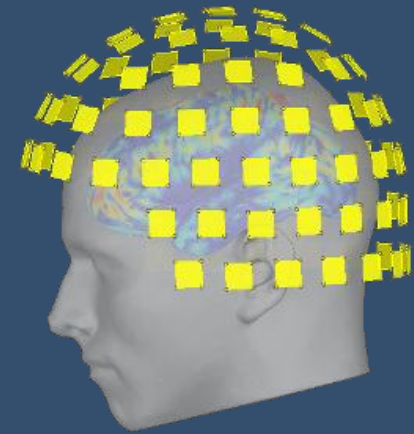


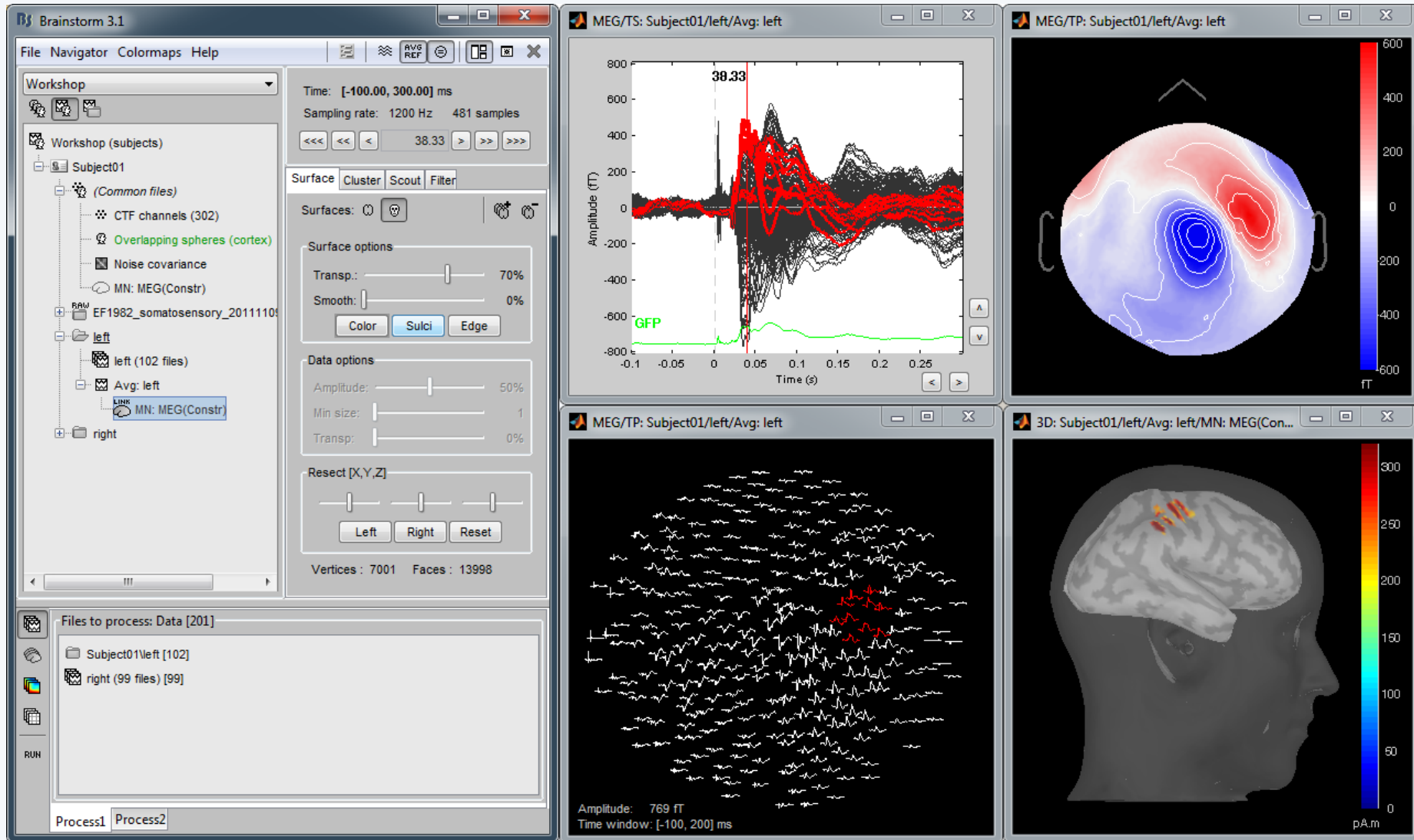
MEG and EEG analysis using

Brainstorm 3.1

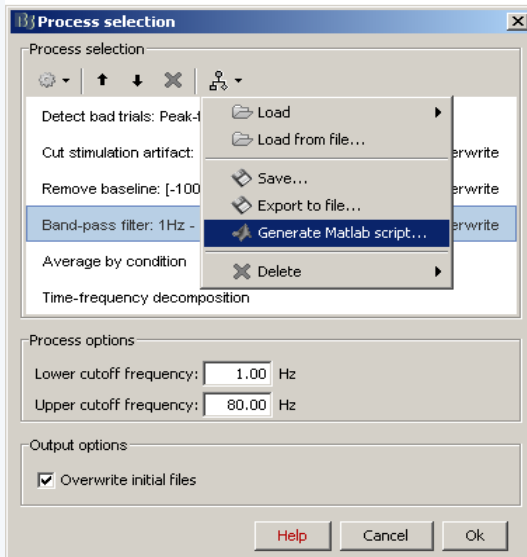
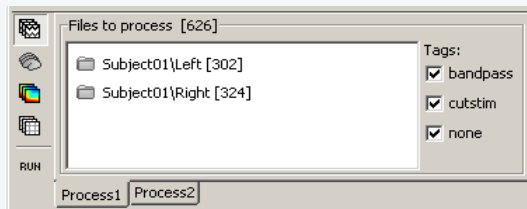
<http://neuroimage.usc.edu/brainstorm>



François Tadel
Dalhousie University, Halifax
February 16, 2013



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



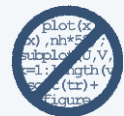
```

1  % Script generated by Brainstorm v3.1 (17-Dec-2010).
2  FileNamesA = ('Subject01\Left\data_average_101213_1558.mat', ...
3              'Subject01\Right\data_average_101213_1559.mat');
4  FileNamesB = [];
5
6  % Process: Detect bad trials: Peak-to-peak MEGGRAD(0-2000)
7  sFiles = bst_process(...
8      'CallProcess', 'process_detectbad', ...
9      FileNamesA, FileNamesB, ...
10     'timewindow', [-0.0998, 0.3000], ...
11     'meggrad', {[0, 2000], 'fT/cm (x 0.04)', 1e-015}, ...
12     'rejectmode', 2);
13
14 % Process: Remove baseline: [-100ms, -1ms]
15 sFiles = bst_process(...
16     'CallProcess', 'process_baseline', ...
17     sFiles, [], ...
18     'baseline', [-0.09983, -0.00056], ...
19     'overwrite', 1);
20
21 % Process: Band-pass filter: 1Hz - 80Hz
22 sFiles = bst_process(...
23     'CallProcess', 'process_bandpass', ...
24     sFiles, [], ...
25     'f1', 1, ...
26     'f2', 80, ...
27     'overwrite', 1);
28
29 % Process: Average by condition
30 sFiles = bst_process(...
31     'CallProcess', 'process_average', ...
32     sFiles, [], ...
33     'avgttype', 3, ...
34     '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

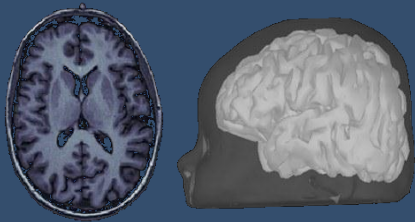


A bit of history

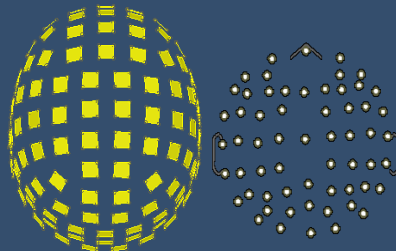
- 12 years of research and development
- Active collaboration between multiple groups:
 - University of Southern California, Los Angeles
 - La Salpetriere Hospital / CNRS, Paris
 - Neurospin / Inserm / CEA, Paris
 - Los Alamos National Lab, NM
 - Medical College of Wisconsin, Milwaukee
 - Cleveland Clinic, 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

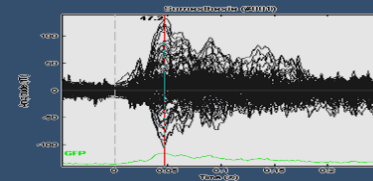
Anatomy



Sensors



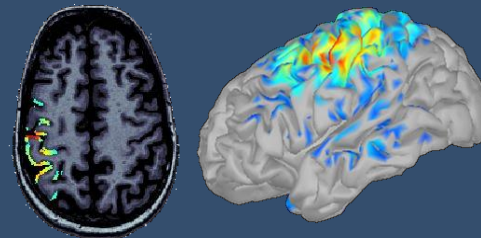
EEG/MEG



Co-registration

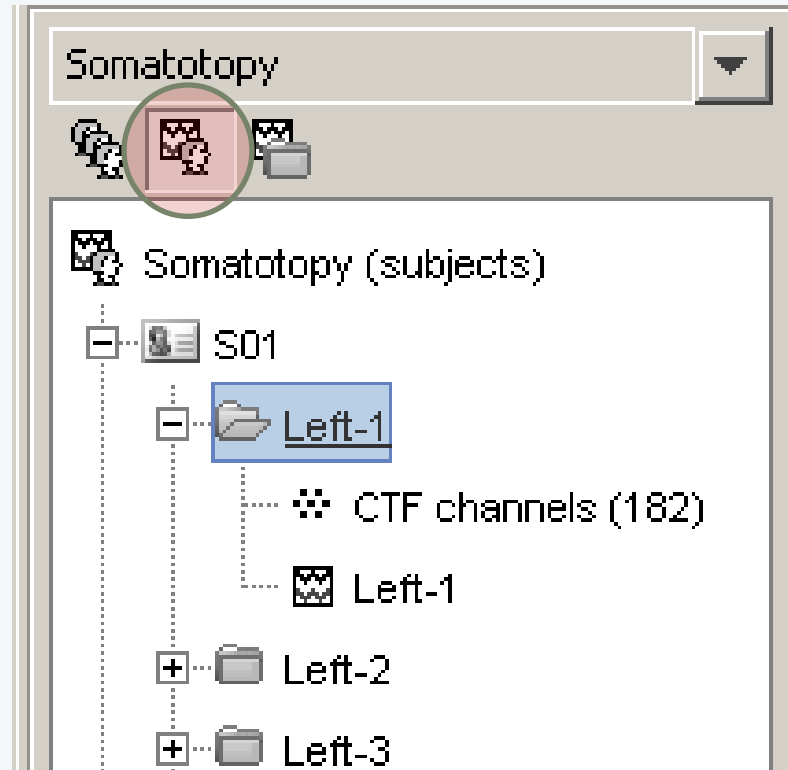
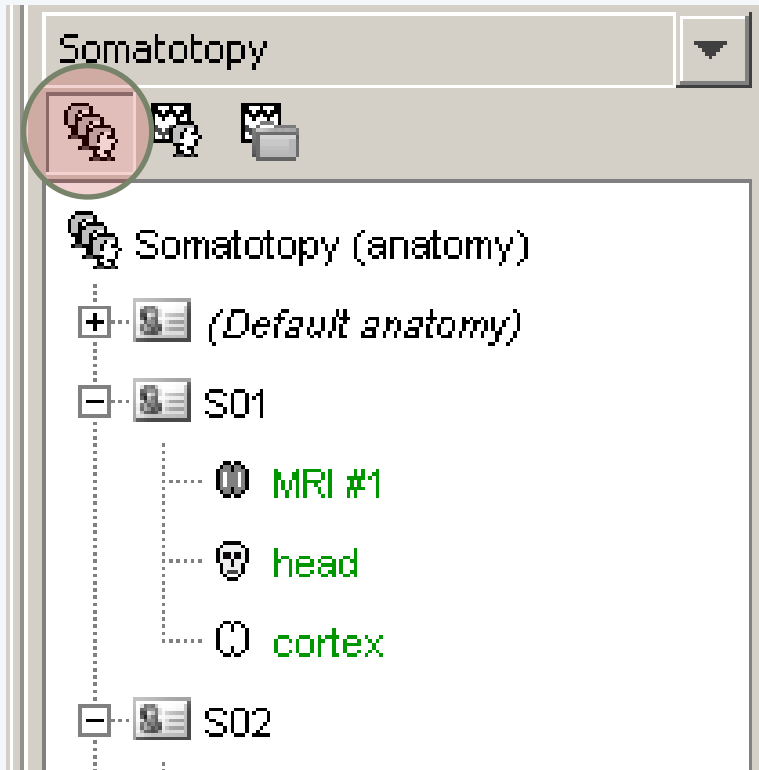


Source estimation



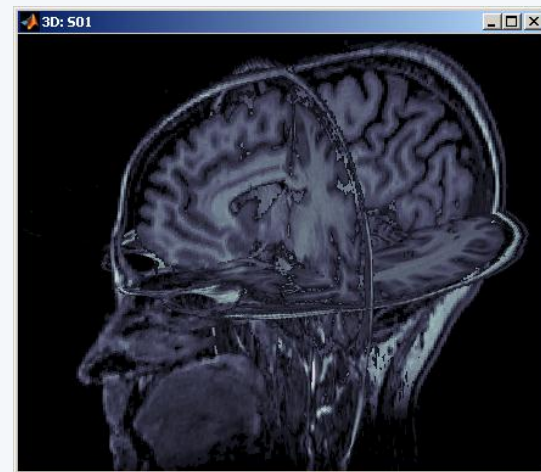
Analysis

Database

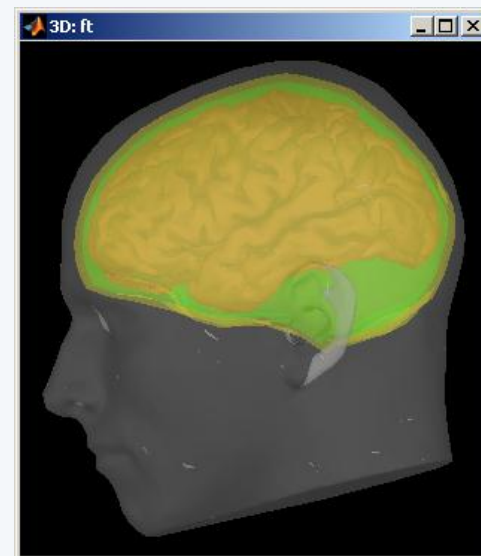
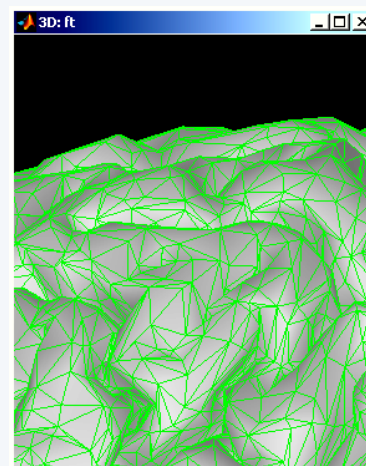
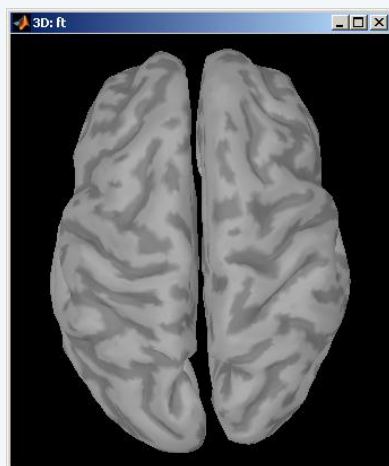


- Three levels:
 - Protocol
 - Subject
 - Condition
- Popup menus
- All files saved in Matlab .mat
- Same architecture on the disk

- T1-MRI volume

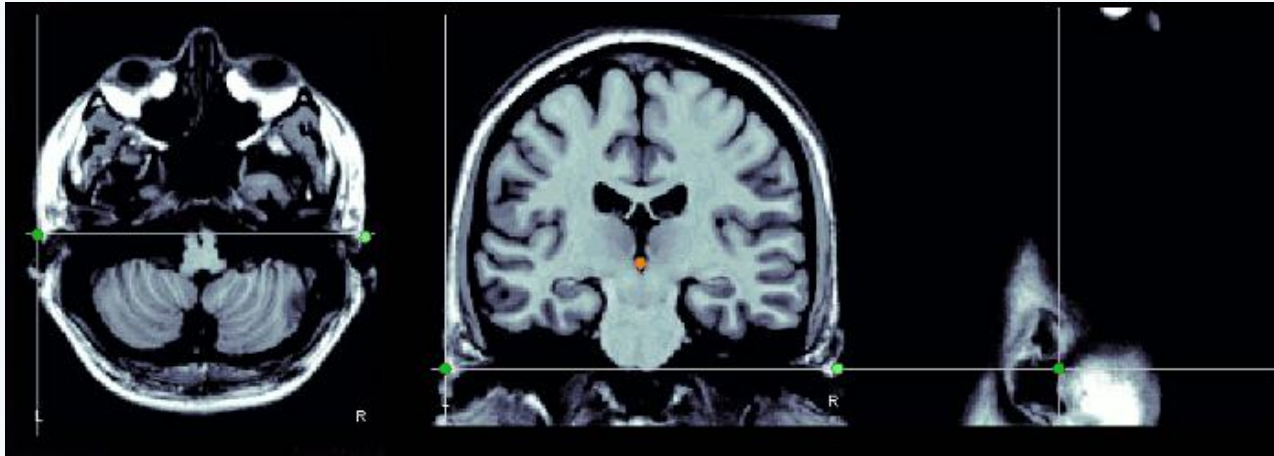


- Surfaces extracted with a dedicated software:
BrainVISA, FreeSurfer, BrainSuite



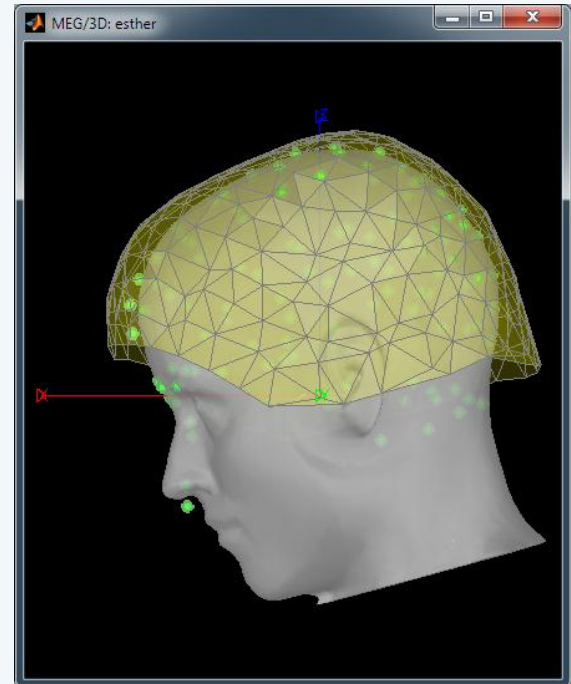
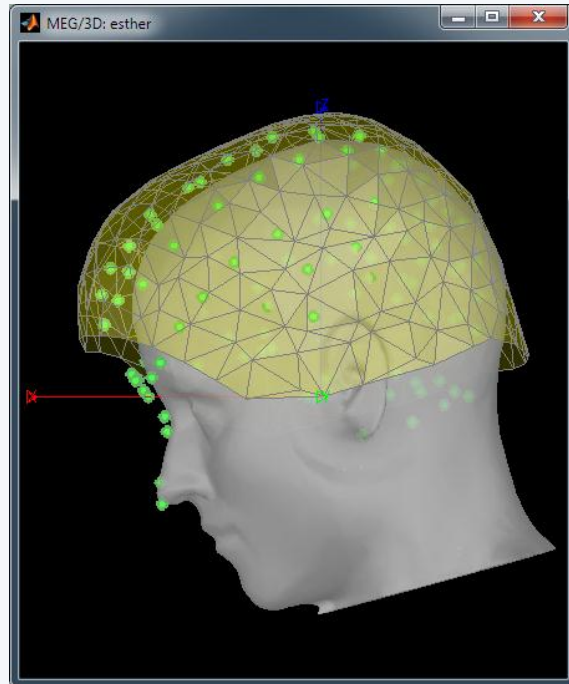
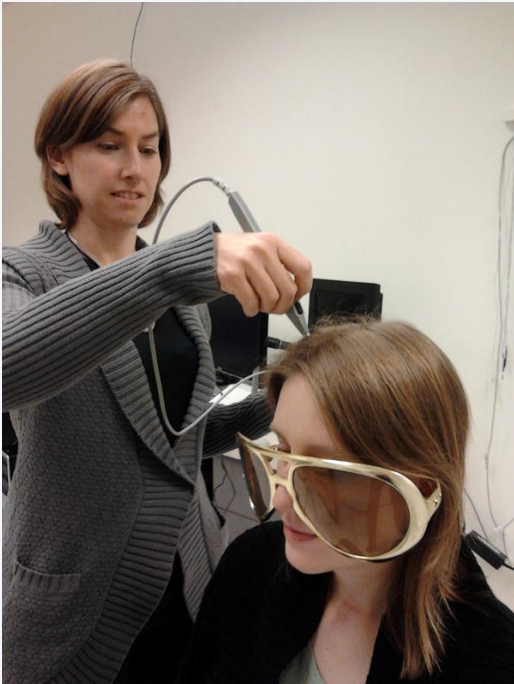
Co-registration MEG / MRI (I)

- 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)



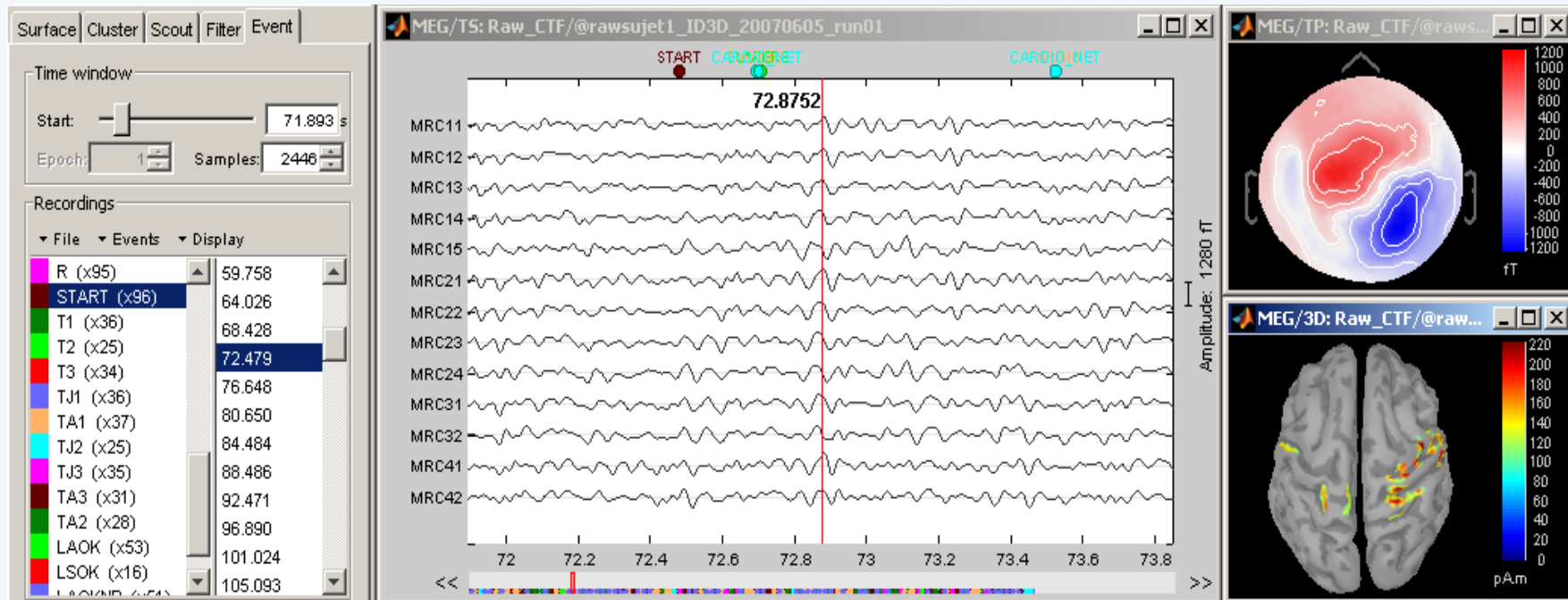
Co-registration MEG / MRI (2)

- 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

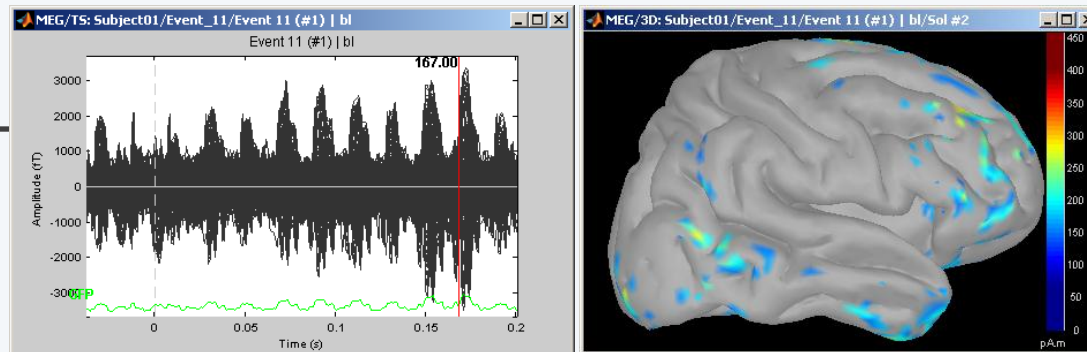


Continuous recordings

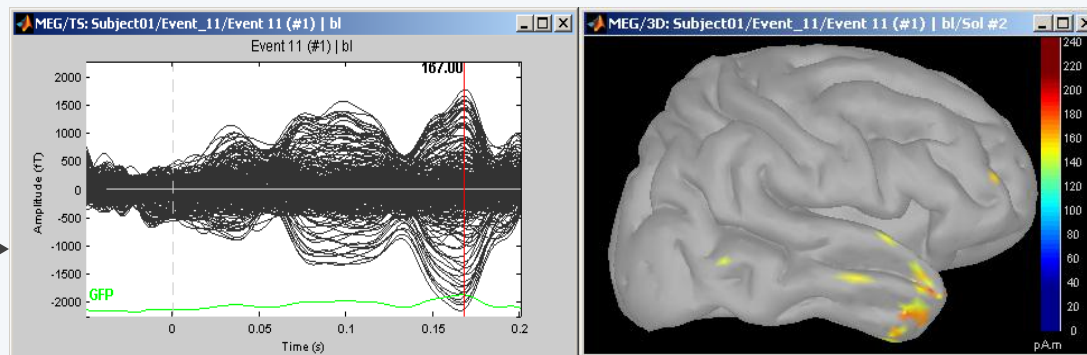
- Review continuous file
- Supports most common EEG/MEG file formats
- Edit markers, display 2D projections and sources



- Frequency filtering



Not filtered



Low-pass
40Hz

Frequency filtering

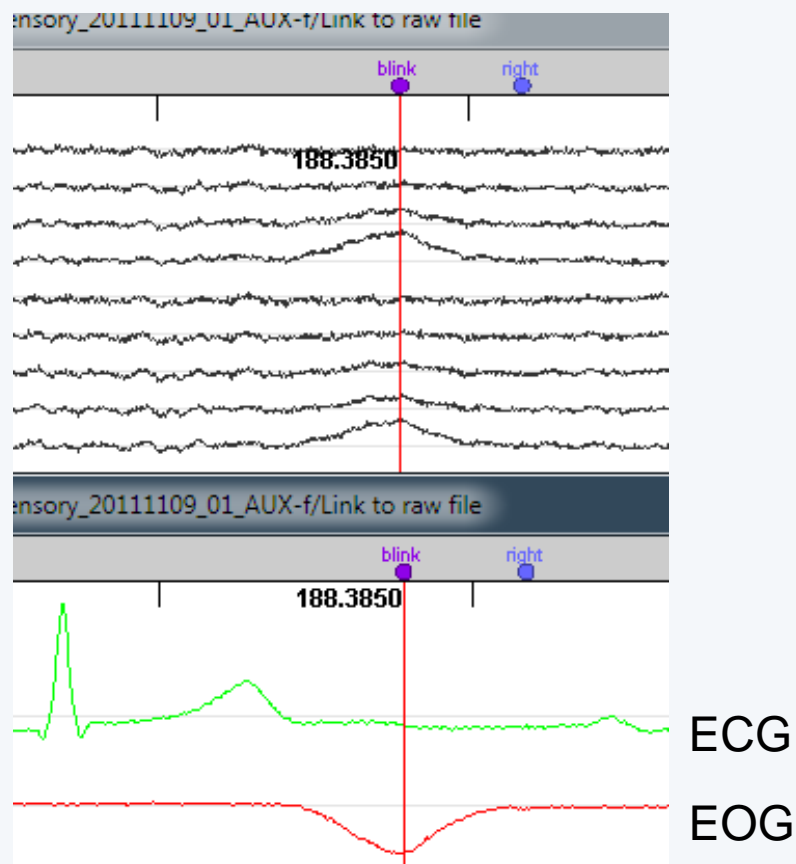
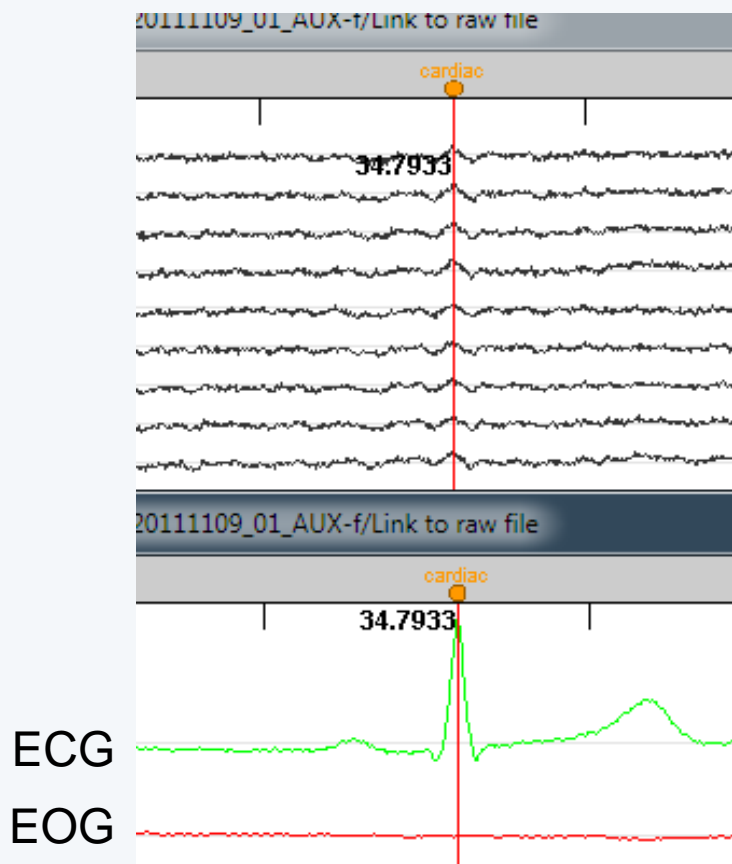
High-pass: 1.00 Hz

Low-pass: 40.00 Hz

Sin. removal: Hz

Mirror signal before filtering

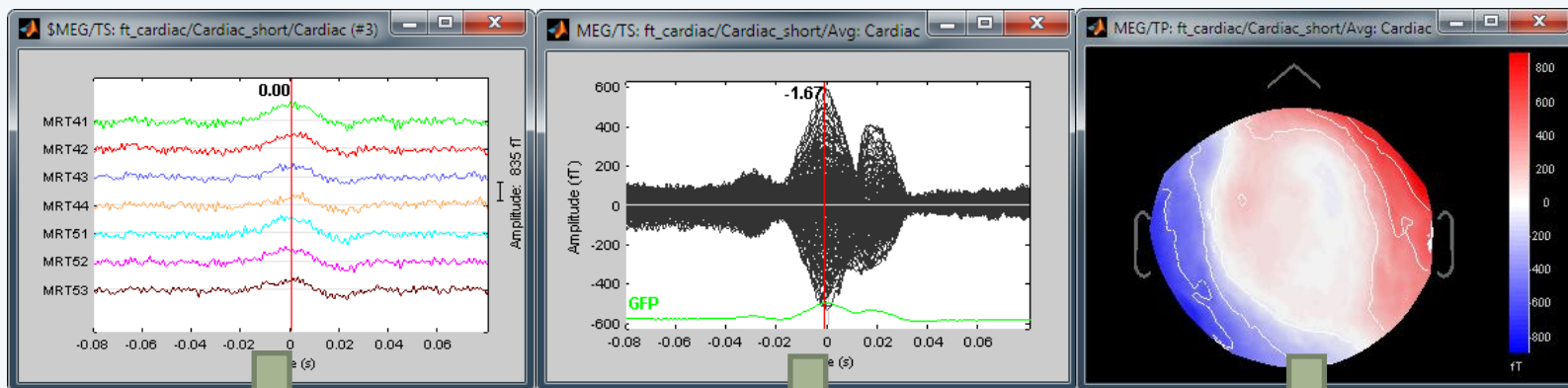
- Artifact detection and removal:
 - heartbeats, eye blinks, movements, ...



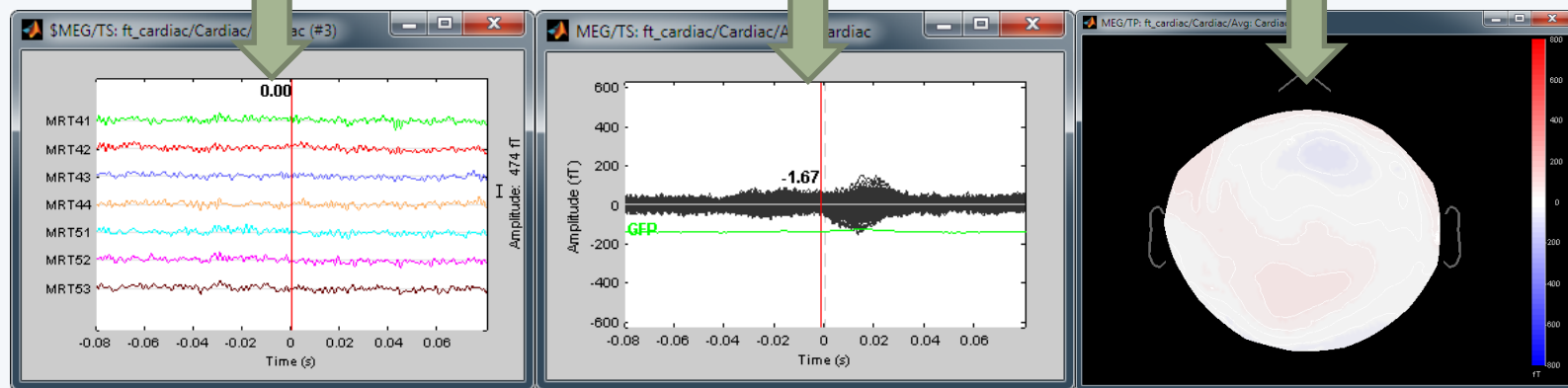
- Two categories of artifacts:
 - Well defined, reproducible, short, frequent:
 - Heartbeats, eye blinks, some stimulators
 - Unavoidable and frequent: we cannot just ignore them
 - Can be modeled and removed from the signal efficiently
 - All the other events that can alter the recordings:
 - Movements, 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



The image illustrates the transition from pre-processing to cleaning in MEG/TS software. On the left, the 'Pre-processing' stage is shown with a 'Signal-space projections' dialog box. The 'Projector categories' list includes 'cardiac: 18-Apr-2012 16:14:58' and 'blink: 18-Apr-2012 16:15:32'. The 'Projector components' list shows 'Component #1 [20%]', 'Component #2 [7%]', and 'Component #3 [5%]'. The 'Save' button is highlighted. On the right, the 'Cleaning' stage is shown with the same 'Signal-space projections' dialog box, but the 'blink' component is now checked in the 'Available components' list. The 'Save' button is highlighted. A green arrow points from the pre-processing window to the cleaning window.

Page settings

Epoch: 1

Start | Duration: 96.0000 | 2.0000 s

Recordings

File	Events	Display	SSP
left (x103)			54.398
right (x99)			65.551
cardiac (x346)			76.639
blink (x18)			96.677
BAD (x1)			119.102

Signal-space projections

Projector categories

- cardiac: 18-Apr-2012 16:14:58
- blink: 18-Apr-2012 16:15:32

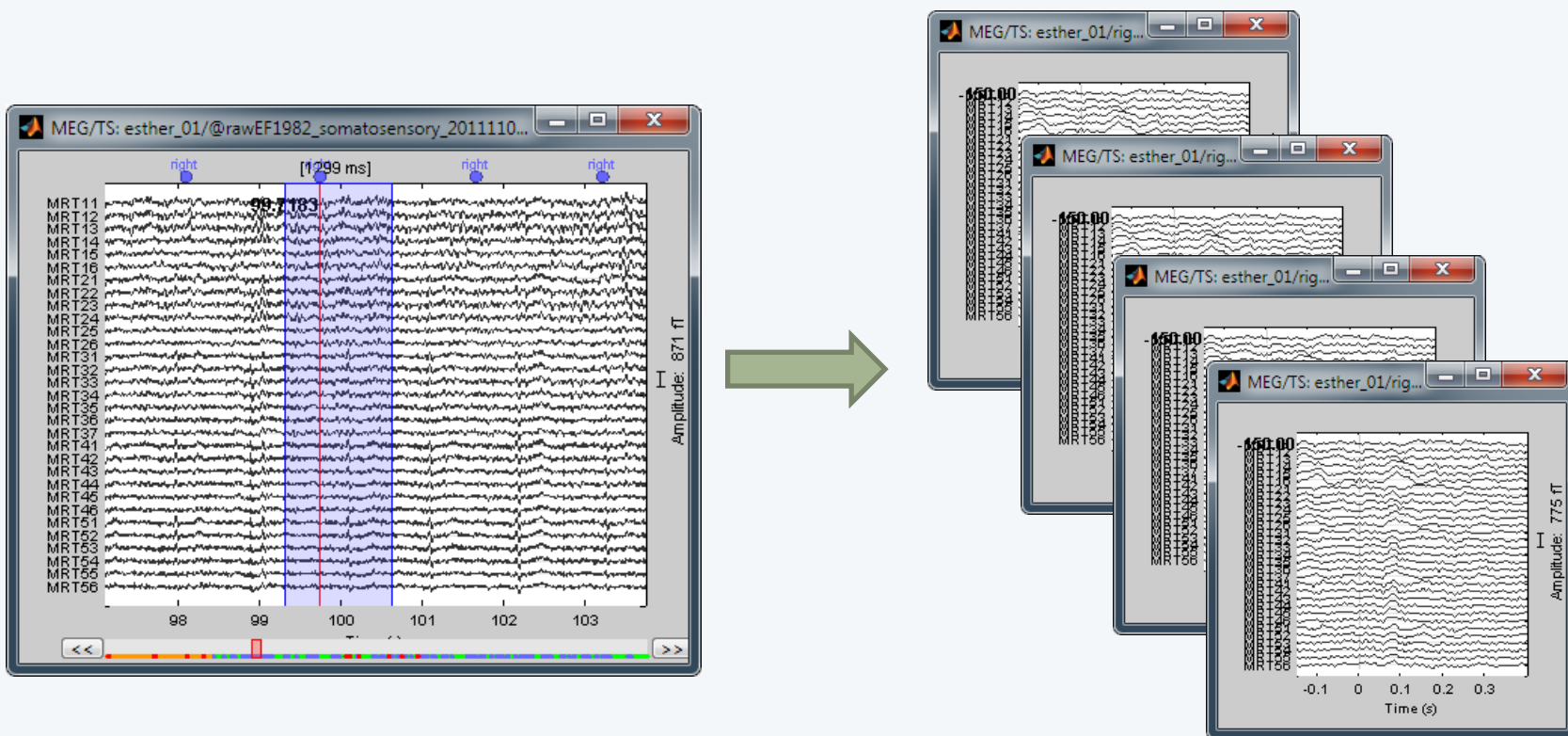
Projector components

Available components:

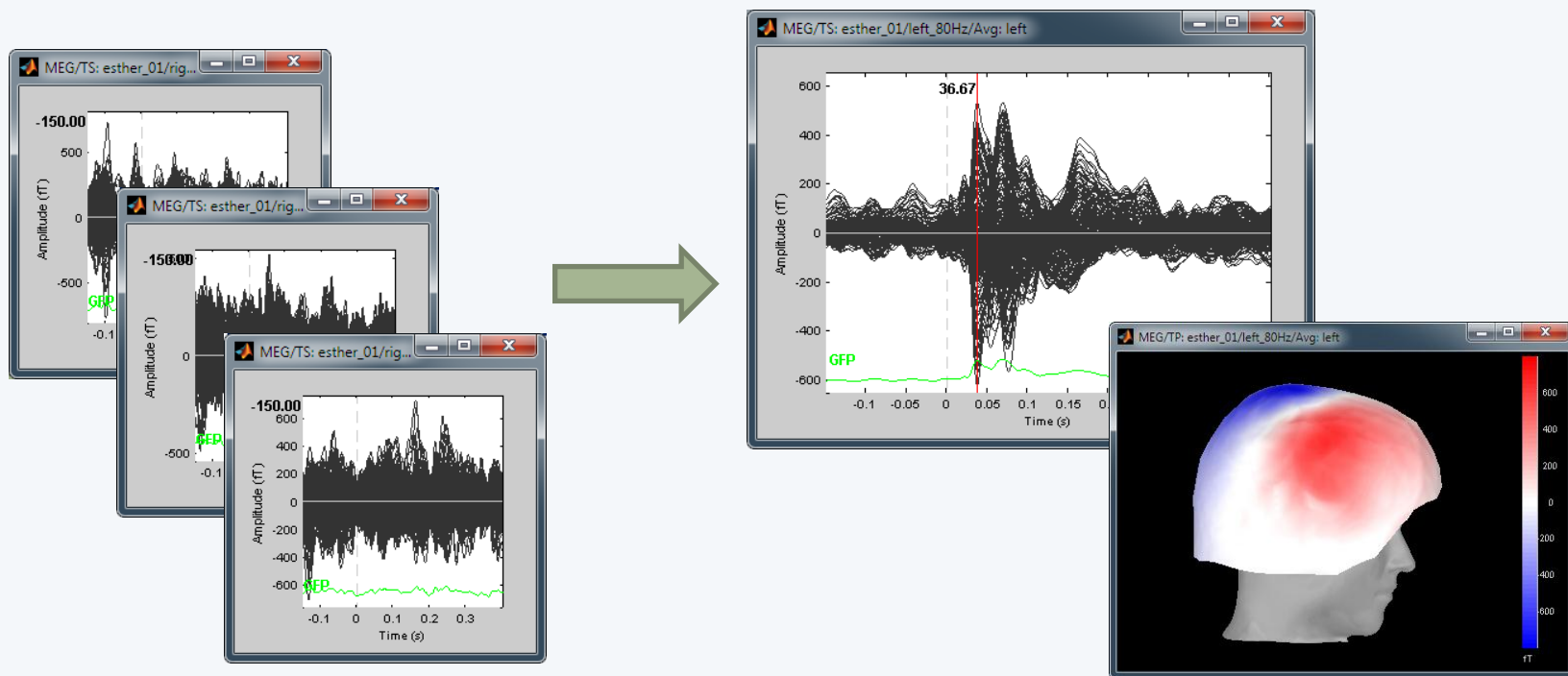
- Component #1 [20%]
- Component #2 [7%]
- Component #3 [5%]

Cancel Save

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

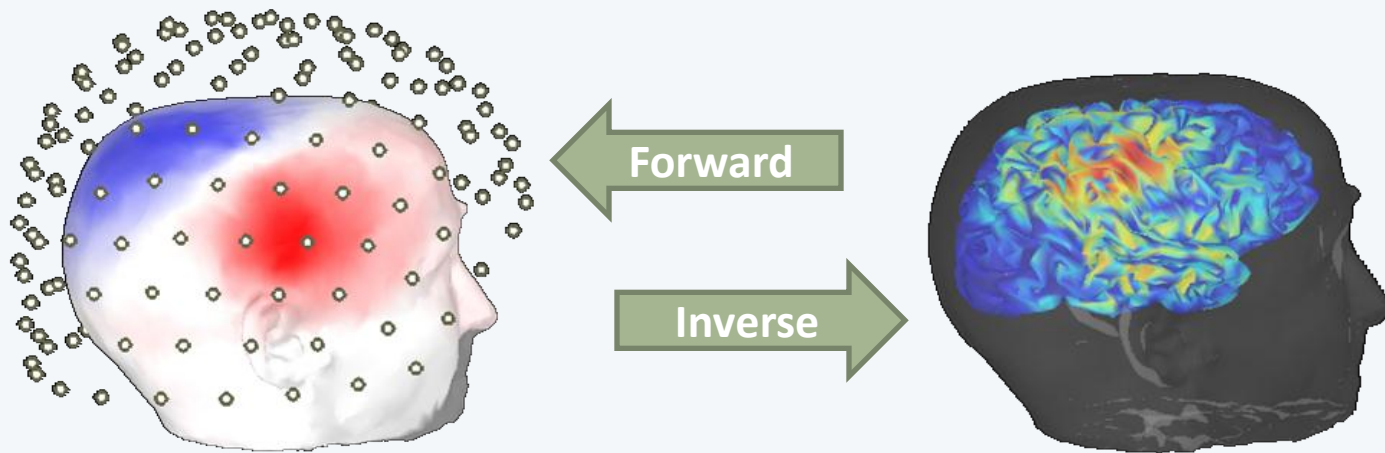


- Averaging all the trials: Reveals the features of the signals that are locked in time to a given event
=> Evoked-response field (or potential)

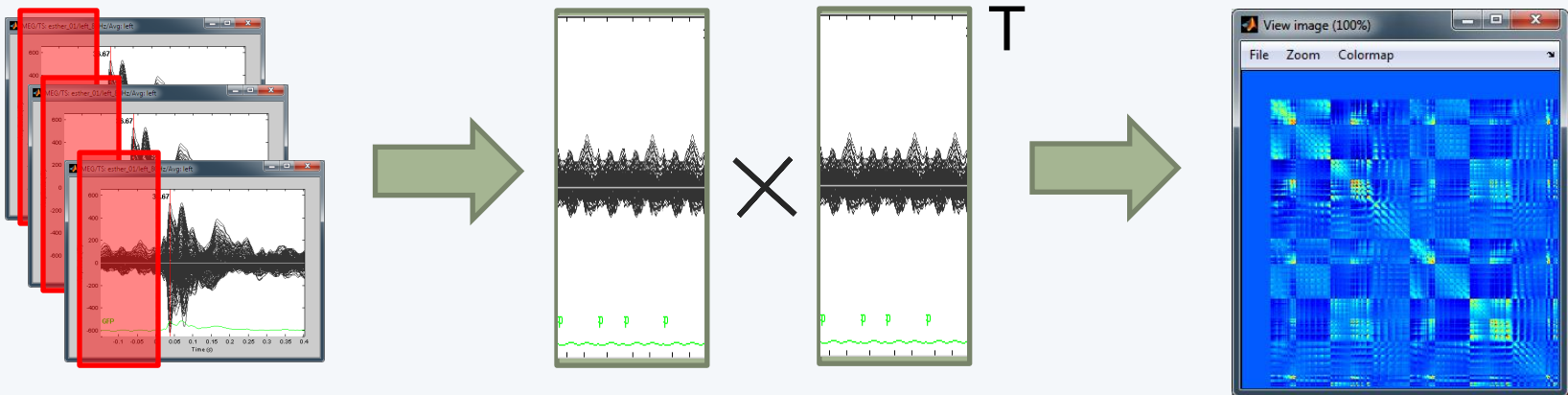


Source estimation

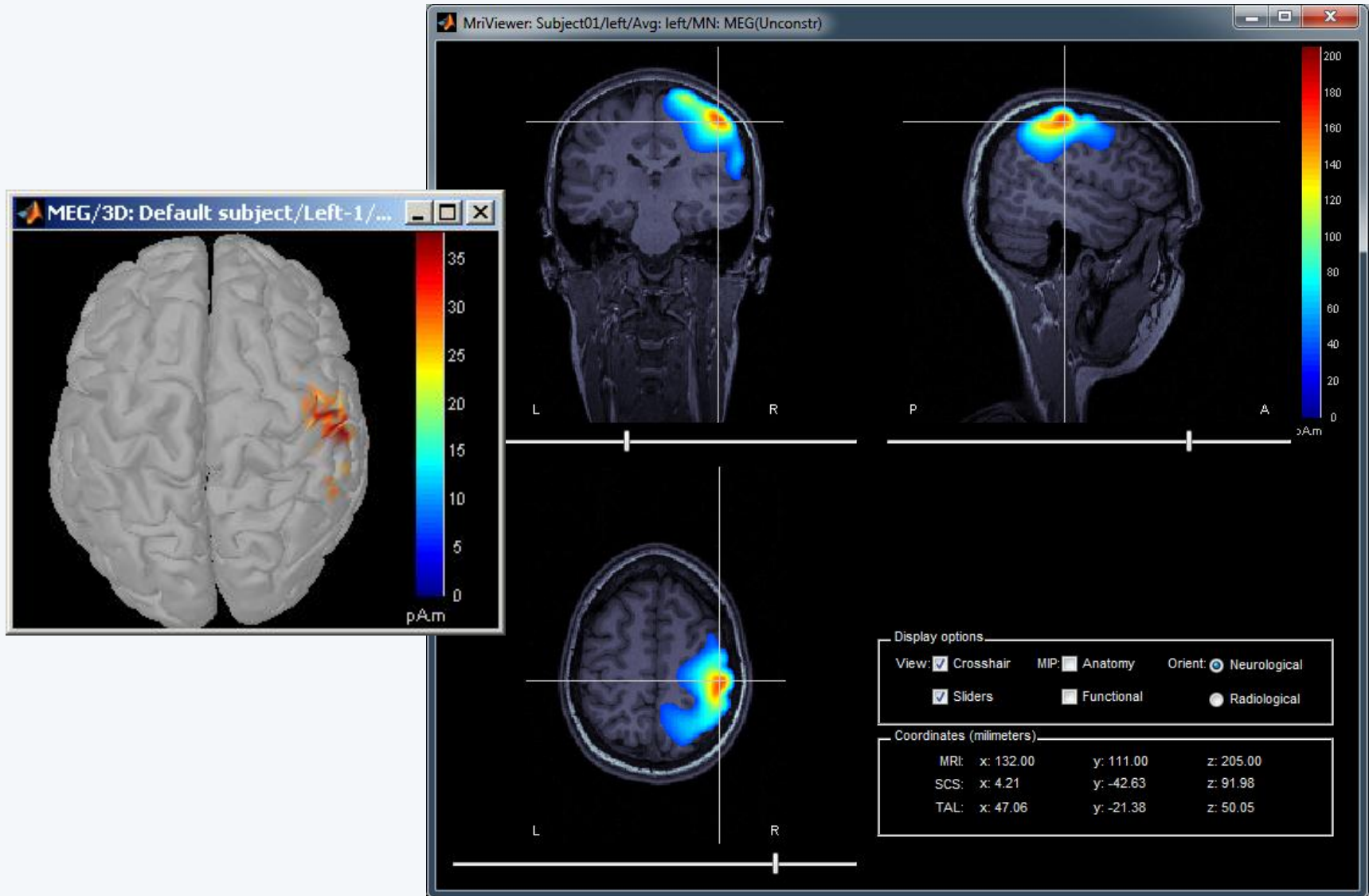
- Source space: cortex surface (or full head volume)
- Forward model = head model
Sources => Sensors
- Inverse model: Minimum norm estimates
Sensors => Sources



- 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

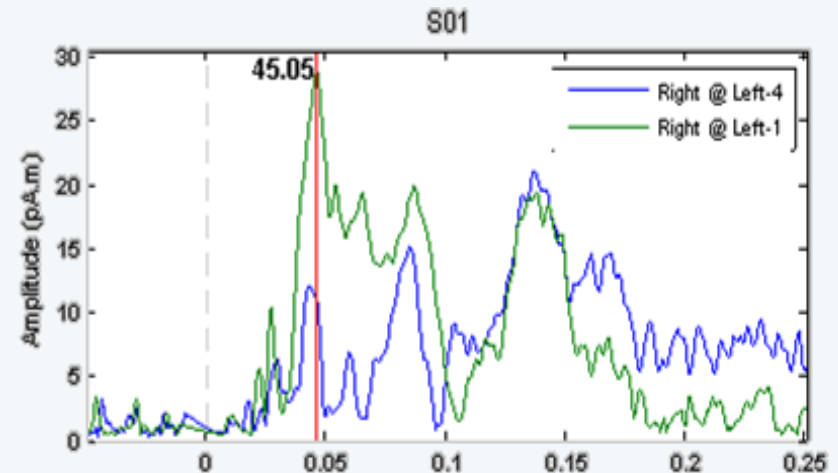
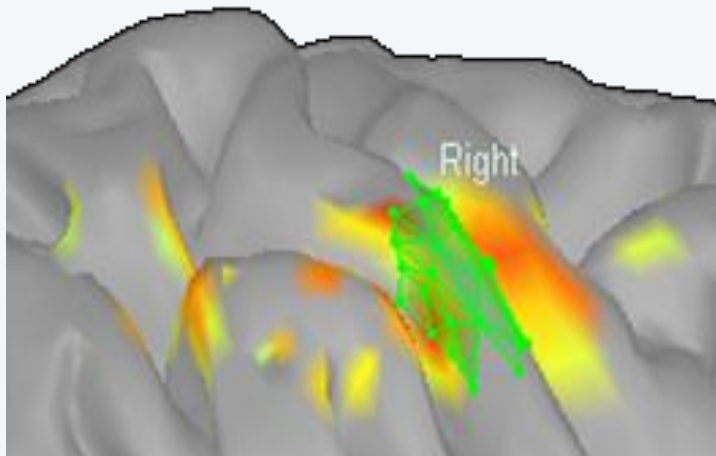


Sources activity



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

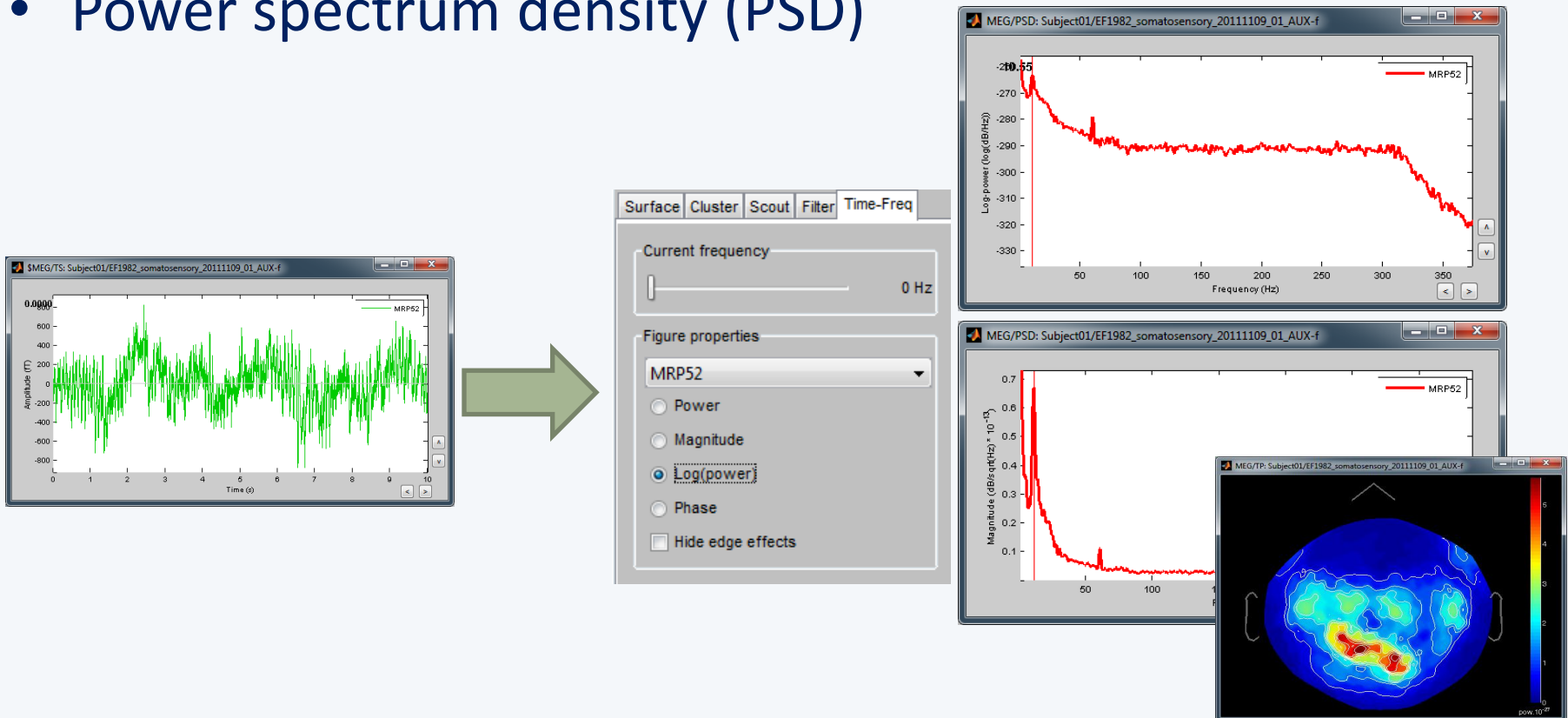


Post-processing

- 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)



Time-frequency / Hilbert transform

Time-frequency (Morlet wavelets)

Comment:

Time definition

Same as input files
[-500.00 : 0.42 : 1000.00] ms

Group in time bands (ms)

t1: 0.00, 999.17
t2: 1000.00, 1999.17
t3: 2000.00, 2999.17
t4: 3000.00, 3999.17
t5: 4000.00, 4999.17
t6: 5000.00, 5999.17

Frequency definition

Linear (start:step:stop)
1:1:80

Group in frequency bands (Hz)

delta: 2, 4
theta: 5, 7
alpha: 8, 12
beta: 15, 29
gamma1: 30, 59
gamma2: 60, 90

Morlet wavelet options

Central frequency: Hz (default=1)

Time resolution (FWHM): s (default=3)

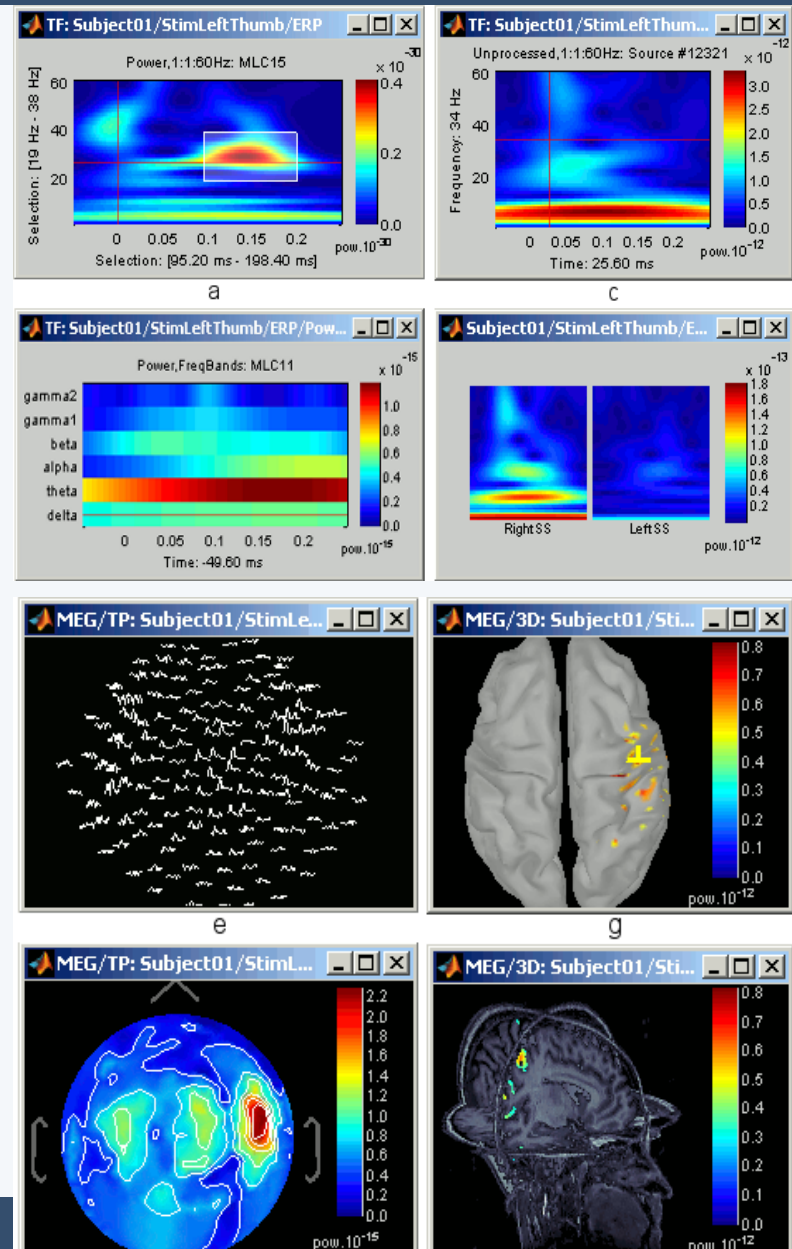
Processing options

Compute the following measure:

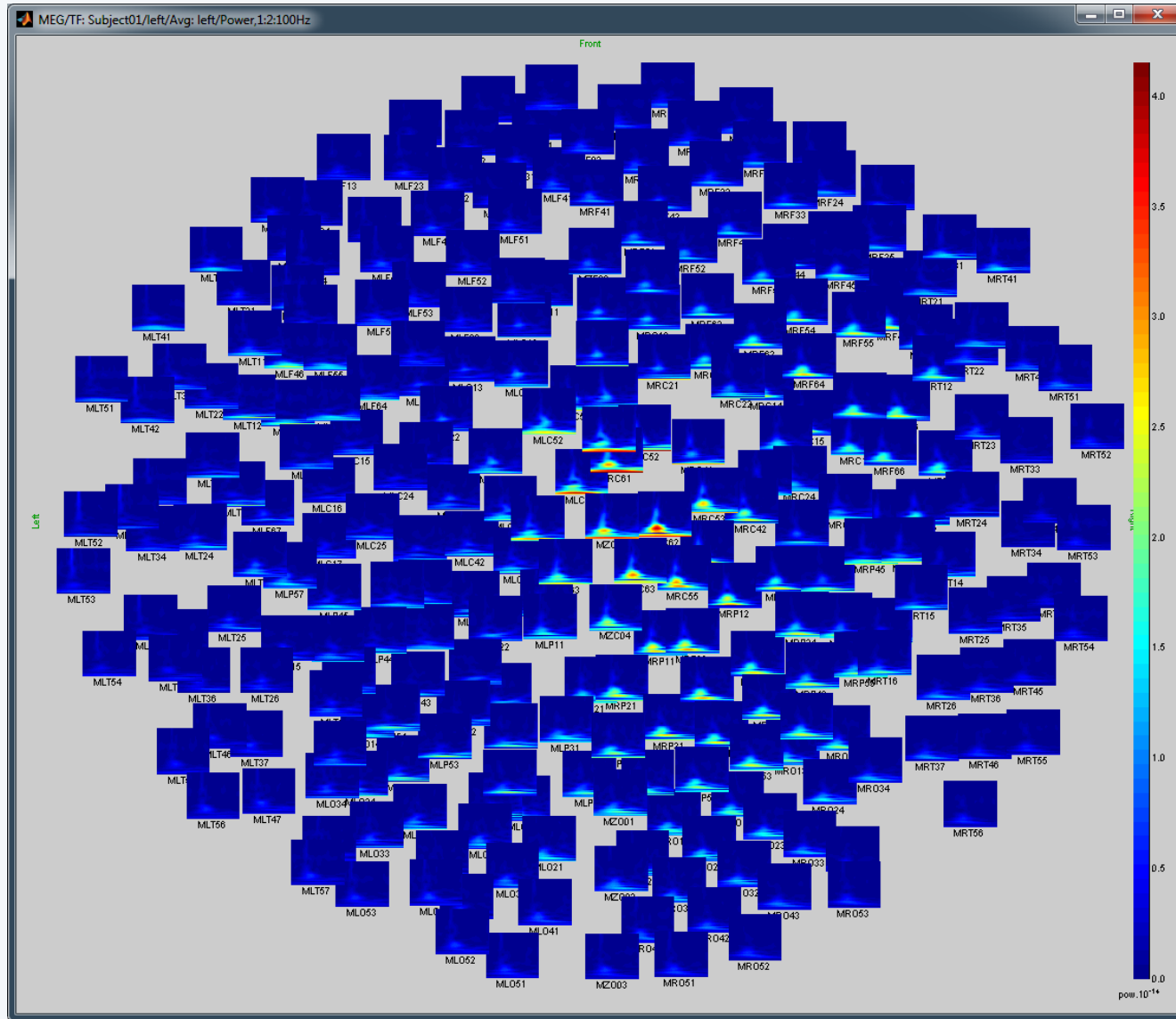
None (save complex values)

Power

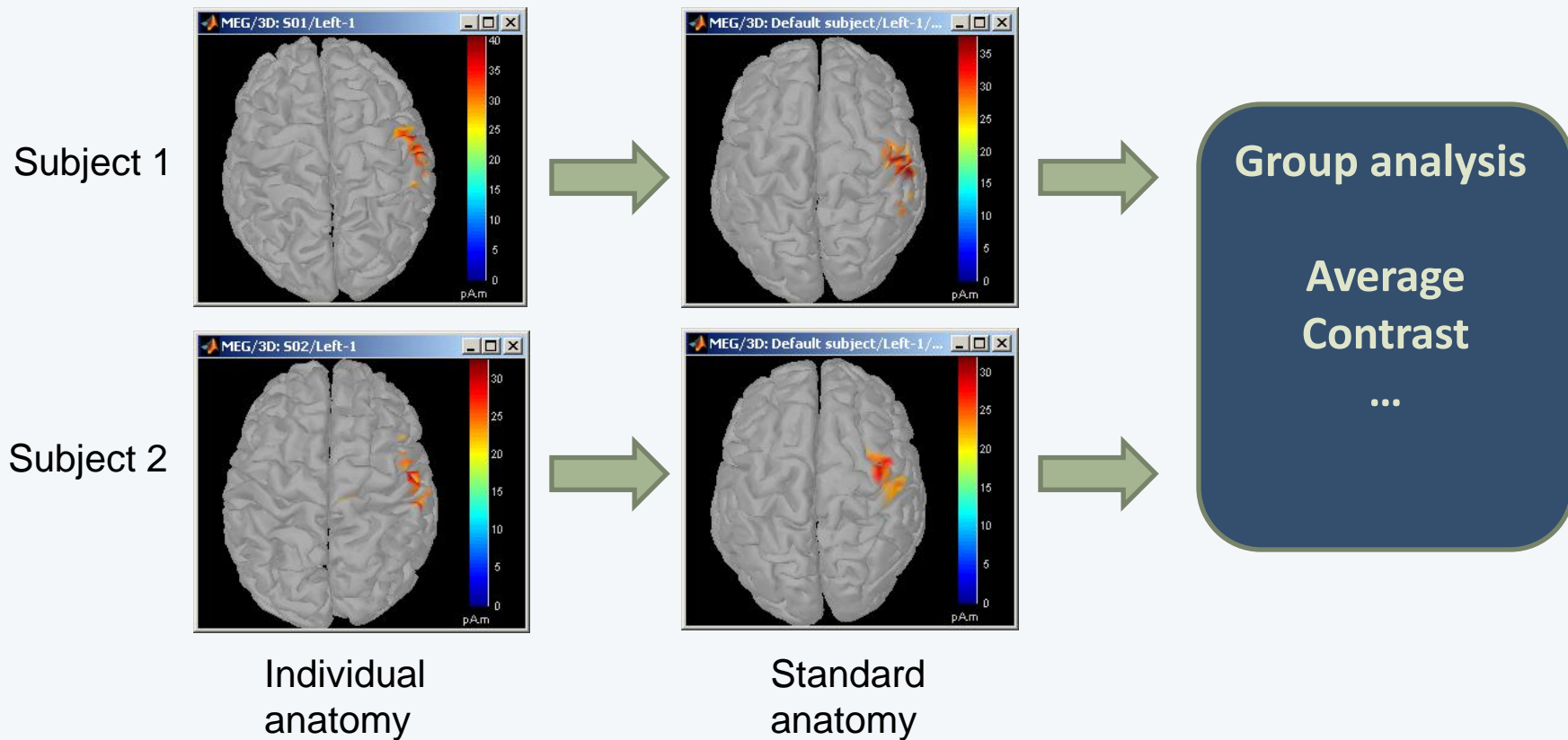
Estimated output file size: 45 Mb



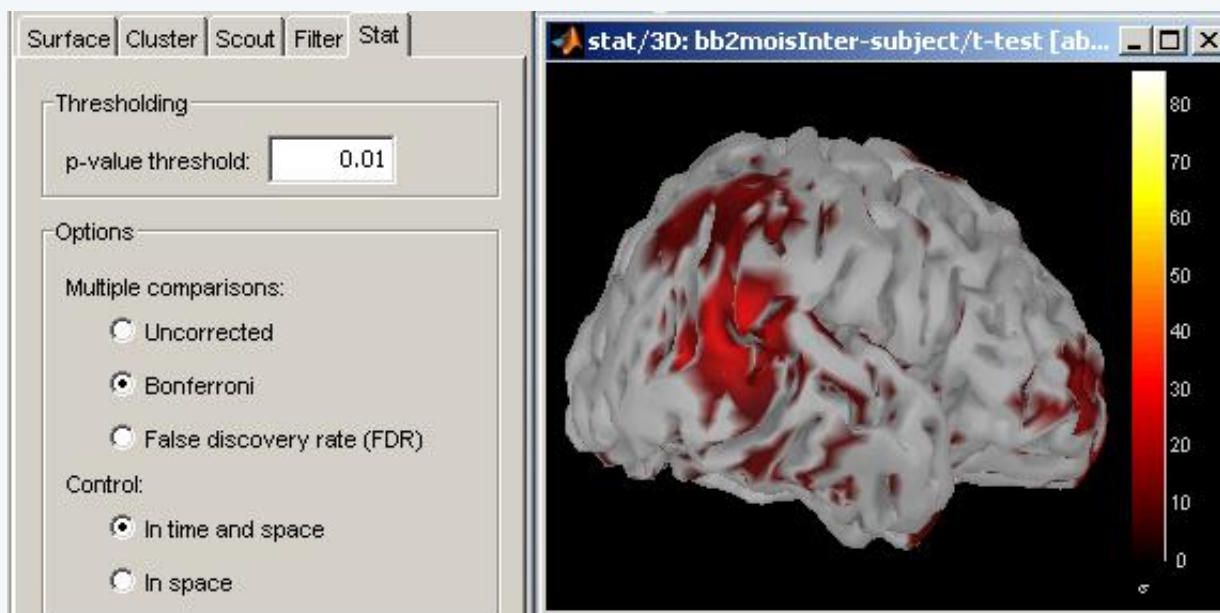
Time-frequency / Hilbert transform



- Registration of individual brains on a template

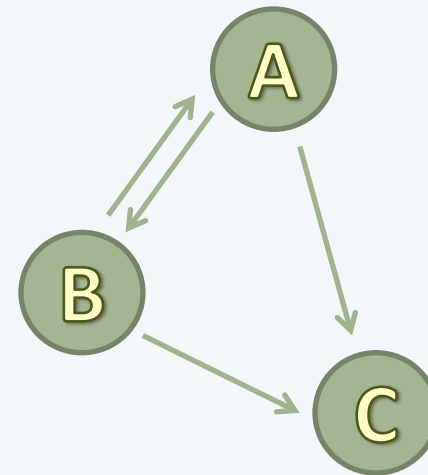


- Contrasts between subjects or conditions
- Statistical analysis: z-score, t-test
- Quick extraction of measures from complex paradigms
=> Export to: R, Excel, Statistica, SPSS, Matlab...

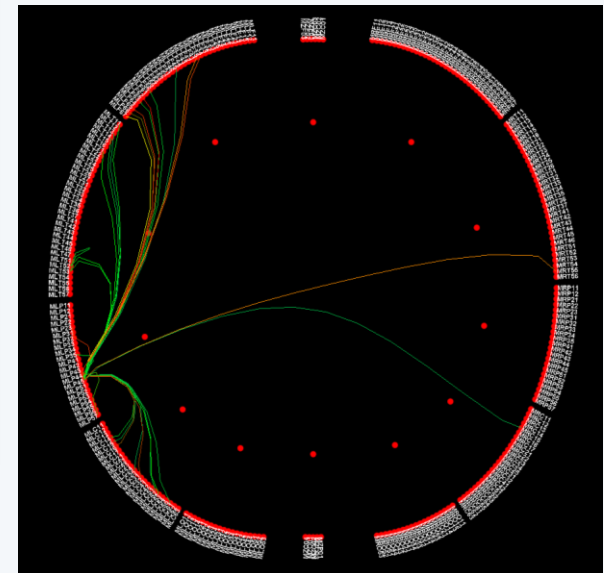
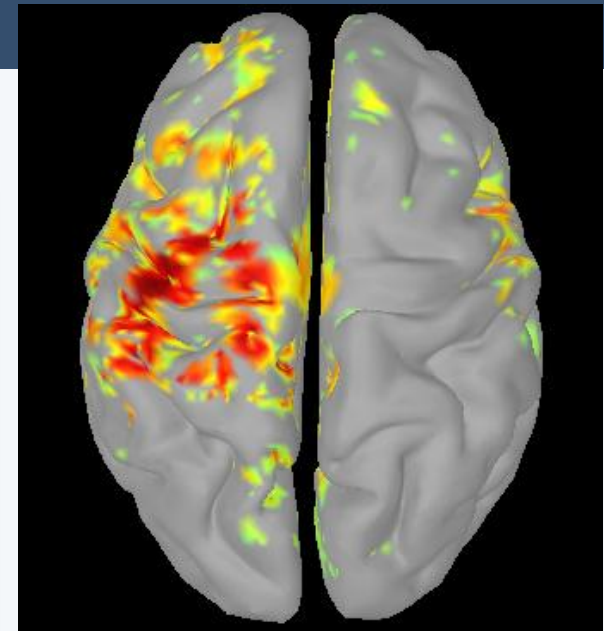
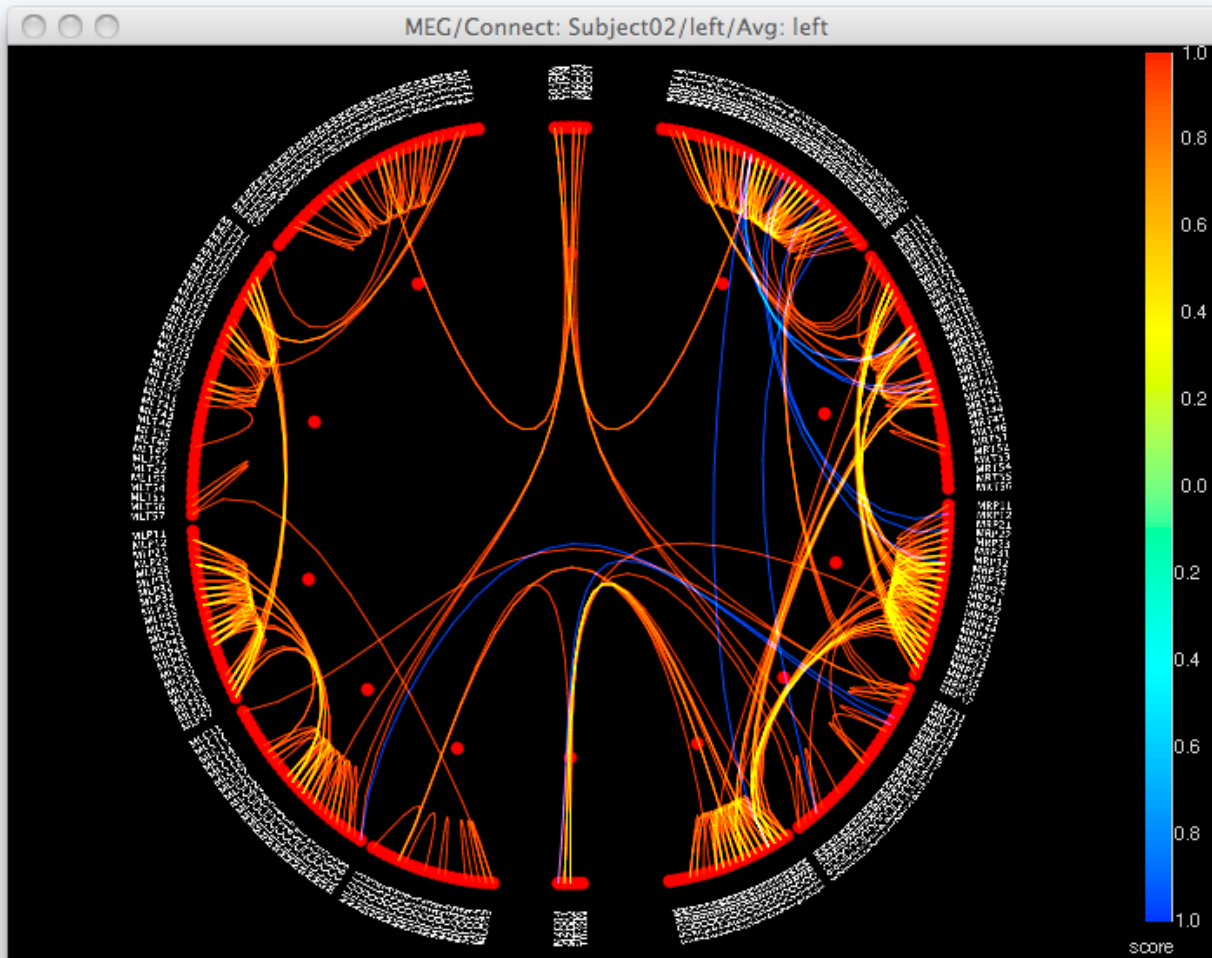


functional connectivity

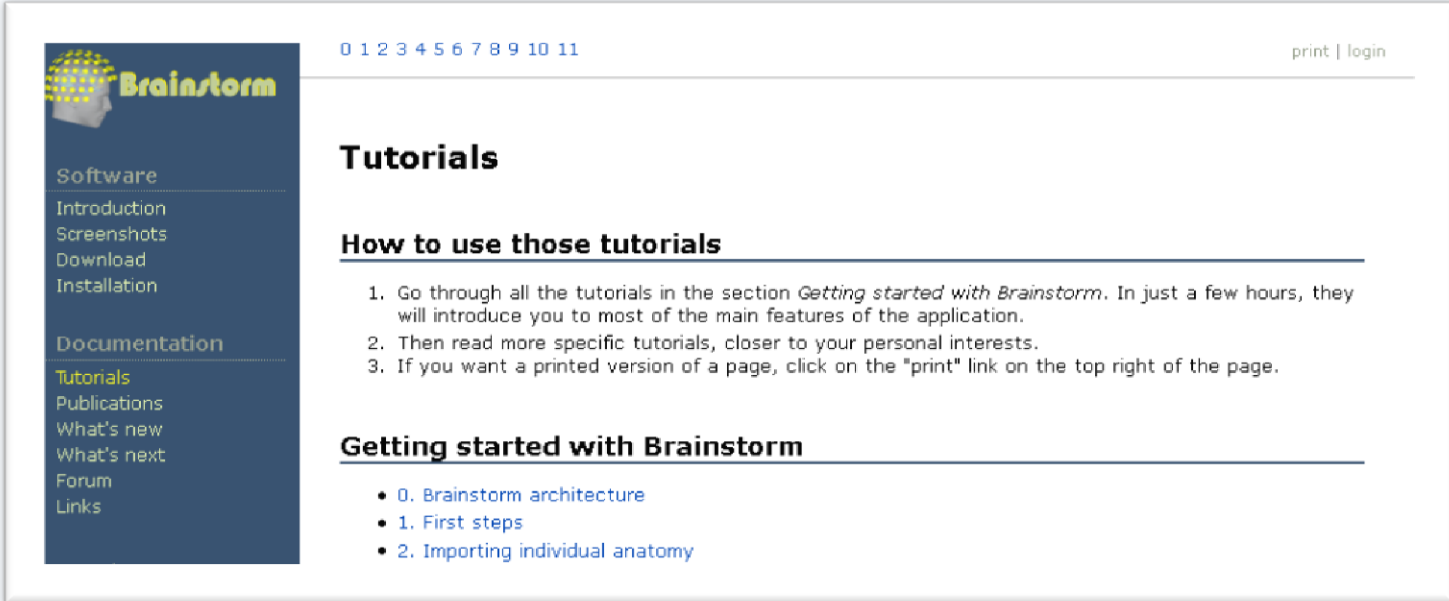
- Objectives: Describe the interaction between two brain regions, identify the brain networks
- Measures:
 - Correlation
 - Coherence
 - Granger causality
 - Phase locking value
- Both at sensor and source levels



functional connectivity



- Brainstorm online tutorials and forum:



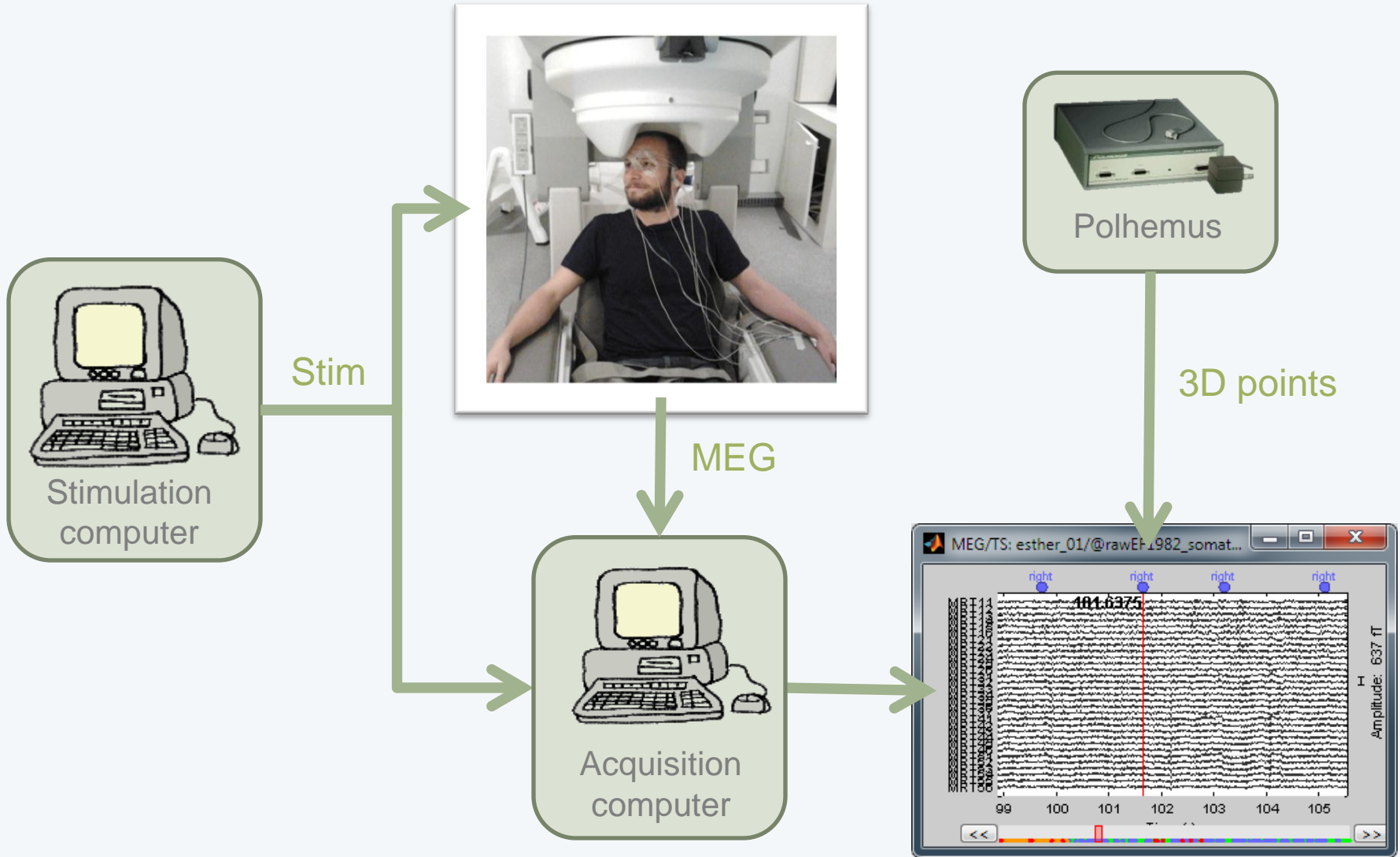
The screenshot shows the Brainstorm website's support page. On the left is a dark blue sidebar with the Brainstorm logo (a head with yellow dots) and a menu with categories: Software, Documentation, and Tutorials. The main content area has a breadcrumb trail '0 1 2 3 4 5 6 7 8 9 10 11' and a 'print | login' link. The page title is 'Tutorials', followed by a sub-section 'How to use those tutorials' with three numbered steps. Below that is another sub-section 'Getting started with Brainstorm' with a bulleted list of links: '0. Brainstorm architecture', '1. First steps', and '2. Importing individual anatomy'.

- 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



- Creation of a new protocol, with one subject
- Preparation of the anatomy (MRI, surfaces)
- Anatomical atlases
- Co-registration MRI / MEG
- Reviewing the continuous file
- Correcting for eye blinks with SSP
- Epoching and averaging
- Source estimation

- Regions of interest (scouts)
- Frequency analysis: FFT, time-frequency, Hilbert
- Functional connectivity analysis:
Correlation, Granger
- Statistics: Student's t-test
- Registration on default anatomy
- Warping the default anatomy
- Scripting

Contributors

Investigators



Sylvain Baillet
MNI



Richard Leahy
USC

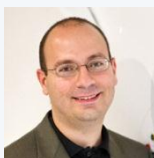


John Mosher
Cleveland Clinic

Key collaborators



Alexandre Gramfort
MGH / INRIA



Dimitrios Pantazis
MIT

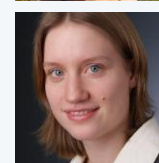


Rey Ramirez
UW

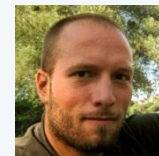
MEG @ McGill



Elizabeth Bock
MNI



Esther Florin
MNI



Francois Tadel
MNI

France

Lucie Charles
Ghislaine Dehaene-Lambertz
Claude Delpuech
Antoine Ducorps
Line Garnero
Etienne Labyt
Karim N'Diaye
Lauri Parkkonen
Denis Schwartz

USA

Syed Ashrafulla
Sergul Aydore
Felix Darvas
Belma Dogdas
Guillaume Dumas
John Ermer
Matti Hamalainen
Sheraz Khan
Esen Kucukaltun-Yildirim
Alexei Ossadtchi
Darren Weber