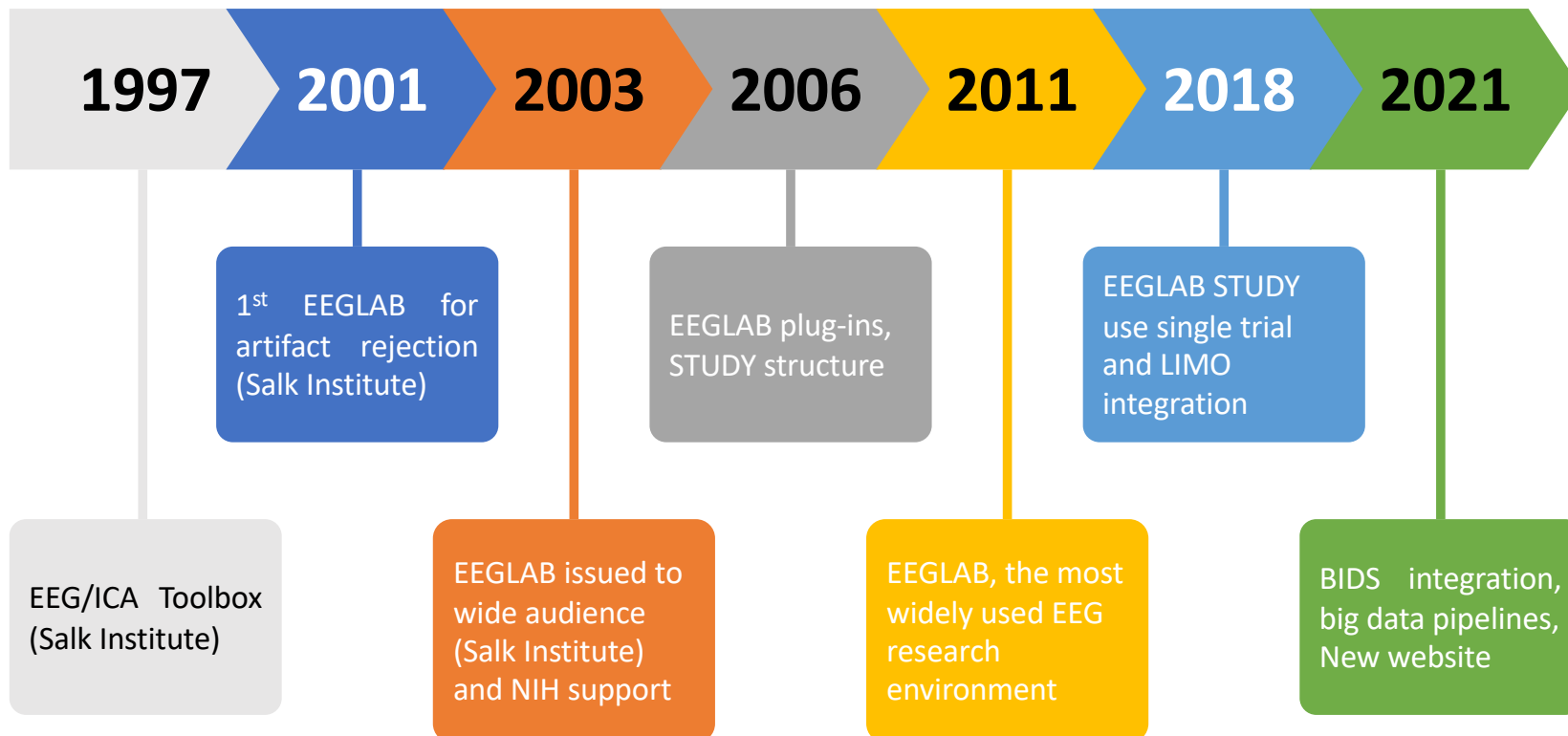
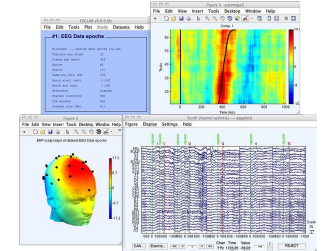


# EEGLAB overview

Arnaud Delorme

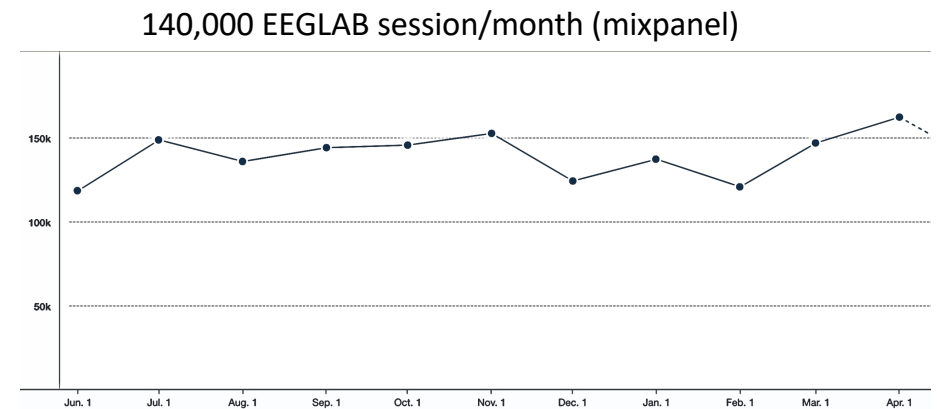


# EEGLAB History Timeline

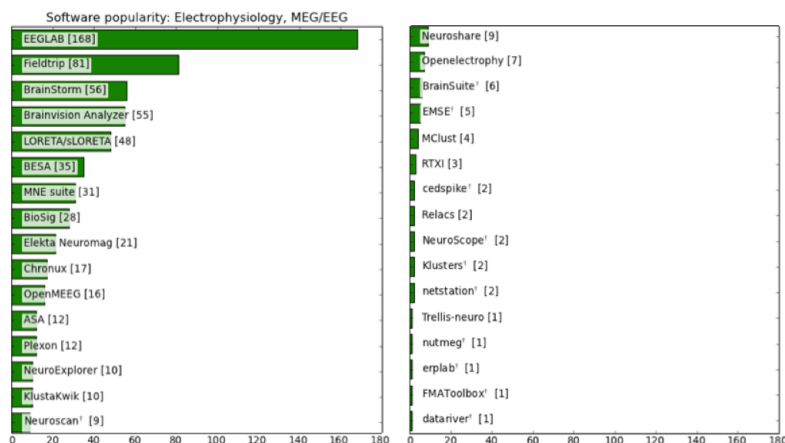


# EEGLAB in a few numbers

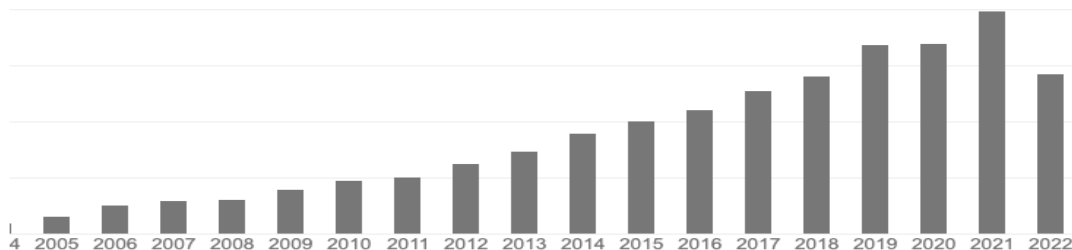
- About **600** functions (**150 000** lines of code)
- About 400,000 download over the past 10 years
- **15,500** users on the diffusion list
- Supporting **423 million** of dollars of research as of 2022
- NIH funding since **2003**
- **143** plugins



## Hanke & Helcenko, 2011, Frontier in Neuroinformatics



EEGLAB reference article 18,194 citations (September 2022)



## Most popular EEG tool on NITRC

### EEGLAB

[Visit Website](#)

EEGLAB is to date the most popular EEG/MEG/ECOG software with about 100,000 download worldwide since 2003. EEGLAB provides an interactive graphic user interface (GUI) allowing users to flexibly and interactively process their high-density EEG and other dynamic brain data using independent component analysis (ICA) and/or spectral time/frequency and coherence analysis, as well as standard methods including event-related potentials (ERP). EEGLAB also incorporates extensive tutorial and help windows, plus a command history function that eases users' transition from GUI-based data exploration to building and running batch or custom data analysis scripts. EEGLAB offers a wealth of methods for visualizing and modeling event-related brain dynamics, both at the level of individual EEGLAB 'datasets' and/or across a collection of datasets. For experienced Matlab users, EEGLAB offers a structured programming environment for storing, accessing, measuring, manipulating and visualizing event-related EEG data.

### Statistics

Home Page  
 RRID: SCR\_007292  
 Funding: NIH  
 Documents: 3893  
 Total Downloads: 39108  
 Registered: Nov 4, 2011  
 Organization: UCSD  
 Center: Swartz Center for Comput...



### Assessments

### Participate!

Monitor a file release  
 Subscribe to RSS feed  
 Bookmark this page  
 Add a review

Download Now

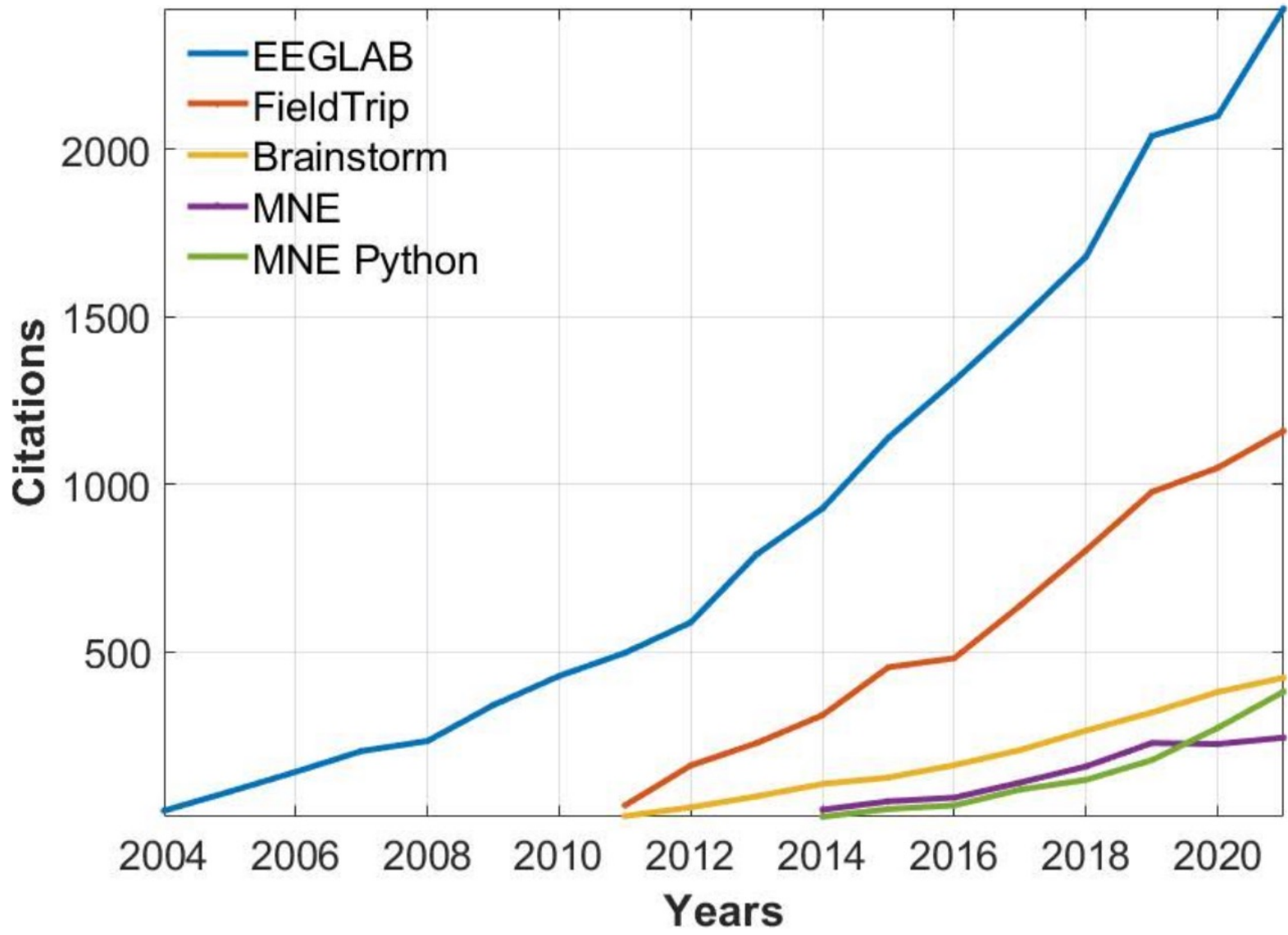
EEGLAB latest release:

OR

See All Files











H  
O  
M  
E

Search EEGLAB Wiki

- [EEGLAB news](#) ▼
- [Download EEGLAB](#) ▼
- [Tutorials](#) ▼
- [Workshops](#) ▼
- [Interoperability](#) ▲
- EEGLAB and FieldTrip
- EEGLAB and HPC
- EEGLAB and Python
- EEGLAB on Octave
- EEGLAB vs. commercial soft.**
- [Support](#) ▼

[Interoperability](#) / EEGLAB vs. commercial soft.

## EEGLAB vs Commercial EEG software packages

*Can we trust the results of a new paper if they depend on calculations carried out by proprietary software with non-public source code? M. Buchanan, Nature Physics, 2016*

This page compares the feature of EEGLAB some of the most common features in what is currently best in the industry.

	EEGLAB	Leading EEG commercial softwares
Binary file import	EEGLAB offers a comprehensive library of file import functions. Most data formats can be imported using three different methods.	File import and export are usually limited to a few formats.
Memory requirements	EEGLAB must be able to hold in memory any single data set. When processing multiple data sets, they may stay on disk.	Most commercial software has been designed to allowing processing of large datasets using relatively little memory.
Features	EEGLAB has more features than any current commercial software. In general EEGLAB provides the user with a wider range of processing choices.	Some leading (though frequently expensive) commercial software might offers more methods for source localization than are available in EEGLAB tools.

# EEGLAB plugin manager

The screenshot shows the EEGLAB plugin manager window. At the top, there are two search filters: "No install s..." and "No topic fil...". Below these is a list of plugins. The plugin "xdffimport v1.14" is highlighted in blue and is bolded, indicating it is installed. Other plugins in the list include SASICA, PrepPipeline, MFFimport, corrmmap, iirfilt, LIMO, BCI2000import, biopac, loadcurry, PACT, VisEd, std\_envtopo, mass\_univ, trimOutlier, NihonKoden, ICLLabel, and loadhdf5. The ICLLabel plugin is also bolded and has a red text indicating an update is available. Below the list are three buttons: "Rate this plugin", "Web documentation", and "Upload new plugin". Underneath these buttons, the "Tags" section shows "import" and the "Status" section shows "installed". The "Description of the plugin:" section contains text about importing XDF files. At the bottom of the window are three buttons: "Cancel", "Remove", and "Install/Update".

List of plugins (bolded plugins are installed)    No install s...    No topic fil...

- no rating - SASICA v1.3.4 (1521 downloads)
- no rating - PrepPipeline v0.55.3 (1407 downloads)
- ★★★★★ - MFFimport v2.2 (1365 downloads; 2 rating)
- ★★★★★ - **xdffimport v1.14 (1363 downloads; 1 rating)**
- no rating - corrmmap v2.02.1 (1267 downloads)
- no rating - **iirfilt v1.03 (1240 downloads)**
- no rating - LIMO v2.0 (1238 downloads)
- no rating - BCI2000import v0.36 (1086 downloads)
- no rating - biopac v1.00 (1039 downloads)
- no rating - loadcurry v2.0 (1005 downloads)
- no rating - PACT v0.20 (984 downloads)
- no rating - VisEd v1.05 (970 downloads)
- no rating - std\_envtopo v4.03 (934 downloads)
- no rating - mass\_univ v03272017 (927 downloads)
- ★★★★★ - trimOutlier v0.17 (898 downloads; 1 rating)
- ★★★★★ - NihonKoden v1.11 (796 downloads; 1 rating)
- ★★★★★ - **ICLabel v1.1 update available (793 downloads; 1 rating)**
- no rating - loadhdf5 v1.1 (754 downloads)
- no rating - SASICA v1.00 (750 downloads)

Rate this plugin    Web documentation    Upload new plugin

Tags:    import

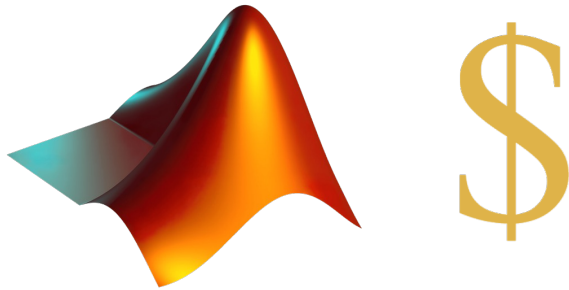
Status:    installed

Description of the plugin:

Import files in XDF format saved by the LabRecorder Python program to record LSL streams. This plugin only imports EEG and Marker streams. To import a multi-stream XDF file and sync the different data streams at the same sampling frequency for subsequent processing in EEGLAB, use the Mobilab extension.

Cancel    Remove    Install/Update

# Which MATLAB version?



Download R2020b



Download earlier release

R2010a
R2009bSP1
R2009b
R2009a
R2008b

## Additional MATLAB toolboxes

- Signal processing toolbox
- Statistics toolbox
- Optimization toolbox
- Image processing toolbox

# Matlab based open source



## Pros

- Easy to program, highly modular and extendable
- Not dependent on any platform (64-bit) and highly optimized
- Large community of users (latest development in signal processing research)
- Powerful scripting capabilities

## Cons

- Matlab commercial license required
- Matlab commercial toolboxes recommended (signal processing, statistics)

# EEGLAB version?

Stable



Vs.

Dev.



**GitHub**



# Which Operating System?





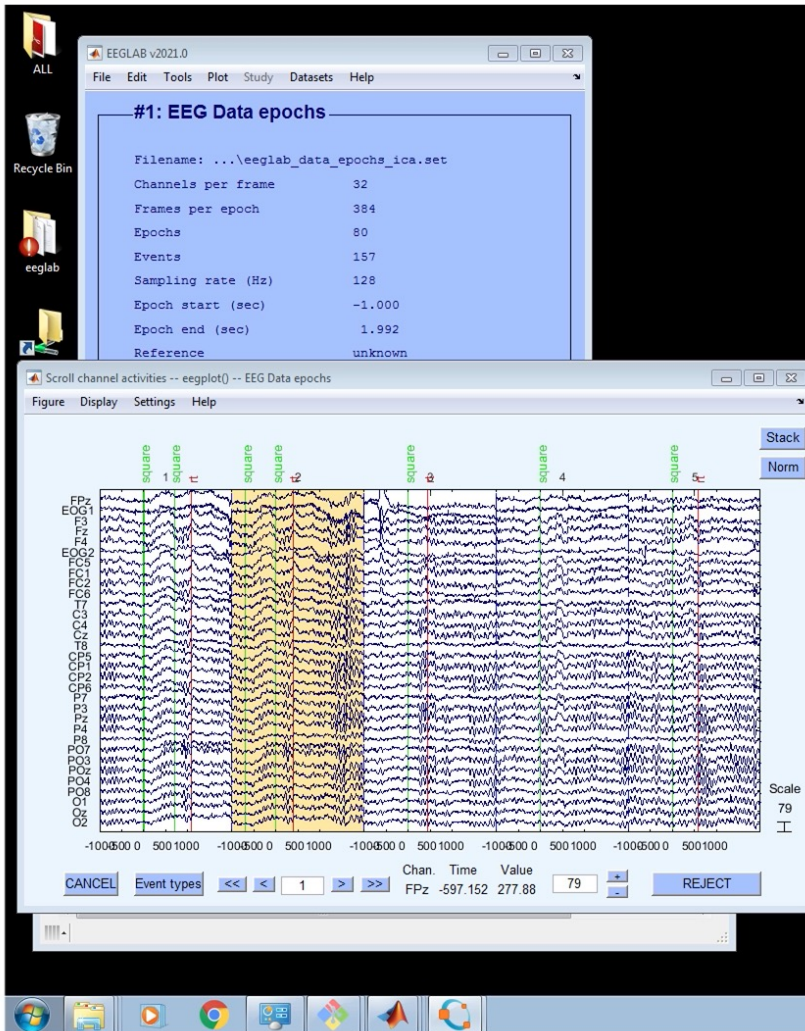
# EEGLAB on MATLAB vs EEGLAB compiled



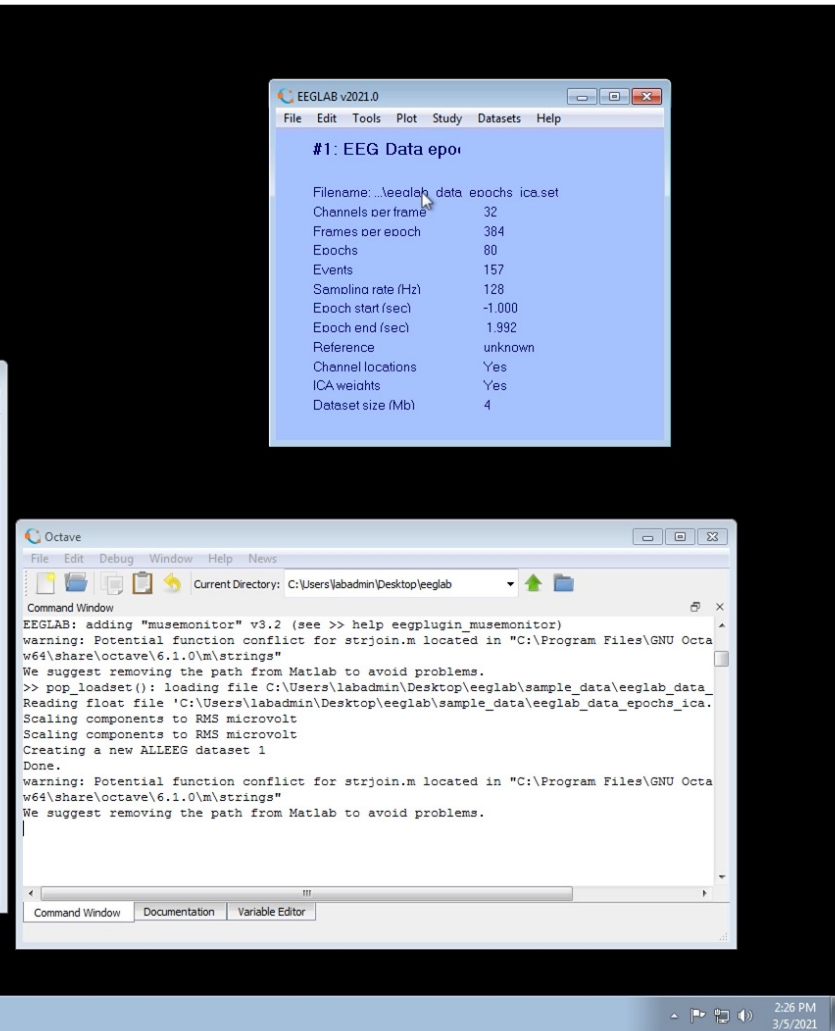
# EEGLAB on Octave



# EEGLAB MATLAB

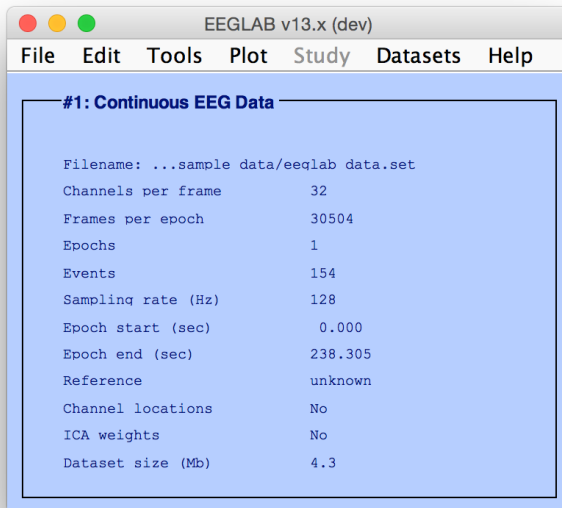


# EEGLAB Octave

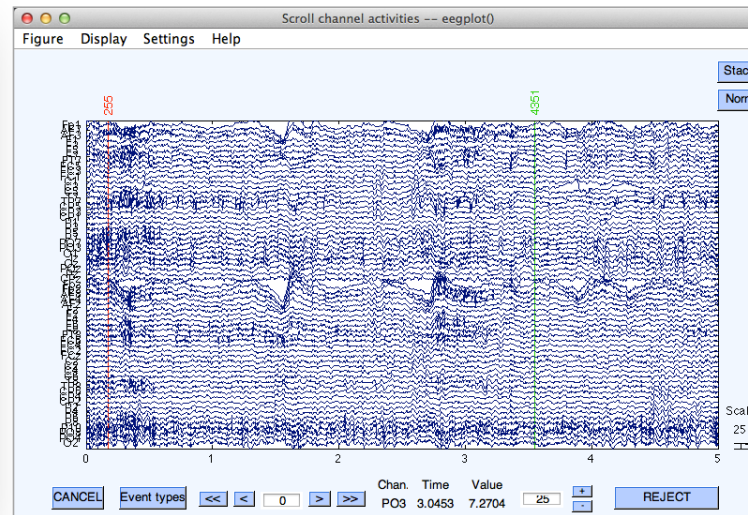


# Importing data

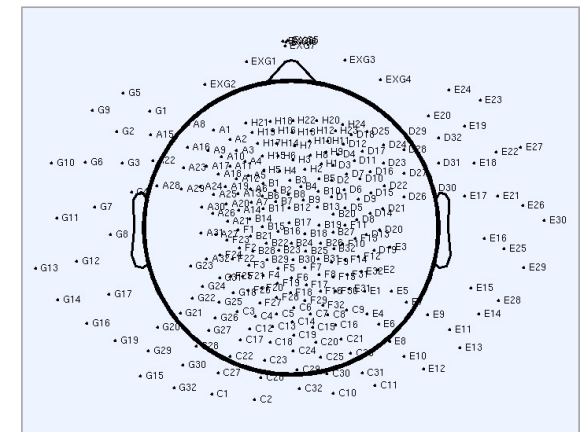
## Data info



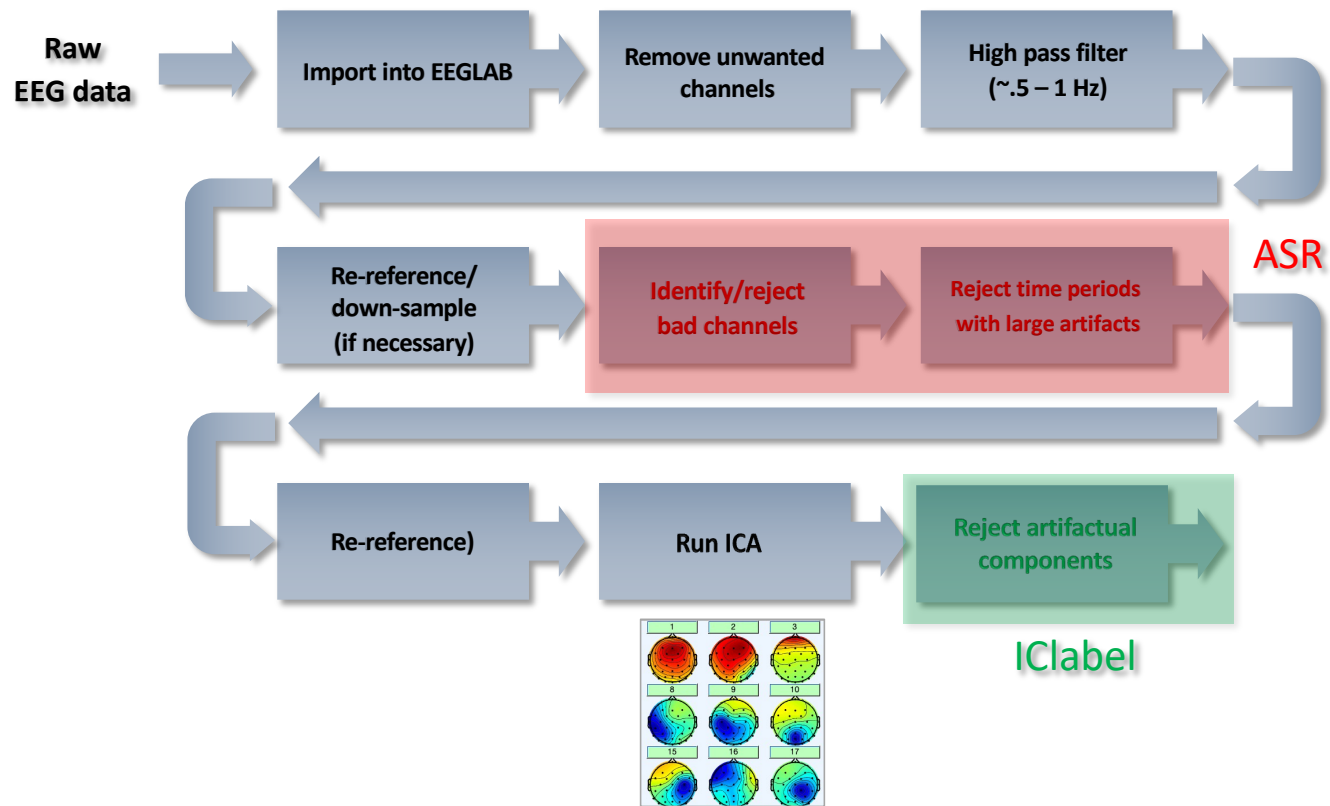
## Scrolling data



## Channel location

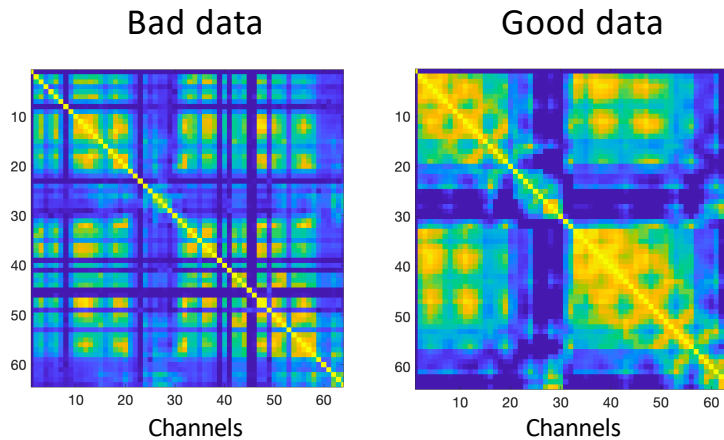


# Preprocessing pipeline



# ASR – Artifact Subspace Reconstruction

Pairwise correlation to find bad channels



ASR finds and reconstructs bad portions of data

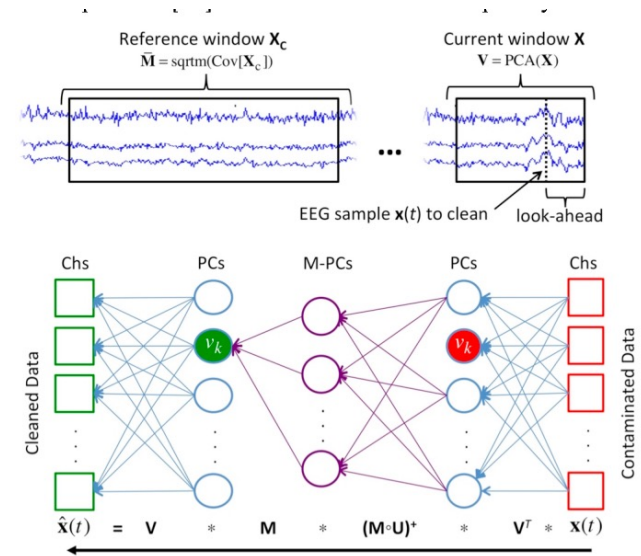
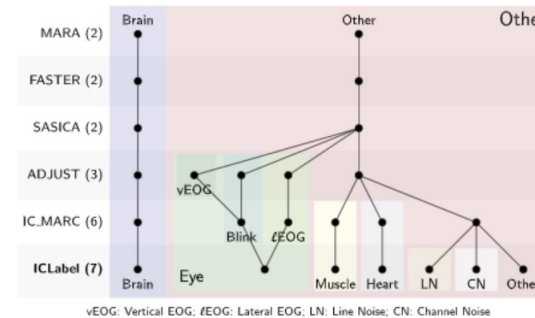


Fig. 3. The Artifact Subspace Reconstruction method. High-variance

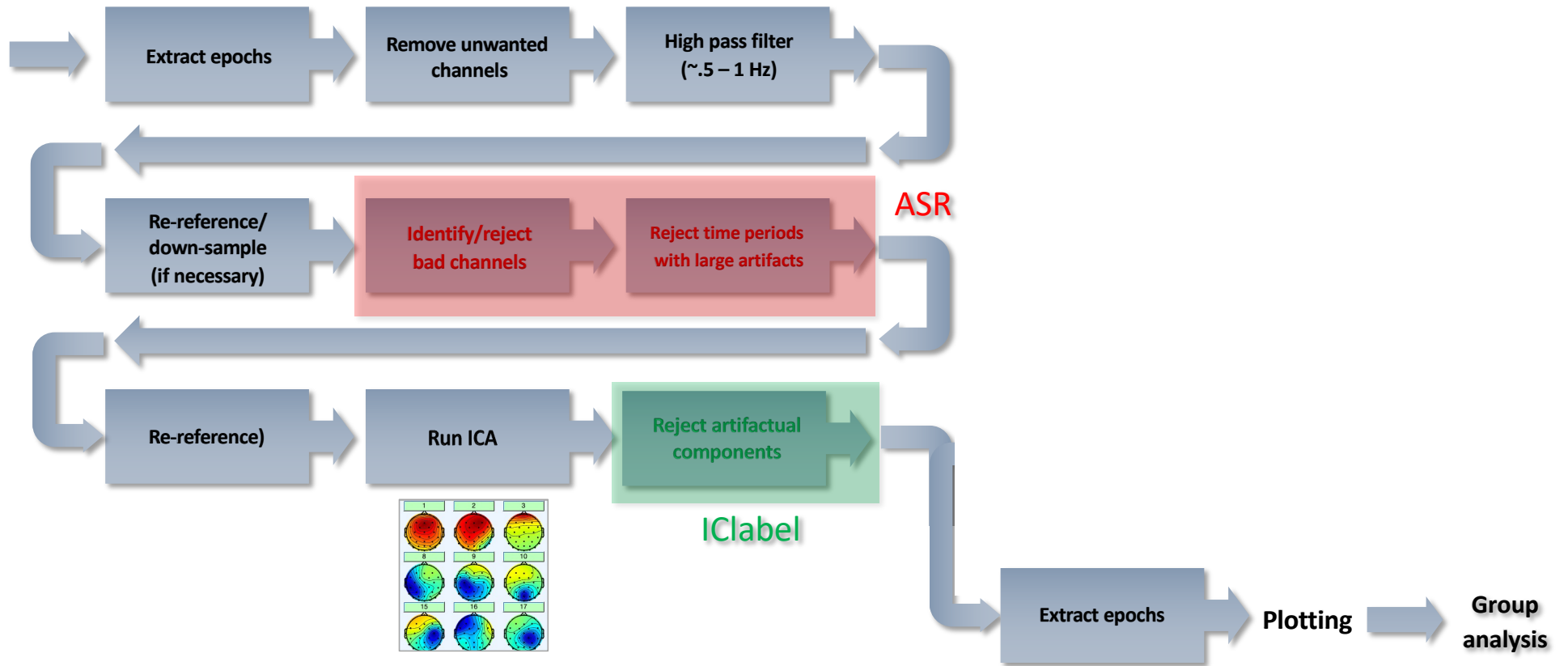
Tim R. Mullen, Christian Kothe, et al.(2015) Real-time neuroimaging and cognitive monitoring using wearable dry EEG. *IEEE Transactions on Biomedical Engineering*. DOI:10.1109/TBME.2015.2481482

# ICLabel: Automated ICA component labeling



Pion-Tonachini L et al. (2019) ICLabel: An automated electroencephalographic independent component classifier, dataset, and website. *Neuroimage*, 98:181-197. doi: 10.1016/j.neuroimage.2019.05.026.







# Extract epochs from data

The image illustrates the process of extracting epochs from EEG data in EEGLAB. It shows the 'Tools' menu with 'Extract epochs' selected, the 'Extract data epochs - pop\_epoch()' dialog box, and a plot of EEG data with epochs highlighted in orange.

**EEGLAB v13.x (dev) Tools Menu:**

- Change sampling rate
- Filter the data
- Re-reference
- Interpolate electrodes
- Reject continuous data by eye
- Extract epochs**
- Remove baseline
- Run ICA
- Remove components
- Automatic channel rejection
- Automatic continuous rejection
- Automatic epoch rejection
- Reject data epochs
- Reject data using ICA
- Remove artifacts using ACSTP
- Clean continuous data using ASR
- Locate dipoles using DIPFIT 2.x
- LIMO EEG 2.0

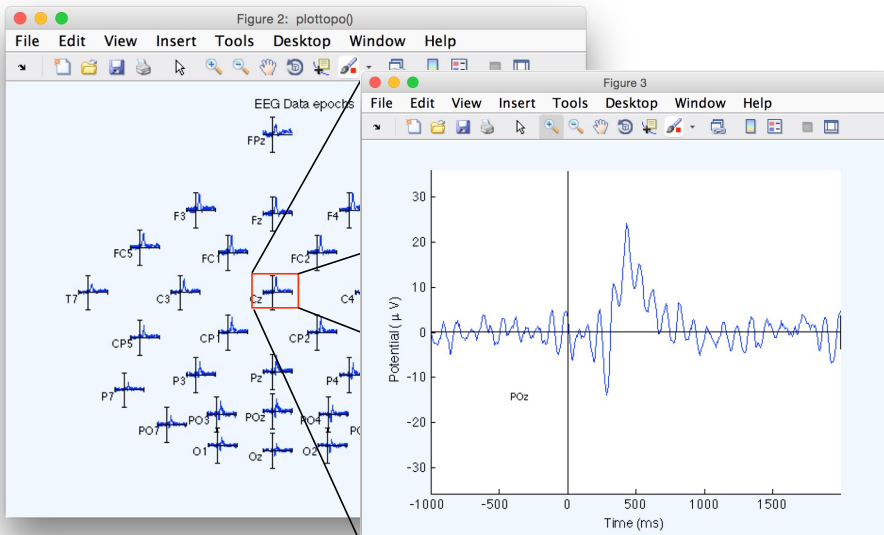
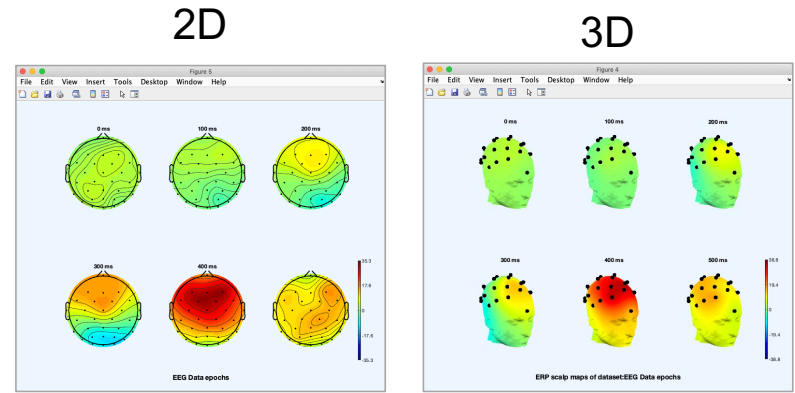
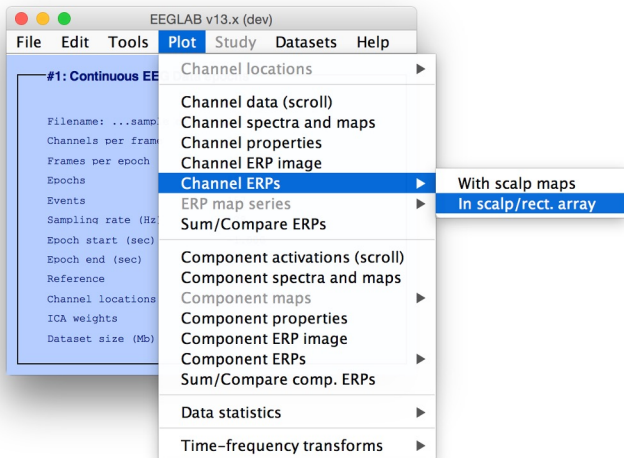
**Extract data epochs - pop\_epoch() Dialog Box:**

- Time-locking event type(s) ([])=all: square
- Epoch limits [start, end] in seconds: -1 2
- Name for the new dataset: Continuous EEG Data epochs
- Out-of-bounds EEG limits if any [min max]:
- Buttons: Help, Cancel, Ok

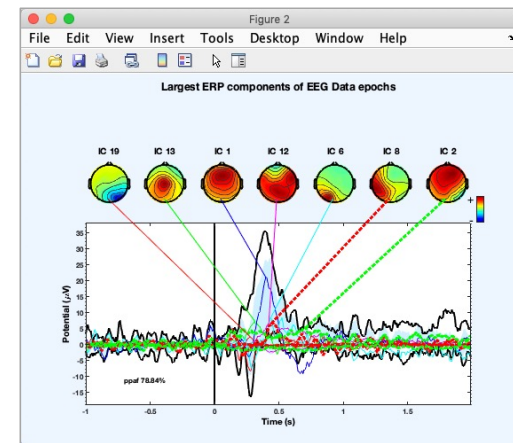
**EEG Data Plot:**

The plot shows multiple channels of EEG data. The x-axis represents time, and the y-axis represents channels. Vertical orange bars highlight specific epochs of data. The y-axis labels include: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100.

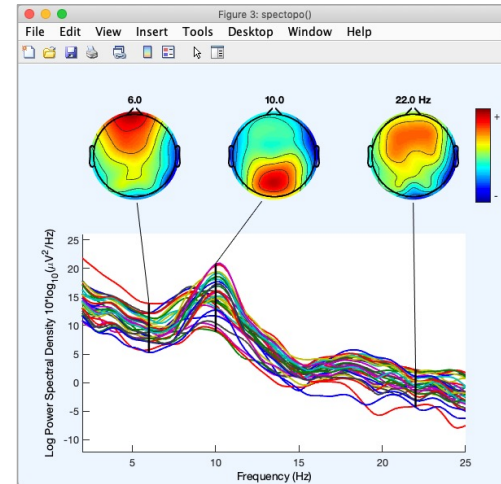
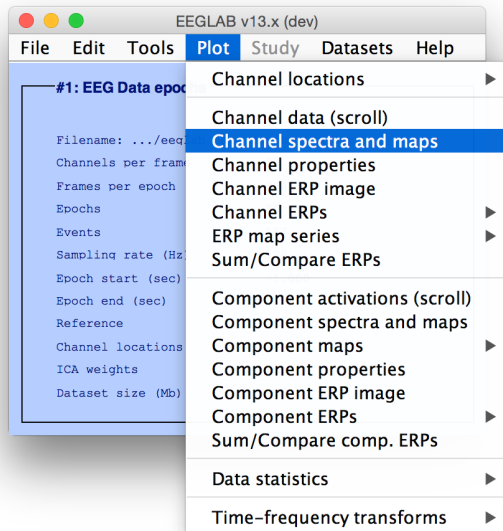
# Plot ERPs



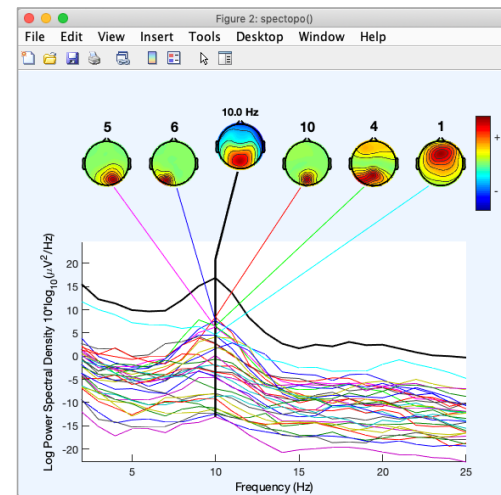
## Component contrib. to ERPs



# Plot spectrum and maps

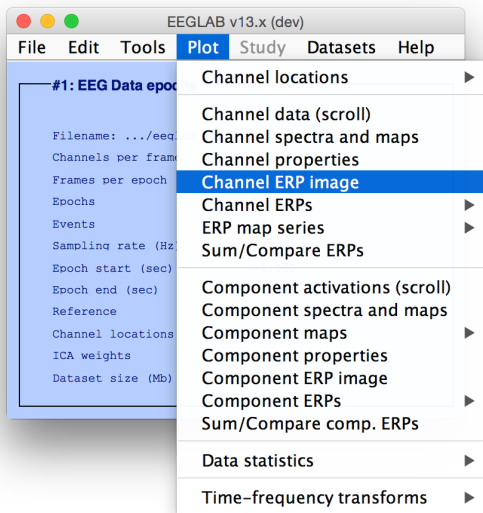


Channel spectrum

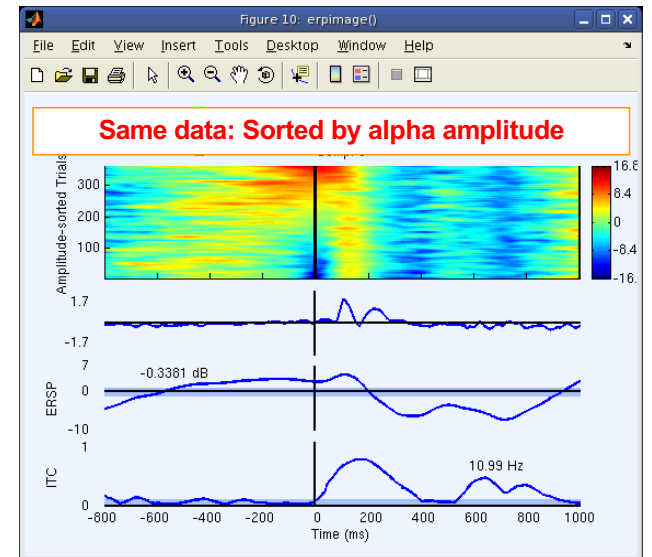
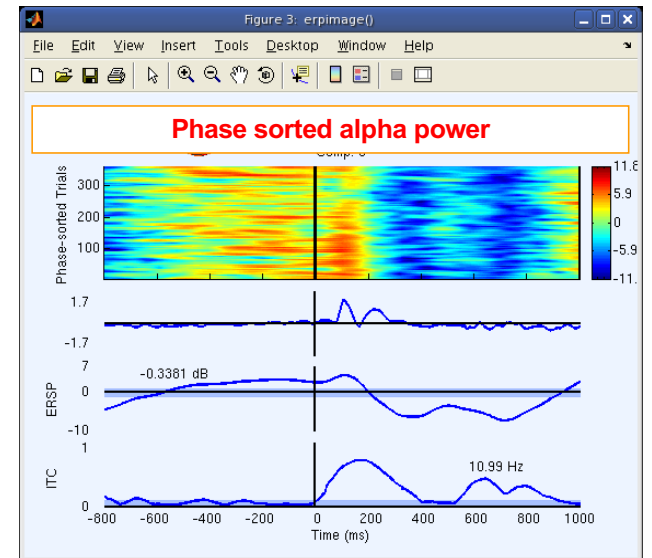
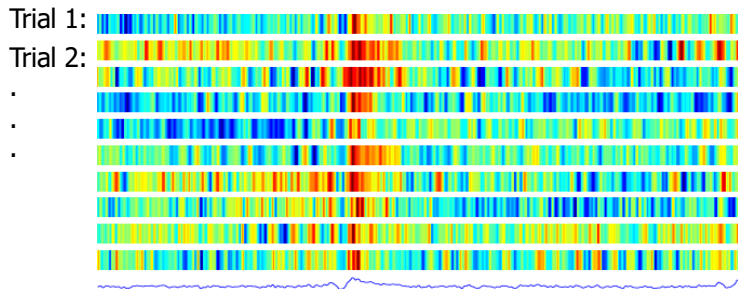
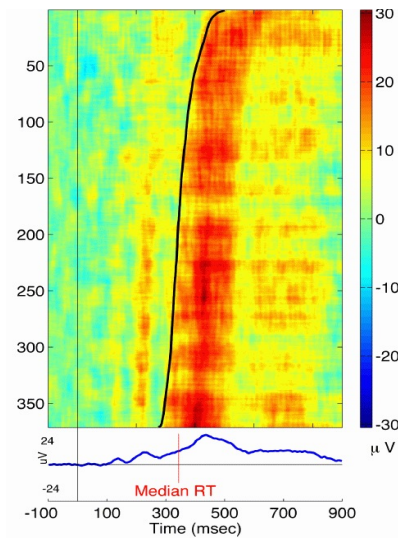


Component contrib. to spectrum

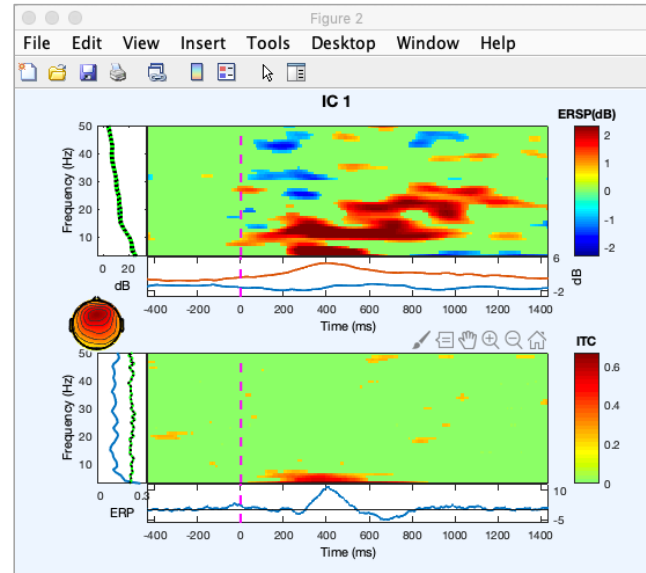
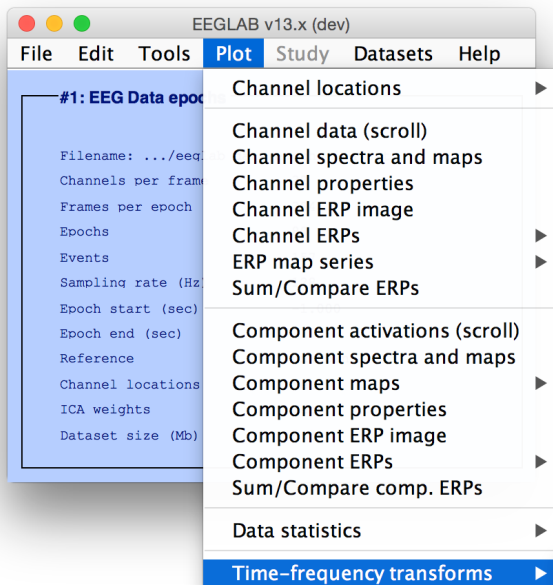
# Plot ERPimage



Trials sorted by reaction time

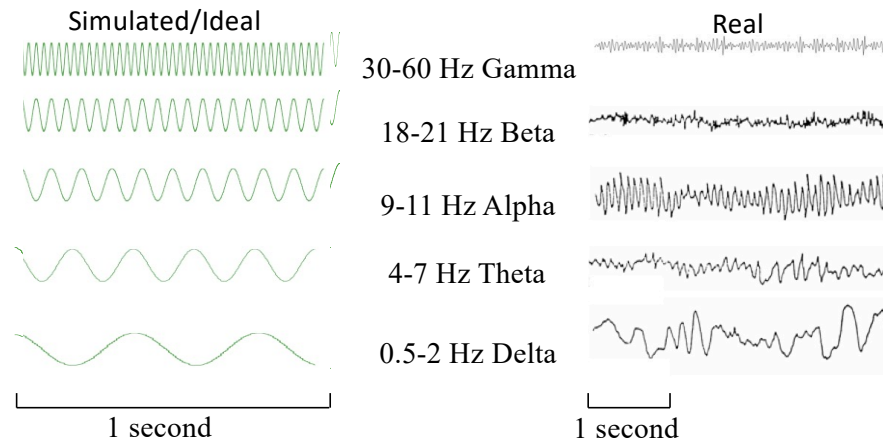


# Plot time-frequency decomposition

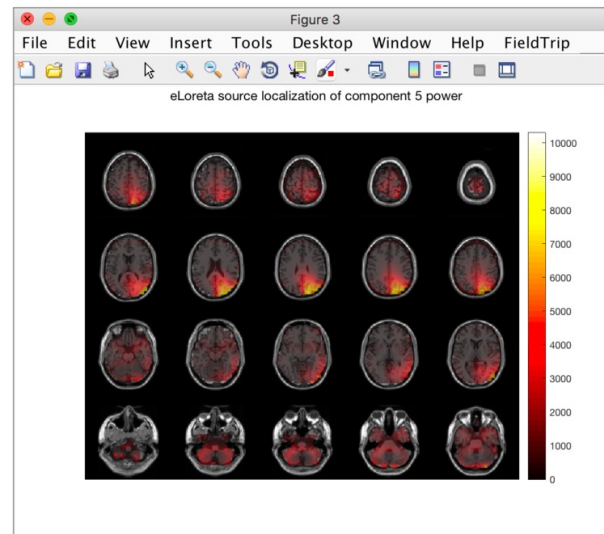
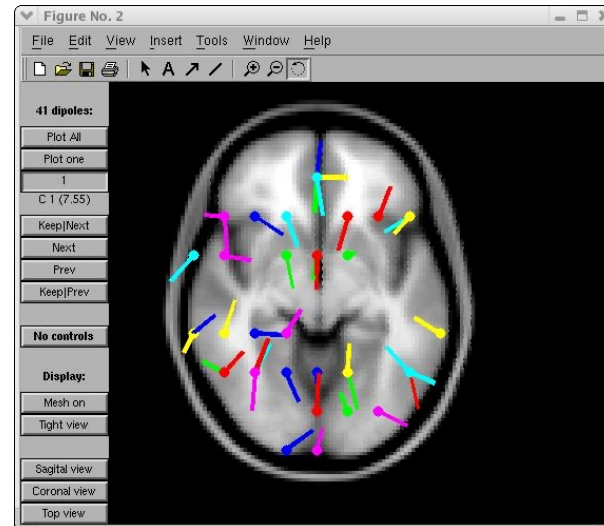
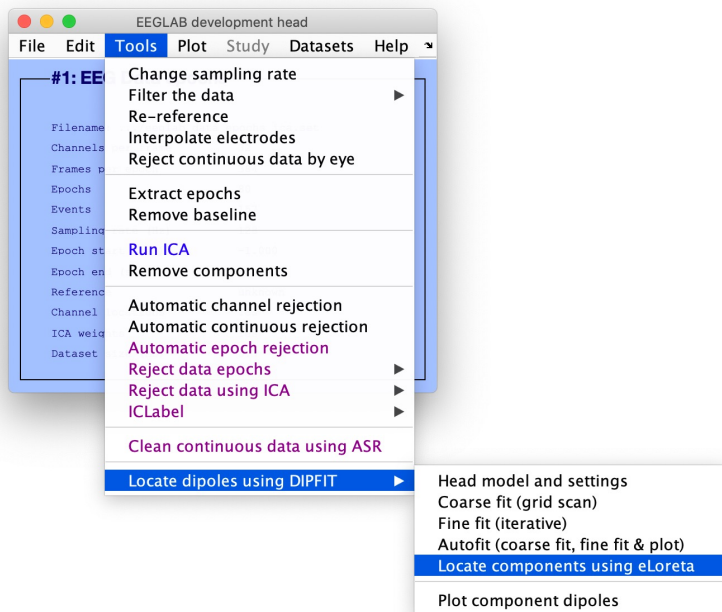


ERSP

ITC

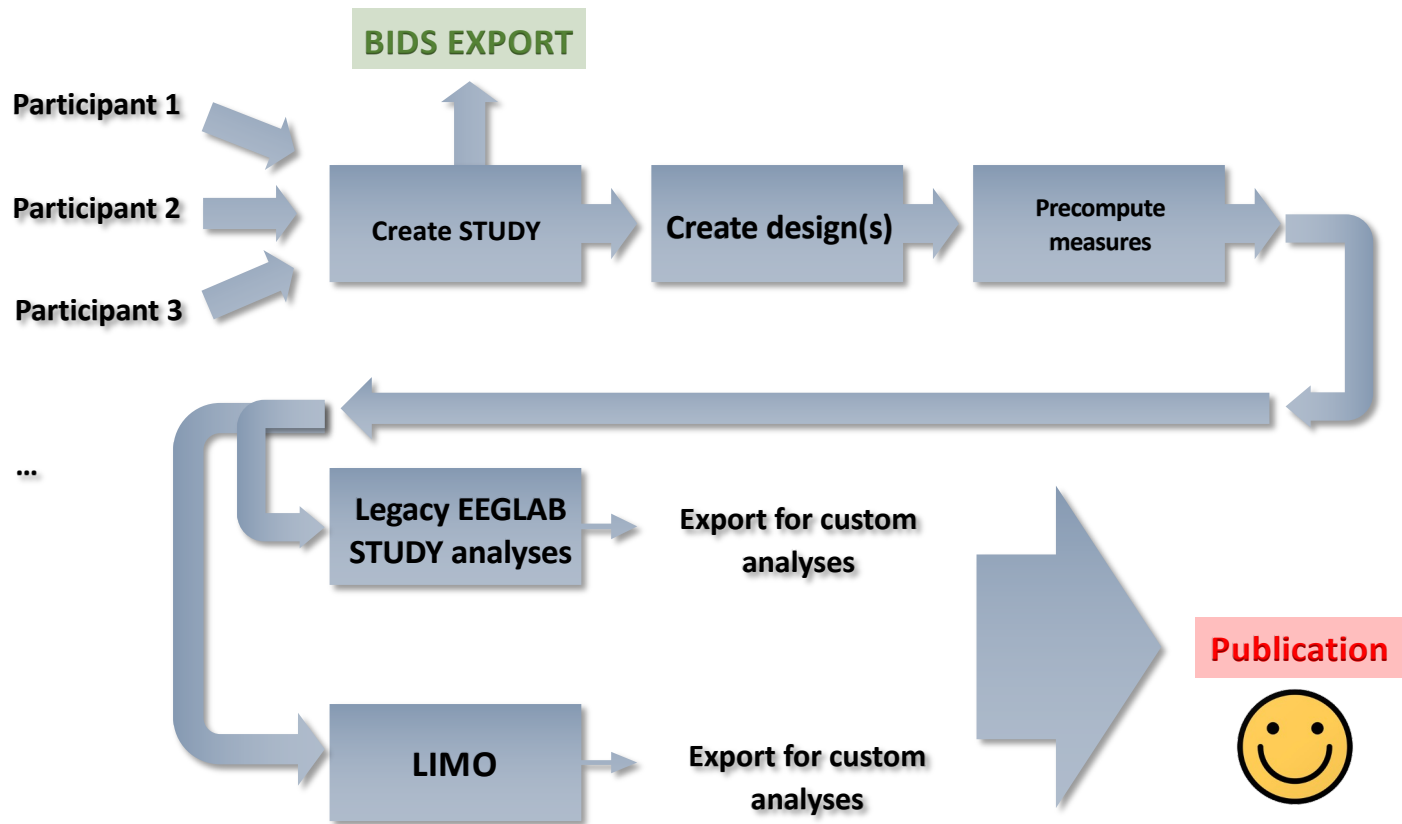


# Localizing components





# Group analysis pipeline



# EEGLAB and BIDS

- Export EEGLAB STUDY to BIDS
- Import BIDS to EEGLAB STUDY
- HED support
- Mapping the BIDS architecture

<https://github.com/scn/bids-matlab-tools>

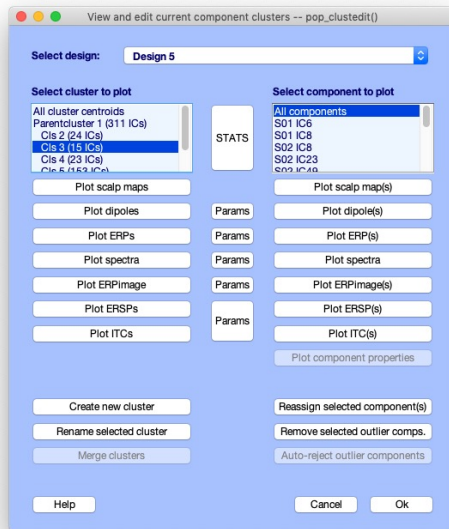
## OpenNeuro BIDS repository website

The screenshot shows the OpenNeuro BIDS repository website for an EEG meditation study. The page is titled "EEG meditation study" and is uploaded by Arnaud Delorme on 2019-03-09. It features a "Download" button and a "BIDS Validation" section showing a "Valid" status with 2 warnings. The "Dataset File Tree" on the right lists various files and folders, including "code", "stimuli", "sub-001" through "sub-012", "README", "task-meditation\_events.json", "participants.json", "participants.tsv", "dataset\_description.json", and "changes". The main content area includes sections for "Available Tasks", "Available Modalities", "README", "AUTHORS", "DATASET DOI", "LICENSE", "ACKNOWLEDGEMENTS", "HOW TO ACKNOWLEDGE", "FUNDING", and "REFERENCES AND LINKS".

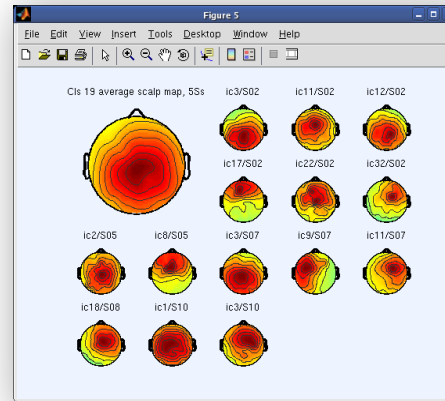


# Group analyze channel/component clusters

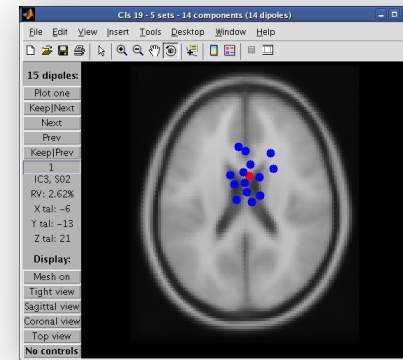
Plotting interface



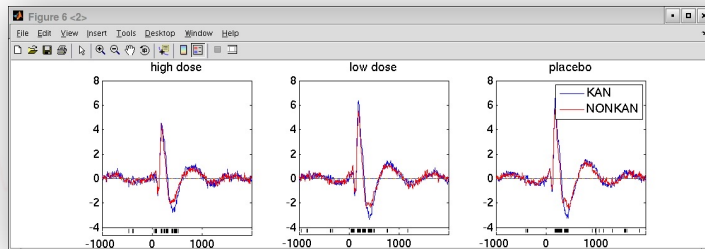
Components making up a cluster



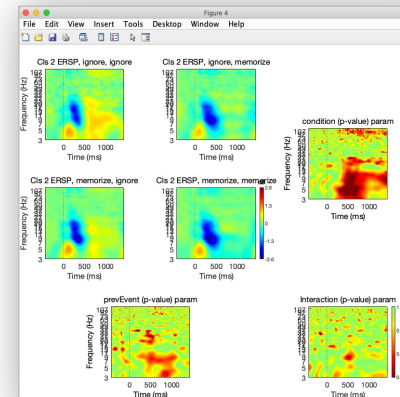
One cluster component dipoles



One cluster ERPs (2x3 conditions)

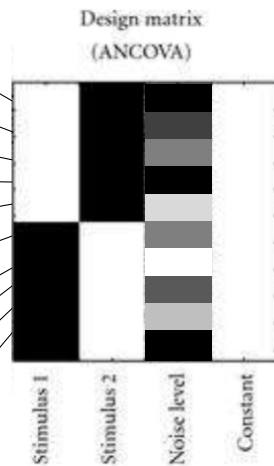
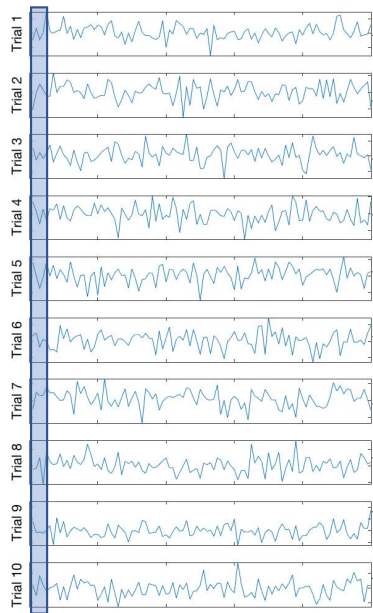


One cluster ERSPs (2x2 conditions)

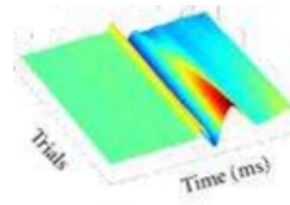


# Linear Modeling of EEG data: level 1

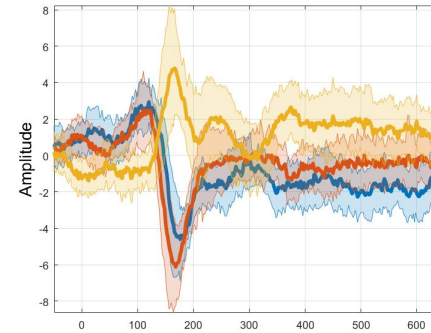
Electrode 1



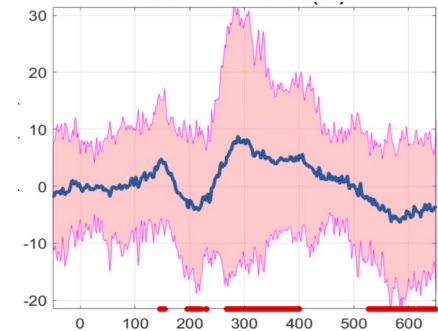
Continuous var.



Categorical var.



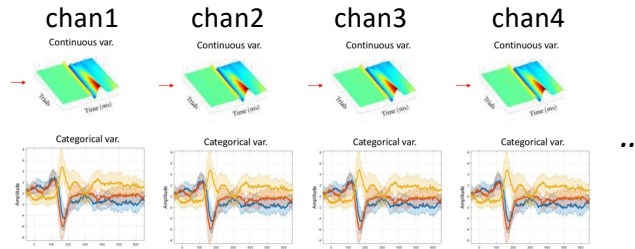
Electrode difference  
Between conditions



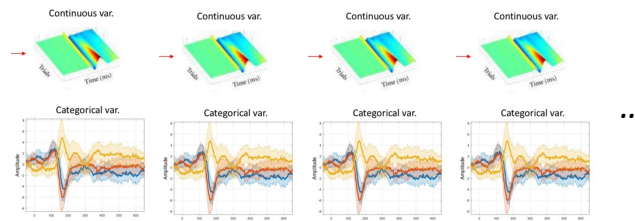
**Significance:** bootstrap trials to get confidence interval of  $\beta$ s

# Linear Modeling of EEG data: level 2

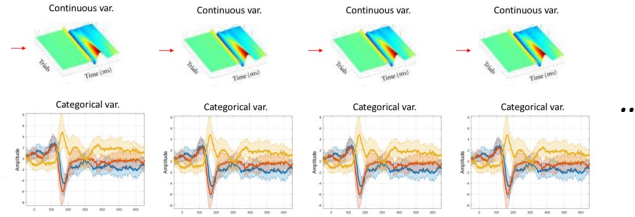
## Participant 1



## Participant 2



## Participant 3



...

## Level 2

Standard stats.  
2<sup>nd</sup> level-GLM

**GLM:** ordinary least square (OLS) vs.  
weighted least square (WLS)

# EEGLAB automatically writes scripts for you

- Automated processing pipelines
- Exporting data and results
- Custom processing
- Tight integrations with other tools
  - Fieldtrip back and forth conversion
  - Python integration for Deep Learning

## Raw data preprocessing

```
datainfo;
pop_editoptions('option_storedisk', 1);
outputEEGFolder = 'preprocessed_data';
if ~exist(outputEEGFolder), mkdir(outputEEGFolder); end;

for iSubj = 1:length(sInfo)

    % load dataset
    EEG = pop_biosig(sInfo(iSubj).file);
    EEG.setname = sInfo(iSubj).name;

    % preprocess data
    chanFile = 'plugins/dipfit2.3/standard_BEM/elec/standard_1005.elc';
    EEG = pop_chanedit(EEG, 'lookup', fullfile(fileparts(which('eeqlab.m'))), chanFile);
    EEG = pop_iirfilt(EEG, 0.5, 0, [], 0, 0); % high pass filtering
    EEG = pop_iirfilt(EEG, 0, 55, [], 0, 0); % low pass filtering
    EEG = pop_select(EEG, 'nochannel', sInfo(iSubj).bad_channels); % remove bad channels
    EEG = pop_reref(EEG, []); % average reference (optional)
    EEG = eeg_regrj(EEG, sInfo(iSubj).bad_data); % remove bad portions of data

    % run ICA
    EEG = pop_runica(EEG, 'icatype', 'sob');

    % tag bad components
    EEG = pop_findmatchingregrjcomps(EEG, 'matchcomps', sInfo(iSubj).bad_comps, 'corrthresh', 0.92);

    % extract data epochs
    EEG = pop_epoch(EEG, { 2 4 }, [-1 2]);

    % save dataset
    EEG.saved = 'no';
    EEG = pop_saveset(EEG, 'filepath', outputEEGFolder, 'filename', [ sInfo(iSubj).name '.set' ]);
end
```

## Group level analysis

```
datainfo;
pop_editoptions('option_storedisk', 1);
outputEEGFolder = 'preprocessed_data';
studyCommand = {};

% generate STUDY commands
for iSubject = 1:length(sInfo)
    fileName = fullfile(outputEEGFolder, [ sInfo(iSubject).name '.set' ]);
    studyCommand = [ studyCommand { 'index' iSubject 'load' fileName 'subject' ...
        sInfo(iSubject).name } ];
end;

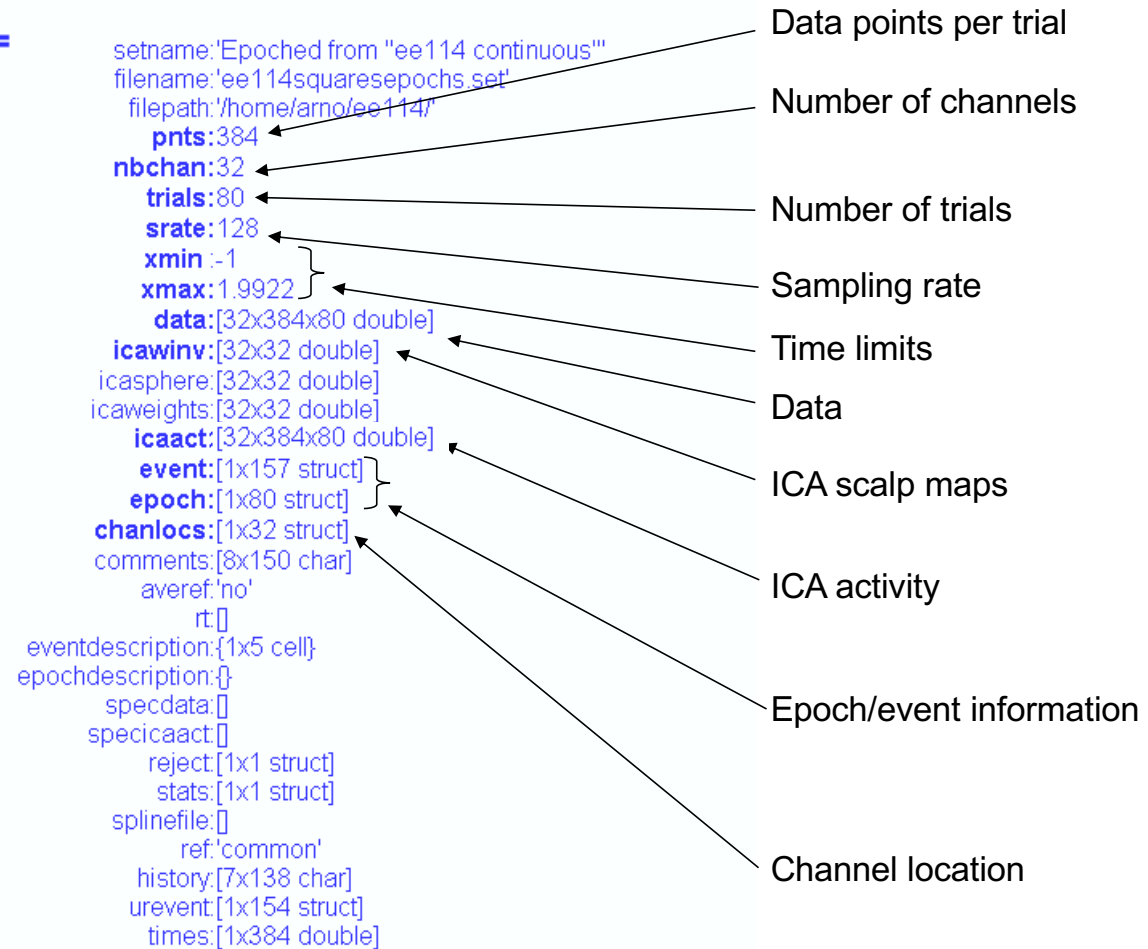
% create data
[STUDY ALLEEG] = std_editset([], [], 'name', 'test', 'commands', studyCommand, ...
    'updatedat', 'off', 'filename', 'test_study', 'resave', 'on');
STUDY = std_makedesign(STUDY, ALLEEG, 1, 'name', 'STUDY_design 1', 'delfiles', 'off', ...
    'defaultdesign', 'off', 'variable', 'type', 'values', {'2' '4'});

% update workspace variables and redraw EEGLAB
CURRENTSTUDY = 1; EEG = ALLEEG; CURRENTSET = [1:length(EEG)];
[STUDY, ALLEEG] = std_checkset(STUDY, ALLEEG);
eeglab redraw

% precompute and plot data
allchanlocs = eeg_mergelocs(ALLEEG.chanlocs);
[STUDY ALLEEG] = std_precomp(STUDY, ALLEEG, {}, 'interp', 'on', 'recompute', 'on', 'erp', 'on');
STUDY = pop_statparams(STUDY, 'condstats', 'on', 'singletrials', 'on', 'mode', 'fieldtrip', ...
    'fieldtripmethod', 'montecarlo', 'fieldtripcorrect', 'cluster');
[STUDY erp] = std_erpplot(STUDY, ALLEEG, 'channels', {allchanlocs.labels}, 'topotime', [300 400]);
print results.eps -depsc
```

# The EEGLAB main structure is simple

EEG =



## BIDS meta-data analysis

	README	Task Description	Instructions	Event Description	EEG Reference	Power Line Frequency	Channel Types	Electrode Locations	Participants' Age and Gender	Subject Artefact Description	Event Consistency	Channel Consistency	Aggregated Score
ds000117													0.18
ds001784													0.73
ds001787													0.67
ds001810													0.75
ds001849													0.45
ds001971													0.83
ds002034													0.58
ds002094													0.45
ds002158													0.33
ds002218													0.67
ds002336													0.36
ds002338													0.36
ds002578													0.75
ds002680													0.67
ds002691													0.75
ds002718													0.83
ds002720													0.5
ds002721													0.5
ds002722													0.42
ds002723													0.42
ds002724													0.42
ds002725													0.42
ds002778													0.45
ds002791													0.45
ds002833													0.64
ds002893													0.83
ds003061													0.83
ds003190													0.55
ds003194													0.45
ds003195													0.55

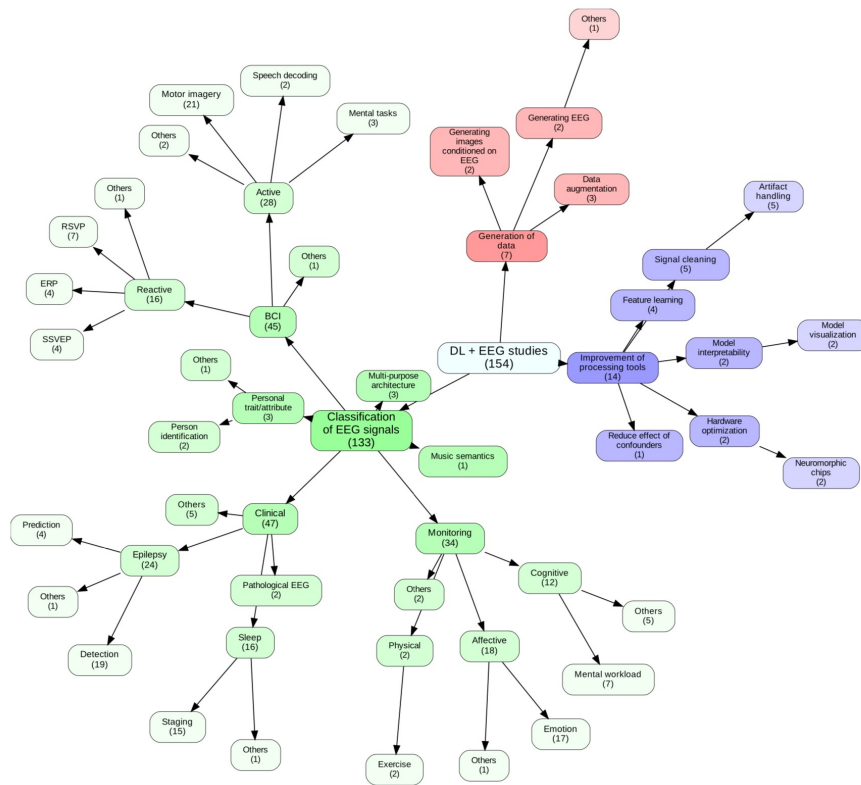


## BIDS data analysis

Dataset	n	Flat	Chan.	Good chan.	Good data	Brain ICs
ds000117	84	-	74	89 - 90	68 - 78	28 - 32
ds001784	30	-	60	85 - 92	63 - 77	5 - 11
ds001787	40	-	64	93 - 95	85 - 90	24 - 30
ds001810	263	-	64	78 - 80	71 - 74	35 - 37
ds001849	120	-	30	86 - 88	66 - 70	41 - 45
ds001971	273	-	112*	91 - 95	81 - 84	8 - 10
ds002034	167	21	62	95 - 98	47 - 52	29 - 33
ds002094	43	-	30	88 - 93	66 - 77	37 - 45
ds002158	8	-	63	80 - 86	19 - 66	11 - 23
ds002218	18	-	32	94 - 97	66 - 78	35 - 46
ds002336	54	1	63	81 - 83	74 - 89	33 - 39
ds002338	85	-	63	74 - 77	87 - 95	24 - 28
ds002578	2	-	18	78 - 89	96 - 97	46 - 60
ds002680	350	-	19	92 - 93	81 - 84	53 - 56
ds002691	20	-	32	93 - 97	82 - 87	30 - 40
ds002718	18	-	74	95 - 96	58 - 76	20 - 28
ds002720	165	-	19	93 - 95	68 - 72	52 - 56
ds002721	185	-	19	95 - 96	67 - 72	45 - 49
ds002722	94	-	32	92 - 95	63 - 70	36 - 39
ds002723	44	-	32	95 - 97	66 - 76	36 - 40
ds002724	96	-	32	94 - 96	72 - 77	35 - 39
ds002725	105	-	31	90 - 94	80 - 85	53 - 58
ds002778	46	-	32	90 - 95	68 - 78	41 - 48
ds002791	92	-	256	90 - 92	62 - 70	6 - 7
ds002833	80	-	256	91 - 94	82 - 88	6 - 8
ds002893	55	12	36	89 - 93	76 - 83	29 - 37
ds003061	39	-	64	84 - 89	86 - 92	22 - 28
ds003190	384	2	8	81 - 83	89 - 91	74 - 78
ds003194	29	-	19	93 - 97	90 - 95	72 - 79
ds003195	20	-	19	90 - 97	89 - 94	65 - 76



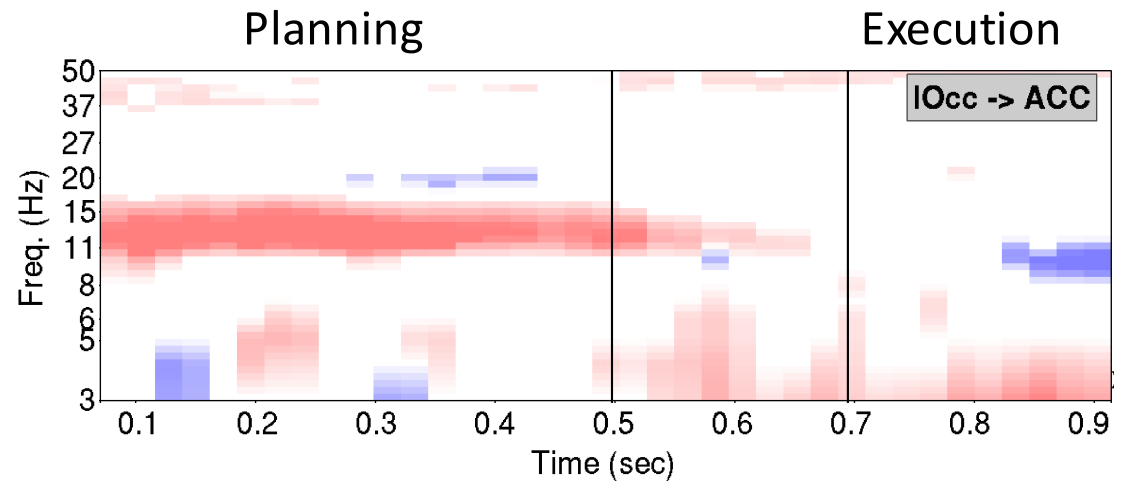
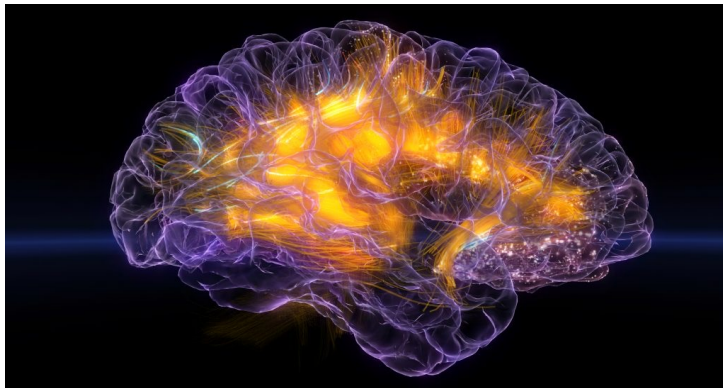
# BIDS-DL



Roy Y, Banville H, Albuquerque I, Gramfort A, Falk TH, Faubert J. Deep learning-based electroencephalography analysis: a systematic review. *J Neural Eng.* 2019 Aug 14;16(5):051001. doi: 10.1088/1741-2552/ab260c. PMID: 31151119.

# Brain connectivity in SIFT/EEGLAB

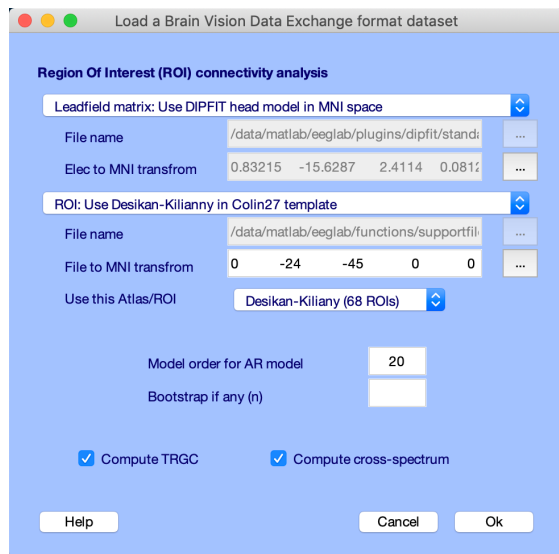
## Occipital -> ACC



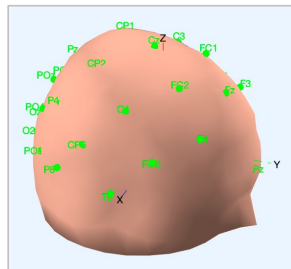
John R. Iversen, Alejandro Ojeda, Tim Mullen, Markus Plank, Joseph Snider, Gert Cauwenberghs, Howard Poizner (2014) EMBC Conference, Osaka, Japan.



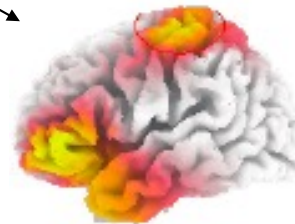
# New EEGLAB ROI connectivity plugin



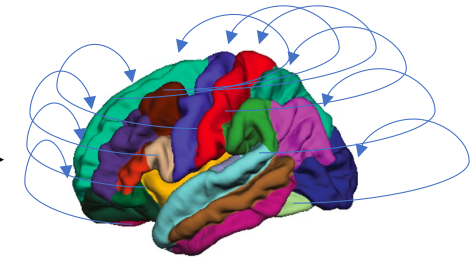
Align electrodes  
with scalp model



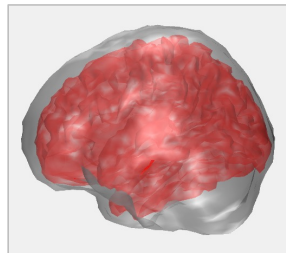
Distributed source  
modeling



Group voxels in regions  
and compute connectivity



Align atlas with  
cortex model



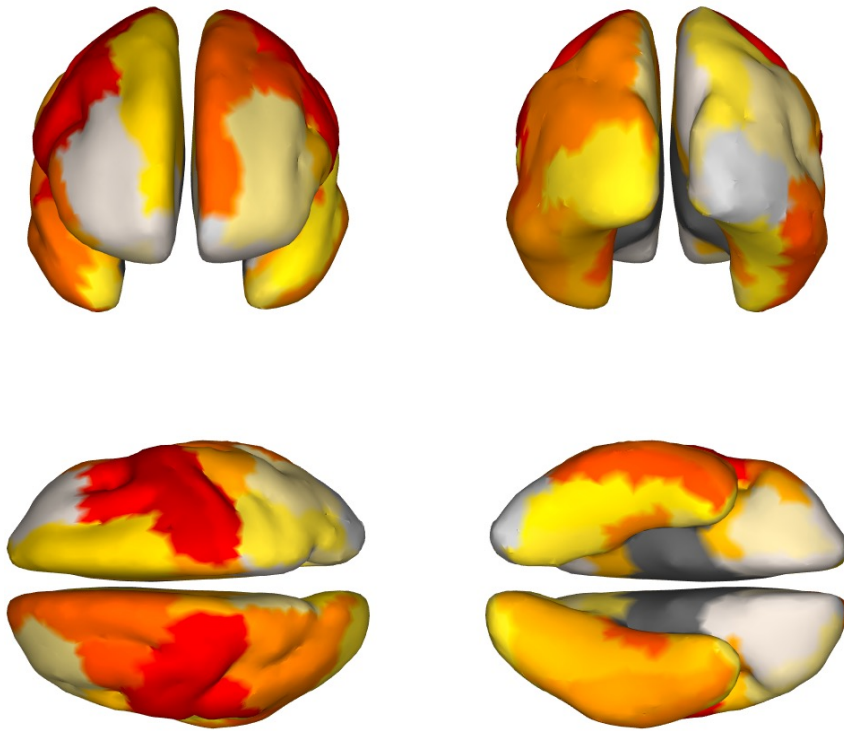
Measures **TRGC**, GC, TRPDC,  
PDC, TRDTF, DTF and **CS**



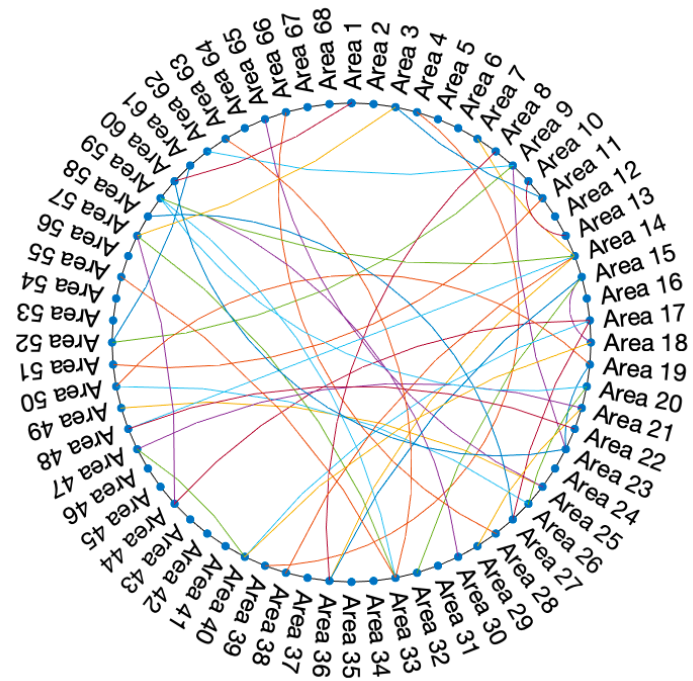
<https://github.com/arnodelorme/roiconnect>

Haufe, S., Nikulin, V. V., Miller, K. R., & Nolte, G. (2013). A critical assessment of connectivity measures for EEG data: a simulation study. *Neuroimage*, 64, 120-133.

Red regions are highly interacting

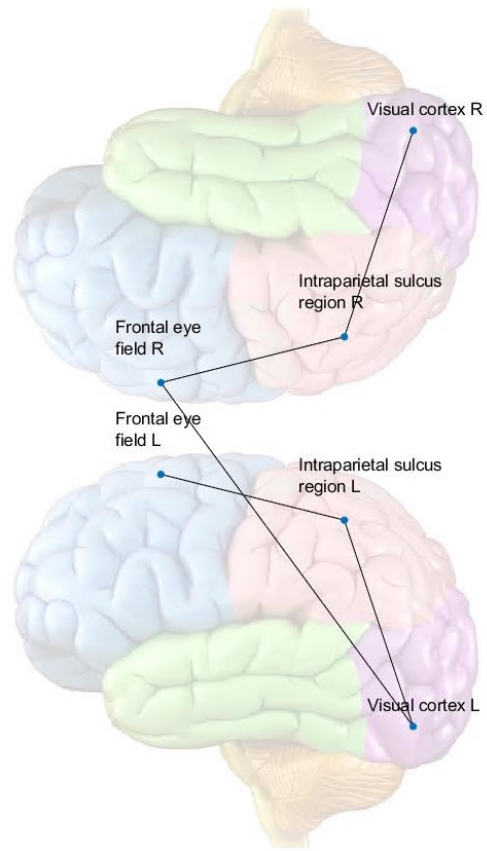


Connectivity matrix between 68 ROIs

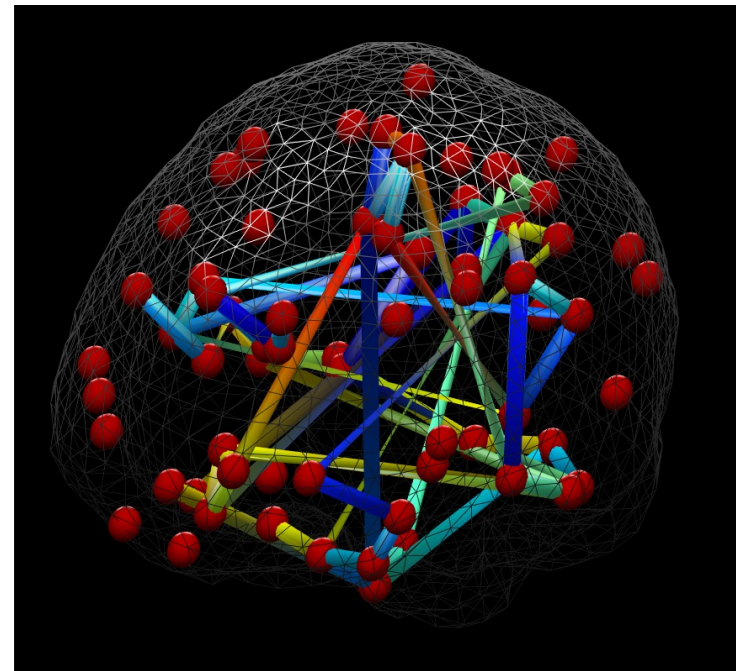


# Connectivity

## 2-D representations



## 3-D representations



# EEGLAB reference articles

**Delorme, A., Makeig, S. (2004) EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *Journal of Neuroscience Methods*, 134(1), 9-21.**

Makeig, S., Debener, S., Onton, J., Delorme, A. (2004) Mining event related dynamics. *Trends in cognitive Neuroscience*, 8(5), 204-210.

Delorme, A., Mullen, T., Kothe, C., Bigdely-Shamlo, N., Akalin, Z., Vankov, A., Makeig, S. (2011) EEGLAB, MPT, NetSIFT, NFT, BCILAB, and ERICA: New tools for advanced EEG/MEG processing. *Computational Intelligence*, article ID 130714.

Delorme, A., Kothe, C., Bigdely, N., Vankov, A., Oostenveld, R., Makeig, S. (2010) Matlab Tools for BCI Research? In "human-computer interaction and brain-computer interfaces". Editors : Tan, D. and Nijholt, A. Springer Publishing.

Delorme, A., Makeig, S. (2009) Open Source Programming for Interpreted Language: Graphic Interface and Macro Bridging Interface. 2009 Fifth International Conference on Signal-Image Technology & Internet-Based Systems (SITIS, indexed in IEEE), Nov. 29 2009-Dec. 4 2009, 430-434.

Delorme, A., Palmer, J., Onton, J., Oostenveld, R., Makeig, S. (2012) Independent EEG sources are dipolar. *PLoS One*, 7(2).

Delorme, A., Miyakoshi, M., Jung, T.P., Makeig, S. (2014) Grand average ERP-image plotting and statistics: A method for comparing variability in event-related single-trial EEG activities across subjects and conditions. *J Neurosci Methods*. 2014 Oct 22. pii: S0165-0270(14)00363-X. doi: 10.1016/j.jneumeth.2014.10.003

