

EEG Preprocessing for ICA

25th EEGLAB Workshop JAIST Tokyo Satellite, Japan Day 1 John Iversen

Installing EEGLAB and data folder



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

MATLAB R2013b				
HOME PLOTS	APPS		1 i 9 c 5 ?	Search Documentation 🛛 🔎 🕽
New New Open Compare	Import Save Data Workspace	Analyze Code	(a) Preferences	② ▷ Community Help → Request Support ↓ Add-Ons ▼
FILE	VARIABLE	CODE	ENVIRONMENT	RESOURCES
	marissa > Documents > MATLAB			Command History
	ieo, see <u>Examples</u> , or read <u>Getting Started</u> . n Files\MATLAB\R2013b\eeglab11_0)_5_4b');		Heip Clicopo % 11/14/2013 5:45 eeglab EEG
				EEG.history eeg_eventtypes eeg_eventtypes(EE eeglab redraw
				eeglab EEG.history EEG.comments EEG.history
				EEG

The EEGLAB Matlab software



main graphic interface

MATLAB R2013b	
HOME PLOTS	APPS 🔂 🗟 🖉 🔂 🔂 🖄 Search Documentation 🔎 🗖
New New Open Decompare Script FILE	🔁 Open Variable 👻 🏠 Run and Time 🤤 Request Support
🖨 🔶 🔁 🔀 🌗 🕨 C: 🕨 Users	s 🕨 marissa 🕨 Documents 🕨 MATLAB
Current Folder	Command Window
Name 🔺	New to MATLAB? Watch this <u>Video</u> , see <u>Examples</u> , or read <u>Getting Start</u>
🚵 pathdef.m	fx >> eeglab File Edit Tools Plot Study Datasets Help
	No current dataset - Create a new or load an existing Use "File > Import data" (new) Or "File > Load existing dataset" (old) - If new. "File > Import epoch info" (data "File > Import event info" (continuous "Edit > Dataset info" (add/edit dataset "File > Save dataset" (save dataset) - Prune data: "Edit > Select data" - Reject data: "Tools > Reject - Epoch data: "Tools > Remove - Run ICA:
Details	
Ready	

"Secrets" to a good ICA decomposition



Garbage in, garbage out (GIGO: it's not magic)

a market was a second when a second second

- Remove large, non-stereotyped artifacts
- Do you have enough data? (based mostly on time, not frames)
- High-pass filter to remove slow drifts (no low-pass filter needed)
- Remove bad channels
- Data must be in double precision (not single)

The Goal of Preprocessing



• Create a complete EEGLAB data set with

mand of the second water and the second water and the second of the seco

- EEG time series signal
- Channel Locations
- Event information
- Applying singnal processings on EEG time series to help ICA decompositions
 - Data 'cleaning'—artifact rejection.
 - Removing noisy channels.
 - Removing noisy segments of data.
 - Applying frequency filter.

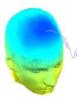
Pre-processing pipeline



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Importing a dataset



EEGLAB v11.0.5.4b

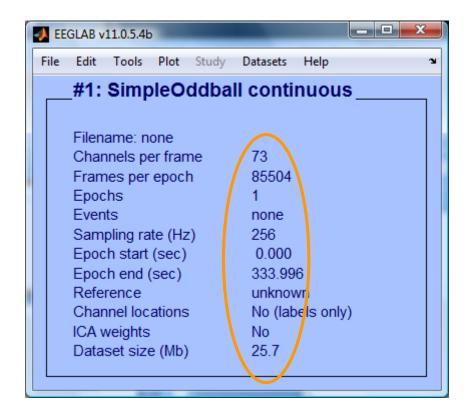


Edit Tools Plot Study		ъ.	mound and many many many
Import data	Using EEGLAB functions and plu	ugins	From ASCII/float file or Matlab array
Import epoch info	Using the FILE-IO interface		From Netstation .mff (FILE-IO toolbox)
Import event info	Using the BIOSIG interface		From Netstation binary simple file
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 set" (save dataset) > Select data" Is > Reject Is > Extract epochs"		From Neuroscan .CNT file
Create study			From Neuroscan .EEG file
Load existing study			From Biosemi BDF file (BIOSIG toolbox)
Save current study			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 Brain Vis. Anal. Matlab file
Tip for Bioser	ni users:		From CTF folder (MEG)
			From ERPSS .RAW or .RDF file
Use the BDF	plugin' version		From INStep .ASC file
of the Biosem	ni BDF/EDF importer		From 4D .m4d pdf file
			From Procom Infinity Text File

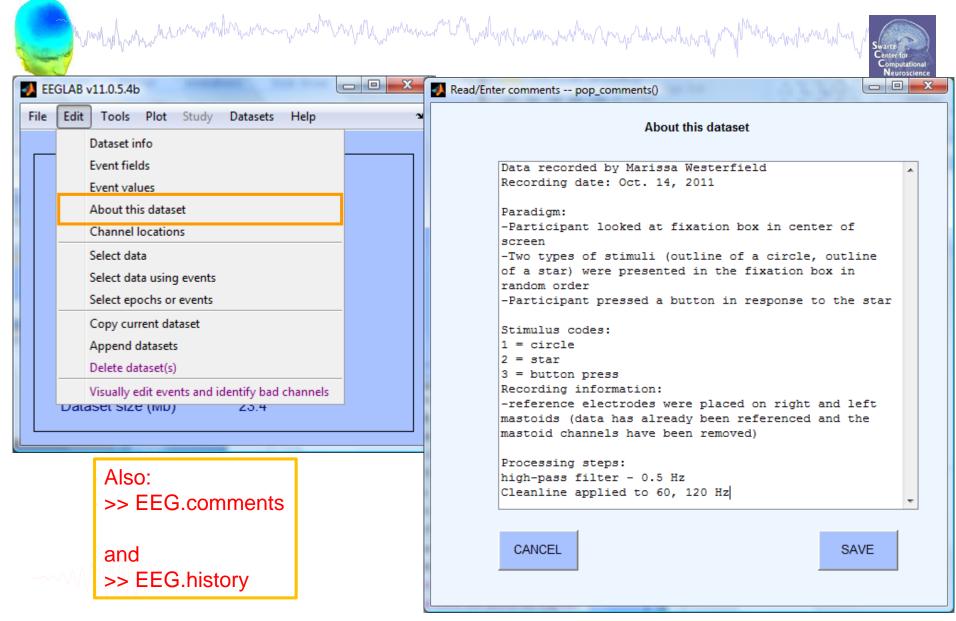
Imported EEG data



8



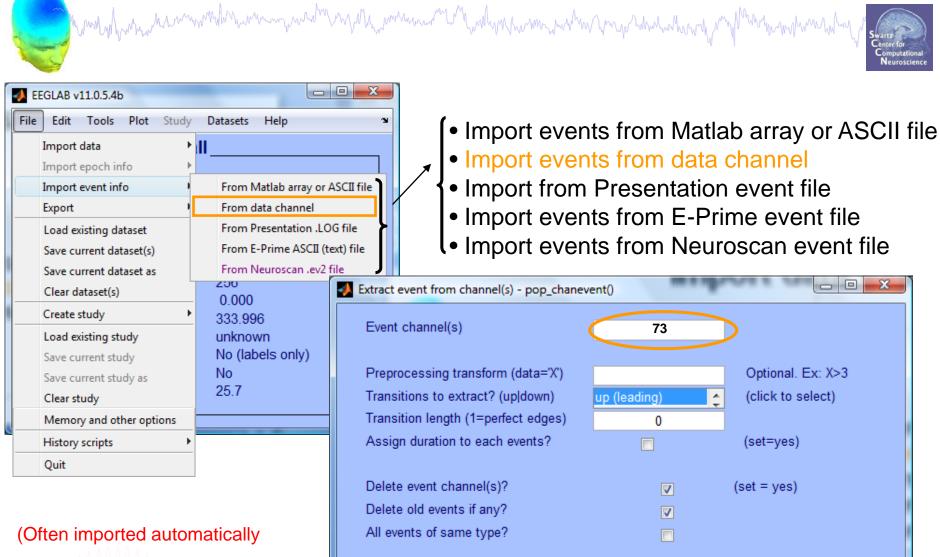
Comments and dataset history



Pre-processing pipeline



Import data events



Help

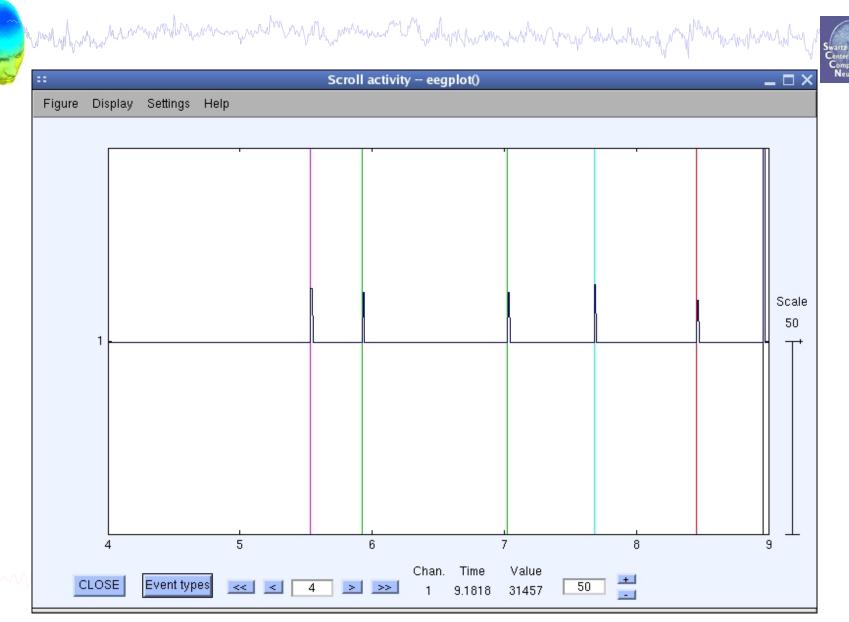
during data import)

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Cancel

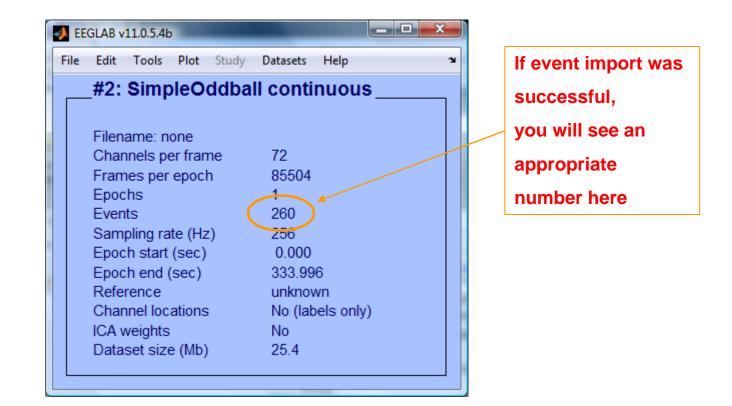
Ok

Appearance of an event channel in raw data



Imported data events





Sample data: basic P300 paradigm

and all and a second a



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

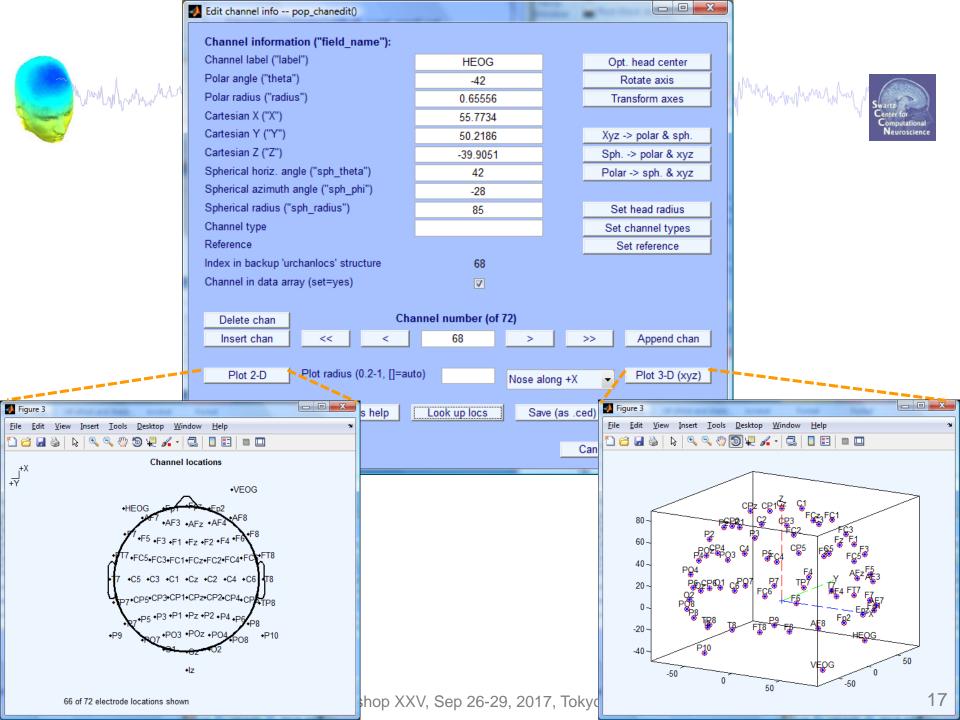
speeded button press response to star shape (no response to circle shape), 100 ms presentation duration, 200 trials

Import channel locations

home of home have a server and have a server a ser	Edit channel info pop_chanedit()		
a chief with	Channel information ("field_name"):		
	Channel label ("label")	Fp1	Opt. head center
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 Dataset Size (IVID) 20.4	Delete chan Cha	annel number (of 72)	
	Insert chan << <	1 >	>> Append chan
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7 file forme etc. et up p orte d			
7 file formats supported	Read locations Read locs help	Look up locs Save	a (as .ced) Save (other types)
(Polhemus, BESA,)			
(Help		Cancel Ok
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	use BESA file for 4-shell		
	use MNI coordinate file f		
	Use spherical file with ev		el Ok
		,	

Import channel locations



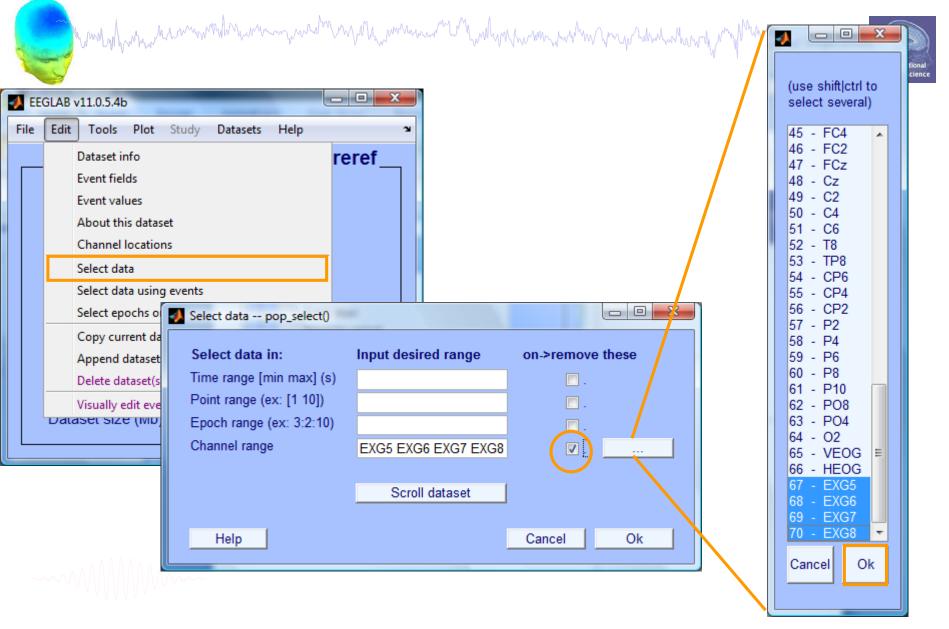


Imported channel locations



File	Edit	Tools	Plot	Study	Datasets	Help		3
	#1:	Simp	leO	ddba	ll conti	nuou	IS	
	Filen	ame:	.imple	Oddba	ll_cont_re	eref.set		
	Char	nnels pe	er frar	ne	72			
	Fram	nes per	epoc	h	85504			
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	Even	its			260			
	Sam	pling ra	ite (Hz	z)	256			
	Epoc	h start	(sec)		0.000			
	Epoc	h end ((sec)		333.99	6		
	Refe	rence			unknow	wn		
	Char	nnel loc	ations	s 🕻	Yes			
	ICA v	veights			No			
	Data	set size	e (Mb))	25.5			

Remove unwanted channels



Pre-processing pipeline



High-Pass Filter the data



an mound when we were and the second when he was a second of the second Reason: To improve data stationarity.

ICA is biased to amplitude, and EEG data has 1/f power specrum density.

E E	EGLAB v:	11.0.5.4Ь	Filter the data pop_eegfilt()	x
File	Edit Edit Filen Char Fram Epoc Even Sam Epoc Epoc Refe Char ICA v Data	Reject continuous data by eye Extract epochs Remove baseline Run ICA Remove components Automatic channel rejection Automatic epoch rejection Reject data epochs Reject data using ICA	Lower edge of the frequency pass band (Hz) Basic FIR filter ERPLAB Butterwort ERPLAB Polynomia Short non-linear IF Use (sharper) FFT linear filter instead of FIR filtering (Use the option above if you do not have the Signal Pro Use causal filter (useful when performing causal and Plot the filter frequency response Use fir1 (check, recommended) or firls (uncheck, let Help Dataset info pop_newset() What do you want to do with the new dataset?	SS
	~~~\.	Locate dipoles using DIPFIT 2.x Peak detection using EEG toolbox FMRIB Tools Locate dipoles using LORETA CleanLine	Name it:       SimpleOddball hipass0.5       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)	
		EEGLA	Help Cancel Ok	2

Neuroscier

#### **Good resource for learning filters**





# https://sccn.ucsd.edu/wiki/Firfilt_FAQ

# https://cloud.github.com/downloads/wi dmann/firfilt/firfilt.pdf



Andreas Widmann from Leipzig

## **Pre-processing pipeline**





O O EEGLAB	v12.0.2.1	b		
le Edit Tools Plot	Study	Datasets	Help	
Import data Import epoch info Import event info Export Load existing dataset Save current dataset(s) Save current dataset as Clear dataset(s)	ora e <b>r</b> te	isting g dataset" ' (data ' (continuous		
Create study Load existing study Save current study Save current study as Clear study	av st ie ie ie ie ie	//edit /e dataset) : data" ect ect epochs" Remove :CA"		
Memory and other optic	ons			
History scripts	•			
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Quit			lata processir leactivated pl	



Doc

Ok

Cancel



#### 00 Plutings available for install on the internet Install Plugin Version Description ERPLABfilters Interface ERPLAB filters (requires seperate ERPLAB instalati... 1.00 Cleanline 1.21 Automatic artifact rejection BERGEN 1.1 Removal of fMRI-related gradient artifacts from simultaneous... Deactivate Jpdate Installed plutings Plugin Version Description Brainmovies (command line only) New version 1.03 available. Click update to install. Interface EEG toolbox functions for ERP peak detection Remove fMRI artifacts from EEG Measure projection clustering of ICA components Mutual information clustering Add envtopo capabilities to STUDY

Non linear filtering

New version 1.04 available. Click update to install.

New version 1.0 available. Click update to install.



Preprocessing

**Tim Mullen** Qusp CEO

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_	_			
		brainmovie	0.1	
		corrmap	2.00	
		eeg_toolbox	1.0	
		fMRIb	1.21	
		MP_clustering	1.00	
		MutualInfoClustering	1.00	
		StudyEnvtopo	0.9	
		VisEd	1.05	
		iirfilt	1.02	

loreta

1.1

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



ile Edit	Tools Plot Study Datasets Help	CleanLine Options
#1: Filen Char Fran Epoc Ever Sam Epoc Refe Char ICA v Data	Interpolate electrodes Reject continuous data by eye Extract epochs Remove baseline Run ICA Remove components Automatic channel rejection Automatic epoch rejection Reject data epochs	t Line noise frequencies to remove Scan for line noise p-value for detection of significant sinusoid Bandwidth (Hz) Type of signal to clean Indices of Channels/Components to clean Sliding window length (sec) Sliding window step size (sec) Window overlap smoothing factor FFT padding factor Visualize Original and Cleaned Spectra Normalize log spectrum by detrending Produce verbose output Plot Individual Figures Line noise frequencies to remove (set) (set) (set) (set) (set) (set) (set) (set) (set) (set)
	FMRIB Tools	Help Cancel Ok

#### **Filter comparisons**

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#### 0.5 Hz high-pass filter

#### - O -X - O -X pop_prop() - Channel 31 properties - O -X pop_prop() - Channel 31 properties pop_prop() - Channel 31 properties <u>File Edit View Insert Tools Desktop Window Help</u> File View Insert Tools Desktop Window Help <u>Edit View Insert Tools Desktop Window</u> <u>H</u>elp Edit File 🗋 🖆 🛃 🎍 | 🔖 | 🔍 🔍 🖑 🕲 🐙 🖌 - | 🛃 🔲 📰 🔲 🛄 🗋 🗃 🛃 🖕 🔍 🤍 🕲 🐙 🔏 - 🛃 🗋 🖆 🛃 🌭 🔍 🔍 🕲 🐙 🔏 - 🗔 🔲 🖽 💷 💷 📃 📰 🔲 🛄 Channel 31 Channel 31 Channel 31 Continous data Continous data Continous data 38.6 39.4 37.8 19.3 19.7 18.9 Trials Trials Trials 100 100 0 100 0 0 -19.7 -18.9 -19.3 -38.6 39.4 -37.8 300 400 200 300 400 300 400 100 200 100 100 200 Frames Frames Frames Activity power spectrum Activity power spectrum Activity power spectrum Power 10*log $_{10}(\mu V^2/Hz)$ Power 10*log $_{10}(\mu V^2/Hz)$ Power 10*log₁₀(µ\^{/2}/Hz) 20 10 10 0 0 0 -20 -10 -10 -40 20 60 80 20 40 20 60 80 40 60 80 40 Frequency (Hz) Frequency (Hz) Frequency (Hz)

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

#### 0.5 Hz high-pass filter Cleanline



# **Data Cleaning for ICA**

# 1. Continuous Data

## **Pre-processing pipeline**



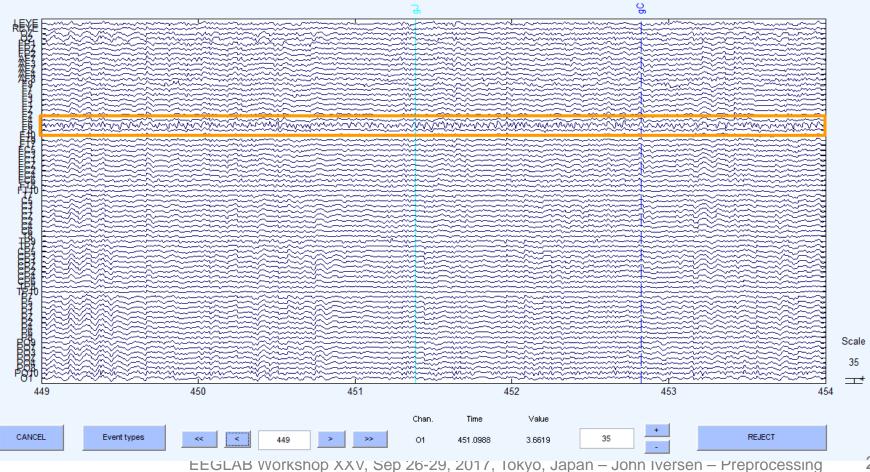
## Manually identifying bad channels

wartz Center for Computational Neuroscience

Scroll channel activities -- eegplot()

Figure Display Settings Help

#### 1) Identify bad channel



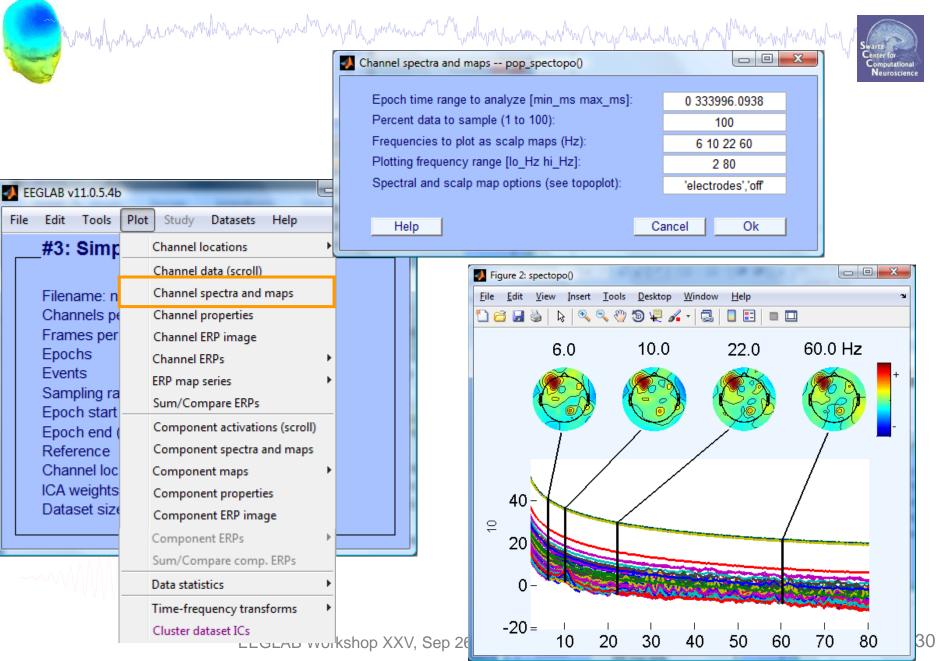
29

## Manually identifying bad channels

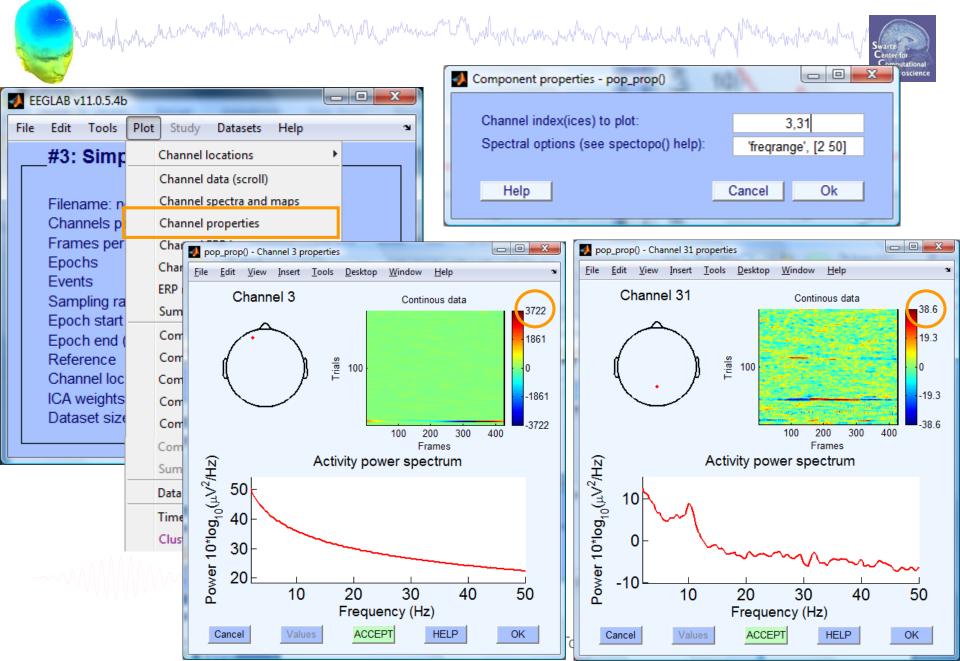
File

Epochs

Events



#### Manually identifying bad channels



# Removing channel(s)

	and have a complete and a second with the second se	Manual Marked Swartz Center for Computational Neuroscience
<b>- 1</b>	EGLAB v11.0.5.4b	
File	Edit Tools Plot Study Datasets Help	<u>الا</u>
	Dataset info Event fields Event values About this dataset Select data pop_select()	
	Channel locations Select data Time range [min may1 (s)	put desired range on->remove tr If not checked, will result
	Select data using e Select epochs or ev Epoch range (ex: [1 10]) Epoch range (ex: 3:2:10)	in dataset with one channel
	Append datasets Delete dataset(s) Channel range	F6
	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

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3Z

## **Pre-processing pipeline**

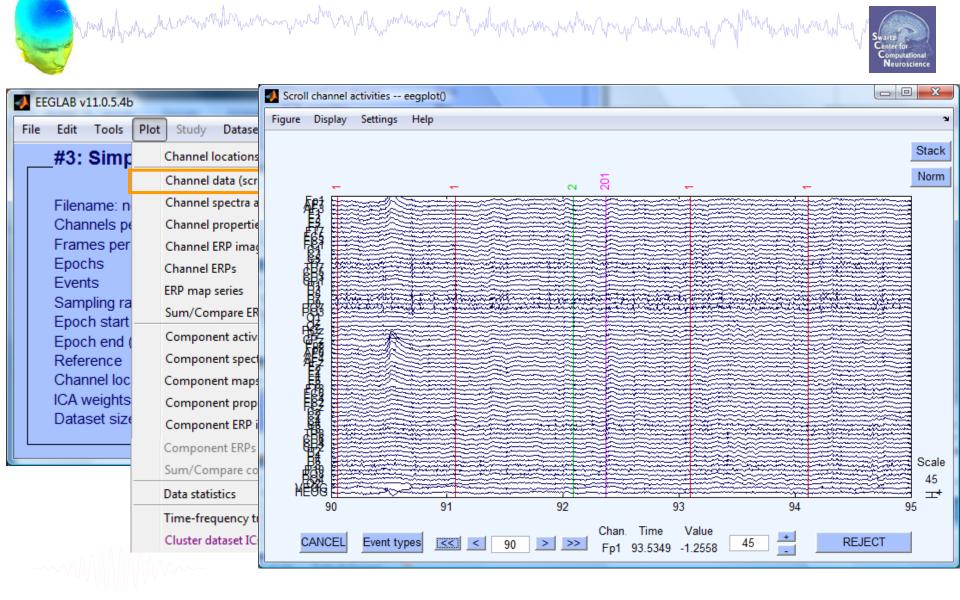


#### **Plot channel spectra**

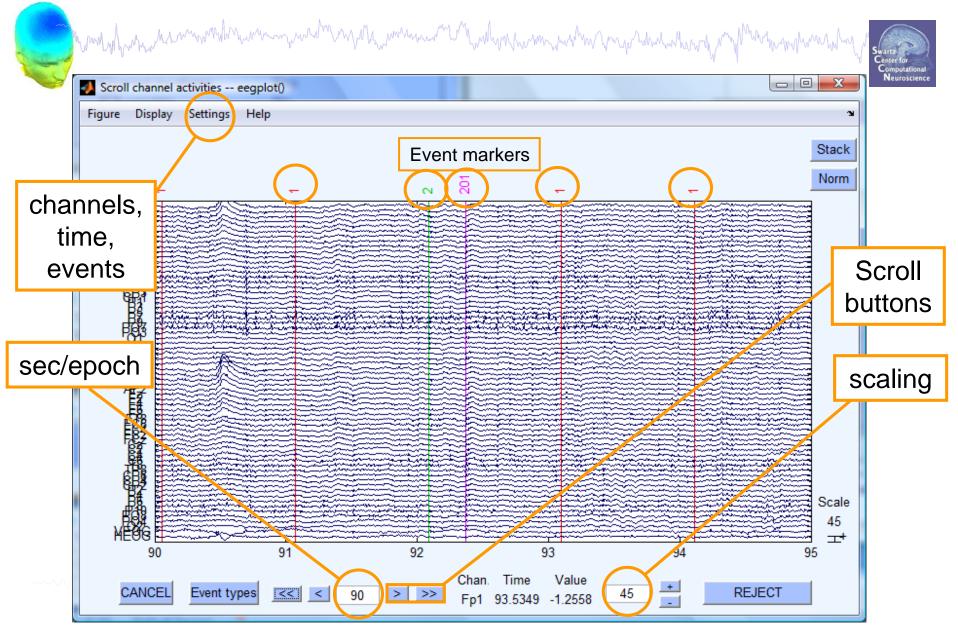
and have her and the second of the second of

- O X EEGLAB v11.0.5.4b Edit Tools Plot Study Datasets Help File Channel locations #1: Simp ۲ Channel data (scroll) Channel spectra and maps Filename: Component properties - pop_prop() Channels pe Channel properties Frames per Channel ERP image Channel index(ices) to plot: 31 Epochs Channel ERPs Spectral options (see spectopo() help): 'freqrange, [2 90] Events ERP map series Sampling ra Sum/Compare ERPs Epoch start Help Cancel Ok Component activations (scroll) Epoch end Component spectra and maps Reference Channel loc Component maps ۲ ICA weights Component properties Dataset size Component ERP image Component ERPs Sum/Compare comp. ERPs Data statistics Time-frequency transforms Cluster dataset ICs

#### Scroll channel data



#### Scroll channel data



#### **Pre-processing pipeline**



#### **Reject continuous data**

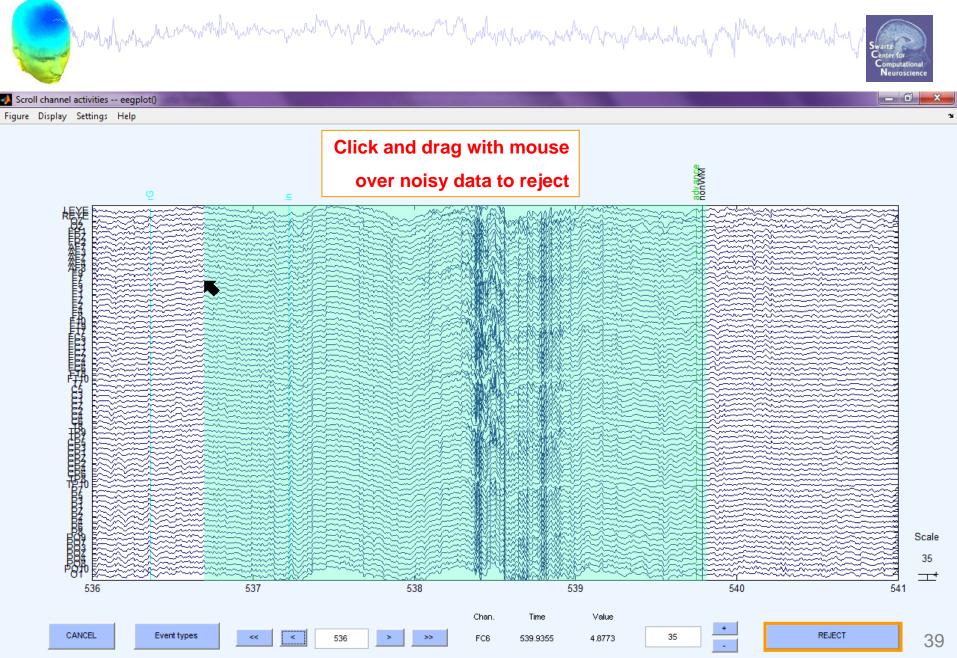
and have a marked and a second a second

Equivalent

X EEGLAB v7.1.7.18b File Edit Tools Study Datasets Plot Help Channel locations ٠ #2: Ster Channel data (scroll) Channel spectra and maps Filename: Channel properties Channels. Channel ERP image Frames pe Channel ERPs Epochs ERP map series Events Sampling i Sum/Compare ERPs Epoch sta Component activations (scroll) Epoch end Component spectra and maps Reference Component maps Channel Id Component properties ICA weight Component ERP image Dataset si Component ERPs Sum/Compare comp. ERPs Data statistics Time-frequency transforms Cluster dataset ICs

#### x EEGLAB v7.1.7.18b Plot Study Datasets Help File Edit Tools Э Change sampling rate #2: Filter the data Re-reference Filer Interpolate electrodes Cha Reject continuous data by eye Frar Extract epochs Epo Remove baseline Eve San Run ICA Epo Remove components Epo Automatic channel rejection Refe Automatic epoch rejection Cha Reject data epochs ICA. Reject data using ICA Data Locate dipoles using DIPFIT 2.x - -X **Warning** Mark stretches of continuous data for rejection by dragging the left mouse button. Click on marked stretches to unmark. When done, press "REJECT" to excise marked stretches (Note: Leaves rejection boundary markers in the event table). Cancel Continue

#### **Reject continuous data**



#### **Rejecting data for ICA**

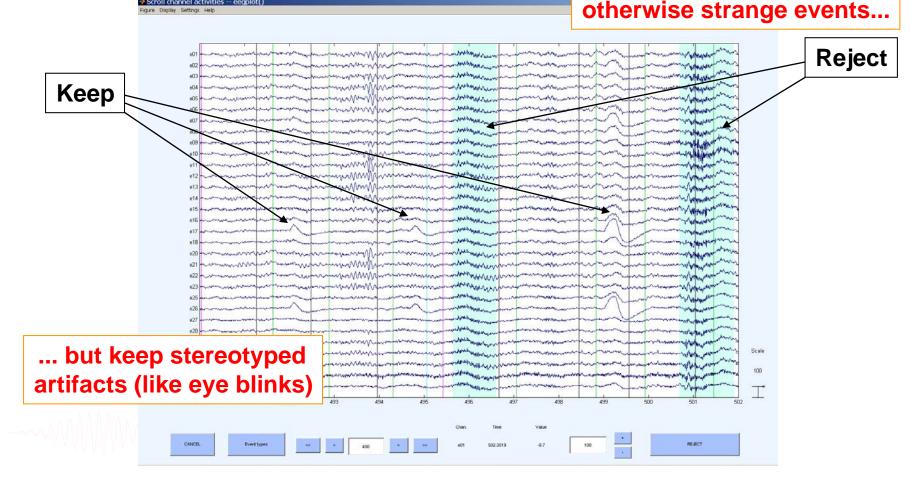
and the and the second of the



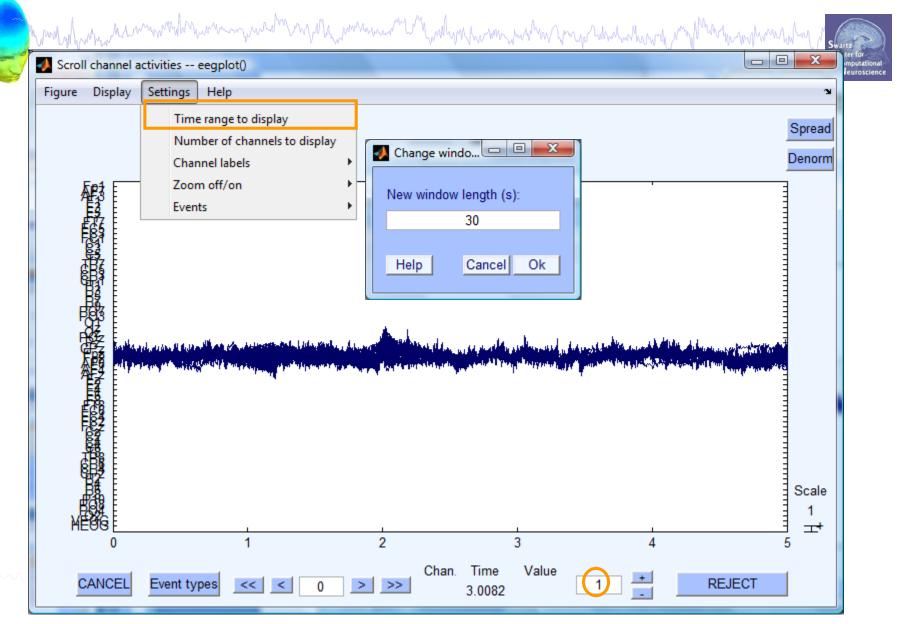
**Reject large muscle or** 

#### To prepare data for ICA:

Scroll channel activities -- eegplot



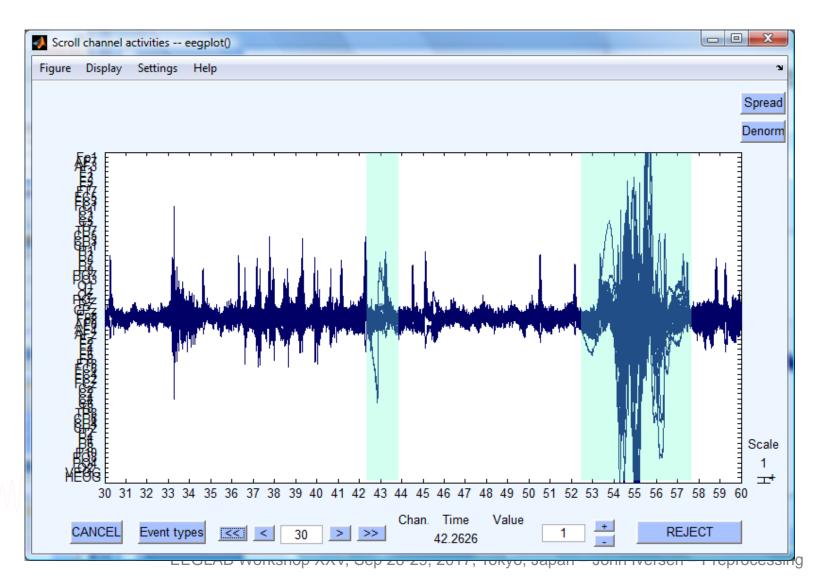
#### Fast (but sloppy) artifact rejection



#### Fast (but sloppy) artifact rejection

and have a second when a second we all a second when a second of the second and the second of the second of the





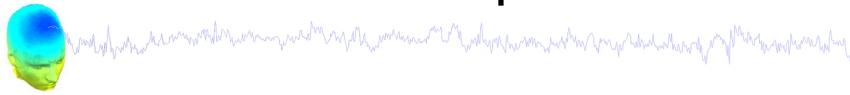


## **Data Cleaning for ICA**

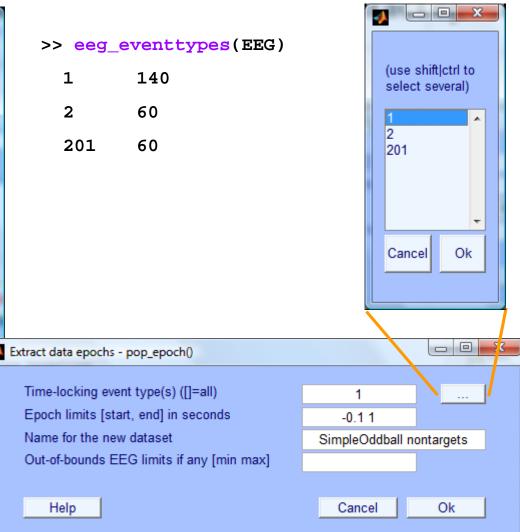
#### Variant 2: Epoched Data



#### **Extract epochs**



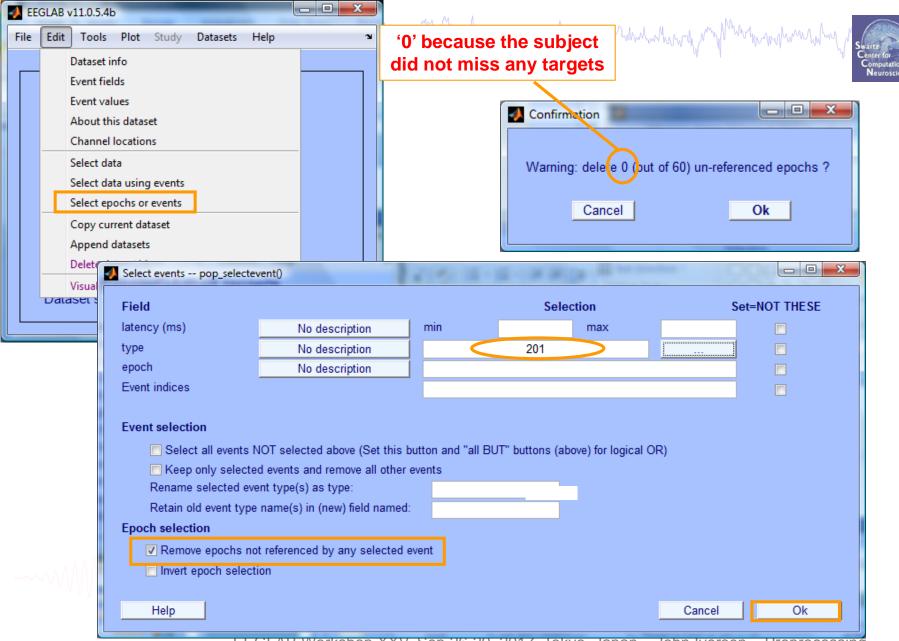
EEGLAB v	11.0.5.4b		
File Edit	Tools Plot Study Datasets Help	¥د ا	>>
#1: Filen Char Fram Epoc Sam Epoc Refe Char ICA v Data	Interpolate electrodes Reject continuous data by eye Extract epochs Remove baseline Run ICA Remove components Automatic channel rejection Automatic epoch rejection Reject data epochs	t	
	Locate dipoles using DIPFIT 2.x       Peak detection using EEG toolbox       FMRIB Tools       Locate dipoles using LORETA       CleanLine		Extract dat Time-lo Epoch Name f Out-of-l

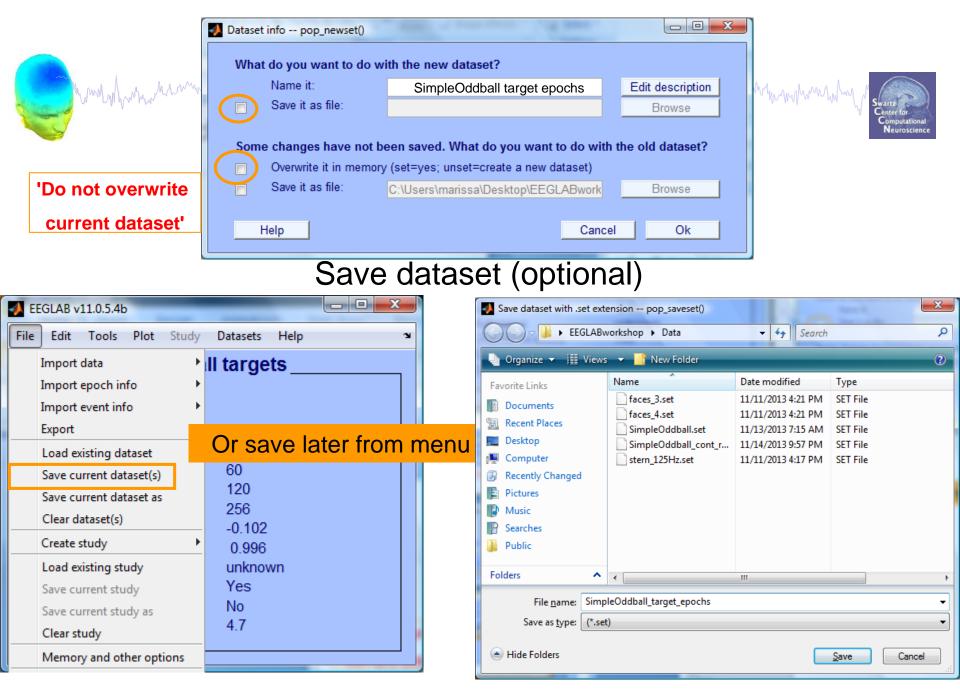


#### **Extract epochs**

What do you want to do with the new dataset?   Name it:   Save it as file:	
Save it as file:     Browse       Some changes have not been st     Epoch baseline removal pop_rmbase()       Overwrite it in memory (set=     Baseline latency range (min_ms_max_ms) (I) = 1	
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Some changes have not been st       Coverwrite it in memory (set=         Overwrite it in memory (set=       Baseline latency range (min, ms, may, ms) (II = )	
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-101.5625 0 #2: SimpleOddball nonta	argets
Help Else, baseline points vector (ex:1:56) ([] = whole	
(overwritten by latency range above). Filename: none	
Channels per frame 66	
Frames per epoch 202	
Help Cancel Events 140	
Sampling rate (Hz) 256 Epoch start (sec) -0.102	
Epoch and (sec) 0.996	
Reference unknow	wn
Channel locations Yes	

#### Select a subset of epochs

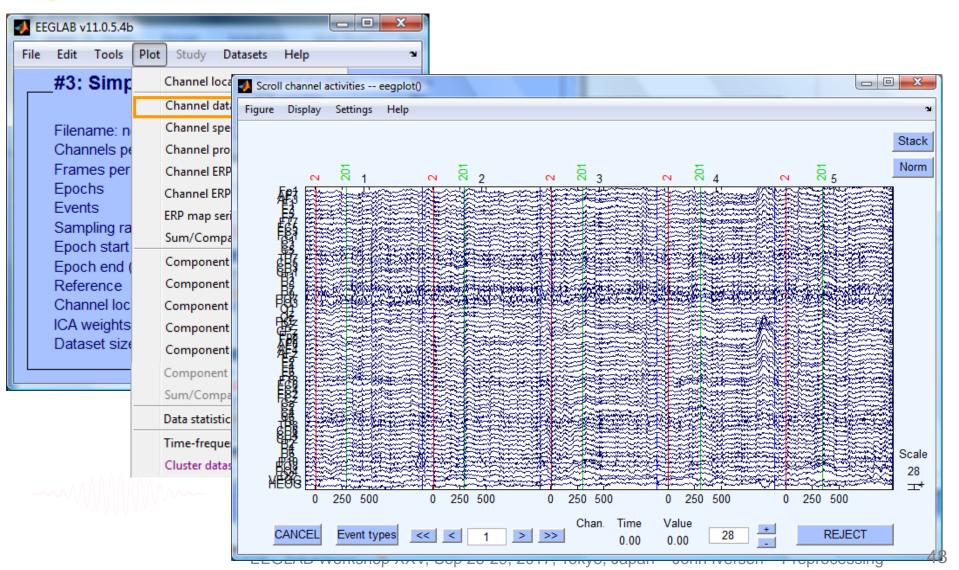




#### Scroll (epoched) channel data

and have a second and a second a se





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





1			EEG	LAB v6.	0b				×	
File	Edit	Tools	Plot	Study	Datasets	Help		1	И	
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	Avera Chani		ect data		-	×.	i i	Rejec	t d	lata (all methods)
	ICA w Datas	Rej	ect data	using		•	ł	Rejec	tb	y inspection extreme values
			ate dipo Iacian	les usi	ng DIPFIT 2	.x →	Reject by linear trend/variance Reject by probability			
		Gra	RIB Tool: Ind aver	age da	tasets ng LORETA	*		Rejec	tb	iy kurtosis iy spectra marks to ICA reject
			ate uipe X plugin	ies usi	ng concra					narked epochs

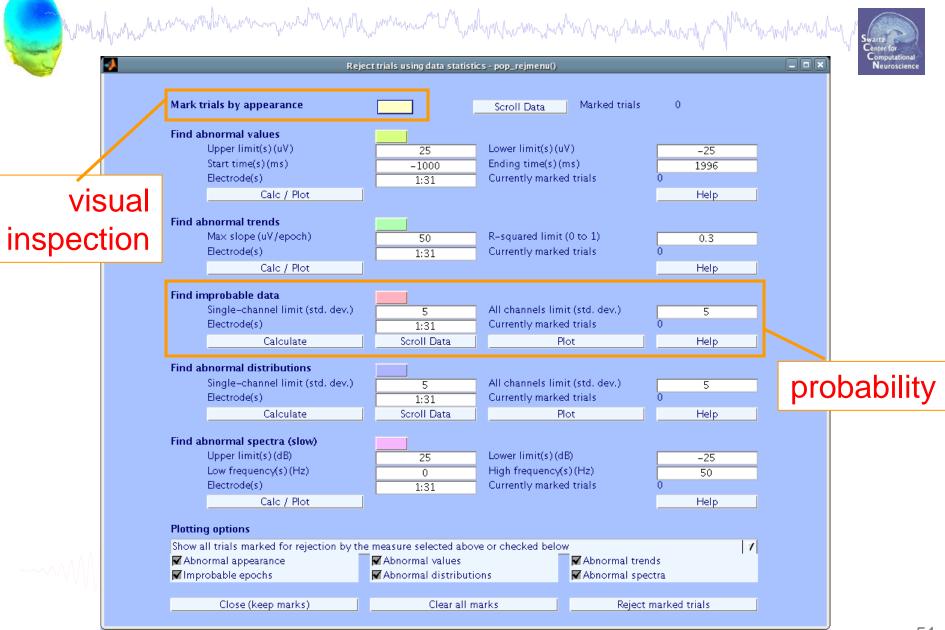
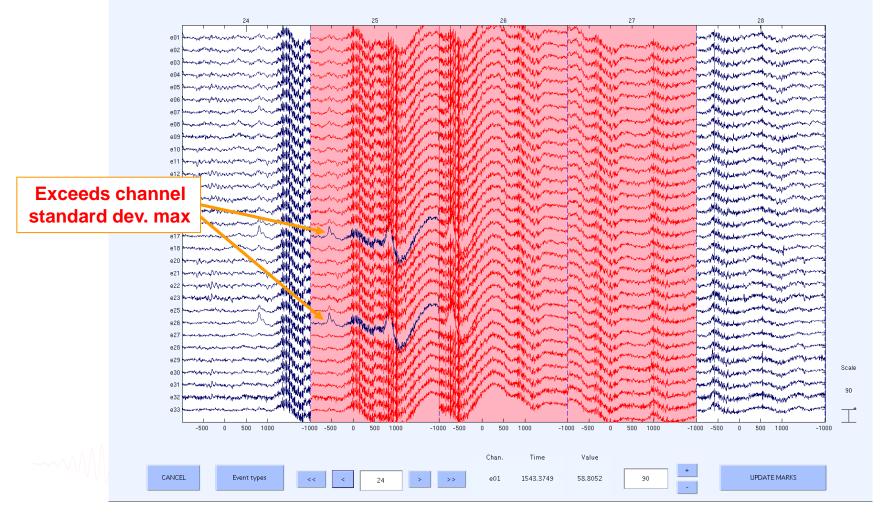






Figure Display Settings Help



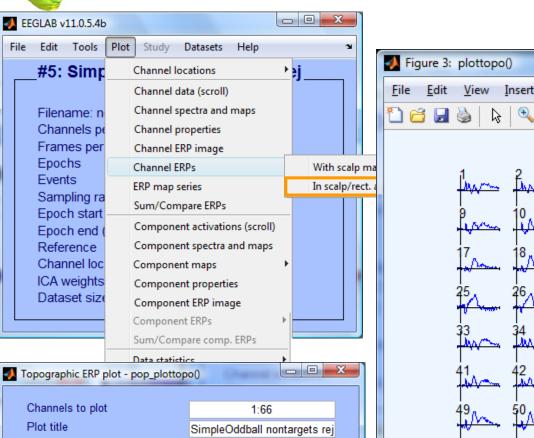


1			EE	GLAB v6.	0b				X	
File	Edit	Tools	Plot	Study	Datasets	Help	_		ъ	
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	Frame Epoch Event	LAG	ract ep nove b	ochs aseline			_			
	Samp Epoch	Rer	n ICA nove c	ompone	nts		_			
	Epoch Avera	Aut		-	ejection					
	Chani ICA w			a epoch a using		•	Reject data (all methods) Reject by inspection Reject extreme values Reject by linear trend/variance Reject by probability			
	Datas	Loc	ate dip	ioles usi	ng BESA	•				
			ate dip Ilacian	ioles usi	ng DIPFIT 2.	.x •				
		EME	RIB Too	ls		•	Reject by kurtosis			
				rage da		•	Reject by spectra			
			ate dip X plugir		ng LORETA	*	Export marks to ICA reject Reject marked epochs			

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#### Visualize ERP in rectangular array

and have been and the second of the second o



EEGLAB v11.0.5.4b

Edit Tools

#5: Simp

Filename: n

Channels pe

Frames per

Sampling ra

Epoch start

Epoch end

Reference Channel loc

ICA weights

Dataset size

Channels to plot

Plot single trials

Plot in rect. array

Help

Other plot options (see help)

(set=yes)

(set=yes)

'ydir', 1

Ok

Cancel

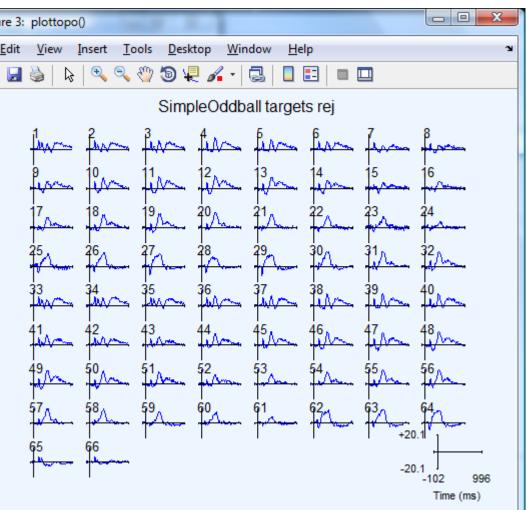
Plot title

Epochs

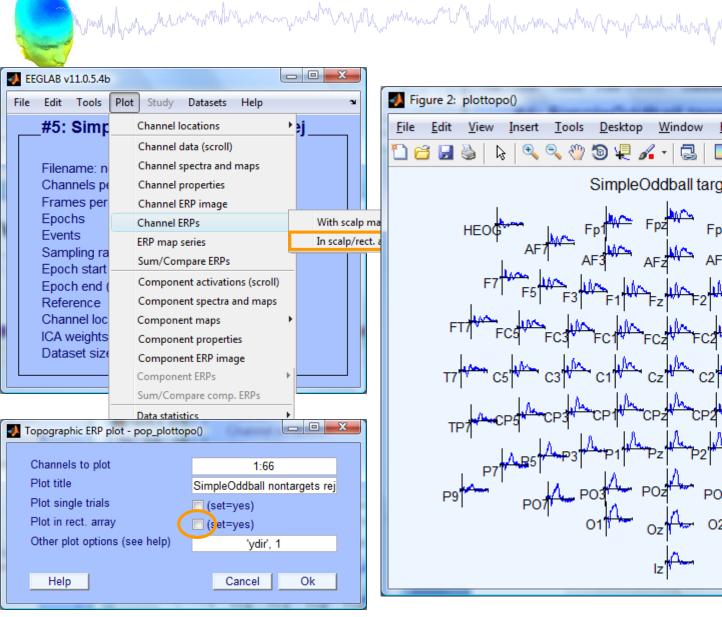
Events

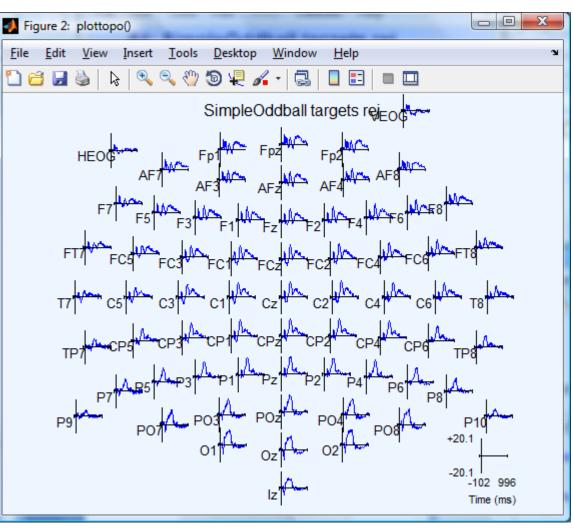
File

Plot

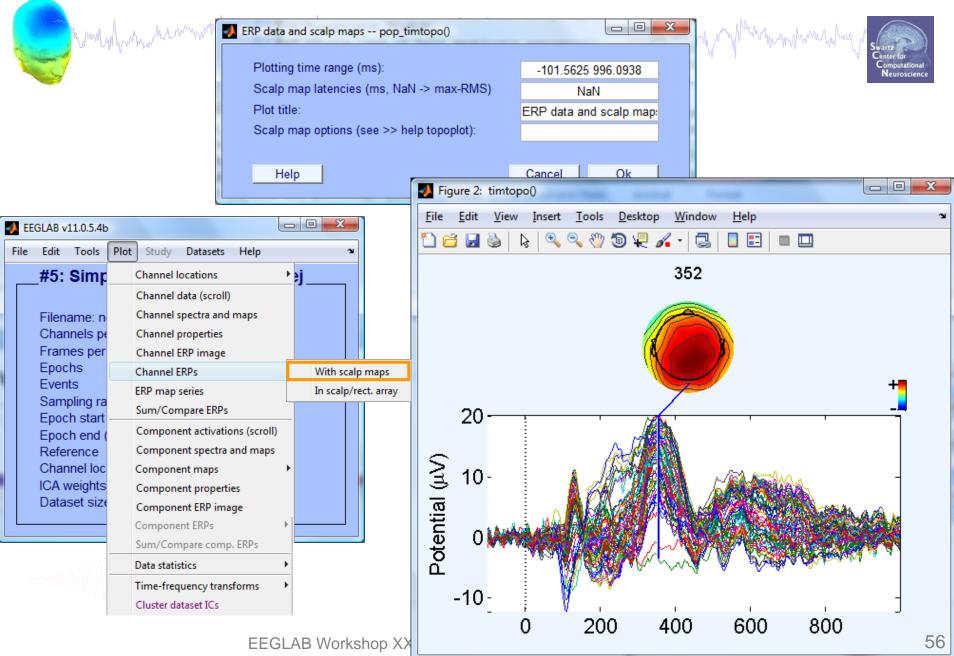


#### Visualize ERP in topographic array

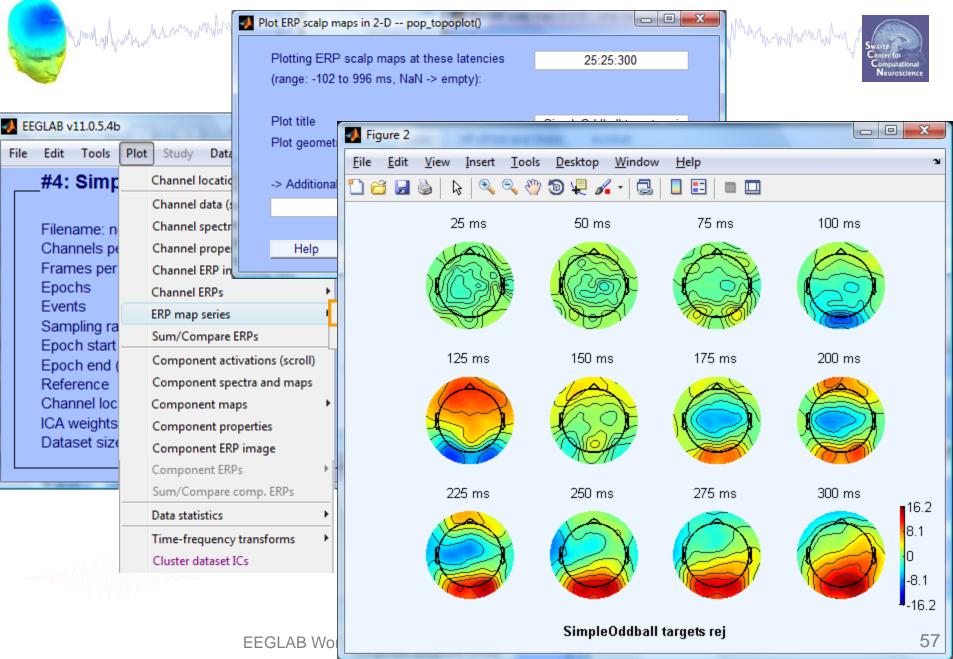




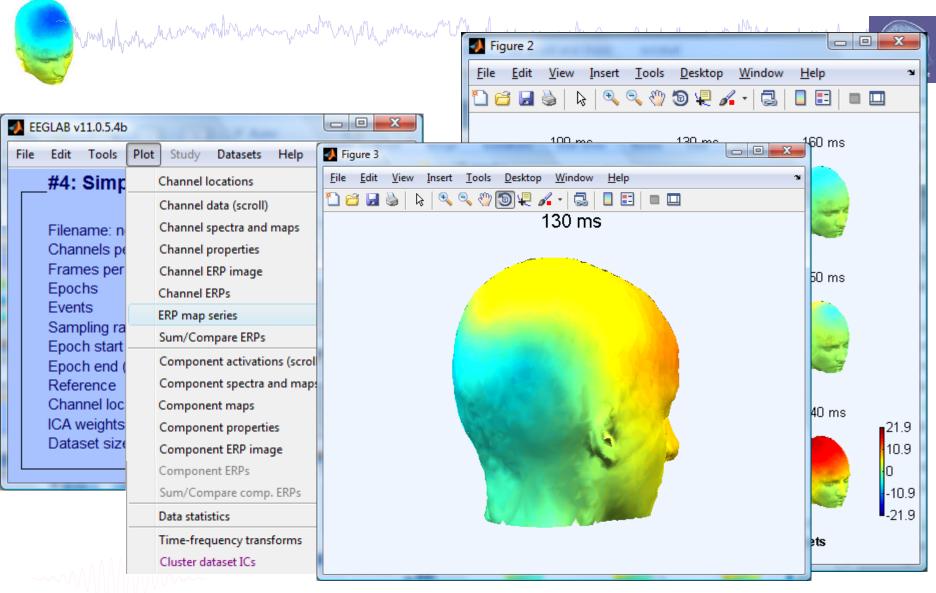
#### **Visualize ERP scalp distribution**



#### Visualize channel ERPs in 2D



#### Visualize channel ERPs in 3D



#### **Pre-processing pipeline**



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

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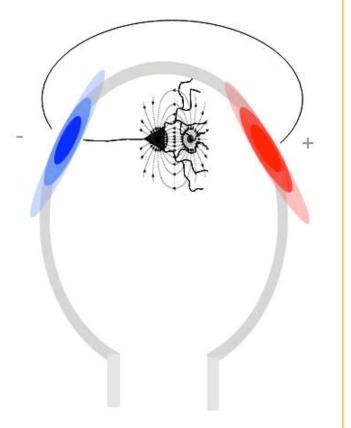
- х EEGLAB v10.2.2.1b Plot Study Datasets Help File Edit Tools ъ Change sampling rate #1 uous Filter the data average reference Re-reference V.set File Interpolate electrodes Cha Reject continuous x Frai pop_reref - average reference or re-reference data Epd Extract epochs Eve Remove baseline Current data reference state is: unknown Sar Run ICA Compute average reference Epd Remove componer Re-reference data to channel(s): Epc Automatic channel Ref Automatic epoch r Cha Retain old reference channels in data Reject data epochs ICA Exclude channel indices (EMG, EOG) Reject data using IC Dat Add current reference channel back to the data NFT plugin SIFT Help Ok Cancel Locate dipoles usin Peak detection using EEG toolbox FMRIB Tools Locate dipoles using LORETA



### **On Average Referencing**

and have a second when a second s





- In theory, positive and negative current across entire head should balance—no net current source or sink: Average referencing enforces this.
- ICA is invariant to re-referencing, except for
  - Effect of rank deficiency
  - DC difference.
- Average referencing reduces data rank by 1, so you must remove one channel (Cz often) See update below.

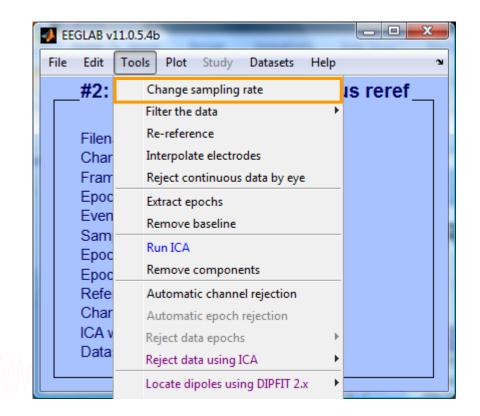
https://sccn.ucsd.edu/wiki/Makoto's_preprocessing_pipeline#Re-reference_the_data_to_average

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

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Reason: Reduce space, time. But keep nyquist and ICA data length requirements in mind...



	curr 💷 💷	x
New samp	ling rate	
	256	
Help	Cancel	Ok



# END

#### **Exercises (optional homework)**

Swartz Center for Computational Neuroscience

• Preprocess data of your choice or load a previously filtered dataset e.g. faces_4.set

 Identify and remove non-task portions of continuous data; see if the previously flagged channels are still identified as bad

• Epoch on event of interest. Scroll the epoched data and perform visual rejection of epochs

