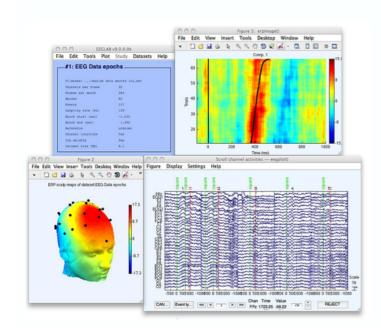
EEGLAB overview

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- Collection of about 600 functions (70 000 lines of code)
- About 100 000 download over the past 10 years
- 6 500 users on the discussion list and 10 500 on the diffusion list
- NIH funding since 2003

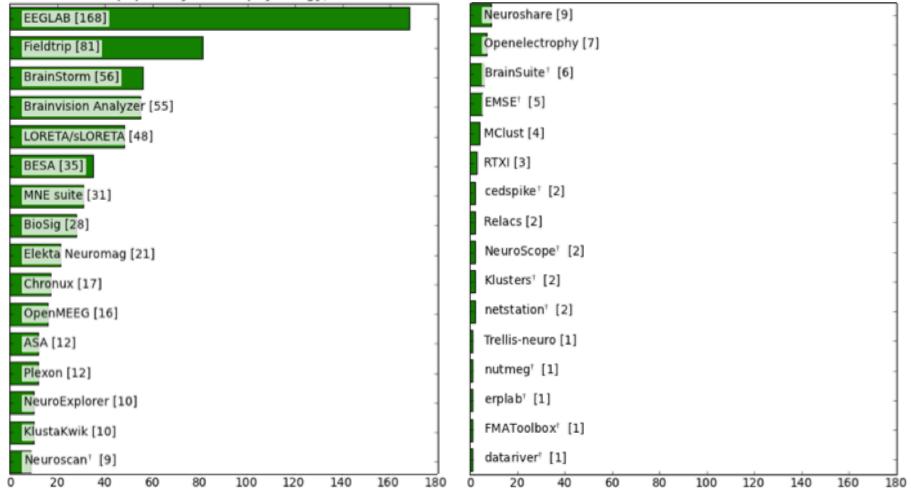
http://sccn.ucsd.edu/eeglab http://sccn.ucsd.edu/wiki/eeglab



Hanke & Helcencko, 2011, Frontier in Neuroinformatics

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Software popularity: Electrophysiology, MEG/EEG



EEGLAB standard processing pipeline

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Single subject

- 1. Import binary data, events and channel location
- 2. Edit, Re-reference, Resample, High pass filter data
- 3. Reject artifacts in continuous data by visual inspection
- 4. Extract epochs from data & reject artifactual epochs
- 5. Visualize data measures
- 6. Perform ICA decomposition
 - Perform source localization of components
 - Analyze components contribution to ERP
 - Analyze components contribution to spectrum

Multi-subjects

- 1. Build study and STUDY design
- 2. Pre-compute measures
- 3. Cluster components
- 4. Analyze clusters

Advanced analysis using scripting and EEGLAB command line functions

The EEGLAB Matlab software

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000 MATLAB R2012a File Edit Debug Parallel Window Desktop Ŋ. 0 2 E C¹ Shortcuts 🖪 How to Add 🛛 🖪 What's New >> >> >> >> >> >> >> >> >> >> >> >> >> >> >> >> $f_{\underline{x}} >> \text{ eeglab}$ 📣 Start

• •	\bigcirc	E	EGLAB	v13.x dev	,	
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	No cur	rent data	set —			
	-	Create a n	new or l	oad an ex	istina	
		Use "File	e > Impo	rt data"		
		Or "File	e > Load	existing	dataset"	
	-	If new,				
		"File > Im	port ep	och info"	(data	
		"File > Im	wort ev	ent info"	(continuous	
		"Edit > Da	taset i	nfo" (add	/edit	
		"File > Sa	ve data	set" (sav	e dataset)	
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		Reject dat				
		Epoch data				
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	-	Run ICA:	"Tool	s > Run I	CA"	
				•		

1. Importing data

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Import/load data

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Import epoch info D	From Biosemi .BDF file						
Import event info D	From European Data Format .EDF file						
Export D	From EGL.RAW file						
Load existing dataset	From Segmented EGI .RAW files						
Save current dataset	From BCI2000 ASCII file						
Save datasets	From Snapmaster .SMA file						
Clear dataset(s)	From Neuroscan .CNT file						
Maximize memory	From Neuroscan .EEG file						
Save history D	From ERPSS .RAW or .RDF file						
Quit	From Brain Vis. Anal. Matlab file						
Dataset size (Mb)	From CTF folder (MEG)						
	From ANT .CNT file						
	From ANT .AVR file						

Import events

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Import epoch info $\square >$	epochs
Import event info 🛛 🖂	From Matlab array or ASCII file
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Load existing dataset	From Presentation .LOG file
Save current dataset	75
Save datasets	75
Clear dataset(s)	128
Maximize memory	1.992
Save history D	No
Quit	Yes
ICH Weights	Yes
Dataset size (Mb)	14.9

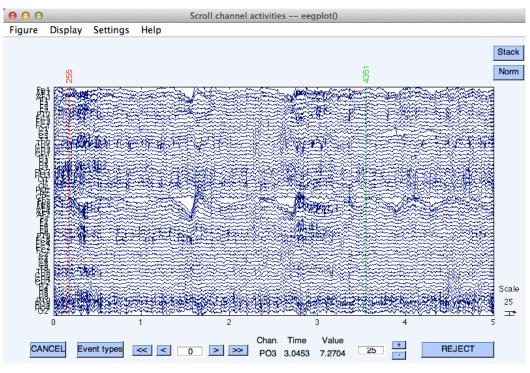


1. Importing data

Data info

File	Edit	Tools	Plot	Dataset	s Help	DTU Si	dekick	
_	#1: C	ontin	uous	EEG	Data			
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	Frames	per epo	och	30	504			
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	Events			154				
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ICA weights			No					
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Scrolling data

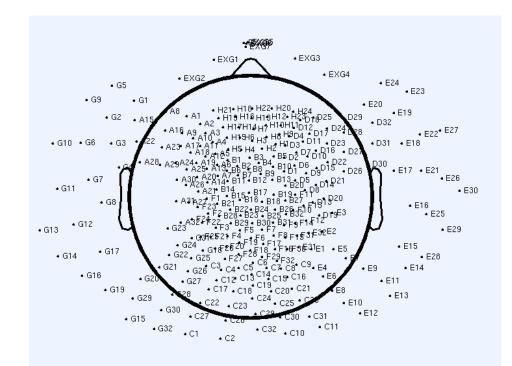


1. Importing channel location

Import channel location

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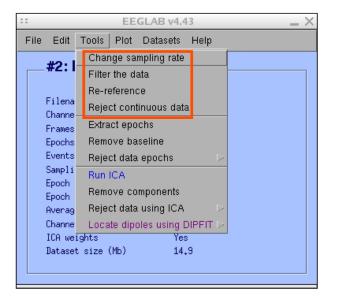


2. Edit, Re-reference, Resample, High pass filter data

Edit/select data

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Channel locations Yes ICA weights Yes Dataset size (Mb) 14.9								

Preprocessing data





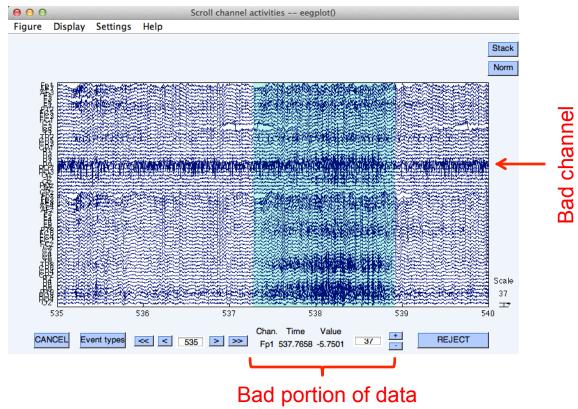
3. Reject artifacts in continuous data by visual inspection

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Data info

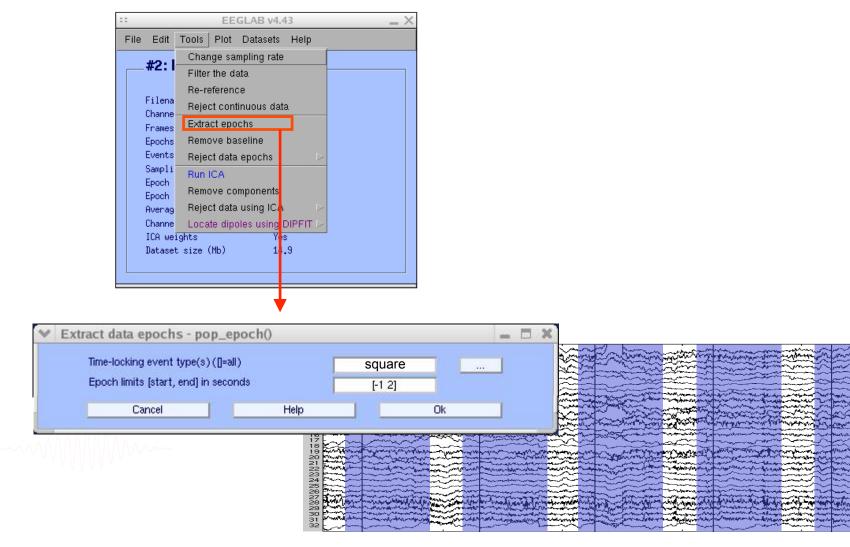
	EEGLAB v4.43
File Edit	Tools Plot Datasets Help
File Edit	Change sampling rate Filter the data Re-reference Reject continuous data Extract epochs Remove baseline Reject data epochs Reject data epochs
Avera Chann ICA w	9 Reject data using ICA 🕞

Reject portions of continuous data



4. Extract epochs from data & reject artifactual epochs

Preprocessing data

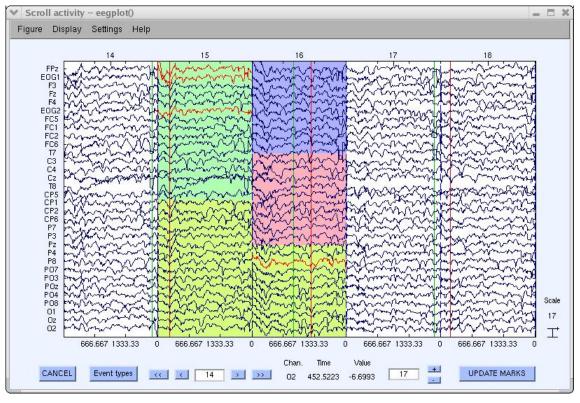


4. Extract epochs from data & reject artifactual epochs

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	1	Averag	Reje	ct data	using ICA		Þ	Reject flat line data	l
		Channe	Loca	ite dipo	oles using l	BESA	\triangleright	Reject by probabilit	ty
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			Filter	r the da	ata (IIR)			Reject marked epoc	chs

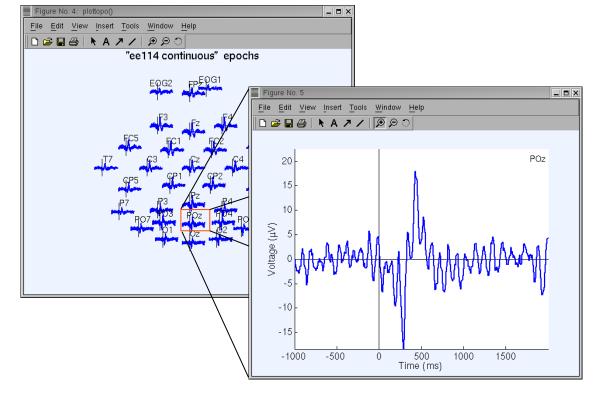
Different color = different rejection methods



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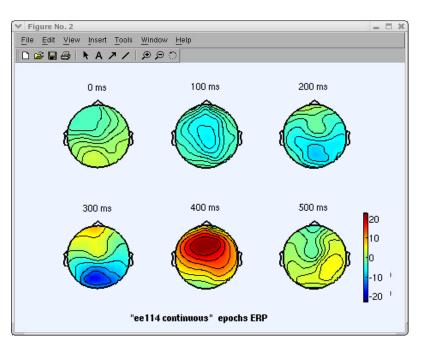
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	Average refere			
	Channel locat:	Component maps	\triangleright	
	ICA weights	Component properties		
	Dataset size '	Component ERP image		
		Component ERPs	\triangleright	
		Sum/Compare comp. ERPs		
		Data statistics	\triangleright	
		Time-frequency transforms	\triangleright	

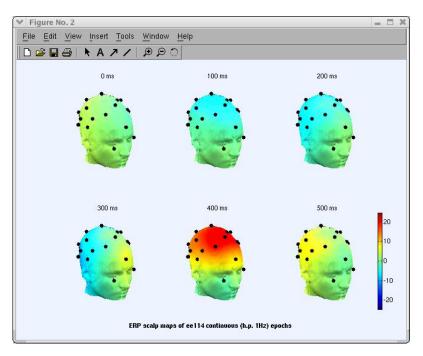
Plot ERP



Plot ERP map series

	EEGLAB v4.43	_ ×
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#1. EEG I	Channel data (scroll)	
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Average refere		
Channel locat:	Component maps 🕞	
ICA weights	Component properties	
Dataset size •	Component ERP image	
	Component ERPs	
	Sum/Compare comp. ERPs	
	Data statistics 🛛 🕞	
	Time-frequency transforms	

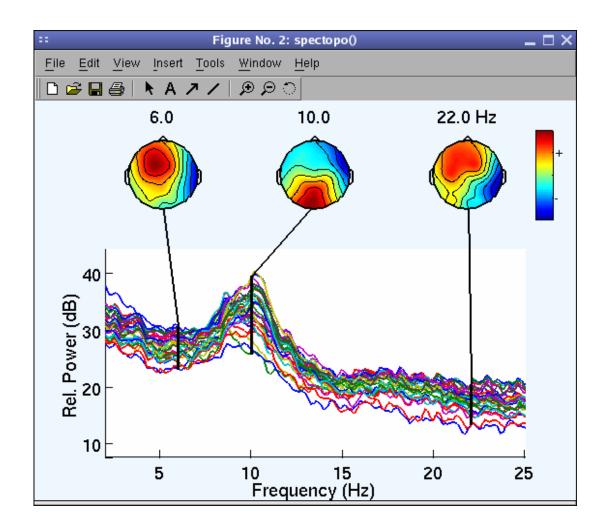




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Plot data spectrum and maps

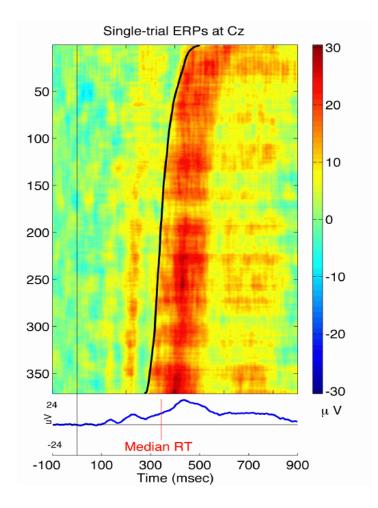
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Plot channel ERPimage

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	Data statistics D
	Time-frequency transforms



EEGLAB standard processing pipeline

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Single subject

- 1. Import binary data, events and channel location
- 2. Edit, Re-reference, Resample, High pass filter data
- 3. Reject artifacts in continuous data by visual inspection
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- 6. Perform ICA decomposition
 - Perform source localization of components
 - Analyze components contribution to ERP
 - Analyze components contribution to spectrum

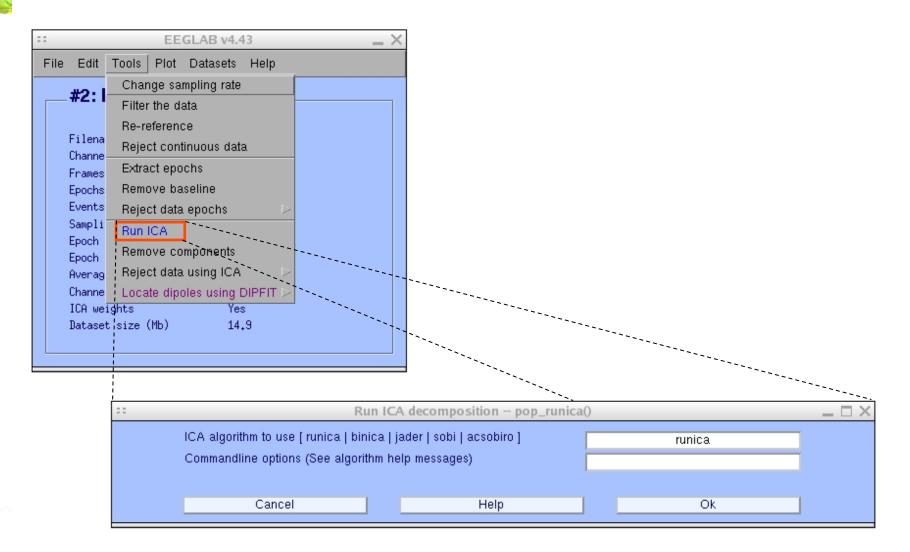
Multi-subjects

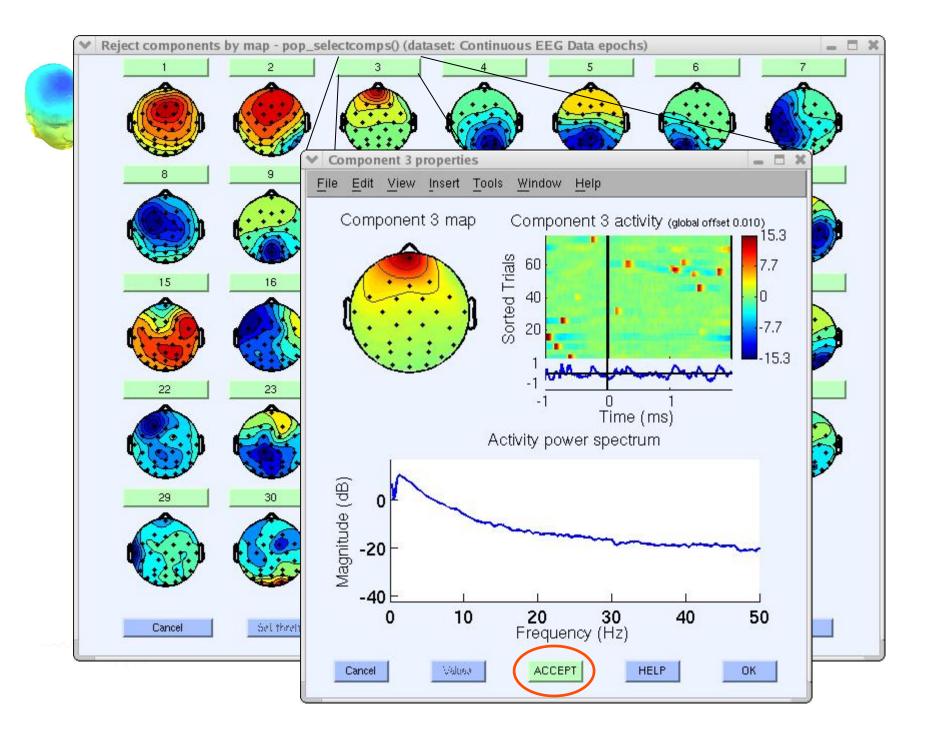
- 1. Build study
- 2. Pre-compute measures
- 3. Cluster components
- 4. Analyze clusters

Advanced analysis using scripting and EEGLAB command line functions

6. Perform ICA decomposition

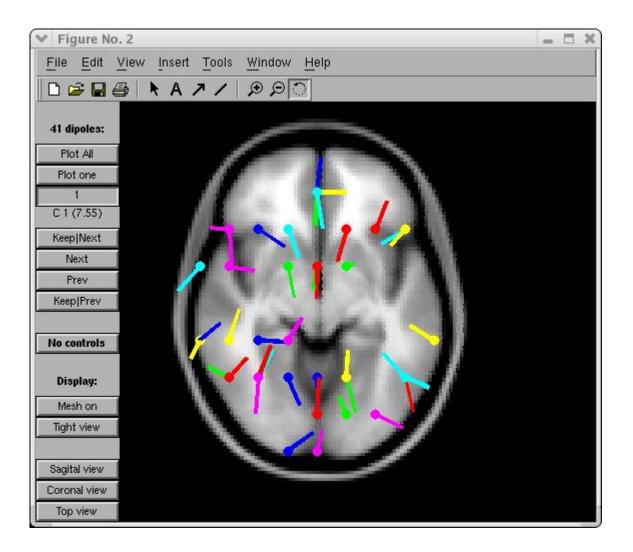
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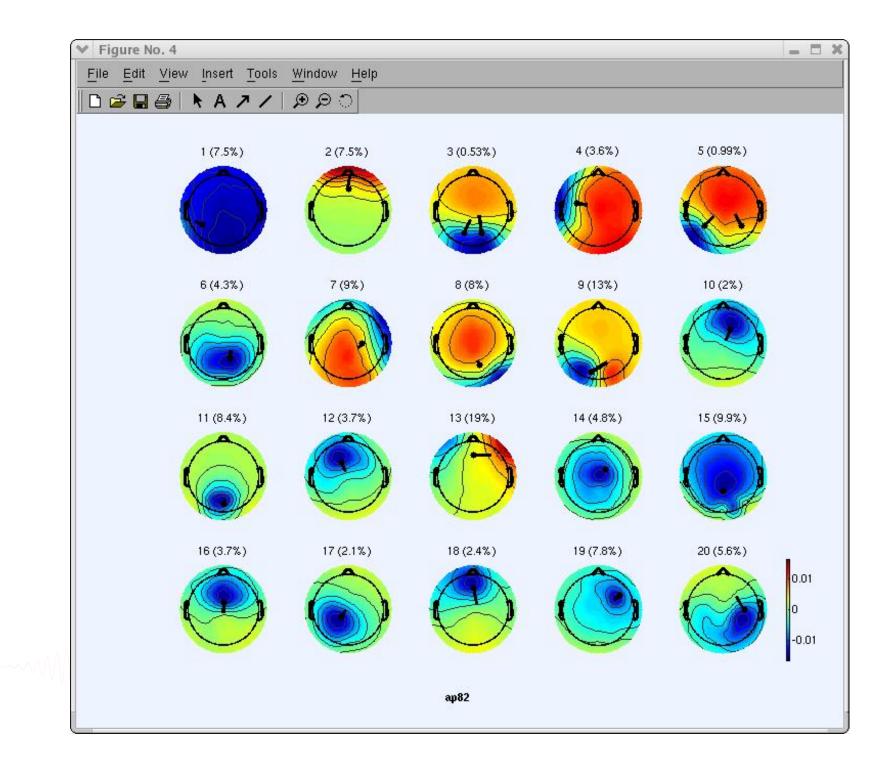




	EEGLAB v4.43	_ × _
File Edit	Tools Plot Datasets Help	
Filena Channe Frames Epochs Events Sampli Epoch Averag	Change sampling rate Filter the data Re-reference Reject continuous data Extract epochs Remove baseline Reject data epochs Run ICA Remove components Reject data using ICA	
Channe ICA we Datase	Locate dipoles using DIPFIT (* ights Yes t size (Mb) 15,9	Autofit components Head model and setting Coarse fit (grid scan) Fine fit (iterative)
		Plot component dipoles

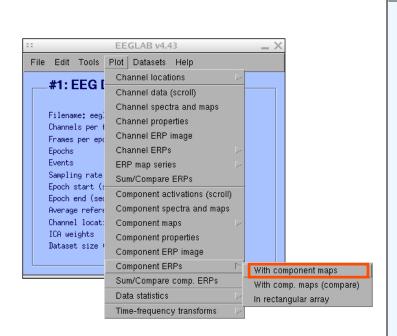






Component contribution to the ERP

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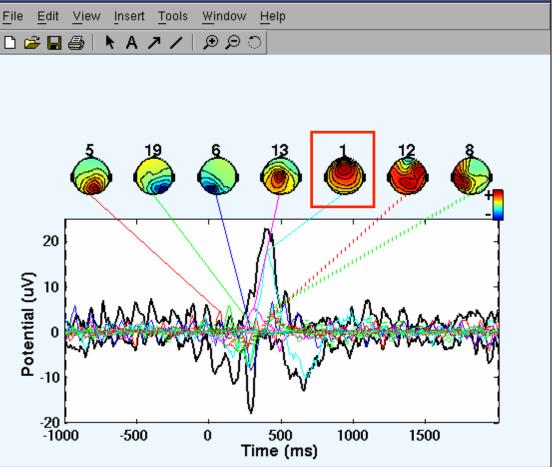
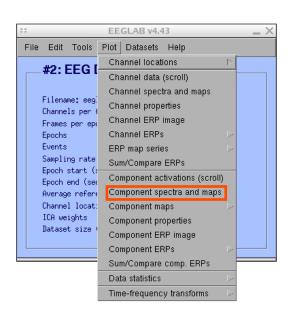


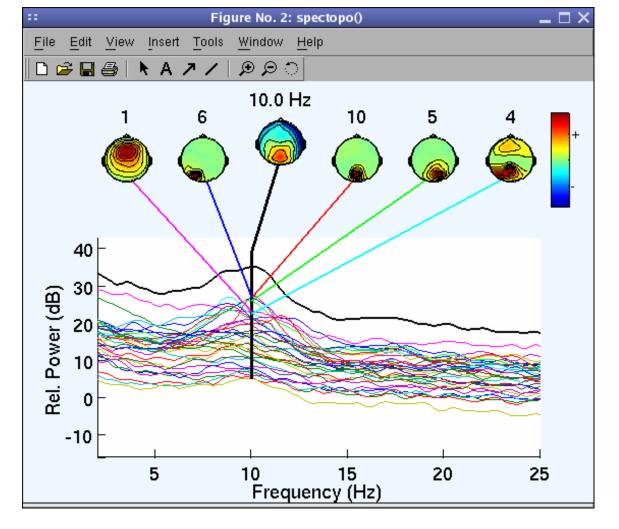
Figure No. 2

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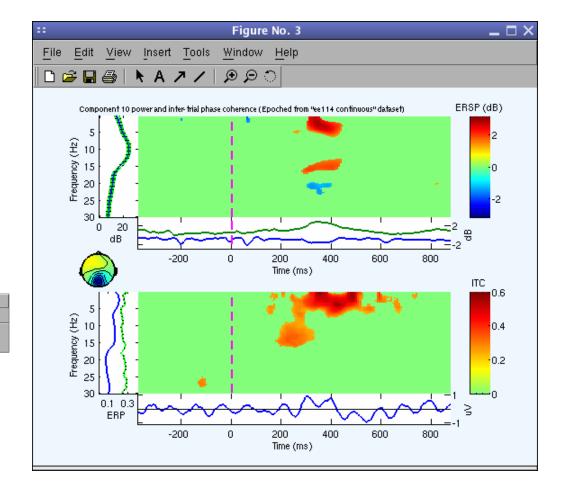
Component contribution to the EEG spectrum



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EEGLAB v4.43 _ X File Edit Tools Plot Datasets Help Channel locations #1: EEG I Channel data (scroll) Channel spectra and maps Filename: eeg Channel properties Channels per (Channel ERP image Frames per epo Channel ERPs Epochs Events ERP map series Sampling rate Sum/Compare ERPs Epoch start (: Component activations (scroll) Epoch end (sea Component spectra and maps Average refere Channel locat: Component maps ICA weights Component properties Dataset size Component ERP image Component ERPs Sum/Compare comp. ERPs Data statistics Time-frequency transforms Channel time-frequency Channel cross-coherence Component time-frequency Component cross-coherence



EEGLAB standard processing pipeline

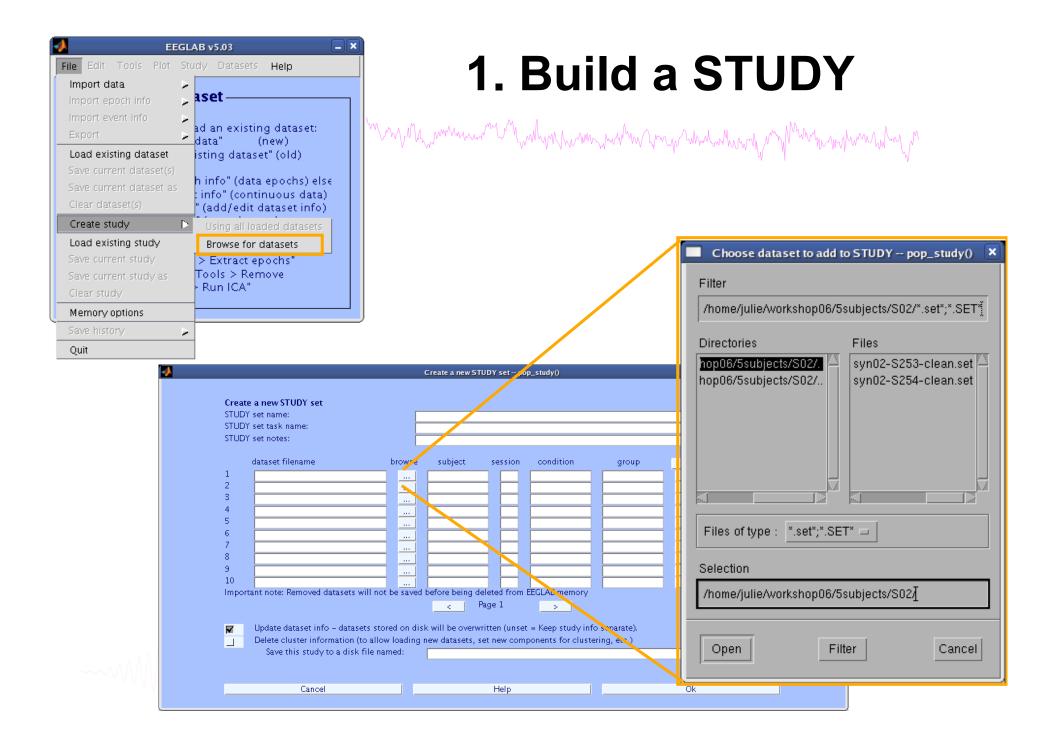


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Multi-subjects

- 1. Build study and STUDY design
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- 4. Analyze clusters

Advanced analysis using scripting and EEGLAB command line functions



00	0	E	EGLAB	v9.0.0.0Ł)			
File	Edit	Tools	Plot	Study	Datasets	Help		
–	STUD	Y set:			tudy info t/Edit study	/ design(s	5)	
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(Channels	per fram	e	61				
(Channel	locations		yes				
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	Status			Pre-cl	ustered			r
1	Total si	ze (Mb)		8.2				

dit STUDY design

man Marken was a show when the show of the show the show

e dit ST	UDY des	sign po	p_stuc	dydesign()		
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Comparing conditions Memorize-Ignore Load Probe Only Load Design 4 Ignore+Menorize vs Prob My design						
Resave STUDY						
Edit selected design						
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Independent variables	ndition - V	/alues (igr	nore - r	nemol	S07 S08 S09 S10 S11 S12 S13	

2. Pre-compute measures

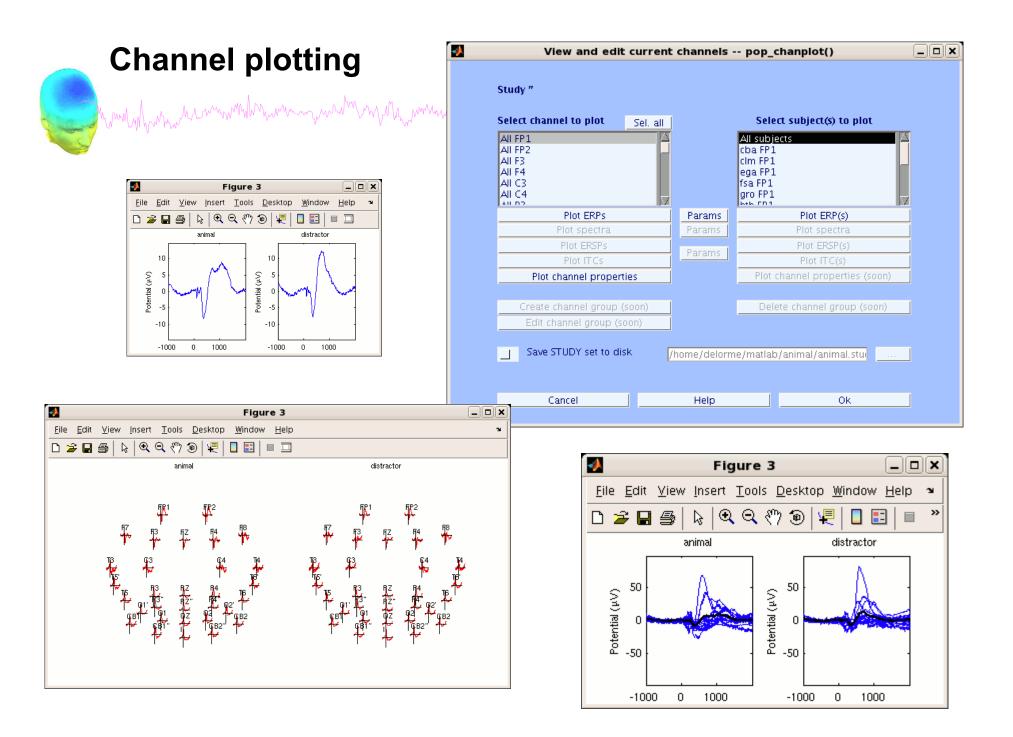
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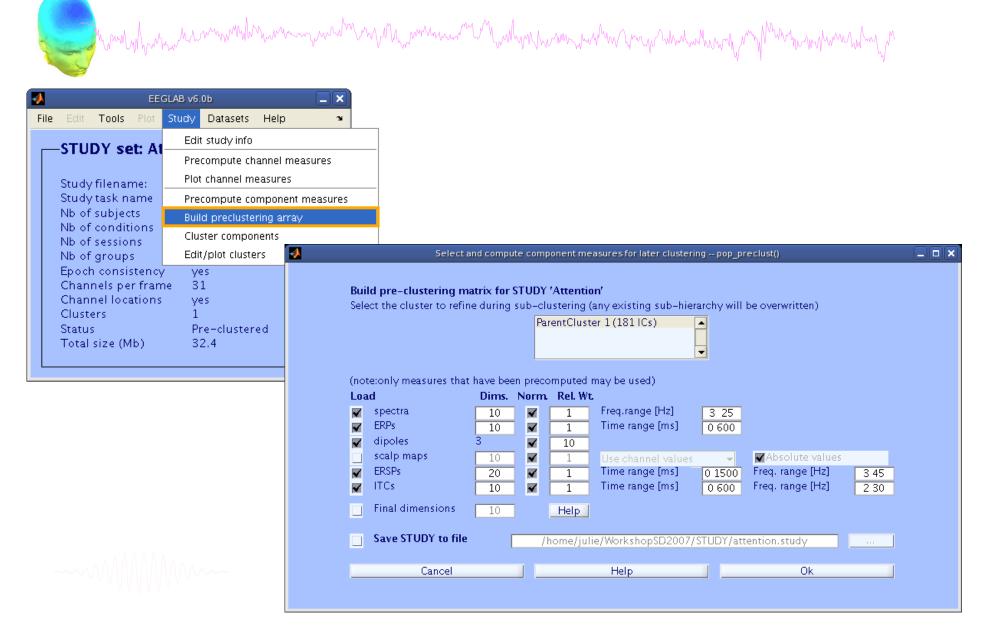
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Select and compute component measures for later clustering pop_precomp()									
Pre-compute channel m	easures for STUDY " - 'STUDY.des	sign 1'							
Channel list (default:all)									
7									
Spherical interpolation of missing channels (performed after optional ICA removal below)									
Remove ICA artifactual components pre-tagged in each dataset									
ParentCluster 1									
Remove artifactual ICA cluster or clusters (hold shift key)									
List of measures to pred	compute								
	•								
ERPs	Baseline ([min max] in ms)	Test							
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🗏 пся 🛄	Time/freq. parameters	ies, [5 0.5], filleds, 100							
- 1103									
Save single-trial measures for single-trial statistics - requires disk space									
Recompute even if present on disk									
Help		Cancel Ok							

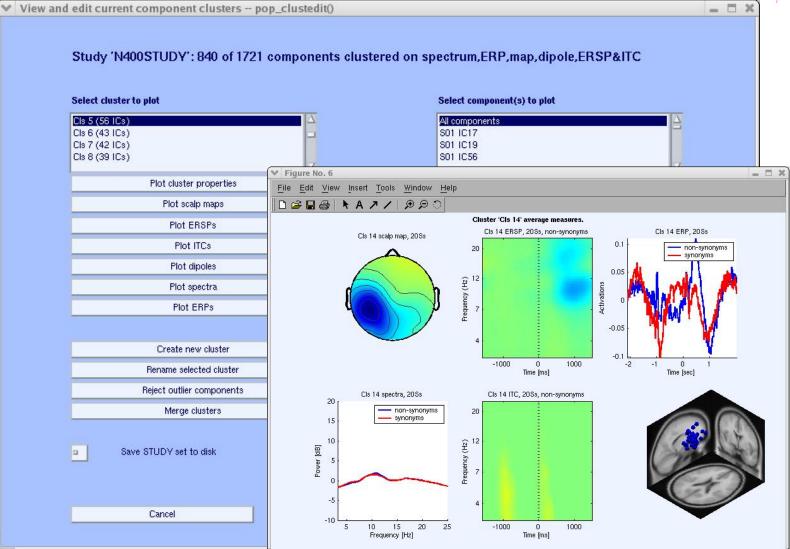


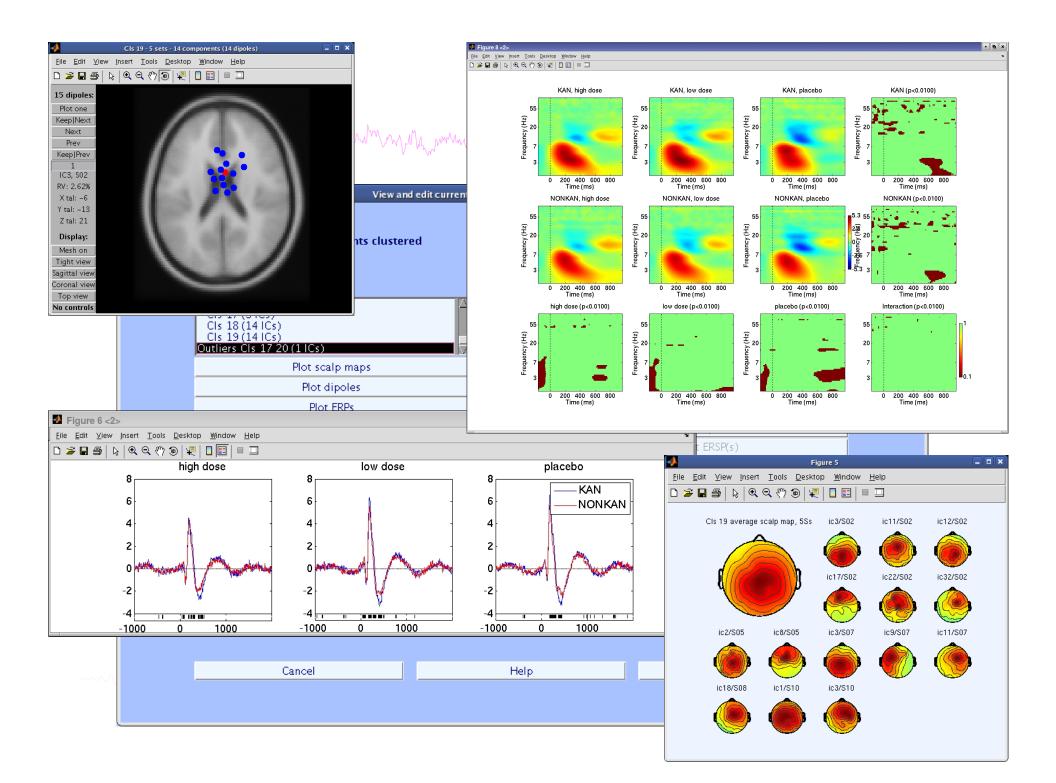
3. Cluster components



4. Analyze clusters







EEGLAB standard processing pipeline



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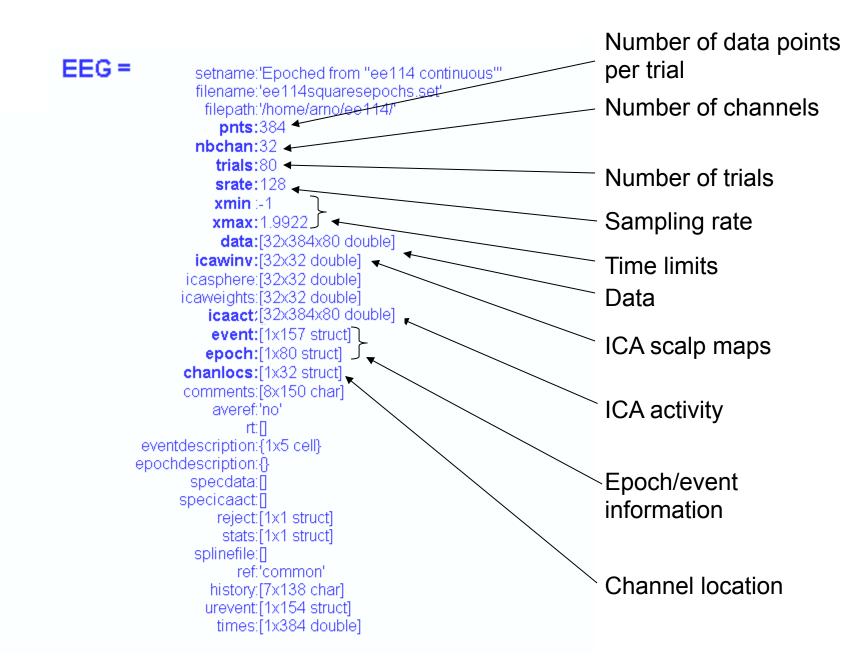
Multi-subjects

- 1. Build study and design
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- 4. Analyze clusters

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Advanced analysis using scripting and EEGLAB command line functions

## **EEG** structure



## 3 levels of functions

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Administrative functions: handle EEG and ALLEEG structures eeglab(), eeg\_checkset(), pop\_delset(), ...

Pop functions: interactive functions using EEG structure pop\_erpimage(), pop\_topoplot(), pop\_envtopo(), ...

Signal processing functions: perform signal processing erpimage(), topoplot(), envtopo(), ...

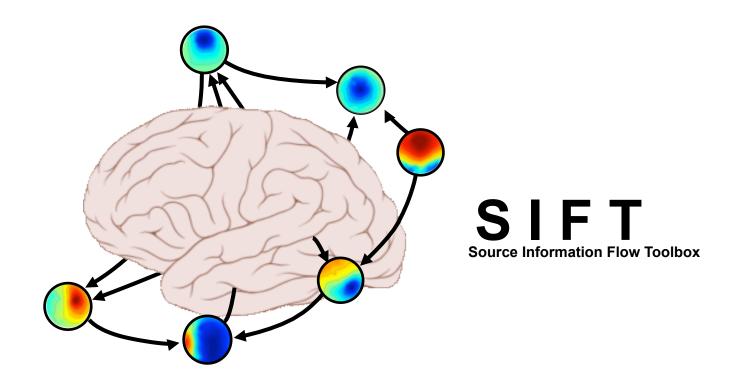


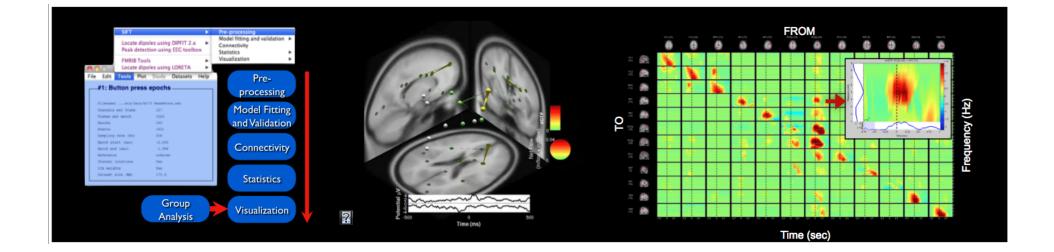
## 

("eegh" Menus write both dataset and global history)

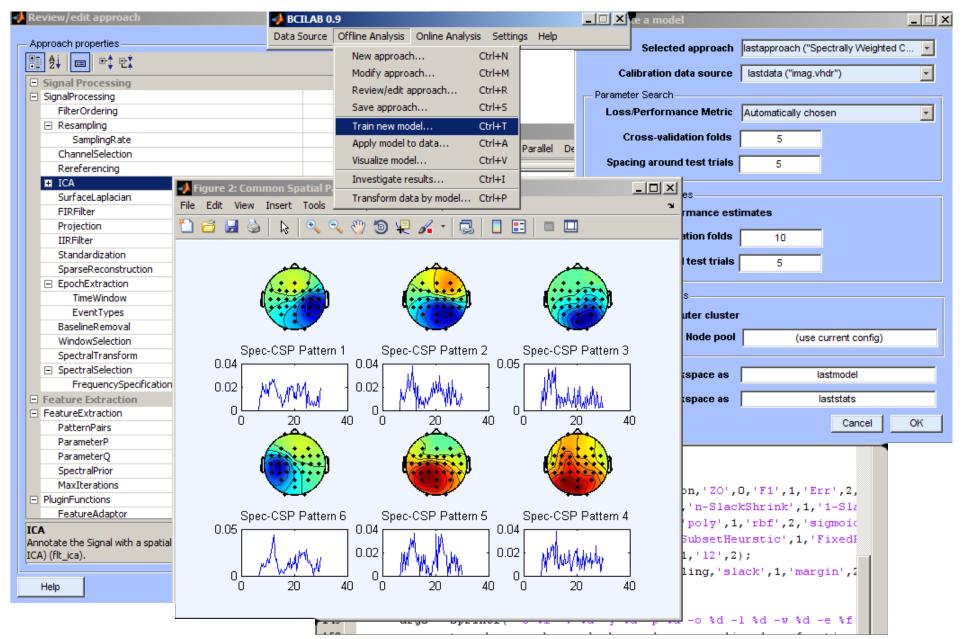
- Automated processing on groups of subjects (possibly on several processors).
- Richer options for plotting and processing functions (time-frequency decompositions, ...)
- Custom processing...







## BCILAB - C. Kothe



### Pros/Cons of 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 required for which you have to pay
  - Large memory requirements
  - Matlab bugs, possible version differences, crossplatform compatibility problems
  - Poor graphical interface

## 

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