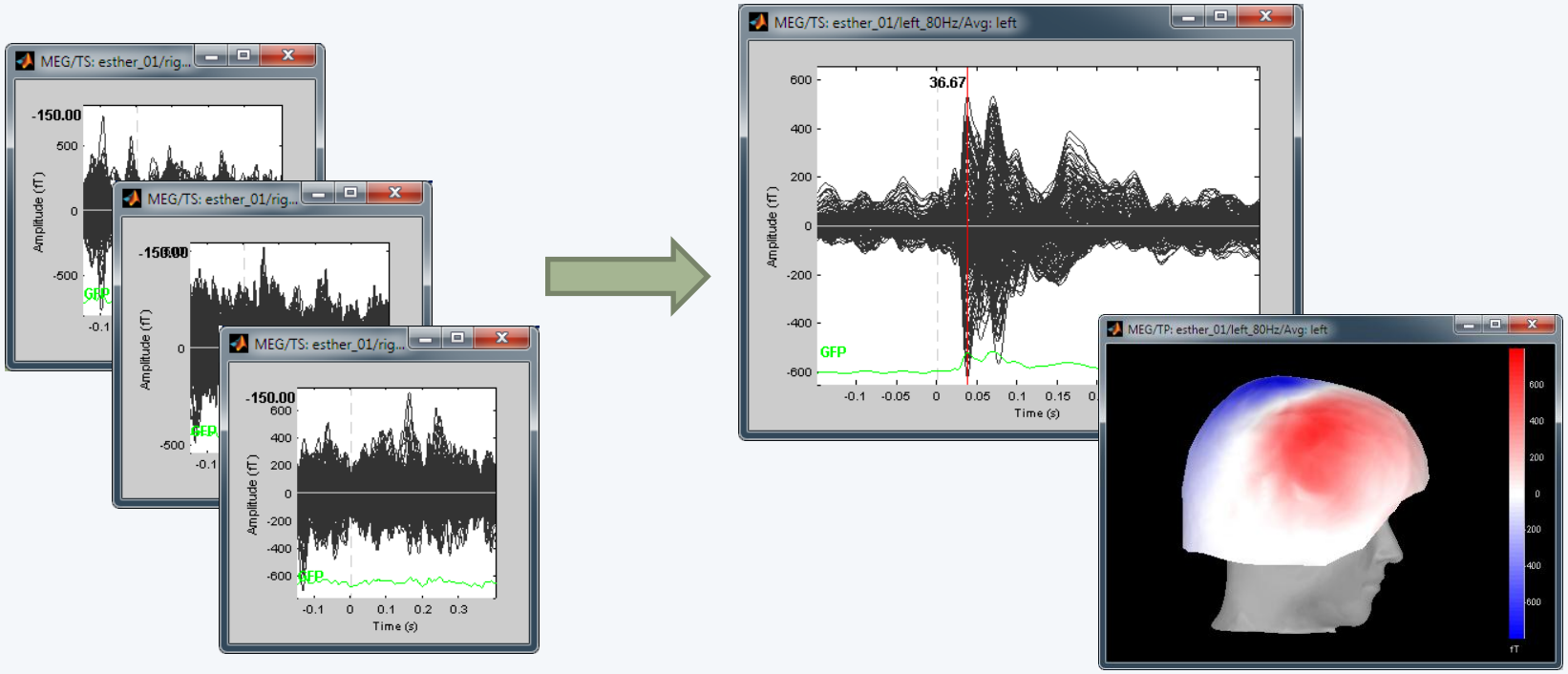
Brainstorm

- Epoching: extraction of small blocks of recordings around an event of interest (stimulus, spike…)



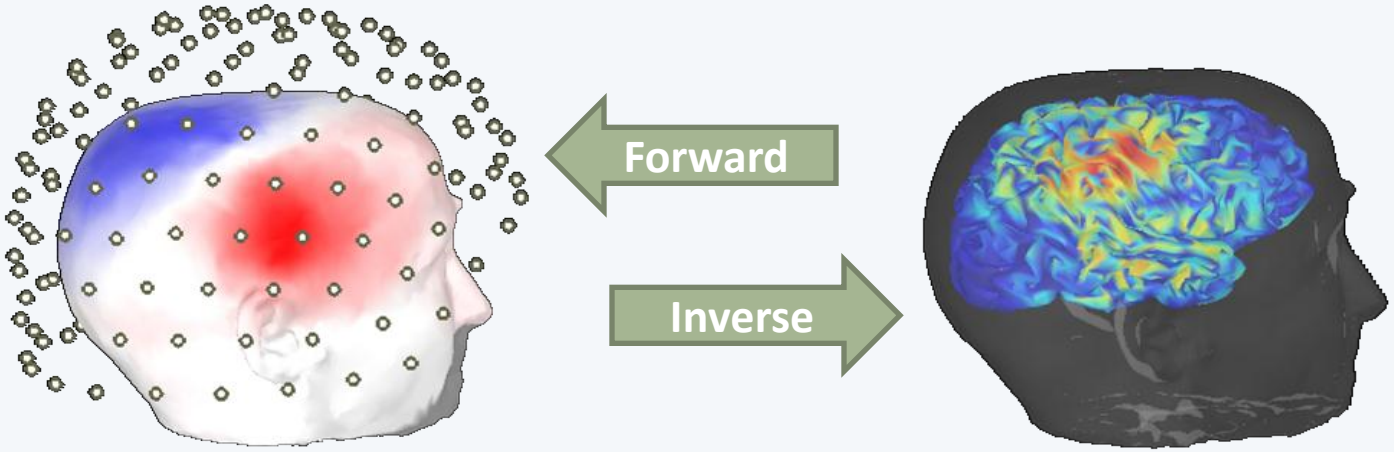
- Averaging all the trials: Reveals the features of the signals that are locked in time to a given event

  => Evoked-response field (or potential)



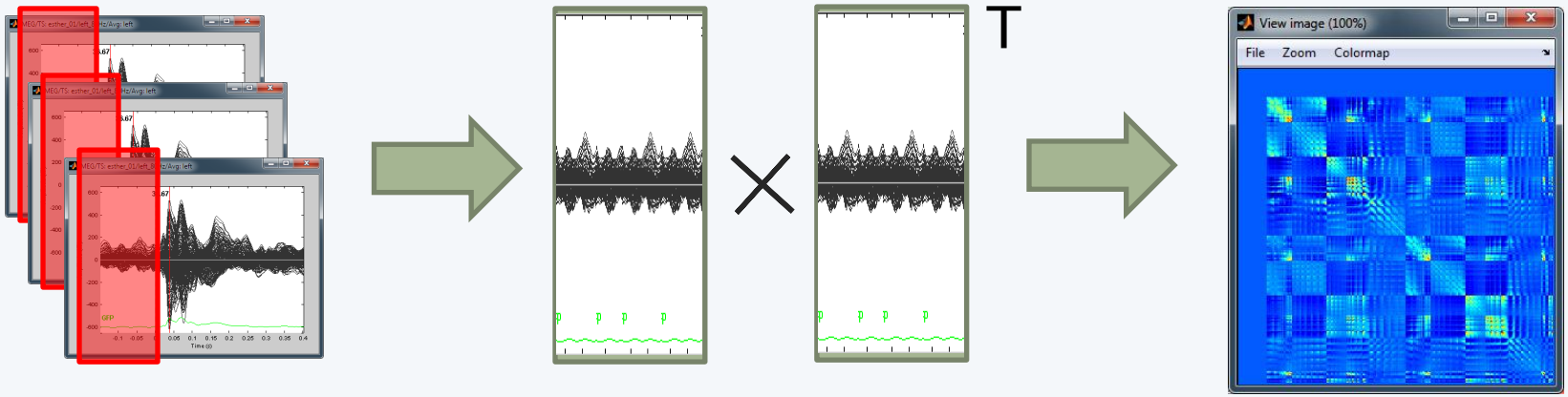
Source estimation

- Source space: cortex surface (or full head volume)
- Forward model = head model
  Sources => Sensors
- Inverse model: Minimum norm estimates
  Sensors => Sources

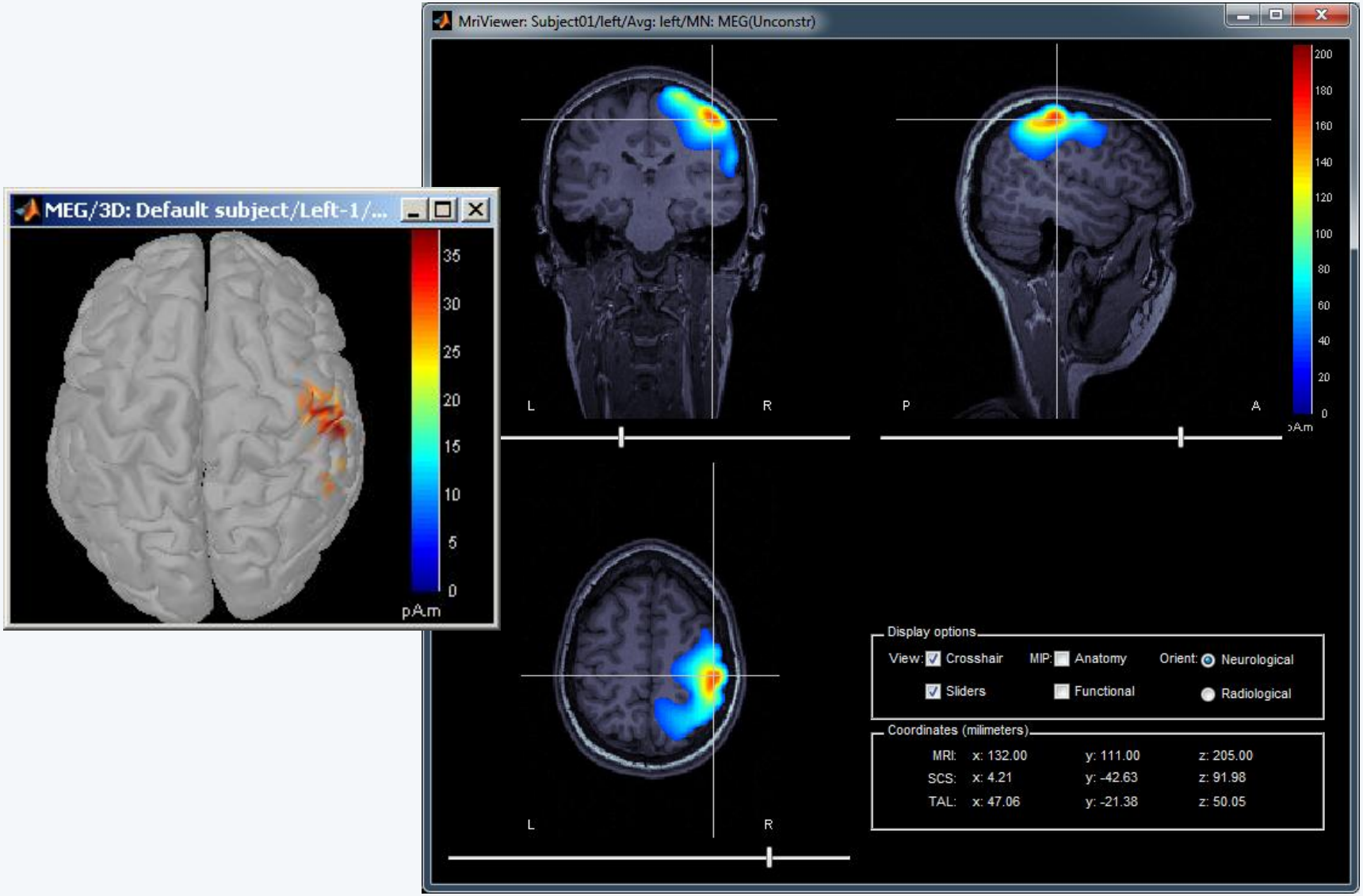


Noise covariance matrix

- Inverse model (minimum norm estimates) requires an estimation of the level of noise on the sensors
- Noise covariance matrix = covariance of the segments that do not contain any “meaningful” data
- Typically: empty room measures, or pre-stim baseline

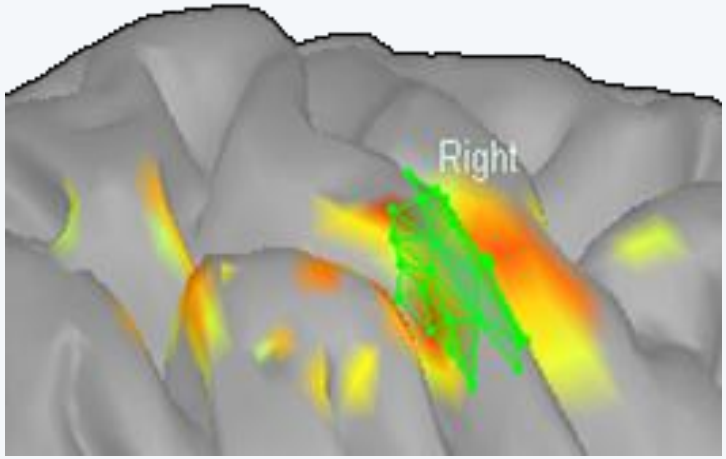


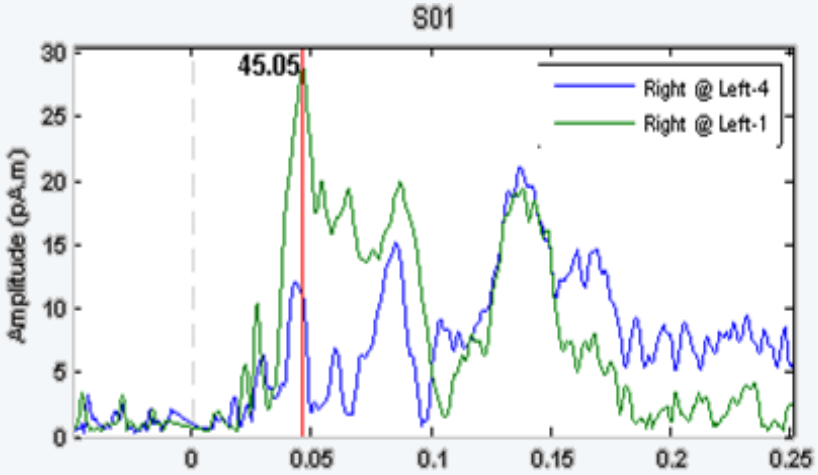
Sources activity



Regions of interest

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



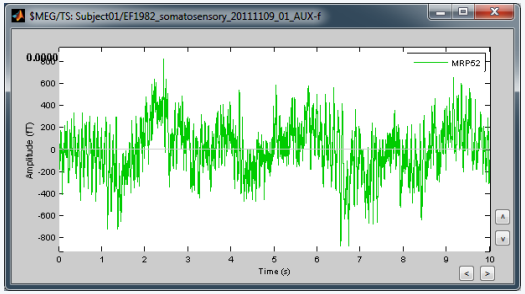


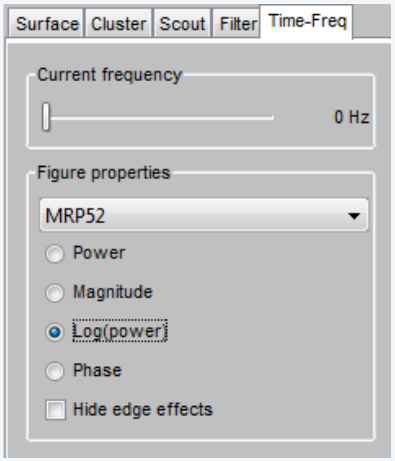
Post-processing

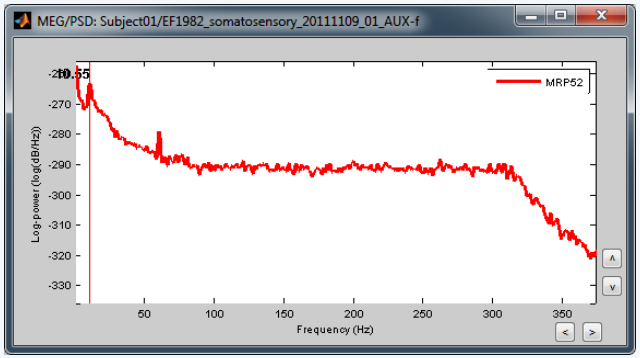
- Noise normalization (z-score)
- Spectral and time-frequency analysis
- Group analysis:
  - Anatomical registration and normalization
  - Statistical inference
- Connectivity measures

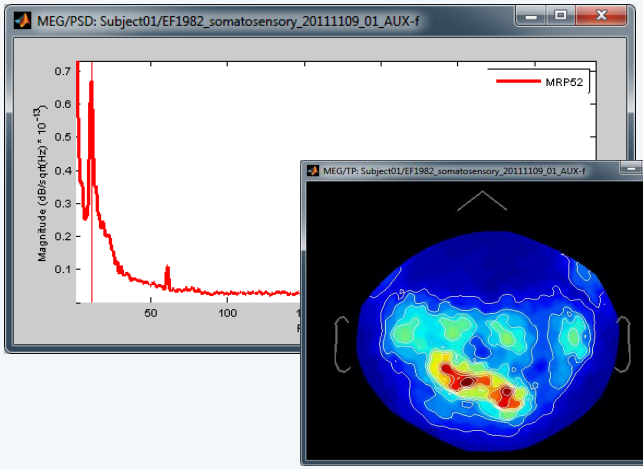
Spectral analysis

- Fast Fourier transform (FFT)
- Power spectrum density (PSD)



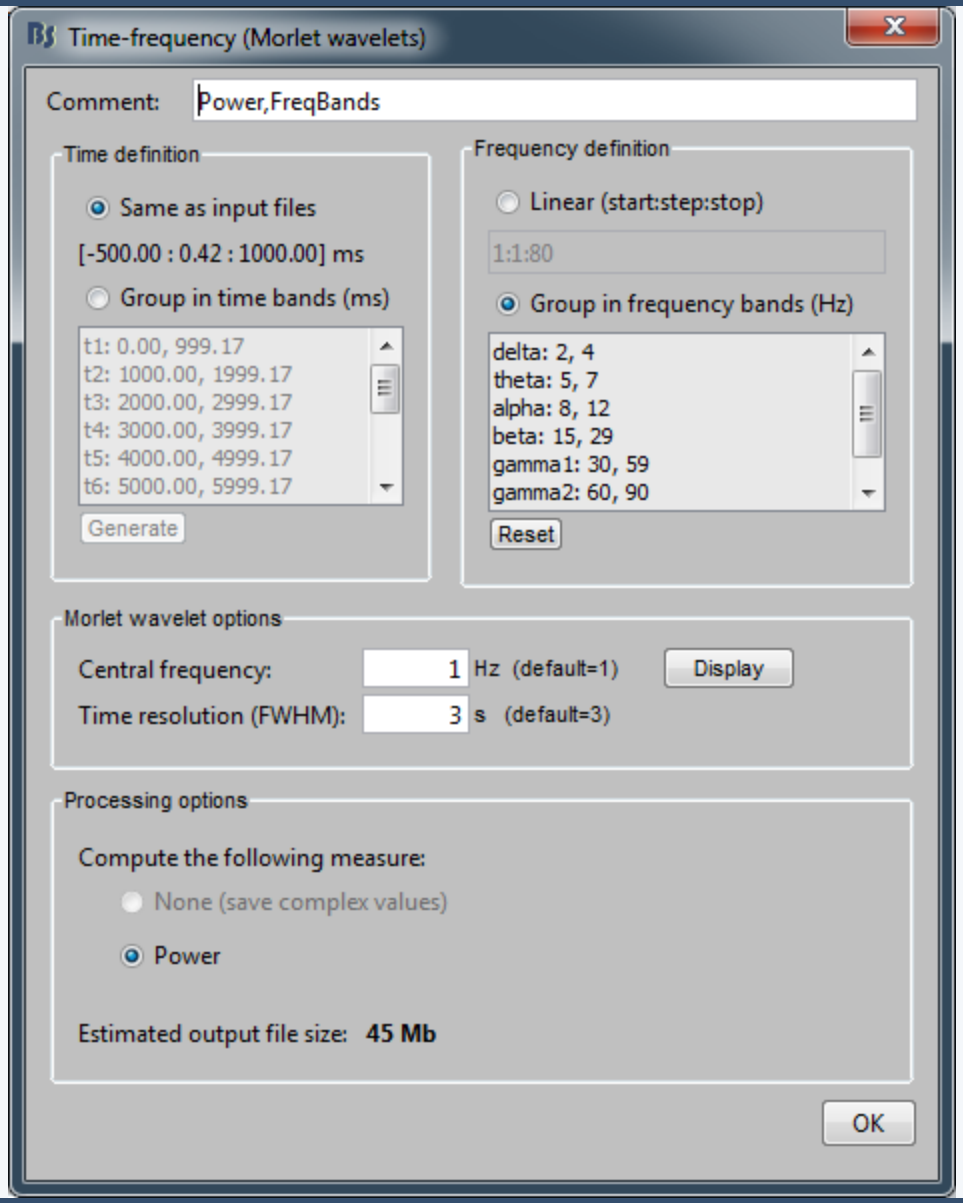


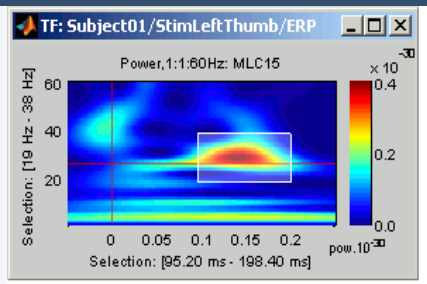




Brainstorm

Time-frequency / Hilbert transform





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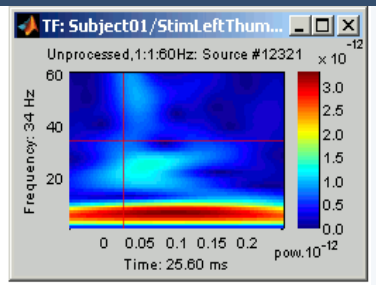

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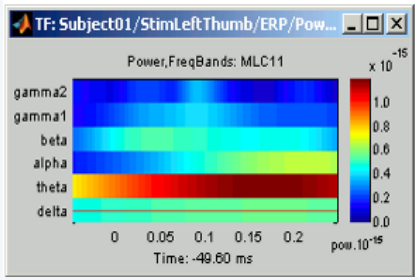
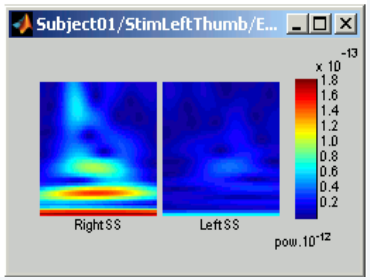
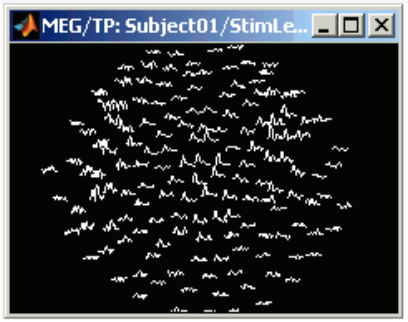
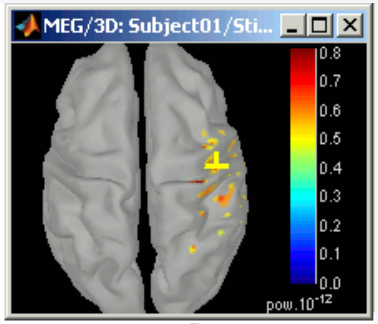






e



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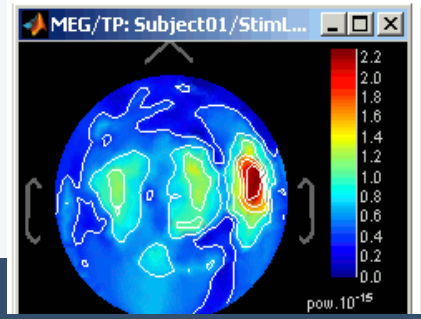
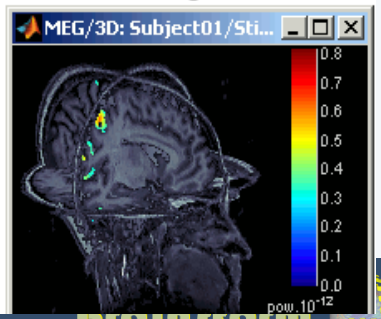
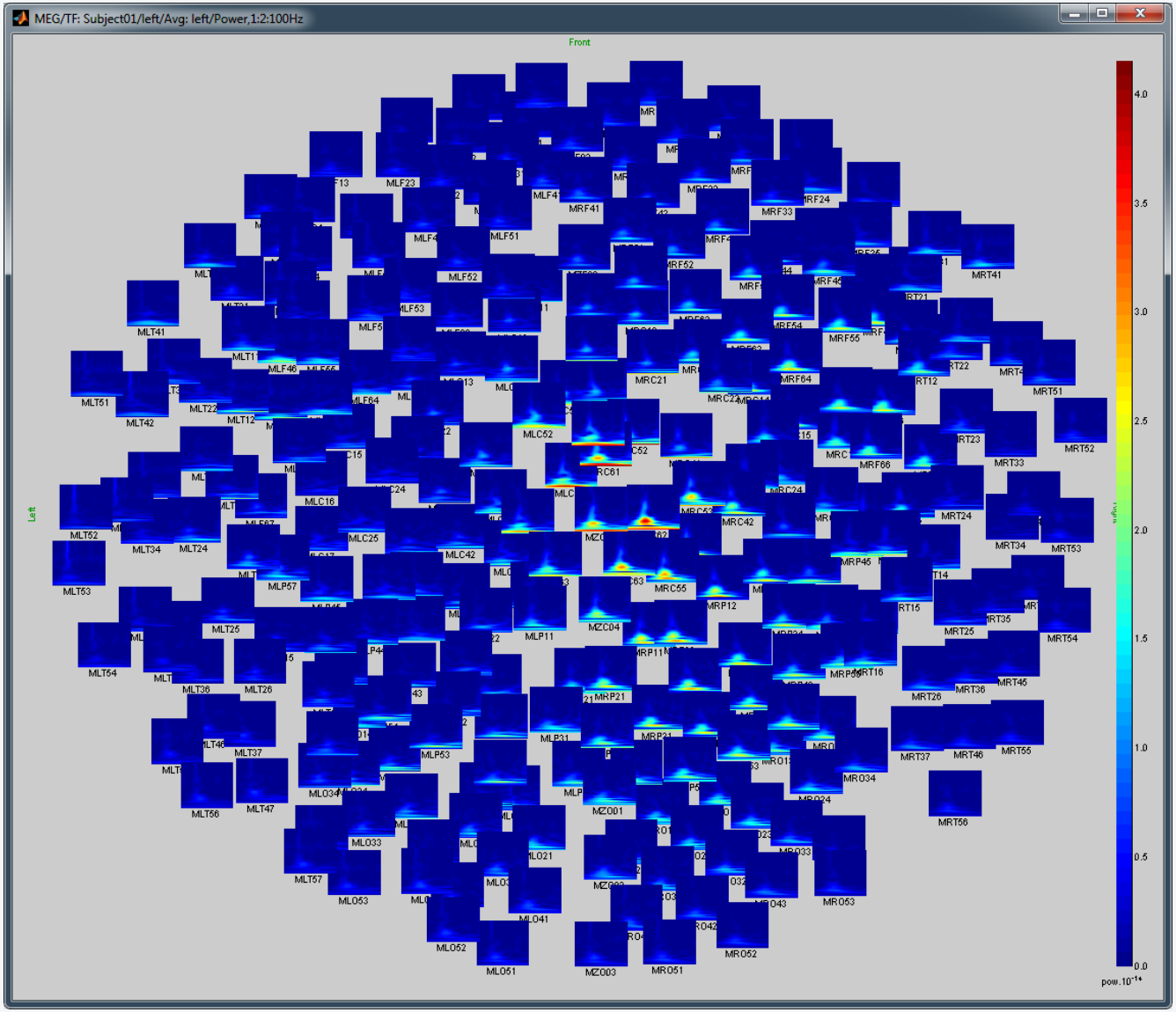


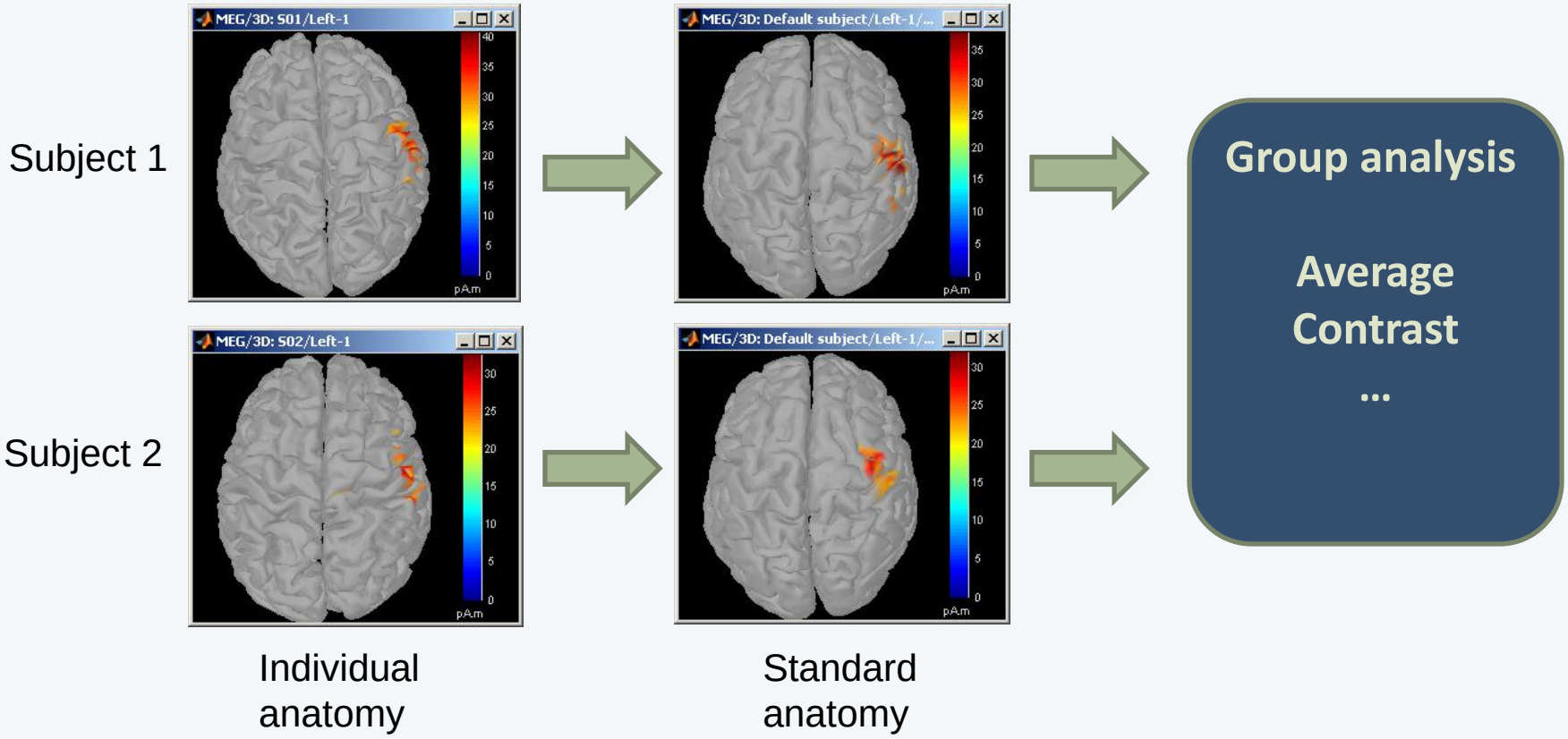


Time-frequency



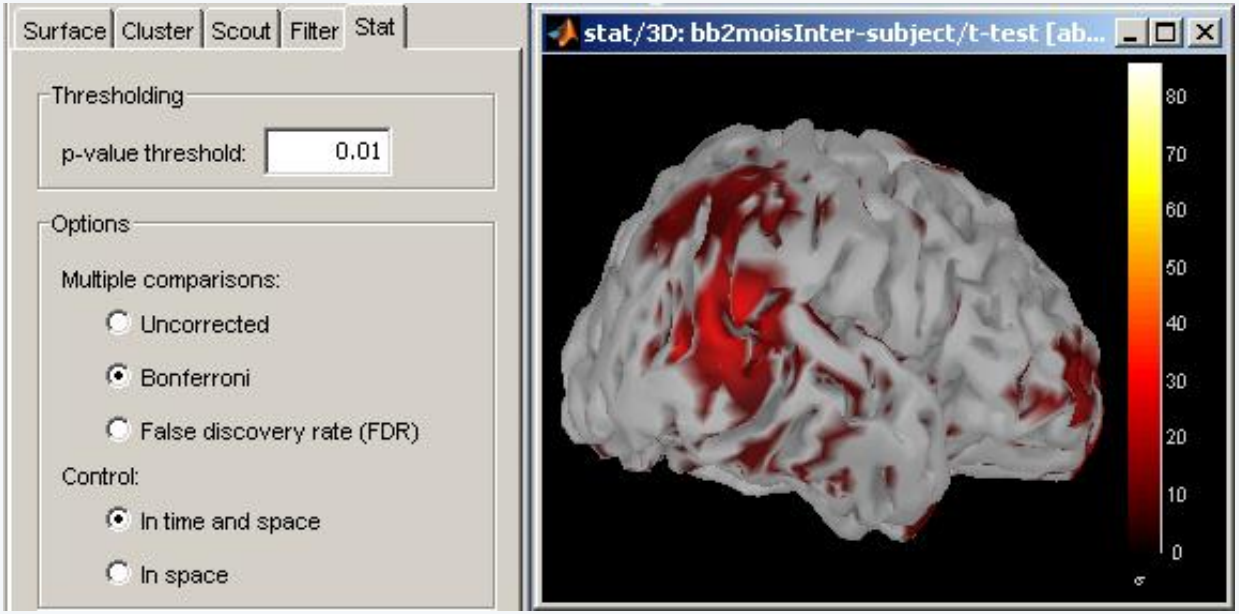
Brainstorm

- Registration of individual brains on a template



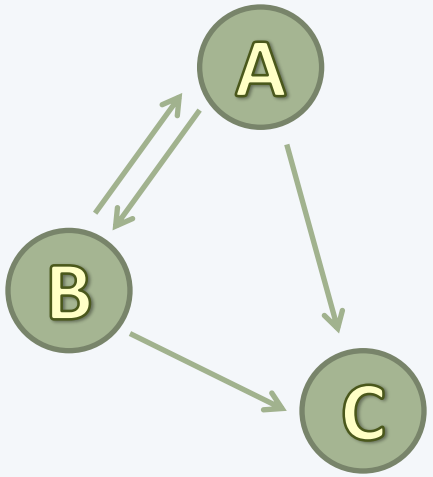
- Contrasts between subjects or conditions
- Statistical analysis: z-score, t-test
- Quick extraction of measures from complex paradigms

  => Export to: R, Excel, Statistica, SPSS, Matlab…

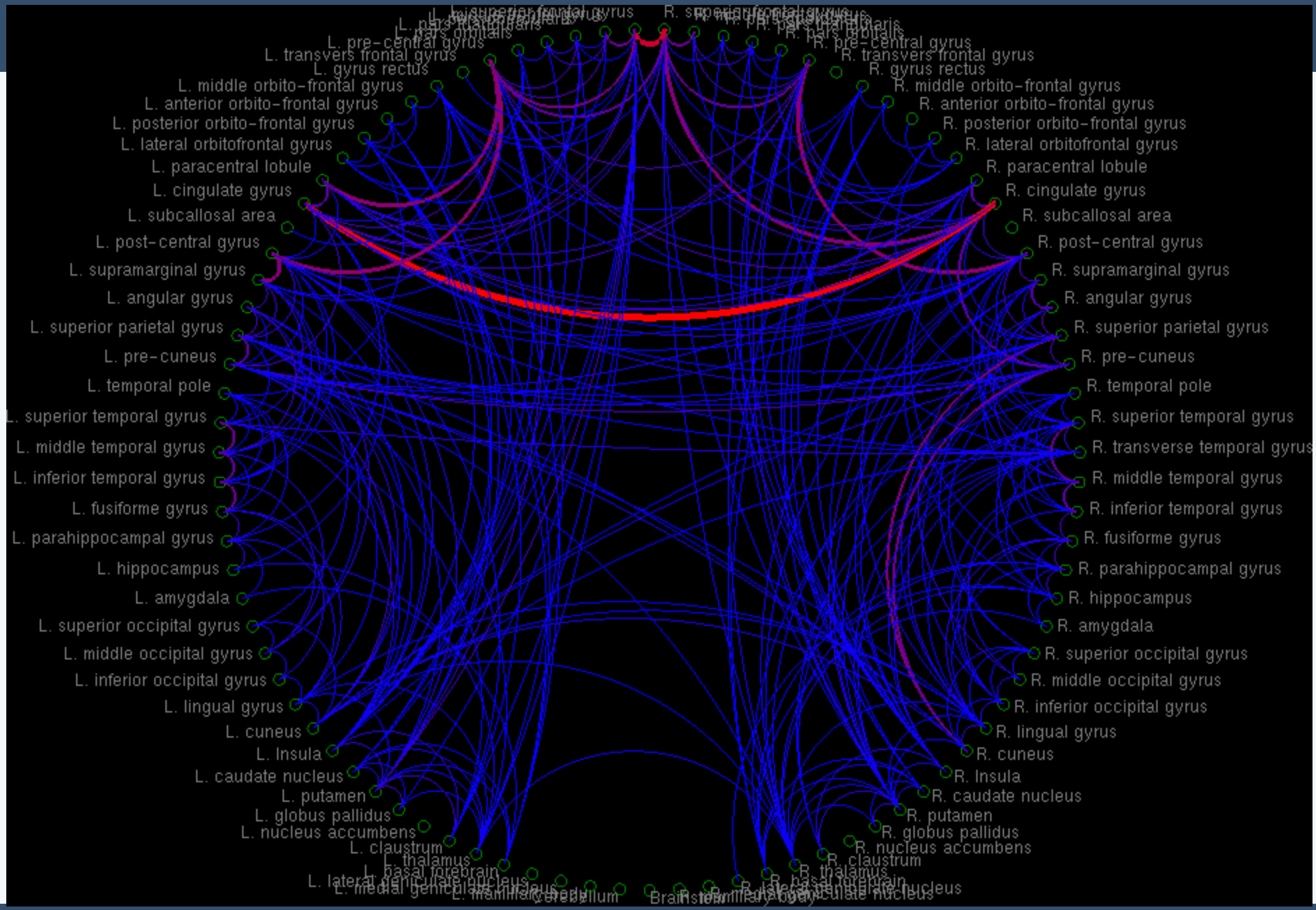


Coming next : Functional connectivity

- Objectives: Describe the interaction between two brain regions, identify the brain networks
- Measures:
  - Correlation
  - Coherence
  - Granger causality
  - Phase locking value



- Both at sensor and source levels
- Problem of representation: too many dimensions


L. pars orbitalis
L. pre-central gyrus
L. transvers frontal gyrus
L. gyrus rectus
L. middle orbito-frontal gyrus
L. anterior orbito-frontal gyrus
L. posterior orbito-frontal gyrus
L. lateral orbitofrontal gyrus
L. paracentral lobule
L. cingulate gyrus
L. subcallosal area
L. post-central gyrus
L. supramarginal gyrus
L. angular gyrus
L. superior parietal gyrus
L. pre-cuneus
L. temporal pole
L. superior temporal gyrus
L. middle temporal gyrus
L. inferior temporal gyrus
L. fusiforme gyrus
L. parahippocampal gyrus
L. hippocampus
L. amygdala
L. superior occipital gyrus
L. middle occipital gyrus
L. inferior occipital gyrus
L. lingual gyrus
L. cuneus
L. Insula
L. caudate nucleus
L. putamen
L. globus pallidus
L. nucleus accumbens
L. claustrum
L. thalamus
L. basal forebrain
R. pars orbitalis
R. pre-central gyrus
R. transvers frontal gyrus
R. gyrus rectus
R. middle orbito-frontal gyrus
R. anterior orbito-frontal gyrus
R. posterior orbito-frontal gyrus
R. lateral orbitofrontal gyrus
R. paracentral lobule
R. cingulate gyrus
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R. angular gyrus
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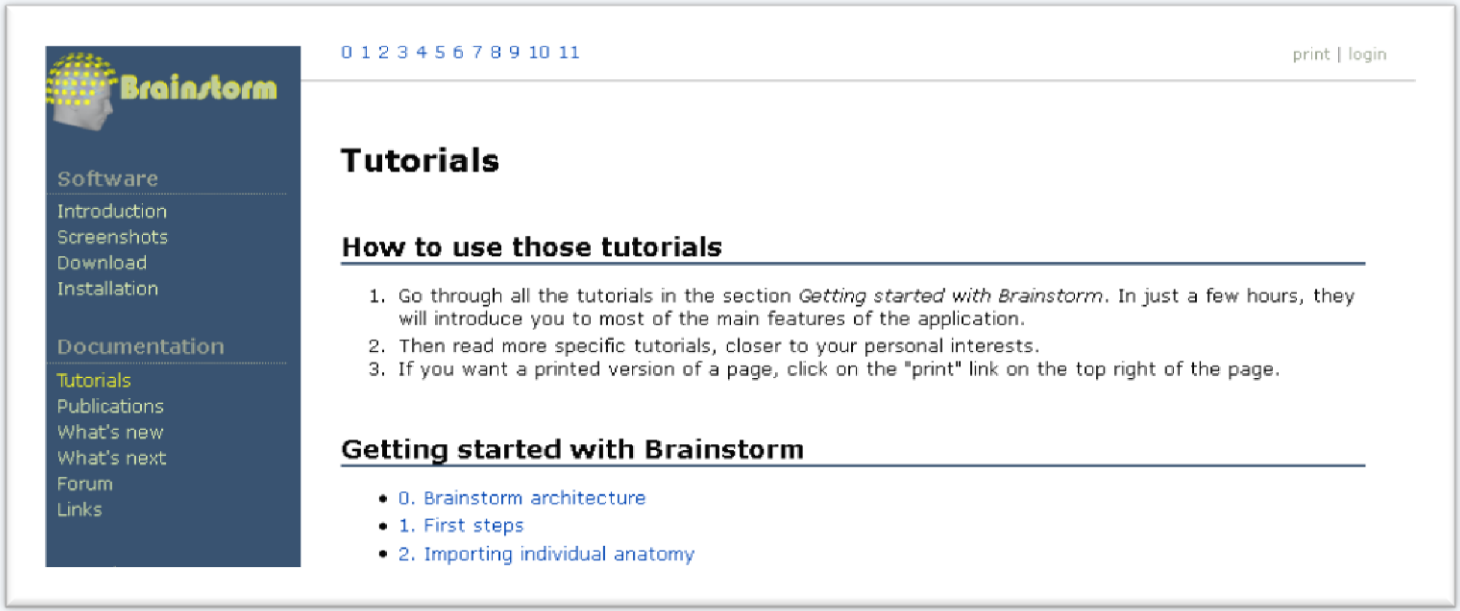
R. lingual gyrus
R. cuneus
R. Insula
R. caudate nucleus
R. putamen
R. globus pallidus
R. nucleus accumbens
R. claustrum
R. thalamus

Support

- Brainstorm online tutorials and forum:

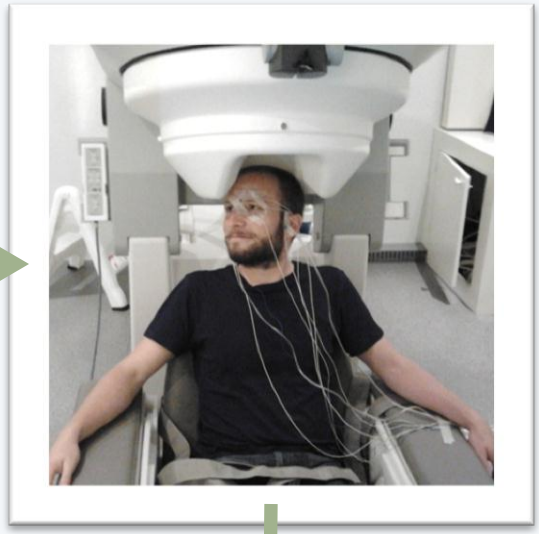


- Contact us for specific questions and requests:
  We will help you adding the features you need

- Median nerve stimulation
  (Nov 2011, Montreal Neurological Institute, McGill)
  - Random electric stimulation of both arms
  - ~ 100 trials per arm
  - Acquisition at 1200 Hz
  - Recorded on CTF 275 MEG sensors
    + 26 reference sensors
    + EOG + ECG + STIM + … = 302 channels
  - 6 minutes of recordings, 500 Mb

Sample data

Acquisition setup



Polhemus

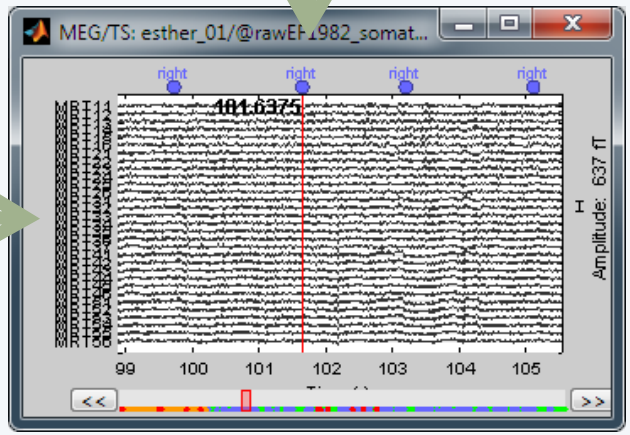
Stimulation computer

Stim

MEG

3D points

Acquisition computer

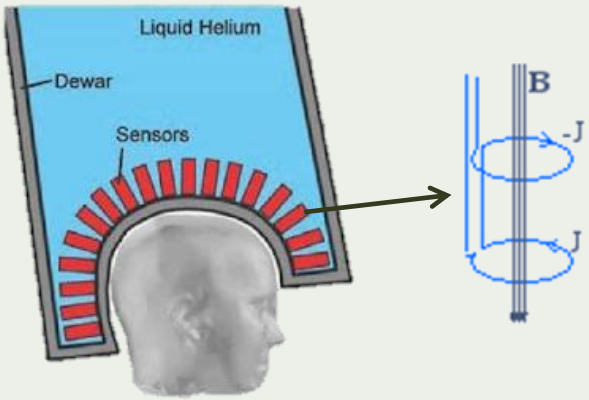


Brainstorm

CTF vs. Elekta Neuromag

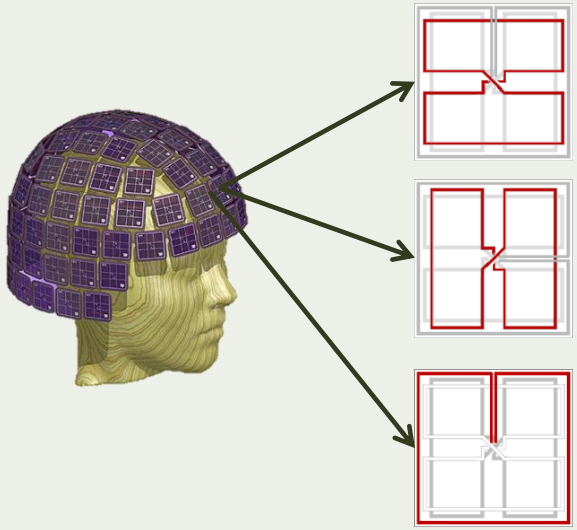
CTF (MNI)

275 axial gradiometers



Neuromag (MIT)

204 planar gradiometers
102 magnetometers



- Create a protocol, with one subject
- Anatomy
  - Import the MRI, define the anatomical landmarks
  - Import the surfaces
  - 2D / 3D display
- Recordings:
  - Review the continuous file
  - Mark cardiac peaks + eye blinks
  - Remove the ocular artifact (SSP)

- Recordings:
  - Import trials: [-100, +300] ms around each stimulus
  - Average the trials (left and right)
  - Explore the average at the sensor level
- Source estimation:
  - Head model
  - Noise covariance matrix
  - Sources time series
  - Review visually the results for left and right stim
  - Create a couple of regions of interest (scouts)

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