



Practicum: Performing ERP analysis in BCILAB

EEGLAB Workshop 2016, Track B

Christian A. Kothe
Qusp

Questions welcome any time! 😊



Outline

1. Preparations
2. Offline ERP Analysis
3. Online ERP Analysis
4. Customizing Approaches
5. Optional analyses: Using an Advanced ERP Paradigm



1 Preparations

Preparations

- ... please start unzipping your BCILAB distribution file to some directory on your disk if you haven't done so already.
- Should take 5-10 minutes (if you're on Windows, try to use 7-zip or WinZip/WinRAR).
- Don't put it inside the EEGLAB folder (BCILAB includes an EEGLAB distribution).

System requirements

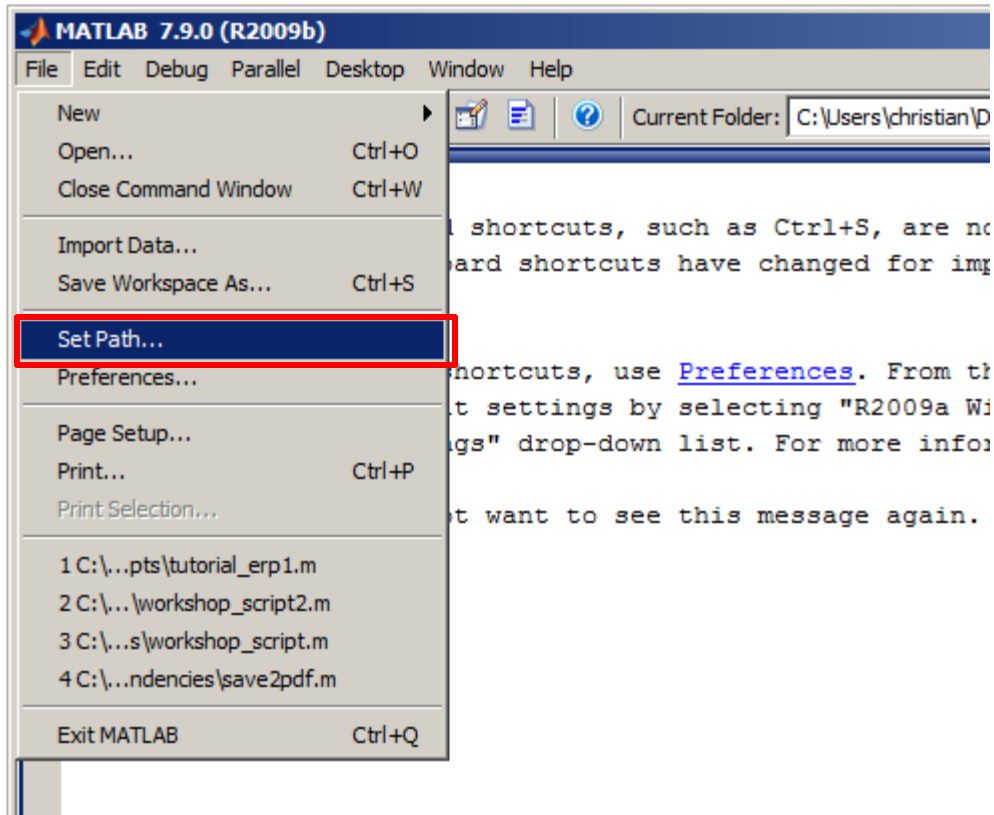
- MATLAB 2008a+
- 1GB+ RAM (better: 2GB+)
- Windows, Linux, or Mac
- For smooth workshop: **No** toolboxes in MATLAB path other than Mathworks toolboxes (or EEGLAB)
- To use certain additional features (not covered today):
Signal Processing Toolbox, Statistics Toolbox
- To use certain advanced features (also not covered today):
Correct MEX compiler setting (this requires Microsoft Visual C++ Express under Win64 and Xcode/gcc under Mac)



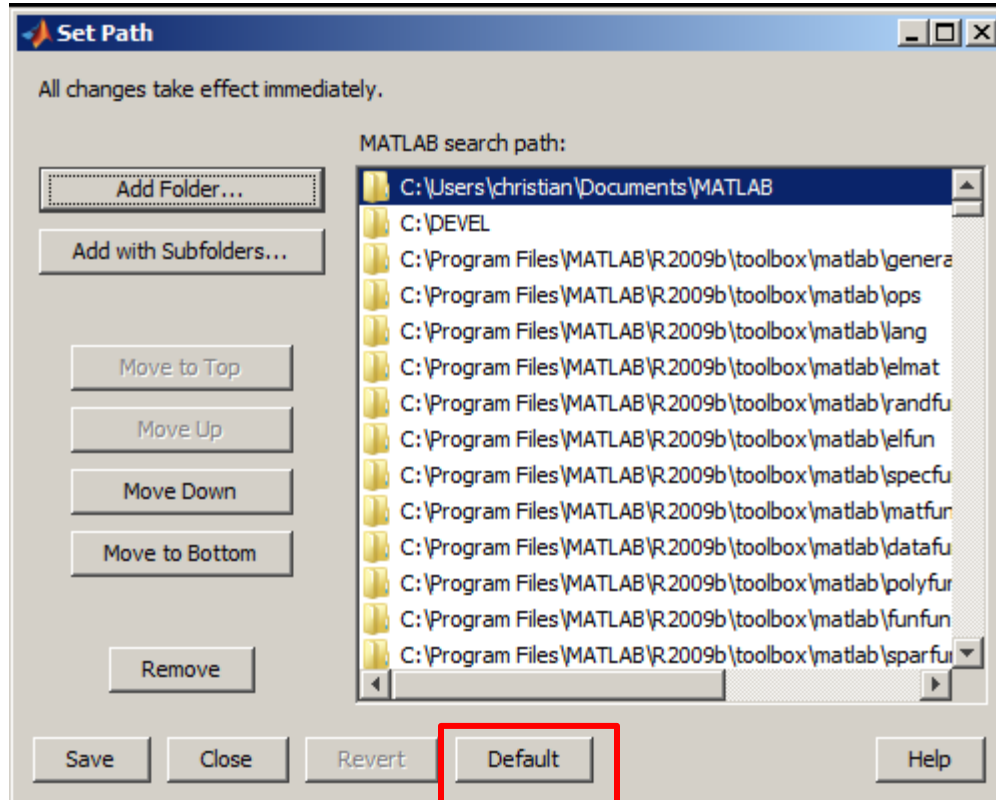
Note: When Processing your own Data

- Note the following requirements:
 - You need proper channel labels (usually the 10-20 labels); 3d locations not necessary
 - You need event markers in your data at time points where the BCI should predict outputs
 - BCILAB needs raw (unprocessed) data
 - Make sure you have a file format supported by EEGLAB
- Rawr!
-
- An arrow points from the word "Rawr!" located below the list to the word "raw" in the third list item, "BCILAB needs raw (unprocessed) data".

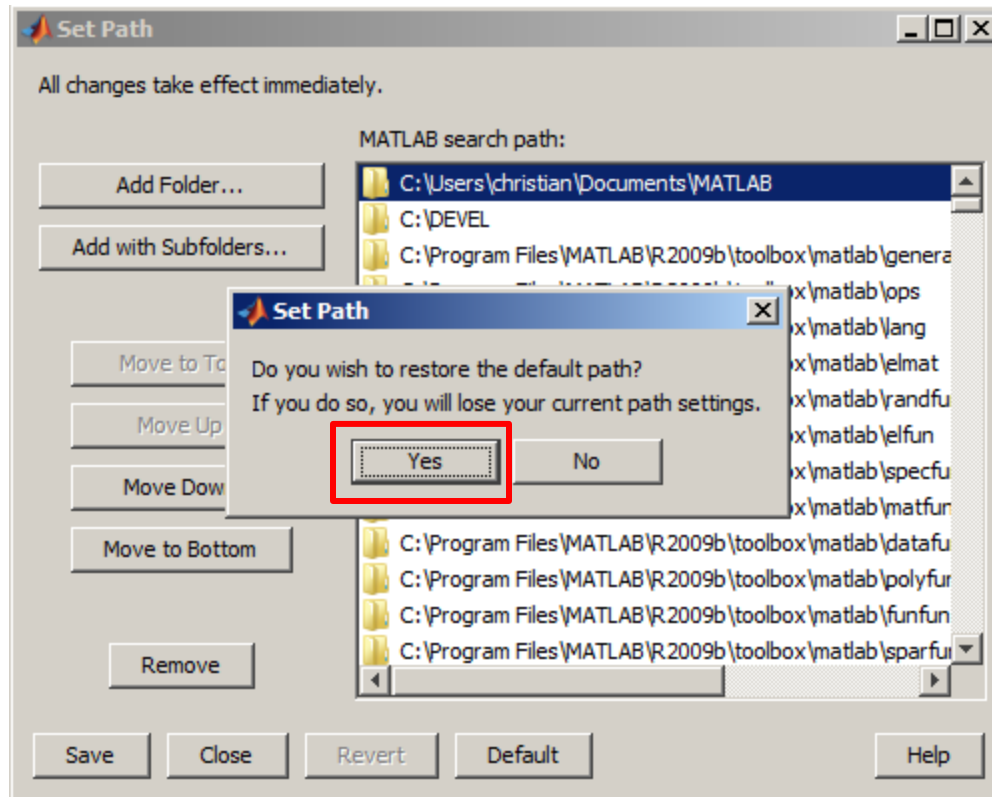
Clearing the Path



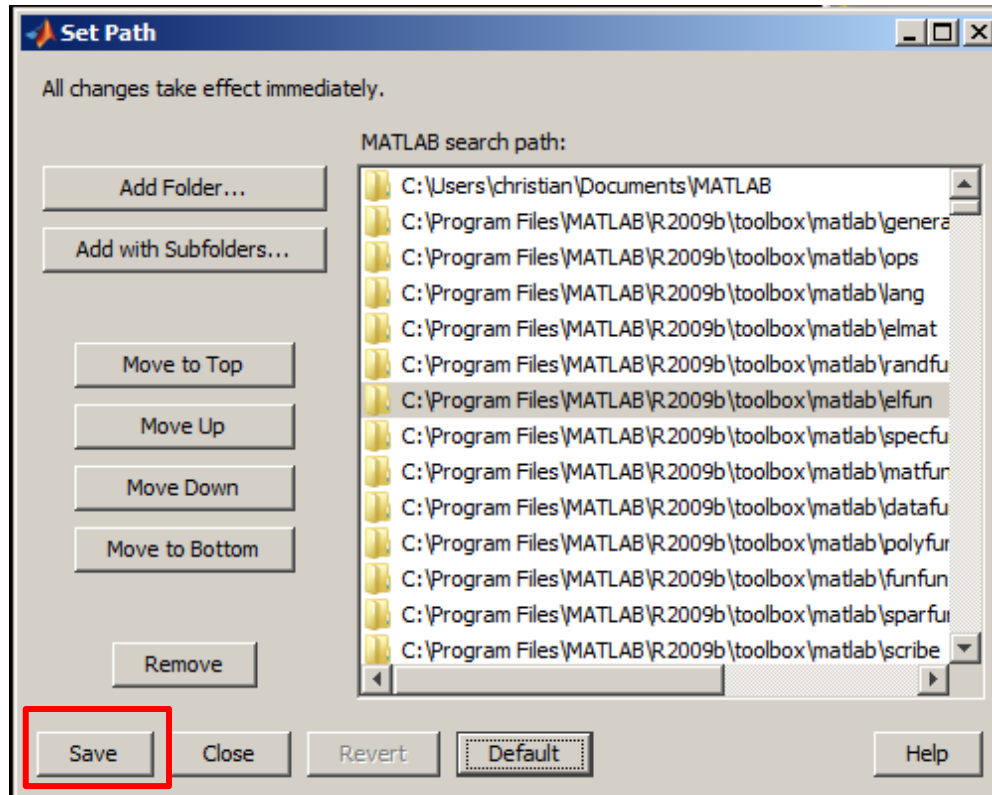
Clearing the Path



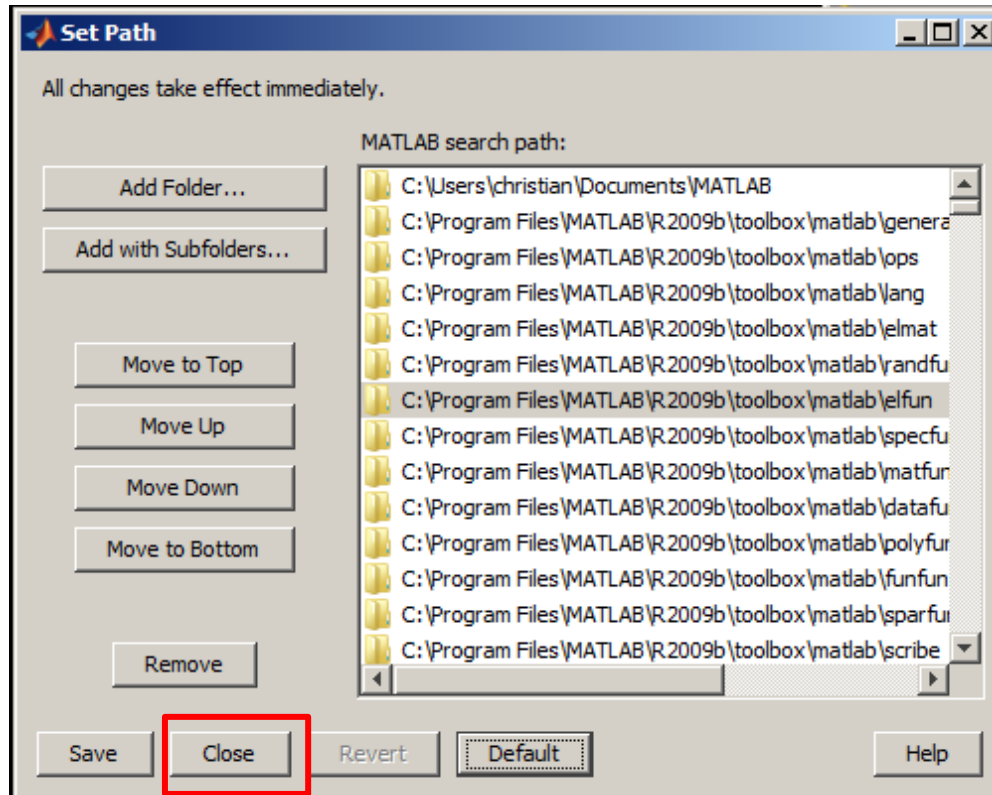
Clearing the Path



Clearing the Path

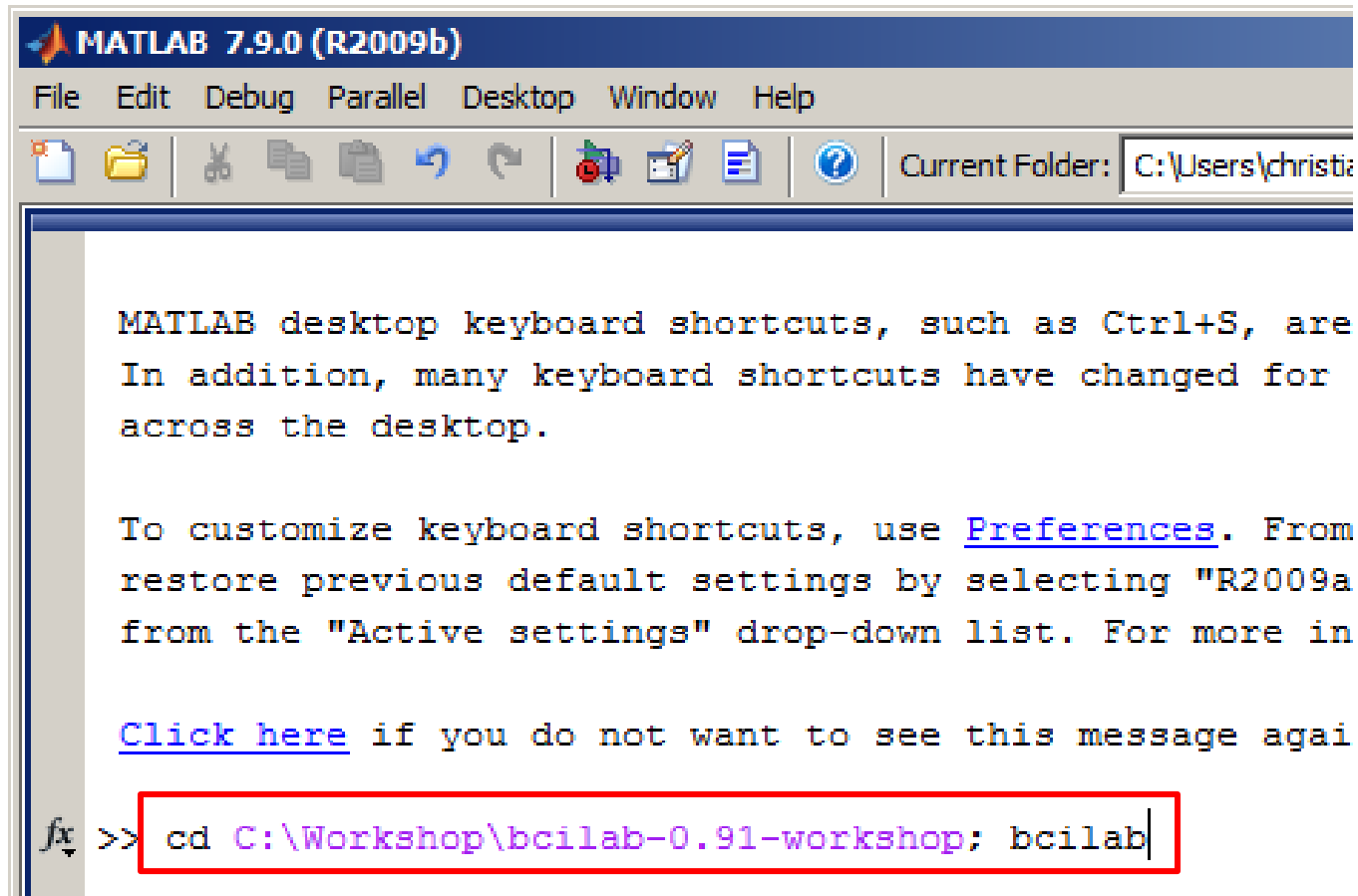


Clearing the Path



Starting the Toolbox

- Type: `cd C:\your\path\to\bcilab; bcilab`



MATLAB 7.9.0 (R2009b)

File Edit Debug Parallel Desktop Window Help

Current Folder: C:\Users\christia

MATLAB desktop keyboard shortcuts, such as Ctrl+S, are
In addition, many keyboard shortcuts have changed for
across the desktop.

To customize keyboard shortcuts, use [Preferences](#). From
restore previous default settings by selecting "R2009a
from the "Active settings" drop-down list. For more in

[Click here](#) if you do not want to see this message agai

```
fx >> cd C:\Workshop\bcilab-0.91-workshop; bcilab
```



Starting the Toolbox

- Or if your path contains spaces, type:
`cd('C:\your\path\to\bcilab'); bcilab`



Starting the Toolbox

- If you have an unsupported OS/MATLAB combination, BCILAB might ask you some question about compiling functions
 - Just type n (for no) to continue
- If you have things on your MATLAB path that override BCILAB function names, you will get some warnings about it (it's best to remove them from the path)

Starting the Toolbox

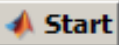
- You should now see the welcome message

```
temp directory \tmp\bcilab_temp does not exist and could not be created
Could not probe cache file system speed; reason: Error using ==> save
Unable to write file \tmp\bcilab_cache\_probe_cache_1450493820_.mat: 1

code is in C:\Workshop\bcilab-0.91-workshop\code
data is in C:\Workshop\bcilab-0.91-workshop\userdata
results are in C:\Workshop\bcilab-0.91-workshop\userdata
cache is in \tmp\bcilab_cache (location_1)
temp is in \tmp\bcilab_temp

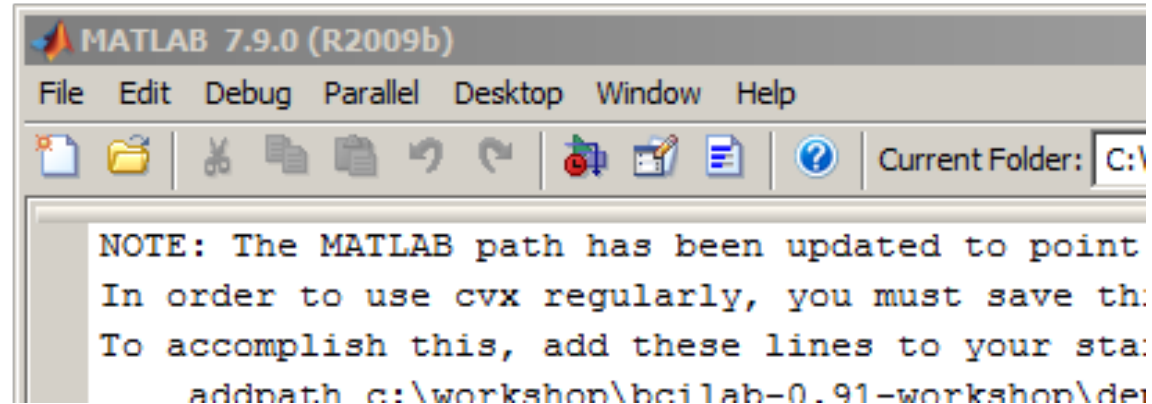
Welcome to the BCILAB toolbox!

fx >>
```

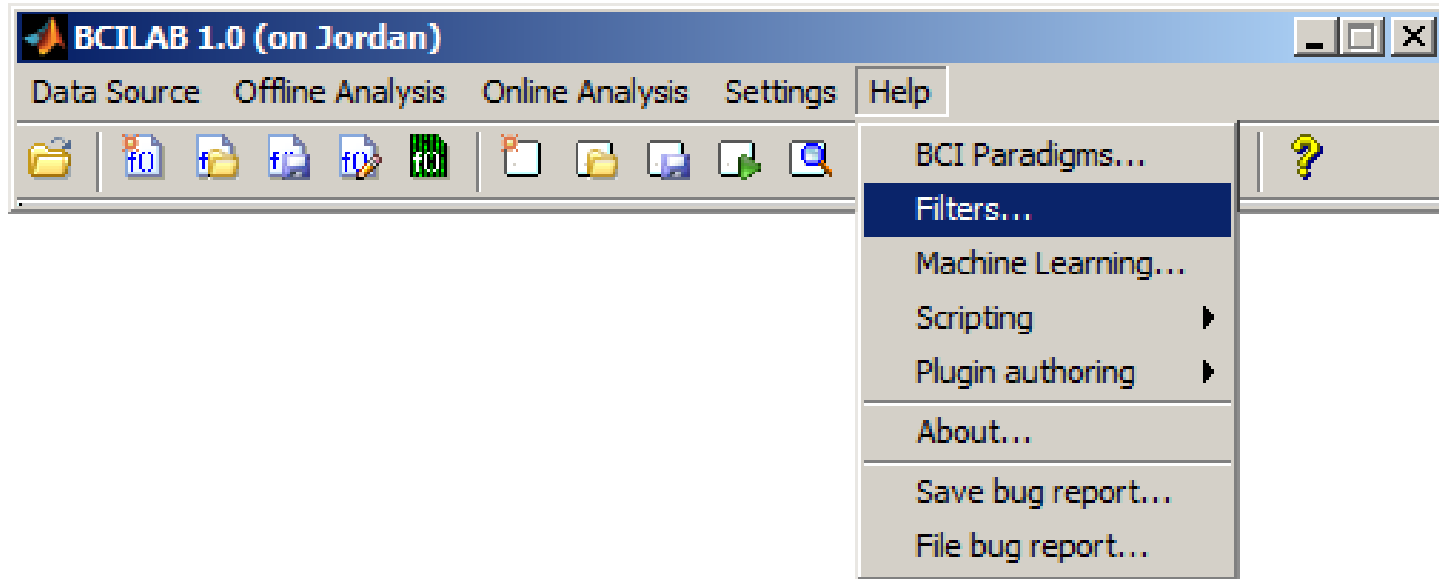


Starting the Toolbox

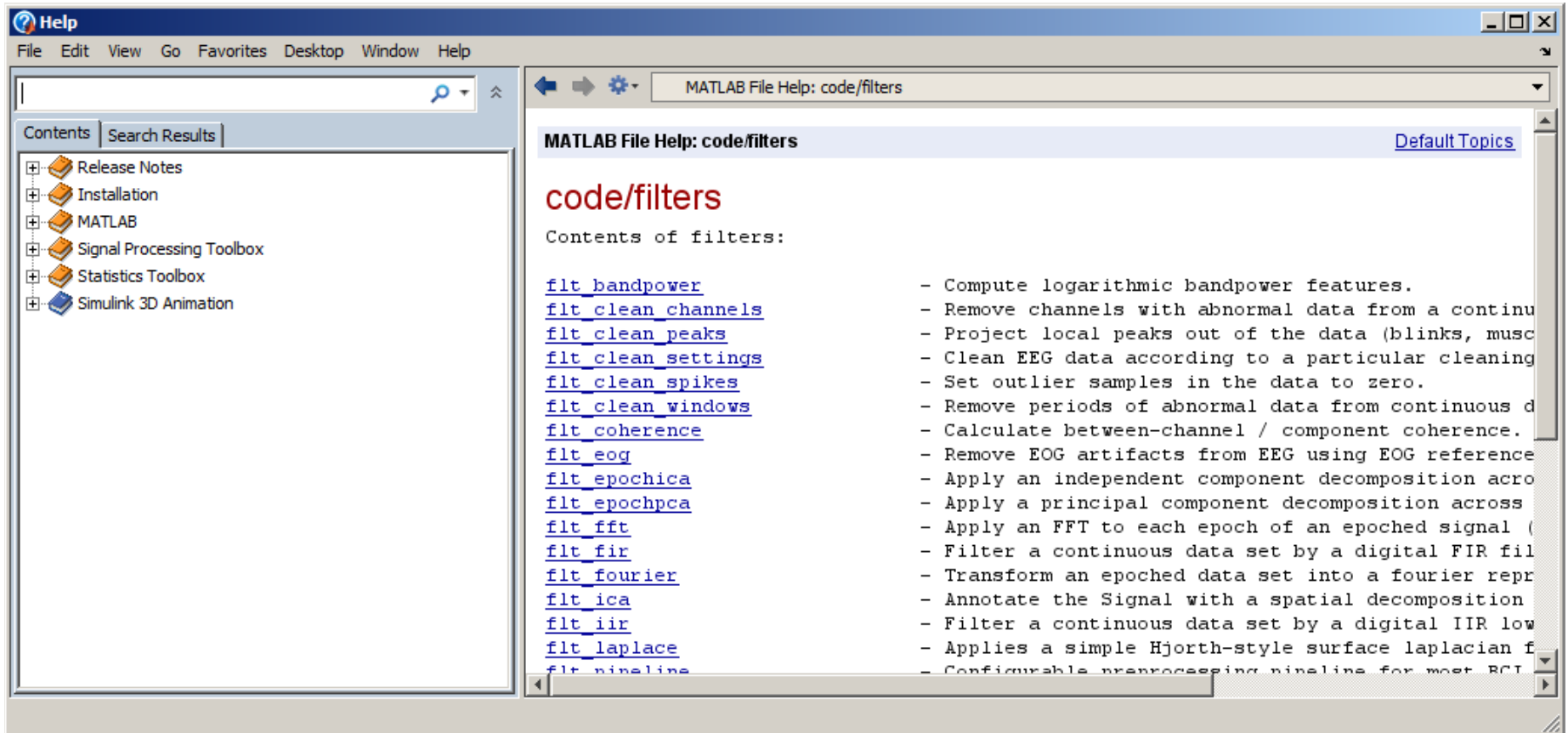
- ... and the main menu



Getting help (if needed)

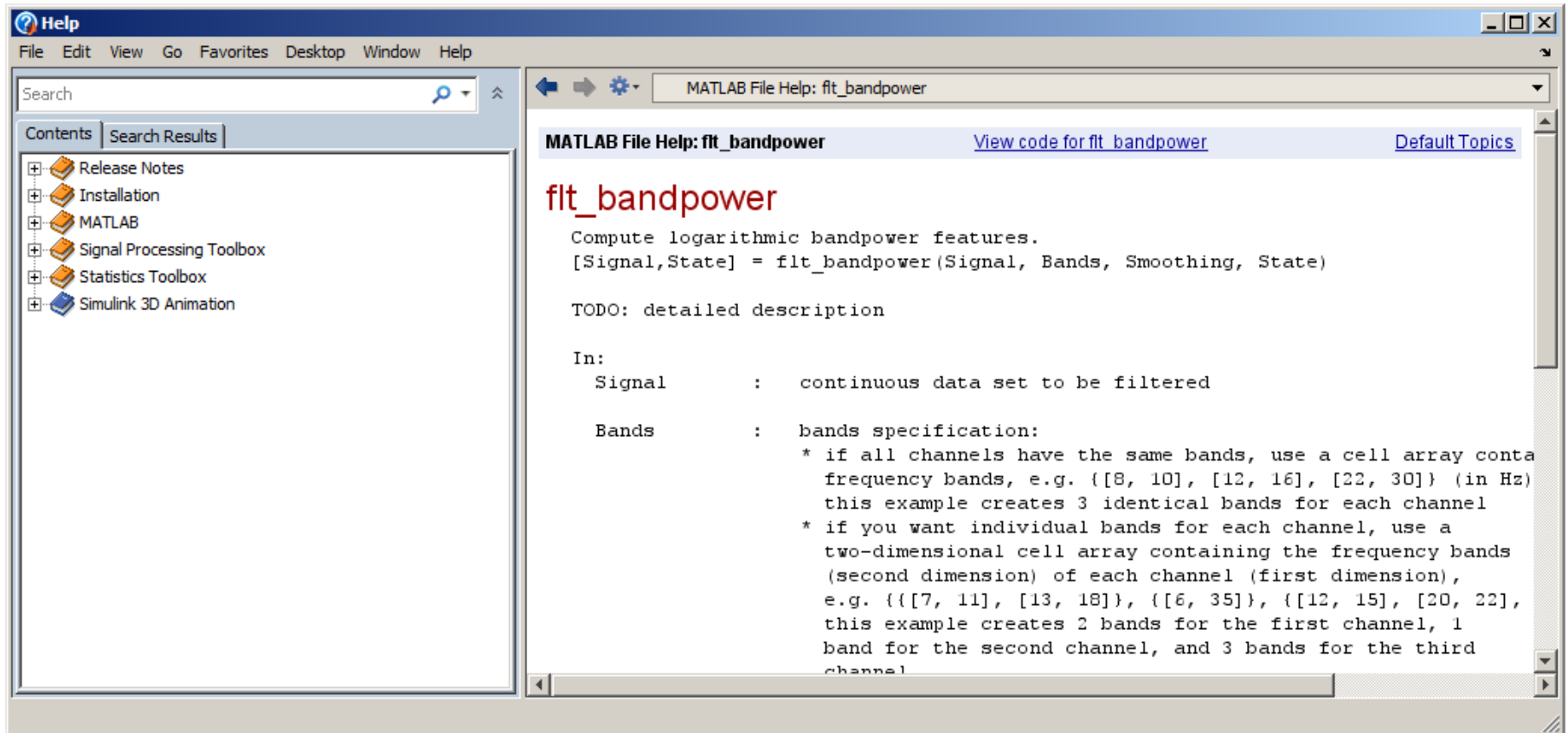


Getting help (if needed)



The screenshot shows the MATLAB File Help window. The title bar reads "MATLAB File Help: code/filters". The left sidebar contains a "Contents" pane with a tree view of help topics: Release Notes, Installation, MATLAB, Signal Processing Toolbox, Statistics Toolbox, and Simulink 3D Animation. The main content area displays the "code/filters" section, titled "MATLAB File Help: code/filters" with a "Default Topics" link. Below the title, it says "Contents of filters:" followed by a list of filter functions with blue underlined links: [flt_bandpower](#), [flt_clean_channels](#), [flt_clean_peaks](#), [flt_clean_settings](#), [flt_clean_spikes](#), [flt_clean_windows](#), [flt_coherence](#), [flt_eog](#), [flt_epochica](#), [flt_epochpca](#), [flt_fft](#), [flt_fir](#), [flt_fourier](#), [flt_ica](#), [flt_iir](#), [flt_laplace](#), and [flt_pipeline](#). To the right of these links is a list of brief descriptions for each function, such as "Compute logarithmic bandpower features.", "Remove channels with abnormal data from a continu...", "Project local peaks out of the data (blinks, musc...", "Clean EEG data according to a particular cleaning...", "Set outlier samples in the data to zero.", "Remove periods of abnormal data from continuous d...", "Calculate between-channel / component coherence.", "Remove EOG artifacts from EEG using EOG reference...", "Apply an independent component decomposition across...", "Apply a principal component decomposition across...", "Apply an FFT to each epoch of an epoched signal (...", "Filter a continuous data set by a digital FIR fil...", "Transform an epoched data set into a fourier repr...", "Annotate the Signal with a spatial decomposition...", "Filter a continuous data set by a digital IIR low...", "Applies a simple Hjorth-style surface laplacian f...", and "Configurable preprocessing pipeline for most BCI..."

Getting help (if needed)



The screenshot shows the MATLAB Help window for the `fit_bandpower` function. The window title is "MATLAB File Help: fit_bandpower". The left sidebar shows a "Contents" pane with a tree view of help topics: Release Notes, Installation, MATLAB, Signal Processing Toolbox, Statistics Toolbox, and Simulink 3D Animation. The main content area displays the function signature and description:

MATLAB File Help: fit_bandpower [View code for fit_bandpower](#) [Default Topics](#)

fit_bandpower

Compute logarithmic bandpower features.
`[Signal,State] = fit_bandpower(Signal, Bands, Smoothing, State)`

TODO: detailed description

In:

Signal : continuous data set to be filtered

Bands : bands specification:

- * if all channels have the same bands, use a cell array containing frequency bands, e.g. `{[8, 10], [12, 16], [22, 30]}` (in Hz) this example creates 3 identical bands for each channel
- * if you want individual bands for each channel, use a two-dimensional cell array containing the frequency bands (second dimension) of each channel (first dimension), e.g. `{{[7, 11], [13, 18]}, {[6, 35]}, {[12, 15], [20, 22]}}`, this example creates 2 bands for the first channel, 1 band for the second channel, and 3 bands for the third channel



2 Offline ERP Analysis

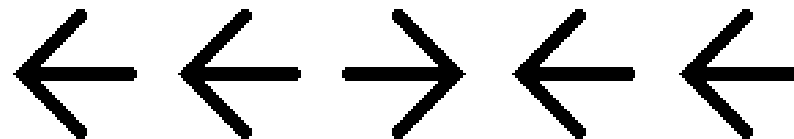


The Data

- Provided by Grainne McLoughlin
- Contains data from a Flanker task
- Two groups of markers:
 - S101, S102: person presses a button and **commits no error**
 - S201, S202: person presses a button and **commits an error**

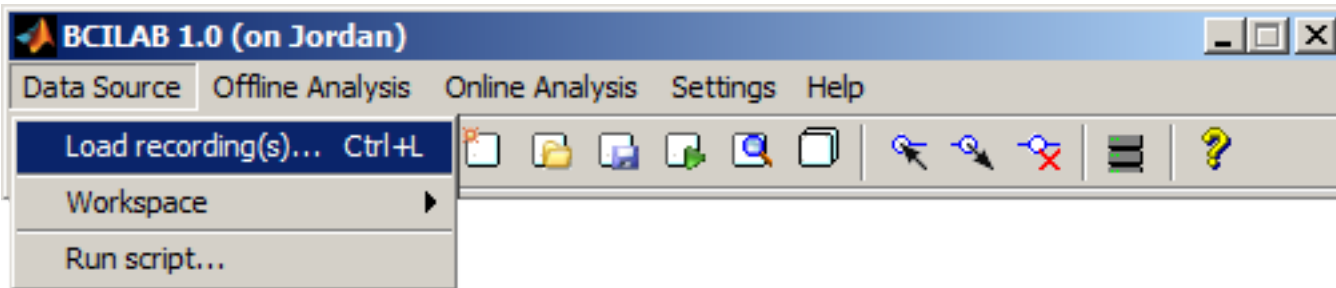
Experimental Task

- **Flanker Task:** The experiment consists of a sequence of ca. 330 trials with inter-trial interval of 2s +/- 1.5s
- At the beginning of each trial, an arrow is presented centrally (pointing either left or right)
- The arrow is flanked by congruent or incongruent “flanker” arrows:

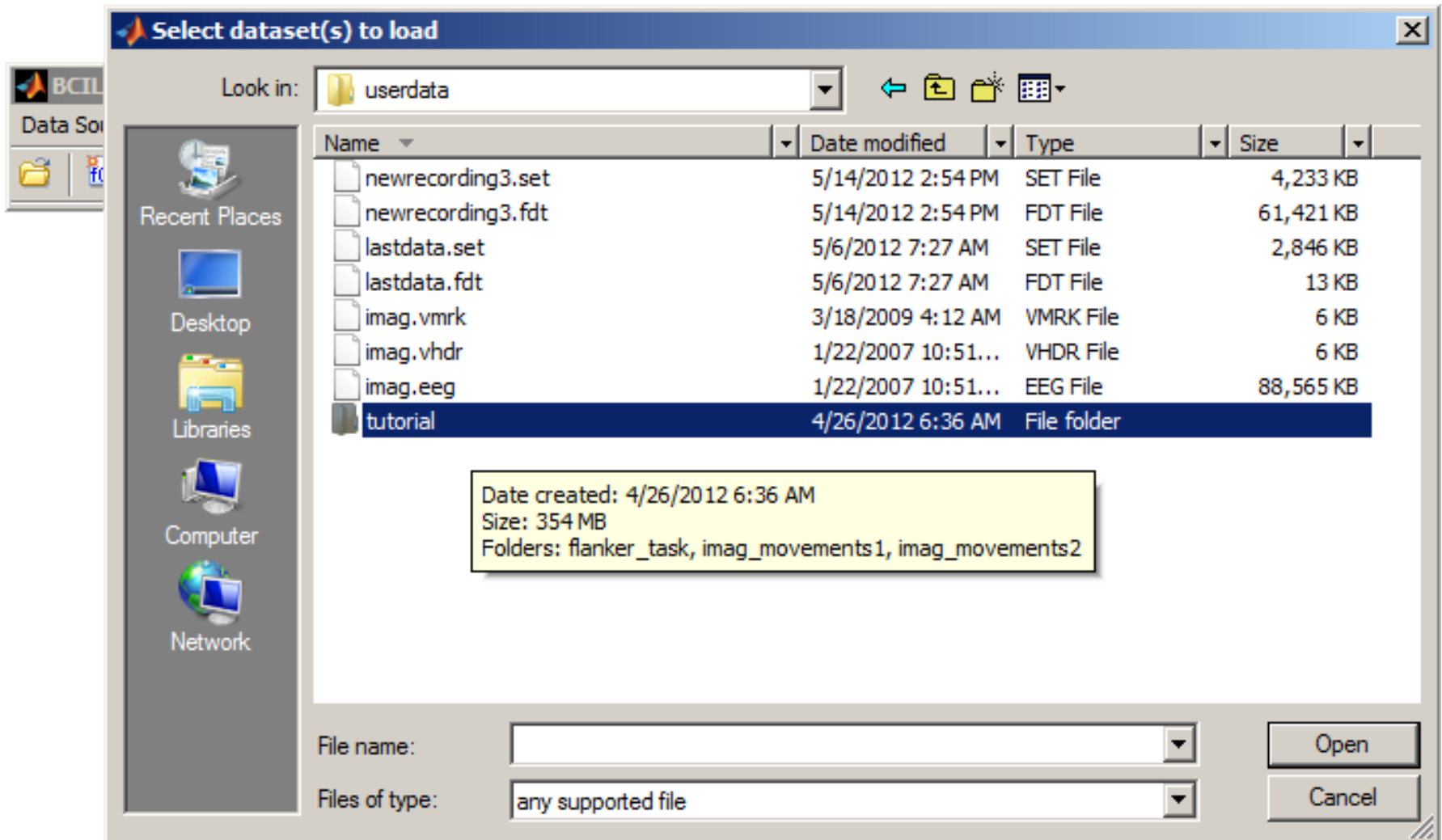


- The subject is asked to press the left/right button, according to the central arrow, and makes frequent errors (25%)

Loading the Data



Loading the Data



Select dataset(s) to load

Look in:

Name	Date modified	Type	Size
newrecording3.set	5/14/2012 2:54 PM	SET File	4,233 KB
newrecording3.fdt	5/14/2012 2:54 PM	FDT File	61,421 KB
lastdata.set	5/6/2012 7:27 AM	SET File	2,846 KB
lastdata.fdt	5/6/2012 7:27 AM	FDT File	13 KB
imag.vmrk	3/18/2009 4:12 AM	VMRK File	6 KB
imag.vhdr	1/22/2007 10:51...	VHDR File	6 KB
imag.eeg	1/22/2007 10:51...	EEG File	88,565 KB
tutorial	4/26/2012 6:36 AM	File folder	

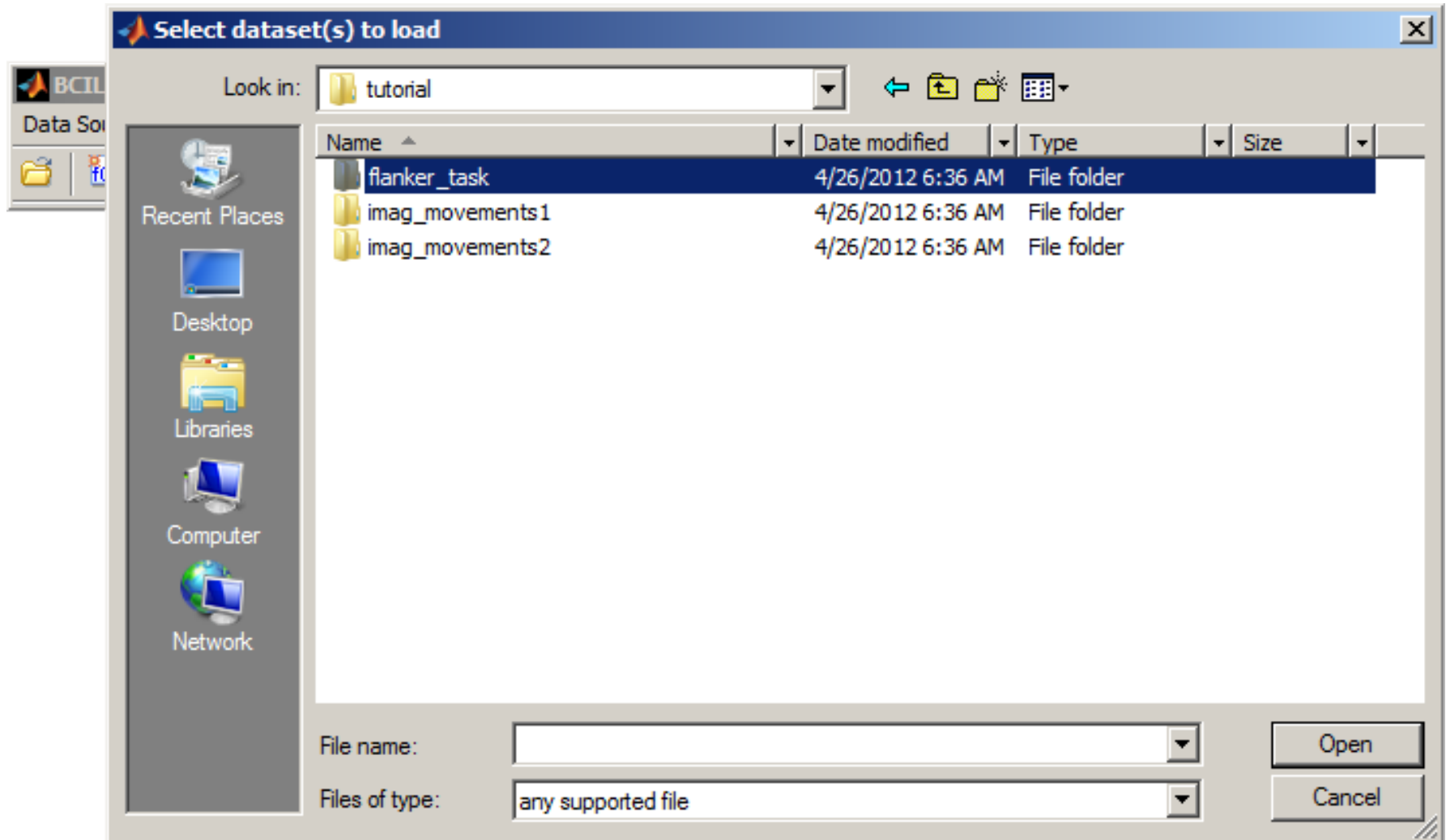
Date created: 4/26/2012 6:36 AM
 Size: 354 MB
 Folders: flanker_task, imag_movements1, imag_movements2

File name:

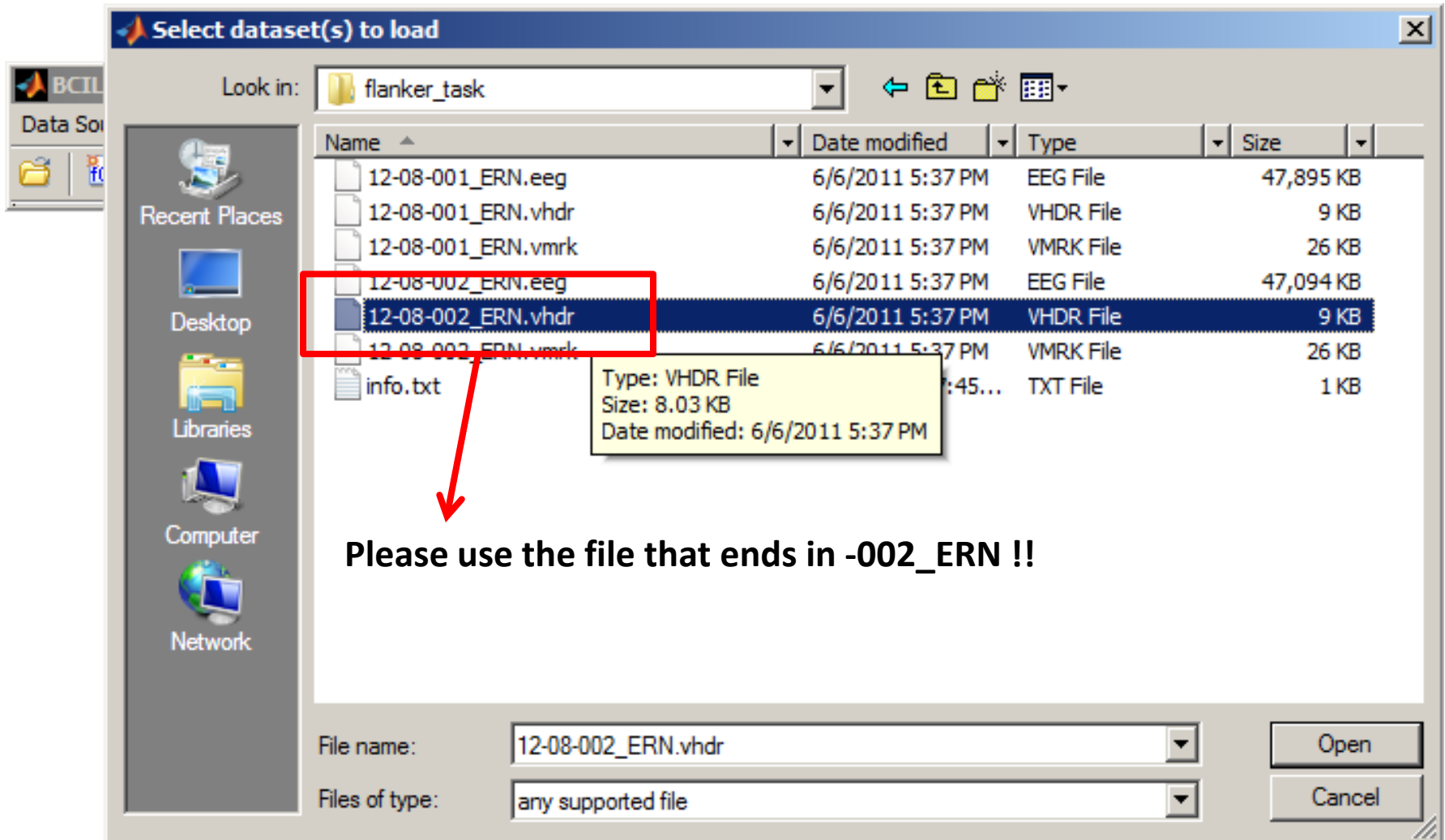
Files of type:

Open Cancel

Loading the Data



Loading the Data



BCIL
Data Source

Look in: flanker_task

Name	Date modified	Type	Size
12-08-001_ERN.eeg	6/6/2011 5:37 PM	EEG File	47,895 KB
12-08-001_ERN.vhdr	6/6/2011 5:37 PM	VHDR File	9 KB
12-08-001_ERN.vmrk	6/6/2011 5:37 PM	VMRK File	26 KB
12-08-002_ERN.eeg	6/6/2011 5:37 PM	EEG File	47,094 KB
12-08-002_ERN.vhdr	6/6/2011 5:37 PM	VHDR File	9 KB
12-08-002_ERN.vmrk	6/6/2011 5:37 PM	VMRK File	26 KB
info.txt	6/6/2011 5:37 PM	TXT File	1 KB

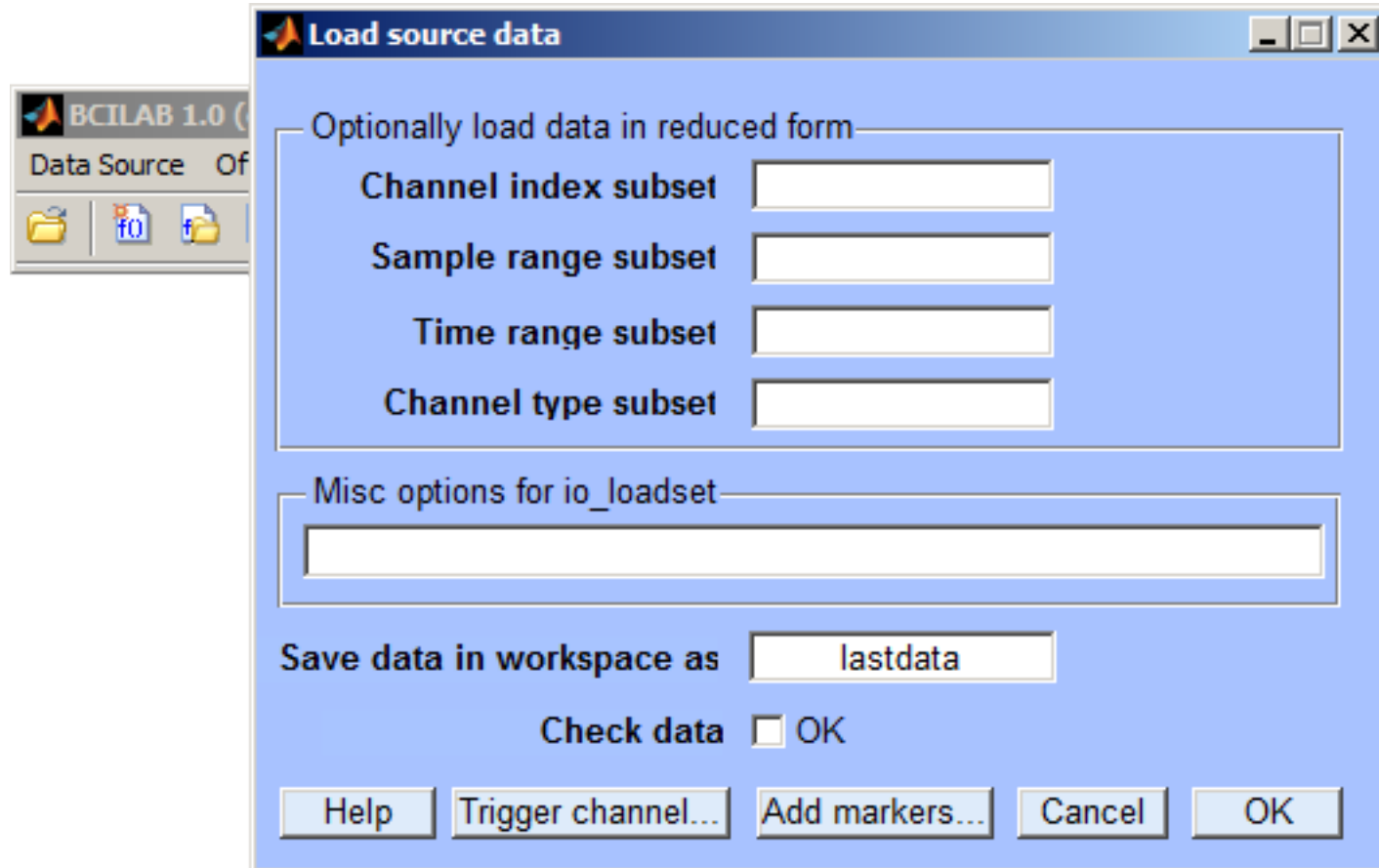
Type: VHDR File
Size: 8.03 KB
Date modified: 6/6/2011 5:37 PM

Please use the file that ends in -002_ERN !!

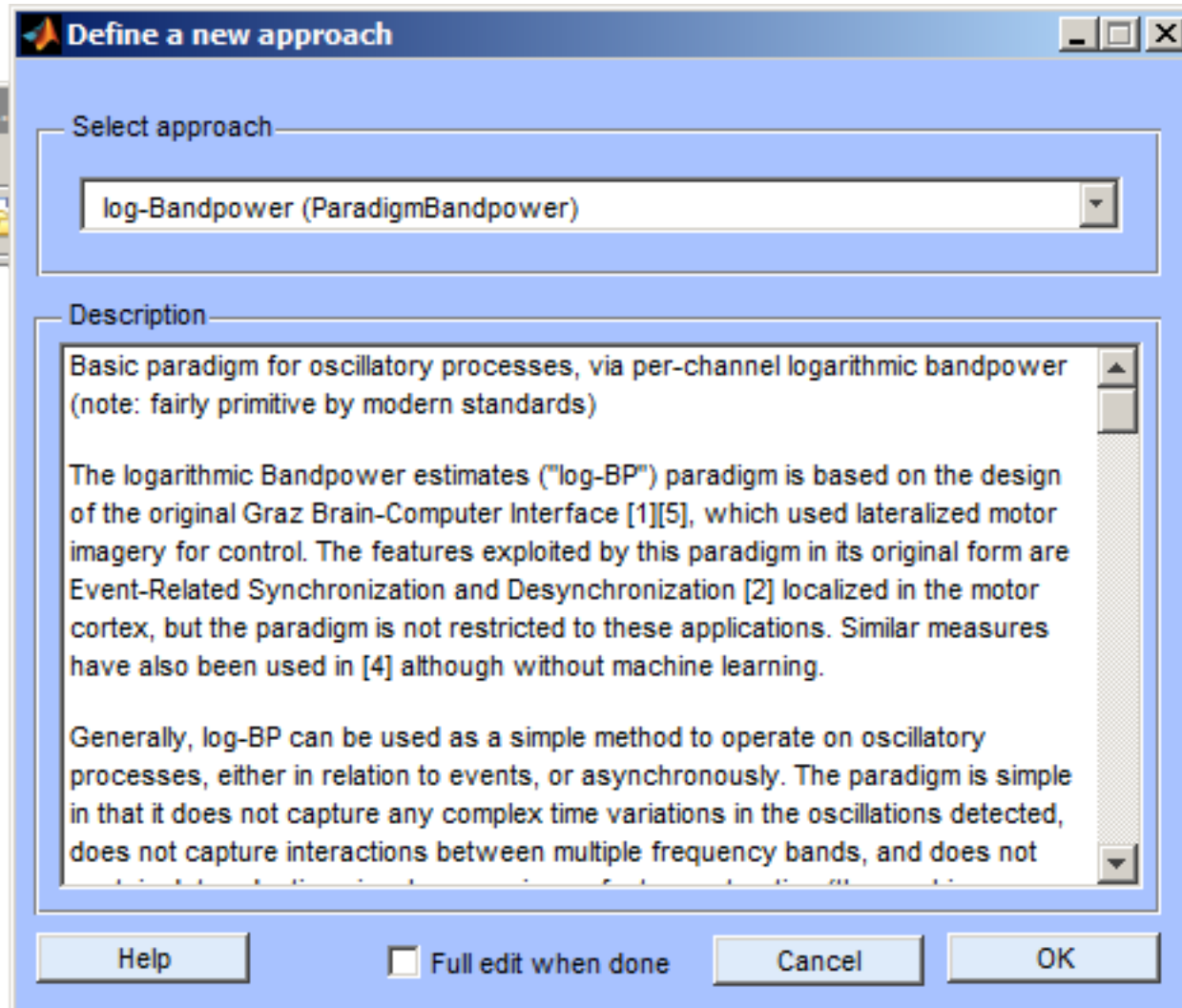
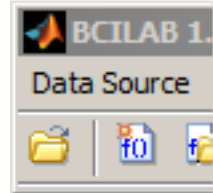
File name: 12-08-002_ERN.vhdr
Files of type: any supported file

Open
Cancel

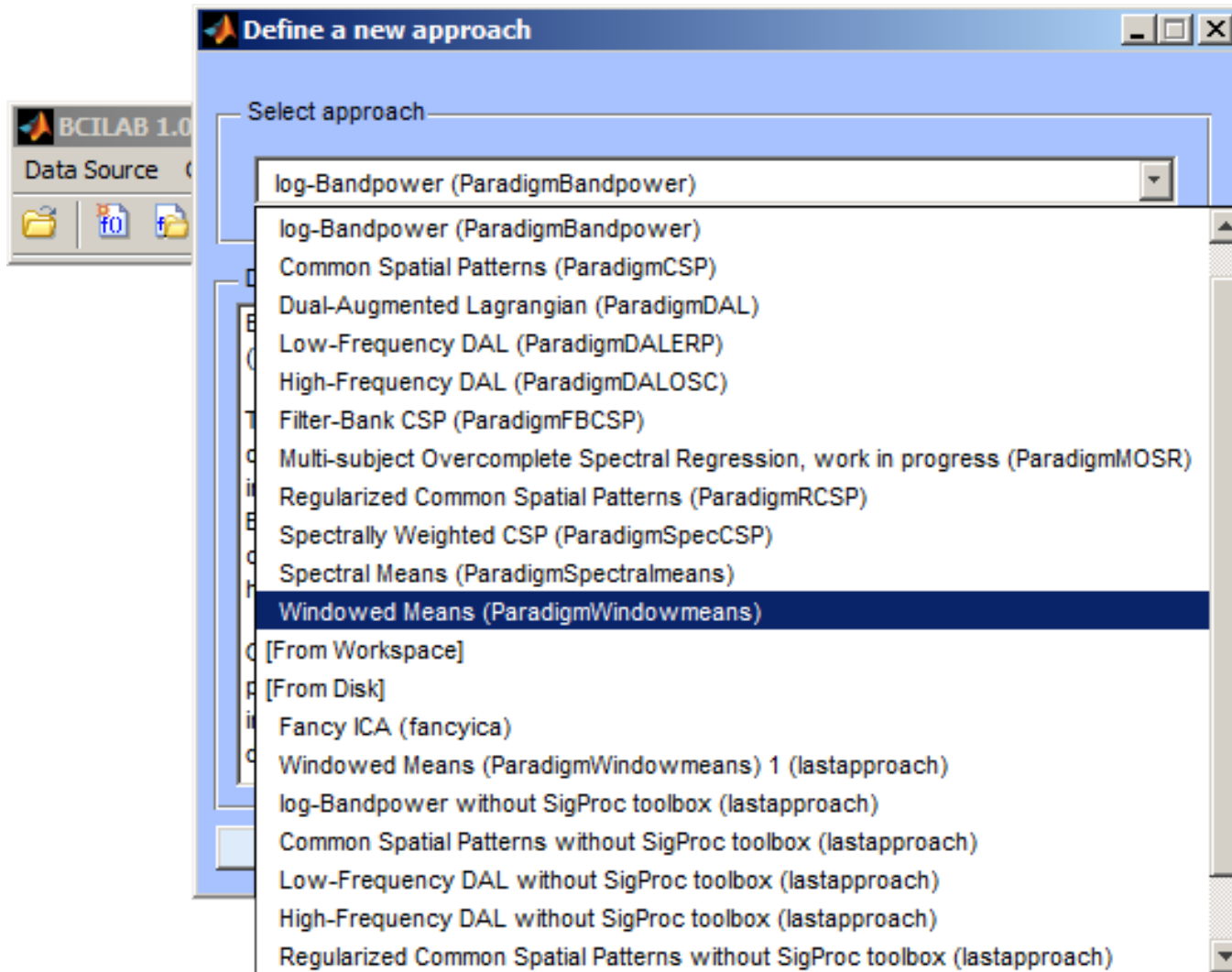
Confirming Import Options



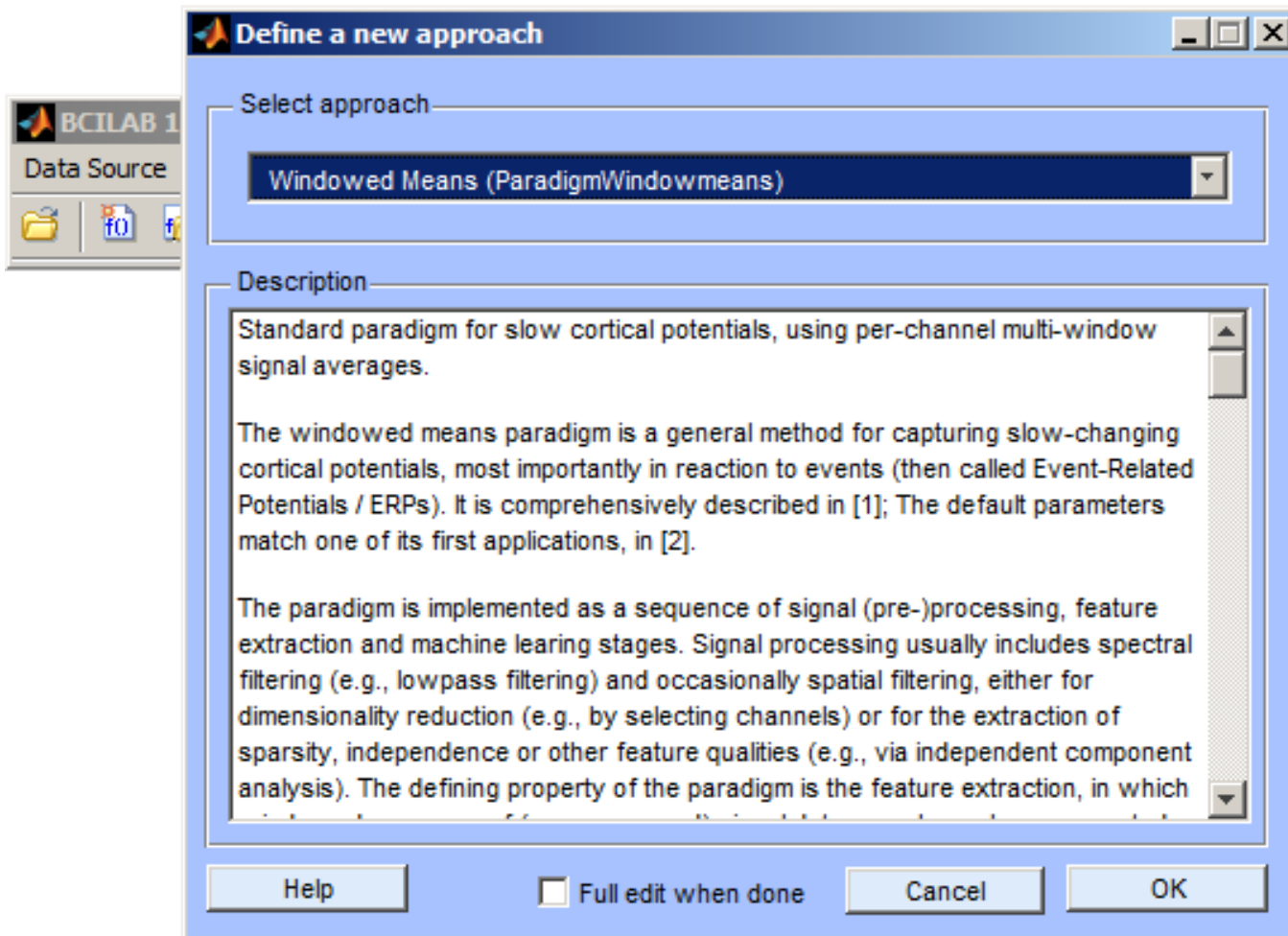
Creating a New Approach



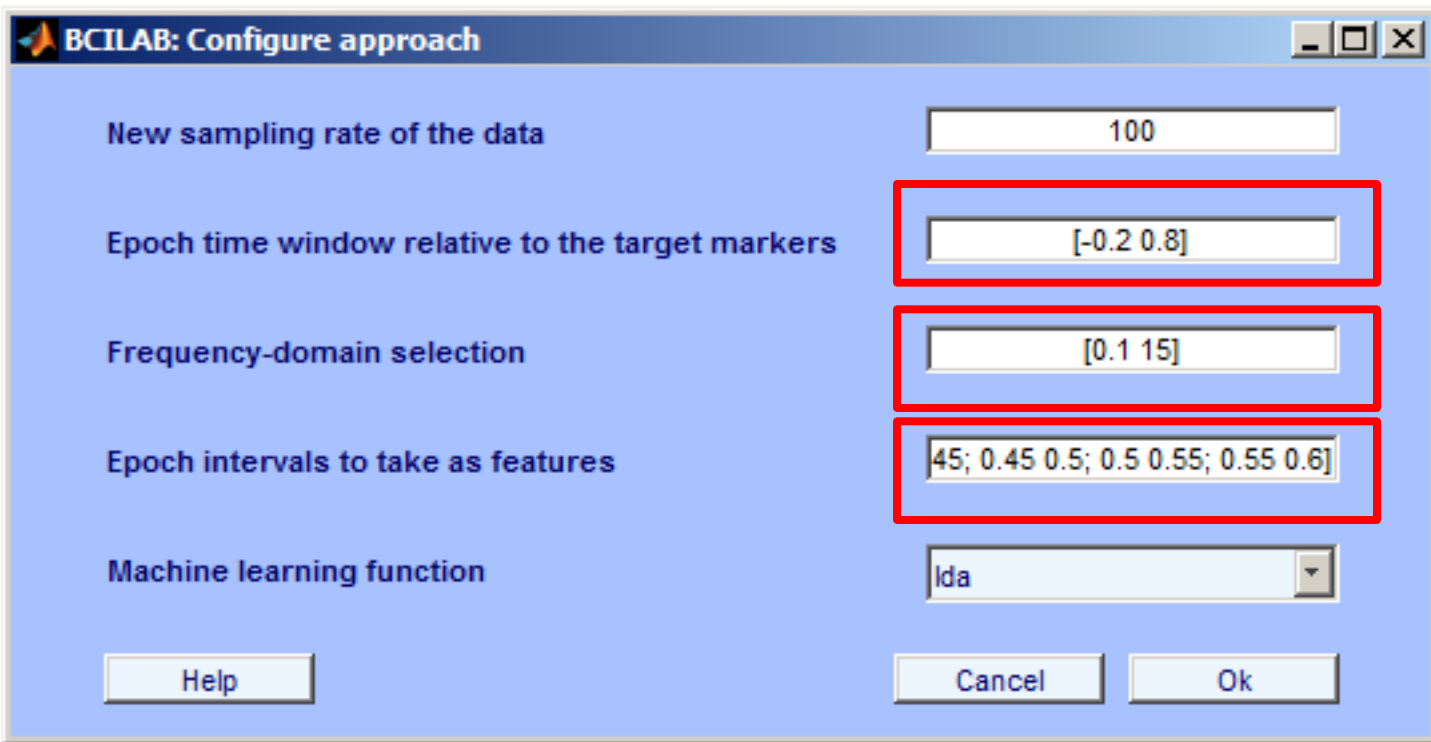
Select an ERP Paradigm



Select an ERP Paradigm



Configuring the Approach



The screenshot shows a dialog box titled "BCILAB: Configure approach" with a blue background. It contains several configuration options, each with a text input field. Three of these fields are highlighted with red rectangles:

- New sampling rate of the data:** 100
- Epoch time window relative to the target markers:** [-0.2 0.8]
- Frequency-domain selection:** [0.1 15]
- Epoch intervals to take as features:** [45; 0.45 0.5; 0.5 0.55; 0.55 0.6]
- Machine learning function:** lda

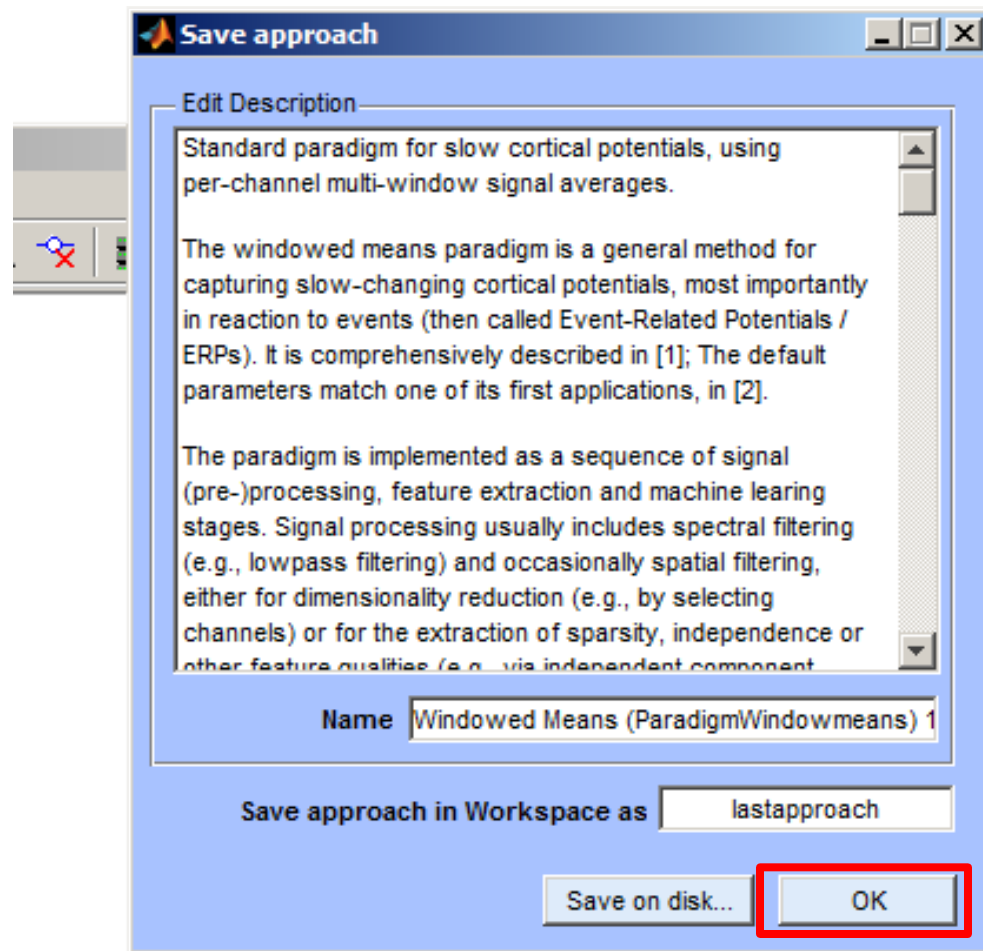
At the bottom of the dialog box, there are three buttons: "Help", "Cancel", and "Ok".

Type into the lowest of the 3 highlighted fields:

[0.25 0.3; 0.3 0.35; 0.35 0.4; 0.4 0.45; 0.45 0.5; 0.5 0.55; 0.55 0.6]

Note: On macOS, the latest MATLAB version likes to pop up this window in full screen; For the time being it is best to resize it to something similar to the above

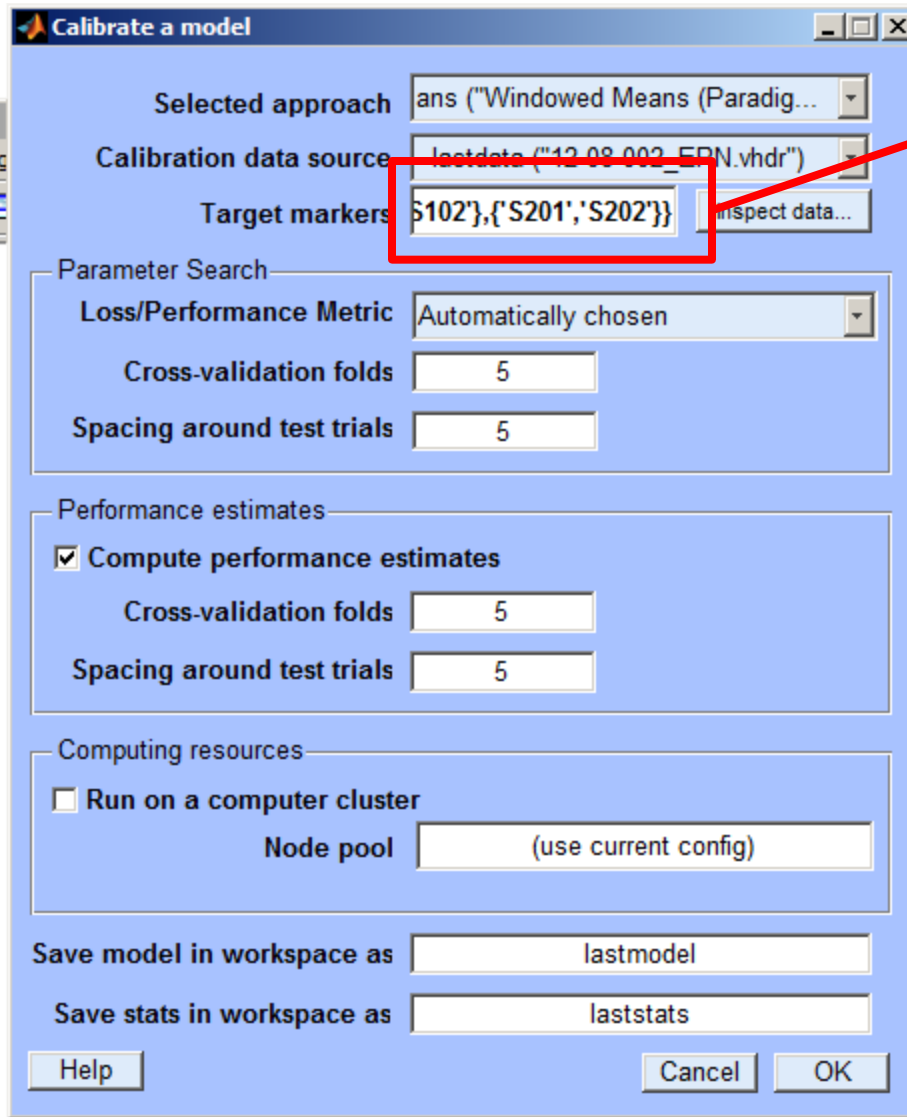
Saving to the Workspace



Calibrating a New Model



Calibrating a New Model



Calibrate a model

Selected approach: ans ("Windowed Means (Paradig...)

Calibration data source: lastdata ("12-08-002_FPN.vhdr")

Target markers: **`{'S102'}, {'S201'}, {'S202'}}`**

Parameter Search

Loss/Performance Metric: Automatically chosen

Cross-validation folds: 5

Spacing around test trials: 5

Performance estimates

Compute performance estimates

Cross-validation folds: 5

Spacing around test trials: 5

Computing resources

Run on a computer cluster

Node pool: (use current config)

Save model in workspace as: lastmodel

Save stats in workspace as: laststats

Buttons: Help, Cancel, OK

This is the set of marker labels that determine our two possible error conditions. For each of the two conditions, there is a group of multiple markers (different types of errors and non-errors).

Type the following here:
`{{'S101','S102'}, {'S201','S202'}}`

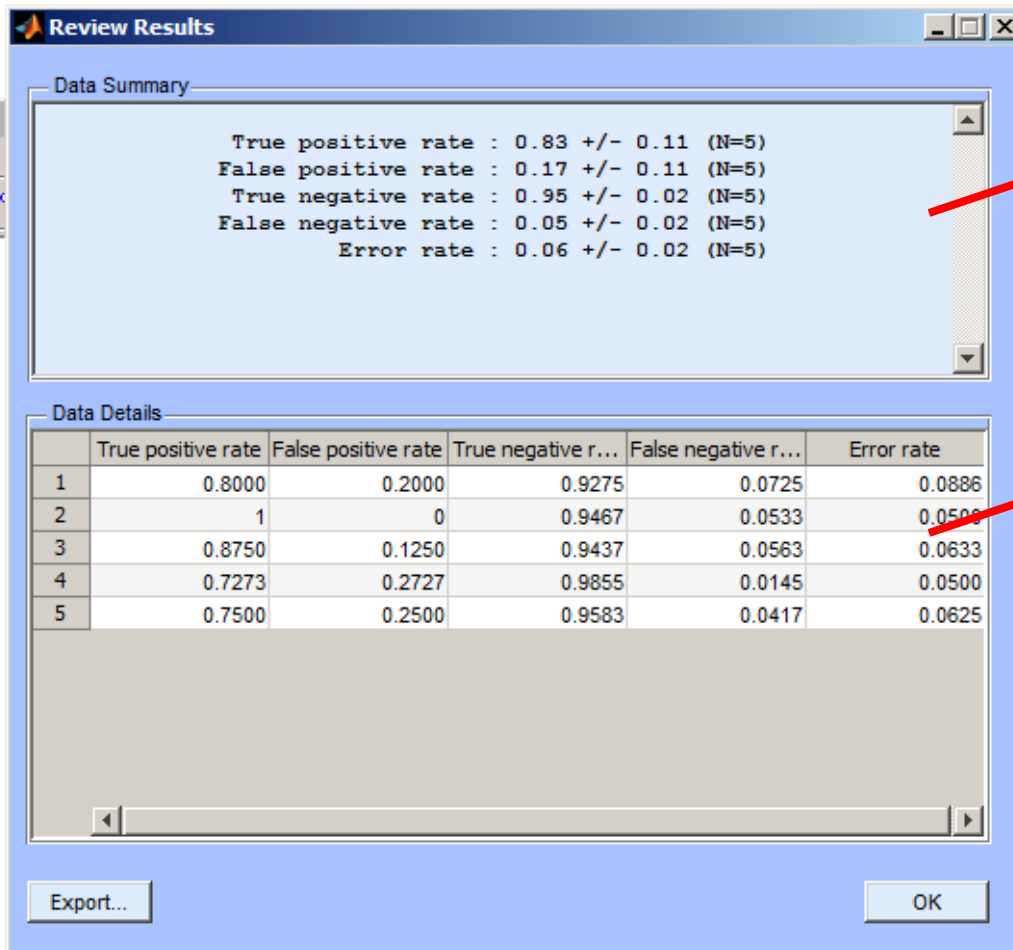
Watching the Computation...

```
io_loadset(): loading C:\DEVEL\bcilab-1.0\userdata\tv
pop_loadbv(): reading header file
pop_loadbv(): reading EEG data
pop_loadbv(): scaling EEG data
pop_loadbv(): reading marker file
readlocs(): 'sfp' format assumed from file extension
Channel lookup: no location for RE,LE,VEOG
Send us standard location for your channels at eeglab
Radius values: 0.0999117 (mean) +/- 4.20252e-005 (std)
Note: automatically convert XYZ coordinates to spherical
pop_epoch():408 epochs selected
Epoching...
pop_epoch():408 epochs generated
eeg_checkset: found empty values for field 'target'
                filling with values of other events in
pop_epoch(): checking epochs for data discontinuity
Extra common reference electrode location detected

beginning new computation...
fx >>
```

OVR

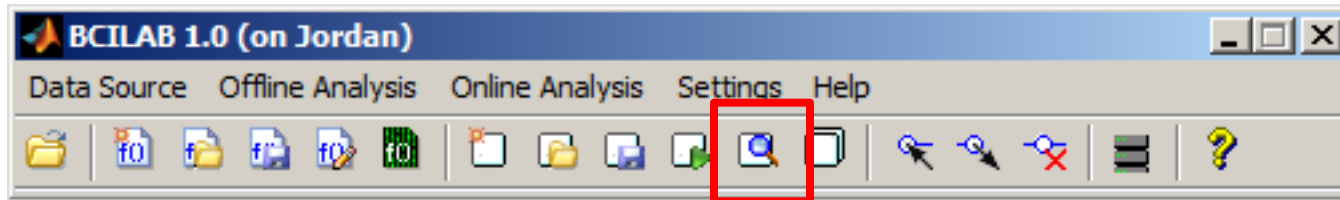
Reviewing Results



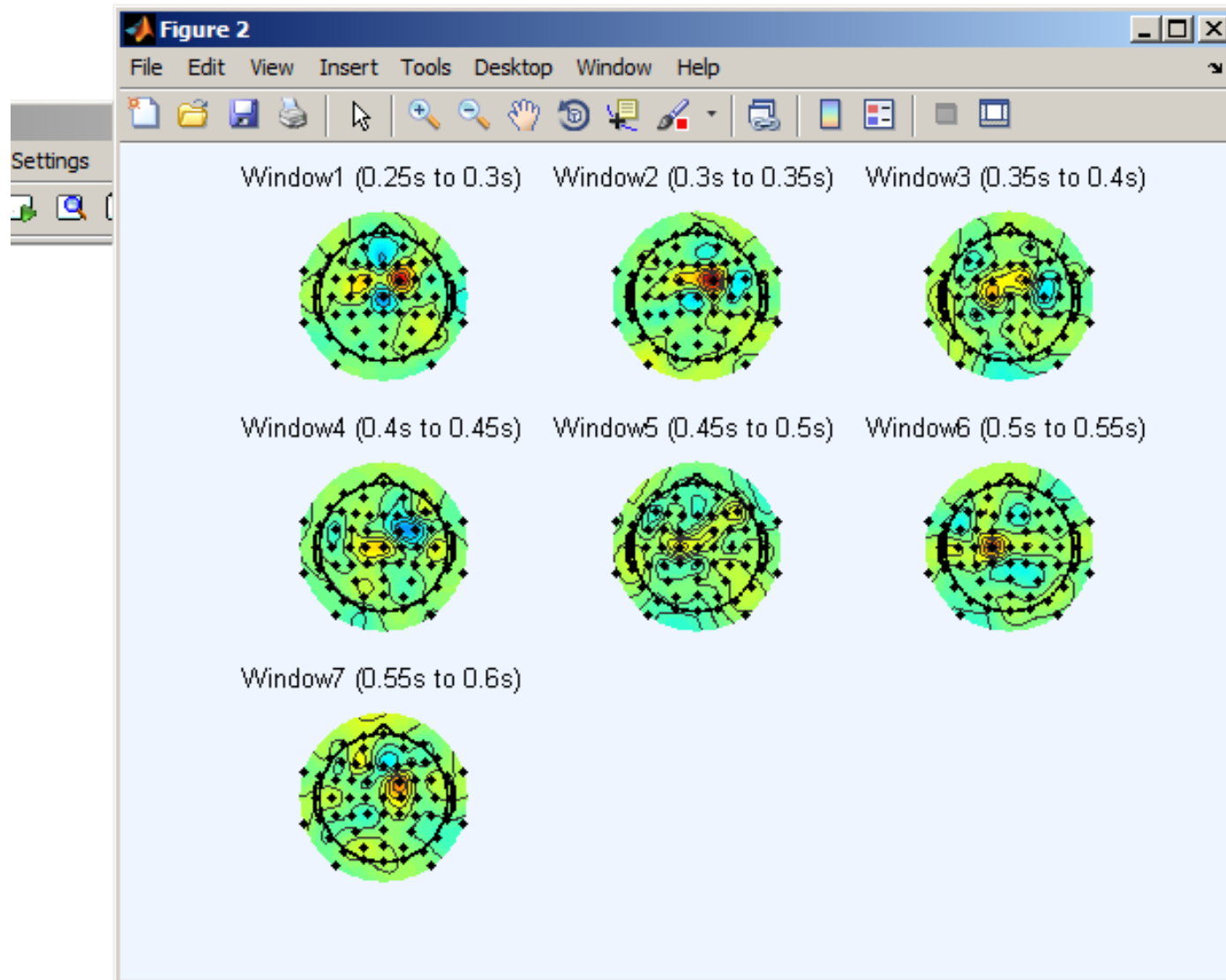
Summary Statistics

Statistics for each fold of the Cross-Validation (here 5x).

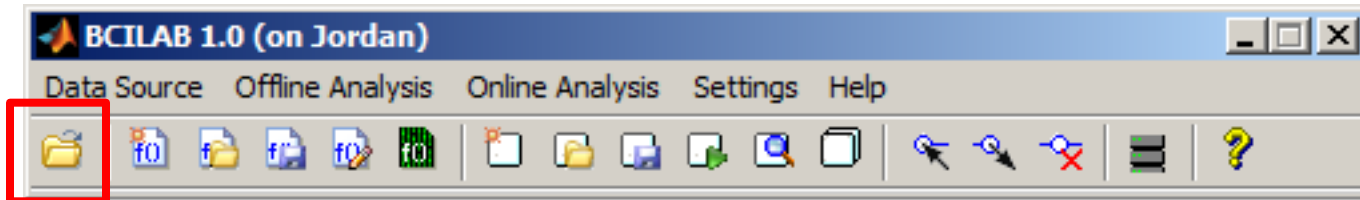
Visualizing the Model



Visualizing the Model

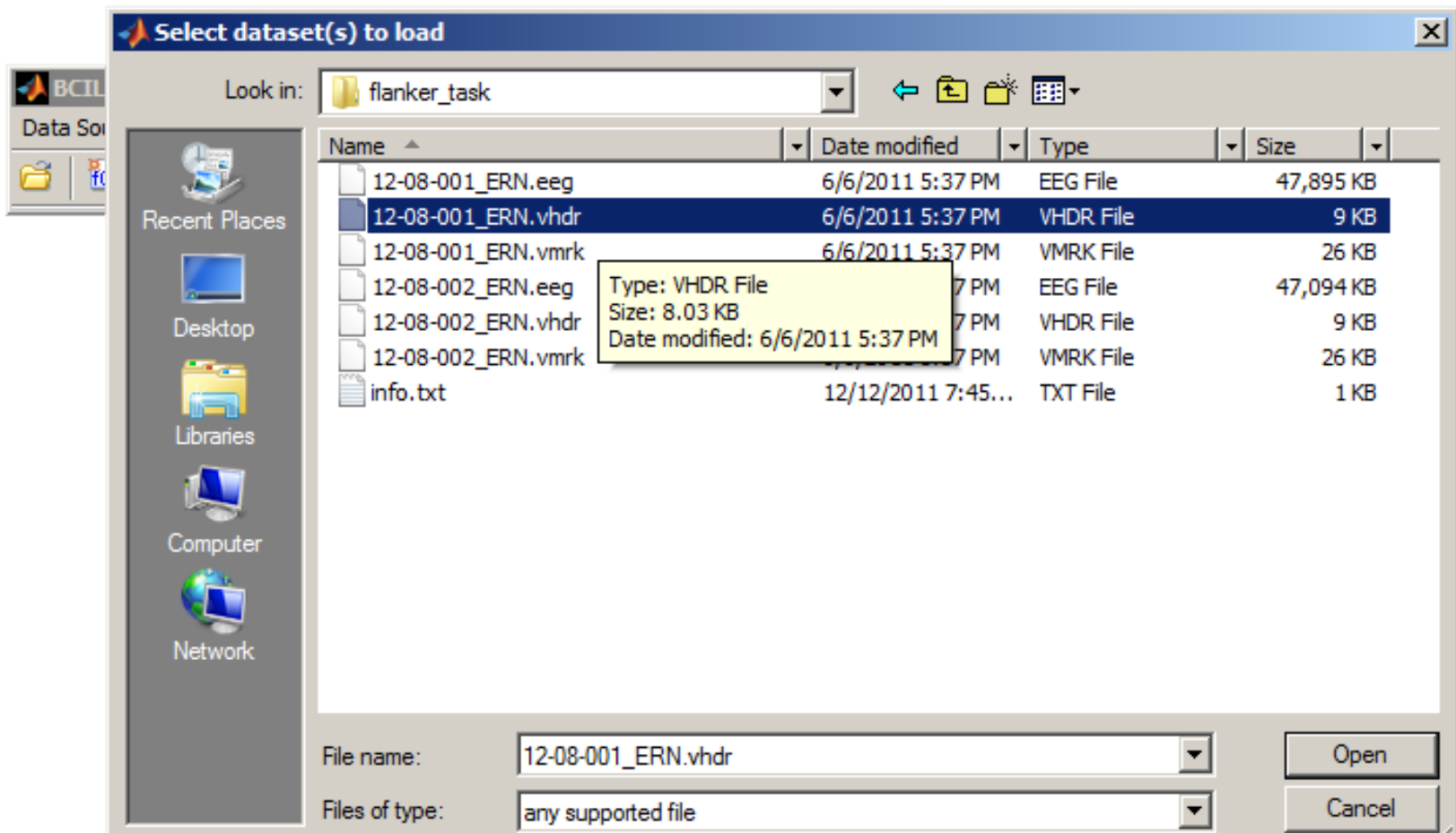


Loading a Separate Test Set

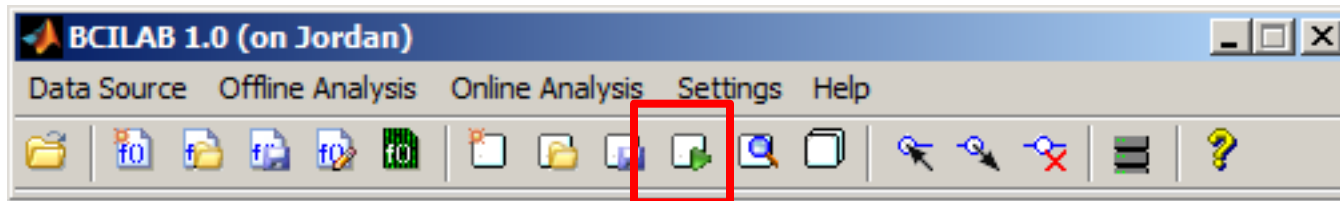


Loading a Separate Test Set

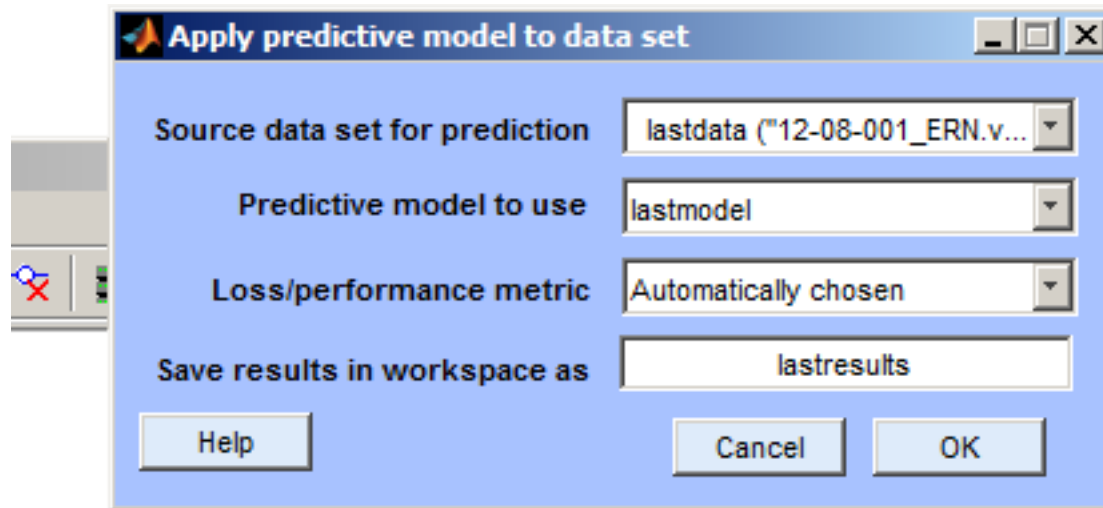
Note: This data set is from an identical twin doing the same task.



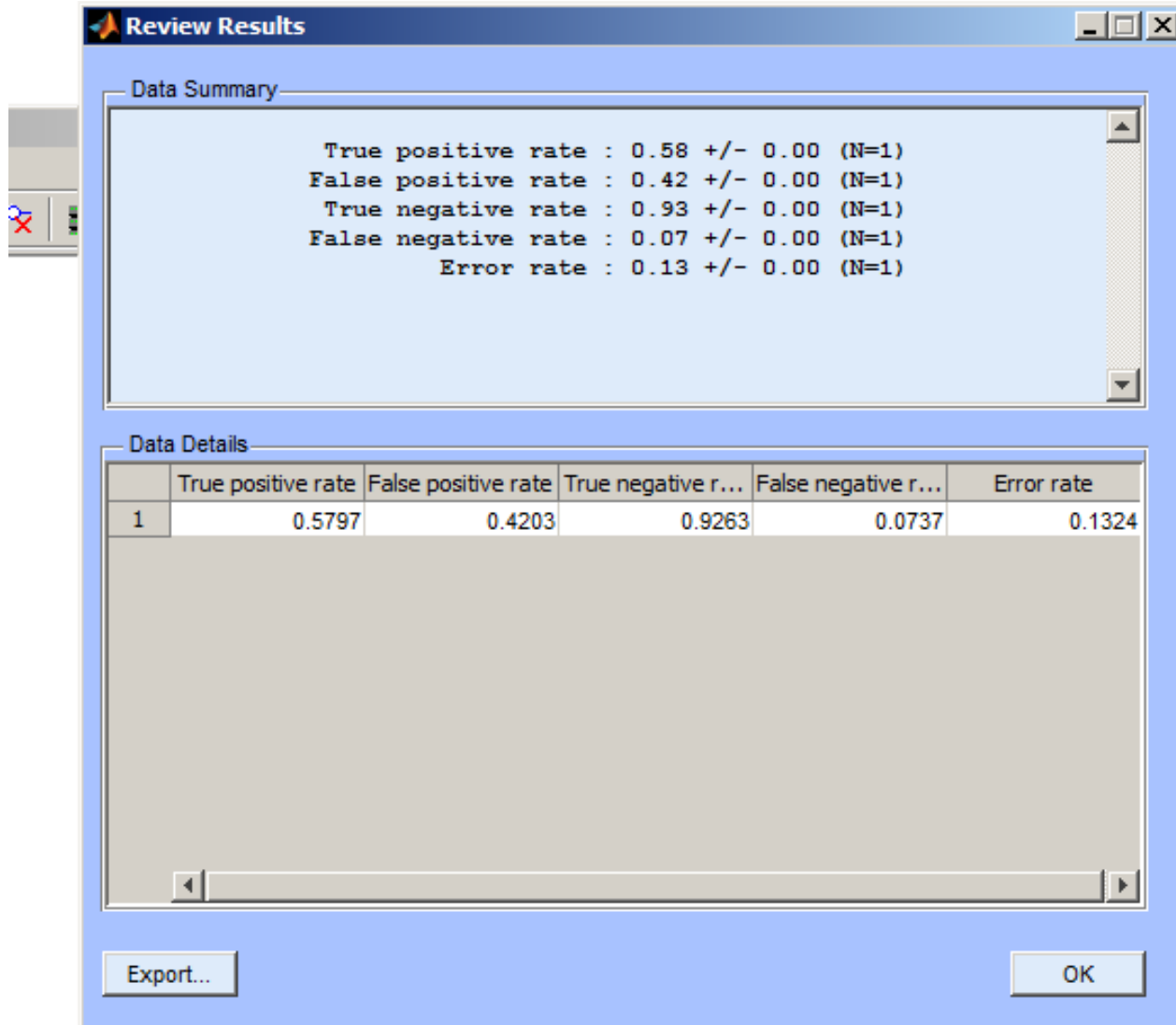
Applying the Model to Test Data



Applying the Model to Test Data



Reviewing Statistics



The screenshot shows a software window titled "Review Results" with a blue border. It contains two main sections: "Data Summary" and "Data Details".

Data Summary

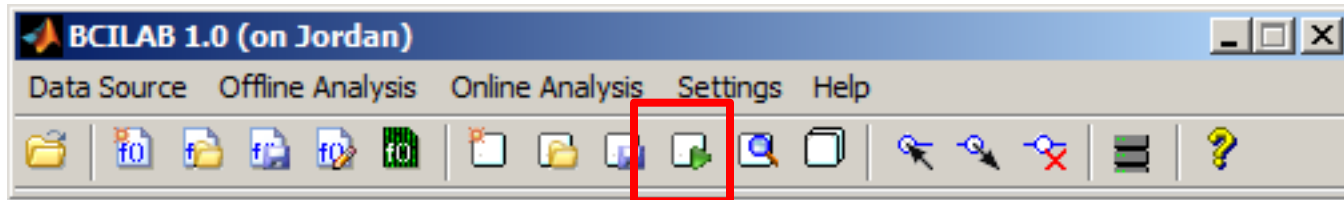
```
True positive rate : 0.58 +/- 0.00 (N=1)
False positive rate : 0.42 +/- 0.00 (N=1)
True negative rate : 0.93 +/- 0.00 (N=1)
False negative rate : 0.07 +/- 0.00 (N=1)
Error rate : 0.13 +/- 0.00 (N=1)
```

Data Details

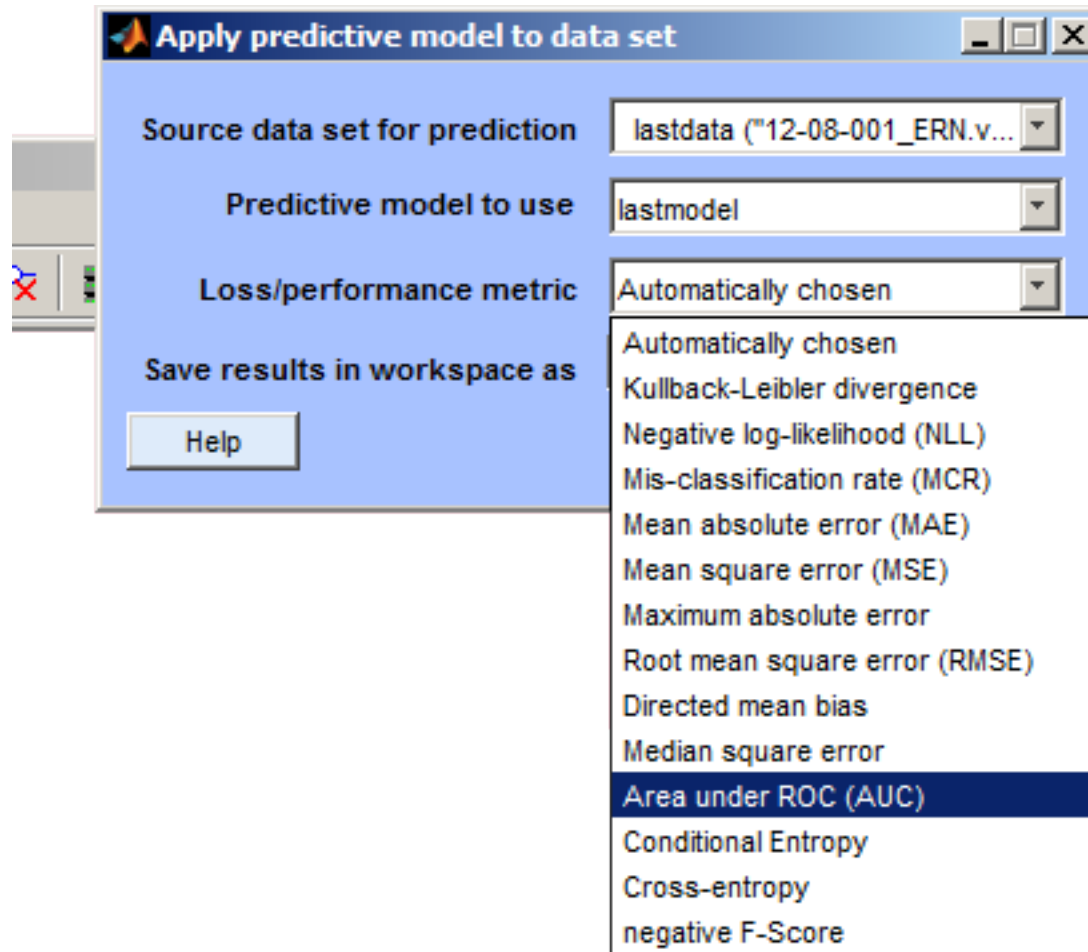
	True positive rate	False positive rate	True negative r...	False negative r...	Error rate
1	0.5797	0.4203	0.9263	0.0737	0.1324

At the bottom of the window, there are two buttons: "Export..." on the left and "OK" on the right.

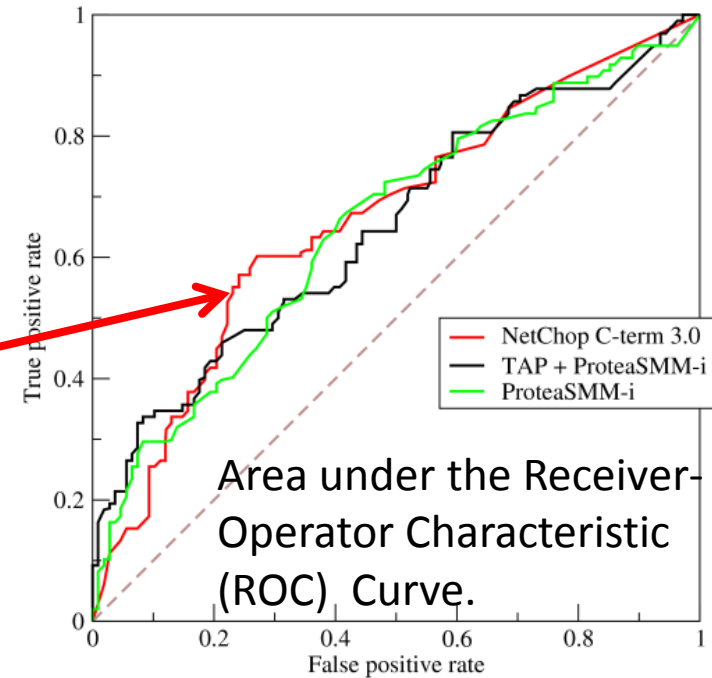
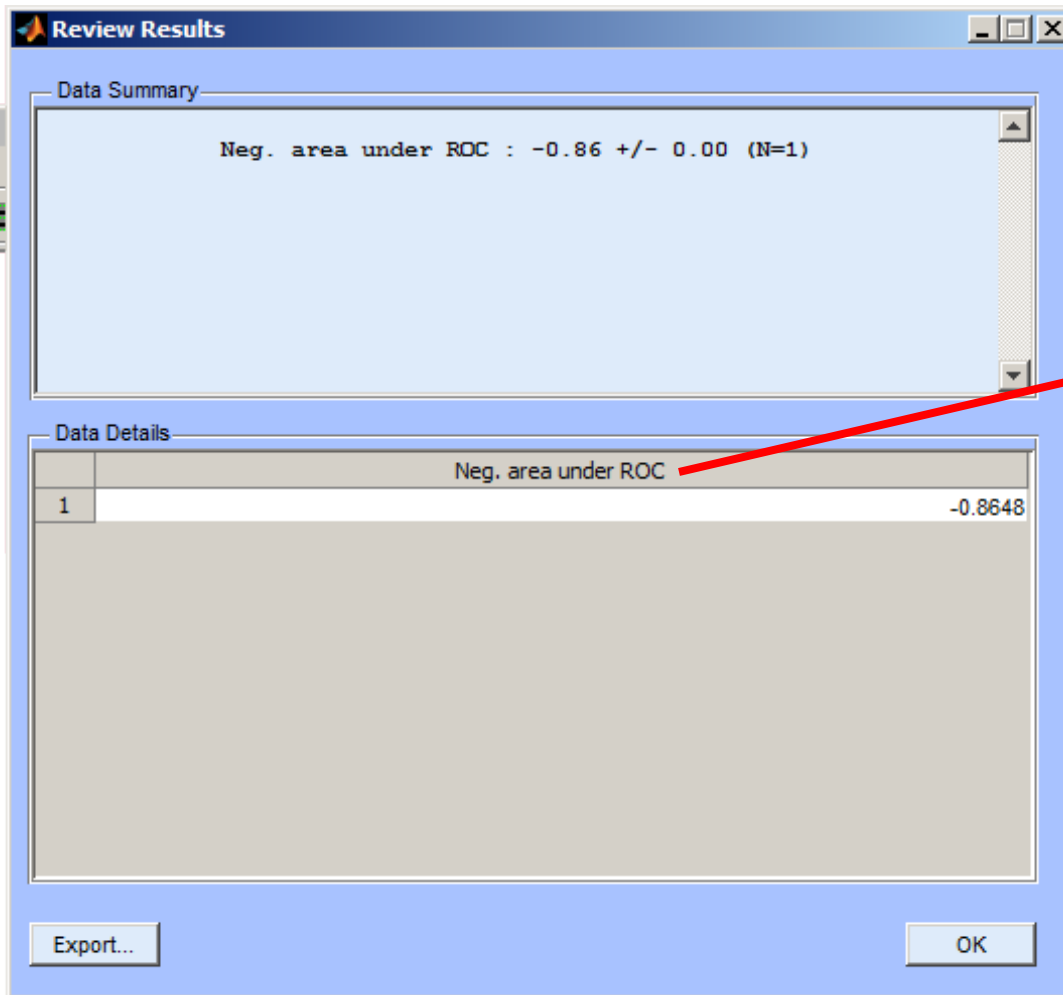
Using Another Loss Measure



Using Another Loss Measure



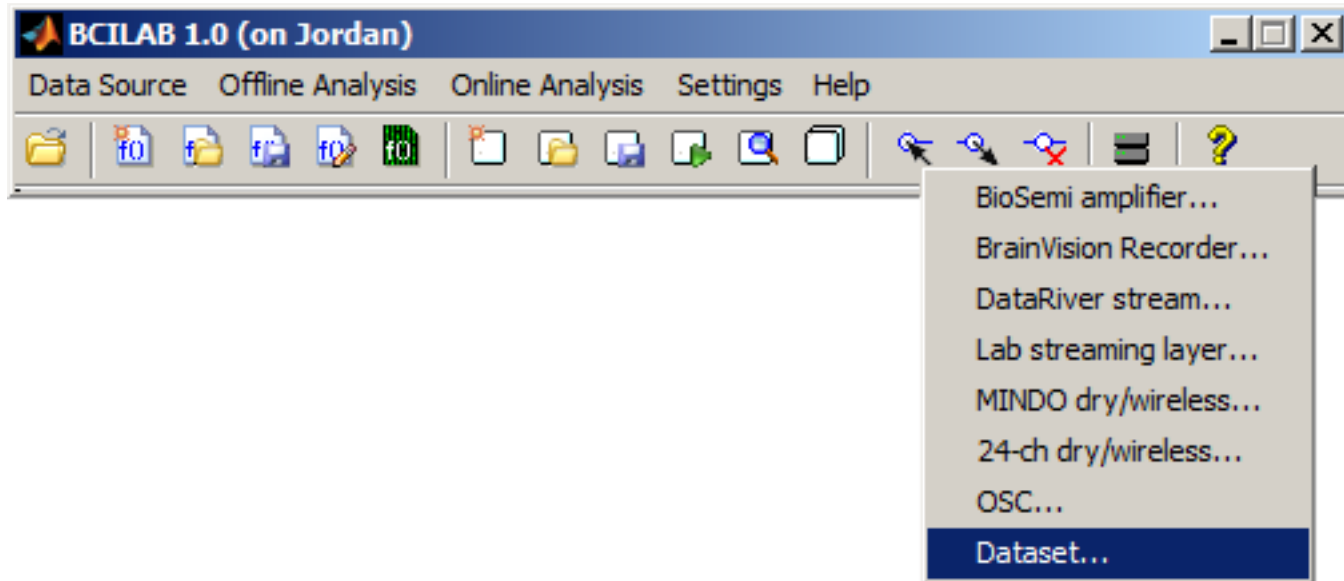
Using Another Loss Measure





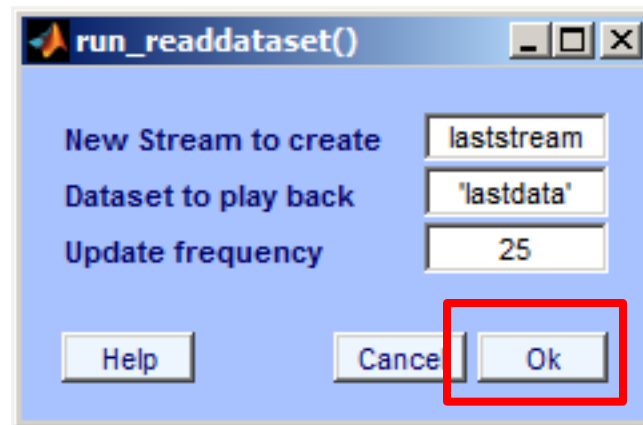
3 Online ERP Analysis

Starting an Online Data Stream



The selected stream will be played back in the background.
In this course we'll be playing back the test data set in real time
(instead of reading from an actual device).

Configuring the Online Stream



Meanwhile in the MATLAB Workspace...

If you type **whos** you could see the data structure (laststream) that is updated in the background.

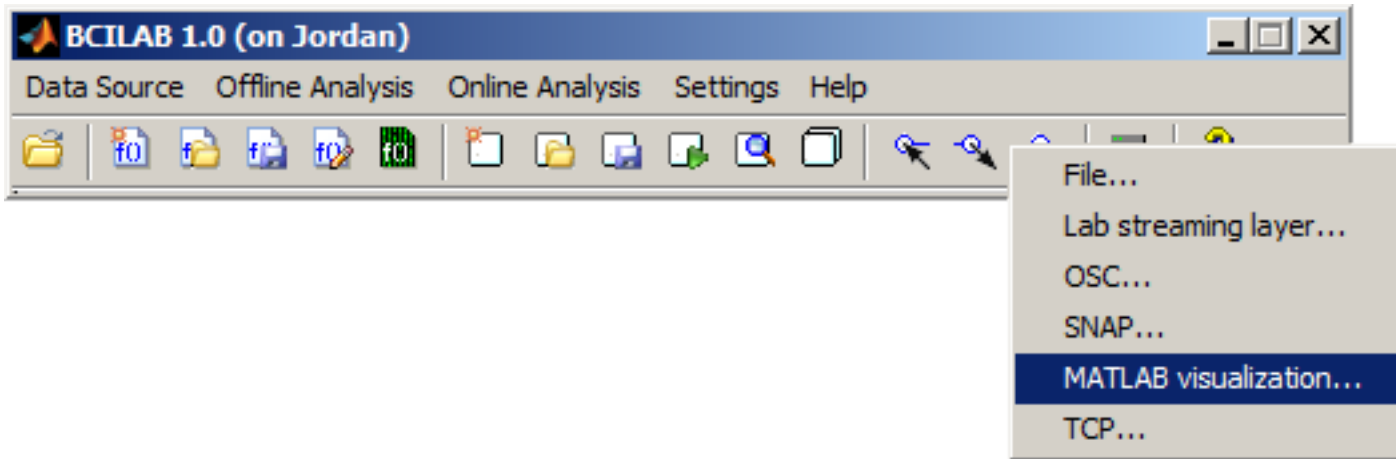
```
beginning new computation...
beginning evaluation...
Extra common reference electrode location detected
>> whos
```

Name	Size	Bytes	Class
ans	1x1	38164	struct
f	1x1	8	double
lastapproach	1x1	38164	struct
lastchunk	64x15	3840	single
lastdata	1x1	874	struct
lastmodel	1x1	356657	struct
lastresults	1x1	12543	struct
laststats	1x1	418464	struct
laststream	1x1	7804880	struct
y	1x2	16	double

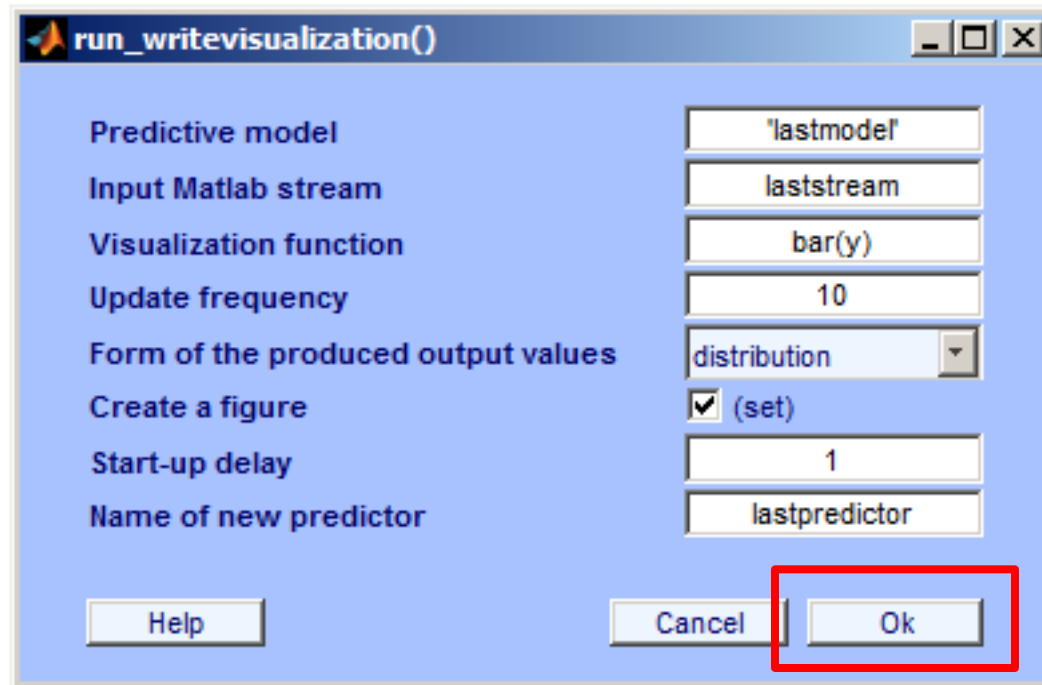
```
fx >> |
```

OVR

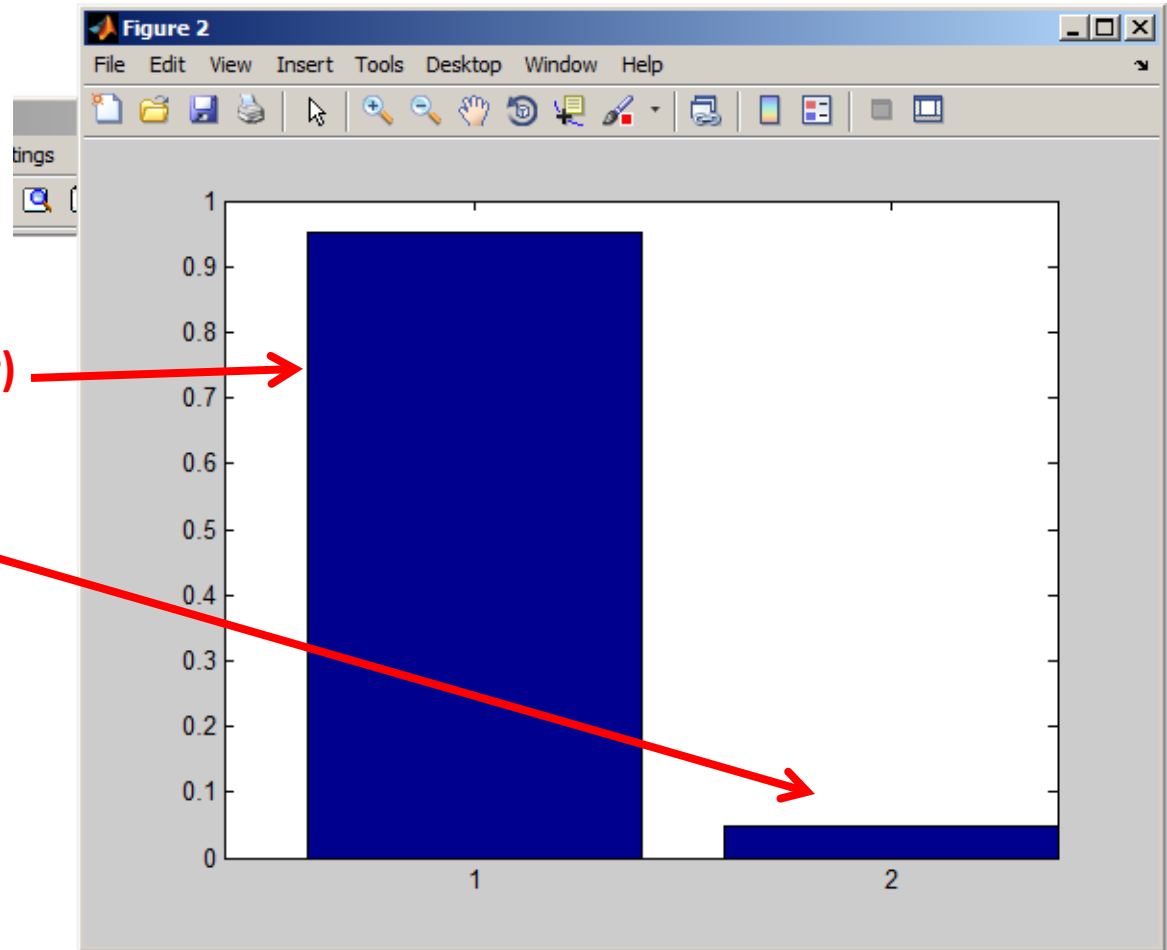
Selecting the Destination for BCI Outputs



Selecting the Destination for BCI Outputs



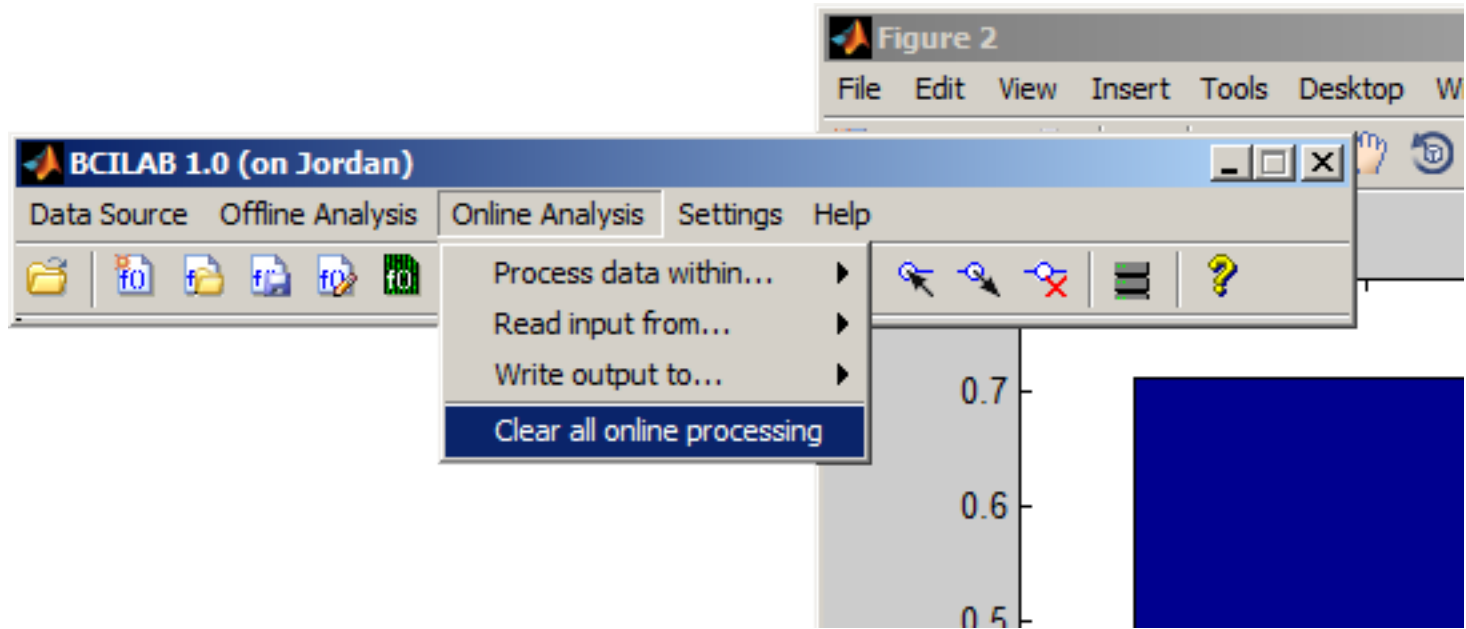
Visualized Real-Time Outputs



Probability of class 1 (no error)

Probability of class 2 (error)

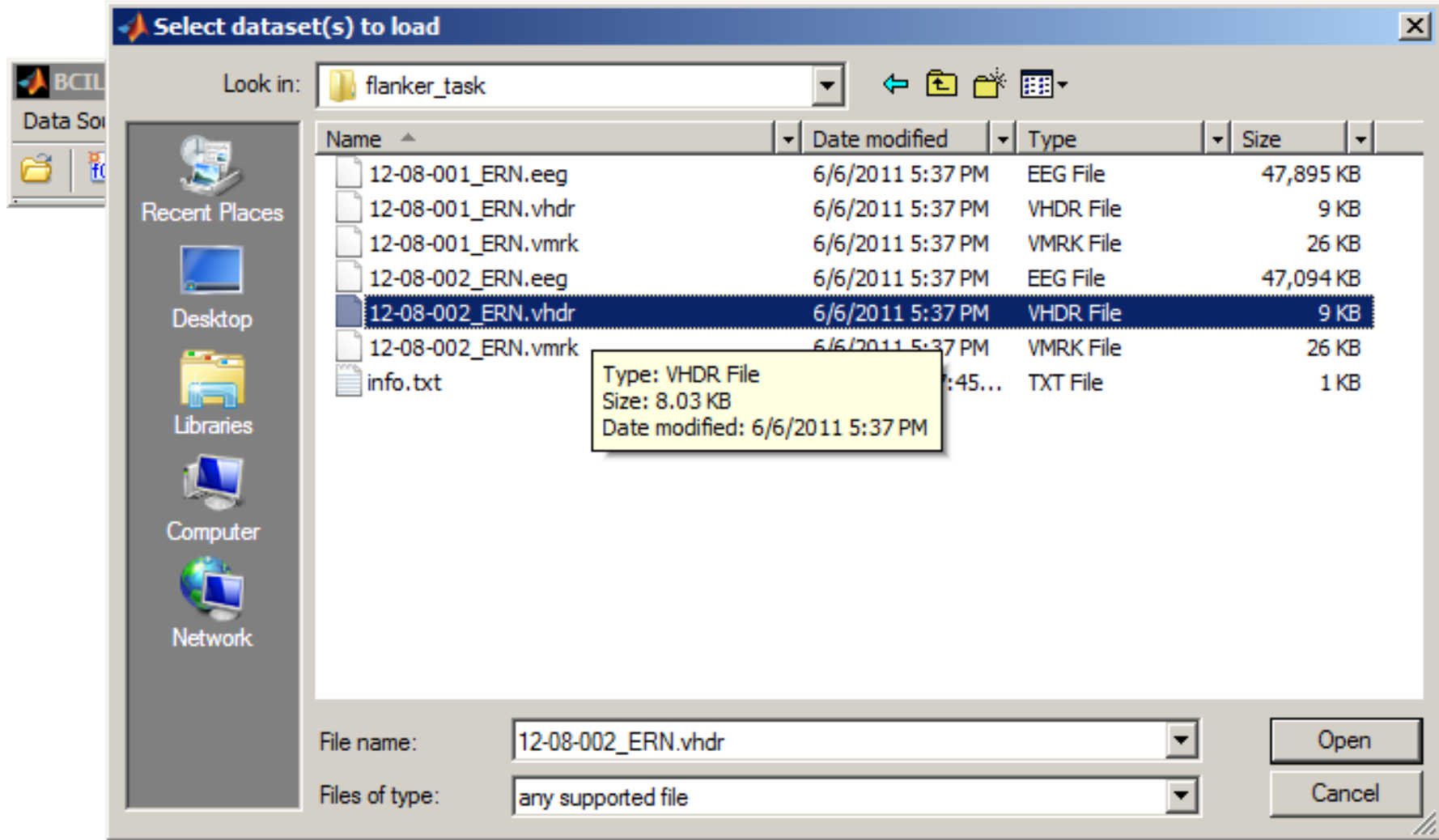
Stopping the Online Processing





4 Customizing Approaches

Loading the Training Data Again



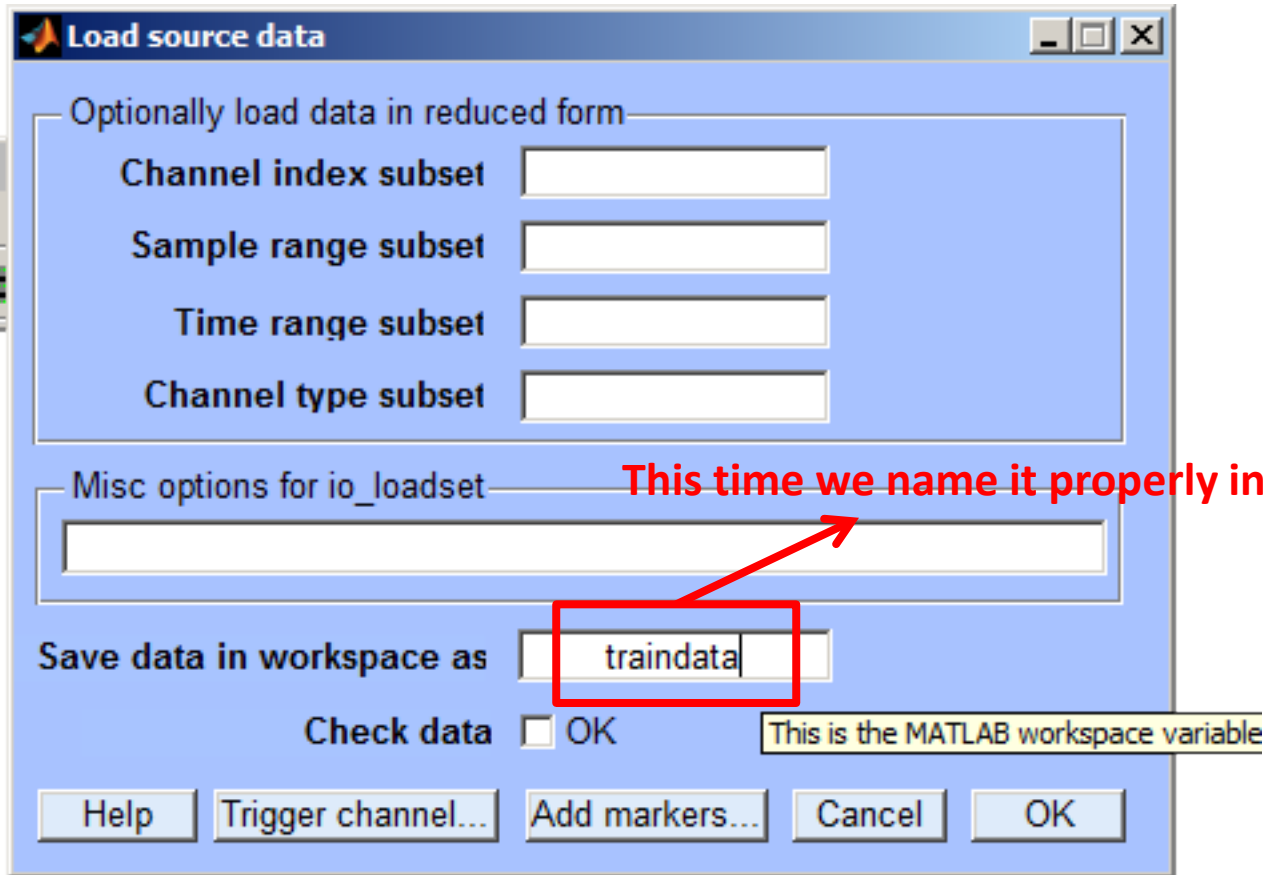
The screenshot shows a Windows file explorer window titled "Select dataset(s) to load". The "Look in:" field shows the path "flanker_task". The left sidebar shows "Recent Places" with icons for Desktop, Libraries, Computer, and Network. The main pane displays a list of files with columns for Name, Date modified, Type, and Size. The file "12-08-002_ERN.vhdr" is selected, and a tooltip is displayed over it.

Name	Date modified	Type	Size
12-08-001_ERN.eeg	6/6/2011 5:37 PM	EEG File	47,895 KB
12-08-001_ERN.vhdr	6/6/2011 5:37 PM	VHDR File	9 KB
12-08-001_ERN.vmrk	6/6/2011 5:37 PM	VMRK File	26 KB
12-08-002_ERN.eeg	6/6/2011 5:37 PM	EEG File	47,094 KB
12-08-002_ERN.vhdr	6/6/2011 5:37 PM	VHDR File	9 KB
12-08-002_ERN.vmrk	6/6/2011 5:37 PM	VMRK File	26 KB
info.txt	6/6/2011 5:45...	TXT File	1 KB

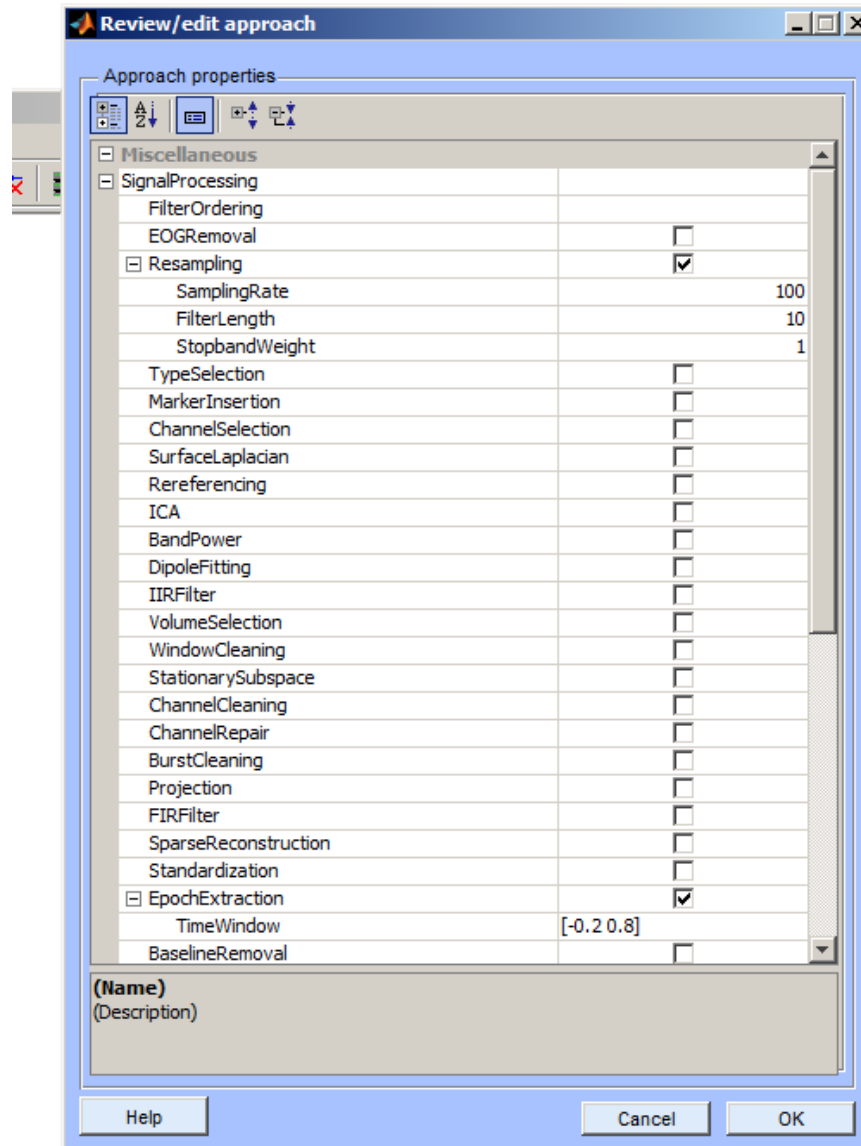
File name: 12-08-002_ERN.vhdr
Files of type: any supported file

Open
Cancel

Loading the Training Data Again

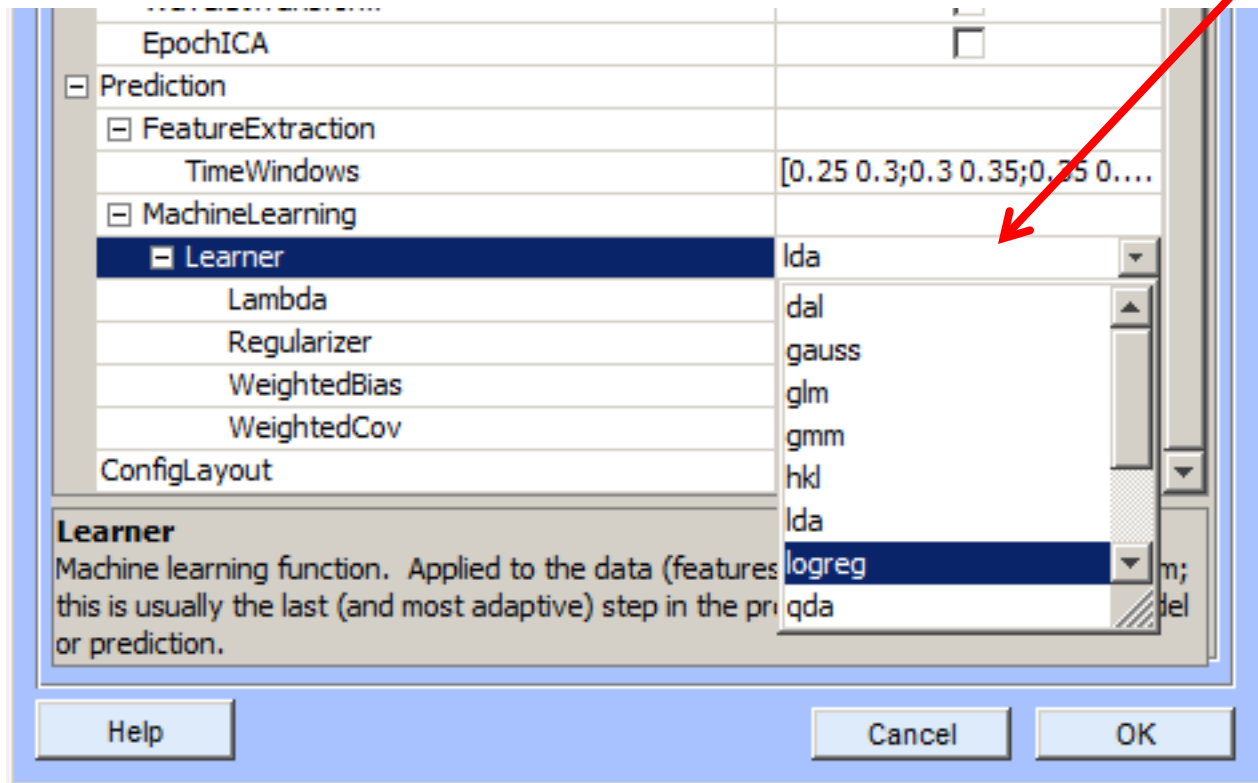


Editing the Previous Approach In Detail



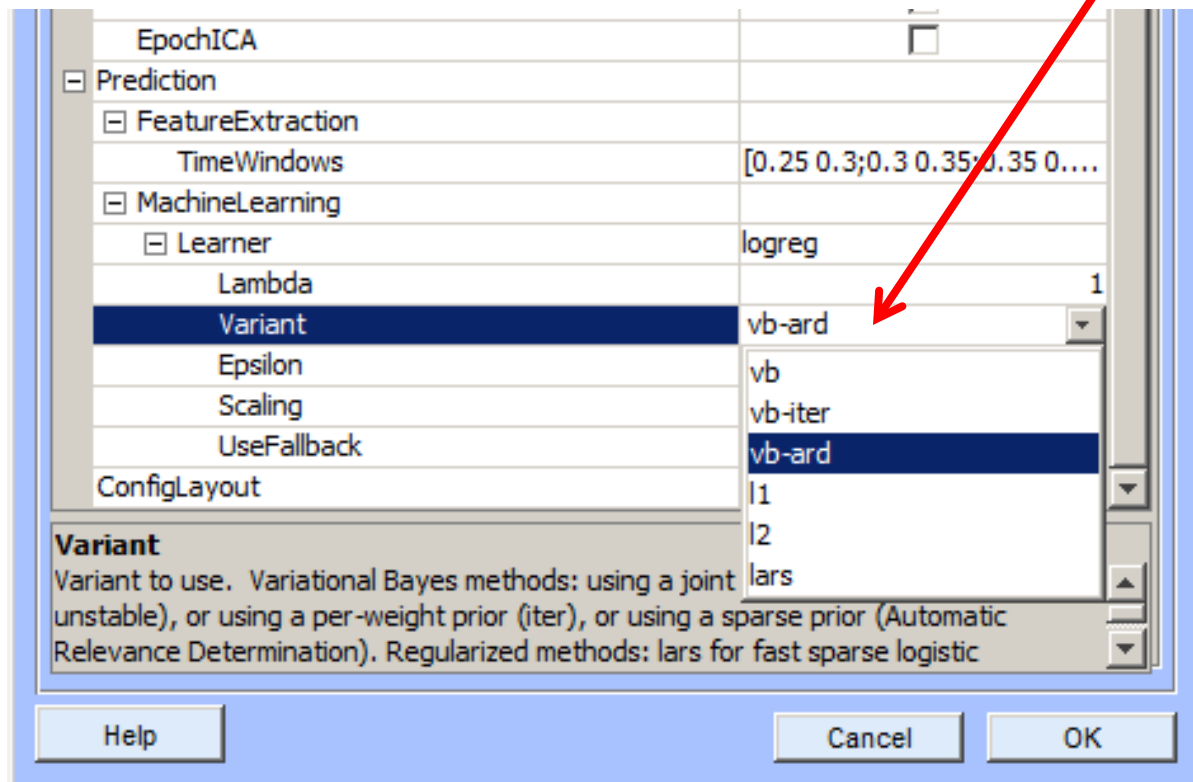
Changing the Classifier

Instead of LDA we choose logistic regression.

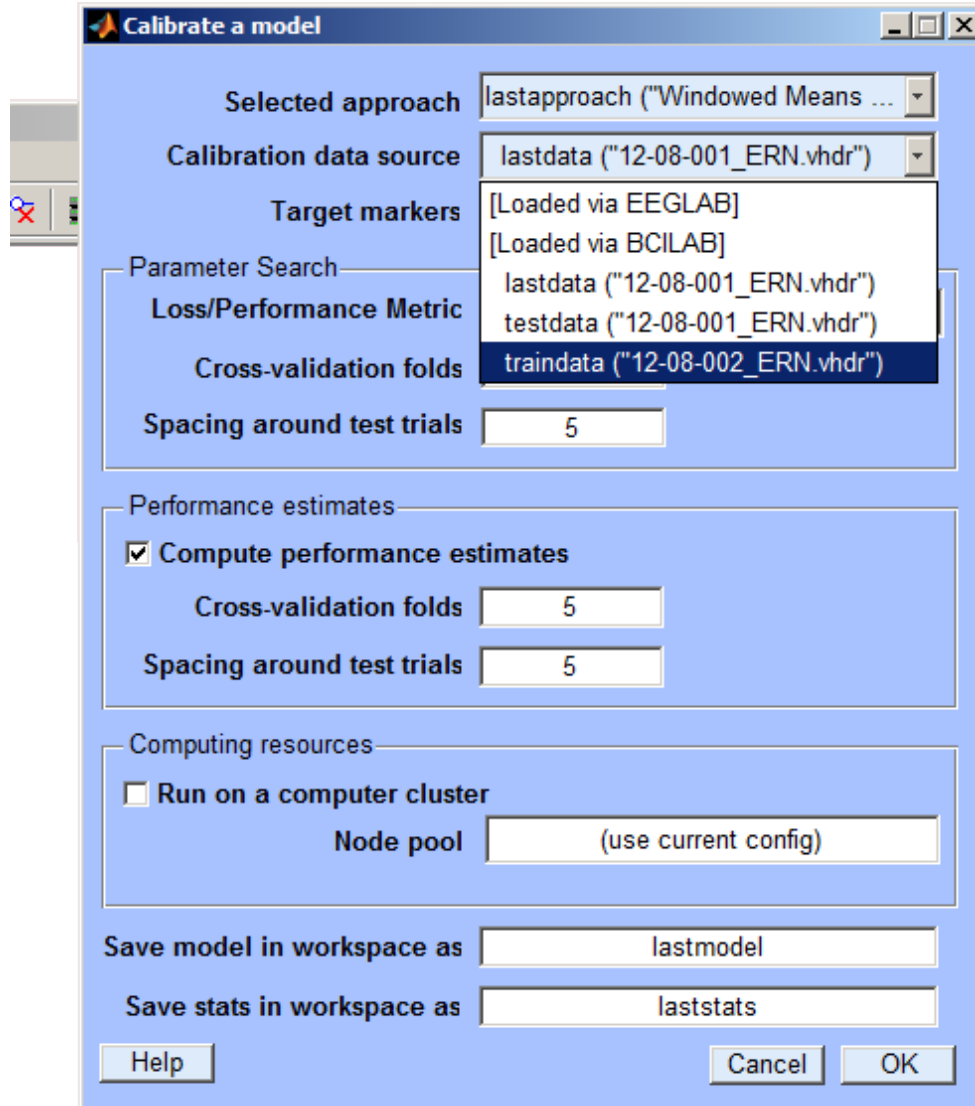


Changing the Classifier

We don't use the VB (Variational Bayes) variant but the sparse version (with Automatic Relevance Determination).



Learning a New Model...

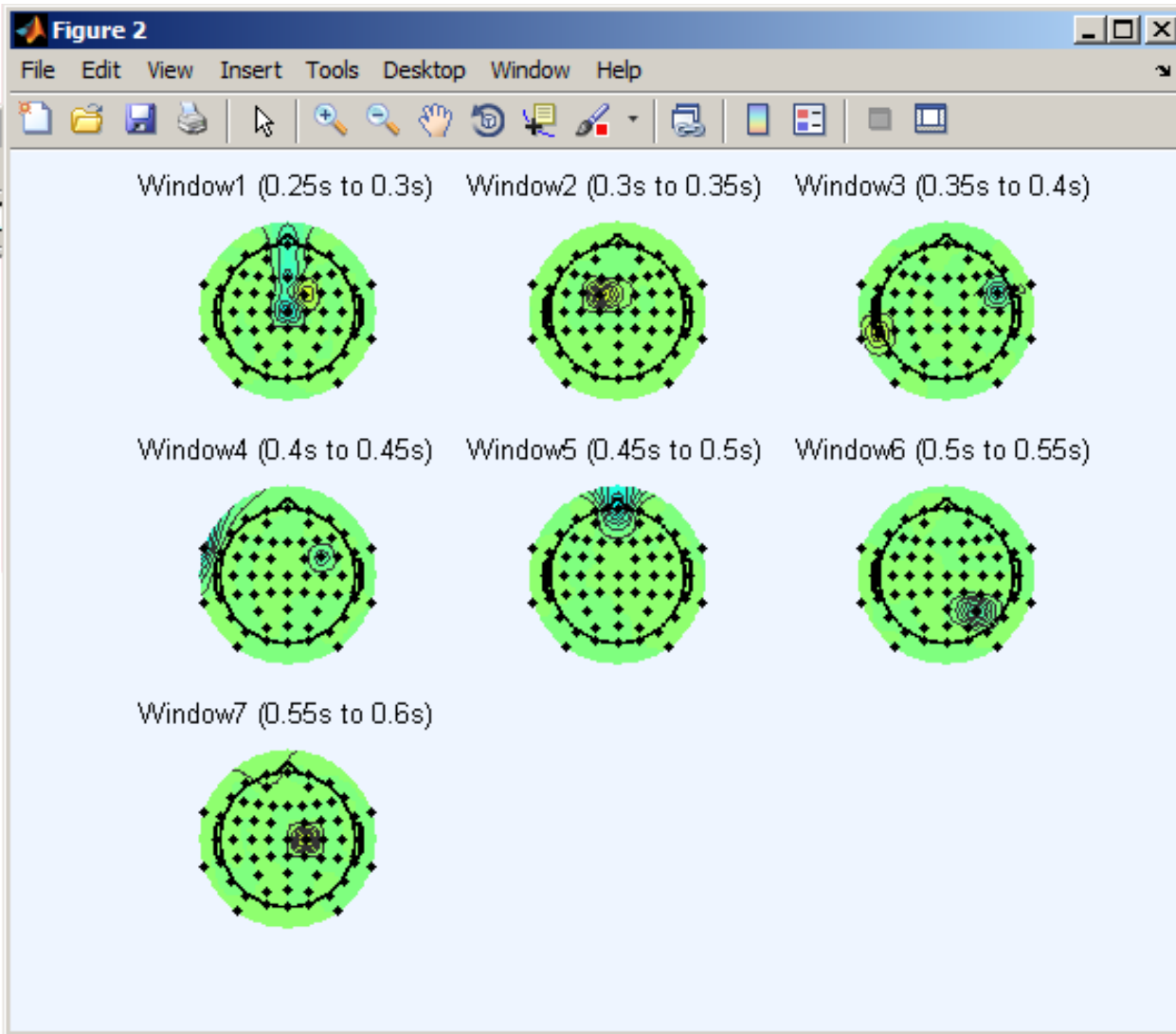


The screenshot shows the 'Calibrate a model' dialog box with the following settings:

- Selected approach:** lastapproach ("Windowed Means ...")
- Calibration data source:** lastdata ("12-08-001_ERN.vhdr")
- Target markers:** [Loaded via EEGLAB], [Loaded via BCILAB], lastdata ("12-08-001_ERN.vhdr"), testdata ("12-08-001_ERN.vhdr"), traindata ("12-08-002_ERN.vhdr")
- Parameter Search:**
 - Loss/Performance Metric:** (empty)
 - Cross-validation folds:** (empty)
 - Spacing around test trials:** 5
- Performance estimates:**
 - Compute performance estimates**
 - Cross-validation folds:** 5
 - Spacing around test trials:** 5
- Computing resources:**
 - Run on a computer cluster**
 - Node pool:** (use current config)
- Save model in workspace as:** lastmodel
- Save stats in workspace as:** laststats

Buttons: Help, Cancel, OK

Visualizing The Model

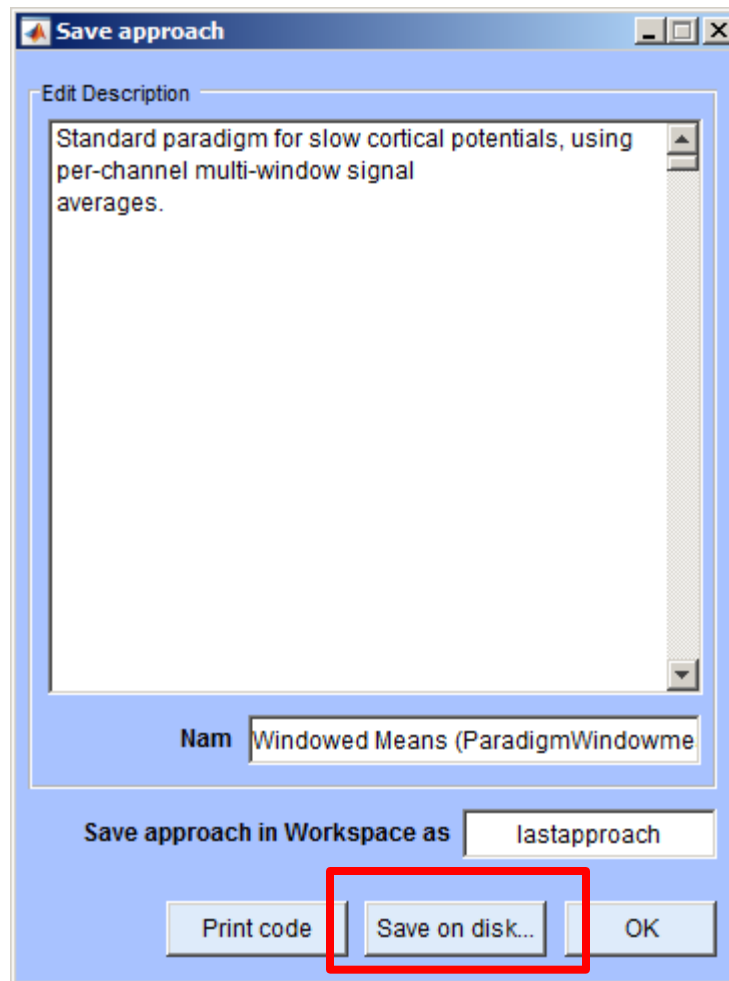


**This model uses
a minimal
subset of
channels.**

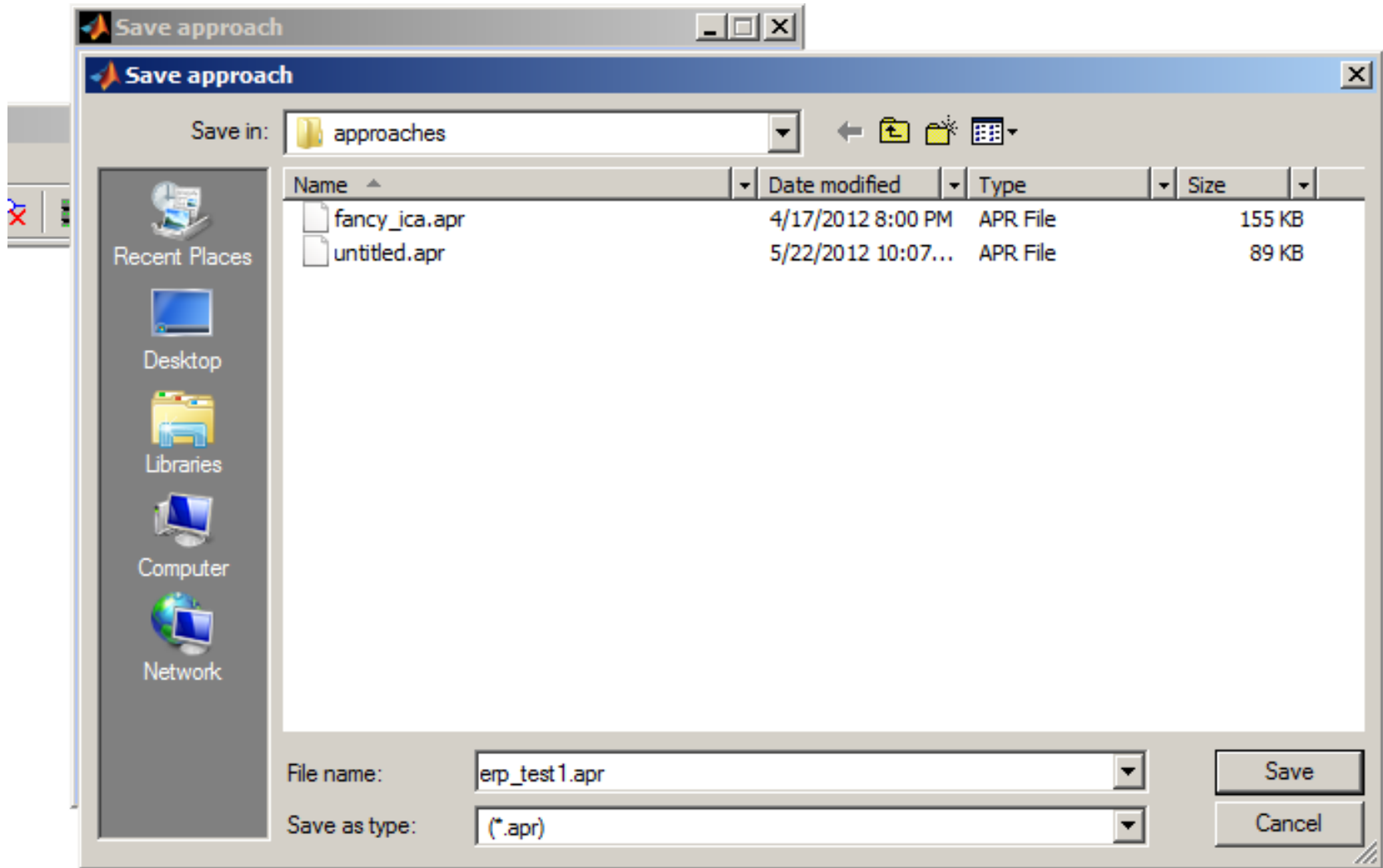
Saving the Approach for Later



Saving the Approach for Later



Saving the Approach for Later





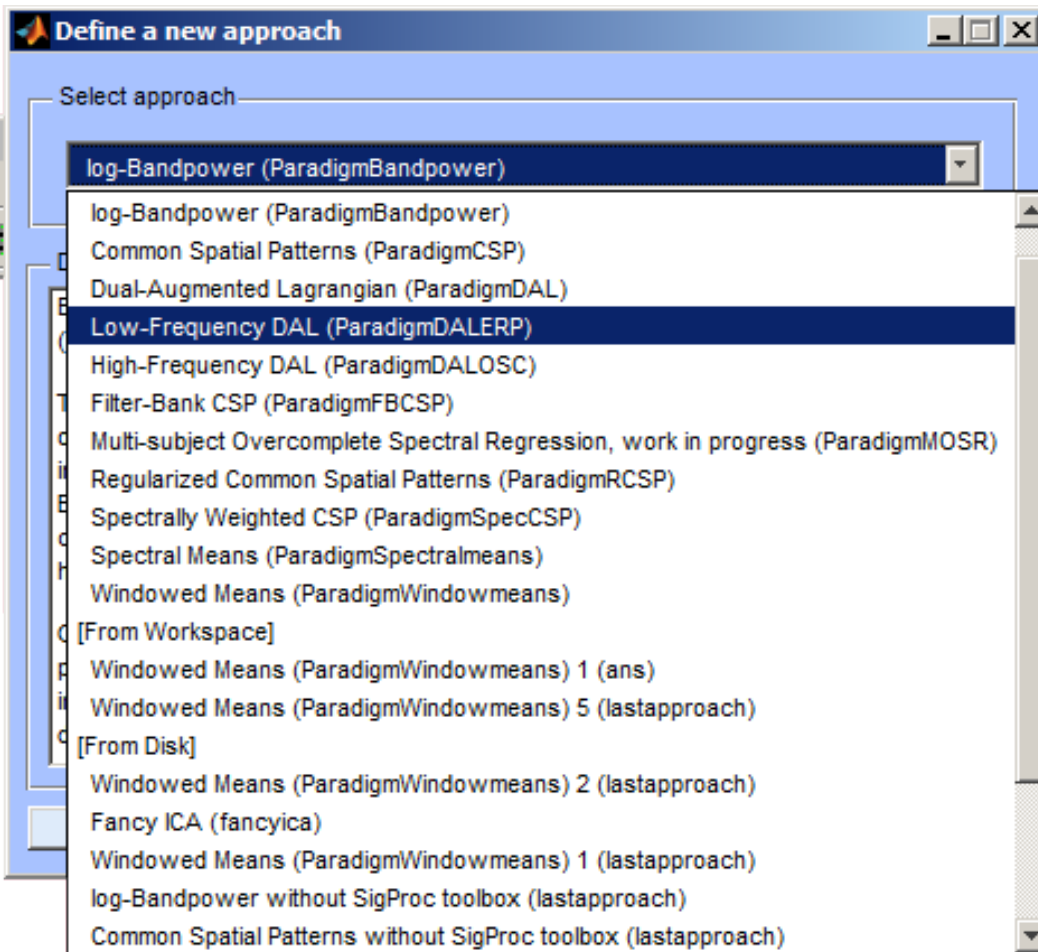
5 More Analyses: Using an Advanced ERP Paradigm

Note: this computation uses a method that will run for up to 15 minutes.

New Approach....



Selecting DAL-ERP



This is one of the best known approaches for ERP-based BCIs. It assumes that there is a small set of latent spatial sources with their own characteristic time course weights, and learns *both simultaneously*.

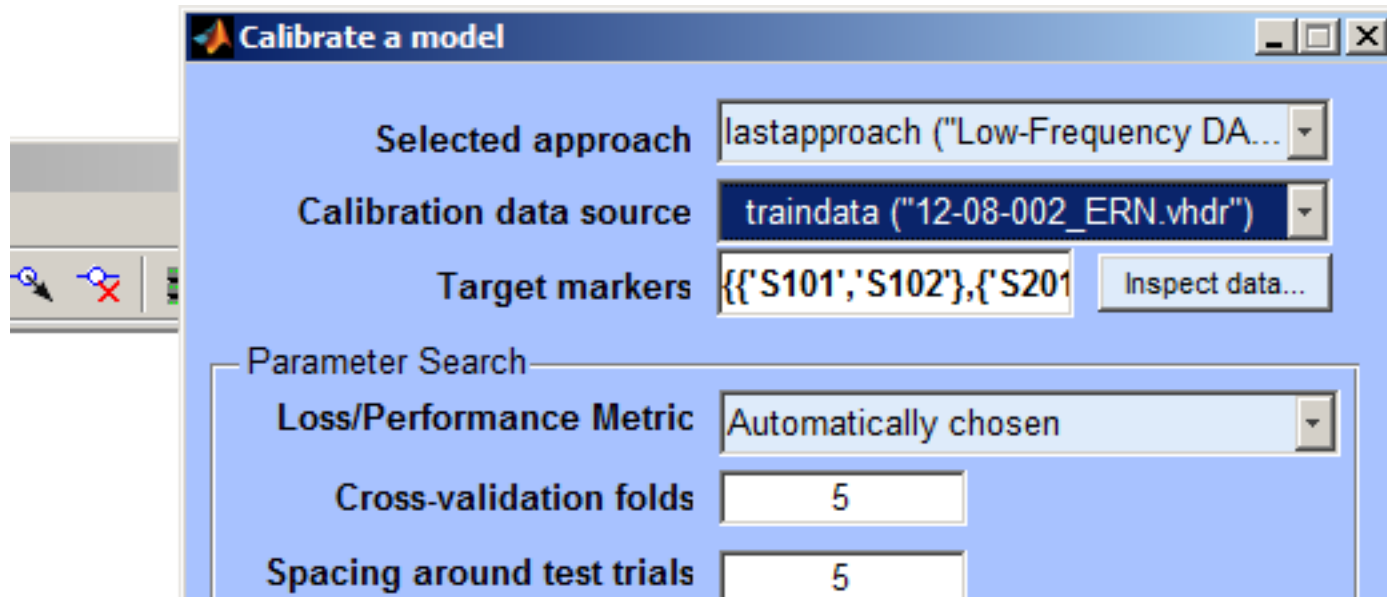
Configuring DAL-ERP

BCILAB: Configure approach

New sampling rate of the data	60
Frequency specification of the filter	[0.1 0.5]
Filter type	butterworth
Epoch time window relative to the target markers	[-0.2 0.8]
Frequency-domain selection	[0.1 15]
Regularisation parameters	[1024 861.077929219804 724.0]
Loss function to be used	logistic
Type of regularisation to use	dual-spectral

Help Cancel **Ok**

Calibrate Model...



The image shows a software dialog box titled "Calibrate a model". It contains several configuration options for model calibration. The "Selected approach" is set to "lastapproach ('Low-Frequency DA...)". The "Calibration data source" is set to "traindata ('12-08-002_ERN.vhdr')". The "Target markers" field contains the text "{{'S101','S102'},{'S201'" and has an "Inspect data..." button next to it. Under the "Parameter Search" section, the "Loss/Performance Metric" is set to "Automatically chosen", "Cross-validation folds" is set to 5, and "Spacing around test trials" is set to 5.

Field	Value
Selected approach	lastapproach ("Low-Frequency DA...")
Calibration data source	traindata ("12-08-002_ERN.vhdr")
Target markers	{{'S101','S102'},{'S201'
Loss/Performance Metric	Automatically chosen
Cross-validation folds	5
Spacing around test trials	5

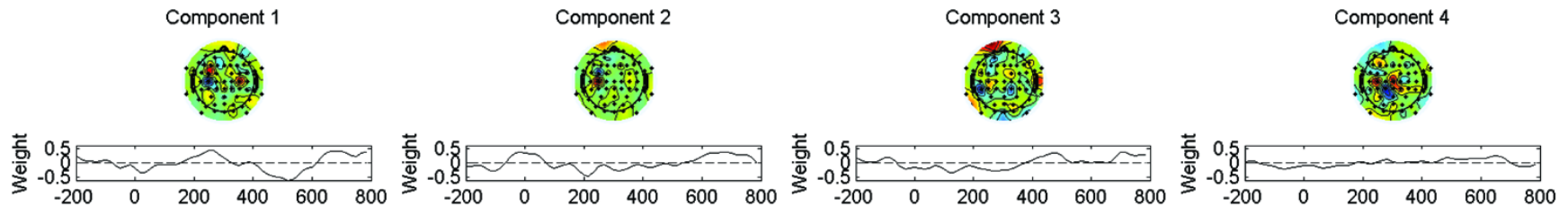
Wait for a Few Minutes...

```
beginning evaluation...

beginning new computation...
pop_epoch():398 epochs selected
Epoching...
pop_epoch():398 epochs generated
eeg_checkset: found empty values for field 'target'
              filling with values of other events in
pop_epoch(): checking epochs for data discontinuity
learning ensemble...
  scanning lambda = 1024.000000... model rank = 0
  scanning lambda = 861.077929... model rank = 0
  scanning lambda = 724.077344... model rank = 0
  scanning lambda = 608.874043... model rank = 0
  scanning lambda = 512.000000... model rank = 0
  scanning lambda = 430.538965... model rank = 1
  scanning lambda = 362.038672... model rank = 1
  scanning lambda = 304.437021... model rank = 1
  scanning lambda = 256.000000... model rank = 1
  scanning lambda = 215.269482... model rank = 1
  scanning lambda = 181.019336... model rank = 1
  scanning lambda = 152.218511... model rank = 1
  scanning lambda = 128.000000... model rank = 2
  scanning lambda = 107.634741... model rank = 3
  scanning lambda = 90.509668... model rank = 3
  scanning lambda = 76.109255... model rank = 3
  scanning lambda = 64.000000... model rank = 3
  scanning lambda = 53.817371... model rank = 3
  scanning lambda = 45.254834... model rank = 4
  scanning lambda = 38.054628... model rank = 6
  scanning lambda = 32.000000...>> |
```

OVR.

Some of the Resulting Components



Note that these are the spatial filters rather than the forward projections!