TopoToolbox Manual
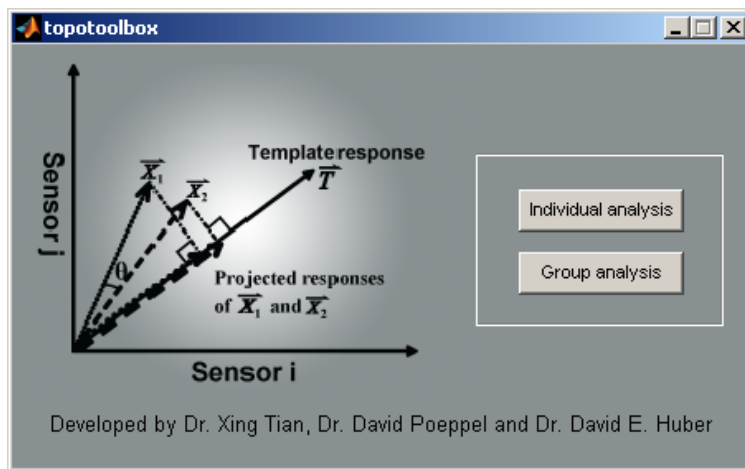

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by

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1. Introduction

TopoToolbox is an open-source software interface for topographic analysis on the event-related electrophysiological (EEG/MEG) data based on the method proposed by Tian and Huber (2008). The spatial-temporal configuration of neural electromagnetic activity recorded over scalp provides important information for investigating the neural functions underlying cognition. TopoToolbox provides a tool for researchers to directly derive robust measures of response pattern (topographic) similarity and psychological meaningful response magnitude using electromagnetic signals in sensor space. These measures are useful for testing psychological theories without anatomical descriptions.

This toolbox is developed by Dr. Xing Tian, Dr. David Poeppel and Dr. David E. Huber. It requires MATLAB (The Mathworks, Inc.) environments and supports various of standard data format imported from EEGLAB (Delorme & Makeig, 2004) as well as user-defined dataset. Please cite the following references if you use the TopoToolbox for publications or public releases:

Tian, X., & Huber, D. (2008). Measures of spatial similarity and response magnitude in MEG and scalp EEG. *Brain Topography, 20*(3), 131-141.

Tian, X., Poeppel, D., & Huber, D.E. (2011) TopoToolbox: Using sensor topography to calculate psychologically meaningful measures from event-related EEG/MEG. *Computational Intelligence and Neuroscience*, 2011. doi:10.1155/2011/674605

2. Start to use

TopoToolbox requires MATLAB environment and uses scalp plotting functions in EEGLAB and imports EEGLAB datasets to operate in the toolbox. If one wants to work on self-define datasets, they must be first saved in MATLAB format (see 'load .mat file for data structure information) and a channel configuration text file is needed to visualize the topography (see 'channel configuration' for details).

2.1. Setup

- Download the TopoToolbox package at https://files.nyu.edu/xt235/public/ and unzip it.
- Add '\TopoToolbox' to the MATLAB path by 'MATLAB → File → Set Path → locate the 'TopoToolbox' folder then Add with Subfolders → Save
- Start the TopoToolbox by typing 'topotoolbox' in the MATLAB command window and pressing the ENTER key

2.2. Main Window

The main window of the toolbox is shown in Figure 1. There are buttons on the right for *individual* and *group* analyses. Click either one to start the specific level analysis (or type in **'topo_individual_analysis'** for *individual* analysis and **'topo_group_analysis'** for *group* analysis). However, the results from *individual* analysis are needed to run *group* analysis.
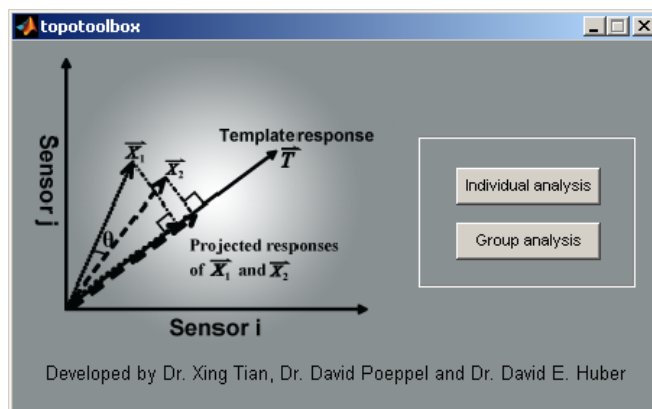
Figure 1 Main window

2.3. Individual analysis

The individual analysis window includes five panels. The options in each panel will change according to different function selection and as the analysis progressing. The common options among different functions are explained below and the unique options to each function are specified in each function section (see below).

Figure 2 Individual analysis window

- **'Function selection'** panel: on the top-left. Switch between 3 functions.

- **'Data location'** panel: on the top-middle. input the location of epoch data file and the channel configuration file (optional, needed for topographic plot for self-defined data)

Figure 3 Data location panel in Individual analysis

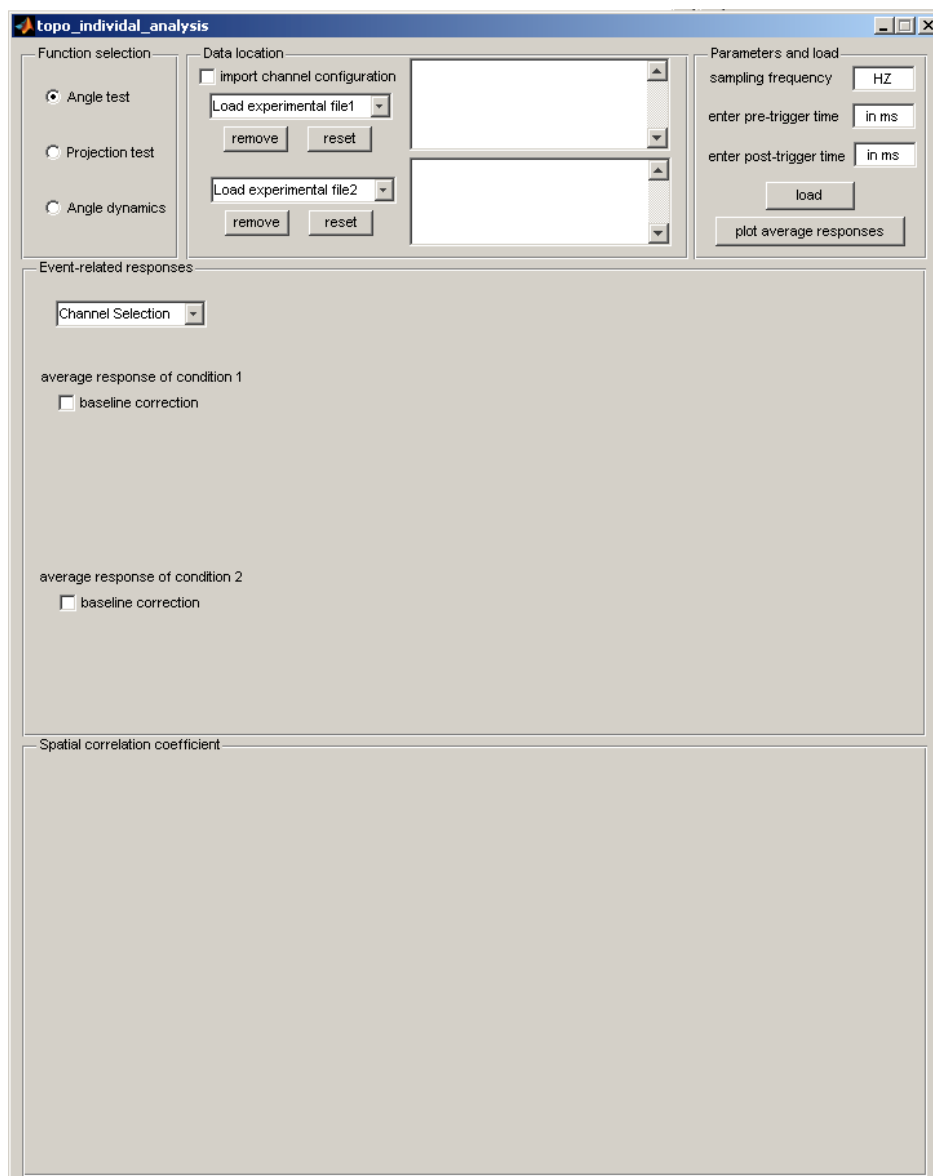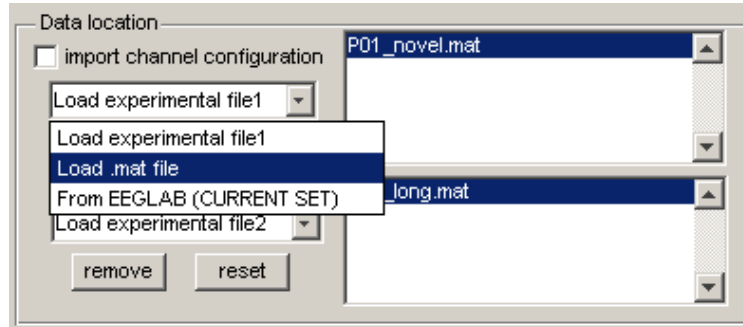 ➢ **'import channel configuration'** checkbox: popup a window to locate the text file containing the channel configuration information. It is used to plot the channel location in topography for self-defined dataset (dataset that includes the channel information imported from EEGLAB doesn't need to use this checkbox). The sample data were recorded using KIT MEG system in University of Maryland and the sample channel configuration text file was included in the 'samples' folder. The text file includes a 157 x 3 matrix that specify the [x, y, z] coordinates of 157 sensors. The topographic plotting function for self-defined dataset, 'megtopoplot.m' calls the channel configuration information when pressing the 'plot average response' button. If user would like to plot the self-defined dataset according to other channel configuration, change the 'megtopoplot.m' function and the text file accordingly.

  ➢ **'load file'** drop box: two drop boxes for locating files in different experimental conditions (or template, depending on different function). There are two options: from a self-defined pre-saved in MATLAB format dataset, or from current set in EEGLAB (requires running EEGLAB).

    o **'Load .mat file':** a window will popup and guide to load in a '.mat' file. The data structure should be [channels x time x epochs];

    o **'From EEGLAB (CURRENT SET)'**: If user would like to import a dataset from EEGLAB, first run EEGLAB and read in the

dataset (File → Load existing dataset). *While the EEGLAB is still open*, make sure the file one wants to import is the current set by checking the information on EEGLAB main window or the 'datasets' selection on the top-right. The current set is marked with a check before the file name (see Figure 4). Go back to the **'load file'** drop box and select **'From EEGLAB (CURRENT SET)'**. (The dataset should be after extracting epochs. Detailed tutorial of EEGLAB can be found at http://sccn.ucsd.edu/wiki/EEGLAB)
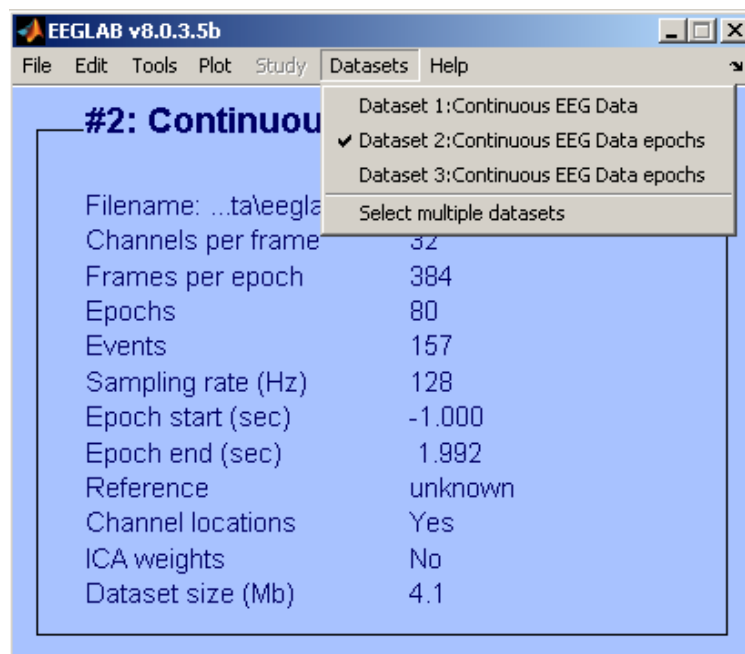
Figure 4 EEGLAB current dataset

➢ **'file display'** box: the name of selected files will be displayed for each condition in separate box. Should multiple files in one box, the highlighted ones are used for further analysis (such as plotting, except calculating projection values, see **'Projection test'** for more details). One can change the selection by switch the highlight at any time.

➢ The **'remove'** button: remove the highlighted file in **'file display'** box;

➢ The **'reset'** button: clear all files in display box;

• **'Parameters and load'** panel: on the top-right. Specify the recording parameters, load in the selected files and plot the event-related responses in the panel below (optional)

- ➢ **'Sampling frequency'**: enter the recording sampling frequency (Hz).
- ➢ **'Pre-trigger time'**: the time (in ms) included in epoch data before the onset of an event. It should be a positive number.
- ➢ **'Post-trigger time'**: the time (in ms) included in epoch data after the onset of an event. It should be a positive number. (Note: it starts at time **zero**.)
- ➢ **'Load'** button: Load all specified data files. Only work when loading the self-defined dataset. Should any changes occur in **'file display'** box, one should press this **'Load'** button to reload the data. After pressed this button, options will be visible in **'Individual results'** panel. The **'Load'** button will be hidden when datasets are imported from EEGLAB. (Options in **'Individual results'** panel will be visible after loading dataset from EEGLAB in both **'file display'** boxes.)
- ➢ **'Plot average responses'** button: (optional, for visualization of event-related responses and selection of time instance for following analysis. If one already examined the responses and determined the latencies in other software, this step can be skipped.) Calculate and plot the event-related response in the panel below. Only highlighted data file in **'file display'** box will be plotted. (Note: one file in each display box should be selected.)

- • **'Event-related response'** panel: (Fig. 5) on the middle. Most parts that are initially hidden will be visible after loading the data and press the **'plot average responses'** button.
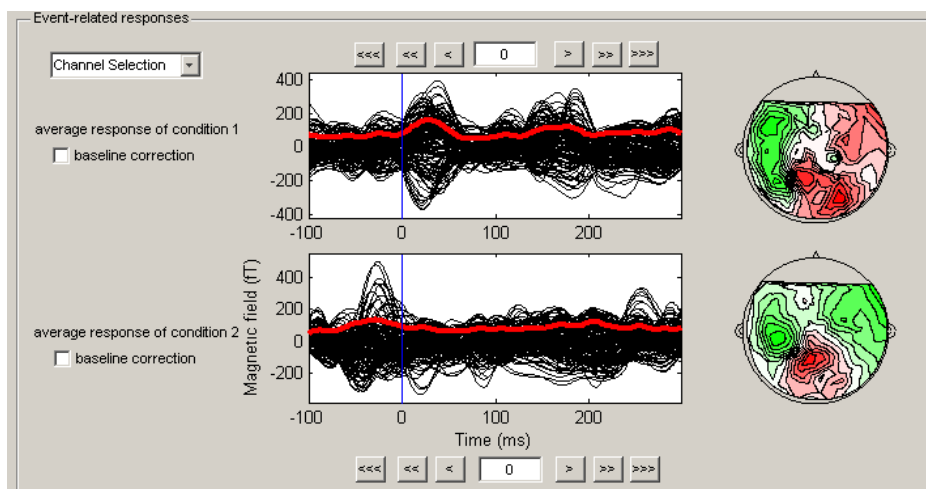

Figure 5 Event-related response panel

- ➢ **'Channel selection'** drop box: two options, using all channels (default, same as leave it unselected) or custom channel selection by loading a text file that includes the selected channel numbers. This text file should include the channel numbers that user would like to retain (see an example in 'samples' folder).

- ➢ **'Baseline correction'** checkbox: using pre-trigger data to do baseline correction. Separate for each plot.

  NOTE: After selecting the 'Channel selection' and 'baseline correction, those functions will also apply on the data for further analysis.

- ➢ **Time** instance controllers: move the line cursor forward or backward in 3 speed (1, 10 or 100 sample points). The box in the middle displays the current cursor time. One can also directly enter the time (in ms) in this window to move the cursor. The topography will be plotted at the current time instance.

- ➢ **Waveform and topography plots**: Two separate rows for plotting the data specified in two separate **'file display'** boxes. All selected channels are plotted in the waveform figures and each channel is as one black line. The red line is the root-mean-square waveform of all selected channels. The topography is plotted at current time instance indicated by the line cursor.

- • **'Individual stats results'** panel: on the bottom, hidden before loading the data and the options depends on the function selection.

2.4. Group analysis

The group analysis window includes 4 panels. The options in each panel will change according to different functions and as the analysis progressing. The common options are explained below and the unique options are specified in each function section below.

- • **'Function selection'** panel: on the top-left. Switch between 3 functions.
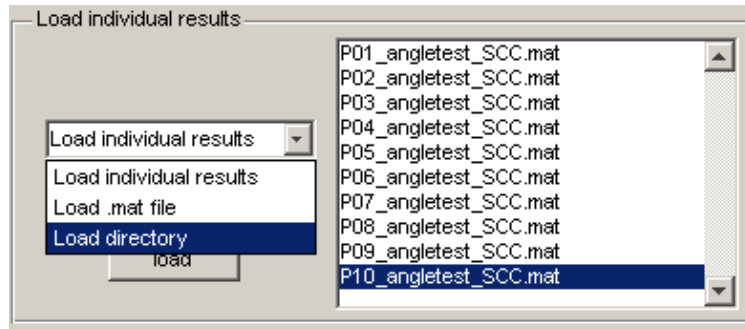- • **'Load individual results'** panel: (Fig. 6)

Figure 6 Load individual results in group analysis window

> **'Load individual results'** drop box: two options. **'Load .mat file'**, loading a single .mat result file saved from *Individual analysis*; **'Load directory'**, loading all saved results file from a folder. After specifying the files, all file names will be display on the right **'file display'** box.

> **'remove'**, **'reset'** buttons: same as in Individual analysis window.

> **'Load'** button: loading all the data appearing in the **'file display'** box. Should any changes occur in the display box, one should press this **'Load'** button to reload the data.

- **'Plot'** and **'Group stats results'** panels: hidden until loading the data, depending on the function selection.

3. Functions

Currently, TopoToolbox includes three major functions:

a) *Angle test*: testing pattern similarity between the topographies

b) *Projection test*: deriving a psychological meaningful response magnitude measure after normalizing individual difference by projecting all responses onto a common template

c) *Angle dynamics*: providing the dynamics of a given topography occurrence

All functions have two-step procedure in which the measure of interests is first calculated in within-subject manner (individual analysis) followed by group analysis in which inferential statistics is carried out using subject factor as a random factor.

3.1. Angle test of topographic similarity

the topographic similarity between responses in different experimental conditions can be assessed by *angle test* (Tian & Huber, 2008) that calculates the cosine value of the angle (*spatial correlation coefficient*, SCC) between two responses (high dimensional vectors) at given time instance. The SCC is then compared with a null hypothesis to obtain statistical results.

- **Individual analysis window**:
  - ➢ **'Data location'** Panel: (Fig. 7) After selecting the function **'Angle test'**, the **'load file'** drop box will indicate to load in two data sets, each for one experimental condition. (The angle test will be run on these two responses to assess the pattern similarity at given time instance). One filename will display in each **'file display'** box.
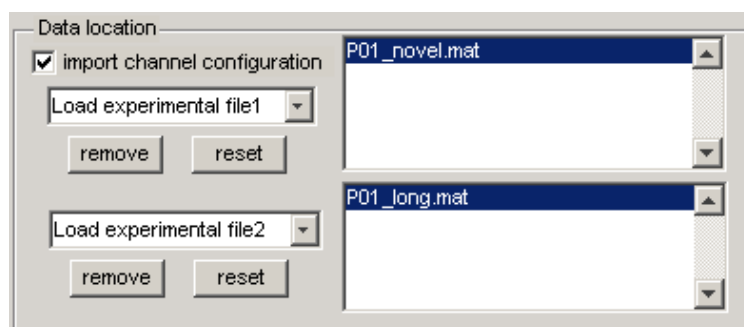

Figure 7 Data location panel for angle test in individual analysis

➢ **'Individual stats results'** panel: After specify the parameter and press the **'Load'** button, the name of this panel will be updated to **'Spatial correlation coefficient'** and several options will appear, which is need to specify to calculate the SCC and run *angle test* (Fig 8).
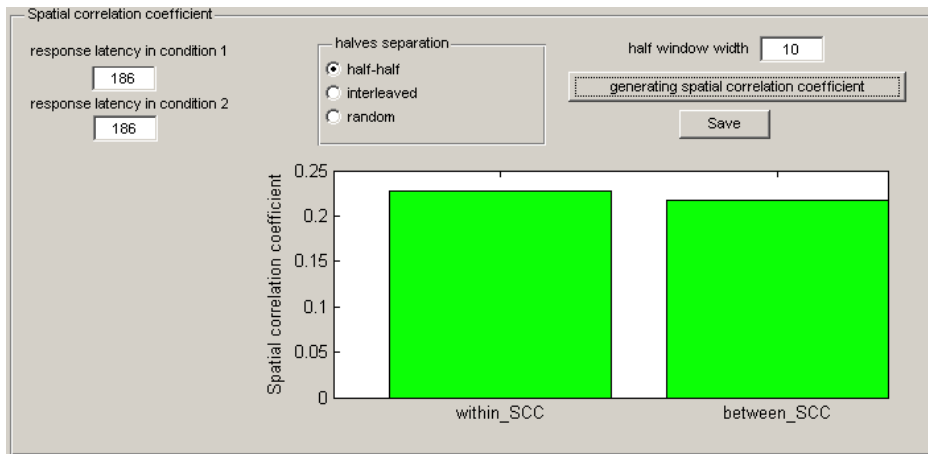
Figure 8 Individual stats results panel for angle test in individual analysis

o **'Response latency'** in each condition: this is the latency at when the component of interest will be compared. The **'response latency'** boxes are sync with the timing of line cursor in **'Event-related responses'** panel. One can selects the latency by moving the line cursor or directly input it into the 'response latency' box. The latency in condition 1 is for data loaded in the *upper* **'file display'** box in **'Data location'** panel and link to the *upper* plot in **'Event-related responses'** panel; whereas the latency in condition 2 is for *lower* ones.

o **'Halves separation'** panel: Data in each condition are separated into halves that contain equal number of epochs. The SCC between two responses and the null hypothesis can be calculated based on those halves (after press **'generating spatial correlation coefficient'** button). There are three options to separate data into halves. The first one, **'half-half'** is to separate according to trial number: the first half vs. the second half epochs. The second one, **'interleaved'** is by odd-even number. The third one **'random'** is randomly draw half number of epochs. The third selection can be

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done iteratively to create different halves to estimate the confident interval (an input box will appear after selecting the **'random'** and the number of iteration can be specified).

- o **'Half window width'** input box: define the half window width of a time window around the defined response latency (in ms, should be a positive number). The actual time window width will be double of the defined half window width plus one sample point at the center latency. All SCC in that time window will be averaged to increase measure reliability.

- o **'Generating spatial correlation coefficient'** button: One SCC is calculated within each condition by comparing the topographies at give time instance of those responses obtained by averaging each half (*within* SCC). The average of two *within* SCCs in those two conditions serves as the null hypothesis. One *between* SCC is calculated by comparing the average response from the first half epochs in the first condition to the average response from the second half epochs in the second condition. Another *between* SCC is obtained by comparing the average response from the second half epochs in the first condition to the average response from the first half epochs in the second condition. The true *between* SCC is obtained by averaging of those two *between* SCCs. The results will be plot in the figure below.

- o **'Save'** button: after press **'Generating spatial correlation coefficient'** button, the individual results can be save (a popup window will appear to specify the save location).

- **Group analysis window:**
  - ➤ **'Group stats results'** panel: (Fig. 8) This panel will be visible after loading the individual results data
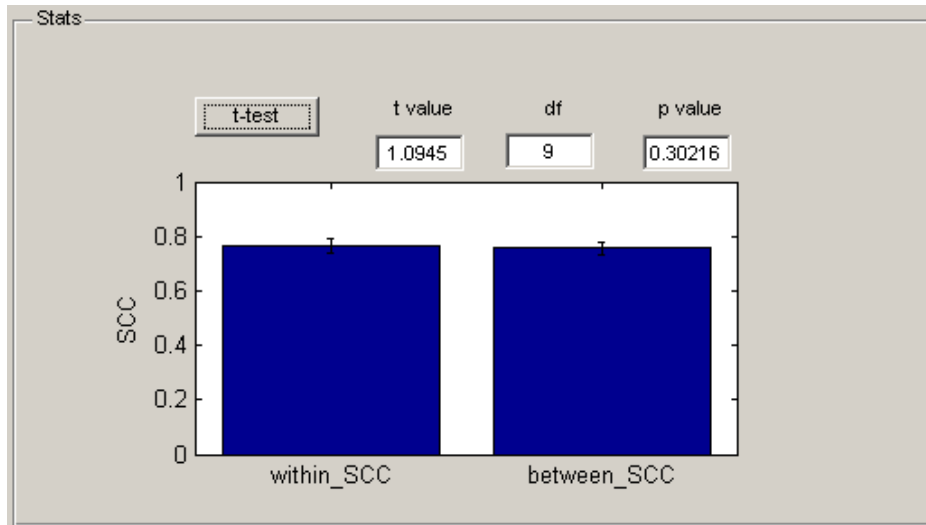
Figure 9 Group stats results panel for angle test in group analysis

- o **'t-test'** button: carrying out a paired *t*-test between *within* and *between* SCCs across all loaded individual results. The *t* value, degree of freedom and *p* value will be displayed, as well as a bar plot on the bottom.

3.2. Projection test

Responses in all experimental conditions were projected onto a template that obtained individually. The projection yields a standardized and normalized magnitude measure in each condition for each participant (Tian & Huber, 2008). The group analysis is then carried out on those individual results.

- **Individual analysis window:**
  - ➤ **'Data location'** panel: (Fig. 10) after selecting **'Projection test'**, the **'Load file'** drop boxes will be updated to **'load a template file'** (top) and **'load experimental file'** (bottom). Only one template will be accepted in the projection test for an individual (the highlighted one in top **'file display'** box). So we recommend only load one template file for each participant in this analysis. Up to **six** files (one for response in each experimental condition) can be taken and normalized by the template in the *projection test*.
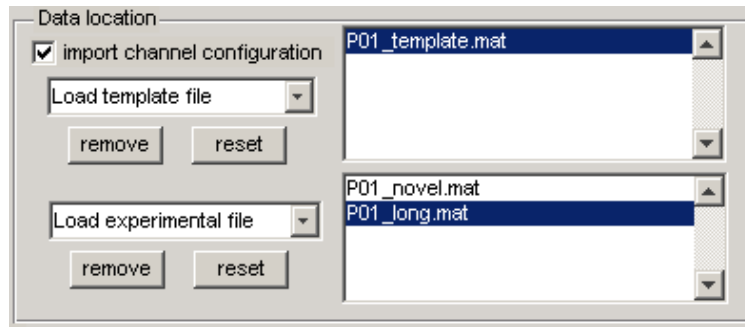
Figure 10 Data location panel for projection test in individual analysis

➢ **'Event-related responses'** panel: (Fig. 11) the average response of template will plot in the top row; the **highlighted** response in experimental condition (in the bottom **'file display'** box) will plot in the bottom row. One can switch the highlight to update the plot for response in different conditions.
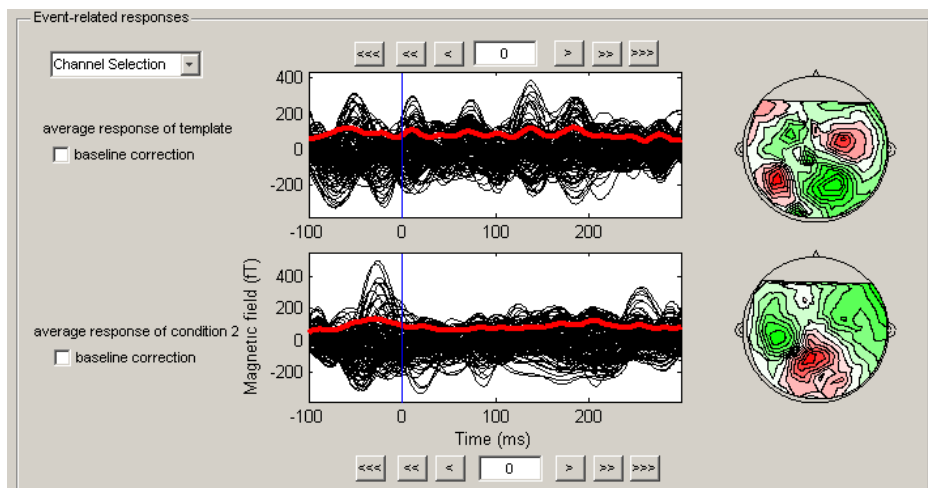

Figure 11 Event-related responses panel for projection test in individual analysis

➢ **'Individual stats results'** panel: (Fig. 12) this panel will update to **'Projection value'** and various options will be visible.
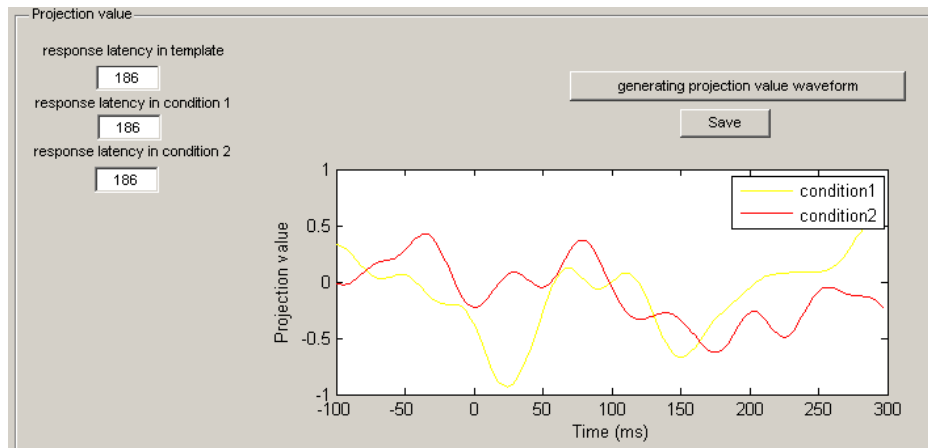
Figure 12 Individual stats results panel for projection test in individual analysis

- o **'Response latency'** input boxes: the first input box is used to specify the latency at when the standard topography (template) will be selected (out of the template response, the file in the top **'file display'** box); the following input boxes are the latencies for topographies of interests in each experimental conditions. The number of the latency boxes will equal to the number of file loaded. Because multiple latencies are needed to specified, the sync between the latency selection in this panel and cursor time in **'Event-related responses'** panel is off. One needs to manually input all the latencies.
- o **'Generating projection value waveform'**: projection values as the function of time will plot in the bottom. The number of waveforms depends on the number of conditions loaded and the order in the legend is the same as the order in bottom **'file display'** box in **'Data location'** panel.
- o **'Save'** button: after generating the waveforms, individual results can be saved.

- **Group analysis window:**
  - ➢ **'Plot'** panel: (Fig. 13) after loading individual results for projection test, this panel will be visible to plot the mean projection value across participants.

o **'plot half width'** input box: define the half width of time window around the response latency that will be used for time averaging

o **'plot in separate figure'** checkbox: check it for plotting in a separate MATLAB figure

o **'Generate mean projection value waveform'** button: plotting the mean projection values for each condition with two standard error of the mean (SEM) in the figure below (the order of the condition is the same as the one in individual analysis). The plot is centered at the latency of experimental conditions specified in individual analysis (time zero in this plot). The width of the plot is determined by the parameter specified in **'plot half width'** input box. If the plot half width is out of the data range, it will plot the maxim data points.
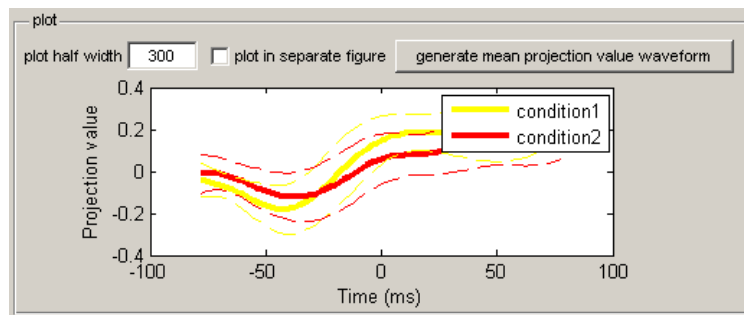

Figure 13 plot panel for projection test in group analysis

➢ **'Group stats results'** panel: after loading the individual results for projection test, this panel will be visible. Depending on the number of experimental conditions, this panel will appear differently.

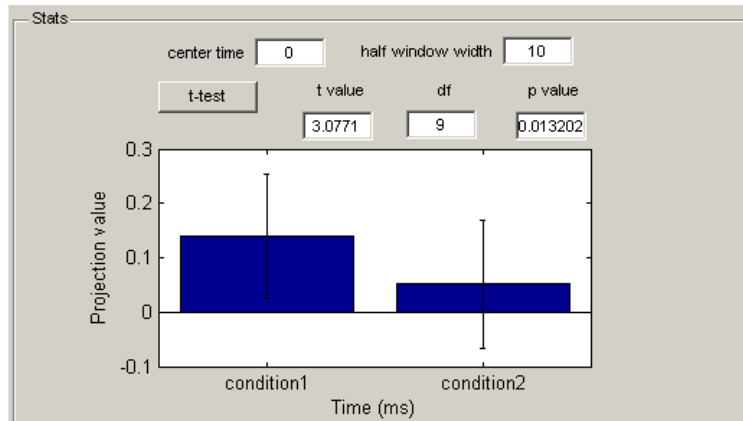1) **With two experimental conditions:** (Fig. 14)

Figure 14 Group stats results with two experimental conditions for projection test in group analysis

- o **'center time'** input box: the time instance at when the projection values are taken from the plot above for the further statistical test. The default is time zero, which is identical of selecting the projection values at the latency of experimental conditions (because the plot above is centered at the latency of experimental conditions specified in individual analysis).

- o **'half window width'** input box: define the half window width of a time window around the center time. The projection values in this time window will be averaged to increase measure reliability. The actual time window width will be double of the defined half window width plus one sample point at the center latency.

- o **'t-test'** button: run a paired *t*-test between projection values of two conditions.

2) **With more than two experimental conditions:** (Fig. 15) **'ANOVA'** button with option of **post-hoc *t*-test** will appear; other options are the same as the Group stats results panel with two experimental conditions
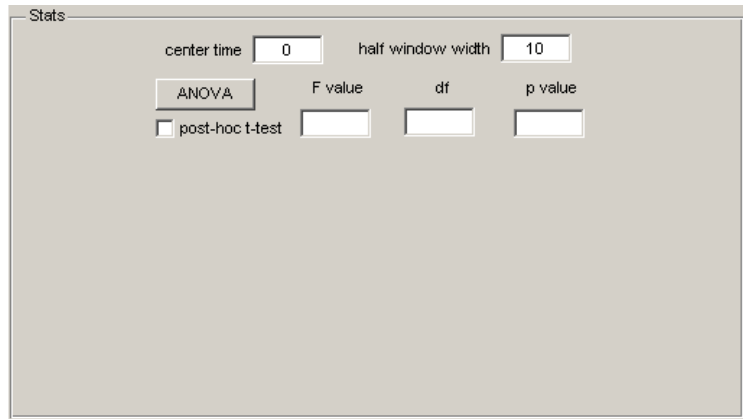
Figure 15 Group stats results with more than two experimental conditions for projection test

- o **'ANOVA'** button: run a one-way ANOVA
- o **'post-hoc t-test'** checkbox: if the box is check, a popup window will appear in which one can specify the two conditions on which the post-hoc *t*-test will run.

3.3. Angle dynamics

Response activity in an entire time course is compared to a target response pattern (template) at every time instance using the *angle test*. The dynamics of the occurrence of such pre-determined response pattern can be assessed by compare to a null hypothesis.

- **Individual analysis window:**
  - ➢ **'Data location'** Panel: similar as the one in **'Projection test'**, where one needs to locate the files for template and experimental condition. We also suggest only load one template file for each participant. However only one experimental condition is allowed in the *angle dynamics*. That is, only one response can be compared to template across the entire epoch time.
  - ➢ **'Individual stats results'** panel: similar as the one in **'angle test'**, with exceptions that the **'half window width'** input box is invisible and the waveform of SCC will be plotted against time instead of bar plot.
- **Group analysis window:**
  - ➢ **'Plot'** panel: similar as the one in **'Projection test'**, with an exception that the mean *within* and *between* SCCs will be calculated and plotted.

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➤ **'Group stats results'** panel: similar as the one in **'Projection test'** with **two experimental conditions**.

4. References

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.

Tian, X., & Huber, D. (2008). Measures of spatial similarity and response magnitude in MEG and scalp EEG. *Brain Topography, 20*(3), 131-141.

Tian, X., Poeppel, D., & Huber, D.E. (2011) TopoToolbox: Using sensor topography to calculate psychologically meaningful measures from event-related EEG/MEG. *Computational Intelligence and Neuroscience*, 2011. doi:10.1155/2011/674605