



# **EEG Preprocessing in EEGLAB**



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## Why preprocess data?





EEG data out of the recording device is a continuous unprocess signal. It is like measuring a difference of potential on an oscilloscope.



To make sense of the data, we need to:

- Extract meaningful measures from it (such as brain oscillations; brain source activations)
- Compare brain data in different conditions
- Assess reliable changes due to external stimuli (event-related potentials)

Before we do all that, we apply a series of transformation to the data.

## **Pre-processing pipeline**



# Installing EEGLAB and data folder



- Download and install Matlab (2008b or later)
- Download EEGLAB (http://www.sccn.ucsd.edu/eeglab)

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- Unzip EEGLAB
- Add the EEGLAB folder to your Matlab path:

MATLAB R2013b		a with the		
HOME PLOTS	APPS		h L 9 C 🗗 🤉 s	earch Documentation 🛛 🔎 🔼
New New Open Compare Script	Import         Save         Open Variable           Data         Workspace         Zear Workspace         ✓	Analyze Code	(a) Preferences	? <sup>2</sup> Community          Help <sup>2</sup> Request Support          ↓       Add-Ons ◆
FILE	VARIABLE	CODE	ENVIRONMENT	RESOURCES
🗭 🔁 🔁 🏭 🕨 C: 🕨 Users	▶ marissa ▶ Documents ▶ MATLAB			•
New to MATLAB? Watch this <u>Vide</u> fx     >> addpath('C:\Program	o, see <u>Examples</u> , or read <u>Getting Started</u> . Files\MATLAB\R2013b\eeglab11_0	_5_4b');	×	<pre>ncip thtops ncip thtops eeglab -EEG -EEG.history eeg_eventtypes eeg_eventtypes(EE -eeglab redraw -eeglab redraw -eeglab -EEG.history EEG.comments -EEG.history EEG - 11/15/2013 11:11 &lt; III &gt;</pre>
Ready				

## The EEGLAB Matlab software

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#### main graphic interface



## Importing a dataset



LEGLAB v11.0.5.46	dy Datasets Help a		martines and reach more months the command
Import data	Using EEGLAB functions and plug	ins I	From ASCII/float file or Matlab array
Import epoch info	Using the FILE-IO interface		From Netstation .mff (FILE-IO toolbox)
Import event info	Using the BIOSIG interface		From Netstation binary simple file
Export	Troubleshooting data formats		From Multiple seg. Netstation files
Load existing dataset	existing dataset (Old)		From Netstation Matlab files
Save current dataset(s)	ch info" (data		From BCI2000 ASCII file
Save current dataset as	nt info" (continuous		From Snapmaster .SMA file
Clear dataset(s)	fo" (add/edit dataset		From Neuroscan .CNT file
Create study	set" (save dataset)	t)	From Neuroscan .EEG file
Load existing study	> Select data" Is > Reject		From Biosemi BDF file (BIOSIG toolbox)
Save current study	Is > Extract epochs"		From Biosemi BDF and EDF files (BDF plugin)
Save current study as	: "Tools > Remove		From EDF/EDF+/GDF files (BIOSIG toolbox)
Clear study	s > Run ICA"		From ANT EEProbe .CNT file
Memory and other options			From ANT EEProbe .AVR file
History scripts	•	-	From BCI2000 .DAT file
Quit			From BIOPAC MATLAB files
			From Brain Vis. Recvhdr file



From ASCII/float file or Matlab array
From Netstation .mff (FILE-IO toolbox)
From Netstation binary simple file
From Multiple seg. Netstation files
From Netstation Matlab files
From BCI2000 ASCII file
From Snapmaster .SMA file
From Neuroscan .CNT file
From Neuroscan .EEG file
From Biosemi BDF file (BIOSIG toolbox)
From Biosemi BDF and EDF files (BDF plugin)
From EDF/EDF+/GDF files (BIOSIG toolbox)
From ANT EEProbe .CNT file
From ANT EEProbe .AVR file
From BCI2000 .DAT file
From BIOPAC MATLAB files
From Brain Vis. Recvhdr file
From Brain Vis. Anal. Matlab file
From CTF folder (MEG)
From ERPSS .RAW or .RDF file
From INStep .ASC file
From 4D .m4d pdf file
From Procom Infinity Text File



#### Install extension for importing data files

Manufal man and the second of the second of

EEGLAB development head File Edit Tools Plot Study Datasets Help Import data Import epoch info Import event info dataset: Export (new) et" (load) Load existing dataset ata folder) Save current dataset(s) Save current dataset as up locations) Clear dataset(s) continuous data) Create study tinuous data" take time) Load existing study ata using ICA" Save current study chs" Save current study as In scalp arrav" Clear study / Clear all Memory and other options History scripts Manage EEGLAB extensions **>** Data import extensions Data processing extensions Quit

Extensions available for install on the internet Install Plugin Vers. Score Description BDFimport 1.10 1920 Import BDF data files Doc ANTeepimport 1.13 1436 Import ANT .cnt data and trigger files Doc MFFimport 2.1 978 Import MFF files from the EGI company Doc BCI2000import 0.36 861 Import BCI2000 data files biopac Import BIOPAC data files 1.00 771 Doc Import Neuroscan Curry 6, 7 and 8 data files loadcurry 2.0 623 erpssimport 1.01 611 Import ERPSS data files NihonKoden 1.01 585 Import Nihon Koden M00 files loadhdf5 1.1 534 Load hdf5 files recorded with g.recorder neuroimaging4d 1.00 528 Import Neuroimaging4d data files INSTEPascimport 1.00 526 Import INSTEP ASCII data files Update Installed extensions Dea Vers. Pluair Score Description Doc Biosig 3.3.0 22642 Import multiple data files formats Doc Fileio 170623 9130 Import multiple data files formats Doc bva-io 1.5.13 4299 Import Brain Vision Analyser data files 879 Import files in XDF format xdfimport 1.13 < Prev. page Next page > Cancel Ok

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#### **Supported data formats**

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#### EEGLAB tutorial: https://sccn.ucsd.edu/wiki/A01: Importing Continuous and Epoched Data

#### Supported Data Formats

File Format 🜩	File Extension \$	File type 🔶	Events 🜩	Channel Labels 🜩	EEGLAB 💠	Biosig 🖨	File IO 💠	Support \$
ANT EEProbe	.avr	_	_	_	_	_	_	Comments
ANT EEProbe	.cnt	_	_	_	y	y	y	Comments
ASCII .txt _		_	_	у	у	_	Comments	
BCI2000	.bci2000	continuous	_	_	p	_	_	Comments
BCI2000	.gdf	continuous	_	_	p	_	_	Comments
Biologic	.eeg	_	_	_	_	_	_	Comments
Biopac	.mat/.acq	_	_	_	p (see comments)	_	_	Comments
Biosemi	.bdf	continuous	Channel	_	у	у	У	Comments
Blackrock	.NEV .NSx	_	_	_	see comments	_	_	Comments
Brain Vision Analyzer	.mat	continuous & segmented	Embedded	_	у	у	n	Comments
Brain Vision Analyzer	.vhdr	_	file	_	у	у	n	Comments
BrainStorm	.vsm	_	_	_	_	_	_	Comments
Cogniscan	_	_	_	_	р	_	_	Comments
Compumedics Profusion	.raw	_	_	_	see comments	_	_	Comments
CTF/BrainStorm	.ctf	_	_	_	у	у	у	Comments
EGI/Netstation	.RAW	continuous & segmented	Channel	_	у	у	у	Comments
Elektra (MEG)	.fif	_	_	_	n (see comments)	y	n	Comments
Emotiv	.edf	_	_	_	y (see comments)	y (see comments)	y (see comments)	Comments
ERPSS	.raw	_	_	_	у	n	n	Comments
ERPSS	.rdf	_	_	_	у	n	n	Comments
European Data Format (16-bit)	.edf	_	Channel	_	y	у	n	Comments
EDF+	.edf	_	Channel	_	у	у	n	Comments
INSTEP	.asc	_	_	_	у	n	n	Comments
Matlab Array	.mat	_	Channel	_	у	у	n	Comments
Micromed	_	_	_	_	р	_	_	Comments
Neuroimaging4D	.m4d	_	_	_	у	n	n	Comments
Neuromag	.fif	_	_	_	see comments	n	see comments	Comments
Neuroscan	.avg	_	_	_	_	_	_	Comments
Neuroscan	.CNT	_	Embedded (see comments)	_	у	у	У	Comments
Neuroscan	.eeg	continuous	_	_	у	у	У	Comments
Nihon Kodhen	.eeg	continuous	_	_		y (see comments)		Comments
Profusion	.slp	_	_	_	_	-	_	Comments
Snapmaster	.SMA	_	Channel	-	У	у	n	Comments
Spike2	.mat	_	-	_	y (see comments)	n	n	Comments
Tucker-Davis Technology	.tdt	_	_	_	р	_	_	Comments



BIOSIG: <u>http://pub.ist.ac.at/~schloegl/biosig/TESTED</u>

File-IO: http://www.fieldtriptoolbox.org/development/fileio





#### File

SimpleOddball.set

#### Data

68 channel EEG, 256 Hz sampling rate, Biosemi system, re-referenced during import to averaged left and right mastoid electrodes

#### Task

speeded button press response to star shape (no response to circle shape), 100 ms presentation duration, 200 trials

#### Load a dataset

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Load "SimpleOddball.set"

#### Imported EEG data







## **Pre-processing pipeline**



#### Import data events



#### Appearance of an event channel in raw data





#### Imported data events

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#### Import channel locations

mand of home many many many many many	Edit channel info pop_chanedit()	-	
	Channel information ("field_name"):		n
	Channel label ("label")	Fp1	Opt. head center
M EEGLAB v11.0.5.4b	Polar angle ("theta")	-17.926	Rotate axis
File Edit Tools Plot Study Datasets Help 🏻	Polar radius ("radius")	0.51499	Transform axes
Dataset info	Cartesian X ("X")	80.784	
Event fields	Cartesian Y ("Y")	26.133	Xyz -> polar & sph.
Event values	Cartesian Z ("Z")	-4.0011	Sph> polar & xyz
About this dataset	Spherical horiz. angle ("sph_theta")	17.926	Polar -> sph. & xyz
Channel locations	Spherical azimuth angle ("sph_phi")	-2.698	
Select data	Spherical radius ("sph_radius")	85	Set head radius
Select data using events	Channel type		Set channel types
Select epochs or events	Reference		Set reference
Copy current dataset	Index in backup 'urchanlocs' structure	1	
Append datasets	Channel in data array (set=yes)		
Delete dataset(s)			
Visually edit events and identify bad channels	Delete chan Cha	annel number (of 72)	
Dataset Size (MD) 20.4	Insert chan << < 1 > >> Appe		
	Plot 2-D Plot radius (0.2-1, []=aut	to) Nose along +>	χ 🚽 Plot 3-D (xyz)
10 file	Read locations Read locs help	Look up locs Save (as .	.ced) Save (other types)
File format:			
Polhemus native .elp file	Help		Cancel Ok
Matlab xyz file			
EESA or EGI3-D cartesian .stp file	use button Read location	n in the following gut. If you do n	or know, just press ork.
Neuroscan polar .asc file (Polhemus,			
ASA.elc 3-D file	use BESA file for 4-shell	dipfit spherical model	
	use BESA file for 4-shell	l dipfit spherical model	
	use MNI coordinate file f	or BEM diptit model	
	Use spherical file with ey	ye channels	
Help Cancel Ok			



#### **Imported channel locations**





-	EE	GLAB v	11.0.5.4	<b>)</b>		-			x
1	File Edit Tools Plot Study D					Datasets	Help		Ľ
		#1:	nuou	IS					
		Filen	ame:	.imple	Oddba	ll_cont_re	eref.set		
		Char	nels p	er fran	ne	72			
		Fram	nes per	epocl	h	85504			
		Epoc	hs			1			
		Even	ts			260			
		Sam	pling ra	te (Hz	z)	256			
		Epoc	h start	(sec)	-	0.000			
		Epoc	h end	(sec)		333.99	6		
		Refe	rence			unknow	wn		
		Char	nnel loc	ations	; (	Yes			
		ICA v	veights	;		No			
		Data	set size	e (Mb)		25.5			



#### **Comments and dataset history**

✓ EEGLAB v11.0.5.4b	Read/Enter comments pop_comments()
File       Edit       Tools       Plot       Study       Datasets       Help       N         Dataset info       Event fields       Event fields       Event values       Image: Study of the study of th	About this dataset          Data recorded by Marissa Westerfield         Recording date: Oct. 14, 2011         Paradigm:         -Participant looked at fixation box in center of screen         -Two types of stimuli (outline of a circle, outline of a star) were presented in the fixation box in random order         -Participant pressed a button in response to the star         Stimulus codes:         1 = circle         2 = star         3 = button press         Recording information:         -reference electrodes were placed on right and left matoids (data has already been referenced and the matoid channels have been removed)         Processing steps:
~~~~MMM///	Cleanline applied to 60, 120 Hz SAVE

## **Pre-processing pipeline**



## **Re-reference data (if necessary/desired)**

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#### Save new dataset, keep old one



#### **Multiple active datasets**











## **Re-reference data (if necessary/desired)**

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EEGLA	B v10.2.2.1b		Or,		
File Edit	<ul> <li>Tools Plot Study Datasets Help</li> <li>Change sampling rate</li> <li>Filter the data</li> <li>Re-reference</li> </ul>	uous	average reference		(use shift ctrl to select several)
Fill Ch Ep Ev Sa Ep Ch Ch	Interpolate electrodes         Reject continuous data by eye         Extract epochs         Remove baseline         Run ICA         Remove components         Automatic channel rejection         Automatic epoch rejection         Reject data epochs	V.: pop_reref - av Current data reference state is Compute average reference Re-reference data to channel Interpolate removed channel Retain old reference channel Exclude channel indices (EMG Add current reference channel	<ul> <li>pop_reref - average reference or re-reference data</li> <li>Current data reference state is: unknown</li> <li>Compute average reference</li> <li>Re-reference data to channel(s):</li> <li>Interpolate removed channel(s)</li> <li>Retain old reference channels in data</li> <li>Exclude channel indices (EMG, EOG)</li> </ul>		
	Reject data using ICA NFT plugin SIFT Locate dipoles using DIPFIT 2.x Peak detection using EEG toolbox FMRIB Tools Locate dipoles using LORETA	Help	Cancel	Ok	$\begin{array}{ccccc} 16 & - & F3 \\ 17 & - & F1 \\ 18 & - & FZ \\ 19 & - & F2 \\ 20 & - & F4 \\ 21 & - & F6 \\ 22 & - & F8 \\ 23 & - & F10 \\ 24 & - & FT9 \\ 25 & - & FT7 \\ 26 & - & FC5 \\ \hline \hline$

## **On Average Referencing**

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In theory, positive and negative current across entire head should balance—no net current source or sink: Average referencing enforces this.

In practice, depends on distribution of electrodes.

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#### Average reference

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1. Average Reference assumption

Fpz + Fp1+ AF3 + F8+ FT8 + ... + TP10 = 0

## **Re-reference data (if necessary/desired)**

hand have a second with a second with a second of the seco



🙏 El	EGLAB	v10.2.2.1b	average reference
File	Edit	Tools Plot Study Datasets Help	
	_#1	Change sampling rate Filter the data	uous
	File Cha Epc Eve Sar Epc Ref Cha ICA	Re-reference Interpolate electrodes Reject continuous data by eye	V. pop_reref - average reference or re-reference data Current data reference state is: unknown
		Extract epochs Remove baseline Run ICA Remove components	Compute average reference Re-reference data to channel(s): Interpolate removed channel(s)
		Automatic channel rejection Automatic epoch rejection Reject data epochs Reject data using ICA	Retain old reference channels in data         Exclude channel indices (EMG, EOG)         Add current reference channel back to the data
		NFT plugin SIFT	Help Cancel Ok
		Locate dipoles using DIPFIT 2.x Peak detection using EEG toolbox FMRIB Tools	Fpz + Fp1+ AF3 + F8+ FT8 + + REF = 0 (REF is a
		Locate dipoles using LORETA	OR

Fpz + Fp1 + AF3 + F8 + FT8 + ... = 0 (REF is not on the scalp, ear reference, ...)

channel)

## **Resample data (if desired)**

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#### Reason: Reduce space, time.





## **Pre-processing pipeline**



#### Scroll channel data



📣 EE	GLAB v	11.0.5.4b				
File	Edit	Tools	Plot	Study Datasets Help		צ
	#3:	Simp		Channel locations	•	
				Channel data (scroll)		
	Filen	ame: n		Channel spectra and maps		
	Char	nnels pe		Channel properties		
	Fram	nes per		Channel ERP image		
	Epoc	:hs		Channel ERPs	•	
	Even	its 		ERP map series	•	
	Sam	pling ra		Sum/Compare ERPs		
	Epoc	h end (		Component activations (scr	oll)	
	Refe	rence		Component spectra and ma	ps	
	Char	nnel loc		Component maps	•	
	ICA v	veights		Component properties		
	Data	set siz∉		Component ERP image		
				Component ERPs	F	
				Sum/Compare comp. ERPs		
				Data statistics	►	
				Time-frequency transforms	×	
				Cluster dataset ICs		



#### Scroll channel activities -- eegplot() Figure Display Settings Help э Data select/mark Stack Grid **Remove DC offset** Norm ✓ Show scale Title Stack channels Normalize channels Scale 68 1 2 3 0 4 5 Chan. Time Value + CANCEL << < REJECT > >> Event types 0 68 A18 0.042687 -1425.6

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#### **Remove DC offset**



• •	•	EEGL	AB deve	elopment	head				
File	Edit	Tools	Plot	Study	Datasets	Help	'N		
E C	#1:BD	Chan Filter Re-re Interp	ge san the da ferenc polate	npling ra ita ce electrod	ate es	•			
E	Frames p Epochs Events	Extra Remo	Extract epochs Remove baseline						
E	Sampling Epoch st Epoch en	<mark>Run I</mark> Remo	<mark>CA</mark> ove cor	nponent	:S				
F C I I	Referenc Channel ICA weig Dataset	Autor Autor Autor Rejec	matic c matic c matic e t data t data	hannel continuo poch re epochs using IC	rejection us rejectior jection A				
		Artifa	ct rem	oval usi	ng AAR 1.3				

DC offsets introduce large filter artifact at signal boundaries, so it better to remove them prior to filter the signal.



## **High-Pass Filter the data**

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#### Reason: remove slow, possibly large amplitude, drift

🥠 E	EGLAB v	11.0.5.4b			🛑 😑 🔵 🛛 Filter the data p	op_eegfiltnew(	)
File	Edit	Tools Plot Study Datasets Help	¥د.				0.5
	#1:	Change sampling rate			Lower edge of the frequency pass band	(Hz)	0.5
		Filter the data	Basic FIR filter		igher edge of the frequency pass band	l (Hz)	
	Filen Char	Re-reference	ERPLAB Butterwo	orth Filter	IR Filter order (Mandatory even. Defaul	t is automatic*)	
		Interpolate electrodes	ERPLAB Polynom	nial Detrendin	9 See help text for a description of the de	efault filter orde	
	Fram	Reject continuous data by eye	Short non-linear	IIR filter	lanual definition is recommended.		Hign-pass
	Epoc	Extract epochs			Notch filter the data instead of pass	band	needed
	Even Sam	en Remove baseline			Use minimum-phase converted cau	ısal filter (non-li	for ICA
		Run ICA			Plot frequency response	l	
	Epoc	Remove components			Channel type(s)		
	Refe	Automatic channel rejection					
	Char	Automatic epoch rejection			On channel habers of mulces		
	ICA v	Reject data epochs			Help	Can	
	Data	Reject data using ICA			Dataset info pop_newset()	Oan	
		Locate dipoles using DIPFIT 2.x					
		Peak detection using EEG toolbox	What do you w	vant to do with	BDF file	Edit descri	ption
		FMRIB Tools	Save it	as file:		Brows	e
		Locate dipoles using LORETA					
		CleanLine	Some change	s have not bee	n saved. What do you want to do with the old	dataset?	
			Overwrite it in memory		v (set=ves; unset=create a new dataset)		
			Save it	as file:		Brows	ie

Help

Cancel

Ok

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#### High pass (0.5 Hz)

#### Low pass (50 Hz)











#### 00

all		Plutings available for install on the internet				
Inst		Plugin	Version	Description		
		ERPLABfilters	1.00	Interface ERPLAB filters (requires seperate ERPLAB instalati	Doc	
		Cleanline	1.21	Automatic artifact rejection	Doc	
		BERGEN	1.1	Removal of fMRI-related gradient artifacts from simultaneous	Doc	
	'ate					
date	activ			Installed plutings		
Ğ.	Ĕ	Plugin	Version	Description		
		brainmovie	0.1	Brainmovies (command line only)	Doc	
		corrmap	2.00	New version 1.03 available. Click update to install.	Doc	
		eeg_toolbox	1.0	Interface EEG toolbox functions for ERP peak detection	Doc	
		fMRIb	1.21	Remove fMRI artifacts from EEG	Doc	
		MP_clustering	1.00	Measure projection clustering of ICA components	Doc	
		MutualInfoClustering	1.00	Mutual information clustering	Doc	
		StudyEnvtopo	0.9	Add envtopo capabilities to STUDY	Doc	
		VisEd	1.05	New version 1.04 available. Click update to install.	Doc	
		iirfilt	1.02	Non linear filtering	Doc	
		loreta	1.1	New version 1.0 available. Click update to install.	Doc	

CleanLine uses an approach for line noise removal advocated by Partha Mitra and Hemant Bokil in

"Observed Brain Dynamics" (2007), Chapter 7.3.4.

Cancel

Ok
## **Remove line noise (Cleanline)**

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# **Plot channel properties**

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#### **Filter comparisons**







#### 0.5 Hz high-pass filter

#### 0.5 Hz high-pass filter 50 Hz low-pass filter

#### 0.5 Hz high-pass filter Cleanline





# **Pre-processing pipeline**



#### Scroll channel data

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#### Scroll channel data



# **EEG** artifacts

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The amplitude of artifacts (such as eye movements) is often larger than the amplitude of brain data which potentially decrease signal/noise ratio, bias data analysis and potential results



# **Type of artifacts**



#### Looking for bad channels



# **Pre-processing pipeline**



#### **Remove unwanted channels**



# Manually identifying bad channels



# Manually identifying bad channels



# Removing channel(s)

a hand all a second and a second and a second and a second a secon	when my Market
EEGLAB v11.0.5.4b	
File Edit Tools Plot Study Datasets Help	к С
Dataset info reref_ Event fields	
About this dataset Select data pop_select()	
Channel locations Select data Time range [min max] (s)	uput desired range on->remove the lf not checked, will result
Select data using e Point range (ex: [1 10]) Select epochs or ev Epoch range (ex: 3:2:10)	in dataset with one channel
Copy current datas Append datasets	F6
Delete dataset(s)	Scroll dataset
Visually edit events DataSet Size (IVID) Cancel	Dataset info pop_newset()
	What do you want to do with the new dataset?
	Name it:         SimpleOddball hipass0.5 CL - F6         Edit description
	Save it as file:       Browse         What do you want to do with the old dataset (not modified since last saved)?         Overwrite it in memory (set=yes; unset=create a new dataset)         Help       Cancel       Ok

# Auto-detection of noisy channels

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🛃 El	EGLAB	v7.1.7.18b	<u> </u>
File	Edit	Tools Plot Study Datasets Help	ъ
	-#1:	Change sampling rate Filter the data	ן ן
	Filer Cha	Re-reference Interpolate electrodes Reject continuous data by eye	
	Frar Epo Eve	Extract epochs Remove baseline	
	San Epo Epo	Run ICA Remove components	
	Refe	Automatic channel rejection	
	Cha ICA	Automatic epoch rejection Reject data epochs	
	Data	Reject data using ICA 🔹	
		Locate dipoles using DIPFIT 2.x  Peak detection using EEG toolbox	
		FMRIB Tools	
		Locate dipoles using LORETA	

🛃 Re	eject channel po	p_rejchan()		x
	Electrode (number(s	s); Ex: 2.4.5):	1:71	
	Measure to use:		Probability 🚽	
	Normalize measure (	(check=on):	<b>V</b>	
	Threshold limits (ma:	<]:	5	
	Cancel	Help	Ok	

See also clean\_rawdata plugin of EEGLAB

#### **Auto-detected noisy channel**





# **Removed channel(s)**



- In EEGLAB, removed channels are not only labeled for rejection, they are actually removed from the data.
- Interpolating channels instead of removing them?

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# **Pre-processing pipeline**



# **Reject continuous data**

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Continue

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#### Equivalent



X

#### **Reject continuous data**



# **Rejecting data for ICA**







# Fast manual artifact rejection



# Fast manual artifact rejection

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#### Automatic rejection of continuous data



# Manufall and a second with the second of the



		EEGL	AB deve	elopment l	head		
File	Edit	Tools	Plot	Study	Datasets	Help	ъ
	#1: EE	Chan Filter	ge san the da	npling ra ata	ate	•	
	Filename Channels	Re-re Inter Rejec	efereno polate t conti	ce electrod nuous d	es ata by eye		
	Epochs Events	Extra Remo	ct epo ove bas	chs seline			
	Epoch st Epoch en	<mark>Run I</mark> Remo	<mark>CA</mark> ove cor	nponent	S		
	Referenc Channel ICA weiq	Auto Auto	matic c matic c	hannel i continuo	rejection us rejectior	۱	
	Dataset	Autor Rejec	matic e t data t data	epoch re epochs	jection	•	
		Artifa	ict rem	ioval usi	ng AAR 1.3	•	
		Clear SIFT	ıLine			•	
		Clear	onti	nuous da	ata using A	SR	

Channel range	[1:32]
Frequency range (Hz)	20 40
Frequency threshold in dB	10
Epoch segment length (s)	0.5
Minimum number of contiguous epochs	4
Add trails before and after regions (s)	0.25
Use hanning window before computing FFT	✓
Са	ncel Ok

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Contaminated 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. Published in IEEE Transactions on Biomedical Engineering. DOI:10.1109/TBME.2015.2481482

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**Validation:** Chang CY, Hsu SH, Pion-Tonachini L, Jung TP. Evaluation of Artifact Subspace Reconstruction for Automatic EEG Artifact Removal. Conf Proc IEEE Eng Med Biol Soc. 2018 Jul;2018:1242-1245. doi: 10.1109/EMBC.2018.8512547.

**Variation:** Sarah Blum\*, Nadine S. J. Jacobsen, Martin G. Bleichner and Stefan Debener (2019) A Riemannian Modification of Artifact Subspace Reconstruction for EEG Artifact Handling. Front. Hum. Neurosci., https://doi.org/10.3389/fnhum.2019.00141.



# 



• •		EEGL	AB dev	elopment l	nead		
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Remove line-noisy channels [std -1->off]	4	
Repair bursts using ASR [std]-1->off]	5	
Remove time windows [0-1 'off']	0.5	
Show results for comparison? (beta version)	Yes	\$
Help	Cancel Ok	

#### **Extract epochs**



# **Extract epochs**

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# Scroll (epoched) channel data

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#### **Reject epochs with artifact**





-			EE	GLAB v6.	0b				×	1
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		FMH Gra Loc	kib Loc ind ave ate dip	us trage da toles usi	itasets ng LORETA	*		Rejet Expo	nt r	ny spectra narks to ICA reject
		PCA	A plugir	n		•		Reje	t n	narked epochs







File       Edit       Tools       Plot       Study       Datasets       Help       Image: Change sampling rate         #1:1       Change sampling rate       Filter the data       Image: Change sampling rate       Image: Change sampling rate	-			EE	GLAB v6.	0b			_ >		
#1:1       Change sampling rate         Filer       Filter the data         Filens       Re-reference         Chani       Reject continuous data by eye         Frame       Extract epochs         Epoch       Remove baseline         Event       Samp         Run ICA       Remove components         Epoch       Remove components         Epoch       Automatic epoch rejection         Avera       Reject data using ICA         ICA w       Reject data using BESA         Locate dipoles using DIPFIT 2.x       Reject by linear tree         Laplacian       Reject by probabilities	File	e Edit	Tools	Plot	Study	Datasets	Help		3	ч	
Avera       Reject data epochs       Reject data (all me         ICA w       Reject data using ICA       Reject by inspectio         Datas       Locate dipoles using BESA       Reject extreme value         Locate dipoles using DIPFIT 2.x       Reject by inspectio         Laplacian       Reject by probabilition		-#1: Filer Char Epoc Even Sam Epoc	Ch Filt Re Re Ext Ext C C C C C C C C C C C C C C C C C C C	ange s er the -refere ject co ract ep move t n ICA move c	ampling i data ence ntinuous pochs paseline componer	rate data by eye nts ejection	2	<b>s</b> —			
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Grand average datasets       Reject by spectra         Locate dipoles using LORETA       Export marks to IC											

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# **Pre-processing pipeline**

