

Removal of artifact and noise for MEG data can be divided into two parts; (1) isolate signals and (2) project the raw data onto this signal space.

The first step is accomplished primarily by using channels rich in noise and artifact and poor in signal to construct a basis for the artifact and noise which is subtracted from ALL MEG channels. This is followed by construction of the signal subspace basis from channels rich in signal relative to remaining noise and artifact.

NOTE: The raw 50 trials of Unfiltered MEG data are used for the Noise and artifact removal step. Next, these cleaned trials are averaged. Then the averaged data is band-pass filtered 1 to 25 Hz before extracting the signal subspace components. The final stage of artifact removal makes use of the known temporal characteristics of the signal. In particular, signal components are selected which have large amplitudes during the first 12 seconds and small during the last 12 seconds where no signal is expected. Additional signal separation is achieved in this step by implementing an ECD narrow band adaptive filtering technique.

Access the Artifact Removal menu by pressing the SIGNAL PROCESSING BUTTON on the main MEG_TOOLS MENU. A menu with a list of option will be presented; Choose: “Artifact Removal” to obtain the MENU BELOW.

Heart & Other Artifact Removal

Artifact channel Choice

Select

Removal Method

MEG artifact as SVD

EEG artifact as SVD

Number/Fraction: MEG Components

2

Remove Bad MEG Channels

Select

Data Segmentation Length

12208

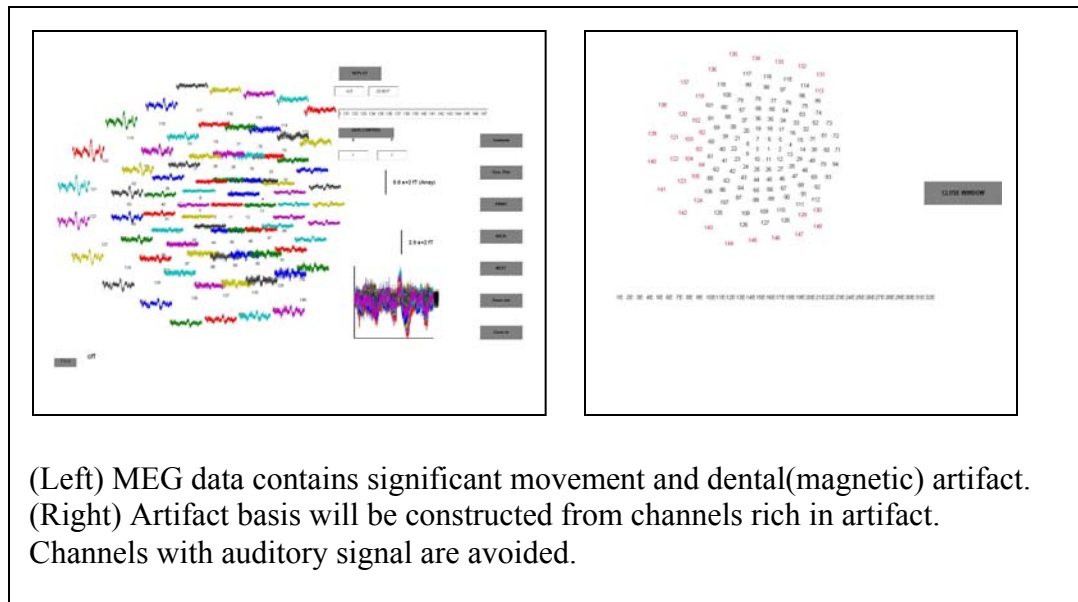
All in Directory

Remove Artifact

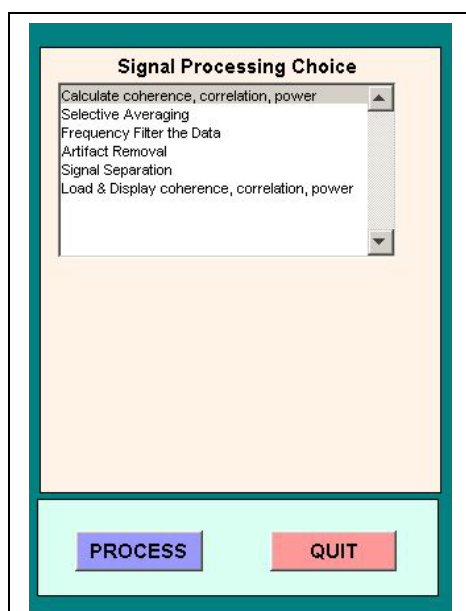
QUIT

I recommend that you use default settings. Artifact will be removed based on amplitude using SVD; Better for movement artifact. In contrast, removal using ICA is recommended for artifact characterized by burst activity, such as heart artifact. Press the SELECT button to choose the MEG channels with large artifact and little signal; Avoid channels near the auditory cortex (bilateral temporal). Your channel selection should

incorporate a review plots of the original set of trials consisting of repeated blocks of 24 seconds of MEG data. For this study, if EEG channels appear, make sure to deselect them. In some studies EEG channels without input were accidentally acquired. My choice is shown in the next figure for this subject.



I suggest you choose 2 components on the menu (See above menu). This will remove the 2 greatest sources of noise and artifact from ALL 148 channels of MEG data for each trial individually. Thus, artifact removal is adapted to be optimal for each 24 second block of data. The set of cleaned data trial will be stored in a subdirectory of the data being processed (afilt_#/).



The menu on the left appears when the SIGNAL PROCESSING BUTTON is pressed on MEG_TOOLS main menu.

Artifact Removal is selected for the previous artifact removal step.

Selective Averaging is chosen to select trials for averaging.

Signal Separation will be used in the final step to finish creation of the Signal Space Basis; Project the original trial on this basis and create the final averaged block of MEG data containing only signal components.

After removing artifact, use the Selective Averaging option (SEE ABOVE MENU) to average these cleaned MEG trials. Prior to averaging, I recommend you look at the results of previous cleaning step using the MEG SENSOR plot. Occasionally, you may observe that one or two of the epochs still have very large artifacts. After pressing the PROCESS BUTTON, the program will then scan all the files looking for trigger channel identifications that can be used to segregate different types of trial conditions. There is only one trigger ID for these files. The results will be displayed in the following menu. On the signal averaging menu you can select these few bad trials and delete them from the average (SEE MENU BELOW).

You can change the name of the directory as desired (no blank spaces, no special characters). If you know that one of the epochs still has a very large artifact then you can choose it and delete it from the average. (You can view the epochs one by one before doing the average using the sensor layout and choosing the next epoch button to change the trial that is displayed.) When ready press the Process button to create the average MEG Block Data, which is saved in the subdirectory named in the menu window above.

SELECTED DATA

c:\image_data\fmri009_meg\fmritone\raw\DATA1\FILT1\afilt_1\

Epoch Averaging Identifier:

128

Save Directory as:

average_data

Epoch versus Identifier

1 128

2 128

3 128

4 128

5 128

6 128

7 128

8 128

9 128

10 128

11 128

12 128

13 128

14 128

15 128

16 128

17 128

18 128

19 128

20 128

21 128

Process

<- delete

<- Save List

<- Load List

HELP

QUIT

Heart & Other Artifact Removal

Artifact channel Choice

Select

Removal Method

MEG signals as ICA

EEG artifact as SVD

**Number/Fraction:
MEG Components**

15

Remove Bad MEG Channels

Select

Data Segmentation Length

12208

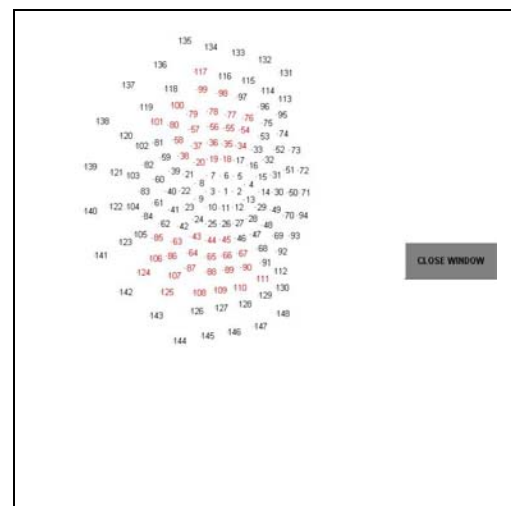
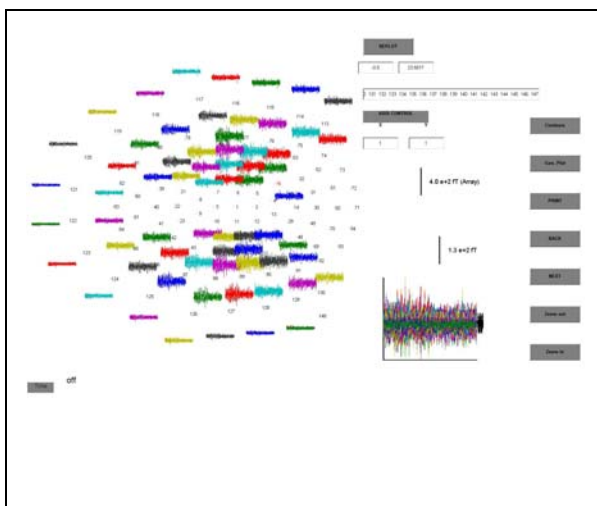
All in Directory

Remove Artifact

QUIT

The first step to isolate the auditory signals is performed next.

Load the AVERAGED MEG Data created in the previous step and use the SIGNAL PROCESSING Button to access the Frequency filtering tools. Load the 1 to 25 Hz filter. Then filter the data. These filtered data are stored in a subdirectory, “filt#”. Load the frequency filtered data and choose Artifact Removal in the signal processing menu. Then, on the above menu, choose “MEG Signals as ICA” on the ARTIFACT REMOVAL MENU. I suggest you choose 15 components. This is an upper bound on the number of components that will define the estimated signal subspace. Then use the SELECT BUTTON to choose channels relatively rich in signal compared to artifact and noise. See Sensor Layout plot of Averaged MEG data and my choice of channels below.



Press the REMOVE ARTIFACT BUTTON. However, rather than removing artifact, the signal subspace spanned by the data of the selected channels will be extracted. All the averaged MEG data will be projected on this subspace. MOST important, the signal subspace basis vectors will be saved with the MEG data in the EPOCH data structure as a field “data_components”. These results are saved to disk in a subdirectory named “afilt_1/”.

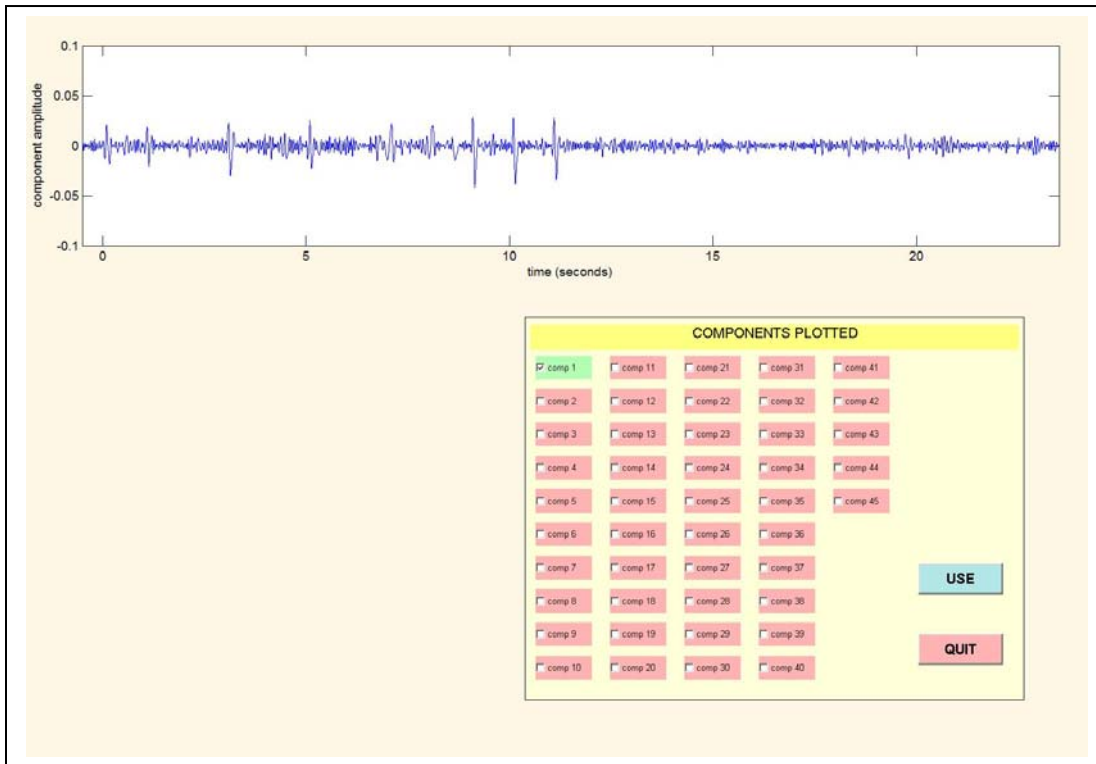
Now, the final step, to isolate the auditory signals, can be performed.

Load the cleaned data created in the previous step. PRESS the Signal Processing BUTTON on MEG_TOOLS main menu and choose “Signal Separation” option. This menu has input fields for defining the start and end of the times during which signal amplitudes are expected to be large and the start and end of the time interval where brain response is expected to be low or absent. I suggest that you choose the ECD method and a 1.3 to 1.5 signal-to-noise threshold for selecting signal components base on their amplitude during the high level time interval relative to the low level amplitude.

The image displays two screenshots of the MEG_TOOLS software interface. The left screenshot shows the 'Signal Processing Choice' menu, which lists several options: 'Calculate coherence, correlation, power', 'Selective Averaging', 'Frequency Filter the Data', 'Artifact Removal', 'Signal Separation' (highlighted), and 'Load & Display coherence, correlation, power'. Below the menu are two buttons: 'PROCESS' and 'QUIT'. The right screenshot shows the 'Temporal Signal Selection Properties' dialog box. It has a yellow header. The main area is divided into two columns. The left column has two sections: 'High Signal Interval' with 'Start' (-1) and 'End' (12) fields, and 'No Signal Interval' with 'Start' (12) and 'End' (24) fields. Below these are labels for 'Data Start = -0.5 sec' and 'Data End = 23.4998 sec'. The right column has a 'Signal/noise Threshold' field set to 1.5, three radio buttons for 'ECD basis' (selected), 'ICA basis', and 'SVD basis', a 'Process' button, and a 'QUIT' button.

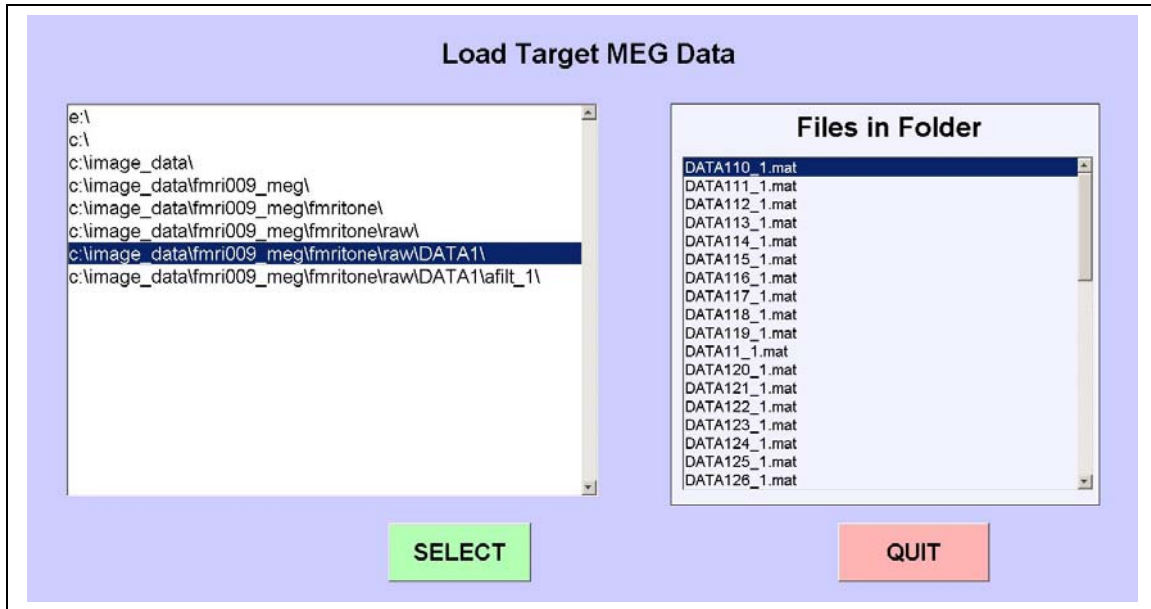
The TEMPORAL SIGNAL SELECTION PROPERTIES MENU will be generated. Edit the input fields for the start and end of the signal ON block and start and end of the signal OFF block. Choices beyond the start and end of the data will be automatically adjusted after pressing enter on the keyboard or clicking anywhere on the menu. With all 4 fields filled, the PROCESS Button will be activated. After pressing the PROCESS BUTTON, a menu for choosing the target data will be presented, (ORIGINAL 50 trials of data). With the ECD basis checked, the data component basis vectors will each be separated into a sequence of narrow band signals and those that match the signal/noise threshold criterion will be retained for display and the final manual selection of signal components. Similarly, for an ICA basis, an ICA decomposition of the data components is performed and judged against the signal/noise threshold criterion. Use of the ECD technique will generate more signal components than ICA or SVD basis selections. This allows better

resolution of the time sequence of events within the auditory cortex sources. When, this process completes the final signal selection menu appears.



Check the box or multiple boxes of components you wish to plot. Most of the components will be nearly flat or represent artifact (possibly from magnetic artifact from the sound transducers that were relatively close to the back of the head. For this subject only the first two components corresponded to signal from the auditory cortex. (NOTE: you can return to the previous menu to change the threshold or basis type by choosing the QUIT button.)

- (1) Identify all the signal components (probably 1 to 3).
- (2) Check the boxes corresponding to these components and press the USE BUTTON.
- (3) A MENU to select the target data will be presented. Choose the original sequence of MEG trial data that was imported (SEE my choice below)



Each trial of MEG data will be projected onto the final auditory signal subspace components. These data will be saved and also averaged. The results will be stored in a subdirectory of the target data. These directories are “afactor1/” and “afactor/ave_data/”.

The afactor/ave_data/dataave.mat” file contains the final whole array auditory response for use in your study. Alternatively the raw data could be averaged first then selected as the target data. However, by projecting each trial on the signal space, trial to trial variability or time dependent factors can be assessed if desired. See final auditory signal below.

