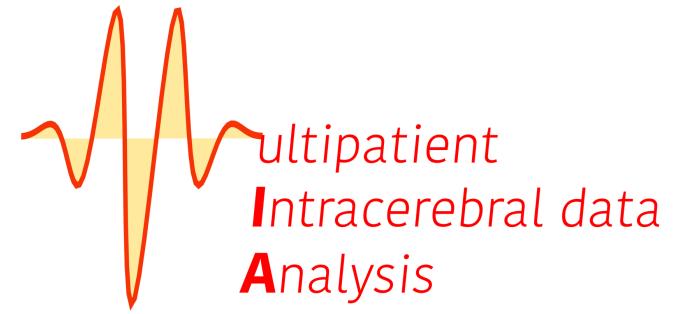


Brainstorm



Anne-Sophie Dubarry & Maximilien Chaumon
WIRED Hands-on tutorial, March 13th

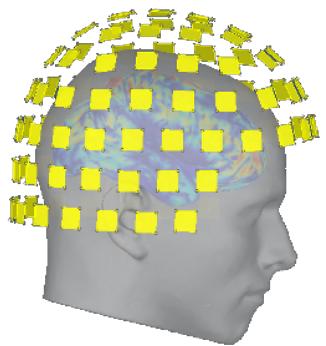
Outline

- Brainstorm presentation (~15 min)
- Brainstorm hands-on tutorial (~1h45)
- MIA methodology (~20 min)
- MIA group analysis hands-on tutorial (~40min)



Hands-on tutorial, March 13th

- Part 1 -

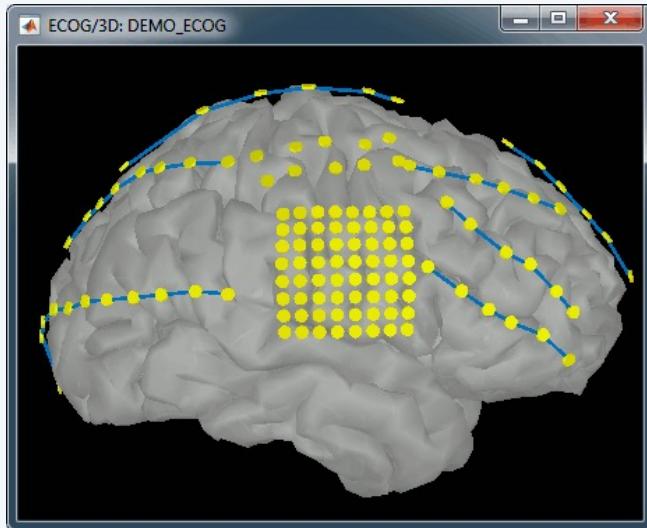


Brainstorm

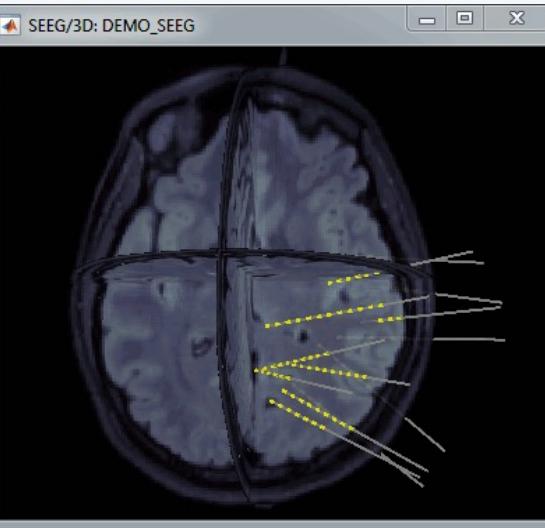
Anne-Sophie Dubarry & Maximilien Chaumon

Multi-modal imaging

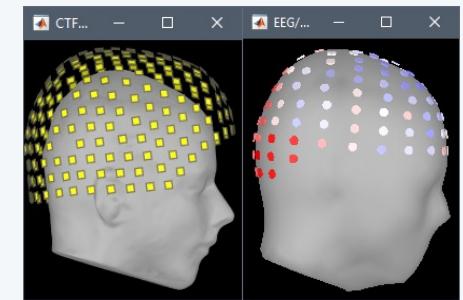
ECoG



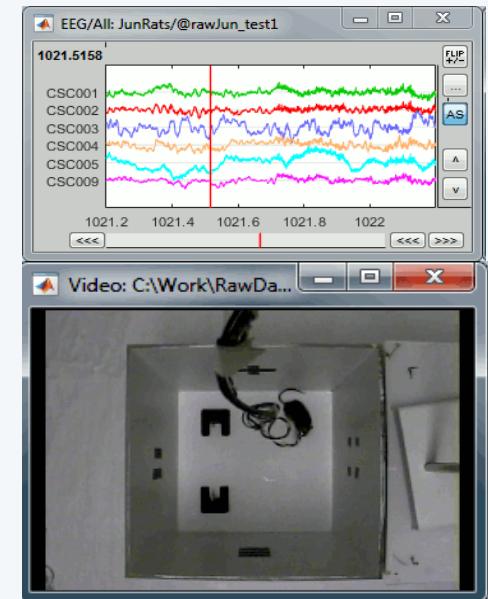
Depth electrodes



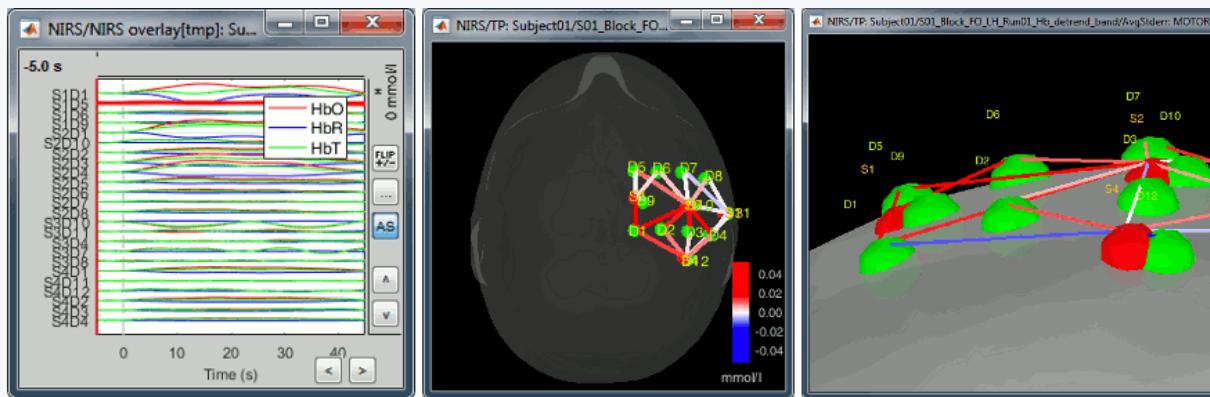
MEG/EEG



Electrophysiology



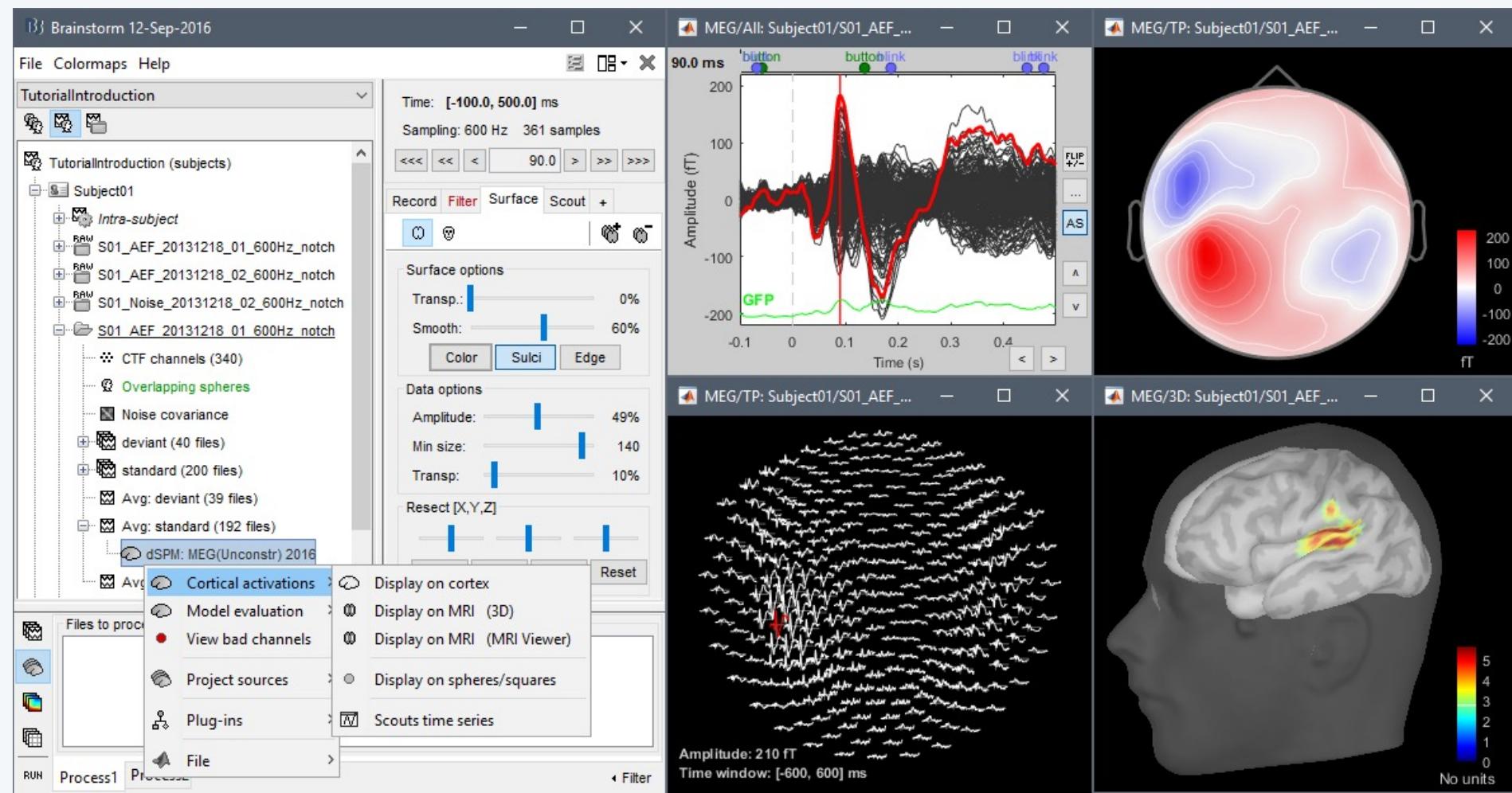
fNIRS



- 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

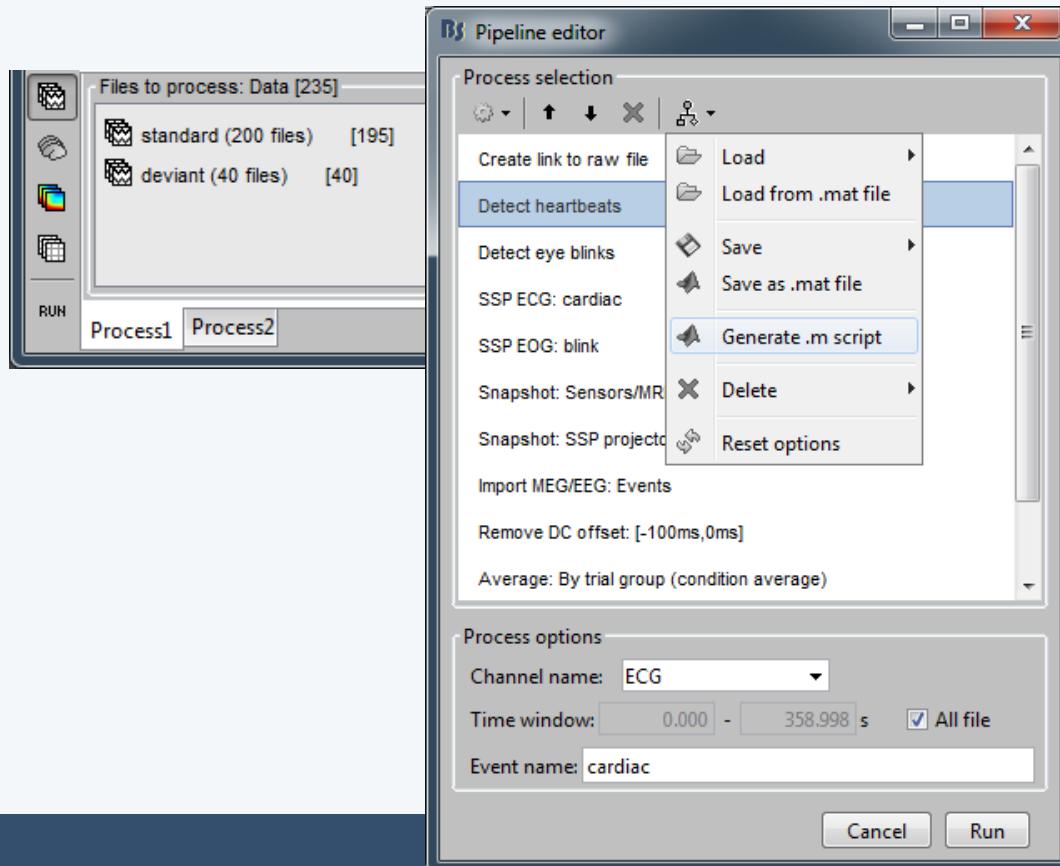


Graphic interface



Scripting environment

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



```
% 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);
```

User support

- Online tutorials: 30-hour self-training program
- Active user forum: 800 posts/month
- Daily updates: 1500 downloads/month

Brainstorm

Get started

Software

- Introduction
- Gallery
- Download
- Installation

Users

- Tutorials
- Forum
- Courses
- Community
- Publications

Development

- What's new

Starting a new study

1. Create a new protocol [9]
2. Import the subject anatomy [8]
3. Explore the anatomy [13]

Reviewing

4. Channel file / MRI registration [11]
5. Continuous recordings [9]
6. Multiple windows [5]
7. Event markers [10]

Pre-processing

8. Stimulation delays [9]
9. Select files / Run processes [11]
10. Power spectrum / Frequency filters [15]
11. Bad channels [6]
12. Artifact detection [8]
13. Artifact cleaning with SSP [16]
14. Additional bad segments [7]

Epoching and averaging

15. Import epochs [9]
16. Average response [7]
17. Visual exploration [10]
18. Colormaps [5]
19. Clusters of sensors [4]

Source modeling

20. Head model [9]
21. Noise/data covariance
22. Source estimation [28]
23. Scouts [17]

Advanced processing

24. Time-frequency [33]
25. Difference [13]
26. Statistics [30]
27. Workflows [10]
28. Scripting [31]

Brainstorm

Log In

3-sphere shell gives near-identical results to openmeg bem?

Discussions R 1 14 11d

Reference and channel types

Discussions S 2 8 11d

How to add missing atlas

Discussions C 6 36 11d

Canonical Correlation Analysis

Discussions R 2 15 12d

PSD calculation bug

Bugs L 2 13 12d

Correspondence EEG signals / electrode labels

Discussions S 3 17 12d

Exporting source-localized time series directly to matlab?

Discussions R 1 13 12d

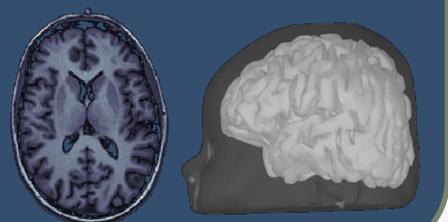
Importing ECOG electrodes from Curry seeg, ecog

Discussions S 16 210 13d

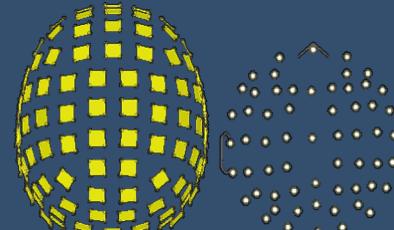
  

Workflow

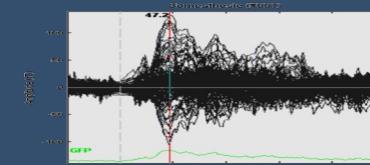
Anatomy



Sensors



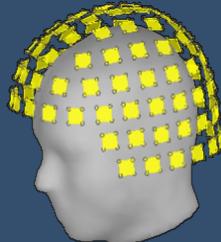
EEG/MEG



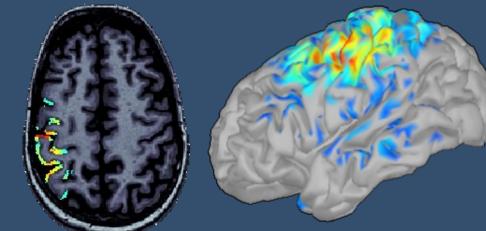
Analysis

Averages
Contrasts
Group analysis
Time-frequency
Connectivity

Co-registration



Source estimation



Contributors

Investigators



Sylvain Baillet
MNI



Richard Leahy
USC



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UT Houston



Dimitrios Pantazis
MIT



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Software, Grenoble

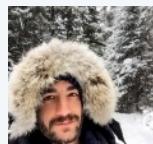


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Software, MNI



Marc Lalancette
MEG manager, MNI

MEG @ McGill



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Takfarinas Medani
Research assistant

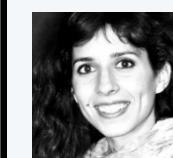


Chinmay Chinara
Research assistant

Key collaborators



Elizabeth Bock
MEGIN, Chicago



Guiomar Niso
Politécnica Madrid

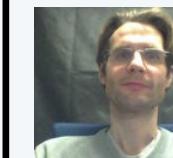


Guiomar Niso
Politécnica Madrid

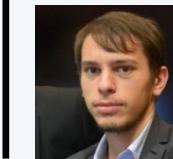
NIRSTORM



Christophe Grova
Concordia



Thomas Vincent
Montreal Heart Inst



Edouard Delaire
Concordia



TODAY

Disclaimer

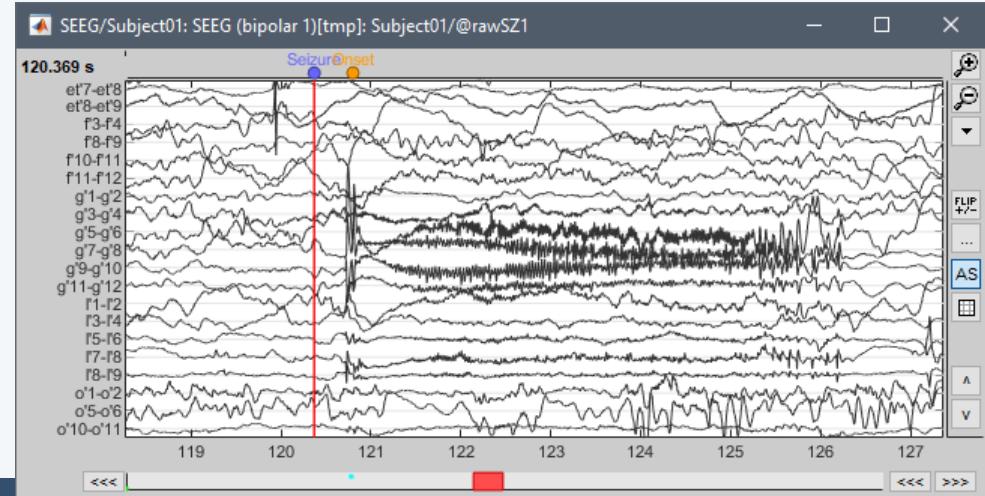
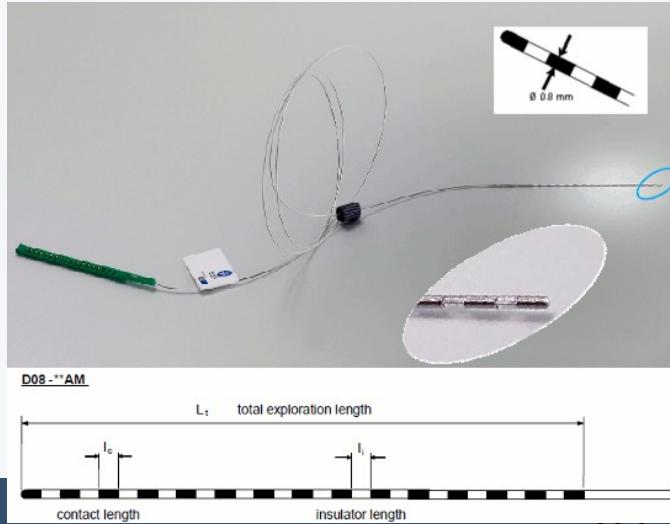
NOT FOR CLINICAL USE:

The performance characteristics of the methods and software implementation presented in this tutorial have not been certified as medical devices and should be used for research purposes only.

Sample data

Epilepsy recordings:

- Patient recorded at the Grenoble University Hospital
- Focal epilepsy of the left temporo-occipital junction, MRI-negative, implanted in the surrounding areas
- Depth electrodes: DIXI D08-**AM Microdeep (8-18 contacts)
- Recorded with a Micromed system at 512Hz
- 4 minutes of recordings with one generalized seizure



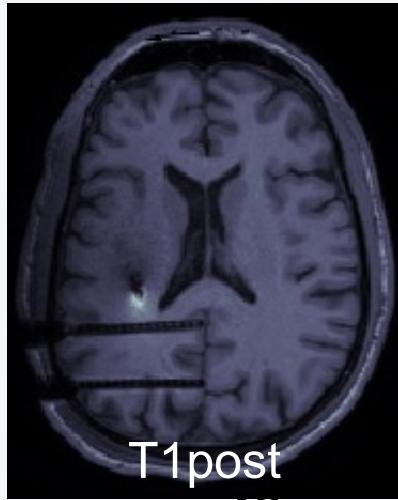
Sample data

Patient anatomy:

- T1 MRI pre-implantation, processed with CAT12 (r12.8)
- T1 MRI post-implantation
 - Registered on the pre-implantation image with SPM
 - Used to get 3D positions for the SEEG contacts



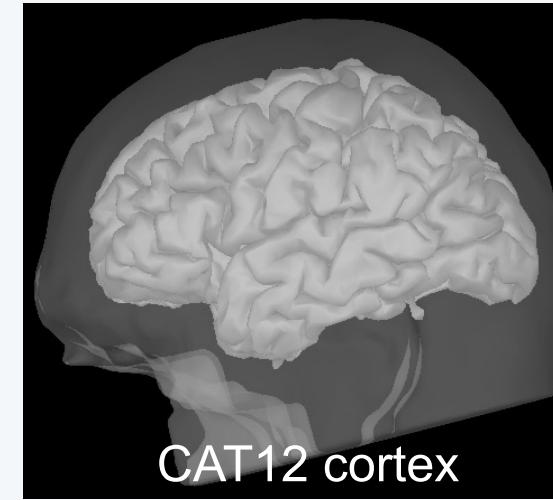
T1pre



T1post



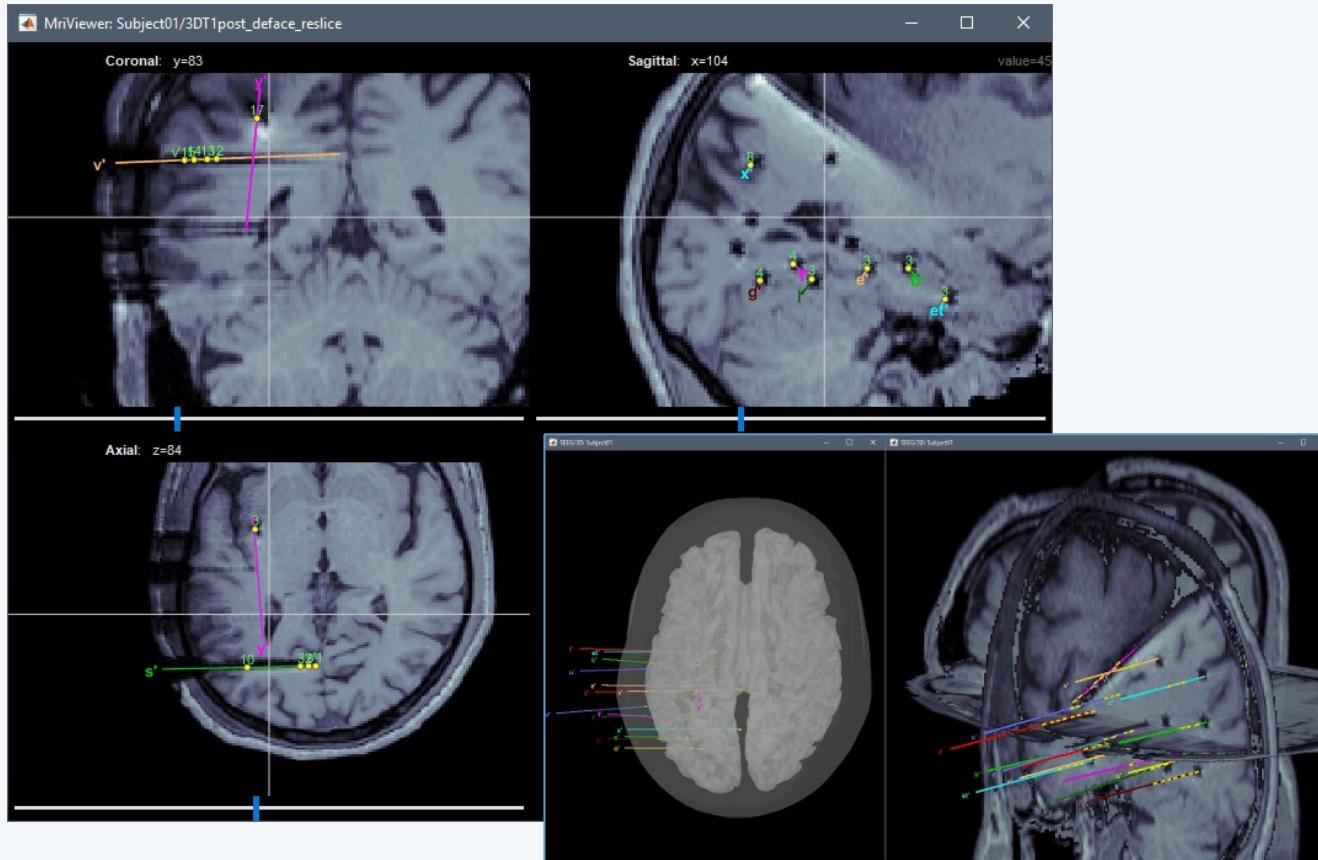
SPM coreg



CAT12 cortex

Sample data

SEEG electrodes marked in the T1post:



Automatic labeling of
the SEEG electrodes

Channel	SCS	aal3	hammers	tissues_cat12	Schaefer2018_100_7net (MNI-cat)
g'1	[-46.734, 12.724, 33.596]	Left Lingual gyrus	OL lingual gyrus L	Gray	Vis_3 L
g'2	[-46.713, 16.224, 33.526]	Left Lingual gyrus	OL lingual gyrus L	White	Vis_3 L
g'3	[-46.692, 19.723, 33.455]	Left Lingual gyrus	OL lingual gyrus L	White	Vis_3 L
g'4	[-46.671, 23.222, 33.385]	Left Lingual gyrus	OL lingual gyrus L	White	Vis_2 L
g'5	[-46.649, 26.721, 33.315]	Left Lingual gyrus	OL lateral remainder occipital lobe L	Gray	Vis_2 L
g'6	[-46.628, 30.220, 33.244]	N/A	OL lateral remainder occipital lobe L	White	N/A

Record Filter Surface Scout iEEG +

+ - | Contacts

Electrodes

	b'		f'		t'
	c'		g'		u'
	d'		r'		v'
	e'		o'		x'
	et'		s'		y'

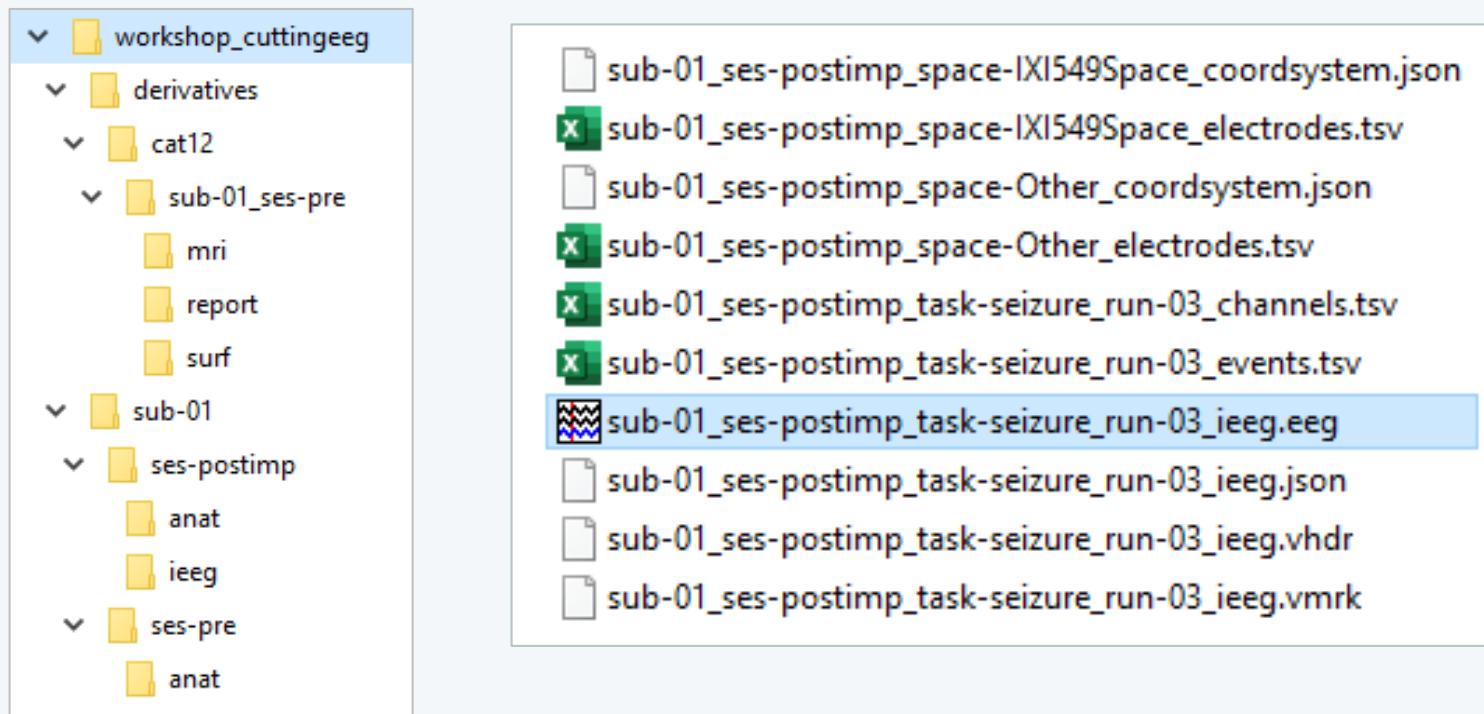
» Use default positions
 » Project on electrode
 Save modifications
 Export contacts positions
 Compute atlas labels

SEEG contact labels

Channel	SCS	tissues_segment	AAL3 (MNI-segment)	Hammers95 (MNI-segment)	spm_cortex_7861
g'1-g'2	[-46.942, 14.973, 33.907]	Gray	Lingual L	OL Ling_G L	N/A
g'2-g'3	[-46.999, 17.971, 33.815]	White	Lingual L	OL Ling_G L	N/A
g'3-g'4	[-47.065, 21.469, 33.707]	White	Lingual L	OL Ling_G L	OL Rest Lat L
g'4-g'5	[-47.141, 25.466, 33.583]	Gray	Fusiform L	OL Rest Lat L	OL Rest Lat L
g'5-g'6	[-47.207, 28.964, 33.475]	White	Background	OL Rest Lat L	N/A
g'6-g'7	[-47.263, 31.962, 33.383]	White	Background	OL Rest Lat L	N/A
g'7-g'8	[-47.330, 35.460, 33.275]	Gray	Occipital_Inf L	OL Rest Lat L	N/A
g'8-g'9	[-47.405, 39.457, 33.151]	White	Occipital_Inf L	OL Rest Lat L	OL Rest Lat L
g'9-g'10	[-47.471, 42.955, 33.043]	White	Temporal_Inf L	OL Rest Lat L	OL Rest Lat L
g'10-g'11	[-47.528, 45.953, 32.951]	Gray	Temporal_Inf L	PosteriorTL L	N/A
g'11-g'12	[-47.594, 49.451, 32.843]	Gray	Temporal_Inf L	PosteriorTL L	N/A

BIDS-iEEG specification

- **(Gorgolewski, 2016)**: The brain imaging data structure, a format for organizing and describing outputs of neuroimaging experiments
- **(Holdgraf, 2019)**: iEEG-BIDS, extending the Brain Imaging Data Structure specification to human intracranial electrophysiology
- <https://bids.neuroimaging.io/>



sub-01_ses-postimp_space-IXI549Space_coordsystem.json
sub-01_ses-postimp_space-IXI549Space_electrodes.tsv
sub-01_ses-postimp_space-Other_coordsystem.json
sub-01_ses-postimp_space-Other_electrodes.tsv
sub-01_ses-postimp_task-seizure_run-03_channels.tsv
sub-01_ses-postimp_task-seizure_run-03_events.tsv
sub-01_ses-postimp_task-seizure_run-03_ieeg.eeg
sub-01_ses-postimp_task-seizure_run-03_ieeg.json
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sub-01_ses-postimp_task-seizure_run-03_ieeg.vmrk

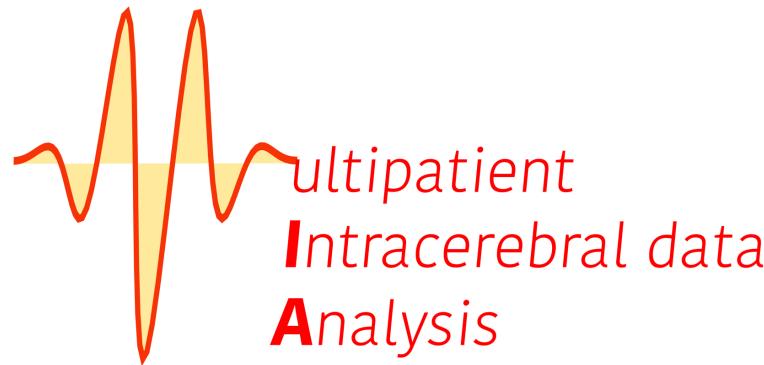
Sample data

Let's practice!



Hands-on tutorial, March 13th

- Part 2 -



Anne-Sophie Dubarry & Maximilien Chaumon

History

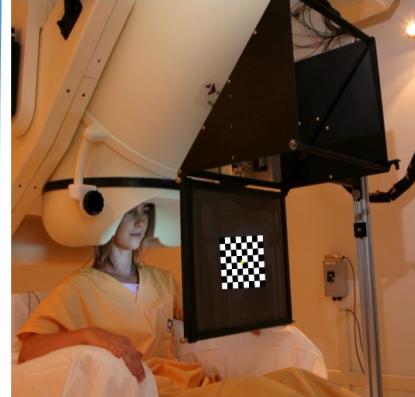
SEEG



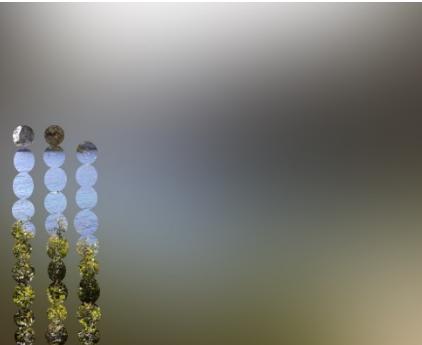
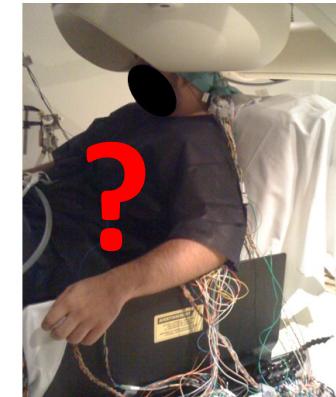
EEG



MEG



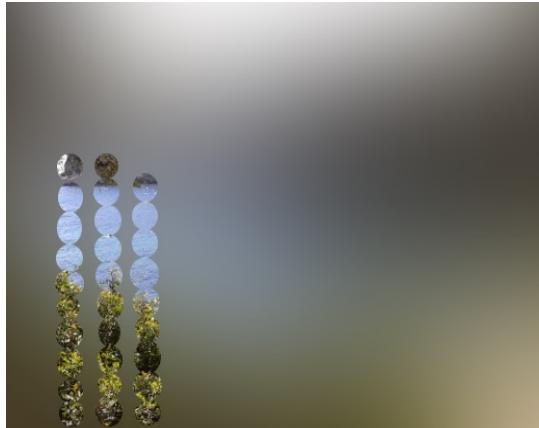
Combined techniques?



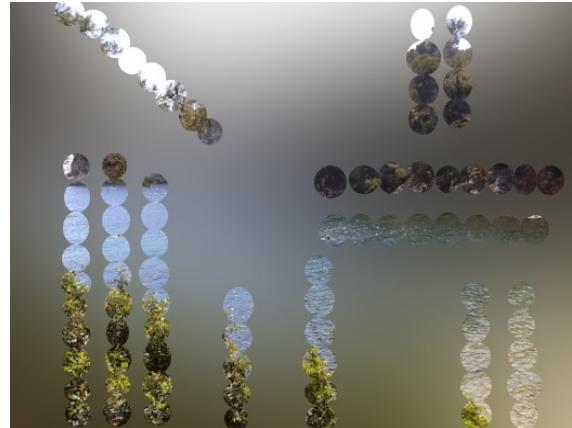
Simultaneous recording of MEG, EEG and intracerebral EEG during visual stimulation: from feasibility to single-trial analysis. Dubarry et al. *Neuroimage*. 2014

History

- Multiple patients with SEEG



PT01



PT02

PT05

- Similar activity

- 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 
- Supports most common file formats 
- Daily updates of the software 

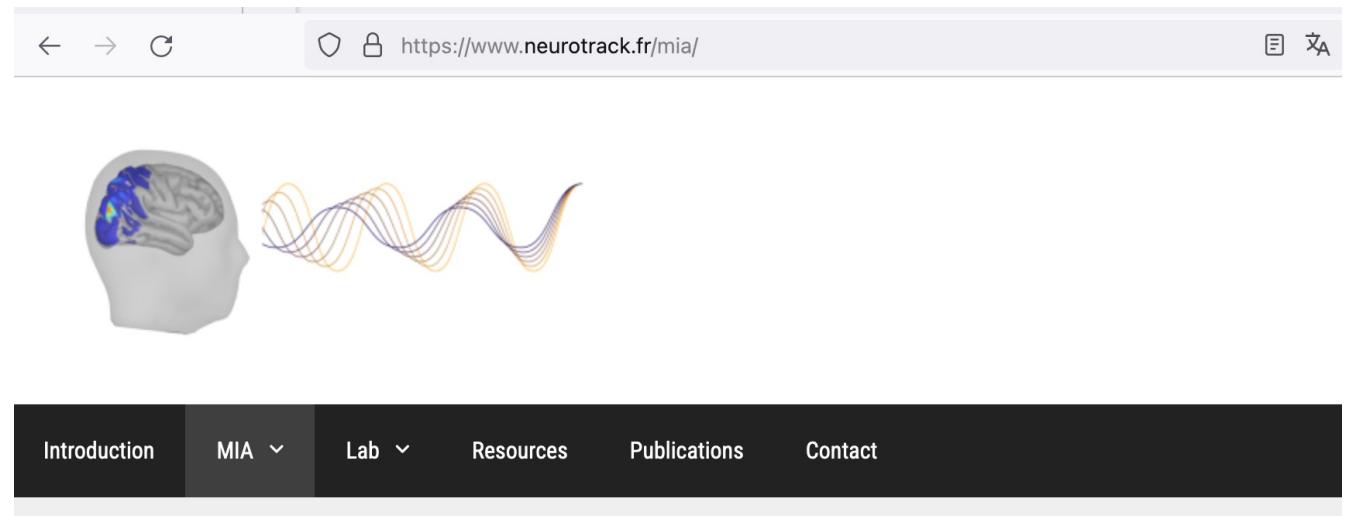
Contributions are welcome!!!

Thanks
to
Brainstorm

Docs

Tutorials

Courses



The screenshot shows the main navigation menu of the MIA website. The 'MIA' item is highlighted with a dropdown arrow, indicating it's the active page. Other menu items include 'Introduction', 'Lab', 'Resources', 'Publications', and 'Contact'. Above the menu, there's a decorative graphic featuring a grayscale brain model with blue and yellow highlights, and a series of overlapping yellow and blue waveforms.

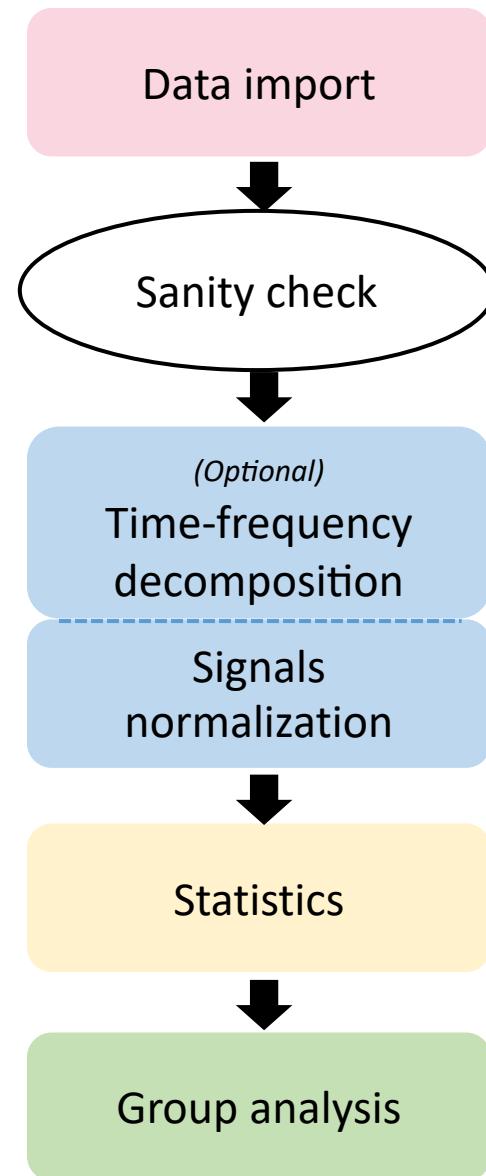
→ [neurotrack.fr/mia](https://www.neurotrack.fr/mia)



MIA™ is a free, open-source Matlab toolbox to analyze intracranial EEG signals over multiple patients.

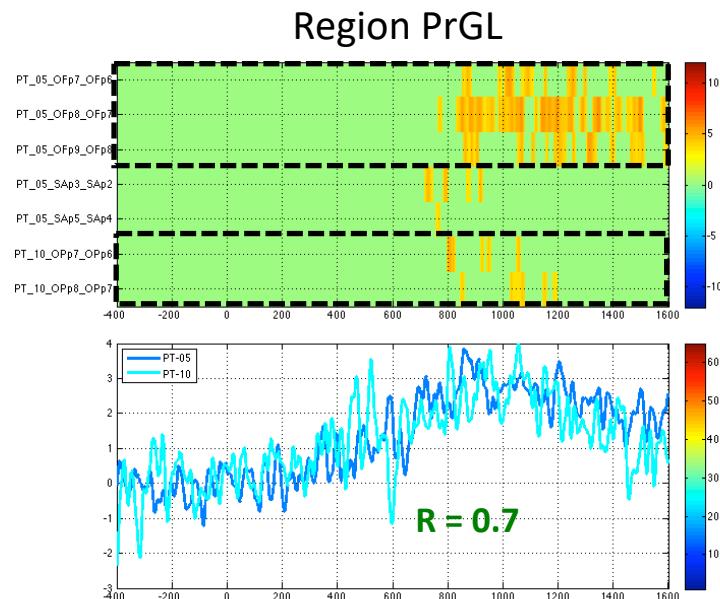
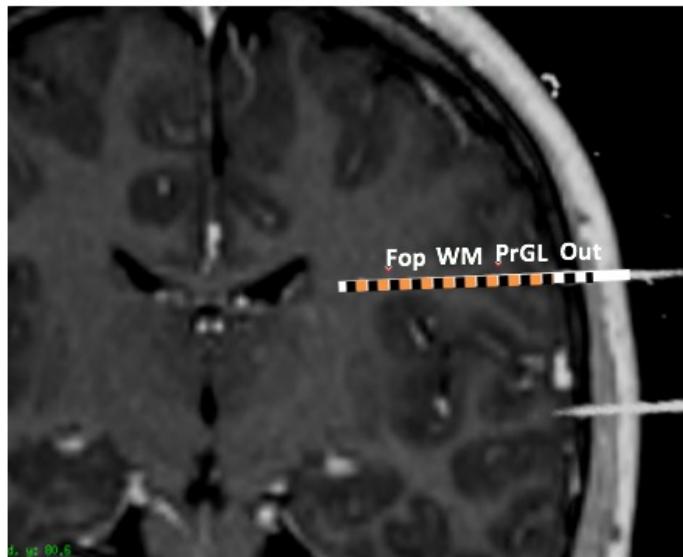
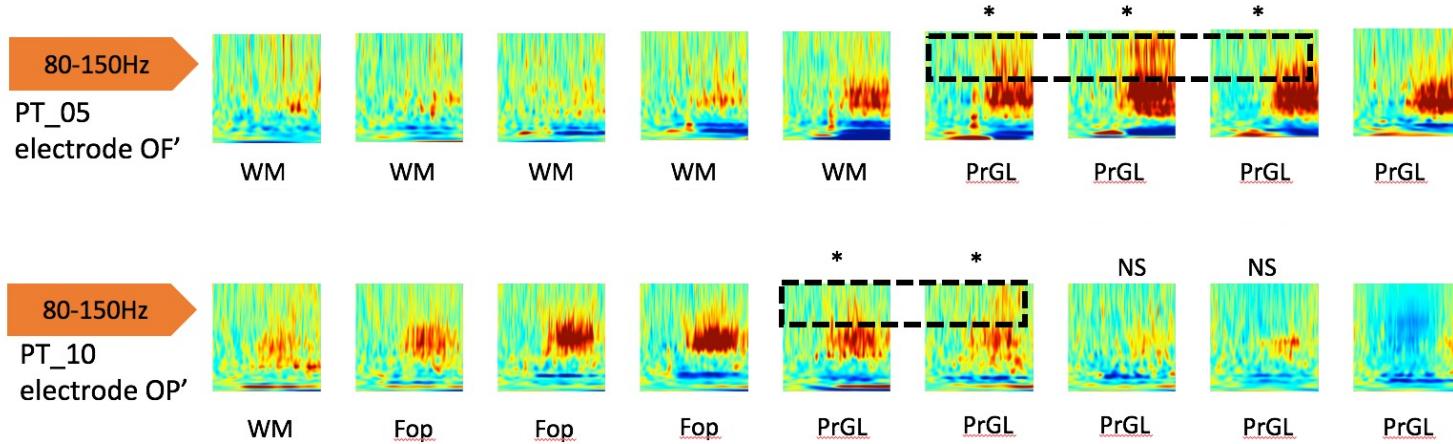
MIA was developed by [A.-Sophie Dubarry](#) at the Laboratoire de Psychologie Cognitive and Laboratoire Parole et Langage (CNRS, Aix-Marseille) in collaboration with [Catherine Liégeois-Chauvel](#), [Agnès Trébuchon](#), [Christian Bénar](#), [F.-Xavier Alario](#). The software has been successfully used since 2017 to support intracerebral EEG signal analysis in studies published in peer-reviewed journals or presented at neuroscience International meetings (see list below).

MIA Workflow



Illustrative example

- Two electrodes from two patients implanted in the same region (PrGL)



Data import

- Input data :



{
 .eeg
 .vmrk
 .vhdr



A. Trébuchon



Special thanks to Francois Tadel ❤️

Thanks the reviewers of the paper

Deltamed
Micromed
NK
Nicolet
BrainVision
EDF



Cleveland Clinic

C. Liegeois Chauvel
John C Mosher

For importing data from Brainstorm see video demonstration on neurotrack.fr/mia (10 min)

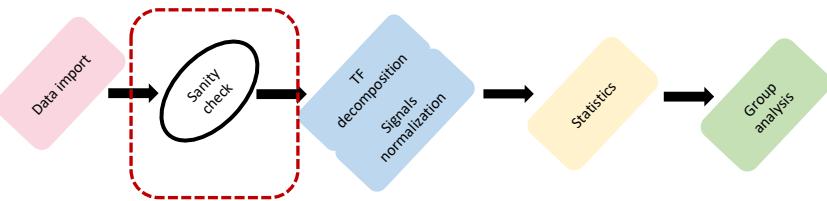


ultipatient
Intracranial data
Analysis

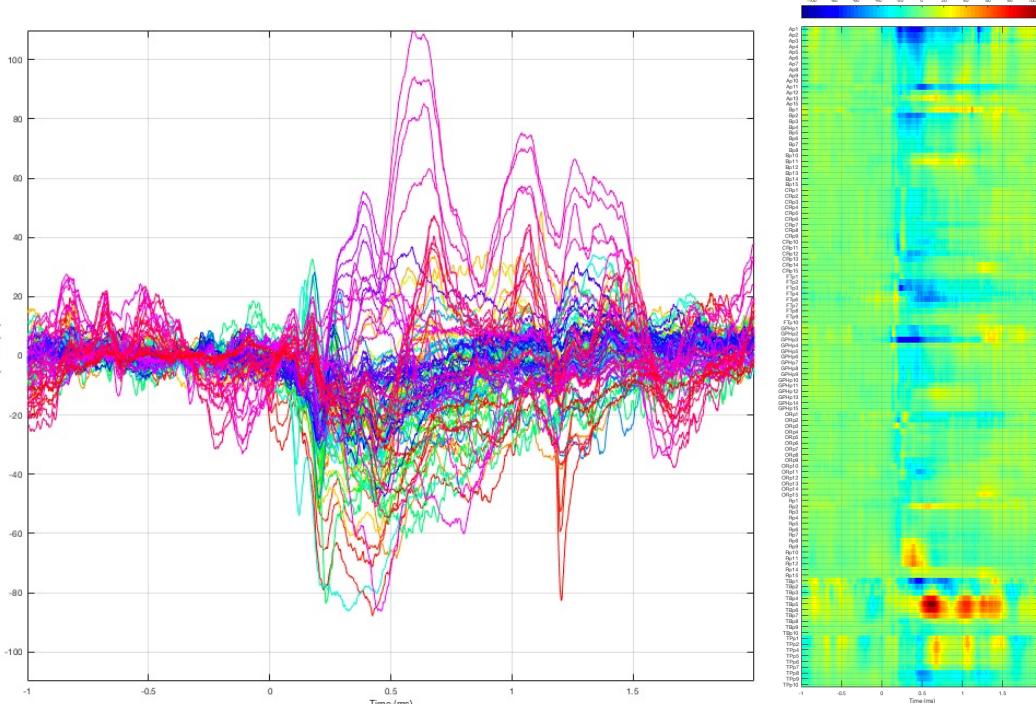
- Preprocessing steps (prior to MIA)

- Epoching (mandatory)
- Filtering artifact rejection (optional)
- Bad channel rejection (optional)

Sanity Check



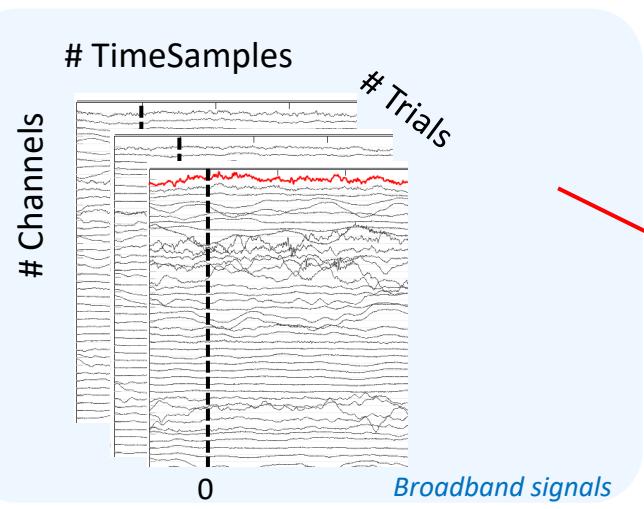
- Getting info about the recording
- Evoked potential computation



Patient :	PT_02
Number of trials :	85
Total contacts :	115
Number of electrodes :	9
Electrodes :	 Ap : 14 contacts Bp : 14 contacts CRp : 15 contacts FTp : 9 contacts GPHp : 15 contacts ORp : 15 contacts Rp : 14 contacts TBp : 10 contacts TPp : 9 contacts
Select channels	
Save channels	

Last chance to remove bad contacts

Input



Data import

Sanity check

TF decomposition
Signals normalization

Statistics

Group analysis

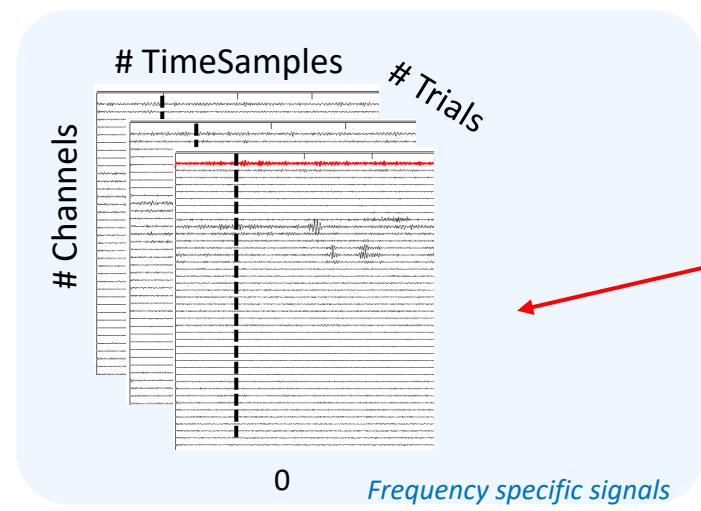
Operation

Time-Frequency
decomposition
 $|C(b, \sigma)|$

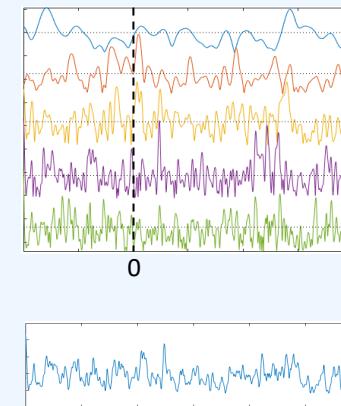
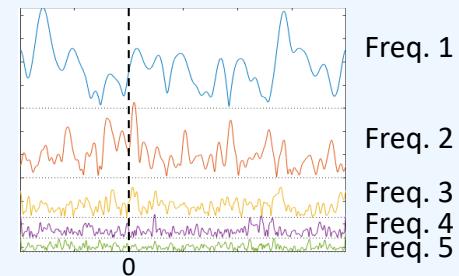
Z-score
normalization

Average

Output

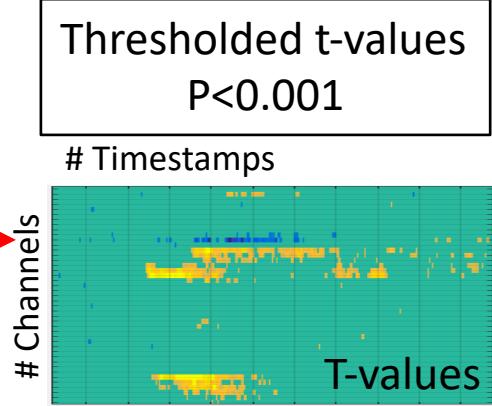
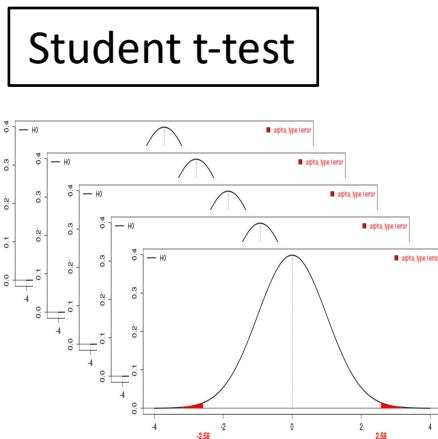
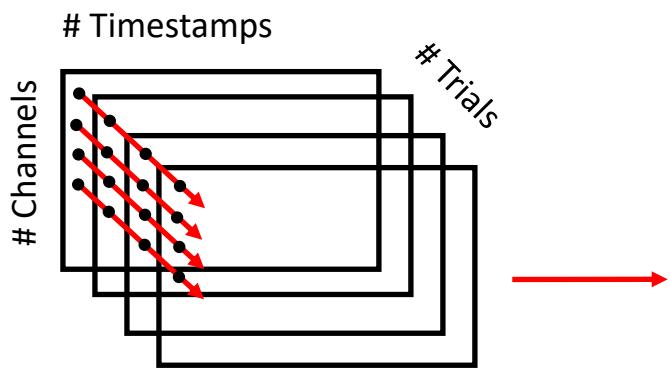
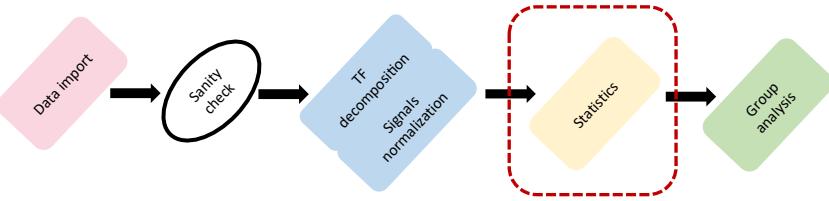


Example



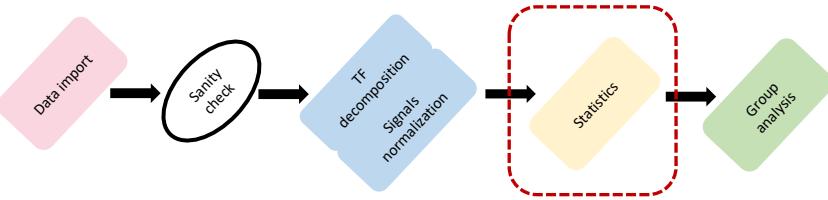
Time-frequency extraction

Statistical analysis



P<0.001, really??
Family Wise Error
(type I error)

Statistical analysis



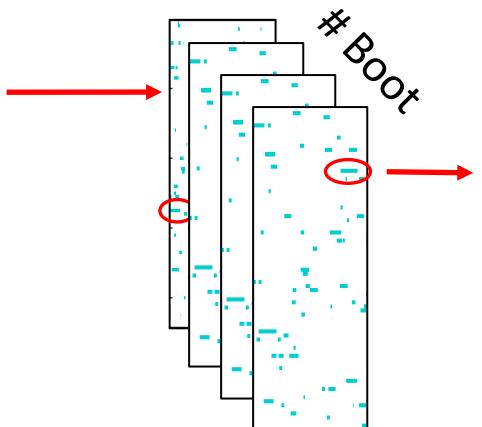
Multiple comparison correction

Duration above which activity is significant

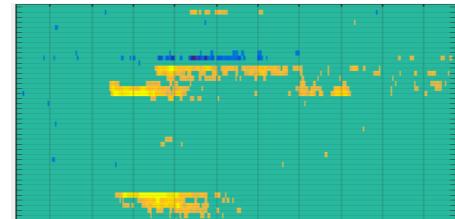
Bootstrap
on baseline



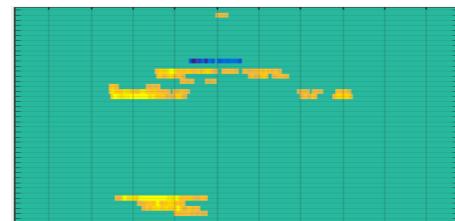
Student t-test

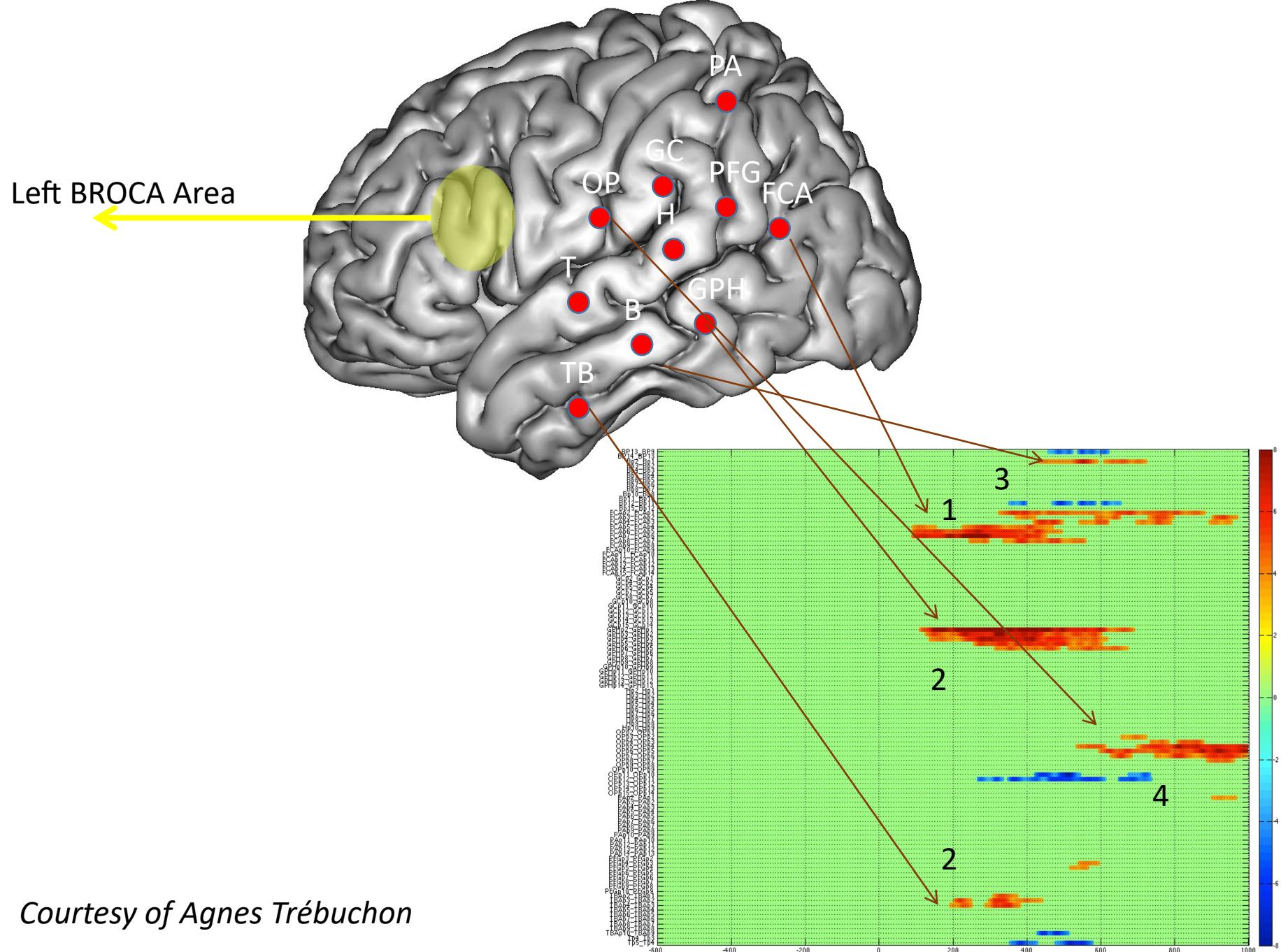


Threshold
on duration
(sec)



Thresholded t-values
 $P < 0.001$ corrected



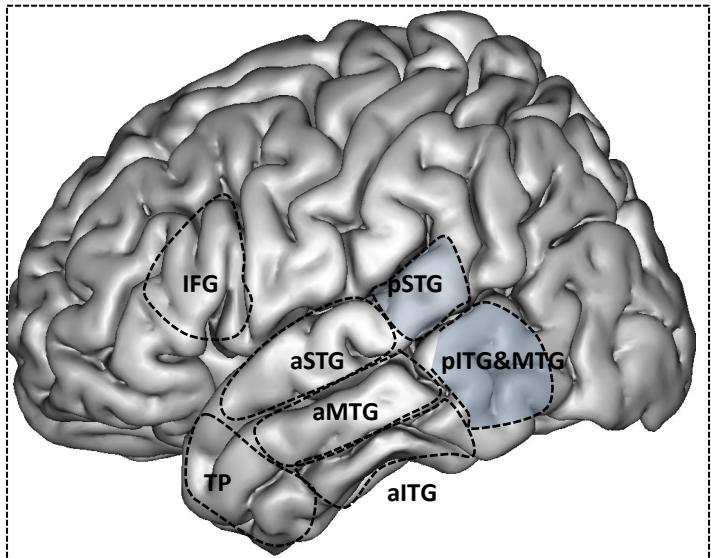
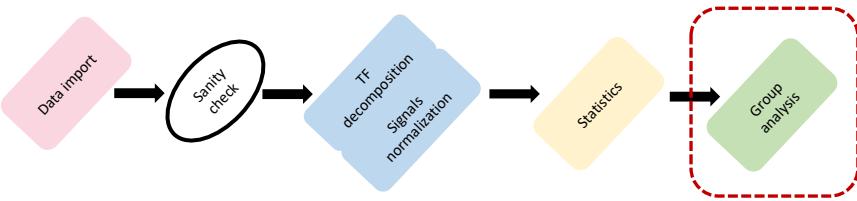
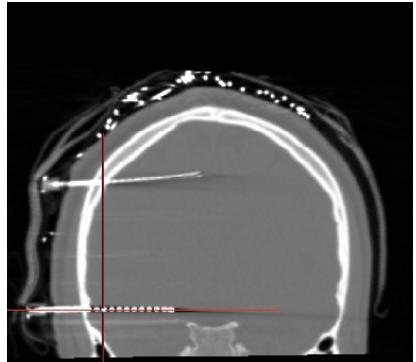


Courtesy of Agnes Trébuchon

Group analysis

Part 1- Anatomy

- Common space : Atlas
- CT-MRI coregistration

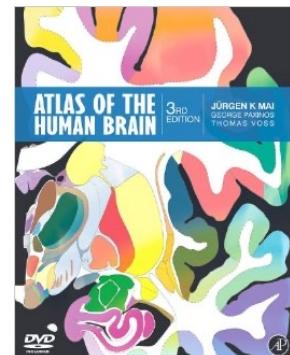
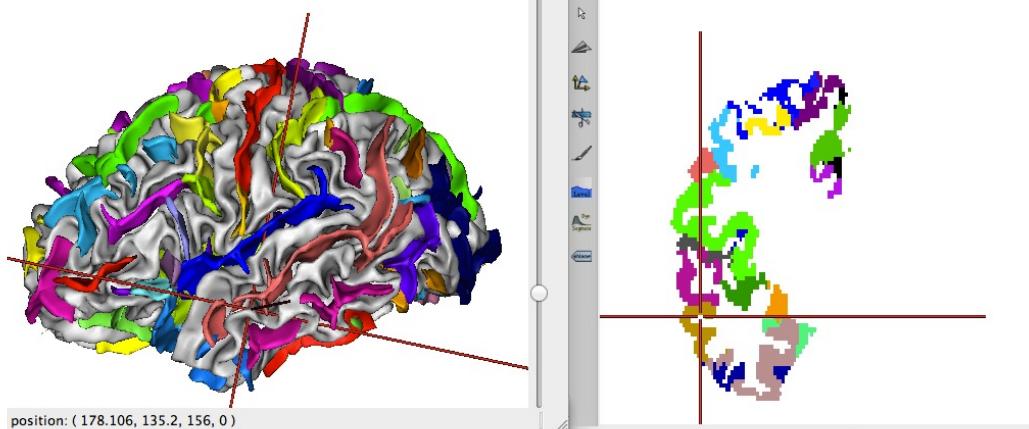


Work from A. Trébuchon

In practice : a table

Contact Laterality Region

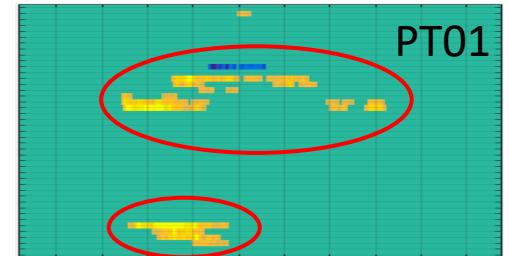
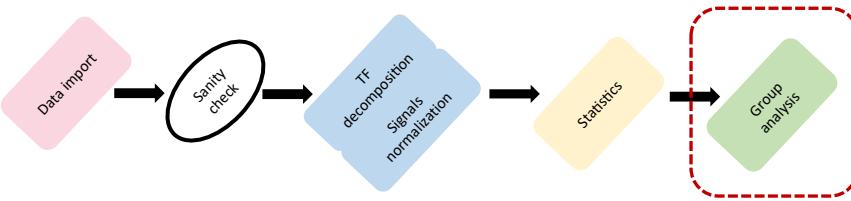
B1	R	'cHi'
B2	R	'cHi'
B3	R	'blanc'
B4	R	'blanc'
B5	R	'blanc'
B6	R	'blanc'
B7	R	'mMTG'
B8	R	'mMTG'
B9	R	'mMTG'
B10	R	'mMTG'
H1	R	'TTG1'
H2	R	'TTG1'
H3	R	'blanc'



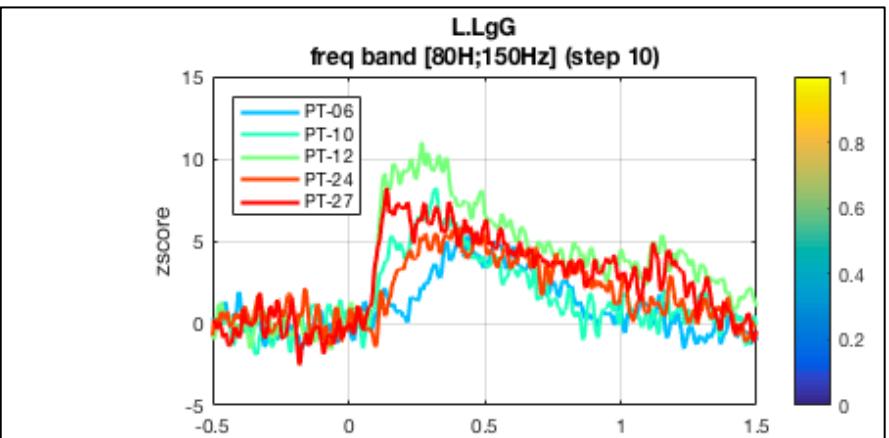
Group analysis

Part 1 - Signals

- Contacts selection based on significance on the time window of interest



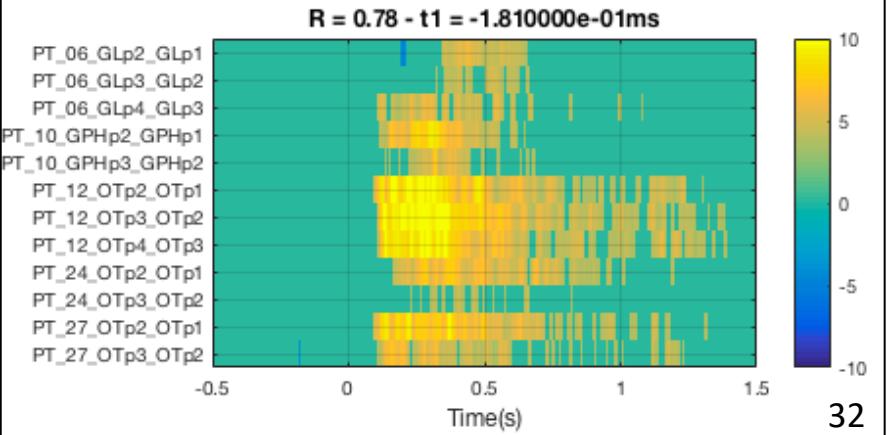
- Average per patient
- Pairwise correlation (time domain – Pearson)



Example: 5 patients

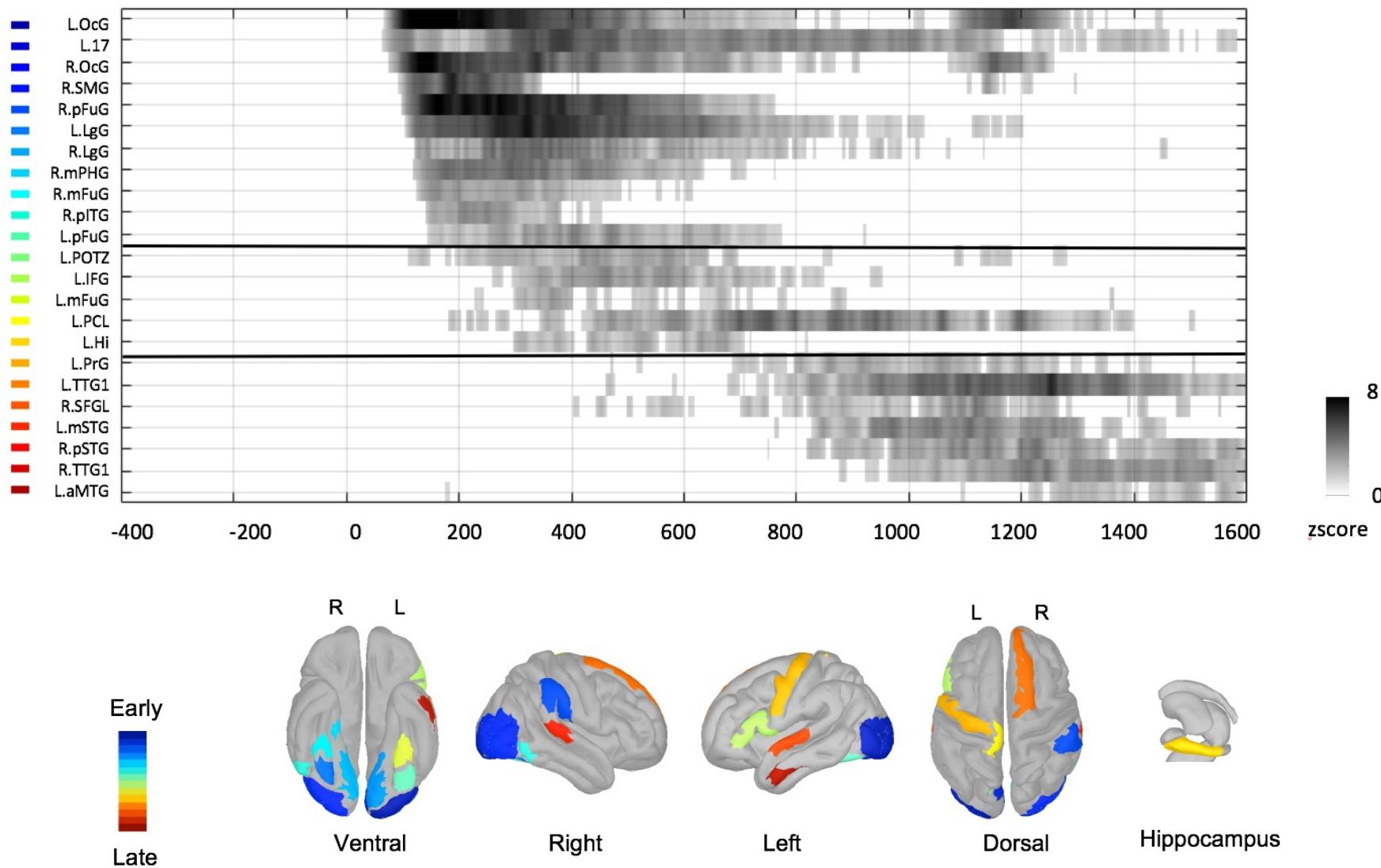
corr[PT-06,PT-10]
corr[PT-06,PT-12]
corr[PT-06,PT-24]
corr[PT-06,PT-27]
Etc.

Average = 0.78

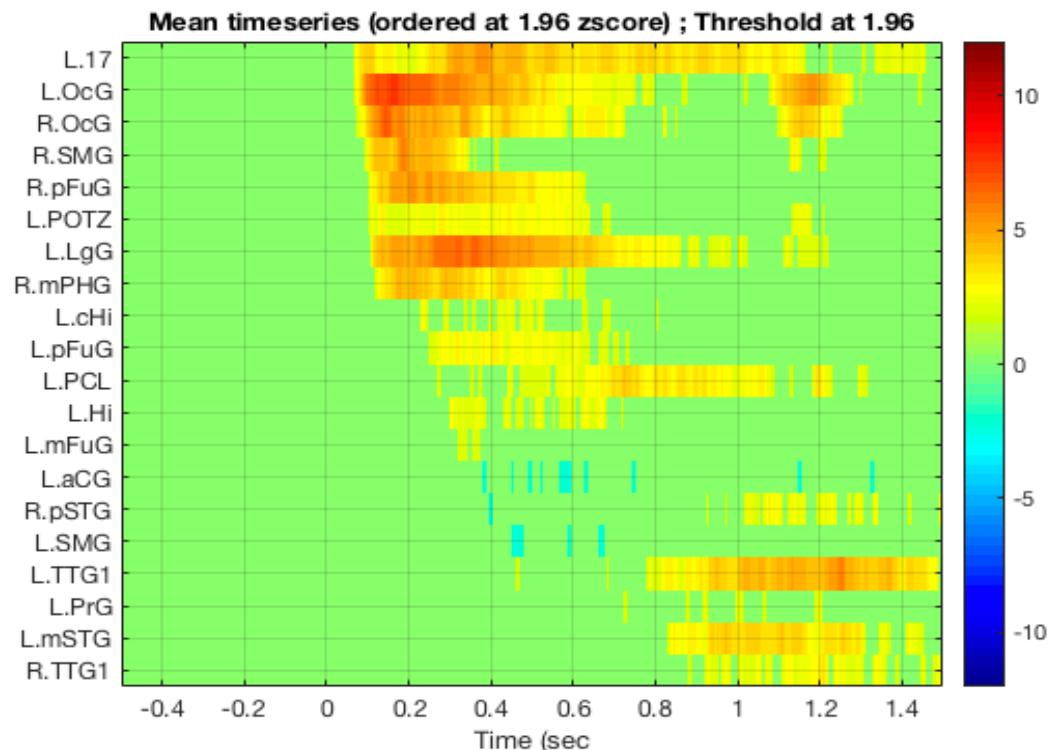
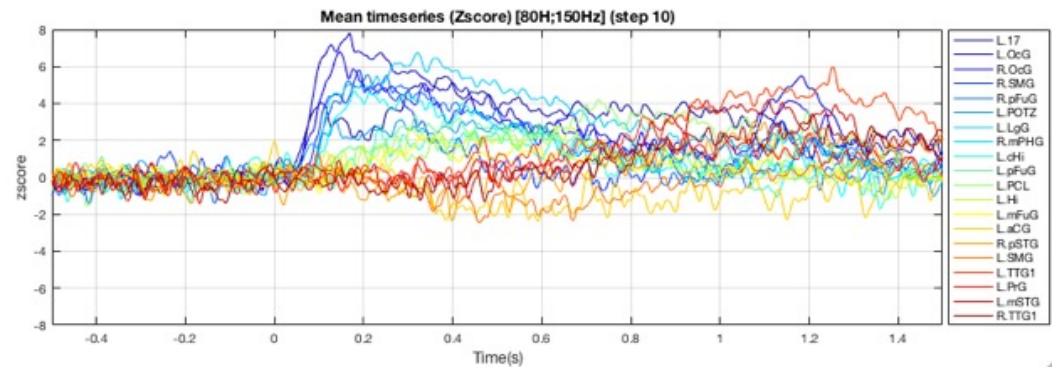
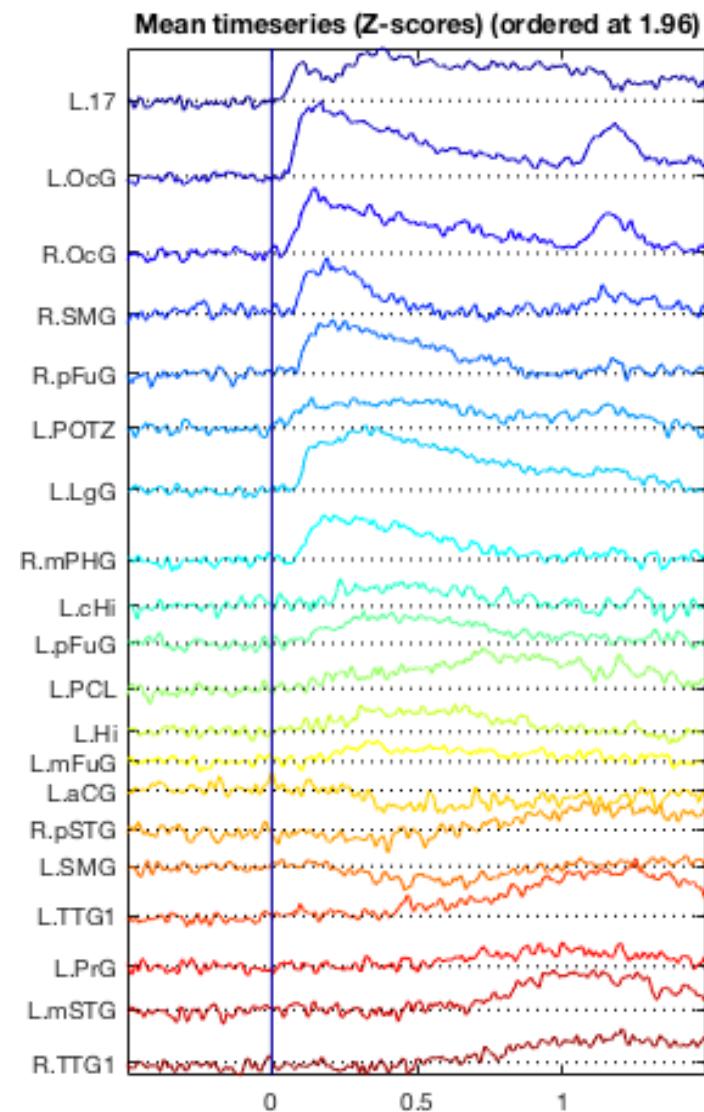


Group analysis : results

$R > 0.3$



Different representations



A ontributors

Many thanks to

A-Sophie Dubarry

Shuai Wang

F.-Xavier Alario

Christian Bénar

Anaïs Llorens

Agnès Trébuchon

Catherine Liegeois-Chauvel

Francois Tadel

John Mosher

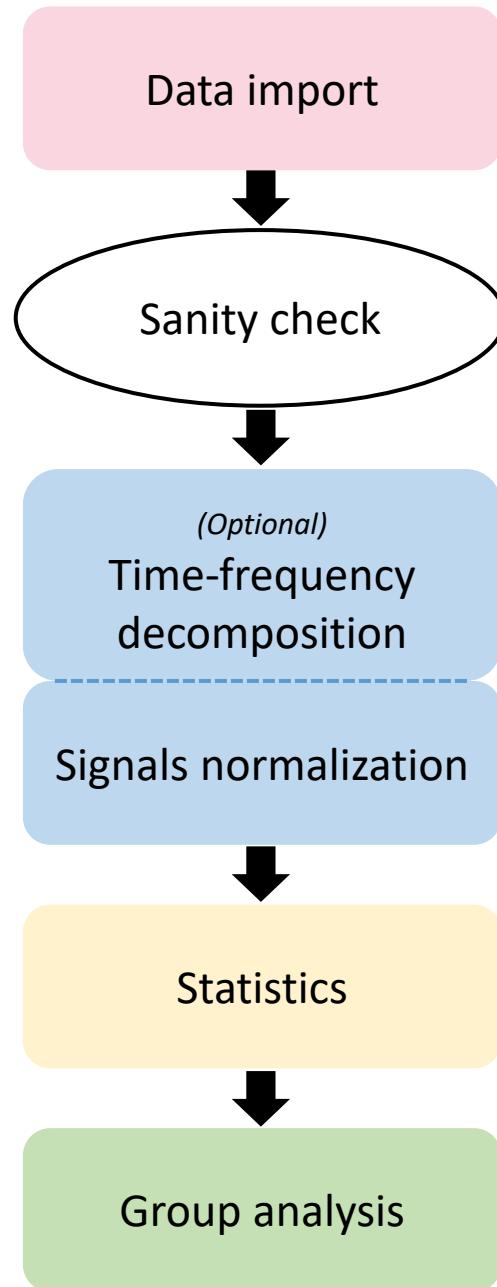
My lab CRPN

My team (DI²S²C)

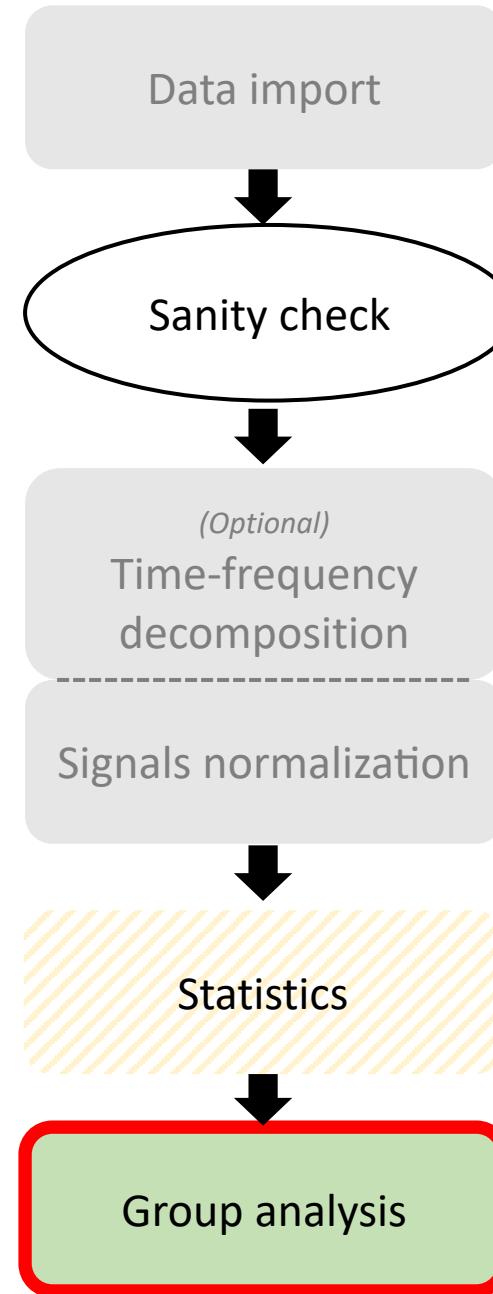
Ali Adeli Koudehi



MIA

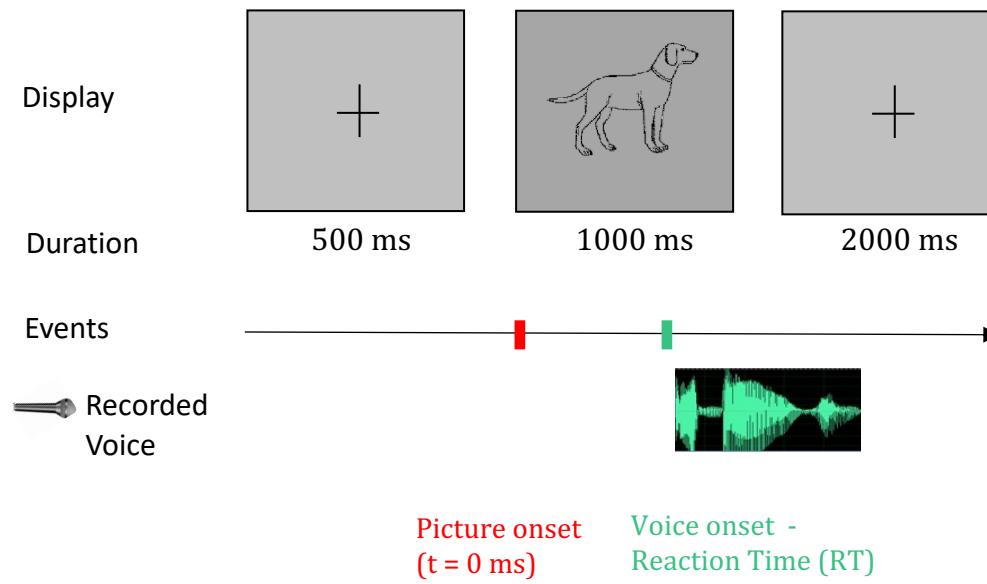


TODAY



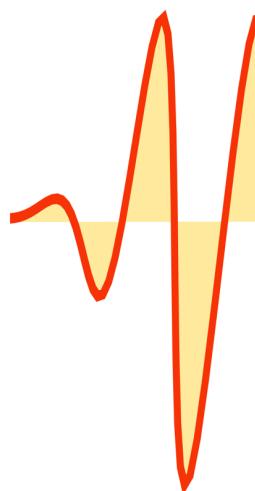
Example from study (subset)

- Study temporal architecture of picture naming
- Spatio-temporal pattern of brain activity
- Task :

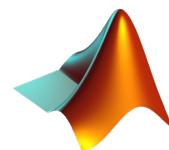


Task from Llorens, A. et al. (2011). Intra-cranial recordings of brain activity during language production.

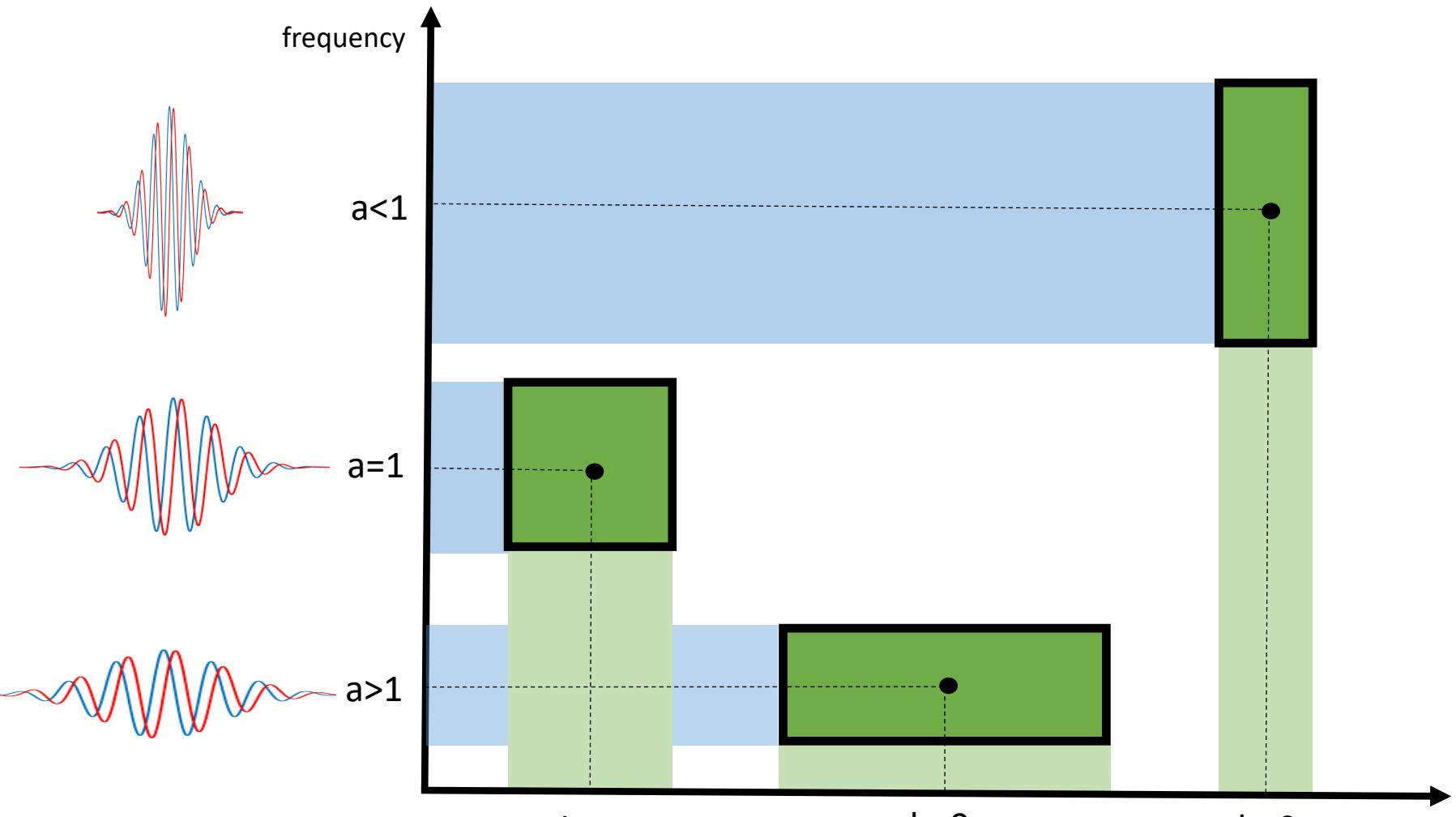
Lets practice!



*Multipatient
Intracerebral data
Analysis*



Contraction/dilation of the Wavelet



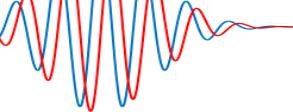
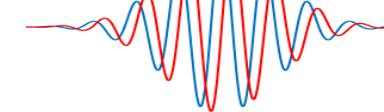
Daughter wavelet :

Morther wavelet

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}} \psi \left(\frac{1-b}{a} \right)$$

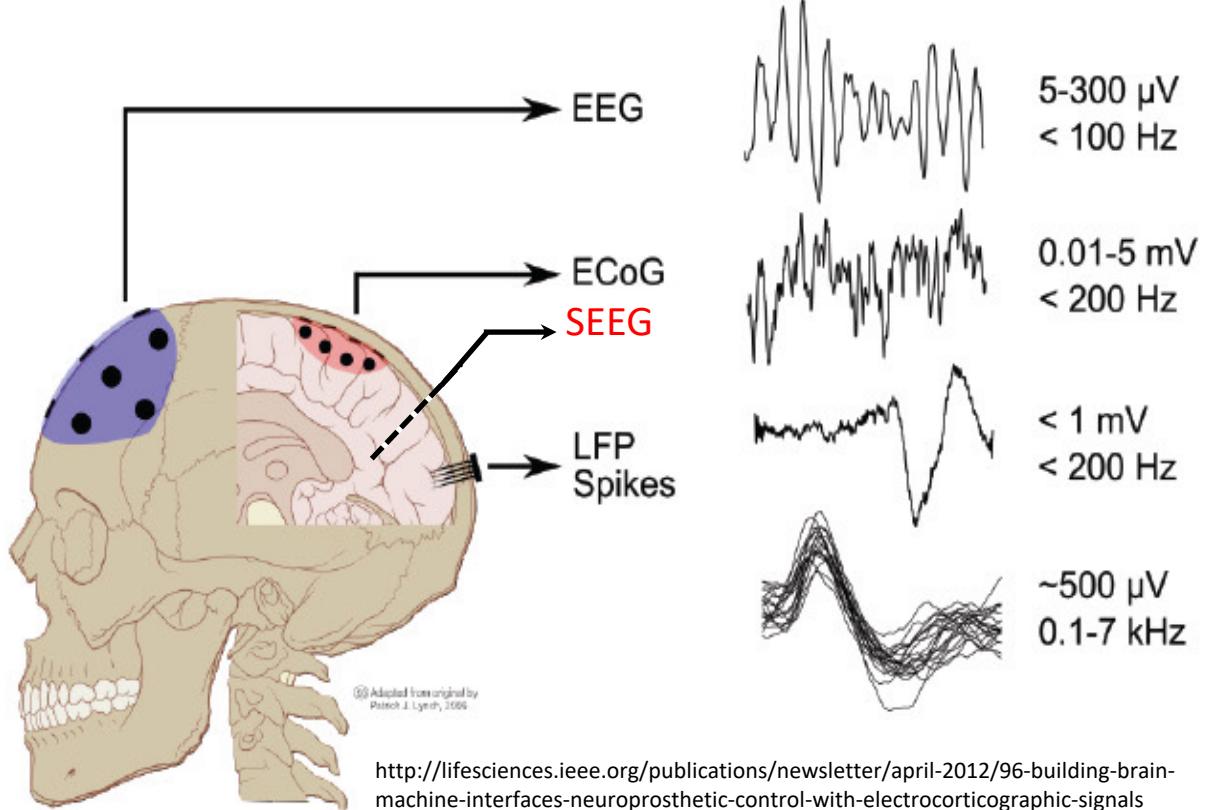


Translation in time



SEEG

Epilepsy
pre-surgical evaluation



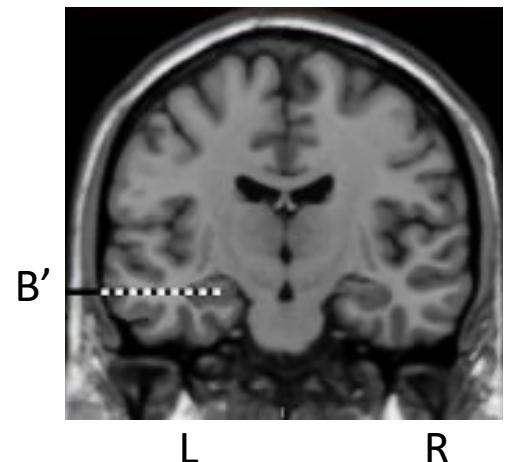
- What do we record? Activity **directly** inside the brain

➤ Terminology :

- Contact, plots, vs electrodes
- Electrode name (single quotation mark = left lateralized)

++ : local accuracy (signal to noise ratio)

-- : spatial sampling



Montages

