Edit 4.5

Offline Analysis of Acquired Data

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SCAN Vol. II

EDIT 4.5

Offline Analysis of Acquired Data

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1.1   Contact Information

For Technical Support...

If you have any questions or problems, please contact Technical Support through any of the following routes.

If you live outside the USA or Canada, and purchased your system through one of our international distributors, please contact the **distributor** first, especially if your system is under warranty.

In all other cases, please use **techsup@neuroscan.com**, or see the other Support options on our web site (*http://www.neuroscan.com*).

Or, if you live in the USA or Canada, please call **1-877-717-3975**. International callers should use **1-704-749-3200**.

For Sales related questions, please contact your local distributor, or contact us at **sales@neuroscan.com**.

Note
The e-mail addresses for Neuroscan Sales and Technical Support have changed. Please use sales@neuroscan.com and techsup@neuroscan.com for e-mail.

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1.2   Introduction

The EDIT Module

The EDIT program performs a variety of offline modifications to EEG data obtained by the ACQUIRE program. The following are some of the capabilities of EDIT:

- Edit for artifacts
- Ocular artifact reduction
- Advanced EKG, BCG and VEOG artifact reduction
- Baseline correction
- Digital filtering
- Sorting on responses, reaction time accuracy, and stimulus type
- Averaging in time or frequency domains
- Epoching of continuous EEG data including overlapping segments
- Global field power
- Phase spectrum
- Coherence
- Forward/backward single sweep FFTs
- Linear derivation
- Linear detrending
- Automatic peak detection
- Script and Tcl BATCH files
- Waveform rectification
- Signal-to-noise computations
- Reference computations
- Spline interpolation
- F_{sp} and Bayesian averaging
- 2D and 3D mapping and cartooning
- Ability to send waveforms to the Waveboard
- Montage Editor for creating and modifying montage and linear derivation files
- Export to and import from ASCII
- Export to and import from MATLAB
- Principle and Independent Component Analyses
- Source reconstruction using SOURCE V2

Typographical Conventions
The following conventions are used in the SCAN manuals.

Mouse Buttons
The use of "click", as in click on a specified option, refers to the left mouse button. If the right mouse button is indicated instead, *right mouse* will be in *italics* to draw attention to it. Similarly, the *mouse wheel* and *keyboard* will be in *italics*.

Options, Buttons and Displays
In general, specific reference to a named option, button or display will have the name printed in **bold** text, as when referring to, for example, **Add Derivation**. In many cases the actual button or icon tab will be displayed, as with ⓘ. File names and paths will typically be in *Italics*.
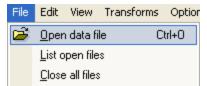
Sequence of Selections

In some instances you will be directed to perform a sequence of selections. For example, if you are directed to click the **Options** option on the **Main Menu** bar, then the **Multiple Window Settings** option, and then the **General** tab, that sequence will be indicated by **Options** → **Multiple Window Settings** → **General** tab.

Alternate Access to the Same Options
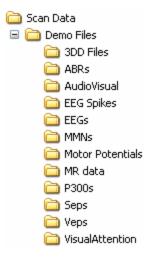
There can be up to three ways to access the same option: from the lists under options on the Main Menu bar, from the Standard Toolbar icons, and from accelerator keys on the *keyboard*. For example, the **Open data file** command can be selected from **File** → **Open data file**, from the 📂 icon on the Toolbar, or by using the *Ctrl+O* keyboard combination.

A complete list of keyboard combination strokes is found at the end of this manual. You may want to print or make a copy of that page to keep at hand for easy reference.

Demo Data Files

As part of the installation, a number of demo files were installed from the SCAN CD. Several of these files are used in the examples in this manual. They are also used in the *SCAN Tutorials*. We recommend that you become familiar with the demo files, as they are often good examples for use in experimentation with the Transforms and other options in EDIT.

1.3   Operating EDIT

The *Operating EDIT* section of the manual is laid out to be a quick reference source, as well as a complete description of the functions in EDIT. The section is organized in a top

to bottom and left to right fashion. The first part starts with the options from the Main Menu bar `File  Edit  View  Transforms  Options  Tools  Window  Help` , and goes through the options for each one. The largest section, and the main one for user reference, is the Transform section, where all of the Transforms are listed in alphabetical order. The next part explains the functions for each of the Toolbar icons [toolbar icons] … The final part explains the functions that are accessed from context menu lists seen when you click the *right mouse* button in a single window display, between electrode displays in a multiple window display, within an electrode window in a multiple window display, on maps, and so forth.
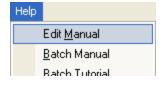
As mentioned above, you will find that some options may be accessed from up to three different ways: from the Main Menu lists, from the Toolbar icons, and from *right mouse* options. Rather than duplicate the information in each of the relevant places in the manual, there is typically one explanation, and other places refer to that section. Usually, the explanation accompanies the method of easiest access to the option. For example, mapping is described in the Toolbar section, rather than from the Main Menu list or *right mouse* option list, as the Toolbar is most easily accessed. The easiest way to find what you are looking for is to keep the organizational structure in mind, and then use the Table of Contents. Words written with a blue, bold, Arial font are hyperlinks. Click the word to go directly to that section.

If you have not worked through the *SCAN Tutorials*, you are encouraged to do so. The Tutorials will help familiarize you with much of the functioning of EDIT (and ACQUIRE).

The Transforms that are available will depend on the type of file you have retrieved. For convenience, all of the Transforms have been listed in alphabetical order, with the exception of **Group Average** and **Script**. These two options are always present at the bottom of the Transform list, regardless of the file type, and are there when no files have been retrieved.

This Help File (as are all of the SCAN 4.5 manuals) is installed on your PC. You may access it from EDIT, by clicking on the **Help → Edit Manual** option. For printing, the PDF versions are also included (in the *...\Scan4.5\Pdf* folder).

Some differences in EDIT 4.2 (and continued in later versions) - Some minor changes have been made to the transforms in EDIT 4.2 (and newer), as compared to earlier versions of EDIT (3.2, 4.0 and 4.1). In general, these modifications do not affect your data, and files recorded with earlier versions should be compatible with newer versions. We recommend, however, that you not switch acquisition or analysis packages in the middle of a study. You should 1) reanalyze your data completely within the new version, 2) continue to use your prior versions until you have completed all studies in progress, or 3) analyze at least a subset of the data files using both packages to demonstrate that there are no differences.

📄 **Note**
There has been one notable change in SCAN 4.2 (and subsequent versions), which is to

make the data point count more accurate. For example, in prior versions, if you had an AD rate of 1000, and epoch spans from -100 to 900ms, the program would show that you have 1000 data points (one per ms). In reality there are 1001 data points, when you include the starting point, the ending point, and the zero point. In 4.2, all points are counted. In the 4.2 Epoching transform, for example, let's say you have an AD rate of 250, and you wish to create epochs from 0 to 1000ms. You will find that there are now 251 points, rather than 250 points in the prior versions. If you wish to create epochs with a "power of 2" number of points, you should go by the points field (512), not the Start/Stop times.

Does this mean you cannot combine your old data files with new ones? No. Your old data files will be read in the new way. For example, retrieve the vep.avg *file in a prior version of EDIT, and it will show an epoch span from -50 to 500ms. Retrieve the same file in 4.2, and it will show -50 to 499ms. The last point is dropped automatically (there is no latency shift). When you retrieve your prior setup files in ACQUIRE 4.2, the epoch settings will be automatically adjusted to insure that old and new files will be compatible. The only way to encounter problems is if you, for example, create a new setup file where you specify -50 to 500ms, and try to compare those files with older ones. The new ones will have one additional data point, so the files cannot be compared. Should that happen, the Cut Epoch transform can be used to remove the additional point from the end of the file.*
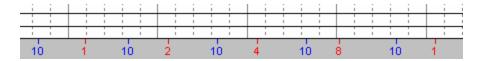
Difference in EDIT 4.3 - Beginning with SCAN 4.3, the transforms are actually executed from BATCH. That means whenever you execute a transform in point-and-click mode, the corresponding Tcl BATCH line is created automatically and displayed in the **Immediate** command line. You can then either use the same command with the next like data file, or else copy and paste the line(s) into a BATCH file you are creating (see the BATCH manual).

1.4   Stim2 Response Devices and EDIT 4.4
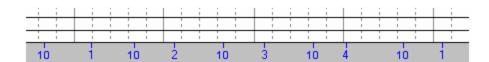
In general we recommend that you use the STIM Response Pad to make responses whenever possible. This will provide the most precise latency measurements, it will avoid confusion between overlapping stimulus and response events, and it will enable you to use all of the Response-related options in SCAN.

If you have the Stim[2] Software Only version, or if you are using the Mouse or Keyboard with the Stim[2] Complete version, there are some special considerations to keep in mind when you perform certain operations with the data files in EDIT.

If you are using the 4-button Response Pad from STIM, the responses will appear in the CNT files as red type codes of 1, 2, 4, or 8, corresponding to buttons 1, 2, 3, and 4.

If you are using the Mouse or Keyboard for the response device, the responses will appear in the CNT files as blue codes of 1 or 2 for the Mouse, and 1, 2, 3, and 4 for Keys #1-4 on the keyboard.

With the Response Pad, the response type codes are automatically distinguished from the stimulus type codes in SCAN. I.e., you can have stimulus and response type codes of 1, and SCAN can interpret them correctly.

With the Mouse and Keyboard responses, SCAN does not differentiate the stimulus and response type codes. You do this by making sure you use stimulus and response type codes that do not overlap.

Automatic Response Type Conversion. Beginning with EDIT 4.3.2, there is an automatic conversion that occurs when you *merge the .dat file with the CNT file*. If you used the mouse or keyboard for responses, these will be converted from the blue responses to red responses, as if they were made from the Response Pad.
   1. For the conversion to function properly, you must select the Stim2 .dat file format

for the behavioral data files . In Stim^2, go to **Options → Program Settings**. Select **Stim2** from the ".dat format" field. This adds an extra column at the end of the .dat file, containing Stim or Resp. Type codes on the Stim lines will be read as the regular stimulus type codes. Type codes on the Resp lines will be converted to red response type codes in the CNT file, after you merge the .dat file with the CNT file.

2. In this case, EDIT will successfully differentiate stimuli and responses, even if they have the same type codes. However, we still recommend that you not use overlapping stimulus and response type codes.

3. Once the conversion has been performed, you can then use all of the options and transforms that require STIM Response Pad responses (described next).

The EDIT software, in several places, expects responses to be coming from the STIM Response Pad.

When you **Epoch** the CNT file, there is an option on the Epoching Properties dialog screen for Response. The Epochs will be created around the Responses only. This can be use to create response-locked averages.
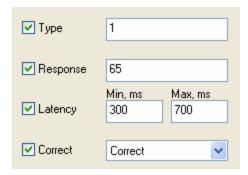
Again, this is assuming you have responses from the STIM Response Pad in the CNT file. It will **not** recognize responses from the Mouse and Keyboard. (Note: KeyBoard, on the same screen, does not refer to Keyboard responses, but rather to manually inserted events - annotations - that were created in SCAN).
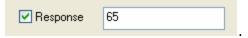
Does this mean you cannot perform response-locked averaging, or you cannot Sort by Response when you use the Mouse or Keyboard? No. You can still do both, *assuming you have merged the Stim2 format .dat file from Stim^2 with the CNT file*. From the same Epoching Properties screen, select the [Set Sort Criteria...] option. For example, you might enter the following settings:

These settings will create epochs around stimulus type codes of 1, where the response is 65, where the Latency of the response is between 300-700ms, and where the response was scored as Correct. The response type code, latency and accuracy information are coming from the .dat file, rather than from the type codes in the CNT file.

To create simple response-locked averages, you must again merge the .dat file with the CNT file, then simply enter the response type code:

.
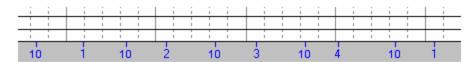
Similarly, the **Event File** transform in EDIT has a Response option. This again assumes that the responses are from the STIM Response Pad. It will not recognize responses from the Mouse or Keyboard. (Note: KeyBoard, on the same screen, does not refer to Keyboard responses, but rather to manually inserted events - annotations - that were created in SCAN). If you select the **Stimulus** Event Type, the resulting event file will contain stimuli and response type codes (undifferentiated from each other).
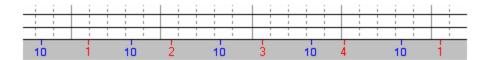
On the other hand, you must use the Response Pad if you want to use the **RespWin** transform in EDIT. RespWin will not recognize responses from the Mouse or Keyboard, so you must merge the .dat file first.

Trigger Conversion Program. There is another method you can use to convert the blue responses from the mouse or keyboard to red Response Pad type responses in the CNT file. This uses the **Stim2Resp.tcl** batch program, and does not require a .dat file.

For example, let's say you have a file similar to the one below, where 1, 2, 3, and 4 are mouse or keyboard responses (the 10's are stimuli).

To convert them all to "response pad" responses, you would need to run the batch file four times: change the stimulus 1's to response 1's, stimulus 2's to response 2's, and so on. The resulting file would then be fully compatible with the EDIT software, and would appear as follows.

📄 **Note**

The batch program can only be run in the SCAN 4.3.2 or newer versions. Older versions will not recognize the REMOVEEVENT command. The program assumes the stimulus and response codes are already differentiated by type code. In other words, it will not distinguish between stimulus and response codes having the same type code, such as 1. All 1's would be converted to response pad responses.

The *Stim2Resp.tcl* batch file is displayed below, if needed (you can copy and paste it to the Tcl Batch Editor). Retrieve the CNT file in EDIT, then run the batch file. You will be asked first for the "Stimulus code to change". (Blue type codes in SCAN are generally regarded as *stimulus* type codes. In this case, "Stimulus code" refers to the response codes that you wish to change). Enter, for example, "1" to change the responses from the left mouse button or Key #1 from the keyboard. Then enter the "Response code to substitute". This might typically be a "1" also, although you could use other numbers. You will then see the changes applied to the CNT file. Repeat the process for additional changes, if needed. Then save the modified CNT file.

```
set stim [GETINPUT "Stimulus code to change" "Stimulus code"]
set resp [GETINPUT "Response code to substitute" "Response code"]
set evcount [GETEVENTCOUNT]

for {set i 0} {$i < $evcount} {incr i} {
        set type [GETEVENTINFO $i -EventType]
        set offset [GETEVENTINFO $i -Offset]
        set code [GETEVENTINFO $i -StimulusCode]

        if {$type == "STIMULUS" && $code == $stim}    {
                REMOVEEVENT $i
                incr i -1
```

> INSERTRESPONSEEVENT $offset $resp
>   }
>   }

1.5   Starting EDIT
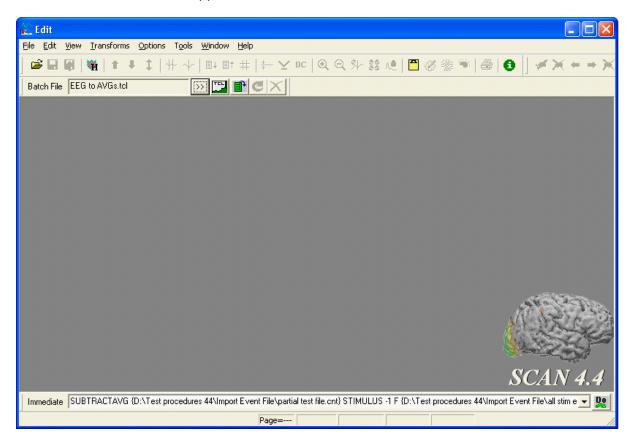
Start the EDIT program by clicking first on the SCAN 4.5 icon SCAN 4 to run the Program Launcher.

Then click the EDIT icon   . You will see a small green rectangle appear in the upper right corner on the EDIT icon on the Program Launcher. This is to let you know that a version of EDIT is open. If EDIT should close due to some illegal operation, and the green rectangle is still there, you will need to close and reopen the Program Launcher before reopening EDIT.

The EDIT main screen will appear.
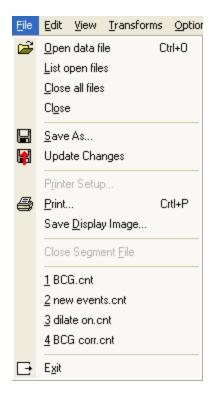
2   Main Menu bar

The Main Menu bar consists of File, Edit, View, Transforms, Options, Tools, Window, and Help.

File   Edit   View   Transforms   Options   Tools   Window   Help

2.1   File

Clicking the File button displays a drop-down menu of additional options. The availability of the options depends upon previous operations, such as, having already opened a file.

📄 **Note**
In this as well as other pull-down menus, the corresponding Toolbar icons are shown adjacent to the menu items, wherever applicable.

2.1.1   Open data file

Clicking this line displays the Select Data File window, which is a standard Open File utility. At the bottom, the **Files of type** region has a pull-down menu that displays the various types of Neuroscan files that may be opened.

```
Neuroscan Average File (*.avg)
Neuroscan Epoch File (*.eeg)
Neuroscan Coherence File (*.coh)
Neuroscan Continuous File (*.cnt)
All Neuroscan data files
ASCII File (*.dat)
European Data Format EDF (*.edf)
Nicolet BMSI (*.bni)
```

Select the type of file, then go to the appropriate folder and select the file either by double clicking it, or by clicking it once and then clicking the Open button.

There are four types of Neuroscan data files: AVG, EEG, COH and CNT. Additionally, there are ASCII files (.dat) and files from other sources.

AVG files *(.AVG* extension). AVG files are averaged files, containing a single sweep of evoked potential or FFT spectrum data. They can be created online in ACQUIRE (when acquiring data in Average mode, or with Sorted averages enabled), or they can be created offline in EDIT when averaging an EEG file. They can result from averaging an EEG file in a single subject, or they can be the group average of AVG files from multiple subjects.

EEG files *(.EEG extension)*. EEG files contain data from multiple sweeps. The sweeps are either the raw EEG sweeps (as with evoked potential recordings), or single sweeps of FFT spectra data (after performing a Forward FFT). EEG files can be created online in ACQUIRE (when acquiring data in Epoched mode), or offline in EDIT when epoching a continuous file.

COH files *(.COH extension)*. COH, or coherence files, result from performing coherence analyses with epoched data files in EDIT (.EEG files). These are single-sweep files, like AVG files.

CNT files *(.CNT extension)*. CNT, or continuous, files are created in ACQUIRE when acquiring data in continuous mode. They appear on replay as a scrolling, continuous recording of the entire session, and include all the stimulus, response and keyboard triggers.

 Note
Behavioral data from Stim (the .dat files) may be merged only with continuous files.

All Neuroscan Files. This option will display all of the Neuroscan files in the folder.

ASCII Files *(*.dat)*. This option will display all of the .dat files in the folder. These will generally be the ASCII files you have created in EDIT (see the ASCII file section below), but the list will also include the .dat files from STIM, and any other .dat files. Only the ASCII data files can be opened by EDIT.

European Data Format EDF *(*.edf)*. European Data Format continuous files may be imported directly into EDIT.

Nicolet BMSI *(*.bni)*. Nicolet BMSI files can be opened directly in EDIT (.bni extension).
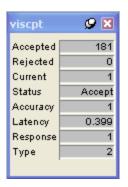
Status boxes. When you retrieve AVG, EEG, or CNT files, you will see a Status box appear. These contain specific file-related information, as follows.

With AVG files - When you retrieve an AVG file, a status box similar to the following one will appear.

The **Accepted** field shows the number of sweeps that were accepted into the average file. The **Rejected** field shows how many sweeps were rejected, or excluded from the average. The **Type** field will be "0" for AVG files. The **% Complete** field (where present) displays the percentage of the file that was acquired, as set by the number of sweeps under Epochs (in Average acquisition mode).

The thumb-tack, or "sticky pin", in the upper right area is used to "stick" the status box to the relevant data display. Click the pin to "push" it, and the status box will remain with that file display.

With EEG files - When you retrieve an EEG file, a status file similar to the one shown will appear.

The **Accepted** field indicates how many of the sweeps in the EEG file are tagged as Accepted sweeps. The **Rejected** field shows how many of the sweeps are tagged as Rejected. These numbers will change as you step through the file and reject bad sweeps. The total of the two will add up to the total number of sweeps in the EEG file. The **Current** field displays the current sweep number. The **Status** field displays whether the current sweep is Accepted or Rejected. The **Accuracy**, **Latency** and **Response** fields will be empty if you have not Merged the Behavioral Data (.dat file) with the continuous data file. **Accuracy** displays a code indicating whether the subject's response was correct (1), incorrect (2), missing (-1), or not expected (0). The **Response** field displays the subject's response, that is, which button was pressed on the STIM response pad. (Again, this assumes you have Merged the Task Data). The **Type** field displays the stimulus trigger type code sent from STIM. The **% Complete** field (where displayed) shows the percentage of sweeps that were acquired, as set in the number of sweeps field under Epochs

(in Epoched acquisition mode).
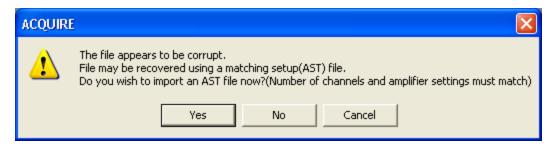
With CNT files - When you retrieve a CNT file, the status box will be similar to the one shown. The **Recording Time** field will start at 00:00:00, and increment in seconds as you replay the file. It displays how far (in seconds) the beginning of the current display is into the entire file. The **Event Count** is the sum of all the events prior to and including those in the current section being displayed. **Event Number**, **Event Time** and **Event Class** are displayed when you position the mouse over one of the events at the bottom of the single window display. The blue numbers are stimulus events, the red numbers are response events, and green characters are keyboard events. The status box will display the number of the event, the current time point in the CNT file, and which type of an event it is.

Opening Corrupted Data Files
From time to time, and for a variety of reasons, acquisition of the data file may be terminated abnormally. In that case, Edit will attempt to salvage as much of the data file as possible. Prior to 4.5, the event table was written at the end of acquisition, so if acquisition ends abnormally, the event table cannot be added to the file. From 4.5 on, the events are written as they are encountered.

When you attempt to open the file in Edit, you will see the following message.

If you have the setup file (.ast), click Yes and supply the file when prompted. If not, Edit will attempt to recover the file anyway. You may see the following second message.

Acquire writes a temporary event file that will have a "_1.ev2" extension (e.g., myfile_1.ev2). That file will be placed in the same folder as the original data file. If you select "Yes" to the above question, you will see the Import Event File dialog, where you can import that file.
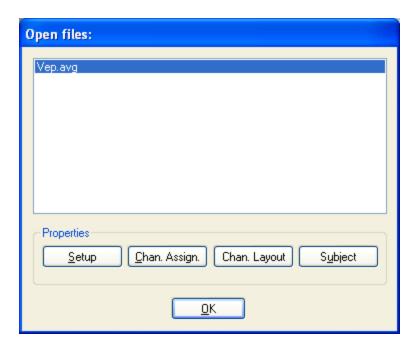
Selecting or not selecting the **Replace the existing event table** option makes no difference, since the event file does not exist. Do not select the "Offsets are in seconds" option. Then select the "_1.ev2" file. This is a temporary file that will be deleted automatically when acquisition terminates normally.

After importing the events, be sure to resave the .cnt file (or **Update** it) to make the change permanent.

2.1.2   List open files

If you have one or more files open, the *List open files* option can be used to display information about the file contents. Clicking the option opens the displayed screen.

The top region displays the list of open files. Highlight one of them, and the Properties information will be available for that file.

> **Properties**. Under Properties there are four buttons: **Setup**, **Chan. Assign.**, **Chan. Layout** and **Subject**. These same options may be accessed from the Edit option on the Main Menu bar, and also by clicking the *right mouse* button in the data window. They are discussed in the Edit section below.

2.1.3 Close all files

Clicking this option will close all open data files in EDIT.

2.1.4 Close

Clicking this option will close only the file that has the focus.

2.1.5 Save As

If you wish to save a file that you have modified, or if you wish to save the file in ASCII format, select the Save As... line. You will see the standard Save As utility display. Select a folder and enter a file name for the new file. If you want to overwrite an existing file, you will see a confirmation display.

If you click the pull-down arrow on the Save as Type line, you will see options similar to the following.

The type of file will depend on which type of Neuroscan file you are saving (e.g., AVG, EEG, CNT, etc.). Enter a new file name, specify a path, and click the Save button to save the file. For many of the Neuroscan files, you have the option to save, or export, the file in ASCII format. Please refer to the ASCII section below for more details. With

CNT files, you have the option to save the file in European Data Format (*.rec extension). See the EDF Export section below. With AVG files, you can save the file in BESA format (*.avr).

2.1.6   Update Changes

The Update Changes option can be used in cases where you have modified a data file, and wish to save it using the same file name. In some circumstances, that could not be done in prior versions of SCAN because the file was already open (in both point and click and BATCH modes). The Update Changes button will preserve the modifications with the open data file when you close it. When you wish to update the open file, click the icon and you will be asked to verify that you want to overwrite the existing file.

2.1.7   Printer Setup

This opens the standard Print Setup display used in Windows for selecting the printer and printing options.

2.1.8   Print

The Print option opens a standard Print display. Note that there is an Output Properties area that has a "Stretch output to fit page" fields. This will stretch the output to fit the printed page.

2.1.9   Save Display Image

This option permits you to save the display as a Windows Metafile, which may then be viewed or attached to a variety of Windows applications.

2.1.10   Close Segment File

The Close Segment File option is related to saving blocks of a CNT file (see the **Mark Block**, **Save Block** options below). When you save a "segment" of a CNT file, you will create a new CNT file that will be comprised of the saved segments of the original CNT file. This new segment file will remain open until you select **Close Segment File**, or until you close the original CNT file. If you do not Close the Segment File (or close the original CNT file), subsequent saved blocks will be written to the first saved CNT file. To view the new CNT file you have created, you must first use the Close Segment File option, or close the original CNT file, then retrieve the new file. The Close Segment File option let's you close the "segment" file without closing the original CNT file.

2.1.11   Recently opened files

The four most recently opened files are listed. Click one of them to open the file directly.

2.1.12   Exit

Exits the EDIT program. If you have modified a data file and not saved it, you will be asked whether or not to save the modified version.

2.1.13 ASCII File Exporting and Importing

Most of the files created in SCAN can be exported to or imported from ASCII. ASCII files are very useful for reading your data into other signal processing or statistical analysis software. Files created by other acquisition systems, after conversion to ASCII with a compatible structure, may be read into EDIT for analysis. It is also possible to export CNT files using the European Data Format (EDF).

The Import/Export options are accessed from the pull-down menu for the **Files of type** line (in Open File displays), and the **Save as type** line on Output File displays. It is not possible to save every file type to ASCII. Basically, if you have a file displayed and you wish to save it in ASCII format, look to see if the option for the ASCII File (.dat) is present. If it is, you may export the file to ASCII.

To export a file to ASCII, make sure that file has the "focus", then select the **Save As** option under **File**. Click the pull-down menu on the **Save as type** line, and select ASCII File (.dat) or European Data Format EDF (.rec). Enter a file name, specify a path, and click Save. With ASCII files, you will see the following display.

Method. The first choice allows you specify the format for the data in the ASCII file.

> **Rows = Points**. Selecting the **Rows = Points** option will result in an ASCII file where the electrodes are displayed on a line across the screen, with the data points for each electrode displayed in a column beneath the electrode label. An example is shown below.

```
[Electrode Labels]
[      FP1]  [      FP2]  [      F3]  [      F4]  [      C3]
[Average Data]
      -0.1249      -0.2709      -0.2762      -0.6129      -0.7910
      -0.0735      -0.2485      -0.2903      -0.5896      -0.7998
      +0.0922      -0.0547      -0.1602      -0.4015      -0.6460
      +0.2930      +0.1962      +0.0446      -0.1211      -0.4030
      +0.3915      +0.3509      +0.1834      +0.0823      -0.2329
      +0.3611      +0.3562      +0.1733      +0.1311      -0.2149
      +0.2983      +0.3228      +0.1035      +0.1460      -0.2430
      +0.2570      +0.3012      +0.0560      +0.1856      -0.2474
```

> **Rows = Electrodes**. If you select the **Rows = Electrodes** option, the data in the ASCII file will be arranged where the electrodes go down the y-axis, and the data points extend along the rows for each electrode.

Whether or not an option is available depends on the type of file it is, as well as other factors described below.

> **Header**. Selecting the **Header** option will include the subject, date, and acquisition parameters in the beginning of the ASCII file. If you plan to retrieve the file in EDIT, you should save it with the Header.

```
[Subject]     Subject Name
[Date]        12/31/99
[Time]        11/59/59
[Channels]    28
[Rate]        1000
[Type]        Average
[Points]      550
[Xmin]        -0.050000
[Sweeps]      200
[Accepted]    200
[Rejected]    2
[Domain]      Time
[Rows]        Points
```

> **Electrode labels**. Select this option to include a list of the electrode labels.

```
[Electrode Labels]
[      FP1]  [      FP2]  [      F3]  [      F4]  [      C3]
```

> **X Units / Y Units**. Enabling the **X Units** or **Y Units** fields will save with the ASCII .dat file any X or Y Unit labels that you have entered (from the **Overall Parameters →** **Channel Attributes** screen). If you used the "Default" unit labels, the word Default will appear in the .dat file for each channel. When you import the .dat file, the Unit

labels you had entered will be preserved. If you used the default unit labels, the program will use its default labels (typically μVs and ms's).

If you disable the X Units or Y Units fields, no unit labels will be stored with the .dat file. When you import the .dat file, the program will use its default unit labels.

Standard Deviation (SD). If you are exporting an AVG file where you computed the Standard Deviation when the file was averaged, you may export the SD values by selecting this option. The SD values will be displayed in a data matrix following the voltage values matrix in the ASCII file.

```
[Standard Deviation Data]
    +3.0802      +1.6276      +1.8747      +1.9816      +1.5593
    +2.9147      +1.5185      +1.6441      +1.9558      +1.8472
    +3.0018      +1.5120      +1.5298      +1.9092      +2.0502
    +3.2260      +1.6399      +1.5722      +1.8563      +2.1044
    +3.3716      +1.7804      +1.6742      +1.8931      +2.0430
    +3.5455      +1.8826      +1.6506      +1.9279      +1.9362
    +3.6540      +1.8762      +1.5916      +1.9474      +1.8311
    +3.6785      +1.9335      +1.6100      +1.9954      +1.6726
    +3.6584      +2.0634      +1.7493      +1.9828      +1.4431
    +3.4608      +2.0549      +1.8922      +1.8479      +1.2046
    +3.0559      +1.8431      +1.8811      +1.4990      +0.9449
```

Bad Channels. If you have designated certain channels to be "Bad" channels, you may elect not to export these channels by not enabling the **Bad Channels** option (enable it if you want to export the Bad channels).

Skipped Channels. If you have designated certain channels to be "Skip" channels, you may elect not to export these channels by not enabling the **Skipped Channels** option (enable it if you want to export the Skipped channels).

Epoch Headers. If you are exporting an EEG file (single sweeps file) to ASCII, you may elect to include additional header information at the beginning of each sweep by enabling the **Epoch Headers** option. The header information will appear in the ASCII file as follows:

```
[Epoch Header]
[Trial Type]        1
[Accept]            1
[Correct]           0
[RT]                0.000
[Resp]              0
[Epoch Data]
    +2.0142      -4.1962      -7.3853     +11.9171     +18.7989
    +3.5248      -1.1749      -6.7139      +6.7139     +12.4207
    +4.1962      +1.5106      -2.6856      +3.3569      +6.0425
    +4.6997      +3.5248      +0.6714      +0.6714      +0.0000
    +3.5248      +3.0212      +2.5177      -1.3428      -5.0354
    +3.5248      +2.5177      +3.8605      -1.0071      -6.2103
    +3.8605      +2.8534      +6.0425      +1.6785      -4.0283
```

The next three options are new to the 4.3 version of EDIT (per user requests):

Data labels. **Data Labels** are the `[Average Data]` and `[Standard Deviation Data]` lines (if SDs are present). Enable this option if you want to include the Data Labels in the ASCII export. Data Labels are often required when importing .dat files. See the Tips section below.

Use Maximum Resolution. Enable this option to export the data points with maximum resolution (up to eight places after the decimal point). Not enabling the option will export values with four places after the decimal point.
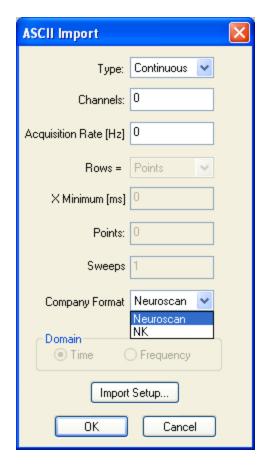
Use comma delimiting. Enabling this option will place a comma between numbers: `-2.28516, 1.75781`, which is especially important when exporting to Excel. *Note: comma delimited files cannot be imported back into EDIT.*

Append if file exists. This option allows you to export data points to an existing file. If enabled, the exported data will be appended at the end of an existing .dat file (when using the same output file name). If not enabled, the existing .dat file will be overwritten.

Channels. The **Channels** option lets you select which channels you want to export. Select the **All** option to export all channels. Click the **Specified** field, then the

`Select...` button to export selected channels. You will see the montage display in which you can select the channels you wish to export (selected will be green, deselected channels will be red).

Importing an ASCII file. To Import an ASCII file, click the Open File icon , set the **Files of type** to ASCII Files (.dat), and select the .dat you wish to import. Note that all types of .dat files will be displayed - not just the data files. Click OK and the data file will appear. If the header information in the .dat file is missing or incomplete, which may be the case if you are importing a file from some source other than SCAN, you will see the display below.

The information in these fields contains everything that SCAN needs to import and display the ASCII data file. If there are missing parts in the data header, you will see the ASCII Import display. Fill in the missing information and click OK.

In some cases, you may see an error message such as the one displayed. This is an indication that some values are missing from the header or are otherwise incorrect. See the header information above and compare it to your .dat file to see what parameters are missing or incorrect.

Type refers to the Type of file this is (AVG, EEG, CNT). The number of channels, AD rate, X-minimum (sweep starting point, in ms), number of points, number of sweeps, and Domain should all agree with the ASCII data file. The "Rows = " field refers to the format of the ASCII data file. If the data are contained in a matrix where the channels go across the display, and the data points go down the display, that is Rows = Points. If the matrix is inverted from that, where the channels go down the display, and the data points go across the display, that is Rows = Electrodes (see the ASCII File Exporting section above

for examples). If you are importing a continuous type of .dat file, you have the option of specifying a Neuroscan file format, or an NK format. NK files are ASCII format Nihon Koden continuous files.

If you have an ACQUIRE setup file that matches the data file, click the **Import Setup** button, and retrieve the .ast file. The information from the setup file is transferred to the ASCII Import display (although you may need to change the File Type manually so it agrees with the ASCII file). You can change the values on the screen, and these will supercede the values that are contained in the setup file. For example, you can modify an AVG file that you are importing by selecting a different Starting point. The number of Points you enter will then determine the ending point, or epoch length. If you are importing files routinely, you should create a setup file that contains the information needed for the .dat file. When you import the .dat file after specifying the .ast file, the header information will be added automatically.

📄 **Note**

When you import FFT files from ASCII, the number of points is half of that with time domain files (this must be entered manually even if you are using a setup file). Be sure the Frequency Domain option has been selected.

Some Tips for Exporting and Importing Files

The most commonly encountered difficulty with importing files from ASCII has to do with the presence or absence of the Data Labels in the .dat file. **Data Labels** include the `[Average Data]` and `[Standard Deviation Data]` lines (if SDs are present). Whether you need the Data Labels depends on the type of file (AVG, EEG or CNT), the Batch command used when the file was exported (and therefore the version of software that you have), and whether or not the Header is present in the .dat file.

Exporting .dat Files Without a Header

If you **Export** the file *without the Header*, then **Data Labels** MUST be enabled in the instances shown below in order to read the file back into EDIT.

	AVG	EEG	CNT
EXPORT*	not needed	not needed	not needed
EXPORT*_EX	not needed	needed	needed
EXPORT*EX2	not needed	needed	needed

If EXPORTAVG, EXPORTEEG, OR EXPORTCNT was used, and the Header was not included, then Data Labels are not needed, nor are they needed for AVG files regardless of the command used to export the file.

If EXPORTEEG_EX, EXPORTEEG_EX2, EXPORTCNT_EX, or EXPORTCNT_EX2 was used, and no Header was included, then Data Labels are needed.

Exporting .dat Files With a Header
If you **Export** the file *with the Header*, then **Data Labels** MUST be enabled in the instances as shown below in order to read the file back into EDIT.

	AVG	EEG	CNT
EXPORT*	not needed	not needed	not needed
EXPORT*_EX	needed	needed	needed
EXPORT*EX2	needed	needed	needed

For example, if EXPORTAVG, EXPORTEEG, or EXPORTCNT were used, and the Header was included, then Data Labels are not needed. In all other cases, Data Labels are needed.

Importing .dat Files With or Without a Header
Similarly, if you want to **Import** an ASCII file *from some other source*, then **Data Labels** may or may not be needed, depending upon the file type and whether there is a **Header** or not.

	AVG	EEG	CNT
Without Header	not needed	needed	needed
With Header	needed	needed	needed
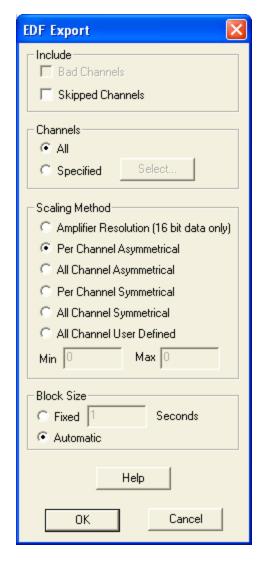
Data Labels are needed in all cases except where there are AVG type .dat files without Headers.

The differences described above are due to:

1. The EXPORTAVG, EXPORTEEG, and EXPORTCNT commands include Data Labels in the Header automatically; whereas, the other commands have it as an option.

2. If a Header is detected during the import of any .dat file, EDIT will attempt to open the file automatically, bypassing the ASCII Import dialog.

2.1.14 Exporting Files in EDF

While SCAN has had the option to export data files in EDF format, the relatively recent acquisition change to 32 bits has presented a problem, since EDF files are only 16 bits. Now when you save a file in EDF format, the Export EDF dialog appears.
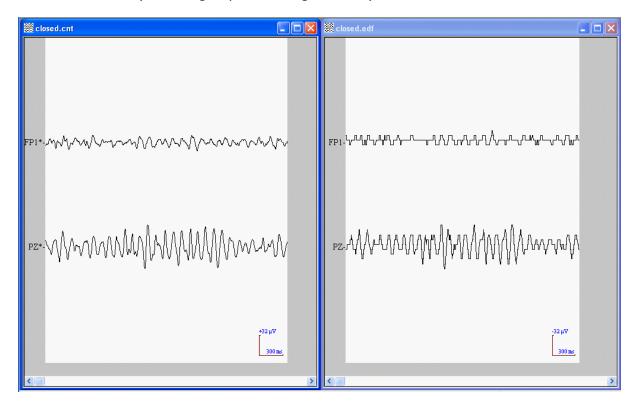
The EDF Export dialog provides options for scaling the output data. As with all digital representations of analog signals, there is a tradeoff between amplitude resolution and dynamic range (the largest or smallest number that can be represented). The goal is usually to choose parameters that represent the full dynamic range of the signal so that no "clipping" occurs at the extremes.

Consider the following example:

A signal is expected to range from +50 to -50μV. Say we have 8 bits to represent this data. Since 8 bits can store only values between 0 and 255, we have 256 discrete amplitudes that we can store digitally. Our dynamic range in this case is 100μV full scale. Therefore we would probably choose our resolution to be 100/256 ˜ .39μV.
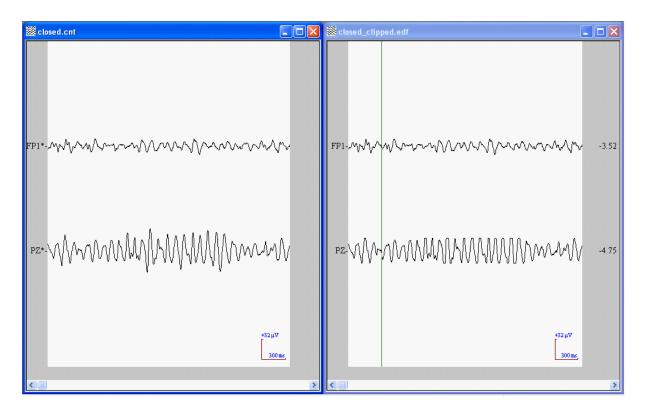
A problem arises when we also want to represent small signals. In this case we cannot represent signals that oscillate in the .4μV range or smaller. If we opt to use 16 bits instead of 8, our resolution improves dramatically. Since 16 bits can hold values between 0 and 65536 we get 100/65536 ~ .0015μV.

The following example illustrates what happens to the data when the resolution that is chosen is too low (i.e. a large dynamic range is used):

The data on the right has a "stair step" appearance. This is because digital data is by definition, discrete. If the resolution is too coarse, the data will not look smooth. In extreme cases, the data may appear completely flat.

The next example shows data for which too low of a range was chosen (resolution too high):

In this case, the higher amplitude peaks of the data are "clipped", while the lower amplitude information is well represented.

Most amplifiers in existence use 16 bits of digital resolution and this is adequate for most situations. Filters on the front-end of AC amplifiers help restrict the values that are seen at the amplifier inputs. *SynAmps*, *SynAmps^2*, *SynAmps RT*, and *NuAmps* are capable of both AC and DC recordings. DC recordings, however, present issues. Since the signal is allowed to drift away from the zero baseline, the values can become very large. The original *SynAmps* used a DC correction that would re-center when it came too close to the limit of the dynamic range. *SynAmps^2, SynAmps RT,* and *NuAmps*, however, employ 24 bits of data, allowing the data to exist in a huge range of values, thus eliminating the need for DC correction. The data files that are created use 32 bits of storage on the disk.

Unfortunately, the EDF specification assumes that 16 bits of resolution is sufficient for all recording of neurophysiologic potentials. There is no provision for larger bit counts, and so a 32-to-16 bit conversion is required. We must be careful in how we use these bits in order to maintain a careful balance between resolution and range when compressing 32 bit data into 16 bits. The EDF Export in SCAN provides several scaling options to handle a variety of data types. You also have the option to export Bad and Skipped channels, as well as selected EEG channels.

The most accurate way to choose the dynamic range is to use the ***actual*** range of the data. Since SCAN only allows export of already recorded data (offline), we can scan the data and determine the minimum and maximum deflection of the data, and then use one of the following methods.

   Amplifier Resolution (16 bit data only). This is *only* for 16 bit data. The data are

not scanned. Rather, the recording resolution of the amplifier is used.

Per Channel Asymmetrical. This is the most accurate method. Each channel is scanned independently and the actual minimum and maximum values are determined and recorded.

	Min	Max	Scale
FZ	-15	20	-15 to 20µV
CZ	-30	25	-30 to 25µV
OZ	-35	40	-35 to 40µV

All Channel Asymmetrical. This method scans *all* channels and determines the maximum and minimum value achieved by any channel. All channels are assigned the same maximum and minimum values. This should be considered if all channels are similar. It is convenient for many readers to have data that is all scaled the same.

	Min	Max	Single Scale
FZ	-15	20	
CZ	-30	25	-15 to 40µV
OZ	-35	40	

Per Channel Symmetrical. This method scans each channel as in the Per Channel Asymmetrical method. The absolute value of the maximum and minimum are compared. The higher value and its negative counterpart are used. For example if the data ranges between -50 and +62µV, the minimum and maximum assigned would be -62 to 62µV. This is useful for readers that employ the min/max of the data when deciding how to display it. In this case, the range would be symmetric about the Y axis. This could be very wasteful for data that has a high DC offset. Say the actual range of the data is -1000 to -800µV. Then the range would be -1000 to 1000µV. In this case, 90% of the range goes unused.

	Min	Max	Scale
FZ	-15	20	-20 to 20µV
CZ	-30	25	-30 to 30µV
OZ	-35	40	-40 to 40µV

All Channel Symmetrical. This is the same as the Per Channel Symmetrical method except that the values are chosen from all channels. This should only be used if there are no high DC components and all channels are similar in their range.

	Min	Max	Single Scale
FZ	-15	20	
CZ	-30	25	-40 to 40µV
OZ	-35	40	

All Channel User Defined. This allows the user to choose a range.

Which method should you use? The **Per Channel Asymmetrical** method is most accurate, and it is selected by default. Ultimately, however, it depends on the EDF reader you are using, and the extremes of the voltage range in your data files. Select the method you think is best, and then verify that no distortion is seen in the EDF reader.

Choosing a block size method

In EDF format, the data are broken into small pieces called *records* within the data file. The EDF specification recommends that these records be no larger than 61440 bytes. In order to meet this specification, often the duration of a block has to be shortened to less than 1 second. The duration of the block is computed automatically when the **Automatic** option is chosen. Some readers do not respond well to records that are smaller than 1 second, so there is an override for this. When checked, the **Fixed** option allows the user to specify the block duration. The value is in seconds, so a value of .1 is 100ms.

2.2   Edit

The Edit option accesses a pull-down menu with the displayed list of options.
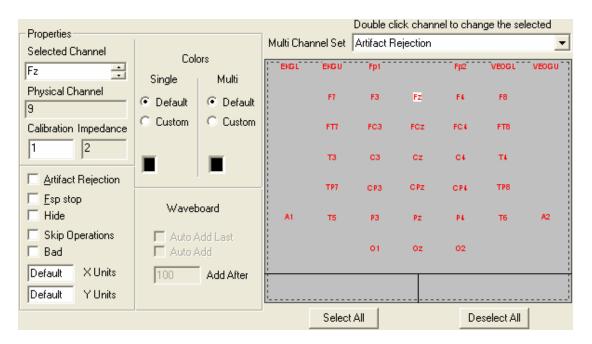
2.2.1   Overall Parameters

This option accesses some of the same parameter dialog screen seen in ACQUIRE.

Amplifiers. The Amplifiers screen will display acquisition parameters as they were when the file was recorded (the information cannot be modified). If you used different Gain or Filter settings across channels, you can double click on the electrode labels in the montage display to see what the individual channel settings were.

Channel Attributes. The Channel Attributes window is used to set a variety of parameters for individual or all channels. The montage display part of the screen is used to select or deselect the electrode channels that you want to modify, and the other fields are used to select attributes to be applied to the selected channels.

Selecting Channels. Channels may be selected through several methods. Click the electrode label once to select an individual channel. The background area behind it will turn white (), and the electrode will appear in the

 field. You can change the "selected" or "deselected" status of an individual channel by double clicking the electrode label. This is useful when you want to select multiple electrodes for the same modification. When selected, the electrode label will be green; when deselected, the label will be red. Use the button to select all the channels, and the button to deselect all channels. Double clicking an electrode label also applies to that channel the modification that is displayed in the **Multi Channel Set** field. The operations may be understood more easily with a couple of examples.

Selecting a single channel for a particular attribute. Click the pull-down arrow at the end of the **Multi Channel Set** field to see the list of attributes that may be assigned. Select the desired attribute (e.g., Bad). Unless previously modified, all channels will be deselected (red). Double click a channel to select it and assign the attribute (the corresponding field will be Enabled in the Properties section).

Selecting multiple channels for a particular attribute. Select the **Multi Channel Set** attribute to be applied (such as, **Auto Add**). Then click the button. The corresponding field will be Enabled in the Waveboard section. Double click any electrode labels to deselect them, if you do not want the attribute applied to those channels.

Additional Features. Additional modifications can be made from this window.

Properties. The Properties area displays many of the attributes that may be modified for each channel. Most of these options can be also accessed by

positioning the mouse over a desired electrode label and clicking the *right mouse* button (CNT files), or by positioning the mouse within an electrode display, clicking the *right mouse* button, and selecting **Channel Properties** (multiple window displays).

Selected Channel. As demonstrated above, the Selected Channel field will reflect the channel that has been selected when a channel label has been clicked. An individual channel is "selected" when it appears in the Selected Channel window. You can also **Rename** the electrode label by overtyping the electrode label in the Selected Channel.

Physical Channel. The Physical Channel field displays the number of the actual amplifier channel that is carrying the signal that is displayed in the Selected Channel field.

Calibration. The Calibration will display the Selected Channel's calibration value. The default calibration value for all channels is 1. After you perform a Calibration, and save the calibration values with the setup file, these values will be seen in the Calibration field.

Impedance. The Impedance field displays the Ohm measurements that were present at the time you left the Impedance routine in ACQUIRE. These are saved with the data file, and may be reviewed in EDIT.

Artifact Rejection. Enabling Artifact Rejection allows you to designate one or more channels that will be scanned for artifact in the automatic artifact rejection of sweeps. Typically, electrodes that monitor eye movement as well as those that pick up other sources of artifact are selected with this option. When viewed in acquisition or in offline editing, the Artifact Rejection channel labels will contain an asterisk (*) after the label.

Fsp Stop. You may designate which channel(s) you wish to have monitored for termination criteria during the F_{sp} Averaging process. If, in ACQUIRE, you selected *All* under the F_{sp} section in the Overall Parameters, then you need not specify the channels again here. If you selected *Select* instead, then you will need to select the channels individually, if you have not already done so.

Hide. This option allows you to *Hide* electrodes on the screen display. Select the channels to be hidden as described above. The data for hidden channels will be recorded even though the waveforms will not appear on the screen.

Skip Operations. This option allows you to set certain electrodes to be skipped in the data analysis process. For example, a setup file could include channels that are used to initiate sweeps or monitor artifact. Skip channels, in contrast to Bad channels, are generally known in advance, and are designated in the setup file prior to acquisition. These channels would not normally be included in other stages of processing, such as for autoscaling and in common average re-referencing, and may be *skipped* using this feature. Select the channels to be Skipped, as described above. When viewed in acquisition or in offline editing, the Skipped channel labels will be in black type, regardless of the color you had selected for Text (under

Options).

Bad. This option allows you to select certain electrodes to be excluded from certain statistical operations, such as averaging, standard deviation computation, mapping, or artifact removal (check mark will appear when toggled on). Select the Bad channels, as described above. Bad channels, in contrast to Skip channels, are encountered during acquisition, resulting from bad electrodes or abnormally high artifact. When viewed in acquisition or in offline editing, the Bad channel labels will be in red type, regardless of the color you had selected for Text (under Options).

📄 **Note**
As a general rule, Bad and Skipped channels will not be included in operations that involve the combination of multiple channels. These include, for example, Autoscaling, Spatial SVD, Common Average Reference and Global Field Power, Mapping, Ocular Artifact Reduction, etc., and the channels marked as Bad or Skip will be excluded from these operations. On the other hand, channel-by-channel operations (such as filtering) are performed on Bad and Skipped channels, as well. That is, if the operation performed on the Bad channel does not affect the same operation performed on other channels (i.e., the Bad is independent from the other channels), then the operation will ignore the Bad or Skip settings.
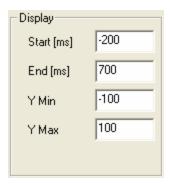
X Units. This option allows you to enter a label for values along the x-axis. You may set the label independently for each channel - the channel that is displayed in the Selected Channel field is the one that you are setting. The *Default* label is "ms". If you change this, and wish to return to the default label later, you must enter the word "Default" (with a capital D).

Y Units. This option allows you to enter a label for values along the y-axis. You may set the label independently for each channel - the channel that is displayed in the Selected Channel field is the one that you are setting. The *Default* label is "μV". If you change this, and wish to return to the default label later, you must enter the word "Default" (with a capital D).

Colors. Use the pull-down bar to see the additional Colors options. These fields allow you to set the waveform colors independently for each channel. Further, you can set the new colors to appear only in a single window display or only in a multiple window display (or both). The Default setting is the color you specified under **Options** → **Multiple Window Settings** → **General** → **Waveform** button. Change "Default" to "Custom", and then click the color bars to access the standard Colors palette. Select a color for the specified channels. Select the channels to be modified in the same way as described above.

Waveboard. The Waveboard fields are used in ACQUIRE to send groups of waveforms to the Waveboard during acquisition. It has no function offline in EDIT.

Epochs. The Epochs settings are entered in ACQUIRE prior to acquisition, and, for the most part, cannot be modified in EDIT. The exceptions are the Display fields.
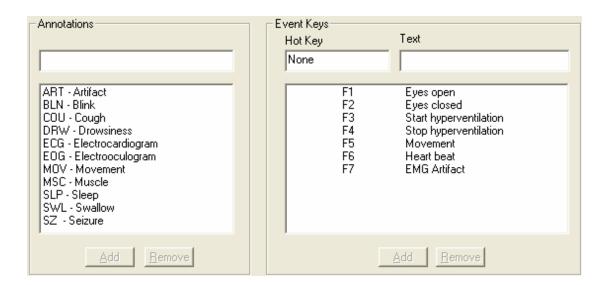
You may enter different Start and Stop times, as long as they are within the original Start and Stop times. The displayed waveforms will change accordingly. You can also set the Y Min and Y Max scale settings, and thereby scale the display manually.

Frequency. If you have retrieved a frequency domain AVG file, or a COH file, you will also see the Frequency tab appear on the Overall Parameters display. This will allow you to choose between a histogram or line display, as well as vary the Start and Stop times and Y Min and Y Max settings for the data file being displayed.
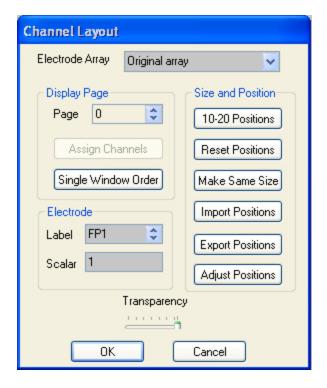
The Stop value is especially useful when you do not wish to display the entire frequency range that was computed.

Events. If you retrieved a CNT file, you will see that the Events tab is included in the Overall Parameters display. This allows you to modify the contents of the events that you may wish to add to the file. Please refer to the Place a Mark section below (and the ACQUIRE manual) for more information.

2.2.2   Channel Layout
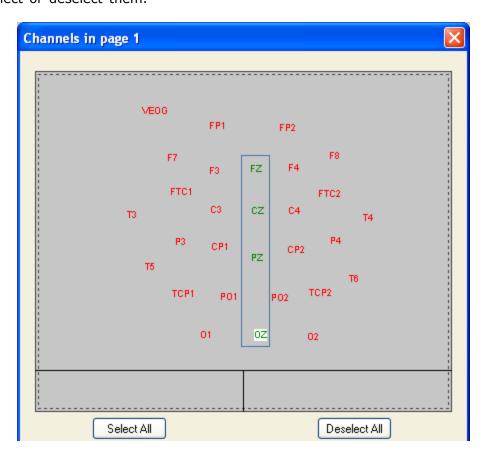
Clicking this button opens the same Channel Layout display used in ACQUIRE to position the individual channels displays, assign electrodes to display pages, import and export electrode position information, and so forth.

You may modify these same options in the saved data file, in the same way as you did when the setup file was created (refer to the ACQUIRE manual). A couple of the more frequently used options are described below. Save the changes using the **Save As** command under Files, if desired.

Creating Display Pages. The Display Page feature allows you to assign electrode

channels to additional screen display pages. To do this, click the up arrow button at the end of the Page field. The field will display a 1 and the [Assign Channels] button will become active. The screen behind the *Channel Layout* screen will be empty. Click the **Assign Channels** button, and see the channels in the Page 1 display. Double click on the individual electrode labels (so they turn green), to add them to the first additional display page, and/or use the [Select All] and [Deselect All] buttons. You may also drag a rectangle around a group of electrodes to select or deselect them.
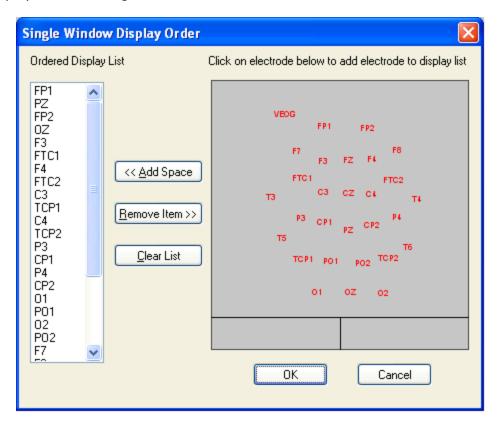
Click **OK** when you are through, and you will see the selected electrode displays. Size and position them as desired. Through this process you can assign electrodes to any display page you wish. You may assign the same channel to more than one display page (for example, you might want the artifact channel to appear on each display page). Use the down arrow button to get back to the original display page. Click **OK** when you are through, and be sure to resave your setup file if you wish to retain the changes you have made.

📄 **Note**
*If you apply the **Add Derivation** option, the additional display pages will be disabled.*

Single Window Order. This option allows you to reorder the sequence of channels on the CNT file display. (The same feature may be selected from the [Channel Order]

option that appears when you click the *right mouse* button on a CNT file). Clicking it displays the following screen.

The current order of channels is in the left side column. To remove a channel from the list, just highlight it and click the [Remove Item >>] button. *Note: this removes the channel from the list, not from the display. There will always be the same number of channels displayed; this option will only alter the order.* To reorder the display completely, click the [Clear List] button. Then click the channel labels in the montage display in the order that you want them to appear. As you rebuild the list, you might want to separate the channels with spaces. Click the [<< Add Space] button to insert a space between the channels when they are displayed (for grouping purposes). If you omit some channels, they will be added at the bottom of the single window display. Click **OK** when you are through to see the new ordering. To save the CNT file with the new order, click **Save As** under File. You will then have the option of either overwriting the existing file, or creating a new one.

Electrode. Notice first in the background screen, with all of the labeled electrode boxes, that you can *select* one by clicking on the darker bar at the top of the box (turns box a highlighted color). The label in the **Label** field will show the highlighted electrode.
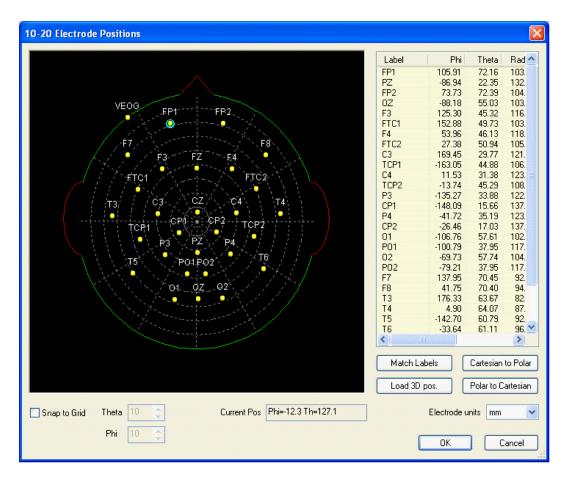
You can Rename the electrode by overtyping the label. You can select an electrode display either by clicking on the display itself (on the label bar at the top of the display), or by using the up and down arrow buttons at the end of the label field.

The *Scalar* feature allows you to alter the display scaling factor for individual channels - the channel that is displayed in the **Label** field is the one that you are setting. For example, you might want the display scale for the VEOG channel to be different from the other EEG channels. In that instance, set the VEOG scalar to 0.5, while leaving the other channels with a scalar of 1. The scalar multiplies the global scale factor you have set during acquisition.
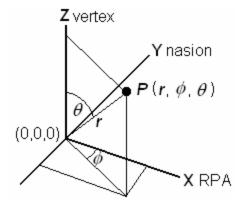
Size and Position. The Size and Position buttons are used to position the electrodes displays automatically, resize the displays, and import/export electrode position files.

10-20 Positions. This button is used to position the electrode displays automatically according to the 10-20 system, or from electrode position information contained in the .3dd file created in 3DSpaceDx when the electrode positions were digitized.

10-20 Electrode Positions

| Label	Phi	Theta	Rad
FP1	105.91	72.16	103.
PZ	-86.94	22.35	132.
FP2	73.73	72.39	104.
OZ	-88.18	55.03	103.
F3	125.30	45.32	116.
FTC1	152.88	49.73	103.
F4	53.96	46.13	118.
FTC2	27.38	50.94	105.
C3	169.45	29.77	121.
TCP1	-163.05	44.88	106.
C4	11.53	31.38	123.
TCP2	-13.74	45.29	108.
P3	-135.27	33.88	122.
CP1	-148.09	15.66	137.
P4	-41.72	35.19	123.
CP2	-26.46	17.03	137.
O1	-106.76	57.61	102.
PO1	-100.79	37.95	117.
O2	-69.73	57.74	104.
PO2	-79.21	37.95	117.
F7	137.95	70.45	92.
F8	41.75	70.40	94.
T3	176.33	63.67	82.
T4	4.90	64.07	87.
T5	-142.70	60.79	92.
T6	-33.64	61.11	96.

Match Labels | Cartesian to Polar
Load 3D pos. | Polar to Cartesian

Snap to Grid   Theta 10   Current Pos Phi=-12.3 Th=127.1   Electrode units mm
Phi 10

OK   Cancel

Two electrode positioning systems are supported: Cartesian and Spherical Polar. The Cartesian positioning system is the X, Y, and Z coordinate system, where the x-axis runs from the left ear (negative) to the right ear (positive), the y-axis runs from the nasion (positive) through the inion (negative), and the z-axis runs from the vertex (positive) though the intersection of the x- and y-axes, to points below (negative). The 0,0,0 point is the intersection of all three axes, in the center of the head.
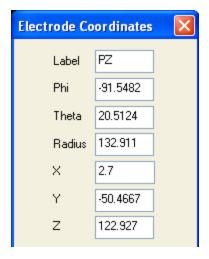

The Spherical Polar Coordinate system uses Phi, Theta and Radius values to express the 3D location of the electrodes. The Phi and Theta values can be

read in the lower part of the display `Current Pos Phi=-60.8 Th=170.6`. Theta and Phi are angles, expressed in degrees. **Theta** is the number of degrees away from the Z axis (in any direction). **Phi** is the number of degrees away from the X axis, where positive degrees are in the counterclockwise direction, and negative degrees are in the clockwise direction. **Radius** is a fixed value for each electrode, derived from group averaged MRI data (unless you load the .3dd file for the subject). The two angles and the distance are used to describe any point in three dimensions.

The same electrode position can therefore be expressed in X, Y, and Z coordinates or in Phi, Theta and Radius values. All six values for a given electrode are shown in the table on the right side of the display.

Label	Phi	Theta	Radius	X	Y	Z
FP1	105.91	72.16	103.47	-27.00	94.72	31.70
PZ	-86.94	22.35	132.91	2.70	-50.47	122.93
FP2	73.73	72.39	104.50	27.90	95.61	31.61

Double click on one of the electrodes to see the following display.

Electrode Coordinates

Label	PZ
Phi	-91.5482
Theta	20.5124
Radius	132.911
X	2.7
Y	-50.4667
Z	122.927

From this screen you may edit the electrode label, and modify the Polar and Cartesian coordinates manually, if desired. Click OK to apply the changes. (If you change the Polar coordinates, click the `Polar to Cartesian` button to modify the Cartesian coordinates automatically, and vice versa).

Electrodes can be repositioned manually on the display. You can place them at any point, or you can have them "snap" to defined positions. The latter option is enabled with the ☑ Snap to Grid field. You can control the sensitivity of the "snapping" by the values you enter in the Theta and Phi fields.

Theta 10
Phi 10

Valid entries for these fields are from .01 to 10 degrees. When theta is set to 10, for example, the moving electrode will snap from one position to the next in discrete 10 degree steps. Similarly, when phi is set for 10, the moving electrode will snap from one position to the next in discrete 10 degree steps. If the "Snap to grid" field is not checked, you can place the electrode at any position.

The Electrode units [mm ▾] field allows you to change the unit of measurement to mm's, cm's, m's, or inches.

The remaining options on the display are as follows.

[Match Labels] [Cartesian to Polar]
[Load 3D pos.] [Polar to Cartesian]

The [Match Labels] button is used to position the electrodes according to the 10-20 placement system. This assumes you are using conventional electrode labels. The program recognizes the labels and positions the electrodes accordingly. This feature is particularly useful when you are creating setup files from scratch (such as, after clicking **Make Default Setup**), or in any circumstance in which the electrode positions are not there (such as when you import data files with no position information). The new positions will be transferred to the Channel Layout display when you click OK. *The placements were computed based on the average of about 60 actual head measurements, and therefore the electrodes may not be perfectly symmetrical between sides, Cz may not be at the actual center, and so forth.*

The [Load 3D pos.] button allows you to retrieve and apply position information obtained from a .3dd file created inn 3DSpaceDx. This will allow you to reposition the electrodes in cases where the labels are not from, or extend beyond (as with 128 or 256 channel data files), the 10-20 system labels. The electrodes will be positioned according to their locations when they were digitized. Retrieve the .3dd file and click OK to transfer the position information.
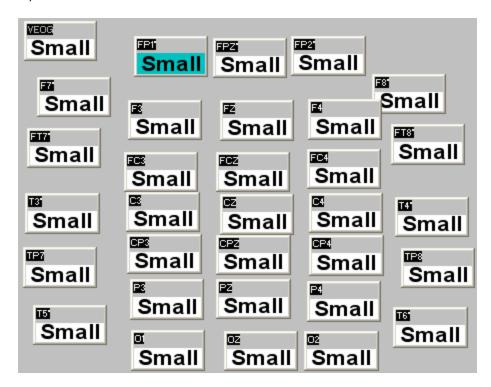
Lastly, when you manually reposition an electrode, you may see the Polar coordinates change, but not the Cartesian coordinates. Click the [Polar to Cartesian] button to compute the Cartesian coordinates automatically. The [Cartesian to Polar] button will do the converse.

Reset Positions / Make Same Size. When one of the electrode channel boxes is highlighted, you may increase its size by clicking on the display area. It will change from SMALL to LARGE (or vice versa). The Small size is the size that the display will have by default. The Large size is the size it will be when you click inside the display once to enlarge it to the intermediary size (double click it to go to full size). Or, you can click and drag a corner of an electrode display to a new size of your choice. If you want all of the boxes to be the size of the one you have just set, click **Make Same Size** and all boxes will be set to the size of the one that is highlighted. You may also reposition the displays

by dragging them from the top label bar on each display. Clicking on the **Reset Positions** button to return the boxes to their original orientation and size. *Note: if you selected 32-64 channels under* Amplifiers *above, and yet only the first 32 are displayed, click Reset Positions to see all the channels*. The positions you set will be reflected in the multiple window displays during acquisition. You can, for example, position the boxes to approximate the 10-20 system, as shown below.

When you have successfully concluded the individual channel assignments, click on OK to enable the changes. Remember to SAVE the Setup file if you plan to use these settings repeatedly. Click on CANCEL to exit the individual setting options without making any changes to existing settings.

📄 **Note**

You must click OK to save the position information before you click the Make Same Size button again. Otherwise, the new position information will be lost when you click Make Same Size, and the electrode displays will return to their original positions.

Importing and Exporting Electrode Positions. Note that there are two buttons used for importing and exporting electrode position information.

This is the size and position information of the electrode displays for the multiple window display. You can export the information from one data file, and then import it with a different (but matching in terms of number of channels
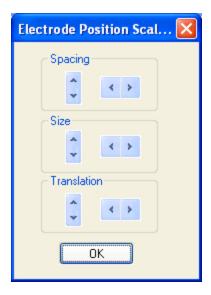
and channel labels) data file.

For example, retrieve the *sepblk.avg* file. Click the *right mouse* button between the electrode display to access the **Properties** → **Channel Layout** option.

When the Channel Layout display appears, click the [Export Positions] button, and enter a file name and path (the .asc extension will be added automatically). Then click the Cancel button to exit the display. This step created an ASCII file that may be applied to a matching data file.

Now, retrieve the *sepnoblk.avg* file, and return to the Channel Layout display. Click the [Reset Positions] button. This returns the electrode channel displays to the default size and position. Imagine now that this is a data file that was recorded with the default positions, and we want to apply those from the

sepblk.avg file. Click the [Import Positions] button, and retrieve the ASCII file that was created above. This will resize and reposition the electrode displays as in the sepblk file.

Adjust Positions. The [Adjust Positions] option is used to reposition or resize the electrode displays automatically. Clicking the button displays the screen to the right. The three groups of adjustments are for Spacing, Size, and Translation. **Spacing** expands or compresses the grouping of the displays either vertically

, or horizontally . Similarly, the **Size** buttons increase or decrease the size of the electrode displays either vertically or horizontally. The **Translation** buttons will shift the entire grouping of the displays vertically or horizontally.
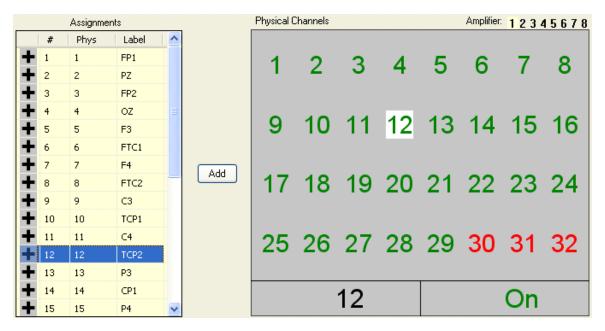
Transparency. Slide the Transparency bar to increase or decrease the transparency of the dialog screen, thereby making it possible to see the multiple window displays behind it.
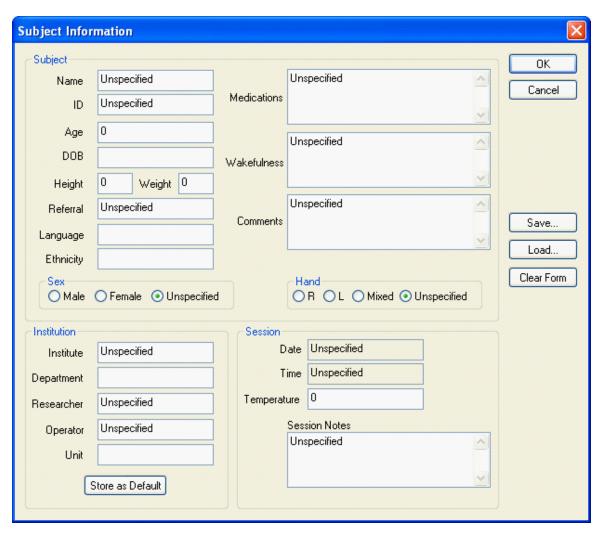
2.2.3 Channel Assignments

This option opens the same Channel Assignment screen used in ACQUIRE to label and order the channels. If desired, you may rename the channels in the data file you have retrieved by entering in a new label. Use the **Save As** option under Files, or the **Update Changes** icon to save the change.

2.2.4 Subject

Clicking this button opens the Subject Information display that was created in ACQUIRE. You may edit the information, as desired.

2.2.5 Sweep

The Sweep option opens a second menu list containing the following options.

Accept Sweep (EEG). As you step through an epoched file, this option will show whether a sweep has been tagged as Accepted or not (check mark will appear). Click the **Accept Sweep** menu item to reject the sweep, or for convenience, use the *Insert key* from the keyboard. The same functions are also accessed from the Toolbar icon .

Reject Sweep (EEG). As you step through an epoched file, this option will show whether a sweep has been tagged as Rejected or not (check mark will appear).
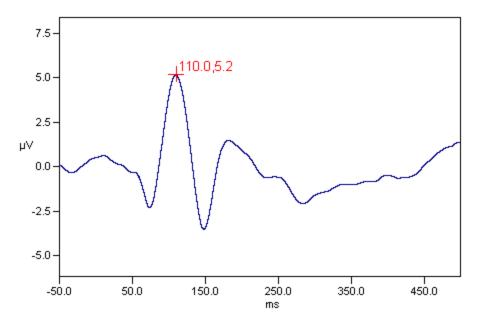
Click the **Reject Sweep** menu item to accept the sweep, or for convenience, use the *Delete key* from the keyboard. The same functions are also accessed from the Toolbar icon .

Mark Block (CNT). The **Mark Block** command is used to designate sections, or blocks, of a CNT file. It is accessed more easily from the Toolbar icon , and its operation is described more completely in the Toolbar section below.

Insert Marks (CNT). The **Insert Marks** option is used to insert Keyboard events in the CNT file using the function keys. It is more easily accessed from the Toolbar icon , and its operation is described more completely in the Toolbar section below.

2.2.6   Markers

These options are used in conjunction with the **Add Marker** option. The Add Marker option lets you add, for example, text comments to points on a waveform. The option is accessed when you click the *right mouse* button within an electrode display in a multiple window display (described in more detail below).

Clear Markers. This option clears any markers than have been placed.

Marker Report. If you have added several markers to an EEG, AVG or COH file, this option will create a text file list of the markers.

With an EEG file, select the **Marker Report** option, and the sweeps in the EEG file will be searched rapidly for markers. At the end of the search, an Output File utility display will appear in which you may enter a file name and path (the .dat extension will be added automatically). The resulting file will look something like the following (from Notepad):

```
Sweep Number      Channel Marker  Latency Amplitude
2          FCZ     New      302.325581      22.060547
7          FCZ     New      277.906977      22.763672
21         FCZ     New      525.581395      4.833984
31         FCZ     New      400.000000      33.662109
31         FCZ     New      400.000000      33.662109
38         FCZ     New      368.604651      47.900391
```

Similarly, multiple markers made in an AVG file will produce a Marker Report similar to the following:

```
Sweep Number      Channel Marker    Latency         Amplitude
1         OZ      P100 component   100.711744      8.308467
1         OZ      N70 component    65.480427       -6.153495
```

Show Markers. This option toggles on and off the display of the markers you have placed.
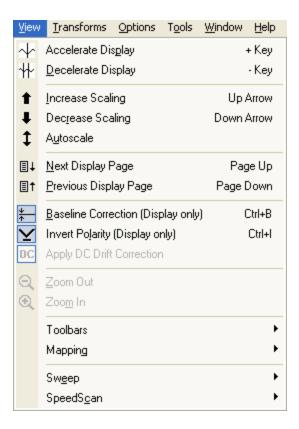
2.2.7   Create AST File

This is a very handy option through which you may create a SCAN 4.2 or newer version setup file from any data file that you have retrieved in EDIT. Retrieve a data file, select **Create AST File**, and the standard Save File screen will appear. Enter a file name and path, and save the .ast file. This can then be used in ACQUIRE for acquisition.

2.2.8   Create SET File

Setup files from SCAN 3.0 used .set extensions. This option allows you to create an .set file from a SCAN 4.x data file. There are some older utility or third party programs that still require .set files, although this option is essentially obsolete now.

2.3   View

The following options are accessed under View. The type of file you have retrieved (CNT, EEG, AVG, or COH) will determine which options will be available. These options may be accessed directly from icons on the Toolbar (refer to that section below for additional details). If you have multiple data files open, be sure to change the focus to the display that you wish to affect.

Accelerate Display Time (CNT). This option decreases the number of seconds displayed on the screen for continuous files, and has the same effect as the **Accelerate** icon on the Toolbar. The + *key* on the keyboard may be used instead. You can also use the *right mouse* button option, Set seconds per page , to select the number of seconds to be displayed.

Decelerate Display Time (CNT). This option increases the number of seconds displayed on the screen for continuous files, and has the same effect as the **Decelerate** icon on the Toolbar. The - *key* on the keyboard may be used instead. You can also use the *right mouse* button option, Set seconds per page , to select the number of seconds to be displayed.

Increase Scaling (all file types). This option increases the display scaling (and has no effect on the stored data).

Decrease Scaling (all file types). This option decreases the display scaling (and has no effect on the stored data).

Autoscale. The Autoscale option will automatically scale data in a multiple window display according to the largest and smallest voltages encountered. Autoscaling may be applied directly from the Toolbar icon, as well.

Next Display Page (all file types). Additional Display Pages can be created either from ACQUIRE or from EDIT, using the options under **Edit → Channel Layout**. The Next Display Page option will step to the next display page that you created.

Previous Display Page (all file types). The Previous Display Page steps backward in the series of display pages you created.

Baseline Correction (Display only; all file types). This option centers the waveform within the display region allocated to it (does not affect the actual data file). *Ctrl+B* has the same effect.

Invert Polarity (Display only; all file types)*.* This option inverts the polarity of the displayed file (does not affect the actual data file). *Ctrl+I* has the same effect.

Apply DC Drift Correction (CNT files recorded with *SynAmps*). The DC Correction is only available for CNT data files recorded with a SynAmps, with a high pass filter setting of DC, and after you perform the DC Offset Correction transform. The option will let you toggle between the corrected and uncorrected waveforms.

Zoom Out (EEG, AVG)*.* Select Zoom Out to return the Zoomed In section to its original size.
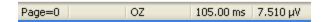
Zoom In (EEG, AVG). The Zoom In option will become active when you enlarge an electrode display to full size (multiple window data files). After selecting Zoom In, you will see a magnifying glass image aside the usual mouse cursor. Drag a rectangle around the section of the waveform that you wish to enlarge, then release the mouse button.

Toolbars. Selecting the Toolbars option displays a secondary list of independently controlled Toolbars.

Main Toolbars. Selecting this option (check mark appears) will display the Toolbar icons. The functions of these are described in detail below.
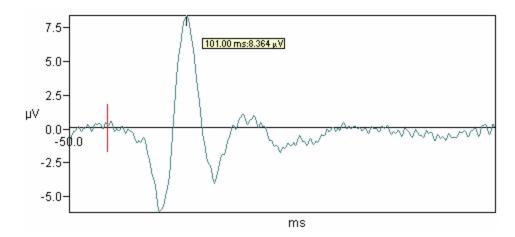
Status Bar*.* Enabling this (check mark appears) will display the Status Bar at the bottom of the screen. On the left-most edge of the screen you will see a brief description of functions when you position the mouse over certain context sensitive areas, such as, the Toolbar icons. Additionally, there are four fields that
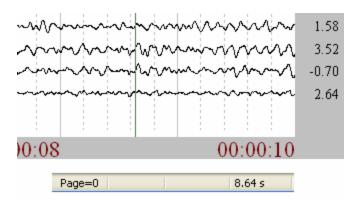
display information when the mouse is positioned inside a multiple window display. The first shows the current Display Page. The next field displays the electrode label. The 3rd and 4th fields show the millisecond and microvolt values corresponding to the exact mouse cursor location. These two fields provide a quick means for measuring points on the waveforms.

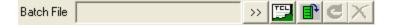With time domain multiple window displays, you can see the millisecond and

voltage for each data point by positioning the mouse at the desired point. A **Tool Tip** display will show the values.

With CNT files, you may read the time point from the Status Bar field, and the voltage for each channel and data point in the column on the right.

Batch. This displays the Batch toolbar, used to retrieve, create, edit, and execute batch files (refer to the Tcl Batch Manual for details).

Immediate. This displays the Immediate toolbar, which is used to execute a single batch command. The 10 most recent transforms are saved (click the pull-down arrow to access them). Click the **Do** button to execute the command (refer to the Tcl Batch Manual for details).
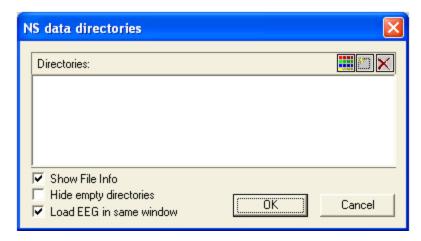

History. The History field saves a list off most operations that are performed. It is helpful for keeping a record of operations performed and for creating batch files that use the same series of operations (refer to the Tcl Batch Manual for more details).

```
QRS EKG+ 10 STD
CORRELATEPEAKS STIMULUS 10 -50 50 20 10 EKG+ T 95
CREATESORT SORT199
SORT199 -TypeEnabled T
SORT199 -TypeCriteria 10
EPOCH_EXPORT_INTERNAL "" N -200 1000 N Y Y N N SORT199 {D:\Combined transforms\output.eeg}
DELETESORT SORT199
```

File Bar. Enabling this option displays an internal data file selection system. This provides a very convenient way to retrieve the data files created by the SCAN programs. After enabling the File Bar option, you will see the following display.

Click the button to select the folders that contain your data files. You will see the following display.
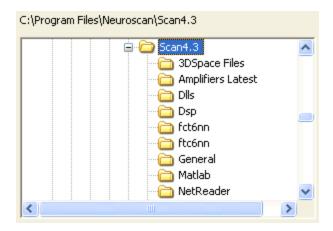

Note the three icons at the far right . The first one is used to change the

background color in the previous display. The second one is used to select your data folders, and the third one is used to delete data folders you have already selected. For now, click the second icon [ ]. You will see the following tree structure.

Select a folder that has data files in it, and click the OK button. Repeat the process for all of the data files you want to access. You may select folders from other drives or across a network, as well. Click OK when you are done. The first display will show the file structure.

The tree structure then operates very much like the Windows Explorer program.

C:\Program Files\Neuroscan\Scan4.3

Scan4.3
3DSpace Files
Amplifiers Latest
Dlls
Dsp
fct6nn
ftc6nn
General
Matlab
NetReader

Note that at the bottom of the display you may select the **File types** you wish displayed.

All types (AVG,CNT,EEG,COH)

Select a data file for retrieval by double clicking it. The Researcher, Subject Name, DOB, etc. fields will display the information that was saved with the data file. Note also that the [Info] button becomes active. Click this to see the complete Subject Information screen.

The [Update] icon is used to update the tree structure. Clicking it will return the structure to the following form.

NS Subject Database
D:\scan4files
D:\scan41files
C:\Scan4.1\Demo

Show File Info
Hide empty directories
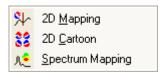Load EEG in same window

Notice also on the "NS data directories" screen (after clicking the [Setup] icon), there are options at the bottom of the screen. If you enable the **Show File Info** option, you will see a pop-up window showing some basic file information

when you position the mouse cursor on a data file. Enable the **Hide empty directories** option excludes directories with no data files. If you enable the **Load EEG in same window** option, a subsequently selected file will replace the previously opened one.

Deselect the File Bar option to remove the File Bar File Bar .

Mapping. Selecting the Mapping option opens a second list of options. These are accessed more easily from the Toolbar icons ⚡ ⚭ ⚮ .

> ⚡ 2D <u>M</u>apping
> ⚭ 2D <u>C</u>artoon
> ⚮ <u>S</u>pectrum Mapping

2D Mapping (AVG, EEG, CNT). This option allows you to present single point or averaged interval data on a flat two-dimensional display. With AVG and EEG files you must first enlarge an electrode display to full size for the option to be available. Please see the <u>mapping</u> 254 section below for more details.

2D Cartoon (AVG, EEG, CNT). This option allows you to display your data using a series of 2D maps in "cartoon" form. With AVG and EEG files you must first enlarge an electrode display to full size for the option to be available. Please see the mapping section below for more details.
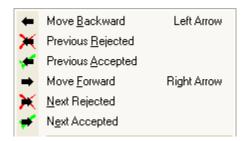
Spectrum Mapping (AVG, EEG, CNT). The Spectrum Mapping option computes an FFT (Fast Fourier Transform) and displays the results in Delta, Theta, Alpha1, Alpha2, Beta1 and Beta2 band maps (these can be modified). With EEG and CNT files, the maps correspond to each sweep (EEG) or the segment of the file that is displayed (CNT). Please see the mapping section below for more details.

Sweep (EEG, CNT). The Sweep section commands are used to move through CNT and EEG files. The options are accessed more easily from the Toolbar icons ← ✕ ← → ✕ → and ↻ ⊙ . The operations are described more fully in the Toolbar section below. The options that are available will depend on the type of file and other factors, such as, whether there are any rejected sweeps or trigger events in the file.

The first set of commands is used primarily for stepping through EEG files.

> ← Move <u>B</u>ackward   Left Arrow
> ✕ Previous <u>R</u>ejected
> ← Previous <u>A</u>ccepted
> → Move <u>F</u>orward   Right Arrow
> ✕ N<u>e</u>xt Rejected
> → N<u>e</u>xt Accepted

Move Backward (EEG, CNT). This option steps one sweep or one display screen backward in the data file. The *left arrow* on the keyboard performs the same

function.

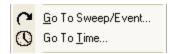**Previous Rejected** (EEG). This option steps backward to the nearest rejected sweep in the file.

Previous Accepted (EEG). This option steps backward to the nearest accepted sweep in the EEG file.

Move Forward (EEG, CNT). This option steps one sweep or one display screen forward in the data file. The *right arrow* on the keyboard performs the same function.

Next Rejected (EEG). This option steps forward to the next rejected sweep in the file.

Next Accepted (EEG). This option steps forward to the next accepted sweep in the file.

The Next two commands are used to go to a specific sweep or event marker.

Go To Sweep/Event (EEG, CNT). Depending on the type of file, this option will allow you to jump directly to a specified sweep number or event in the EEG or CNT files (described in more detail below in the Toolbar section).

Go To Time (CNT). This option will take you directly to a specified time point in the CNT file, and is described in more detail below.

The last option is used to measure the change in amplitude and latency between points on the waveforms.

Show Delta Cursor (AVG, EEG). This option let's you select one data point, and then measure the latency and amplitude differences in relation to that point (described in more detail in the Toolbar section below).

Speedscan (EEG, CNT). The SpeedScan feature will step automatically through the EEG or CNT file, in either direction. The speed is controlled by the SpeedScan Interval. SpeedScanning is controlled more easily from the icons on the Toolbar (and is described in more detail in that section below).
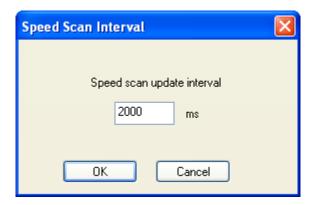
SpeedScan Forward (EEG, CNT). This option automatically scans through the file in a forward direction. The combination keystrokes of *Alt+right arrow* (on the keyboard) perform the same function.

SpeedScan Backward (EEG, CNT). This option automatically scans through the file in a backward direction. The combination keystrokes of *Alt+left arrow* (on the keyboard) perform the same function.

SpeedScan Stop (EEG, CNT). This option is used to stop the SpeedScan. The Spacebar will also stop the scan.

SpeedScan Interval (EEG, CNT). This option is used to control the speed of the automatic Scan Forward and Scan Backward features for reviewing CNT and EEG files. Select the Speed Scan Interval, and the displayed screen will appear. The value that you enter (in ms), controls the update interval that the automatic scan uses. To change the update interval, simply enter a new value and click OK.

2.4   Transforms

Listed below, in alphabetical order, are all of the transforms that are available (with the exception of **Grouping** and **Scripting**, which are at the end of the Transforms section). Not every transform is available for every file type. The information in the parentheses after the Transform name shows the file types that have the particular transform available, where AVG are averaged files, CNT are continuous files, EEG are epoched files, and COH are coherence files. Note that some of the transforms are available for Time Domain files (evoked potential files), Frequency Domain files (power spectrum files), or both.

It is also possible to display the list of Transform options by clicking the *right mouse* button between the electrode displays in a data window, and then select **Transforms**.

Display Dialog During Script Execution. Most of the Transforms will have a field at the bottom that says . This is used during Script operations to display the screen while the Script sequence is being executed. This is described in more detail in the *SCAN Tutorials* and in the Script 223 section below.
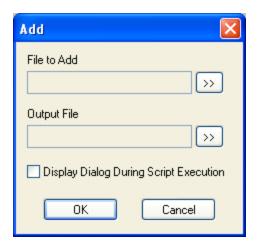
Below are the transforms, listed in alphabetical order.

2.4.1 Add

Add (AVG, time domain EEG). The Add option allows you to add data from two files together. The data files must have the same number of channels, the same electrode labels, the same epoch start and stop points, and the same number of data points per sweep. Retrieve an AVG or EEG file, then click the A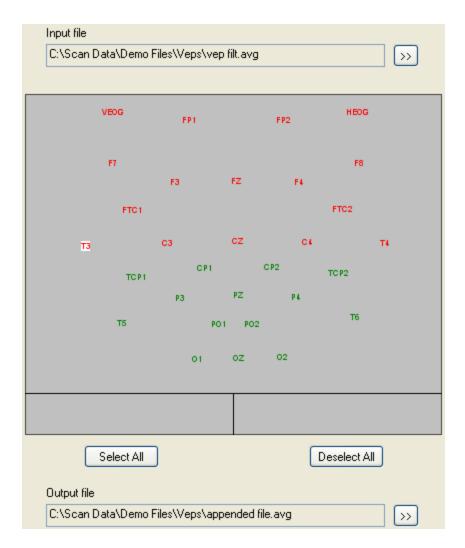dd option. The Add display will appear. Click the [>>] button to access a standard Open File utility, through which you may select the AVG file to be added. If you started with an EEG file, the selected AVG file will be added to each sweep in the EEG file. Then click the [>>] button on the Output File line, and enter an output file name. A new multiple window display will appear with the added waveforms.

2.4.2 Append Channels

Append Channels (AVG, time and frequency domain). This command allows you to append channels from one AVG file to a different AVG file. The files must be equivalent in terms of number of points and Start and Stop times, and there can be no channels in common to both files. Retrieve one AVG file, and click the Append Channels option. You will see the following screen.

Use the Browse button to select the second AVG file. From that file, you may select the channels that you wish to append to the first file. Enter an output file name, then click OK. You will then see the new file with the original and the appended channels.

2.4.3   Append Recording

Append Recording (CNT). Append Recording allows you to attach one CNT file to another. Retrieve one of the CNT files, and then select Append Recording. The Append Recording display will appear. Click the [>>] button to access an Open Files utility window. From it, select the CNT file you want to append to the original CNT file. Then click the lower [>>] button, and a Save As... utility will let you enter a new file name and path.
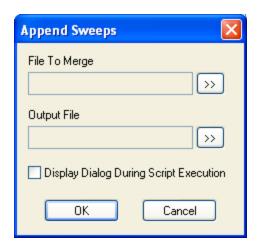
📄 **Note**

When you append CNT files, a SS event (Stop/Start) is added at the file junctures, and at the end of the final output CNT file. These will appear in event counts and in the event file.

2.4.4 Append Sweeps

Append Sweeps (EEG, time and frequency domain). Append Sweeps allows you to attach two EEG files together in a single file. The second file will be attached to the end of the first one. Retrieve the first EEG file, then select Append Sweeps from the Transforms menu. Use the first ⟩⟩ button to select the File to Merge. Use the second ⟩⟩ button to enter an output file name and folder, then click OK to continue. After the file is appended, you will see a multiple window display showing the first sweep of the new EEG file.
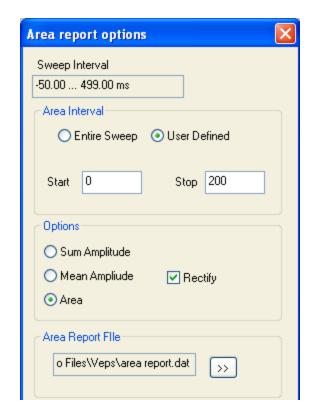
2.4.5 Area Report

Area Report (EEG, AVG; time domain). This option is used to create an ASCII file (.dat extension) that will contain the Sum, Mean Amplitude, or Area information for the interval you specify. The Sweep Interval displays the Start and Stop times for the

data file. The Area Interval lets you select the **Entire Sweep**, or a **User Defined** section by entering new **Start** and **Stop** times. The Options for the report include the following.

Sum Amplitude - This option will total the microvolt values for the data points within the specified range. Enable the **Rectify** option if you want the values to be all positive numbers.

Mean Amplitude - This option will average the microvolt values for the data points within the specified range. Enable the **Rectify** option if you want the values to be positive numbers.

Area - This option will compute an estimate of area under the curve within the specified range. Enable the **Rectify** option if you want the values to be all positive numbers. Area computation uses the "extended trapezoidal rule" to estimate area under the curve. This amounts to summing all points - except the two endpoints are given 1/2 weight - and multiplying by the sampling interval (i.e., 1000/(sampling rate)). The 1000 in the numerator is required for microvolt-millisecond area units.
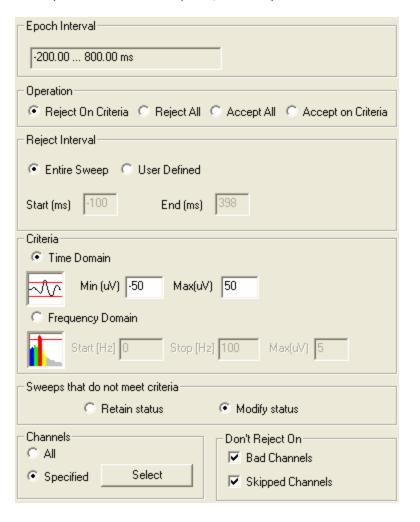
Rectify - Enable this option if you want the values used in the Sum, Mean and Area computations to be all positive numbers.

Use the Browse button [>>] to enter the file name and path (the .dat extension will be added automatically). Click OK to create the .dat file. The resulting file may be read with any text editor, and will look similar to the following.

```
Sweep Number        Channel      Area(0.00->200.00ms)
1       FP1     136.917598
1       FP2     130.730587
1       F3      149.069435
1       F4      168.148301
1       C3      157.803885
1       C4      204.549199
1       P3      203.108881
1       P4      128.310514
1       O1      316.217815
1       O2      292.966036
1       F7      121.844311
1       F8      111.901172
1       T3      99.777337
```

2.4.6   Artifact Rejection

Artifact Rejection (CNT, EEG, time and frequency domain). The Artifact Rejection option will automatically reject (or accept) sweeps in which the voltage in a designated channel(s) exceeds defined criteria. The Artifact channels are designated in ACQUIRE when you create the setup file, but may be modified as described below.
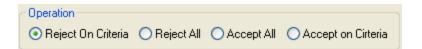
Beginning with SCAN 4.3, you may also reject (or accept) sweeps on the basis the amplitude of activity in a specified *frequency* range. For example, you could reject all sweeps that have amplitude in the delta range (0-4Hz) in excess of a selected voltage (to reject sweeps that may contain artifact). Or, you could accept only those sweeps that have alpha (8-12Hz) in excess of a specified voltage (to include only those sweeps where the subject's eyes were closed, and the person was awake). When you retrieve a time domain epoched file, and select the Frequency domain option (described below), an FFT is performed (a spline fit is applied automatically, if needed). The results of the FFT are used for the criterion.

Clicking the Artifact Rejection option opens the Artifact Display (the options vary between EEG and CNT files). The display contains the following regions:

Epoch Interval - The Epoch Interval displays the length of the epoch, as designated in the setup file created in ACQUIRE.

Epoch Interval

-200.00 ... 996.00 ms

Operation - The Operation field allows you to reject or accept sweeps on the basis of the Amplitude Criteria you specify below (Reject on Criteria), or you may elect to Reject All sweeps or Accept All sweeps without regard for the Amplitude Criteria.
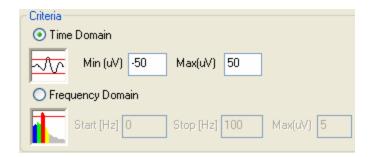
Operation
⦿ Reject On Criteria   ○ Reject All   ○ Accept All   ○ Accept on Cirteria

Reject Interval - The Reject Interval is that part of the epoch that will be included in the voltage scan. Typically, this will be the **Entire Sweep**, although there is a **User Defined** option in which you may specify the **Start** and **End** points (in ms).

Reject Interval

⦿ Entire Sweep   ○ User Defined

Start (ms) -200   End (ms) 996

Amplitude Criteria - Time or Frequency domain files can be used. For basic artifact rejection with Time domain files, click the Time Domain option and enter the threshold values for the Amplitude Criteria. The program will scan the channels you designate, using the rejection interval you specify, for voltages exceeding the **Max.** or **Min.** values (in μVs). The sweep will be rejected (or accepted, depending on which you selected in the Operation region) when the threshold is exceeded. You can also select the Frequency Domain option with time domain files. An FFT is computed (using an automatic spline fit if the number of points is not a power of 2), and then sweeps are either rejected or accepted using the amplitude criterion. Specify the frequency window using the Start and Stop frequencies, and select a voltage criterion.

For Frequency domain files (as with Forward FFT files), the Time Domain option is grayed out. Specify the frequency window using the **Start** and **Stop** frequencies, and enter a voltage criterion. The rest of the process is the same as with time domain files.
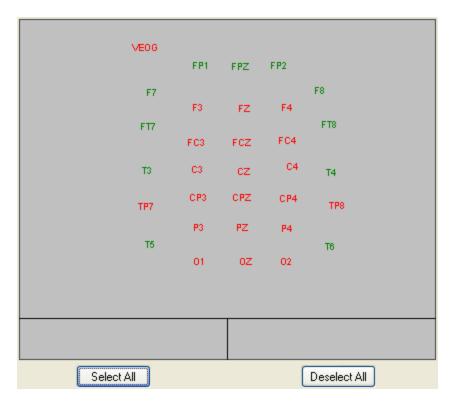

Sweeps that do not meet criteria - If you have already rejected epochs manually, or if you are running the Artifact Rejection routine an additional time, you will have some sweeps that did not meet the rejection criteria. You have the option of retaining these sweeps regardless of whether they meet the new criteria (**Retain status**), or subjecting them to the new criteria for possible modification (**Modify status**). The latter will override any previous accept/reject tags. Those that do not meet the thresholds will be accepted.

Channels - The Channels region allows you to run the Artifact Rejection scan on all channels, the ones that were previously designated as artifact rejection channels in the setup file, or on other channels you specify.

Select the **All** option to use All channels. Click the **Specified** field to use the channels that have already been designated as rejection channels. To modify these, click the Specified field, then click the **Select** button to access a montage diagram.

The initial channels that you selected in the setup file in ACQUIRE will be green, and the electrodes that are excluded will be red. Move the mouse over an electrode label, and the fields below the diagram will show the label and the status. Double click on an electrode label to change its status. The **Select All** button will select all channels for correction; the **Deselect All** will exclude all channels for artifact rejection.

Don't Reject On - In ACQUIRE, you have the option to designate channels as Bad channels, or to Skip operations on certain channels. It is likely that these channels may have higher voltages, either because of noise or higher amplitude activity to begin with. You can exclude these from the Artifact Rejection routine by enabling the Don't Reject On Bad or Skipped channels.
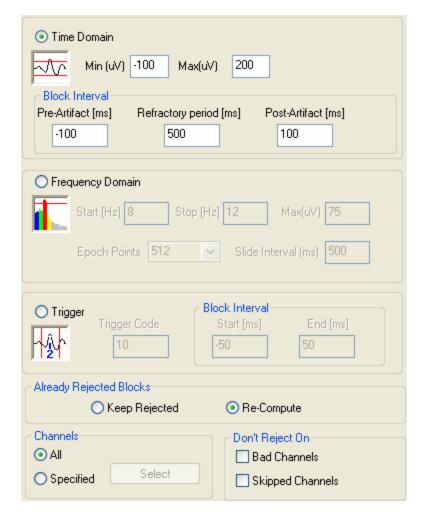

When you have made all the settings you want, click OK, and a progress bar will show the routine being applied. To view the results, click on the Toolbar control buttons to go to single sweeps, or the buttons to play through the file automatically (described in more detail in the Toolbar icon section). The status of each sweep will be indicated by the buttons. The "depressed" button indicates whether the sweep is accepted or rejected. You can, of course, override the settings manually by pushing the alternate button.

Artifact Rejection with CNT files. A slightly different dialog screen appears when you

select artifact rejection for a CNT file.

As with EEG files, you can use Time Domain or Frequency Domain methods for rejection, or you can reject on the basis of trigger events in the CNT file.

Time Domain. With CNT files, the routine scans all, or specified channels for voltages exceeding the criteria you set in the **Min** and **Max** fields. When a voltage exceeds either criterion, a block of data is rejected according to the limits you set in the Block Interval fields. The interval of the rejected block is defined by the **Pre-Artifact** and **Post-Artifact** time spans.
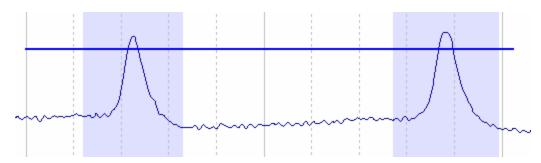
The **Refractory period** has a slightly different use here than in most other places in the SCAN software. The artifact period starts at the first threshold crossing and does not end until the data (in all selected channels) remain below threshold for one entire refractory period. The interval is then back-computed as:

Start = first crossing point minus the pre-artifact span
End = last "above-the-limit" point plus the post artifact span.

The reason this is done is so that you do not have several small disjointed rejected segments during a noisy part of the recording. They are combined into one rejected span. When the artifacts are closer together than the Refractory Period,
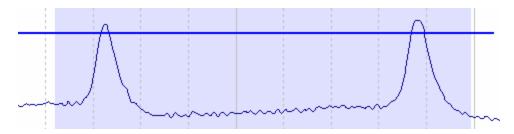
the artifact period is considered ongoing until the voltages (in all selected channels) remain below threshold for an interval after the last detected artifact.

For example, the Refractory Period in the figure below is 600ms. The Pre-artifact span is -200ms, and the Post artifact span is 200.

The line through the peaks is the Maximum Threshold. For each blink, the first threshold crossing is the end of the Pre-artifact span, and the second threshold crossing is the beginning of the Post-artifact span. All of the points in between the two crossings are above threshold, and within the Refractory Period. The second blink occurs after the Refractory Period (600ms) is over.

If you increase the Refractory Period to encompass the second artifact (1400ms in this case), the entire section between blinks is rejected.

A threshold crossing (from any monitored channel) that occurs during the Refractory Period will result in the entire span being rejected.

Frequency Domain. Click the Frequency Domain radio field to activate that option.
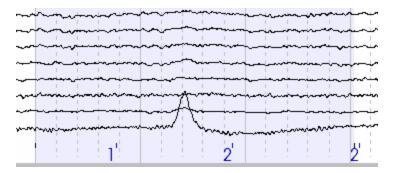
This routine performs a series of FFTs, and then rejects epochs when the power in any frequency bin within the specified range exceeds the specified voltage threshold. The span of the epochs is determined by the **Epoch Points** field, and that will interact with the AD rate used when the file was recorded. For example, if you recorded with an AD rate of 250Hz, and you select 512 Epoch Points, then the FFT will be computed over 2048ms sweeps. (The AD rate of 250 gives points every

4ms. 512 points therefore spans 2048ms).

You then have the option to specify the **Slide Interval**. The FFT is computed on a sliding interval that advances 100ms each time. Continuing the example from above, the first FFT is computed from 1-2048ms, the next one is from 101-2148ms, and so on.

If the FFT results contain a voltage from the specified channels that exceeds the threshold, in any bin in the specified frequency range, then the entire 2048ms epoch is rejected.

The process can take a few minutes, depending on the number of FFTs computed (and the number of channels, the length of the file, the speed of your computer, etc.). If used for rejecting blinks (not recommended), you will find that a much larger epoch may be rejected.
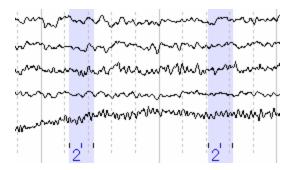
The frequency domain rejection is intended for instances in which you wish to reject sections where there are, for example, periods of drowsiness or sleep (increased theta or delta), or increased EMG that you wish to remove from subsequent analyses.

Trigger. The Trigger option is used where artifacts are time-locked to a stimulus event in the CNT file. Click the Trigger radio button to activate the options.

Enter the type code in the **Trigger Code** field. The Block Interval determines the span of the rejected interval about the trigger code.

2.4.7   Average

Average (EEG, time domain). The Average command is used to average a sequence of single sweeps into an average file of all the sweeps. Clicking the Average line disp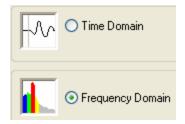lays the Averaging display. There are two types of files - Time Domain and Frequency domain. You must first specify which type of averaging you want to do.

Time domain files measure amplitude changes over a course of time (the x-axis is measured in time). *Frequency domain* files measure amplitude changes over a frequency range (the x-axis is measured in Hz). Evoked potential files are examples of time domain files, and FFT spectra are examples of frequency domain files.

Time Domain or Frequency Domain Averaging. Select whether you wish to perform Time or Frequency Domain averaging.

For Frequency domain averaging, *the number of points in the epochs being averaged must be a power of 2* (e.g., 256, 512, etc.; required for the FFT). If you select Frequency Domain averaging, there are some Scaling and Windowing options to select.

Scaling - Amplitude is computed as a function of frequency, and the results may be scaled in two ways: Amplitude and Power. The **Amplitude** option takes

the square root of the power spectrum to express the units in microvolts. (Amplitude is not precisely the square root of **Power**; different scaling and compensations for windowing effects are used). Amplitude is an approximate measurement of the baseline to peak amplitude (rather than peak-to-peak). (The measurement would be precise if you were analyzing a pure sine wave, with starting and ending points at zero, where no windowing was needed). The **Power** option computes a standard power spectrum (adapted from the Cooley-Tukey method) with values expressed in microvolts squared.

Window - You may select to Window the data to control spectral leakage.

Length [%] - Length determines the extent of taper at the beginning and at the end of the epoch (percentage of epoch duration).

Type - The window Type field determines whether a Cosine, Hamming, Hanning, Parzen, Welch, or Blackman is employed. The differences among these various window types are subtle.
The remaining fields are provided for your information. They display the Resolution (or minimum frequency bin width), the Range of the FFT computations (the largest frequency that may be computed - half the AD rate), the current Duration of the epochs, and the number of Points.
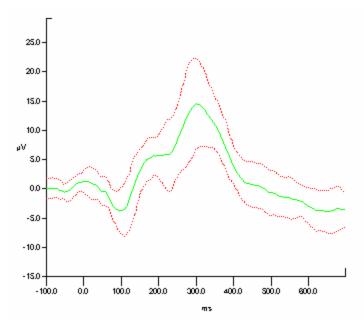
📄 **Note**
On occasion, you may wish to change the frequency resolution, that is, the width of the frequency bins. This can be accomplished by changing the epoch duration; the longer the duration, the narrower the frequency bins (or the greater the frequency resolution).

Options - In the Options section, you have the choices to Compute the Standard Deviation and/or the Signal-to-Noise-Ratio (SNR is available for time domain files only).

Compute Standard Deviation - The Compute Standard Deviation (SD) field when turned ON will compute the SD on a point-by-point basis for both the time and frequency (as described below) domains. Shown below is a waveform that was averaged with the SD flag set to ON. The dotted lines represent + or - one standard deviation. If you are averaging sweeps for an individual subject with the ultimate intent to compute z-scores for that subject versus a group averaged data file, you should NOT enable Compute Standard Deviation. You may also turn on and off the display of the SD using the toggle under **Options → Multiple Window Settings → General**, in the Misc. region (Show Standard Deviation).

SNR Settings - The SNR Settings field will compute an estimate of the signal-to-noise ratio in the same manner as the SNR Transform. The option is available for time domain averaging only. Clicking the button displays the SNR dialog screen.

📄 Note

You may find differences in the SNRs computed with 4.3+ in comparison to prior versions. We have adopted a better method for computing SNRs - the same as that used in CURRY. Please see the SNR section below for complete details).

Briefly, for the Noise estimation you can select the pre-stimulus interval (generally used), the value at the 20th percentile (especially if there is no prestimulus interval), or a user defined interval. For the Signal estimation, you can use the post-stimulus interval (generally used), the entire sweep, or a user defined interval. Click OK when you have made the selections. (*Right click* between electrode displays and select View SNR Values to see the SNRs).
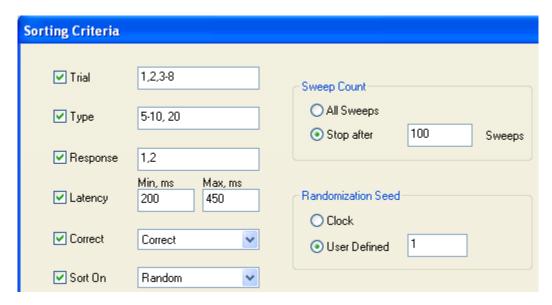
If you enable the ☑ Show Labels option, you will see the electrode labels and the SNR values. Note the particularly large SNR values from the centro-parietal sites.

The same information is listed in the .dat file that can be created with the Save to ASCII... button.

Sorting. When you perform Time or Frequency Domain averaging it is common to wish to include only selected sweeps in the average. EDIT provides many ways for sorting the sweeps to be included. Clicking the Sort Criteria... button displays the Sorting Criteria screen. The screen displays all of the options for sorting the sweeps. If you have multiple sorting options entered, then ALL of the criteria must be met for a given sweep to be included. If an individual Sorting Criterion is not

enabled, then all of the sweeps will be included, regardless of the values for that criterion. For example, if you do not enable and specify Type code values, then all Type codes will be accepted.

Trial - This option allows you to specify the individual trials, or sweeps, that you wish to be included in the average. Enter the individual sweep numbers, separated by commas, with hyphens to indicate a continuous range (e.g., 1-3,5,8,12-30).

Type - Type allows you to sort sweeps according to the trigger type codes sent from STIM. Use the same convention as shown under Trial to indicate the type codes that you wish to be included in the average.

Response - If you have a STIM system, you will see 1, 2, 4 and 8 type codes corresponding to response pad buttons 1, 2, 3, and 4 in the continuous file during acquisition. You may use the response type codes for sorting purposes when averaging. The result will be response-locked averages, rather than stimulus-locked averages. Note: Whether you use 1, 2, 3, and 4 or 1, 2, 4 and 8 in the response field depends upon whether you have merged the .dat file or not (Merge Task Data). Please see the section entitled "**Some notes about response codes** 100 " for more details.

📄 **Note**
In the continuous file acquired in ACQUIRE, you will see the stimulus and response triggers as blue and red numbers at the bottom of the single window display. The continuous file does not have information pertaining to the Latency or Correctness of the subject's responses. That information is stored in the .dat file on the STIM PC. To use the Latency and Correct options below, you must transfer the .dat file from the STIM PC to the SCAN PC, and then perform a Merge Task Data transform, as described below.

📄 **Note**
If you have Stim[2], and are using the Mouse or Keyboard for the Response

Device, please see the section entitled **Stim2 Response Devices** 7 *.*

Latency - You may specify a latency range in which the subject's responses must have occurred. For example, you might want to exclude responses that were too fast (impulse responding), or too late (lapse in concentration). Enter the Minimum and Maximum points for acceptable latencies. (This option assumes you have already performed the Merge Task Data option - see note immediately above).

Correct - This option allows you to include sweeps where the subject's responses were Correct, Incorrect, Correct or Incorrect, or where there was No Response. Click the pull-down arrow for the options. (This option assumes you have already performed the Merge Task Data option - see note immediately above).
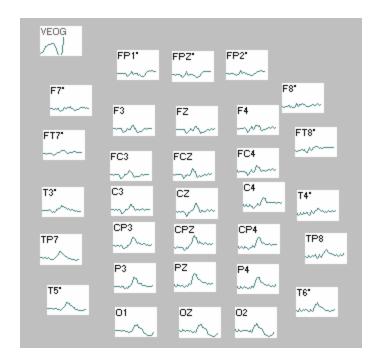
Sort On - Sort On allows you to perform split-half reliability averaging by including just the Odd, Even, or a Random selection of sweeps. If you select Odd, only the odd trial numbers will be included. If you select the Random option, the Randomization Seed field will become active.

Randomization Seed - These two options provide alternate methods for randomly selecting trials to be included in the average. The Clock option uses the current time from the clock to seed the pseudorandom number generator. The User Defined option allows you to specify a "randomization seed". That is a number between 1 and 255 that will determine a computer generated, randomization sequence. There are 255 sequences, and whenever you specify a seed, such as 110, the same sequence will be applied for averaging.
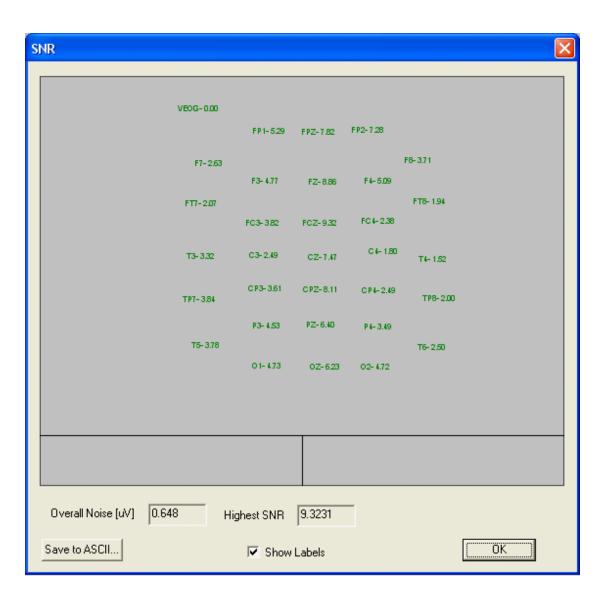
Sweep Count - The Sweep Count feature lets you include All Sweeps in the average, or you may Stop after X number of sweeps. For example, if you want all the sweeps after 100 to be excluded from the average, enter 100 in the **Stop after** field.

Note that you can combine the sorting options. For example, you might include only trials 1-100, where the type codes were between 1-5, the responses were correct, on even numbered trials.

Lastly, use the >> button to select a folder and enter an output file name. Click OK, and the averaging will begin (tracked by a progress bar). A new multiple window display will appear with the averaged waveforms.

Now let's look at the SNR values that were calculated. For this example, we used the *P300.eeg* file, corrected for VEOG artifact, and sorted for the Rare responses. Click the *right mouse* b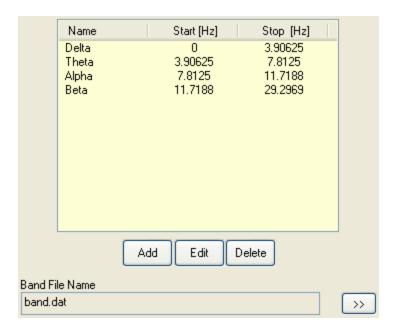utton between the electrode displays, and select **View SNR Values** option. You will see a display with the SNR values at each electrode site.

SNR

VEOG-0.00

FP1-5.29   FPZ-7.82   FP2-7.28

F7-2.63   F8-3.71

F3-4.77   FZ-8.86   F4-5.09

FT7-2.07   FT8-1.94

FC3-3.82   FCZ-9.32   FC4-2.38

T3-3.32   C3-2.49   CZ-7.47   C4-1.80   T4-1.52

CP3-3.61   CPZ-8.11   CP4-2.49

TP7-3.84   TP8-2.00

P3-4.53   PZ-6.40   P4-3.49

T5-3.78   T6-2.50

O1-4.73   OZ-6.23   O2-4.72

Overall Noise [uV] 0.648   Highest SNR 9.3231

Save to ASCII...   ☑ Show Labels   OK

2.4.8   Average Bands

Average Bands (frequency domain AVG, COH) - This option formerly existed as the *AVGBAND.exe* utility program for the DOS version of EDIT. It is used to redefine the frequency bands that are exported to an ASCII file. The output is a text file with a .dat extension. Clicking the option (after retrieving a frequency domain AVG file or a COH file) displays the following display.

The display will contain whatever band names and Start/Stop frequencies there are in the data file header. You may [Add], [Edit], or [Delete] the frequency bands, as desired. When you add or edit the bands, enter whole numbers and the program will automatically select the nearest actual bin frequency. You may overlap bands, if desired.

The Band File Name field lets you select the path and output file name - click the Browse button [>>] to see the standard Save As utility display. The output file (viewed in Wordpad), will look similar to the following (shown in part).

```
Average spectra within selected bands:
                    Delta     Theta     Alpha    Fast Beta
          FP1:      0.363     1.499     2.470      0.670
           PZ:      0.432     1.680     7.375      1.578
          FP2:      0.360     1.456     2.623      0.718
           OZ:      0.238     0.928     3.655      0.883
           F3:      0.326     1.453     2.947      0.780
         FTC1:      0.213     0.967     2.083      0.596
           F4:      0.360     1.532     3.312      0.897
         FTC2:      0.271     1.054     2.629      0.805
           C3:      0.253     1.126     2.945      0.819
```
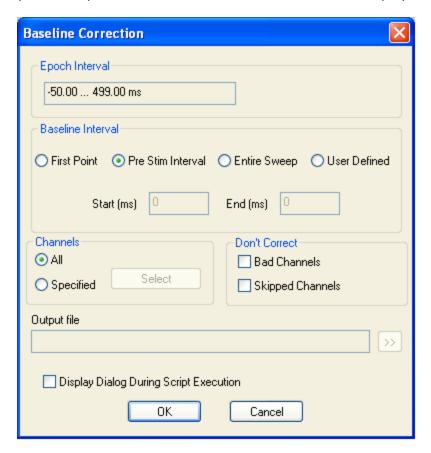
2.4.9   Baseline Correction

Baseline Correction (EEG, AVG; time domain) - The baseline correct dialog box allows you to modify the DC offset of the current average waveform. The mode option provides four methods for correcting offset: First Point, Pre Stim Interval, Entire Sweep, and User Defined.

📄 **Note**

It is ordinarily preferable to correct the baseline of single sweeps (from an epoched EEG file) prior to averaging. Of course, it is unnecessary to re-correct the baseline for any average waveform that is constructed from already-corrected single sweeps.

Select the option and you will then see the Baseline Correction display.

The top of the display shows the epoch interval. The next region gives the options for determining which part of the epoch you want to use for the baseline correction.
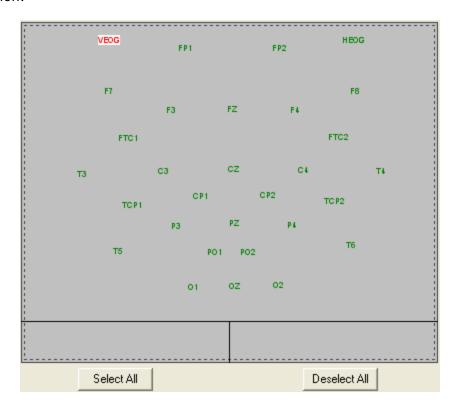
First Point - The First Point option simply sets the first data point to zero voltage (the voltage of the first point is subtracted from all data points).

Pre Stim Interval - Evoked potential studies typically use the pre-stimulus interval to determine the baseline correction. The voltages from the pre-stimulus data points are averaged, and that value is subtracted from all data points.

Entire Sweep - EEG sweeps are typically corrected for baseline drifting by using data points from the entire sweep. All points are averaged, and the average offset is then subtracted from each data point.

User Defined - On occasion you may wish to specify the range to use for baseline correction. When enabled, the **Start** and **End** fields will also be active, and you may enter the times (in ms) which will be used to determine the baseline correction. These points are then averaged, and the average voltage offset is subtracted from all data points.

Channels - You may also specify which channels you wish to have corrected. Enable the **All** button to correct all channels. Enable the Specified field, and the click the Select button, to select specific channels. A montage diagram will appear. Electrodes that are selected will be green, and electrodes that are excluded will be red. Move the mouse over an electrode label, and the fields below will show the label and the status. Double click on an electrode label to change its status. The Select All button will select all channels for correction; the Deselect All will exclude all channels for correction.

Don't Correct - You can also select to not correct Bad and Skipped channels by clicking in their fields. If you do not wish to Baseline Correct Bad channels, for example, enable that option .

For EEG files, you must enter an output file name and path. For AVG files, this line is grayed out. The correction is applied "in place", that is, it is applied directly to the data file. You must save the file to store the changes.

2.4.10 Blink Noise Reduction

Blink Noise Reduction (CNT) - The Blink Noise Reduction computation is similar to the Ocular Artifact Reduction transform. One difference is that online Blink Reduction uses a rolling average of N sweeps, where N is the number entered for Averages. Based on those sweeps, an internal LDR file is computed and applied to all channels except the trigger channel (the coefficient is 1.0 for the trigger channel, therefore the corrected channel would be a flat line), and any Skipped channels. Linear transmission coefficients are computed, and there is a point-by-point proportional subtraction, based on the averaged artifact in the trigger channel. Unlike the Ocular Artifact

Reduction transform, the Blink Noise Reduction routine lets you reject sweeps using Artifact Rejection criteria.

The Blink Noise Reduction transform is part of the Toolbox add-in software, and requires a Toolbox license (your dongle must be programmed for the Toolbox to access the option). Contact sales@neuroscan.com or techsup@neuroscan.com if you want to purchase the Toolbox. The operation of the Blink Noise Reduction transform (online and offline) is described in the Toolbox manual.

2.4.11 Coherence

Coherence (EEG; time and frequency domain) - Coherence is a frequency dependent measure of the degree of linear relatedness between two channels. This symmetric measurement is computed from a collection of EEG epochs sampled from either ongoing or event-related activity. High coherence implies that amplitudes at a given frequency are correlated across EEG samples, and, moreover, that tends to be a constant phase angle (or time lag) between the two signals. The concept of coherence can be understood by starting with the familiar concept of Pearson's correlation, which is defined as:

$$r_{xy} = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (x_i - \bar{x})^2 \sum_i (y_i - \bar{y})^2}} \quad (1)$$

where x_i and y_i is a pair of real numbers sampled on occasion i. The first step from this definition towards that of coherence is to extend it in a natural way when the number pairs are *complex*, as follows:

$$R_{xy} = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})^*}{\sqrt{\sum_i (x_i - \bar{x})(x_i - \bar{x})^* \sum_i (y_i - \bar{y})(y_i - \bar{y})^*}} \quad (2)$$

This extension of Pearson's *r* to complex number pairs will be referred to as *complex correlation*, which is the basis for computing *coherency* (see below). Therefore, the formula for coherency is exactly similar to the formula for Pearson's r, except that the calculations are performed with complex numbers. Thus, it has the form of a covariance divided by the product of two standard deviations. So, in the special case of real number pairs, equation (2) reduces to equation (1). For the case of general complex numbers, the complex conjugation operation has the following two desirable consequences that would not hold if it had been omitted: (i) the denominator is always a real number, and (ii) $R_{xy} = 1$ when $x_i = y_i$ for all pairings i. In general, the complex correlation is a complex number with arbitrary phase and a magnitude ranging between 0 and 1.

The next step is to consider x_i and y_i to be concurrently measured time series, such as EEG sweeps concurrently recorded at two scalp locations. In this example, $x_i(t)$ is the EEG value recorded at electrode x on sweep i at time t. Equation (1) may be

applied at each time to yield a correlation time series. Alternatively, each time series can be translated to the frequency domain as a frequency spectrum of complex numbers $X_i(f)$ and $Y_i(f)$, in which case equation (2) may be applied at each frequency.

The result is a complex correlation spectrum (also referred to as a coherency spectrum, except that the subtraction of mean values in equation (2) is not always implied by the latter term). Finally, the coherence spectrum consists of set of real numbers ranging between 0 and 1, and is obtained by squaring the magnitude of the complex correlation (i.e., coherency) spectrum numbers. For each frequency, this number measures the proportion of variance in the data that can be accounted for by a best-fit linear relationship between the two variables.
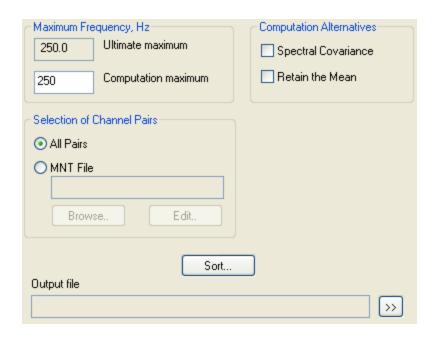
> *Coherence versus Coherency* - You will see that both terms are used, and they have different meanings from each other. Coherency includes phase information. Coherence is a real number, whereas coherency is a complex number. The transform actually computes the coherency spectrum, although only coherence is currently displayed. Coherence is the magnitude squared coherency. The relative phase between two channels is also derived from coherency (the arctangent of the imaginary part divided by the real part).

Statistical analyses with COH values. The COH and ERCoh values, ranging from 0 to 1, are NOT normally distributed. They behave like the square of Pearson's r values (the square root of the COH and ERCoh values resemble the absolute value of Pearson's r). Pearson's r can be Fisher z-transformed to become approximately normally distributed. Therefore, except for the "absolute value" qualification, Fisher's z-transformation (or others) should work well when applied to the square root of the COH and ERCoh values. *You should, however, consult with statistical resources to determine the validity of any further statistical analyses you perform with COH and ERCoh values*.

Follow these steps to compute coherence for an epoched file (.eeg):

After retrieving the EEG file, select Transforms from the Main Menu. *Note: The number of points in the EEG file must be a power of 2 (such as, 512, 1024, etc.). If the number of points in your data file is not a power of 2, use the Spline Fit transform to modify the number of points.* The file used in this demonstration was the *closed.eeg* file (which was epoched with a 1-512ms duration. The AD rate was 500Hz, giving 256 points per sweep).

Select Coherence from the Transforms menu, and see the Coherence display.

Maximum Frequency, Hz - The first field displays the Ultimate maximum frequency, which is half the AD rate, and is the maximum frequency that is calculated in the FFT spectrum. You may enter a lower number in the Computation maximum frequency field (up to the Ultimate maximum frequency). For example, it would not be unusual for the calculations to be conducted on frequencies well beyond those that might be of interest. This field lets you place an upper frequency limit on the calculations. Using a lower Computation maximum frequency will also speed up the calculations.

Selection of Channel Pairs - The electrode pairings field determines the pairwise electrode comparisons that will be computed. If you use the default All Pairs option, all pairwise comparisons are made. A subset of comparisons can be specified by a "bipolar" montage file. You must first have created the montage you wish to use. Please refer to the Montage Editor section in the Appendix at the end of this manual for more details. For demonstration purposes, select the All Pairs option.

Computation Alternatives - There are two additional computation choices.

    Spectral Covariance - Coherency at a frequency f for a pair of channels is the spectral covariance at f normalized by the product of the spectral standard deviations for each channel at f. These "spectral standard deviations" at frequency f are none other than the amplitude (square root of power) spectrum at f. Coherency is normalized so that it falls within the unit circle of the complex plane. Spectral covariance is non-normalized coherency, so it is sensitive to the power spectra of the two channels. For this reason, the results can be vastly different at different frequencies. Very large and very small values are possible. As a more primitive measure, it can be a useful complement to coherency.

    Retain the Mean - The usual formulas for coherence assume that we are dealing with a zero mean process. Thus, they do not explicitly subtract a mean value. In other words, it is usually assumed that there is not an event-related average response. It is safest to remove the mean, whether or not there is an

event-related response, and this is the default setting. Recalling the form of covariance divided by the product of two standard deviations, removal of the mean is equivalent to the subtraction of the mean inside the covariance and standard deviation formulas. Retention of the mean is equivalent to the non-subtraction of these means. This option is included for those who would like to verify that the standard coherence formulas, in fact, do not subtract the mean.
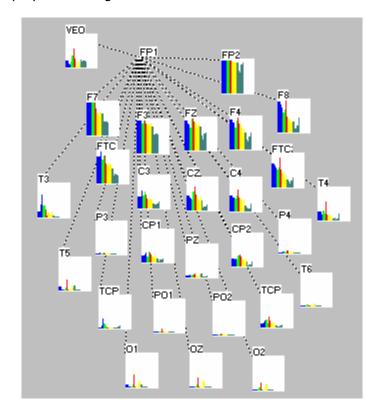
📄 **Note**

If you want to export user-defined frequencies, please use the Average Bands transform.

Sort... - The [Sort...] button accesses the Sorting Criteria display used in many of the transforms to allow you to select the sweeps that use wish to include. If you plan to sort by responses, please see the section entitled "**Some notes about response codes** [100]" for some important details.
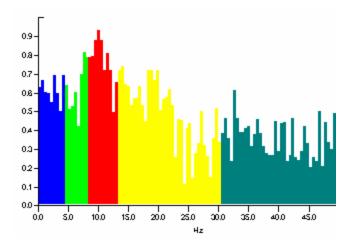
For demonstration purposes, leave these options disabled, and the sweeps not sorted. When you have made the settings you wish, click the OK button.

Output File - Click the [>>] button to select a folder and enter an output file name, then click OK.

A progress bar will track the computations, and you will then see a new multiple window display containing the coherence results.
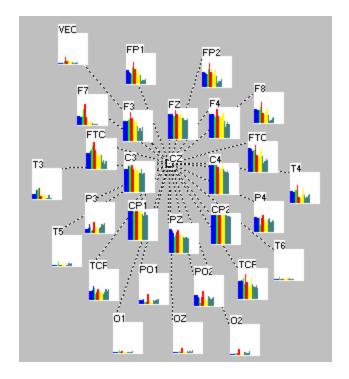
This display shows the coherence values between FP1 and the other electrodes. Zoom into the FZ electrode. You will see the coherence values ranging from 0 to 1.0 on the y-axis, and frequency on the x-axis.

The different colors differentiate Delta, Theta, Alpha and two Beta bands. The colors and the band width delineations are set in the **Multiple Windows Settings** under **Options** (described below).

Since we had selected **All Pairs** above, we can see the coherence values between any given electrode and the remaining ones. To see CZ, for example, click the CZ electrode display with the *right mouse* button, and select Set Coherence Reference .

You will then see the coherence values between CZ and all other electrodes.
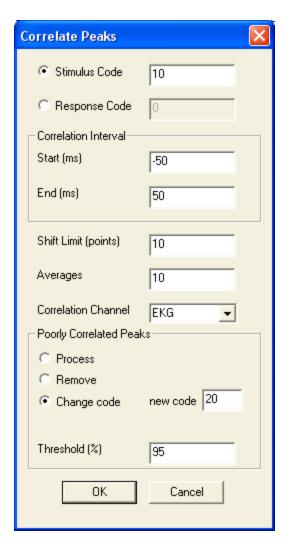
📄 **Note**

In prior versions of SCAN, it was possible to subtract one COH file from another COH file. This is not a valid operation (it is analogous to subtracting correlations from correlations) unless you first perform a transformation on the COH values. The SCAN software does not provide these transformations, so you will need to export the COH values to ASCII, and then perform the additional operations in a statistical package or with a program you write.

2.4.12 Correlate Peaks

Correlate Peaks (CNT) - The Correlation Peaks transform, unlike the EKG Noise Reduction transform (part of the Toolbox), has no option to use a voltage threshold to identify peaks; you must use either stimulus or response codes positioned at the peaks. In most cases, you will not have those events. They can be added easily using the **Voltage Threshold** or **QRS Detection** transforms (see example below). They can also be added manually using the **Insert Multiple Events** option (described below).

Selecting the transform displays the Correlate Peaks dialog screen.

Stimulus/Response Code. Select either the Stimulus or Response type of code, and enter the type value.

Correlation Interval. This functions the same way as in the EKG Noise Reduction transform. A series of intra-class correlations is performed between the **Correlation Interval** of the current sweep (using the **Correlation Channel** you select) and the same interval in the average artifact (relative to the trigger that has already been defined). The correlation interval is defined by the Correlation Interval **Start** and **End** times. The current sweep is shifted by the number of data points necessary to maximize the correlation, then the sweep is averaged in with the previous artifact sweeps. This process can reduce the variability in the average artifact, and thereby improve the subtraction result (using the **Subtract Average** transform). The **Shift Limit** option (measured in data points, not milliseconds) limits the range within which the interval can be shifted. (If you enter, for example 10 points, the span will be 10 points in either direction). It prevents the shifting from extending too far. Avoid excessive Shift Limits as they will place an increasing demand on processing time. As a general rule-of-thumb, the Shift Limit should encompass about half of the peak of interest. Say there is an EKG R wave peak with a duration of about 40ms, with an AD Rate of 500Hz. Try a Shift Limit of half the R wave span - 10 points (20ms).

You do not necessarily have to include the artifact trigger within the Correlation Interval. In some cases, you may want to use a different section for the correlation. The section might delineate a more stable waveform in the artifact.

Averages is the number of artifact sweeps that will be averaged to create the average artifact that is then correlated each successive artifact sweep. The average is rolling, that is, only the N most recent artifact sweeps are averaged, where N is the value you enter for Averages. You should average at least 10 sweeps - more if possible - for adequate EEG cancellation to occur in the average artifact.

Poorly Correlated Peaks. Poorly correlated is defined as any value less than the Threshold (%) you enter. The Threshold (%) is the correlation x 100. If the obtained (maximum) correlation exceeds the **Threshold** you select, that sweep will be included in the accumulating average artifact. If not, the sweep is excluded. This provides a method for ensuring that only genuine artifact sweeps will be included in the average artifact.
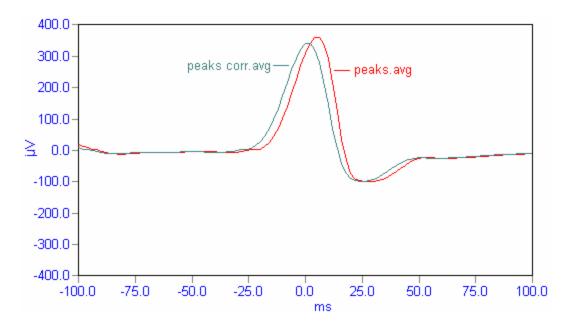
There are three ways to use this option:

Process. If you select this option, no correlation test is performed. The triggers will be positioned as well as possible, regardless of whether the Correlation Intervals are correlated or not.

Remove. If you select Remove, then the type codes will be removed for any sweep not having a correlation that reaches the Threshold you enter.

Change Code. When enabled, any sweep whose correlation does not reach the criterion will be given a new type code (that you select). The idea is to run the transform once, and identify the uncorrelated sweeps. Then run it again specifying that event code, and change the codes of any of those sweeps that do not correlate. Repeat as many times as is needed. In this way, classes of responses that are correlated within themselves - but not correlated with other classes - can be identified. The option was designed for use in files with difficult BCG artifact (where there are classes of BCG artifact that appear through the recording). The EKG Noise Reduction transform can then be used with each stimulus event code. The result is a more effectively corrected file (see the *MagLink RT* manual for more details).

When you apply the Correlate Peaks transform, it may appear as if nothing has happened. In fact, the event marks have been shifted to maximize the correlation. You can see this by creating epochs about the peaks just after using the Voltage Threshold transform to place them, then averaging those sweeps. Then apply the Correlate Peaks transform to the CNT file, and epoch and average the sweeps again. The new average will be based on the aligned peaks, rather than the type codes as they were originally positioned (even then, the difference may be very subtle in some files). In the example below, the original average is the *peaks.avg* file, and the correlated peaks is the *peaks corr.avg* file.
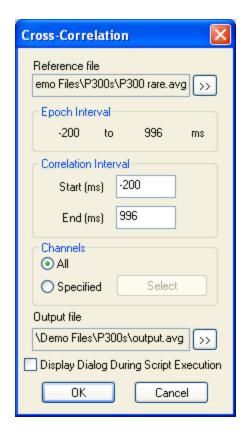
If you have the Change Code option enabled, you will see which event codes have been changed.

📄 **Note**

The Correlate Peaks transform does not have to be used solely with EKG/BCG Artifact Reduction. It aligns by waveform morphology rather than by event codes. It therefore acts like a Woody filter, and can be used with any waveforms that have event marks for the peaks. It may also be useful for other types of activity where "binning" of correlated activity is apparent.
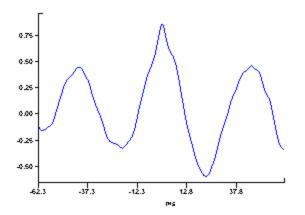
2.4.13 Cross Correlation

Cross Correlation (AVG; time domain) - The Cross Correlation coefficient statistic is created by computing the correlation between electrodes across a lag series. It can be used to examine the relationships between or among electrodes by shifting the waveforms in time, and then recomputing the correlations. The easiest way to explain cross correlation is by means of a demonstration. Retrieve the *sepnopblk.avg* demo file. Select **Cross correlation** from the list of Transforms. You will see the following screen.

You first need to select a **Reference file** to correlate with the working file. Click the Browse button ⟩⟩ , and select the *sepblk.avg* file from the Open File utility display. The Epoch Interval area shows the starting and ending time points of the epoch.

The Correlation Interval fields allow you to select the segment of the epoch to include in the analyses. For this demonstration, use the entire epoch. In the Channels field, select **All** channels. If desired, you may Specify the channels you wish to include (click the Select button, and select the channels from the montage display that will appear).
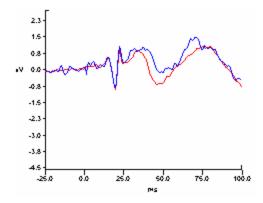
Enter the name and path for the Output File. After a brief pause for the computations, you will see a new multiple window display containing the cross correlation coefficients. Zoom in on the C3 electrode.

The y-axis displays Pearson's r correlation coefficients. The x-axis is time. The cross correlation statistic computes the correlation between two waveforms at various points in time, in a lagged fashion. That is, correlations are calculated first at time zero, where the two waveforms overlay each other with the same 0ms time point. Then, one waveform is lagged (to the next data point), and the correlation is run again. This is repeated in both directions from 0ms (lagging in the positive and negative directions along the x-axis). Note that the waveform in the display above is essentially symmetric about the 0ms time point. This is to be expected since the waveforms are shifted in both directions from zero.

Note that the x-axis extends to +/- half of the original total sample interval. As the waveforms lag farther and farther apart, there are fewer and fewer data points for the correlation. Therefore, we limit the lagging to half of the total interval duration. At 0ms on the cross correlation output file, the r value is the same as if you had calculated the Pearson's r statistic. The waveforms between the two files are very similar.

There is a large negative correlation at about 22ms in the figure above. To interpret this, you should compare the *sepnoblk.avg* and *sepblk.avg* waveforms at C3.
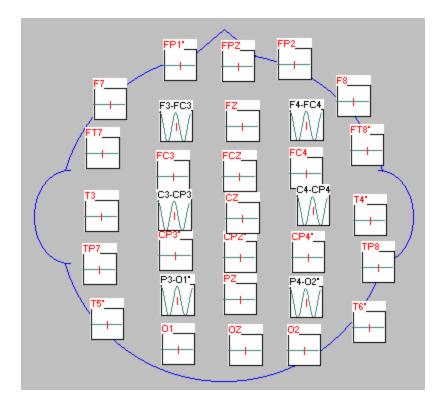

Now, imagine shifting the *sepblk.avg* waveform (in red) to the right by 22ms, and then recalculating the correlation for the entire epoch (or, rather, the remaining sections that still overlap). You can imagine that the resulting waveforms will be largely out of phase with each other, thus the negative correlation.

Files with mismatched labels. If you try to correlate two files where a subset of channels labels differ between files, the mismatch is detected automatically, and the following screen is displayed.
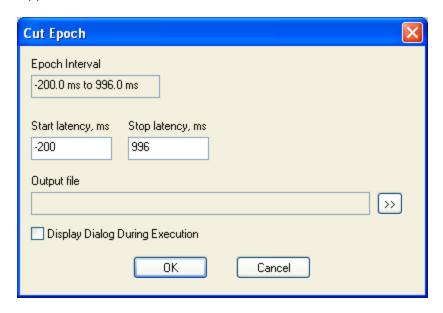
You then have the option of correlating only those channels that have matching electrode labels (the default option), or specifying the pairs of channels using a montage (.mnt) file. In the first case, you will see flat line for the mismatched channels. If you use a .mnt file, you will see results only for the designated pairs (with labels such as F7-F8, F3-F4, etc.). If you do not already have an .mnt file, you may click the Montage Editor button and create one. The resulting file will appear similar to the one below.

2.4.14 Cut Epoch

Cut Epoch (EEG, AVG; time domain) - The Cut Epoch option will create a new AVG or EEG file with Start and Stop time points that are less than the original file. After retrieving an AVG or EEG file, click Transforms, and the Cut Epoch. The Cut Epoch display will appear.

The current Epoch Interval is displayed at the top. Enter the desired **Start** and **Stop latencies** (in ms), then use the ⟩⟩ button to enter a file name and designate the path. Click the OK button to apply the transform, then a new multiple window display will appear with the new Start and Stop latencies.
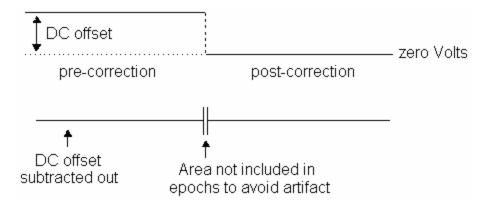
2.4.15 DC Offset Correction

DC Offset Correction (CNT) - This feature is only applicable to files recorded with *SynAmps/SynAmps^2*, and for those channels recorded with a DC high pass filter setting. Manual and automatic DC corrections during *acquisition* are described in the *SynAmps* and *SynAmps^2* manuals. The DC corrections described below may be applied to *recorded* data files.
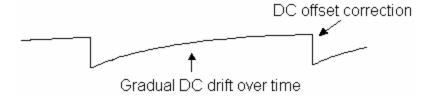
One of the things that we have observed with some regularity since we began offering DC amplifiers is that users who are accustomed to recording in AC mode are concerned by the drifting waveforms they encounter when first recording using a DC high pass filter. Generally we recommend that users who are not specifically interested in steady state, slow DC potentials should record in AC mode or in DC mode with high pass filter settings other than DC. Doing so will avoid or minimize the special concerns that are present with DC recordings.

Many of these special considerations for DC recordings are detailed in the amplifier manuals. If you are experiencing excessive DC drifting, or if you are recording in DC mode for the first time, we urge you to read the "DC electrode considerations" section.

When recording in DC mode, the focus of interest is the relatively slow drifting that is seen, for example, when the subject is in a readiness state, such as when anticipating a meaningful stimulus or preparing a response. DC offsets and drifting can also occur artifactually, and it is important to have the ability to remove spurious DC artifact. The distinction between DC offset versus DC drift is that DC offset is constant, steady offset from zero voltage. When a DC correction is made, that area immediately around the span of the correction is not included in the epoched data, as it would cause a large artifact (see diagram). *In other words, sections of the continuous file that have DC corrections will be excluded from the epoching process.* Continuous recordings should have only a few DC offset corrections, if any. These should be considered as permanent events that cannot be removed.

DC drifting is seen as a gradual shifting that may occur throughout the recording. Several DC corrections may occur during the course of the recordings.
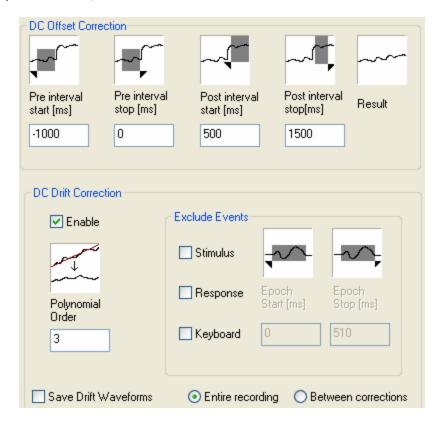

Henninghausen, Heil, and Rosler (1993, *Electroenceph. Clin. Neurophysiol*. 83:199-204) present a method of correcting DC drift for event-related epoched data. The basic principle of the method is to use a low-order polynomial to fit all data points that fall outside time intervals where (slow) event-related responses are expected; in particular, they use pre-stimulus baseline periods of the epochs. The low-order polynomial represents slow changes from the standpoint of the entire recording; these are identified with DC drift artifacts that can be calculated and subtracted at each time point (independently for each channel).

Our problem is to accomplish a similar correction for continuous and piecewise (start/stop) continuous data. In this case, note that we generally have the luxury of more data points that fall outside the time intervals where event-related responses are expected. According to the same principle that the authors have expounded, we should make use of all of these "contextual" data points to establish the drift function (i.e., all points that will not be included in epochs for event-related averaging, etc.). However, selection of an averaging window interval is somewhat arbitrary, will exclude some of the available context points, and may cause overlap problems for the general

case of variable inter-trial intervals. Moreover, note that use of an averaging window: (a) collapses all time points in the window interval to a single time point (say, the interval midpoint) and (b) only estimates the *constant* term of the polynomial in this interval (neglecting the linear, quadratic, etc., coefficients). For these reasons, the method described here treats each context point independently (without windowing). Advantages are: (i) the user does not have to worry about an appropriate window interval, (ii) all context points are included in the estimate, (iii) there is no loss of time resolution due to collapsing of points in an interval, and (iv) each point (taken together with all others) contributes to the estimation of *all* polynomial coefficients -- not just the constant term. Moreover, the same algorithm can be applied to event-unrelated data (e.g., eyes-open EEG), in which case all artifact-free portions of the data record are used to estimate the drift.

Retrieve your CNT file, and select DC offset correction from the Transforms list.

Below is a brief description of each of the parameters on the display.

DC Offset Correction - These fields let you specify the start and stop points of the intervals that will be used. These points are depicted graphically on the display.

Pre-interval start (ms) - Sets the start point of an interval to be used to estimate the DC level before a DC correction.

Pre-interval stop (ms) - Sets the stop point of interval before a DC correction.

Post-interval start (ms) - Sets the start point of an interval to be used to estimate the DC level after a DC correction.

Post-interval stop (ms) - Sets the stop point of an interval after a DC correction.

DC Drift Correction - This option performs a polynomial fit of the DC level for the entire correction interval. Correction coefficients are computed separately for each start/stop interval. Enable the field if you wish to perform DC correction. The order of the polynomial fit and the exclusion criteria are set in the fields described below. The **Save the Drift Waveforms** option will save the DC drift function to an AVG file for each start/stop interval.

Polynomial Order - Sets the order of the polynomial function used to estimate DC drift. If you are not sure what order to use, 1 is a straight line, 2 is a parabolic appearing function, 3 is more similar to a sine wave (an upward and downward parabolic function), and so on. Try different polynomial orders, Save the Drift Waveforms, and see what drift components are being removed with each order. Then decide which order best removes the drift component in your data files.

Exclude Events - The events listed below may be excluded from the correction.

Stimulus - Ignores DC values that fall within the current epoch (see below) for stimulus events.

Response - Ignores DC values that fall within the current epoch (see below) for response events.

Keyboard - Ignores DC values that fall within the current epoch (see below) for function key events.

Epoch Start (ms) - Starting point in ms of the epoch interval.

Epoch Stop (ms) - Stopping point in ms of the epoch interval.

Save Drift Waveforms - When enabled, you will be able to create and save an AVG file that contains the drift functions that were removed.

Entire recording / Between corrections - Prior to SCAN 4.3, the drift correction routine used the entire recording in the analysis. In the correction process, one of the early steps is to remove the DC offset corrections. In longer files with gradual drifting, or shorter files with more severe drifting, this could result in clipping of data toward the end of the file as the signals approach saturation. Beginning with the 4.3 version, you have the option to use the **Entire recording** (same as prior versions), or to use the **Between corrections** option. This avoids (or minimizes) the potential clipping problem by analyzing the sections between the DC corrections independently, rather than using the entire file.

Click on the desired options, and then click on the OK button.

📄 **Note**
DC corrections are applicable only to DC continuous files. Be sure to enable the

drift option before performing any transform such as the Epoch operation. To compare the effects of DRIFT correction on an averaged ERP, first, perform the DC correction with the drift option turned on. Next, epoch the file into the desired interval. Finally, average the EEG file created from the epoch procedure.
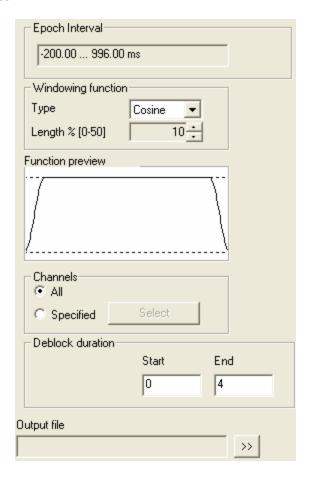
The actual steps that the algorithm employs are as follows:

Step 1. Scan the event table for start/stop events. This determines the number of discontinuous pieces in the CNT file, and starting point numbers for the boundaries.

Step 2. Scan the event table for physical DC correction events. This determines the number of DC corrections, the point numbers where they occur, and the cumulative offset that should be added to points following the corrections.

Step 3. Scan the event table for points to include in the analyses. This counts the number of contiguous intervals to include in the analysis, with starting point number and stopping point number for each interval. These intervals exclude artifact-rejected regions as well as regions that contain event-related responses (as specified by the user).

Step 4. Scan through the continuous file to accumulate certain sums-of-products. If the polynomial order is N, there are N+1 polynomial coefficients to estimate (starting with the constant term). Values are accumulated in an (N+1) by (N+1) symmetric matrix **B** as follows. If T is the time of the present point, we will add $T^i T^j$ to the ij-entry of the matrix. Values are also accumulated for an (N+1)-by-M matrix **C** (where M is the number of channels) as follows. If Y_k is the value of the current time point at channel k (adjusted by cumulative offsets, as required), then we add $Y_k T^i$ to the ik-entry of this other matrix. These need to be accumulated separately for each contiguous piece (between start/stop markers).

Step 5. Solve for the polynomial coefficients, a_k for each channel k. The equation to solve is: **$Ba_k = C_k$**, where **C_k** is the k-th column of C. We can use LU-decomposition of **B** with back-substitution. This also is done separately for each contiguous piece.

Step 6. Correct the data. Subtract the fitted polynomial function values (for each channel and for each contiguous piece) from the original values for all the time points (including previously excluded points).

Step 7. To save the corrected file, select **File → Save As** (or click the 🖫 button), and enable the ☑ Make DC correction permanent option.
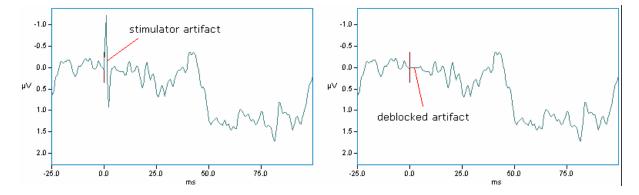
2.4.16 Deblock

Deblock (CNT; time domain EEG and AVG) - The Deblock option has a similar function to Deblocking with the *SynAmps* and *SynAmps*[2] amplifiers, and it can be performed offline. It is used to replace, for example, SEP stimulus artifact with a flat

line. Windowing is performed to minimize any abrupt transitions at the beginning and end of the flat lines.
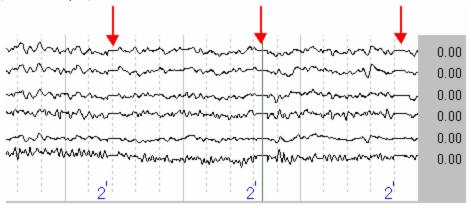
Selecting the transform displays the dialog box shown to the right. Select a **Type** of Window and the **Length** for the taper. Then select All channels, or you may specify only certain channels. In the Deblock duration region, **Start** and **End** define the limits of deblocking. With CNT files, you will also see the **Trigger** field. Enter the event code number about which you want Deblocking to be applied. An output file is required for CNT and EEG files; Deblocking is performed "in place" with AVG files and no output file name is required.

In the example below, Deblocking was performed on the demonstration file - *sepnoblk.avg* - from 0 to 4ms, using a Cosine Window with a 10% taper. The SEP stimulus artifact was removed.

Had we applied it to a CNT file, where the stimuli were presented with a type code of 2, we could have removed the artifact by entering 2 in the Trigger fiel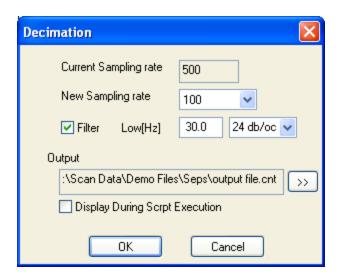d. (The Duration End time was increased to 100ms in the example below to make Deblocking more evident). The arrows indicate where Deblocking occurred. You can bracket the events by using, for example, -100 to 100ms.
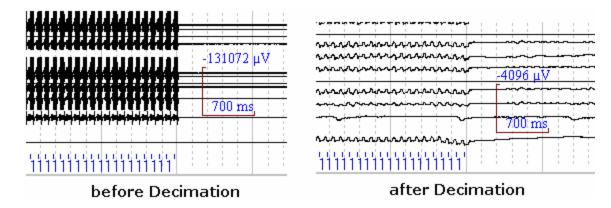
2.4.17 Decimate

Decimate (CNT) - The Decimate transform was created primarily for use with data files recorded in the MRI, and is used to reduce the AD rate (and file size). This is also one method for reducing the noise in the recording. Retrieve the CNT file, select the Decimate transform, and select a **New Sampling rate** from the list of pull-down options. Current Sampling rate is the AD rate of the retrieved file. Valid AD rates are only those rates that are lower submultiples of the AD rate in the data file. The submultiples are computed automatically for each file based on the Current Sample. Enter an output file name, and click OK. A new CNT file will be created with the lower AD rate (and smaller file size). Prior to decimation, an IIR low pass filter should be applied (passed four times) to correct for aliasing. Enter the Low Pass limit and desired slope (from the pull-down list).

In the example below, MR gradient artifact was greatly reduced following decimation from 10000 to 1000Hz, with a 30Hz, 24dB/oct filter (note the Scale tool difference).

before Decimation   after Decimation

For MRI analyses, it is better to use the fMRI Artifact Reduction transform (described in the *MagLink RT* manual), which includes decimation as an option.

2.4.18 Delete Bad Channels

Delete Bad Channels (CNT) - This option will create a new CNT file with the "Bad" channels excluded. Bad channels are designated in ACQUIRE, or in EDIT, from the Channel Attributes screen (or by *right clicking* on the channel label). To create the new file, select the Delete Bad Channels option under Transforms, and Save As display will appear. Enter a file name, designate the path, and click Save. A new single window display will appear with the "Bad" channels deleted.

2.4.19 Delete Rejected Sweeps

Delete Rejected Sweeps (EEG; time and freq domain) - This option will create a new EEG file containing only the sweeps that have been accepted. After retrieving an EEG file, click Delete Rejected Sweeps under Transforms. The standard Save As... screen will appear. Enter a file name, designate the path, and click Save. A new multiple window display will appear without the rejected sweeps.
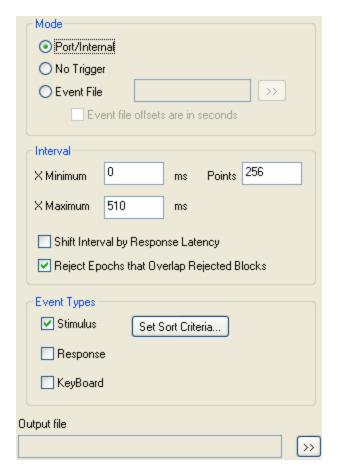
2.4.20 EKG Noise Reduction

EKG Noise Reduction (CNT) - Offline EKG Noise Reduction is part of the Toolbox add-in software. It is designed primarily for the reduction of ballistocardiogram and heart beat artifact encountered with EEG recordings in the MR bore. For more information about obtaining the Toolbox, please contact sales@neuroscan.com or techsup@neuroscan.com. If you have a Toolbox license, please refer to the Toolbox manual for operational details.

2.4.21 Epoch File

Epoch File (CNT) - After retrieving a continuous file, the Epoch File option is used to create an EEG file containing a series of sweeps. The epochs are created around either stimulus, response, or function key events.

After retrieving the CNT file, click Epoch File under Transforms, and the Epoching Properties window will appear. This is divided into three sections: Mode, Interval, and Event Types.

Mode - The Mode region is used to specify the type of triggers, or absence of triggers. For instances where the triggers were sent from STIM or a similar stimulus presentation package, the Mode will be **Port/Internal**. If you are epoching a continuous file with no triggers, and just want to do back-to-back epoching, select the **No Trigger** option. If you are epoching the CNT using an event file,

described below, select **Event File**.

Interval - The **X Minimum** and **X Maximum** fields (in ms) set the start and stop time points for the epochs. For example, if you want epochs to include the 100ms prior to the trigger to the 1000ms after the trigger, enter -100 and 1000.   **Points** is the actual number of data points you have within the specified interval. If you enter the X Min and X Max values and click in the Points field, it will calculate the number automatically. If you enter the X Min time and then the number of desired points, then click in the X Max field, it will automatically calculate the X Max time point. The latter option is useful if you plan to perform FFT or coherence analyses. These both require that the number of points be a power of 2. (See the   **Spline fit** transform if you have epoched or averaged data where the number of points is not a power of 2, and you wish to do an FFT or coherence analysis).

Note

If you have Stim[2], and are using the Mouse or Keyboard for the Response Device, please see the section entitled **Stim2 Response Devices** ⌐7⌐.

Shift Interval by Response Latency - This option provides the preferred method for performing response-locked averaging. To use it, you should 1) have merged the behavioral data from the STIM .dat file with the CNT file, 2) enable the option, and 3) enable the Stimulus field in the Event Types field. The Set Sort Criteria... button will be active, allowing you to do sorting by any of the appropriate fields, including the Correct field (which uses the Accuracy information contained in the .dat file). The program basically takes a given stimulus and shifts the zero time point forward by the response latency. Consequently, there can only be one response per stimulus. If the subject made more than one response, only the first one will be recognized.

In some paradigms, such as the "go - no go" instance, you may have responses to some stimuli and not others. In that instance, if you look in the .dat file, you will see some larger number for the Latency of the absent responses (such as 2.0). The number will vary depending on the timing of the presentation of the stimuli, but it will be a uniformly larger number than the actual responses. In this case, you should sort using a latency that is faster (smaller) than that number, so that these trials are excluded from the epoching process.

Response-locked averaging without the .dat file - If you do not have a .dat file from STIM, or elsewhere, you can still do response-locked averaging, but you will not have access to all of the **Set Sort Criteria** options. The program will create epochs around every Response Pad trigger that is in the file.

It is also possible to perform more limited response-locked averaging without the .dat file. If you have a situation in which the responses are not clearly linked to specific stimuli, such as, where there are intervening stimuli between stimulus-response pairs, use the **RespWin** transform to associate specific responses with specific stimuli.

Reject Epochs that Overlap Rejected Blocks - If you reject a block of data in a CNT file, you would normally exclude that section when you Epoch the file. If you enable this option, those epochs that overlap the rejected blocks will be

excluded. However, you can opt to include them by disabling the option.

Event Types - These options let you specify whether you want the epochs to be created around Stimulus triggers, Response triggers (after the .dat file has been merged - see Response-locked Averaging above), or trigger events placed from the Keyboard (function key events). You may sort the sweeps at the same time as you create the epoched file. Click the Set Sort Criteria... button, and the same Sorting Criteria screen will appear as described above under Average. Enter the criteria as desired, and click the OK button.

Click the >> button to select a folder and enter an output file name, then click Save. A bar will show the epoching progress. When it is completed, you will see a new multiple window display with the first sweep of the epoched file.

📄 Note
The Epoching transform checks to see if any of the following occur:

> *-would the epoch overlap the beginning or end of the file?*
> *-would the epoch contain a DC event?*

If either of these is true, the epoch will not be created.

2.4.21.1 Some notes about response codes

You may encounter some confusion when dealing with the STIM Response Pad codes. There are a few things to keep in mind that will help explain the way this works. First, when the subject presses button 1, 2, 3, or 4 on the response pad, you will see 1, 2, 4, or 8 appear in the CNT file. This merely reflects the bit value at the port. In the STIM .dat file, however, you will see response values of 1, 2, 3 or 4.

When you merge the .dat file (Merge Task Data), the response information for each specific stimulus (code, accuracy, and latency) from the .dat file is merged with the stimulus trigger in the CNT file. Upon resaving the CNT file, this information is stored, and these are the numbers that can be used for sorting. *Note that you do not need to have response codes in the CNT file to merge a .dat file, only the proper stimulus codes.*

However, if response triggers are present in the CNT file, this provides an additional method via which response-code sorting may be achieved. Therefore, there are two separate conditions which enable sorting by response information, and these are outlined below.

> *Sorting based on the code of the response triggers*. When you **Epoch** the CNT file, you will notice that there is a **Response** field under Event Types, and there is also a **Response** field if you select Stimulus, and then the Set Sort Criteria... button. If you select only the Response field under Event

Types, the [Set Sort Criteria...] button is grayed out. In order to perform this type of epoching, response triggers MUST be present in the CNT file. It will not be necessary to merge a .dat file. When the file is then **Epoched**, the epochs are created using only the response triggers in the CNT file. You will have sweeps created around *all* of the responses combined. When you **Average** that file, there is a **Sort Criteria** button that displays a screen identical to the [Set Sort Criteria...] screen. When you **Average** the EEG file containing the response sweeps, you can select which responses to include by indicating them in the Response field. *In this case, the responses are 1, 2, 4 and 8 .*

Sorting based on the response information in the .dat file.   Merging the .dat file gives you access to the latency and accuracy data that is contained in the .dat file, so merging the .dat file with the CNT file is necessary if that information is desired. Now, let's say you are going to **Epoch** the CNT file, but wish to create epochs around the stimulus triggers (NOT the response triggers). However, you only want to epoch around the stimuli where the subject responded with a certain code. To do this, select the [Set Sort Criteria...] button, and you see the **Response** field there. This is used to select only those *stimuli* that have the *merged* response types you enter in the Response field. It is still the *stimuli* that are being averaged, not the responses. *Since the .dat file has been merged in this case, the responses are therefore 1, 2, 3 and 4, rather than 1, 2, 4 and 8.* If you enter "4" in the response field, only stimuli having responses from the 4th button will be averaged. Note: this type of sorting is only possible AFTER a .dat file is merged.
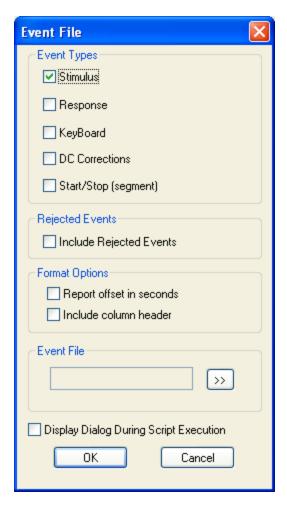
Care

Be careful when you enter the response values because you can encounter problems if you do not fully understand what you are doing. For example, *if you merge the .dat file, a "4" in the Response field is truly the 4th button; whereas, if you have not merged the .dat file, a "4" in the Response field indicates the 3rd button on the response pad, and so forth*.

Note

If you have Stim[2], and are using the Mouse or Keyboard for the Response Device, please see the section entitled **Stim2 Response Devices** [7].

2.4.22 Event File

Event File (CNT) - You can epoch a continuous file without first creating an event file (.EVT or EV2). However, using an event file provides more flexibility in epoching a continuous file. Event files are text files that can be modified prior to epoching — either manually with the aid of an editor, or automatically with the aid of a computer program of your own design. Event files also allow you to view all of the events that have been recorded in the continuous file. The Event file dialog display will appear.

Event File

Event Types
- ☑ Stimulus
- ☐ Response
- ☐ KeyBoard
- ☐ DC Corrections
- ☐ Start/Stop (segment)

Rejected Events
- ☐ Include Rejected Events

Format Options
- ☐ Report offset in seconds
- ☐ Include column header

Event File
[   ] [>>]

☐ Display Dialog During Script Execution

[OK]   [Cancel]

There are two types of event files created and used by the EDIT program - EVT and EV2. The original event files (SCAN 3 and SCAN 4.0) were the EVT type, and contain the following information.

```
(#)     (type) (resp)  (acc)   (RT)   (offset)
 1       10  0       0     0.0000  66884
 2        0  1      -1     0.0000  101444
 3       10  0       0     0.0000  175556
 4       10  0       0     0.0000  284228
 5        0  1      -1     0.0000  309316
 6       10  0       0     0.0000  393028
 7        0  1      -1     0.0000  425668
 8       10  0       0     0.0000  501700
 9        0  1      -1     0.0000  527044
10       10  0       0     0.0000  610372
11        0  1      -1     0.0000  640964
12       10  0       0     0.0000  719172
13        0  1      -1     0.0000  743108
14       10  0       0     0.0000  827844
15       10  0       0     0.0000  936516
```

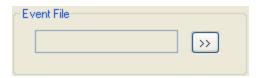Each row corresponds to an event in the CNT file. For each event, the first column

gives the event number; the second column gives event type; the third column gives response type; the fourth column gives response accuracy (1 = correct, 0 = incorrect, or -1 = no response); the fifth column gives response latency in seconds (no responses in the above example); and the final column gives a file offset in bytes which points to the event's location in the CNT file. The behavioral variables — response type, accuracy, and latency — will be set to determinate values only if a .dat file is specified when the event file is created.

(#)	(type)	(resp)	(acc)	(RT)	(offset)
1	2	1	1	0.3990	3106
2	2	1	1	0.2920	3398
3	2	1	1	0.2510	3715
4	2	1	1	0.2700	3997
5	2	1	1	0.3590	4256
6	2	1	1	0.2950	4588
7	2	1	1	0.2700	4905
8	2	1	1	0.2800	5197
9	1	2	1	0.3900	5514
10	2	1	1	0.2990	5756
11	1	2	1	0.4920	6023
12	2	1	1	0.2720	6319
13	2	1	1	0.2630	6607
14	2	1	1	0.2500	6942
15	1	1	0	0.2750	7281
16	2	1	1	0.3260	7612
17	1	2	1	0.4770	7893
18	1	2	1	0.4870	8160

In the initial release of SCAN 4.1.0, the sixth column was changed to display the POINT offset, rather than the BYTE offset. That is, the column contains the number of data points into the file where the event occurred. These event files also had EVT extensions. Beginning with SCAN 4.1.1, there are two event file types - EVT and EV2 (extensions). The EVT files are the same as and compatible with those used in SCAN 3 and SCAN 4.0. They all list the BYTE offsets. The EV2 files contain the POINT, or SAMPLE offsets. The EV2 files in SCAN 4.1.1 are the same as the EVT files created in SCAN 4.1.0.

The EV2 files are in some respects easier to work with than byte offsets: they are independent of the number of channels, the header size, and the number of bytes per sample.

In versions 4.1.1 and later, you will have the option to use either type of event file. When you prepare to run the Event File transform (described in more detail below), and click the browse button in the Event File field, you will see a standard Save File utility.
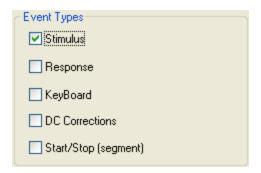

Click the pull-down arrow in the Files of Type field, and you will see the options to

select the type of event file you want to save. When you Epoch a CNT file using an existing event file, you will see a similar option for selecting the type of event file that you wish to use.

Event File (offset in Bytes) (*.evt)
Event File (offset in Points) (*.ev2)
Event File (offset in Bytes) (*.evt)

Follow these steps to create an event file: Retrieve the CNT file, and select Event File from the list of Transforms options. Select whether you want to include Stimulus, Response, Keyboard, DC Corrections (appear in the event file with 'DC' in the second column), and Start/Stop events (appear in the event file with 'SS' in the second column).
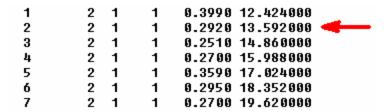
Event Types
☑ Stimulus
☐ Response
☐ KeyBoard
☐ DC Corrections
☐ Start/Stop (segment)

Then decide whether to include Rejected Events (events that occur within rejected sections of the file).

Rejected Events
☐ Include Rejected Events

Next, you have the options to Report the offsets in seconds (as opposed to points or bytes), and to include the column header information in the event file.
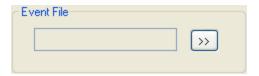
Format Options
☐ Report offset in seconds
☐ Include column header

If you select to **Report the offset in seconds**, you will see the last column as follows:

```
1      2  1    1    0.3990 12.424000
2      2  1    1    0.2920 13.592000  ⬅
3      2  1    1    0.2510 14.860000
4      2  1    1    0.2700 15.988000
5      2  1    1    0.3590 17.024000
6      2  1    1    0.2950 18.352000
7      2  1    1    0.2700 19.620000
```

If you Include the column header, you will see the labels at the tops of the columns:

```
 #      Type    Response    Acc     RT        Offset
 1       2         1         1     0.3990    12.424000
```

Lastly, enter a file name, using the Browse button as needed.

A Save As... screen will appear in which you may enter the file name and path for the event file (the .evt or .ev2 extension will be added automatically). The .evt and .ev2 files are text files, and may be viewed in most text editors.

📄 **Note**

When making an event file from appended CNT files, the SS events (the Stop/Start events inserted at the juncture of the CNT files sections and at the end of the file) will appear as events.

Epoching with an Event File - As mentioned above under Epoching, it is possible to perform the epoching process with the use of the event file. Retrieve the CNT file and select Epoch File under Transforms.

On the epoching display, select **Event File** under Mode, and click the browse button to access an Open File utility. You have the option for using either the EVT or EV2 versions of event files (described above). Select the event file for the particular data file. Then epoch the file as usual. Epochs will be created based on the event information in the event file (which may be modified in a text editor).

2.4.23 Event-Related Band Power

Event-Related Band Power (AVG, EEG; time domain) – This transform computes power (or amplitude) of induced or evoked event-related EEG activity (or both) in a centered frequency band as a function of time. Power computations are based on magnitude squared (μV^2 units), whereas amplitude computations are based on absolute magnitude (μV units). Induced activity is not phase-locked; evoked activity is. That is, the *evoked* variety of event-related band power (or amplitude) is computed on the time-locked *average*, such as with an AVG file, in which the value at a given time point is the average of all of the voltages at that point. Phase-locked, in this context, can also be thought of as time-locked. Evoked Band Power/Amplitude uses the time-locked, averaged data. *Induced* activity uses the *variance* calculated for a given time point across sweeps (it cannot be used with an AVG file, although AVG files may be appended together - in Script mode - and then used with induced activity). The mean is subtracted out. The result is not phase-locked, in the same sense as it is with evoked activity. Thus, *evoked* and *induced* activities are completely complementary aspects of the same data. *Event-related desynchronization/synchronization* (ERD/ERS) is computed by retaining both phase-locked and non-phase-locked activity (it is approximately the sum of Induced

and Evoked activity).

📄 **Note**

In Event Related Band Power (and Event Related Coherence), "power" is not computed using an FFT, and there is not the constraint where the number of points in the epoch must be a power of 2. Instead, complex demodulation is used. Filtering and complex demodulation occur as part of the same operation, as follows: 1a), the raw data for each channel are multiplied, point by point, by a pure cosine having the user-selected center frequency; 1b), in parallel with 1a), the same raw data are multiplied, point by point, by a pure sine having the same center frequency; 2a), the time series from 1a) is lowpass filtered by the half-bandwidth; and 2b) the time series from 1b) is likewise lowpass filtered by the half-bandwidth. This results in a complex time series: the real part comes from 2a) and the imaginary part comes from 2b). In step 3), the ERBP or ERCoh computations are performed using the complex time series.

Steps (1) and (2) make a bandpass filter. Step (1) shifts the entire spectrum "to the left" so that the center frequency is moved to 0Hz; and step (2) lowpass filters the spectrum by the half-bandwidth on either side of 0Hz (including the negative frequencies). This results in a symmetric bandpass around the center frequency, having the given bandwidth.

Complex demodulation is performed on the raw epochs. Averages and variances are computed across epochs on the complex time series, and the ERBP and ERCoh computations are based on these. (In addition, ERCoh also computes the covariances between channels).

The six basic combinations—{induced, evoked, ERD/ERS} x {power, amplitude}— are computed as follows. Here we treat "raw" power (μV^2) or amplitude (μV) scaling—alternative scaling options are treated below.

Induced Band Power is event-related *variance* in a frequency band of interest. Note that the formula for variance removes the mean evoked activity. Variance is computed at each time sample across trials, and the power spectrum is computed based on the variance measures, within the selected frequency band.

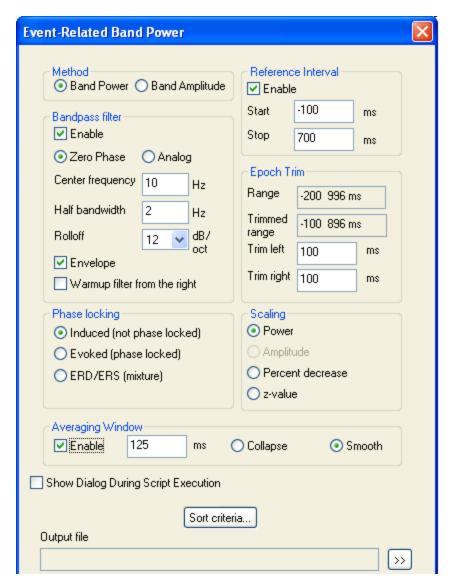*Induced Band Amplitude* equals the square root of Induced Band Power.

Evoked Band Power equals the magnitude squared of the average in a frequency band of interest, i.e., the power of average evoked oscillatory activity within a specified range.

Evoked Band Amplitude equals the absolute magnitude of the average in a frequency band of interest, i.e., the rectified average evoked oscillatory activity.

Event-Related Desynchronization/Synchronization (Power) equals the average magnitude squared activity in a frequency band of interest. This measure mixes induced and evoked responses (and is approximately the sum of the two).

Event-Related Desynchronization/Synchronization (Amplitude) equals the square root of the Event-Related Desynchronization/ Synchronization (Power) measure. Induced and evoked responses are mixed.

After making the basic choice between Band Power and Band Amplitude, there are six main sections to the display.

Bandpass filter – The parameters in this section are used to filter the data in a centered symmetric frequency band as an integral part of the transform. The bandpass filter is **Zero Phase** (i.e., for all frequencies, filtered output phase equals input phase), or you can select an **Analog** filter. The method of complex demodulation achieves symmetric roll-off and enables computation of the signal envelope. If the data have already been filtered in the band of interest—or if it is desired to compute event-related power/ amplitude measures for a broad band—then you can bypass the filtering option. For example, if continuous data have been filtered prior to epoching, then problems associated with filter warm-up time at the ends of the epoch can be avoided.

Center frequency - The Center frequency is the frequency at the center of the frequency band of interest. The filter is "tuned" to this frequency.
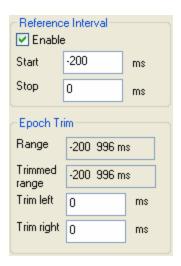
Half bandwidth - The Half bandwidth is used to specify the frequency range about the Center frequency. For example, if the Center frequency is 10Hz, and the Half bandwidth is 2Hz, then the frequency band is 8-12Hz (6dB down at the ends). In this example, maximum sensitivity is centered at 10Hz, and the filtered output of a pure 8Hz (or 12Hz) sinusoid has half the amplitude of the input.

Rolloff - Rolloff controls the steepness of attenuation outside the band and (simultaneously) the flatness within the band. The options are 12, 24, 48, and 96 dB/octave for zero-phase filtering, and 6, 12, 24 and 48 for Analog filtering. Flatness inside the band and steepness of attenuation outside the band both increase with increasing rolloff. There is a price to be paid for increasing rolloff in terms of more pronounced end artifacts ("ringing"), longer warm-up time, and slower computation. 48 dB/octave is the suggested rolloff. Rolloff characteristics are squared Butterworth.

Envelope – The method of complex demodulation permits simultaneous bandpass filtering and signal envelope computation. (See R.K. Otnes and L. Enochson, *Applied Time Series Analysis*, New York: John Wiley, 1978, pp. 212-215.) This option is especially useful for tracking amplitude modulations in time of narrow band signals. Computing the envelope is generally recommended (enabled by default).

Warmup filter from the right – Because the bandpass filter takes time to "warm up", artifacts appear at both ends of the epoch. Zero phase characteristics are achieved by filtering in both directions—forward in time, and reverse in time. "Warmup filter from the right" determines the order of filtering. When this option is disabled, forward filtering precedes reverse filtering, in which case warmup artifacts are predominant on the left (beginning of the epoch). When enabled, reverse filtering precedes forward filtering, in which case warmup artifacts are predominant on the right (end of the epoch). Use *Trim left* and *Trim right* to remove these artifacts.

Reference interval - The Reference interval is tied to the Percent decrease option in the Scaling section. When you calculate the Percent decrease, it must be in relation to some other section of the epoch. The Reference interval lets you specify that section.

Start / Stop - The Start and Stop times are used to specify the beginning and ending of the Reference interval. These must be selected from values within the Trimmed range. Typically, the Reference interval will be the pre-stimulus interval. In that case, Trim left should not be so long that the pre-stimulus interval is trimmed away completely. You can avoid this by Epoching the original CNT file so it has longer pre-stimulus and poststimulus intervals than desired, thereby allowing for the sections that will be trimmed.

Range & Trimming – Filter warmup artifacts at the edges of the full time range can be trimmed away. *It is recommended that generous-sized epochs, longer than otherwise required, be made from continuous data prior to this transform to permit adequate trimming.* The amount of trimming required can generally be determined by inspection. More trimming will be required as the filter Rolloff increases.

Range – The full available time range of input epochs.
Trimmed range – The time range of output epochs after trimming.
Trim left – Number of milliseconds to trim from the beginning of the epoch.
Trim right – Number of milliseconds to trim from the end of the epoch.

Phase locking - The Phase locking options allow you to select phase-locked, non-phase-locked, or both types of activity.
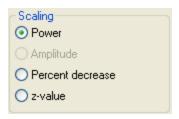

Induced - Induced activity is the non-phase-locked activity that typically dominates the raw recording. As described above, it is computed by removing the contributions from phase-locked activity.

Evoked - Evoked activity is phase-locked activity. As described above, this activity is computed from the average event-related potential waveform.

ERD/ERS - The Event-Related Desynchronization / Event-Related Synchronization option includes phase-locked and non-phase-locked activity, and is approximately the sum of the Induced and Evoked activity.

Scaling - The results in the final output AVG file can be computed with different Scaling options.

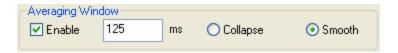*Power* – For Band Power, the Power scaling option will display the raw power in μV^2.

Amplitude – For Band Amplitude, the Amplitude scaling option will display the raw amplitude in μV.

Percent decrease - Percent decrease is tied to the Reference interval, and computes the decrease relative to the Reference interval. This is the option that has been used most frequently in the literature for ERD (see for example, Pfurtscheller and Aranibar, 1977), where ERD% = (band power, reference interval) - (band power, test interval) / (band power, reference interval) * 100.

Band power, reference interval are understood as the mean band power in the interval, and likewise for band power, test interval. That is, the band power is scaled per time sample. Desynchronization is expressed as a percentage of activity decrease relative to the Reference interval. Thus, ERD is positive, and ERS is negative.

Z-score - The z-score option converts the raw power or amplitude values to z-scores on a per channel basis, where the mean and standard deviations are computed across time.

Averaging window - The narrower the bandpass interval, the more you need to smooth or collapse the results to eliminate the ripples that may occur. If you selected the Envelope option above, the smoothing is *automatically* handled as a function of bandwidth (increased smoothing with narrower bandwidth). When the Averaging window is enabled, the window duration field becomes active. This is the duration of the span that is averaged for collapsing or smoothing the results. Some typical values found in the literature are, e.g., 125 or 250ms. If the bandwidth is increased, the averaging window can be made smaller. The Averaging Window is disabled by default.

Collapse - The collapse method averages the points within the Averaging window to a single point. The resulting file will contain fewer points than the original. The convention used here places the output point at the latency of the first point in the Averaging window.
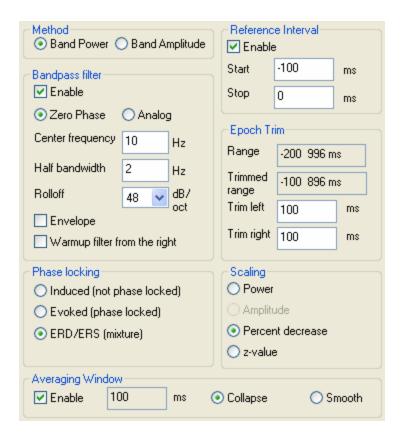
Smooth - The Smooth option averages points by using a moving window. Unlike the Collapse option, where there is a reduction in the number of points (through averaging throughout the window), the Smooth option does not reduce the number of data points.

Sort Criteria - Click the [Sort criteria...] button to access the standard Sorting Criteria dialog box to select various, trials, type code, etc. If you are using the Response field, please see the section entitled "**Some notes about response codes** 100" for some important information.
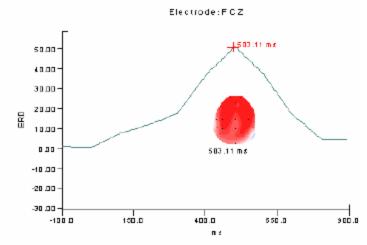
Output file - Click the [>>] button to select a folder and enter an output file name.

Using Event-Related Band Power - From the above descriptions you can see that there is a large range of possible options that may be employed. While analyses with event-related band power are relatively novel in the literature, there are some conventions that have emerged.
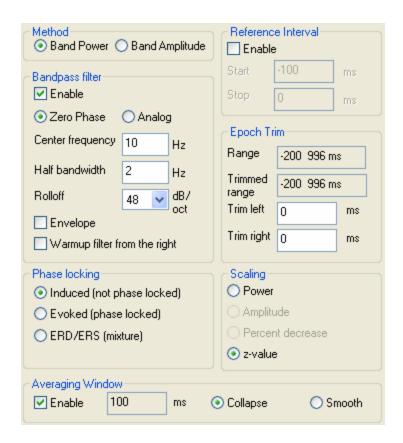
Traditional ERD - The more traditional method for computing event related desynchronization may be replicated here by selecting the following options. Select Band Power or Band Amplitude, as desired (we will use Band Power for this example). Disable the Envelope option, use the Reference interval and the Percent decrease scaling option, use ERD/ERS, and set the Averaging window span to 100ms, with the Collapse option. The settings below might be used to investigate the ERD (positive decrease) and/or ERS (negative decrease) at 10Hz. This example used the *P300.eeg* file, sorted for the RARE responses only (type code of 2), where the VEOG activity had been removed using the Ocular Artifact Reduction transform (you should always remove the EOG artifact before you compute Event-related band power).
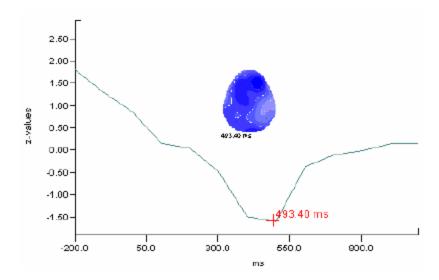
The resulting AVG file would appear as the following. The largest differences in Band Amplitude, in relation to the Reference interval, for 10Hz, occur around 500ms at the areas displayed in the 2D map.

Induced band power - Investigations of Induced band power are increasing in prominence in the literature. They may be replicated here by selecting the following options. Select Band Power or Band Amplitude, disable the Envelope option, disable the Reference window, select Induced activity, select the z-score option, and use an Averaging window of about 100ms with the Collapse option. This example used the *P300.eeg* file, sorting for the RARE responses only, with the VEOG artifact removed.
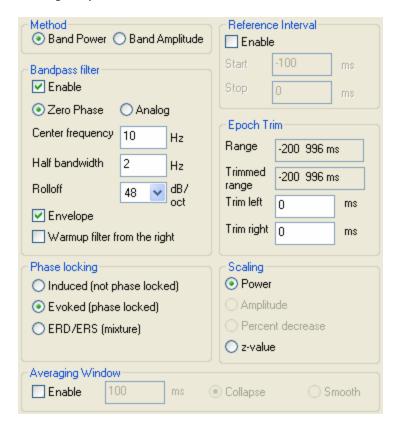
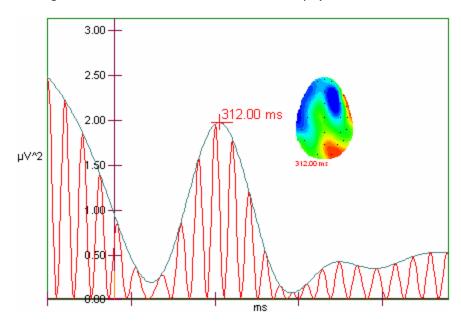The resulting AVG file would appears as follows.

The Envelope option - We recommend also that you perform your analyses using the Envelope option. As described above, this has a similar effect as the smoothing function, and it performs it automatically. We suggest the following as an additional way to investigate event-related band power. Select the Envelope option under Bandpass filter, disable the Reference interval, use Evoked activity (any of the options is OK), Power scaling, and disable the Averaging window. We will also perform the same calculations a second time without the Envelope option, in order to demonstrate its effect. In this

example, we sorted for the RARE responses only (Type 2; using the VEOG corrected *P300.eeg* file).

The figure below shows the results at O2 with and without the Envelope (the red oscillating line is without the use of the Envelope).

The results show that the greatest increase in the Evoked activity in the approximate 8-12Hz band occurs between 200-400ms at the right posterior

sites.

Below are some references that may be useful:

Kalcher, J. & Pfurtscheller, G.; Discrimination between phase-locked and non-phase locked event-related EEG activity. Electroencephalography and Clinical Neurophysiology; 1995; 94, 381-384

Klimesch, W., Doppelmayr, M., Schimke, H., & Ripper B.; Theta synchronization and alpha desynchronization in a memory task; Psychophysiology; 1997; 34, 169-176.

Klimesch, W., Russegger H., Doppelmayr, M., & Pachinger Th.; Induced and evoked band power changes in an oddball task. Electroencephalography and Clinical Neurophysiology; 1998; 108 (2) 123-150.

Pfurtscheller, G. & Aranibar A.; Event-related cortical desynchronization detected by power measurement of scalp EEG. Electroencephalography and Clinical Neurophysiology; 1977; 42, 816-826

2.4.24 Event-related Coherence

Event-related Coherence (EEG, AVG; time domain) - Much of the theory behind Event-related Coherence (ERCoh) has already been described in the Event-related Band Power section of the manual above. ERCoh uses the same method of complex demodulation, as described in Otnes & Enochson, 1978. The first application of this method to compute ERCoh is described in Thatcher, et. al., 1994. To summarize, the method of complex demodulation derives real and imaginary time series (a complex time series) from the original time series. The modulus—sqrt(re*re + im*im)—of this complex time series is the envelope of the original time series at the selected center frequency (e.g., the envelope of 10Hz activity).

ERCoh is computed from epoched EEG data using the coherence formulas already given in the manual under the Coherence section above. However, in this case, the frequency of interest is preselected, and the results are a function of time with respect to the event at time zero. The real and imaginary parts come from sweep-by-sweep complex demodulation rather than from sweep-by-sweep FFT. (Consequently, the data do not need to have a power of 2 number of points for ERCoh; see the Note near the beginning of the Event Related Band Power section above for more details).

Statistical analyses with ERCoh values. The COH and ERCoh values, ranging from 0 to 1, are NOT normally distributed. They behave like the square of Pearson's r values (the square root of the COH and ERCoh values resemble the absolute value of Pearson's r). Pearson's r can be Fisher z-transformed to become approximately normally distributed. Therefore, except for the "absolute value" qualification, Fisher's z-transformation (or others) should work well when applied to the square root of the COH and ERCoh values. *You should, however, consult with statistical resources to determine the validity of any further statistical analyses you perform with COH and ERCoh values*.

ERCoh applies mainly to epoched EEG files, but there is one variation that can be applied to an AVG file.

Type/Phase locking - The possible combinations of Type and Phase locking are

discussed below. As described in the Event-related Band Pass section above, *induced* activity is not phase locked; *evoked* activity is. That is, the *evoked* variety of ERCoh is computed on the time-locked average, whereas the time-locked average is removed from the *induced* variety. Thus, evoked and induced activities are completely complementary aspects of the same data.

Coherence / Induced (not phase locked) - This is the typical case as described above. The mean activity (phase locked) is removed, and the results are normalized in the usual way so that the final result is a number between 0 and 1. The usual coherence formulas apply.

Coherence / Both (mean activity retained) - Same as the previous except that the phase-locked (mean) activity is not subtracted away. Therefore, this result includes both induced and evoked activities.

Complex covariance / Induced - Same as Coherence / Induced except that the results are not normalized. The results are microvolts squared.

Complex cross-products / Evoked (phase locked) - The computation is applied to the mean activity which (of course) is not removed. Rather, the induced activity is ignored. There is no normalization. Thus, this can be applied to an AVG file. The results are microvolts squared.

Complex cross-products / Both (mean activity retained) - Same as Complex covariance / Induced except that the mean activity is not removed. The results have microvolts squared units.

Bandpass Filter - Everything in this section is exactly the same as the analog in Event-related Band Power. The envelope checkbox is not included because the envelope is always computed for ERCoh. Trim left / Trim right is also the same as for ERBP. Portions of the same information are presented below. (Please refer to that section above for more details).

Warmup filter from the right – Because the bandpass filter takes time to "warm up", artifacts appear at both ends of the epoch. Zero phase characteristics are achieved by filtering in both directions—forward in time, and reverse in time. "Warmup filter from the right" determines the order of filtering. When this option is disabled, forward filtering precedes reverse filtering, in which case warmup artifacts are predominant on the left (beginning of the epoch). When enabled, reverse filtering precedes forward filtering, in which case warmup artifacts are predominant on the right (end of the epoch). Use *Trim left* and *Trim right* to remove these artifacts.

Range & Trimming – Filter warmup artifacts at the edges of the full time range can be trimmed away. *It is recommended that generous-sized epochs, longer than otherwise required, be made from continuous data prior to this transform to permit adequate trimming.* The amount of trimming required can generally be determined by inspection. More trimming will be required as the filter Rolloff increases.

Range – The full available time range of input epochs.

Trimmed range – The time range of output epochs after trimming.

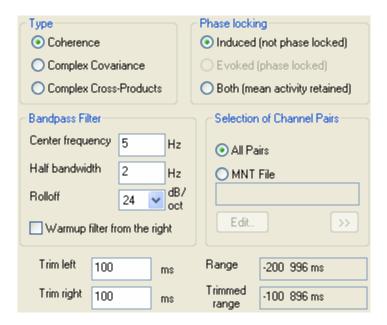Trim left – Number of milliseconds to trim from the beginning of the epoch.

Trim right – Number of milliseconds to trim from the end of the epoch.

Selection of Channel Pairs - This is the same as for the ordinary coherence transform. (Please refer to that section above for more details).
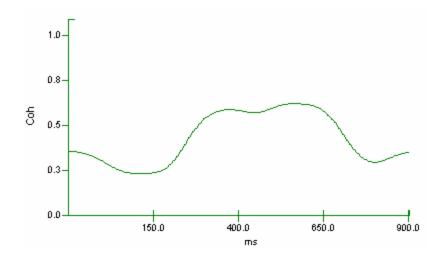
Sort Criteria - The Sort Criteria button displays the regular Sorting Criteria display through which you may select the desired sweeps to be analyzed. If you are using the Response field, please see the section entitled " **Some notes about response codes** 100" for some important information.

Output file - Click the >> button to select a folder and enter an output file name.
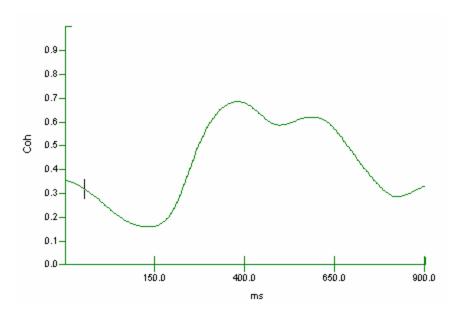
Example. Retrieve the *P300.eeg* demo file. Note that even though the points are not a power of 2, the ERCoh transform may still be applied. Set the fields as in the figure. This will be a basic illustration of ERCoh where the mean activity (phase locked) is removed, and the results are normalized so that the final results are numbers between 0 and 1. The center frequency of interest is 5Hz, and we will compute all pairs of channels. The sweeps have been trimmed by 100ms on each side. Sweeps were sorted for stimulus type codes of 2 (the Rare responses).
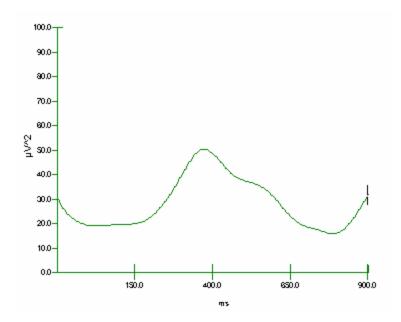

In this example, we set CZ as the Coherence Reference (*right click* inside CZ and select **Set Coherence Reference**). The results from most channels show some potentially interesting increases throughout the endogenous component span (T5 shown below).

The figure below displays the identical results, where the only exception was that we selected **Both** (mean activity retained) under Phase Locking, so the mean phase-locked activity was not subtracted out.
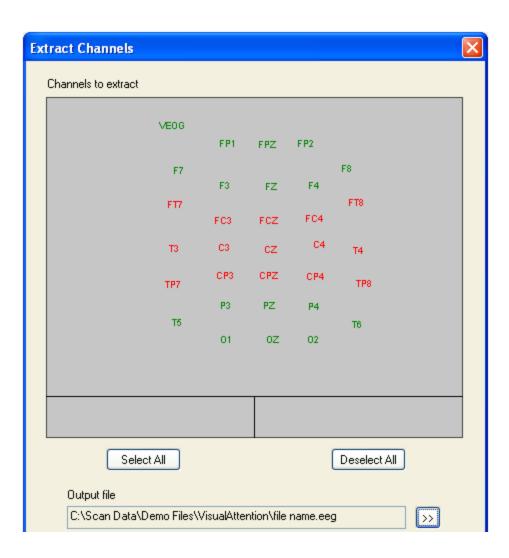

Slightly different results emerge when **Complex Cross Products**, and **Evoked phase locking** are selected (leaving all other settings the same). The results are shown for PZ, where there is an increase closer to the span of the P300 component.

Obviously, there are many ways to vary the ERCoh transform (different methods, frequencies, references, recording conditions, etc.). The above are just a few examples.

2.4.25 Extract Channels

Extract Channels (EEG, AVG; time and frequency domain) - The Extract Channels transform creates a new EEG or AVG containing only the channels you select. Retrieve a data file, then select the option. You will see the Extract Channels display. Select the channels to extract (the green channels will be extracted to the new file), then use the ⟩⟩ button to select a folder and enter an output file name. Then click OK.

2.4.26 Filter

Filter (CNT, EEG, AVG; time domain) - The Filter transform allows you to perform a variety of filtering options on your existing data. These include High Pass, Low Pass, Band Pass, Band Stop, zero phase shift (digital) and analog simulation types of filtering.

The basic details of the filtering operation are as follows. The zero phase shift filter has a cutoff frequency at 6 dB down, i.e., if you input a pure sinusoid at the cutoff frequency, the output amplitude will be half of the input amplitude. The rolloff characteristics are squared Butterworth: a forward Butterworth filter is applied followed by a reverse Butterworth. If you select the 12 dB/octave setting, for example, the output of a sinusoid at twice the cutoff frequency (for a low pass filter) is 0.2 the amplitude of the input. For a high pass filter, the same is true if the input sinusoid is at 1/2 the cutoff frequency.
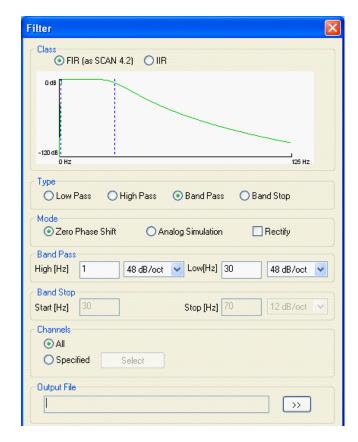
An analog simulation filter is a one-pass (forward) Butterworth filter, which is 3dB down at the cutoff frequency, i.e., the output amplitude is .707 of the input amplitude. The analog rolloff curve is Butterworth rather than squared Butterworth for the zero phase shift filter; otherwise, the rolloff selections have identical meanings for both filter types.

Users with previous versions of SCAN (3.2 and 4.0) should be aware that the 4.1+ version rolloff, in dB/octave, is twice that of the 3.2/4.0 version rolloff. That is because the 4.1 rolloff applies to the complete Butterworth squared filter (zero phase shift), whereas the 4.0 rolloff applies to each of the 2 Butterworth filters that are applied (first forward, then reverse). This change was made in 4.1+ in order to reflect the net filter characteristic rather than the component characteristics. Thus, the following table applies:

	3.2/4.0	4.2
	N/A	12
dB/oct	12	24
	24	48
	48	96

Differences between equivalent filter settings in the two versions are negligible. As a general rule, however, if you are in the middle of a study, we recommend that you either reanalyze your data using SCAN 4.2+, keep using your prior version until the study is complete, or analyze at least a subset of your data files using both packages to demonstrate that there are no differences.

To apply the Filter transform, retrieve your data file, then select Filter from the list of Transforms. The following screen will appear.

The Filter window is divided into 7 main sections: Class, Type, Mode, Band Pass, Band

Stop, Channels, and Output File. The diagram at the top of the window displays the results of the settings you enter.

Class. There are two classes of filters: Finite Impulse Response (**FIR**) and Infinite Impulse Response (**IIR**). SCAN 4.2 and earlier versions used FIR; IIR is being introduced with version SCAN 4.3. FIR (Analog) is a non-recursive filter in which only previous and current input values are included in the calculation of the new output values from the filter. FIR is therefore fundamentally phase blind to output since it does not consider the previous output in the generation of the next output. The nature of the FIR (Analog) filter permits a linear, predictable phase *error* that does not occur with FIR (Zero Phase). FIR (Zero Phase) does not introduce phase errors.

IIR is a recursive filter (in essence, a filter that runs backward), which keeps track not only of previous and current input values, but also the previously calculated output values. It is therefore slightly less prone to phase mismatches than FIR (Analog).

Care

Be careful when using the IIR filter with slopes steeper than 12dB, especially with faster sampling rates. For example, the filter may become unstable with 20kHz AD, when using a 24dB slope and a high pass up to 1.3Hz.

Type - You may select one of the following options:

Low pass filtering only (passes frequencies below the inputted setting, and attenuates faster frequencies). Clicking this option activates the Low (Hz) field in the Band Pass section below.

High pass filtering only (passes frequencies above the inputted setting, and attenuates slower frequencies). Clicking this option activates the High (Hz) field in the Band Pass section below.

Band Pass filtering passes frequencies within the Low and High pass settings (and attenuates frequencies outside of this range). Clicking this option activates the High (Hz) and Low (Hz) fields in the Band Pass section below.

Band Stop filtering passes frequencies outside the Low and High pass settings (and attenuates frequencies within this range). Clicking this option activates the Start (Hz) and Stop (Hz) fields in the Band Stop section below.
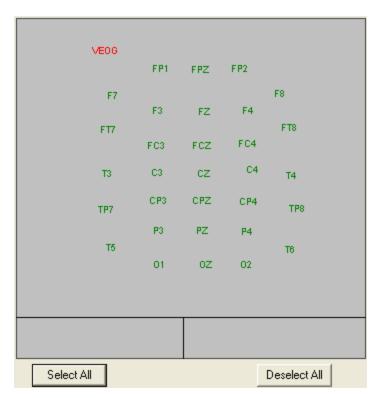
Mode (FIR only) - The Mode field allows you to select **Zero Phase Shift** filtering or **Analog Simulation** filtering. Zero Phase Shift filtering makes two "passes" through the filter, once in each direction. While somewhat slower that the analog filtering, it has no effect on EP component latencies. Analog Simulation filtering makes one "pass" through the filter, and, while therefore faster, it can result in EP latency increases. You may also select whether or not to **Rectify** the waveforms prior to filtering. This option is implemented primarily for EMG recordings, and is useful for identifying the onset of an EMG burst.

Band Pass - Part or all of this region will be active depending on which Type of

filtering you selected above. When active, enter the desired High or Low pass filter setting in the window(s), and use the pull-down arrow to access several different roll-off settings (in dB per octave). The higher the dB/octave selection, the steeper the filter roll-off. Note the changes on the top diagram as you select different dB levels. The High and Low pass values you entered will be represented by vertical lines in the diagram (to see the changes, click, for example, to the High pass field and then back to the Band Pass field).

Band Stop - This region will be active if you selected the Band Stop type of filtering above. Enter or select the desired options as described in the Band Pass section above. *Note: Band Stop filtering is basically the opposite of Band Pass filtering. Band Pass filtering affects frequencies primarily outside the designated range, and Band Stop affects frequencies primarily within the designated range.*

Channels - This toggle allows you to select individual channels for offline filtering, or to set all channels for the same filtering. Select the All button to apply the settings to all channels. To set channels individually, click on the Specified button, and a montage diagram screen will appear. Electrodes that are selected for filtering will be green, and electrodes that are excluded will be red. Move the mouse over an electrode label, and the fields below will show the label and the status. Double click on an electrode label to change its status. The **Select All** button will select all channels for correction; the **Deselect All** will exclude all channels for filtering.

Output File - If you are filtering a CNT or EEG file, this section will be active. AVG files are filtered "in place", and must be saved as a secondary step. Click the

Browse button to enter a new name for the filtered CNT or EEG file, or to overwrite an existing file.

Click OK when you are ready to proceed, and you will see a new display with the filtered data.
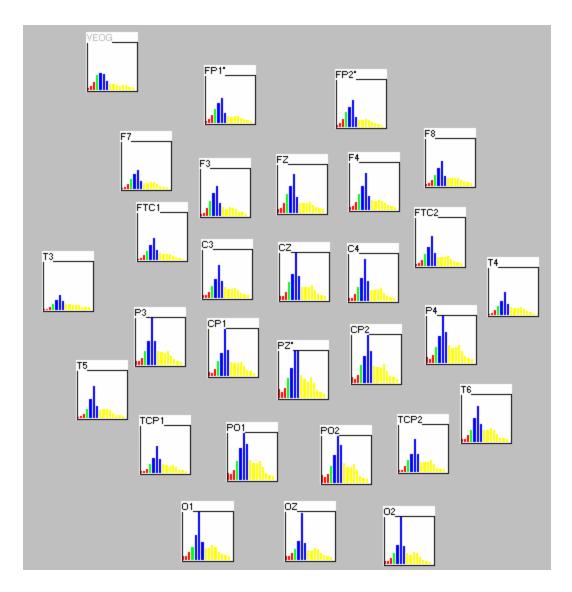
🗎 Note
If you create an averaged data file with Compute Standard Deviations enabled, and then Filter the averaged data file, the SDs will be lost. The SDs are computed across the [raw] sweeps. If you filter the average, the waveforms change, and the SDs are no longer correct. In this case, you should filter the epoched file *before* averaging the sweeps.

2.4.27 Forward FFT

Forward FFT (EEG; time domain) - The Forward FFT option is used to convert time domain data (real or complex) to complex frequency domain data. EEG files converted to the frequency domain via this transform store the full complex information in Cartesian coordinates, although the display shows the amplitude (magnitude) spectra for all channels and for all sweeps. To use this option, the number of Points must be a power of 2 (128, 256, 512, etc.). If the number of points in your data file is not a power of 2, use the Spline Fit option below to adjust it.

After retrieving an EEG file, select the Forward FFT option from the Transform list. Enter a file name and path, and click Save. When the computations are completed, you will see a new multiple window display with the power spectra for each channel. The program will compute the power spectra for the entire frequency range that is possible. If you do not wish to display the entire range, go to the **Frequency** section under **Overall Parameters**. In the Display area, change the **Start [Hz]** and **Stop [Hz]** values to display the range of interest, and click OK. Use the arrows on the Toolbar or the keyboard to step through the file.

You may restore the original time domain data by selecting the Inverse FFT option from the Transform list.

2.4.28 FSP Average

FSP Average (EEG; time domain) - If the brain potential you are interested in has a particularly low signal-to-noise ratio (SNR), then you will need to collect a large number of sweeps. For example, extraction of the auditory brainstem response (ABR) usually requires thousands of sweeps. This situation presents two related problems: (1) the SNR can vary considerably between recording sessions, so that the same number of sweeps may yield averages of different quality; and (2) the SNR can vary considerably within a recording session so that a "bad" block of sweeps can potentially degrade the average which is building.

The first problem (between-session SNR variability) could be handled by collecting sweeps until a prespecified SNR in the average is achieved — if there were a way of estimating the SNR as the average is building. A statistical approach to solving this

problem was detailed by Elberling and Don (1984) who proposed use of the F_{sp} ("single point F") statistic. Please refer to the above mentioned article for complete details. Briefly stated, the F_{sp} is essentially a ratio of two variances: the estimated variance of the signal between two time points, divided by the estimated variance of the noise at a single point. If certain assumptions and approximations are made, the sampling distribution of the F_{sp} statistic can be computed. For each target SNR that one wishes to achieve in an average, there is a critical F_{sp} value such that one can state with confidence p that the actual SNR equals or exceeds the target value. This critical F_{sp} value can be used as a stopping criterion for averaging. All averages obtained in this way — though they be constructed from differing numbers of sweeps — will have about the same quality of SNR.
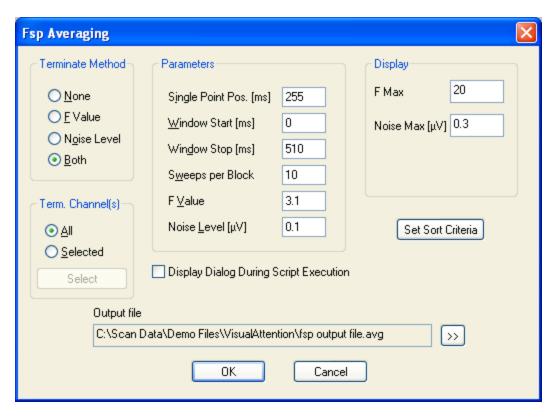
The F_{sp} statistic is computed for blocks of sweeps and saved in the file as well as to a data (.dat) file.

Perhaps of greater significance for offline analysis is a solution to the second problem of within-session variability of the background noise. If the total number of collected sweeps is divided into several blocks, a single point estimate of the background noise (i.e., variance about the mean) can be computed for each block. By "single point" it is meant that a fixed point in time for each sweep is chosen for this computation. There may be considerable variability in the background noise estimates for the different blocks of sweeps. Ordinary averaging would give each block an equal weight. Intuitively, however, one would prefer to assign a higher weight to blocks of sweeps with lower background noise. This intuition is fulfilled by a Bayesian weighting scheme: The total average is constructed by weighting each block average by its reciprocal single point variance, divided by the sum of all block reciprocal sp-variances (Elberling & Wahlgreen, 1985)

Thus, the Fsp average implemented so far is a Bayesian weighted average with computation of the F_{sp} statistic for each block, and for each electrode.

After you have selected a subset of sweeps (see above), follow these steps to initiate an F_{sp} average.

Retrieve your EEG file and then select Fsp Average from the Transforms list. The following display will appear. Listed below is an explanation of each of the parameters.

Terminate Method - Select one of the options below if you want to employ an F_{sp} termination method.

None - The analysis will continue through the entire data file.

F value - The analysis will stop when the current F_{sp} value equals or exceeds a specified F value. The F value field sets the terminate criteria. A typical value for this field for the ABR is 3.1. The F criterion will terminate the analysis when the terminate method is set to F Value or BOTH on the designated channels.

Noise Level - The analysis may be terminated if the background noise is lower than a specified value. The noise value field sets the terminate criteria. A typical value for this field is $0.02\mu V$. The noise criterion will terminate the analysis when the terminate method is set to **Noise Level** or **Both** on the designated channels.

Both - Analysis will be terminated if either the F_{sp} or noise criteria are met.
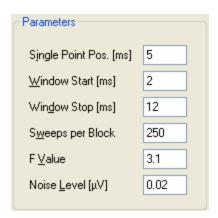
Terminate Channel(s) - The terminate channels fields allow you to specify which channels will be monitored for termination criteria:

All - will terminate if any channel in the current montage reaches a criterion.

Selected - will terminate on user selected channels. Click the Selected radio field, then the Select button, to see the standard channel selection display.

Parameters - The Parameters area contains the fields described below.

Single Point Positive [ms] - The point position value determines the location (in milliseconds) within the sample interval (X min to X max) of the single-point estimate of the background noise. Under normal circumstances this value would be placed within the bounds of the window start and stop point (see below).

Window Start [ms] - The window Start point determines the starting location (in milliseconds) of the response window. For the ABR a value of 2ms is typical.
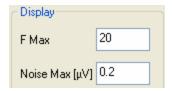
Window Stop [ms] - The window stop point determines the ending location (in milliseconds) of the response window. For the ABR a value of 12ms is typical (this gives a window of 10ms, which is appropriate when using an AD Rate of 20k).

Sweeps per Block - The sweeps per block value determines the number of sweeps that is collected for the ongoing within-block average. For the ABR a value of 250 sweeps is typical.

F Value - Input the desired F value that, when reached, will terminate acquisition. A typical value for the ABR is 3.1.

Noise Level [μV] - Input the desired noise level that, when reached, will terminate acquisition. A typical value for the ABR is 0.02μV.

Display - These fields are used to set the scaling range in the F_{sp} data display. This information is saved as part of the *.avg* file.
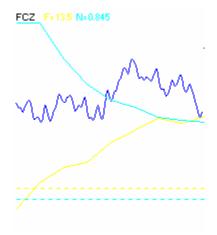
F Max - The F Max sets the upper limit of the range on the F value display. A typical value is 20, although you may go lower for a more sensitive display.

Noise Max - The Noise Max sets the upper limit of the Noise Level display. A typical value is 0.2 μV.

Set Sort Criteria -You may sort the sweeps that you wish to have included in the analyses. Clicking the Set Sort Criteria accesses the same Sorting Criteria display that is described above under the Average transform. From it, you may specify Trials, trigger Type codes, Response type, and so forth. If you are sorting by Responses, please see the section entitled "**Some notes about response codes** 100 " for some important information.

Output file - Use the button to select a folder and enter an output file name, then click OK. A new multiple window display will appear with the Fsp results for each channel.

The example used the *viscpt.eeg* file purely for demonstration purposes. More typically, the Fsp procedure has been used with ABR recordings. Its applicability to cortical EPs is not well known. The point here is to explain the information in the output file.

You may find that you need to rescale the F and Noise threshold levels (if you see flat lines instead of the rising F line and falling Noise line). To do this, go to the Fsp section under Overall Parameters.

In the Display section, enter more appropriate values for F Max and Noise Max, such as, 30 and 2, respectively. Your electrode display should look more similar to the one above.

The waveform in the middle of the screen is the block weighted average. The averaging process takes into account the variability in each block of sweeps. Those with a larger variance are given a smaller weight. In that way, the final average will be "cleaner" than if you had just averaged all the sweeps.

There are two dashed lines. The yellow one is the threshold for the F_{sp} statistic, and the light blue one is the threshold for Noise. The rising yellow line is the F_{sp} value that is calculated across the blocks of sweeps. Note that it is superimposed on top of the waveform, but does not correspond to time points on the waveform. The descending light blue line is the residual Noise estimate that is likewise calculated across blocks. In this example, the Fsp value easily reached the criterion, but the Noise estimate did not reach its criterion.
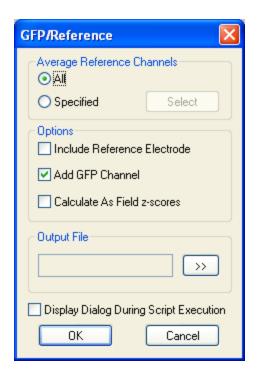
2.4.29 GFP/Reference

GFP/Reference (CNT, EEG, AVG; time domain) - Global Field Power (GFP) is a measure defined as the standard deviation across multiple channels as a function of time within a sample interval (Lehmann and Skrandies, 1980). The intention of the GFP measure is to quantify the instantaneous global activity across the spatial potential field sampled over the scalp. The result of this analysis is a waveform that represents the temporal changes in GFP. A peak of GFP at some point in time is thought to reflect a maximum (and a trough is thought represent a minimum) of the total underlying brain activity that contributes to the surface potential field. Peaks and troughs of GFP have been used to segment multichannel EEG records and to select moments of time for mapping of the potential field (Lehmann and Skrandies, 1986).

Since GFP is a standard deviation across channels, it is naturally related to deviations from the mean across channels, or, the common average reference. Therefore, the GFP transform also computes a common averaged reference across all channels (including Bad and Skip channels). Two new display channels will be added: the *GFP* electrode displays the associated GFP waveform, and the *AVG* electrode displays common averaged waveform.
Follow these steps to compute GFP for a series of waveforms:

After retrieving your CNT, EEG or AVG data file, click on Transforms and select the GFP/Reference option. You will see the following screen.

Average Reference Channels - These fields let you specify which electrodes to include in the analyses. The first one will include All channels (excluding those that you have designated as Skip or Bad channels). The Specified button, when enabled, will let you pick the channels manually that you want to include (click the Select button).

Options - The first field allows you to **Include the Reference Electrode** (when enabled), or exclude it (when disabled). The Reference Electrode is the electrode to which the relative electric potentials at the EEG leads are compared. When computing GFP, the program will use either the active EEG leads (N) alone (excluding Bad or Skip channels), or the active EEG leads plus the presumed inactive reference electrode (N+1). If you enable the field, the computations will be performed with N+1, and the activity from the reference channel will be included. Otherwise, the total N will be used.

The **Add GFP Channel** will display a new channel with the GFP results.

The **Calculate As Field Z-scores** option normalizes the GFP data by using the standard deviation of the topography/field, at each time point. Think of these as spatial Z scores. This is quite useful when making maps. Essentially, the data are "autoscaled" at each time point, so the map color scale is set in terms of standard deviations.
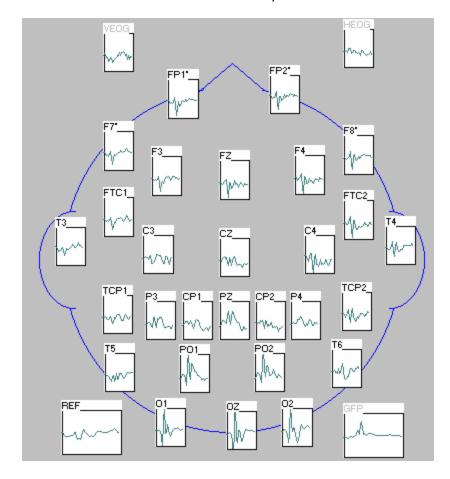
Output File - Use the Browse button [>>] to access the dialog box to enter a file name and path, and click Save, then OK. The new file will have channels for the REF and GFP results.
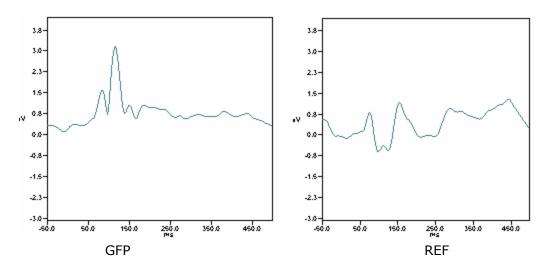
📄 **Note**
GFP should not be used with the .avg file results obtained from Event Related Band

Power - the results will not be valid.

Shown below is a multichannel recording to a reversing checkerboard stimulus. These waveforms have been transformed with the GFP operation.

Notice that the transform creates the *GFP* and *REF* displays and waveforms.

GFP   REF

Two maxima are found in this waveform: one at 70ms the other at 100ms. The maxima

correspond to the N70 and P100 responses located in the occipital leads.

2.4.30 Import Event File

Import Event File (CNT) - The Import Event File transform allows you to retrieve and apply an event file to a CNT file. The new event file can replace an existing event table, or be added to it. (The event table is that section at the end of a CNT file that contains the event information for the file). Therefore, if you have an event file that has, for example, stimulus type codes at every 1250ms, you could import the event file to one or more CNT files and thereby place the events automatically. If you are importing a CNT file from ASCII - which does not contain the event information - you can add the events from an event file you have created.

The Import Event File transform has a use in EKG artifact reduction, when not using the EKG Noise Reduction transform. In some cases (primarily involving BCG), it may be necessary to filter the trigger channel extensively in order for the **Voltage Threshold** transform be able to place events at the R wave peaks accurately. However, you might then want to use the correction with the unfiltered data. Therefore, you can create the event file from the filtered file, and the import the R wave peak events back into the original unfiltered file.

After selecting the Transform, the Import Event File dialog screen appears.

Replace existing event table. Enable this option if you want to replace the existing event table. This means that all previous event information will be deleted. If you do not enable the option, then the new events will be added to the existing event table, and the previous events will be retained.
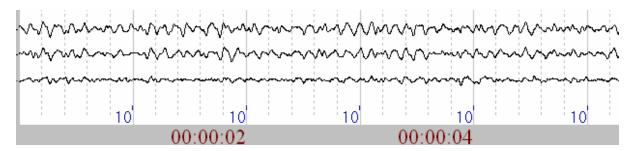
Report offsets are in seconds. When you create the event file (using the **Event File** transform), you have the option to report the point offsets in seconds. The default is ms. If you selected seconds when you created the event file, then you should enable the **Report offsets are in seconds** option when you import the event file. Similarly, if you have created the event file through some other method, then enable or disable this option, as needed.

Event File. Use the browse button to locate and retrieve the event file (.evt or .ev2 types; see Event File in the EDIT manual for a description of the two file types).

For example, the displayed .ev2 file contains Type 10 events at every 1000ms, for 5000ms, with no response, accuracy or latency information included. The AD rate was 500Hz, so a point offset of 500 equals 1000ms. The offsets are in ms, so **Report offsets are in seconds** was left disabled.

```
1       10  0    0    0.0000 500
2       10  0    0    0.0000 1000
3       10  0    0    0.0000 1500
4       10  0    0    0.0000 2000
5       10  0    0    0.0000 2500
```
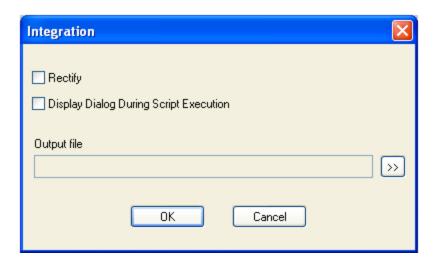
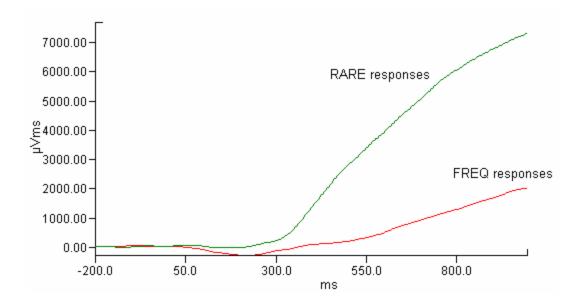Applying it to a CNT file with no events shows the new events that are added.

2.4.31 Integrate

Integrate (AVG, EEG; time domain only) - The Integrate transform computes an accumulation sum of the voltages across each sweep, where each data point is multiplied by the inter-point distance (or dwell time). The result is an approximation of the integrated sum of the waveform (corrected for variations in AD rates among files). You have the option to **Rectify** the waveform first. The transform is used with AVG and EEG time domain files only.

Clicking the option displays the following screen. Select whether you want to **Rectify** the waveforms or not, then use the [>>] button to select a folder and enter an output file name.

The transform is useful in mismatched negativity (MMN) and P300 types of paradigms. In the following figure, you can see the clear differentiation between the P300 rare ("oddball") waveform and the frequent (or standard) waveform.
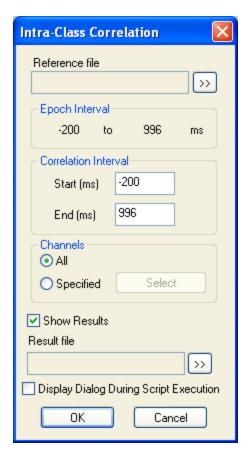

2.4.32 Intra-class Correlation

Intra-class Correlation (AVG, time and frequency domain) - The intra-class correlation statistic is a measure of overlap and related variability between two waveforms (from two files). Values for this statistic will generally range from 0, for dissimilar files, to 1, for identical ERP files. The intra-class correlation is similar to the omega-squared statistic found in analysis of variance. With ERP data, this statistic is sensitive to both wave shape and absolute voltage values. Thus, an intra-class correlation of .5 would mean that the working file waveform accounts for 50% of the variability of a comparison waveform. The intraclass correlation can be computed for all electrode sites over a specified time interval for waveform data. This statistic is useful in determining test-retest reliability.
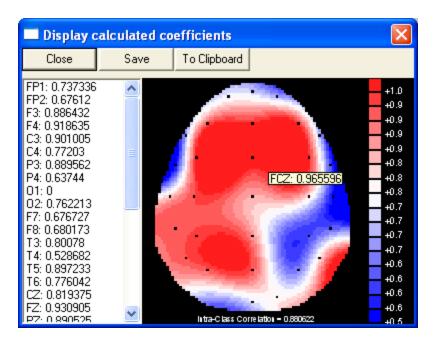
Retrieve your AVG file, and select the Intra-class Correlation option. The Intra Class

Correlation display will appear. Click the browse button [>>], and an Open Files utility will appear through which you may select the comparison file. This file should have the same number of electrodes, the same electrode labels, and the same number of points.

The Epoch Interval displays the span of the epoch. Enter the Start and End times for the Correlation Interval, that is, the interval that is used for the correlation calculations. Select **All** if you wish to use all channels, or select the **Specified** option and then the **Select** button to select individual electrodes. You can elect to **Show the Results** or not. Enter a file name and path to save the Result file. Click OK to proceed.

The correlation coefficients will be displayed in map form, as well as in a list. Position the mouse over an electrode site on the map, and the correlation coefficient for that electrode will be displayed.

Close - Clicking the Close button closes the coefficient display.

Save - Clicking the Save button opens a Save As... utility screen through which you may enter a path and file name for the output file. A text file will be written (the .dat extension is added automatically) that contains the list of electrodes and the correlation coefficients. The overall, or grand correlation is included.

To Clipboard - Clicking this button will send a list of the results to the Windows Clipboard, where the results may be Pasted in other Windows applications.

2.4.33 Inverse FFT

Inverse FFT (EEG, frequency domain) - The Inverse FFT option is available only after you have performed the Forward FFT transform. The Inverse FFT option will restore the data file to its original time domain form. After clicking the option, you will be asked for a file name and path for the new EEG file. Enter these and click Save. When the computations are completed, you will see a new multiple window display with the original waveform data.

2.4.34 Linear Derivation

Linear Derivation (CNT, EEG, AVG; time domain) - The linear derivation transform enables the creation of new channels as arbitrary linear combinations of existing channels. LDR files are used extensively with the Spatial Filter, Spatial SVD, and to a lesser extent with the Ocular Artifact Reduction routine (and elsewhere).

The linear derivation is guided by an ASCII linear derivation file that has the extension ".LDR". The LDR file contains a matrix of linear coefficients that are used to derive new channels from existing channels. The structure of the LDR file is as follows:

N M	<old chan 1>	<old chan 2>	...	<old chan M>
<new chan 1>	C_{11}	C_{12}	...	C_{1M}
<new chan 2>	C_{21}	C_{22}	...	C_{2M}
.	.	.		.
<new chan N>	C_{N1}	C_{N2}	...	C_{NM}

where
N is the number of new (derived) channels;
M is the number of old (recording) channels;
<old chan *j*> is the label used for the *j*th recording channel;
<new chan *i*> is the label to be used with the *i*th derived channel;
C_{ij} is the coefficient of the linear contribution made by recording channel *j* to the
     derived channel *i*.

Thus, at each time point, the value of derived channel *i* is computed by adding C_{i1} times the value of recording channel 1, plus C_{i2} times the value of recording channel 2, ..., plus C_{iM} times the value of recording channel M. The resulting N derived channels are saved to a new file.

Note
The order of the old channel labels in the LDR file need not correspond to the order of the labels in the current working file. It is only necessary that there should be a match for each old channel label. If the working file contains channels that are not named in the LDR file, these channels will be ignored in the linear derivation computation. However, an error message will be produced if the LDR file names channels that are not found in the working file.

Note
When creating or renaming new output channels, do not use spaces in the labels, and also avoid non-alphanumeric characters.

The LDR Montage Editor - Click the **Edit** button after selecting Linear Derivation from the Transforms list. The NS Montage Editor is displayed. (You may access the Montage Editor at any time from the icon on the Toolbar). This is discussed more thoroughly in Appendix B at the end of the EDIT manual. It provides a convenient means for creating and editing LDR files. At the beginning of that manual are some simple examples of LDR files.

After retrieving a data file and selecting the Linear Derivation option under Transforms, you will see the Linear Derivation display. This is basically an Input/Output screen, in which you select the LDR file that you wish to apply to your data file, and an Output File name for the transformed file.

Note that there is a field in which you may specify a label for the **Output units**. The default setting is for microvolts, but you may enter a different option by typing it in from the keyboard [millivolts] [Output units]. This assumes the data really are in millivolts. If you use the Spatial Filter to perform an SNR transform, the units are already labeled SNR. However, if you then apply the LDR file, you should enter SNR as the label for the Output units.

Let's look at a few examples of the uses of LDR files. The first will illustrate a simple example of an LDR file created in the Montage Editor that reduces an existing file into one with fewer channels. The second will take an LDR file created in the Ocular Artifact Reduction routine, and applies it to an existing AVG file. More examples may be found in the Spatial Filter and Spatial SVD sections below.

Creating an Output File with Fewer Channels - You may occasionally wish to create a new file with fewer channels to reduce the size of an exported file, make the file compatible with other files, and so forth. You can do this easily with the Montage Editor (see Appendix B for additional information). This will work with CNT, EEG and AVG files.

As an illustration, let's retrieve the *vep.avg* file, and create a new file containing only the basic 10-20 electrode positions. After retrieving the *vep.avg* file, click the Montage Editor icon , and the Montage Editor will appear. The current electrodes and positions will be shown on the right side of the display, as well as LDR identity matrix on the left (1's down the diagonal). Unclick the Head Contour icon to see the full size matrix.

(0:0)	FP1	FP2	F3	F4	C3	C4	P3
FP1	1	0	0	0	0	0	0
FP2	0	1	0	0	0	0	0
F3	0	0	1	0	0	0	0
F4	0	0	0	1	0	0	0
C3	0	0	0	0	1	0	0
C4	0	0	0	0	0	1	0
P3	0	0	0	0	0	0	1

Click the FTC1 button on the left side of the screen with the *right mouse* button, and select the **Delete Channel** option, and **Yes** to confirm. Click **OK** to the message saying you cannot create an Identity Matrix with an unequal number of channels. Repeat this procedure for all of the nonstandard 10-20 electrodes (FTC1/2, TCP1/2, CP1/2, and PO1/2).

When you are finished, click the **Save Montage File** option under File, and enter a file name (the LDR extension will be added automatically).

Now close the Montage Editor and select the Linear Derivation transform.

Select the LDR file you just created using the Browse button [>>], and then enter a file name for the Output File. Click Save, and you will see a new multiple window display with only the basic 10-20 system channels.

Re-referencing with LDR files. One of the more common uses of LDR files is in re-referencing (see also the **GFP/Reference**[130] command). Let's say you recorded a file with all channels referenced to A1 (left ear), and you also recorded A2-A1 as a separate channel. You want to re-reference the data to have a linked ears reference. For a given channel, such as CZ, you recorded CZ-A1 and A2-A1, and what you want is CZ-(A1+A2)/2. The solution is simple mathematics and an LDR file that combines the existing CZ-A1 and A2-A1 channels using a multiplier for the A2-A1 channel to give the desired linked ears reference. In other words:

(CZ - A1) + x(A2 -A1) = CZ - (A2 + A1) / 2, where x is the value of the multiplier representing the recomputation needed for the new reference.

$$CZ - A1 + x(A2 - A1) = CZ - .5A2 - .5A1$$
$$x(A2 - A1) = -.5A2 + .5A1$$
$$x(A2 - A1) = -.5(A2 - A1)$$
$$x = -.5(A2 - A1) / (A2 - A1)$$
$$x = -.5$$

The scalar for the (A2 - A1) channel is therefore -.5. The LDR file is the regular identity matrix (1's down the diagonal), with a -.5 in the column under A2. You might want to relabel the new channels to reflect the linked ears reference (CZ - A1A2). A section of the final LDR file should be similar to:

	CZ	PZ	CPZ	CP4	FC4	TP8	OZ	FT8	A2
CZ-A1A2	1	0	0	0	0	0	0	0	-0.5
PZ-A1A2	0	1	0	0	0	0	0	0	-0.5
CPZ-A1A2	0	0	1	0	0	0	0	0	-0.5
CP4-A1A2	0	0	0	1	0	0	0	0	-0.5
FC4-A1A2	0	0	0	0	1	0	0	0	-0.5
TP8-A1A2	0	0	0	0	0	1	0	0	-0.5
OZ-A1A2	0	0	0	0	0	0	1	0	-0.5
FT8-A1A2	0	0	0	0	0	0	0	1	-0.5

Applying the Ocular Artifact Reduction LDR file - If you have used the Ocular Artifact Reduction transform (described below), you will have noticed that an LDR file is created as part of the routine. Let's take a closer look at the LDR file created when the reduction routine was applied to the *viscpt.cnt* file. To get the file quickly, run the reduction routine with the Review options Off, and with no output CNT file - just the LDR file.
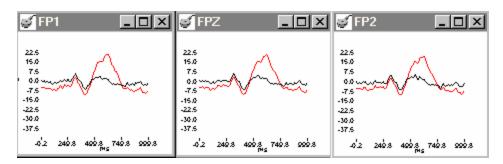
If you look at that output LDR file in the Montage Editor, you will see that it is a 32x32 matrix of numbers. Across the top are the 32 channels in the data file. Think of these as the input channels. Going down the left side are the same 32 channels. Think of these as the output channels. If you look at the intersection of, for example, FP1 input and FP1 output, you'll see there is a 1.0. At every intersection of input and output channels, there is a 1.0 (with the exception of the VEOG channel).

Now just look at the top line. FP1 has a 1.0, and the rest are all 0.0 until you get to the VEOG channel, which has something like -0.37. The key to understanding LDR files is to realize that each input channel is multiplied by the cell number, or weight, and all the channels are then summed to create the new output channel. In this example, FP1 is multiplied by 1.0 (unchanged), all the other channels are multiplied by zero (ignored), and the VEOG channel is multiplied by -.37. In other words, the output FP1 channel is equal to the original FP1 channel after subtracting .37 times the value at the VEOG channel - for every data point. That process is repeated for every channel.

Now that you see what the LDR file does, you can imagine cases where it may be applied. You do not need, for example, to create a new, corrected CNT file at the time you are performing the Ocular Artifact Reduction calculation. You can instead create only the LDR file, and then apply it to the final average files. Or, once you have the LDR file, you may apply it to other files acquired from the same person (under the same circumstances). To complete this demonstration, let's do the former. Take the original *viscpt.cnt* file (from which you have already created the LDR file), then epoch it and create a sorted average for, let's say, the first 100 sweeps (using the Sort Criteria button on the Average display, enter 1-100 for Trials). The resulting AVG file should have a noticeable blink artifact in the anterior channels.

Now, select Linear Derivation from the Transforms list. Enter the LDR file created in the Ocular Artifact Reduction routine, and click OK. Then enter an Output File name for the new, corrected AVG file, and click Save. The new multiple window display will show the corrected channels (the blink artifact will remain in the VEOG channel). Superimposing the files (using the Load

Comparison File option), we see that the LDR file did a good job of removing the blink artifact.
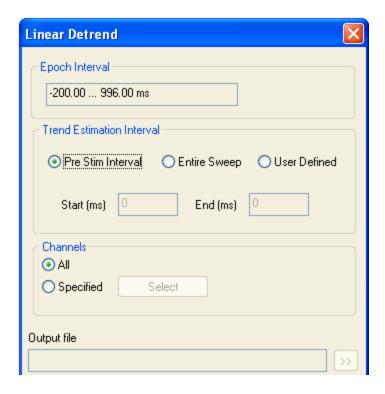

The waveforms in red are the uncorrected ones. For comparison's sake, you might try comparing the LDR corrected file to the one that was corrected with the Ocular Artifact Reduction algorithm (described below).

2.4.35   Linear Detrend

Linear Detrend (EEG, AVG; time domain) - Linear trends can be removed from averaged waveforms. This operation can be used to remove a drift in the data that extends beyond the sample epoch. This form of artifact can occur with AC coupled amplifiers with long time constants. A sudden impulse waveform can cause the filter to 'ring', generating a slow and large recovery waveform. HEOG may also cause a drifting from fronto-temporal sites. The detrend feature is performed by calculating a "line of best fit" to the existing waveforms, and then subtracting that from the waveforms.

Retrieve your EEG or AVG file, and select Linear Detrend from the Transforms list. The transform makes a permanent change in the data file (when you save the file). If you want to maintain the data in its original form, you should create a new file. (Note: we recommend that you always work with a copy of your original data files in any case, preferably backed up on an independent medium).

The Epoch Interval displays the epoch span of the data file. The Trend Estimation Interval lets you specify the interval during which the linear component is estimated. In SCAN 3 and 4, the only option was to use the **Entire Sweep**, and this may work well for most applications. However, you may instead use the **Pre-Stim Interval**, or set your own interval (**User Defined** with **Start** and **End** times you specify). The interval is used to estimate the linear component of the waveform, and this is then subtracted *from the entire sweep*.

You have the option of performing the correction on **All** Channels, or on **Specified** channels. If you select the Specified channel option, the **Select** button will become active, and you will see the Linear Detrend montage display from which you may select the channels to be corrected.

Click the [>>] button to select a folder and enter an output file name. Click OK to continue, and the correction will be applied to the original data.

2.4.36 Merge Task Data

Merge Task Data (CNT) - Continuous files can be merged with behavioral data such as stimulus/response codes, latency, and accuracy. The advantage of merging behavioral data into the file is that sorting decisions can be made based on different performance criteria at subsequent processing stages. For example, we might want to look at the difference between averaged responses to correct and incorrect trials. Alternatively, we might want to accept only those trials on which the subject responds within a certain response window. These types of operations can be performed when the behavioral data are included in the CNT file.

The behavioral data file is created in the STIM software (.dat extension). You will

need to physically transfer the appropriate .dat file(s) to the SCAN PC. Then, after retrieving your CNT file, select the Merge Task Data option from the Transforms list.

📄 Note

If you are using Stim[2] with the Mouse or Keyboard as the response device, you will notice that the responses appear in blue in the CNT files, i.e., as *stimulus* events. In the HTML files, there are Stim and Resp lines, where the Resp lines contain the response type codes that were sent to SCAN. Beginning with EDIT version 4.3.2, the response codes on the Resp lines will be converted automatically to *response* type codes when you Merge the Task Data (see **Stim2 Response Devices** 7).

You will see a Select Task file window from which you may select the .dat file that corresponds to the CNT file. Select Open and the merge will then occur. The merged information will not be visible, but will be there when you sort by accuracy, latency, etc.

If you do not have a STIM system, you can do the same thing with a text file you create. The .dat file should be formatted as follows. This is from the *viscpt.dat* demo file that you should have in your *\Scan Data\ Demo Files\Visual Attention* folder.

```
VISCPT......= Version 3.00
id..........= —
operator....= —
doctor......= —
referral....= —
institution.= —
subject.....= —
age.........= 0
sex.........= 0
hand........= 0
medications.= —
class.......= —
state.......= —
label.......= —
date........= 08/24/93
time........= 17:00:54
eduction....= —
occupation..= —
Trial Resp Type Correct Latency
—    —   —    —––    ––––
1      1      2       1      0.399
2      1      2       1      0.292
3      1      2       1      0.251
4      1      2       1      0.270
5      1      2       1      0.359
6      1      2       1      0.295
7      1      2       1      0.270
8      1      2       1      0.280
9      2      1       1      0.390
10     1      2       1      0.299
11     2      1       1      0.492
```

Include the header lines, the column titles, and line of dashes in your .dat file. "Trial" is just a consecutive numbering of trials. "Resp" is the mouse or STIM Response Pad

button that is pressed. "Type" is the trigger type code that is sent from the stimulus presentation system and seen in ACQUIRE. The numbers must agree with those seen in the continuous file. "Correct" designates whether the response was correct or not (1 = correct, 0 = incorrect). "Latency" is the time between the stimulus and the subject's response (in seconds).

📄 **Note**
The Response pad buttons are numbered 1, 2, 3, and 4 in the .dat file. In the CNT file in SCAN, you will see 1, 2, 4, and 8 instead. When sorting by responses, it therefore makes a difference whether you have merged the .dat file or not. Please see the section entitled "**Some notes about response codes** 100" for more details.

2.4.37 Ocular Artifact Reduction

Ocular Artifact Reduction (CNT, time domain EEG) - Of all the potential sources of artifact in EEG recordings, perhaps the most prominent and frequent are those contributed by eye movements. Ocular artifacts are particularly troublesome for the multi-electrode arrays employed in topographic mapping. Electrodes placed in the frontal and temporal regions of the scalp are susceptible to many types of ocular artifact. Indeed, it is safe to say that most topographical maps are seriously contaminated if no artifact removal method is employed.

One method for dealing with this problem is simply to exclude trials that contain significant eye movements. However, this method often leads to unacceptable data loss. In some instances, with difficult subject populations, it may be impossible to obtain artifact-free data by this method.

A more acceptable method is to "correct" the EEG for eye movements. A variety of computational and analog methods have been employed to remove eye movements from the EEG. In general, these methods subtract a fraction of an electro-oculogram (EOG) from the EEG. We have evaluated these procedures and have adopted a computational method that does an excellent job of removing the EOG. The method employs a regression analysis in combination with artifact averaging to produce a reliable and valid method for artifact removal (Semlitsch, Anderer, Schuster, and Presslich, 1986). A similar method is available with the **Blink Noise Reduction** program. A different method, using the **Spatial Filter** and **Spatial SVD**, is described in the Spatial Filter section.

The eye movement reduction algorithm - Listed below are the three steps used by the algorithm to reduce ocular artifact:

1. *A scan is made for maximum eye movement potentials.* The first step is to search the data for the maximum absolute voltage from the VEOG or other selected channel. A percentage of the maximum is used to define the beginning of the VEOG artifact in the next step.

📄 **Note**
When using the VEOG (or HEOG) channel in artifact reduction, it should have the same filter characteristics as the EEG channels, or distortion of the data may occur.

2. *An average artifact response is constructed.* Averaging is initiated when the ocular channel exceeds a percentage (typically 10%) of the maximum eye movement potential (determined in step 1). From this average, transmission coefficients are computed by estimating the covariance of the averaged potentials of the ocular channel with the EEG channels. The transmission coefficients are computed according to the following equation:

$$b = cov(EOG,EEG)/var(EOG)$$

Where b is the transmission coefficient, cov and var are the covariance and variance statistics, respectively. The coefficients are computed separately for all EEG channels.

At the end of stage two, you can review the artifact waveforms and artifact statistics before initiating stage three. This review is recommended to ensure that the algorithm has performed as expected. Under normal circumstances, with good eye movement recordings and a significant number of sweeps (30 or more sweeps), the algorithm will do a good job of estimating the coefficients. However, with fewer sweeps or noisy recordings, it is advisable to review the transmission coefficients before removing the artifact. It is possible, with erroneous transmission coefficients, to introduce more artifact than was originally in the data.
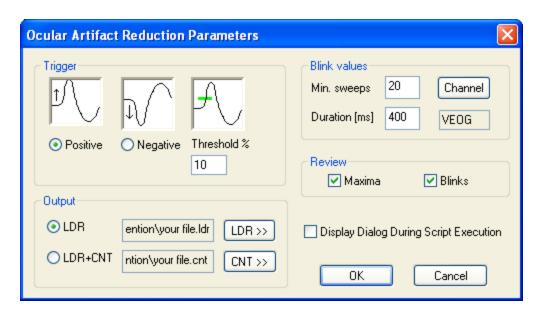
3. *The EOG is subtracted from the EEG channels on a sweep-by-sweep, point-by-point basis in the following manner*:

$$corrected\ EEG = original\ EEG - b \bullet EOG$$

The Ocular Artifact Reduction routine can be used with continuous (CNT) or epoched (EEG) files. There are advantages, however, to performing the reduction on a continuous file rather than an epoched file. First, in an epoched file, a blink or eye movement can occur at any point within the sample epoch. This means that there may be significant number of artifacts that either start too early or too late to be included within the epoch interval. Second, in an epoched recording it is possible to miss the artifacts altogether because they may occur between epochs. Since the algorithm becomes more reliable with increasing numbers of samples, a continuous recording that detects all the artifacts will actually improve the quality of the ocular reduction. Third, you cannot review the Maxima and individual Blinks with epoched files as you can with CNT files.

Using ocular artifact reduction - Follow these steps to perform the ocular artifact reduction (after retrieving the EEG or CNT data file):

1. Click on Transforms.

2. Click on Artifact Reduction and the Ocular Artifact Reduction Parameters display will appear.

The following is a description of each of the fields:

Trigger - Select either **Positive** or **Negative** direction. If you recorded VEOG activity with the + electrode above the eye, and the - electrode below the eye, the most prominent blink artifact will be in the positive voltage direction. The blink artifact should be going in the same direction in the EEG channels as well.

Set the Trigger **Threshold %** value. If set to 10%, for example, the routine will select points that are 10% of the maximum voltage detected to be the beginning points of a blink. 10% is a good starting point. If you are getting too many false positives, that is, too many sweeps that are not at the onsets of genuine VEOG artifacts, then try increasing the threshold.

Blink values - These fields let you set the **Minimum Number of Sweeps** that are required to construct an average artifact, the **Duration** (in ms) of the average artifact, and the **Channel** to use in the routine. There are no absolute, correct values to use in these fields. The recommendations we offer may work well for typical EEG or EP recordings, but you may find other settings work better for your particular data files. Typically you will need at least 20 good sweeps containing representative artifacts. The more there are, the more accurate the transmission coefficients. The Duration is not necessarily the complete duration of the blink artifact. It is more accurate to use the duration of the most stable, representative part of the blink artifact. We recommend about 400ms for the duration if you are using a CNT file to reduce the chances of selecting two segments from the same blink. With EEG files, where the epochs durations may be short, you may need to use a shorter Duration.

Realize that the object of the first and especially the second step of the reduction routine is to calculate the linear transmission coefficients. The more stable, or representative the averaged VEOG artifact, the larger the transmission coefficients will be (and the smaller the variance). That results in a more complete subtraction of the artifact in step 3. It is therefore not necessary, nor even advisable, to use long intervals for the averaged artifact.

Typically the longer intervals increase the variability, and thereby decrease the coefficients and accuracy of the subtraction. We recommend that you experiment with differing Durations to find the range that works best with your particular data files.

Click the [Channel] button to see a diagram of your electrode placements. Select the one that you wish to use for the artifact reduction routine (typically VEOG), and say OK. This should be a bipolar channel.

Review Maxima / Blinks - It is recommended that you enable both of these options, at least until you get a feel for the reduction. The **Review Maxima** option allows you to verify that the maximum voltage detected is from the largest blink, as opposed to some other type of high amplitude artifact. Review Blinks allows you to verify that only genuine blink activity is used in the construction of the averaged blink artifact. Recall that the first data point that reaches the threshold (set above) will be used as the beginning of the blink artifact. The threshold can be reached for any number of reasons besides a blink, such as, ocular drifting, electrode popping, EKG, etc. We recommend you verify that only genuine blinks be used in the construction of the average artifact. Adding other sweeps will result in a greater variability, a lower coefficient, a less accurate average artifact, and less accurate subtraction.

Note
The Review options are available ONLY with CNT files. With EEG files, the maxima determination and blink selection is performed automatically.

When you review the maxima or sweeps, you will see displays with intervals equal to the Duration you set. Rescale the data as needed.
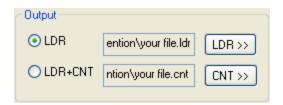
Output - The output options include an LDR file (linear derivation), or a new LDR plus a new data file. The program will always generate an LDR file that can be used to subtract artifact in other data files *from the same subject*. Click on the [LDR >>] button, and a standard Save As... file will appear. Enter a name, designate the path, and click save to continue.
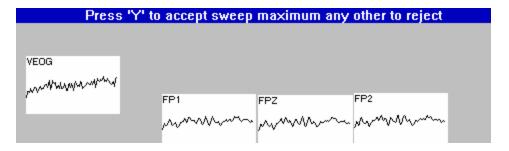
The LDR file (described in the LDR section above) is a numerical matrix, in which new channels are created as a weighted, linear combination of existing channels. In this case, a new EEG channel will be created where the corresponding data point in the VEOG channel is multiplied by the transmission coefficient, and that value is subtracted from the EEG channel. This is the same mathematical operation that occurs when you complete the artifact reduction routine. With the LDR file, you can retrieve a file from the same subject, apply the LDR transform, and subtract the artifact in the same way as if you had applied the artifact reduction routine.

For example, you might create the LDR file with the continuous data file and save it, without actually applying it to the data. You might then epoch the file, and create several sorted averages. You could then apply the LDR transform to the averages to reduce the VEOG artifact. You might also apply the LDR file to different data files recorded from the same subject, assuming that the recording conditions were identical. Doing this presupposes that the distribution

and intensity of the artifact is equal across files. It would not be a valid application to take an LDR file from one subject and apply it to a different subject, nor to the same where the recording was obtained under significantly different circumstances.

With CNT output files, click **LDR** or **LDR+CNT**, and enter a file name, using the browse buttons, if desired. If you have retrieved an EEG file, rather than a CNT file, you will have an opportunity to enter a file name and select a folder for the output file at a later point in the routine.
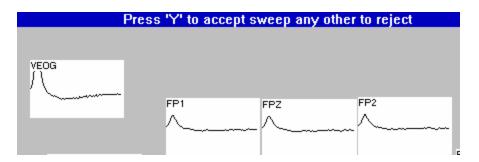
Click OK when you are ready to proceed. Let's assume you have elected to Review the Maxima and the Blinks. The algorithm will display the first

sweep, and will ask if this looks like a genuine maximum, that is, does it contain the greatest voltage peak for a genuine eye blink (in the VEOG channel)? Note that you can use the Up and Down arrows to change the display scale ⬆ ⬇. Chances are that this will not be contained in the first sweep. If you say Yes, the program will go to the next sweep that has a higher voltage value in it. If you say No, it will go to the next sweep. In either case you will see the same screen asking if this is a maximum. Typically, there will be some No's at the beginning until you see a legitimate looking blink. Then click Yes. From then on, the program will only select sweeps where there is a larger voltage. Ultimately, it will accept the blink with the highest voltage. Be sure not to accept a sweep with a higher voltage that is not from a blink. If you are sure that there are no artifacts in the file with voltages greater than that of the largest blink, you can save time by not enabling the Review Maxima option.
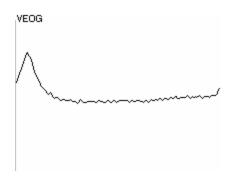
Once the Maxima has been determined, the program will then go through the file looking for blinks to use to create an average blink artifact. If you enabled the review Blinks option, you may manually select the blinks to use, as follows. The beginning of the blink artifact is defined as X% of the Maximum voltage, where X is the value you entered for Threshold (under Trigger; typically 10%). With a CNT file, the routine will search for the first point that exceeds the threshold value. If you look at your designated channel (e.g., VEOG), the very first point is the one that exceeds the threshold. The next X ms (where X is the Duration) should be part of a well defined blink.

If it is, Press "Y", and the next X ms will be used to create the average blink artifact. If you press any other key, the routine will skip the next X ms, and then find the next point that exceeds the threshold.

📄 **Note**
With CNT files, the routine will find the first point in the designated channels that meets the 10% threshold. When you are reviewing the Blinks, you will have the options to include or exclude the next 50, 200, 400ms, or whatever your Duration is, in the averaged artifact. The routine will then skip the Duration time, and find the next point that meets the threshold. If your Duration is short, the next point could easily be IN THE SAME BLINK. You do NOT want to accept the second one. You want to take the same section from each blink, such as, the ascending limb and peak section of the blink. If you accept separately the ascending limb and also the descending limb of the same blink, imagine what will happen when these are averaged together, and what that will do to the variability of the averaged blink (which you want to be as small as possible). We recommend using a Duration of about 400ms with CNT files (to avoid getting two sections from the same blink). With EEG files that have short epoch lengths, you may need to use shorter Durations. The typical blink that you should accept will look similar to the one below.

Continue reviewing the Blinks until you reach the end of the file. At that point, the routine will take over and calculate the averaged artifact and transmission coefficients.
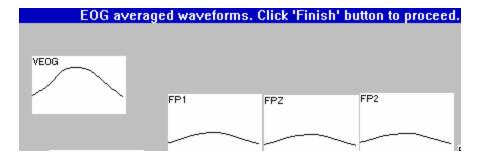
If you make a mistake in the process, and accidentally accept a sweep that is not a blink, you can use the *left arrow key* on the keyboard, or the left arrow icon ◀, to go backwards in the file.

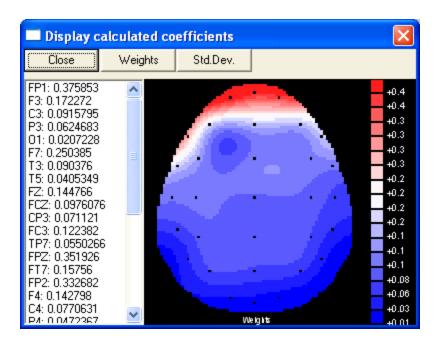When you reach the mistaken sweep, change the Accept status to Reject by

clicking the Reject icon on the Toolbar ✓✗ . Then click the right arrow icon, or the *right arrow* key from the keyboard, to get back to the previous point in the file where you left off the review. When you reach it, the right arrow control will no longer function, and you can continue saying yes and no to the sweeps.

If you did not elect to review Blinks, the routine will do it automatically. Realize, however, that the threshold may be reached for any number of reasons besides blinks, and those sections will then be included in the average blink artifact. This may result in a less than optimal subtraction of the blink. Generally, if you have a recording with blink artifact that is otherwise clean, the automatic routine will often do as good a job as your manual review.

When averaging is completed, you will see a multiple window display displaying the averaged artifact. Vertical eye movements and blinks have a pronounced effect on the frontal electrodes that diminishes as it moves to posterior electrodes.

Viewing the transmission coefficients - To see a complete list of the coefficients, the SDs, and the topographical distribution, click the **Show** button in the lower left hand corner Finish | Abort | Show . On the display screen you will see a list of the coefficients, and a map that shows their distribution. Click the **Std. Dev.** button to see the SDs and their distribution.

The transmission coefficients are typically much higher in the frontal leads than they are in the posterior leads. This is because the vertical eye movements and blinks spread in an anterior-to-posterior manner. Consequently, much more of the VEOG channel is subtracted from the FP1 and FP2 electrodes than from posterior electrodes such as O1 and O2. Horizontal eye movements, on the other hand, have a pronounced effect on lateral electrodes such as F7, F8, T3, and T4. The largest effects are in the anterior electrodes (F7 and F8), with the polarity being reversed across the left and right hemispheres depending on the direction of the movement.

As for the information conveyed by the SD (standard deviation) statistic, recall that the transmission coefficients are determined by a linear regression procedure. First an average artifact waveform is constructed for the EOG channel and for all EEG channels (these waveforms contain a number of points determined by the EOG points parameter). The transmission coefficient for a given channel corresponds to the slope of a least-squares best-fit straight line (through the origin) for a scatter plot of the EOG versus EEG waveforms (each point in time determines one scatter plot point). The standard deviation measures the goodness-of-fit for the estimated straight line through the scatter plot data: Smaller standard deviations are associated with better fits. (As a rough general rule of thumb, standard deviations of 0.05 microvolts or less are acceptable.) Noticeable distortion of the EEG data may result if the correction algorithm is applied in the case of large standard deviations.

If the anterior-to-posterior distribution of the averaged artifact looks reasonable, and the weights and SDs are appropriate, click the Finish button at the bottom of the display to remove the artifact. If not, click the **Abort** button to terminate the routine .

📄 **Note**

If you have recorded the VEOG channel such that its blinks are inverted with

respect to the EEG channels, you can still use the Ocular Artifact Reduction transform - the results will be identical. Remember to set the Trigger direction appropriately (Positive or Negative). This should reflect the direction of the main part of the blink, at its beginning, in the VEOG channel, not the EEG channels. (The Spatial Filter approach will also produce identical results regardless of whether the blink channel is inverted or not).
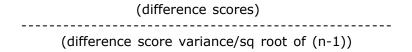
Care

Ocular Artifact Reduction is a skill that develops with practice. We recommend that you spend some time experimenting with different Durations, Thresholds, and manual versus automatic reviews, etc. Calculate and compare the final averages each time. You may find that there is very little difference between obsessing over which blinks to include versus using the automatic processing. If used correctly, it does an exceptionally good job of removing blink artifact. If applied inappropriately, it may alter the data in unexpected and undesired ways. Until you develop an acceptable level of expertise, we recommend that you carefully review the data - with and without Ocular Artifact Reduction - to decide if the results are accurate. This Transform does alter your data, and should be used judiciously.

2.4.38 Paired t-score

Paired t-score (AVG, time and frequency domain) - When comparing two related or matched groups, or when comparing test-retest measures on the same group, you can often use a Paired t-test to increase the likelihood for obtaining a significant difference. A related data set, for example, might consist of a group of subjects that received two treatment conditions. The hypothesis to be tested is that there is a difference between two treatment conditions. A two-stimulus P300 experiment provides another example of a related data set: A rare and a frequent average waveform is obtained for each individual within a group. Other designs might involve matched pairs of individuals, etc.

Suppose that a set of average waveform pairs from a two-condition experiment has been obtained across a group of individuals, and it is desired to test the hypothesis that there is a difference between the two conditions. The formula for calculating paired-t values is:

```
                    (difference scores)
     -------------------------------------------------------
            (difference score variance/sq root of (n-1))
```

where n is the number of individuals in the group.

The following steps should be taken to perform a paired t-test:

1. For each individual in both groups, make and save a waveform subtraction between the two conditions of the experiment. For example, in a RARE and FREQ comparison, retrieve the first subject's RARE waveform, select Subtract from the Transforms list, and then select the same subject's FREQ data file. Repeat for all pairs of files.

2. Make a group average difference waveform composed of the difference waveforms obtained in Step 1. Enable the **Compute Standard Deviation** option when forming the group average.

3. If the group average difference waveform has already been created, retrieve it as the working file.

4. Select Paired t-score from the Transforms list.

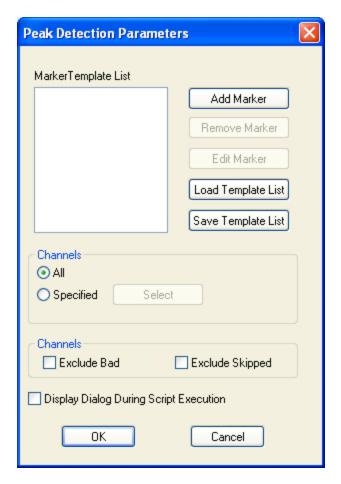5. Enter a file name and path for the t-score results file, and click OK.

A new multiple window display will appear containing the t-value waveforms.

📄 **Note**

The paired t-test can also be used to test if a waveform is significantly different from zero. For example, you may wish to check if an averaged waveform is significantly different from what would be expected from an average of noise-only sweeps. In this case, you must choose the Compute Standard Deviation option when computing the average waveform. The n value for the above paired t-value formula is in this case the number of sweeps included in the average (as opposed to number of individuals in a group). Then, simply retrieve the average file and proceed with the Paired t-test.
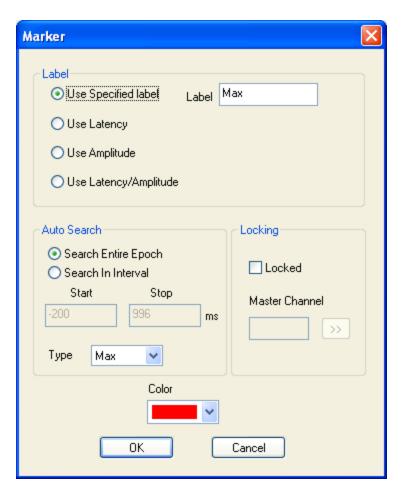
2.4.39 Peak Detection

Peak Detection (AVG, EEG; time and frequency domain) - The Peak Detection routine may be used to detect automatically the peak voltage within a user specified range in EEG or AVG files. (When using frequency domain AVG and EEG files, the "line" style is selected automatically, rather than the histogram display). An ASCII file is produced that contains the latencies and voltages for the peaks at each channel.

For a quick demonstration, let's set up the peak detection routine to locate the P100 component in the *vep.avg* demonstration file. Retrieve the *vep.avg* file, then select Peak Detection from the list of Transforms. The Peak Detection Parameters display will appear.

The first step is to define the markers that you want to add. Click the **Add Marker** button and see the Marker display.

You have the options to use the specified label (the label you enter in the Label field), the latency, the amplitude, or the latency and amplitude. The peak will be marked using the information you select. For example, if you select Use Amplitude, the peak marker will display only the amplitude value at the point of the peak. Select **Use Specified label**, and enter **P100** for the **Label**.

In the Auto Search section, you have the option to Search the Entire Epoch, or to Search In a specified Interval. Since the P100 component should fall within the 80-120ms range, select the **Search In Interval** option, and enter **Start** and **Stop** times of **80** and **120**, respectively.

In the Type field pull-down menu, there are options for Max, Min and None. Select the **Max** option to search for the largest positive voltage in the interval. If the peak of interest were of negative voltage, the Min option should be selected. If you select the None option, the Stop time will be grayed out, leaving only the Start time. When you run the Peak Detection this way, the program will place the peak markers at the Start time point on each channel.

In the Locking area, you have the option to Lock or not lock the search. If you select the Locked option, the Master Channel field will become active. This allows you to select a specific channel for the search. The program will find the peak at that channel, and "lock" the latency for all other channels. In other words, if a peak is found at 100ms from the Master Channel, the peak measurement will be
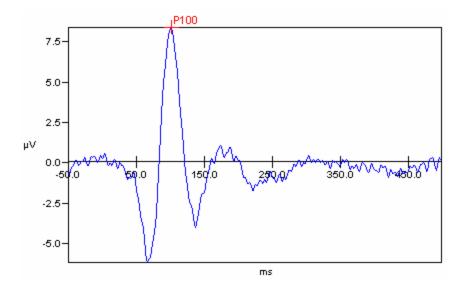
made at 100ms at all channels. If you do not select the Locked option (unchecked), the routine will search for the peak amplitude, within the interval, for each channel independent from any other channel. Leave the **Locked** field unchecked for this demonstration.

The Color button near the bottom of the screen determines the color of the peak marker that is placed on the waveforms. Select the red color, and click OK. You should now see the "P100" label in the Marker Template List. You can enter multiple peaks by repeating the steps above.

MarkerTemplate List

P100

You have the option to apply the Peak detection to **All** channels, or to **Specified** channels. Clicking the Specified field activates the **Select** button. This displays your montage, with all channels initially accepted (green). Double click a channel to exclude it from the search (it will turn red, and show "Off" below). Note the buttons at the bottom to Select All or Deselect All channels. For this demonstration, leave all of them Selected (click OK).

Lastly, you have the option to **Exclude Bad** and **Skip** channels. Leave these unchecked. Then click OK to run the peak detection routine. When the routine is completed you will see the Peak Detection markers added to each channel. The OZ channel is displayed below.

Click the *right mouse* button in the label (crosshairs) to see the **Delete** and **Edit Properties** screens.

Delete
Edit Properties...

Use the Edit Properties option to change the label, latency or color. Note that you can grab the marker with the left mouse button and drag it to a new location, if desired.
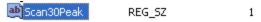
Saving the results to a .dat file. The peak detection results can be saved to an ASCII file (.dat extension). To do this manually, perform the Peak Detection, and the click the *right mouse* button between the electrode displays. Select the **Marker Report** option. You will see the Save As utility for setting the path and entering the file name. The .dat file that is created contains the latency and amplitude for the peak at each electrode and for each sweep (portion of the .dat file shown below):

Sweep	Number	Channel	Marker	Latency	Amplitude
1	FP1	P100		0.101000	-1.868643
1	FP2	P100		0.101000	-2.033156
1	F3	P100		0.101000	-2.007228
1	F4	P100		0.101000	-2.950348
1	C3	P100		0.101000	-0.623584
1	C4	P100		0.101000	-2.942086
1	P3	P100		0.101000	2.130232
1	P4	P100		0.101000	1.385077
1	O1	P100		0.101000	5.798689
1	O2	P100		0.101000	6.215950

In SCAN 3.0, the .dat file had a different format, where all of the results were on a single row (section shown below).

`'C:\SCAN\DEMO\VEP.AVG' 'P100' 'FP1'    0.232   81.000 'FP2'    0.495   79.000`

This format can be selected with SCAN 4.3 and newer versions by doing the following (disregard the following information if you want to use the regular SCAN 4.3 .dat file shown above). Run **regedit** from the **Start → Run** line, and go to *HKEY_LOCAL_MACHINE\Software\Neuroscan\Acquire\State*, and add the following **New → String Value**:
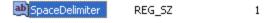
Scan30Peak	REG_SZ	1

When that line appears and is set to 1, the old 3.0 style will be used. If the line is omitted or is set to 0, then the new style will be used.

📄 Note
The old style applies ONLY to AVG files. Even if the flag is set, Epoch files will be written in the new format.

Another setting in the Registry (again in the **[State]** section) controls the type of delimiter used. The SCAN 3.0 software gave a choice of space versus tab delimited .dat files. Only if the SpaceDelimiter is set to a nonzero value will spaces be used. The default is tabs. This only has an effect if the old style file is being used. The command is:
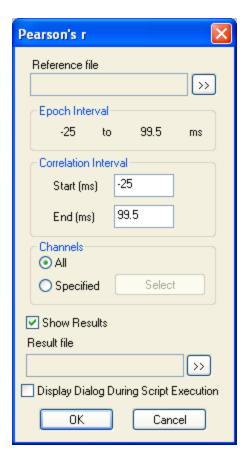
SpaceDelimiter	REG_SZ	1

Again, that command can be ignored if you are using the new format for the .dat files.
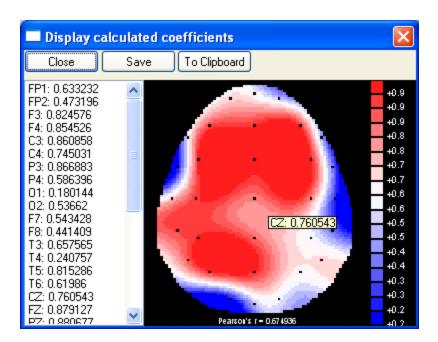
2.4.40 Pearson's r

Pearson's r (AVG, time and frequency domain) - This operation computes Pearson's r correlation coefficients between paired electrodes within a specified latency range. This statistic is sensitive to waveform shape, but is insensitive to absolute amplitude differences (unlike the Intra-class Correlation that is sensitive to amplitude differences).

Retrieve your time or frequency domain AVG file, and select the Pearson's r option from the Transforms list. You will see the Pearson's r display. Use the Browse button [>>] to select the comparison file. It must have the same number of electrodes, the same labels, the same starting and stopping time points, and the same number of points. In the example below, we used the *sepblk.avg* and *sepnoblk.avg* demo data files.

The Epoch Interval displays the span of the epoch. Set the **Start** and **End** time points for the Correlation Interval, that is, the interval over which the correlation coefficients will be calculated. Indicate whether you wish to analyze **All** channels, or **Specified** channels. Click the **Select** button to access the montage display that will allow you to select the channels to include. Click OK to continue. You will see the resulting Display Calculated Coefficients display, in which the coefficients are mapped and listed with the electrodes.

The correlation coefficients will be displayed in map form, as well as in a list. Position the mouse over an electrode site on the map, and the correlation coefficient for that electrode will be displayed.

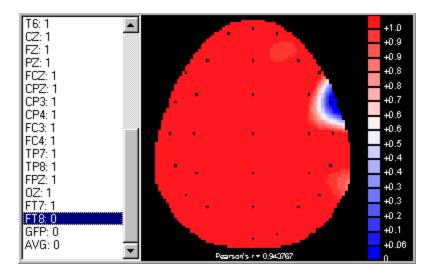*Close* - Clicking the Close button closes the display.

Save - Clicking the Save button opens a Save As... utility screen through which you may enter a path and file name for the output file. A text file will be written (the .dat extension is added automatically) that contains the list of electrodes and the correlation coefficients. The overall, or grand correlation is included.

To Clipboard - Clicking this button will send a list of the results to the Windows Clipboard, from which you may Paste the information into other Windows applications.
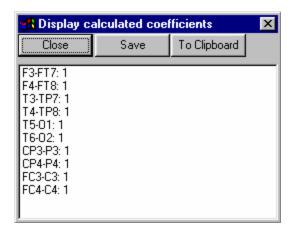
Files with mismatched labels. If you try to correlate two files where a subset of channels labels differ between files, the mismatch is detected automatically, and the Warning screen is displayed.

You then have the option of correlating only those channels that have matching electrode labels (the default option), or specifying the pairs of channels using a montage (.mnt) file. In the first case, you will see zeros for the mismatched channels.
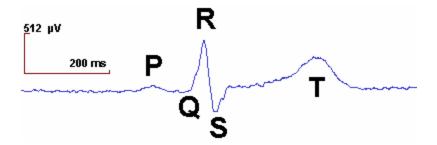

If you use a .mnt file, you will see results only for the designated pairs (with labels such as F7-F8, F3-F4, etc.). If you do not already have an .mnt file, you may click the Montage Editor button and create one. The resulting file will be a list of the correlation values for the designated pairs.
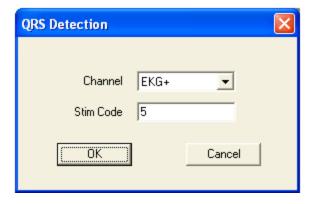
2.4.41 QRS Detection

QRS Detection (CNT) - The QRS Detection transform is used to automatically detect QRS waveforms in CNT files. Recalling the major components of an EKG beat, the Q, R, and S waves are often the most recognizable and most stable components.

The transform will place events based on the detection of the QRS complex. Selecting the transform displays the QRS Detection dialog screen. Select the **Channel** that is to be used, which is typically the EKG channel. Enter the event code that you want to use in the Stim Code field. Be sure to use a code that does not overlap with genuine stimulus codes sent from Stim2 (or other system).

The **QRS Detection** method uses a common domain algorithm for QRS detection (Open Source ECG Analysis Software Documentation; Copyright © 2002 Patrick S. Hamilton). It is used here as one method for placing events in the CNT file for each QRS waveform.

Briefly, beats are detected in two phases: Filters and Detection Rules.

Filters. The signals are filtered to generate a windowed (time limited) estimate of the energy in the QRS frequency band. This is accomplished by:

1. Low pass filtering,
2. High pass filtering,
3. Taking the derivative,
4. Taking the absolute value of the signal, and
5. Averaging the absolute value over an 80 ms window.

The final filter output produces what might be called a "lump" every time a QRS complex occurs. T-waves generally produce smaller lumps than QRS complexes.

Detection Rules. After the signal has been filtered, peaks are detected in the signal. Each time a peak is detected, it is classified as either a QRS complex or noise, or it is saved for later classification. The algorithm uses the peak height, peak location (relative to the last QRS peak), and maximum derivative to classify peaks. The following is an outline of the basic detection rules for the algorithm.

1. Ignore all peaks that precede or follow larger peaks by less than 200 ms.
2. If a peak occurs, check to see whether the raw signal contained both positive and negative slopes. If not, the peak represents a baseline shift.
3. If the peak is larger than the detection threshold it is called a QRS complex, otherwise it is called noise.
4. If no QRS has been detected within 1.5 R-to-R intervals, there was a peak that was larger than half the detection threshold, and the peak followed the preceding detection by at least 360 ms, that peak is classified as a QRS complex.

Threshold Estimation. The detection threshold used in 3 and 4 above is calculated using estimates of the QRS peak and noise peak heights. Every time a peak is classified as a QRS complex, it is added to a buffer containing the eight most recent QRS peaks. Every time a peak occurs that is not classified as a QRS complex, it is added to a buffer containing the eight most recent non-QRS peaks (noise peaks). The detection threshold is set between the mean or median of the noise peak and QRS peak buffers according to the formula:
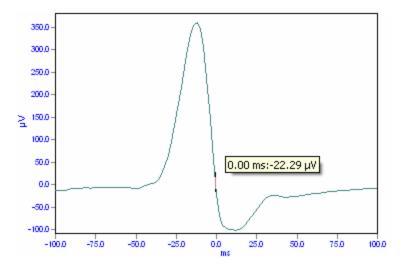
Detection_Threshold = Average_Noise_Peak + TH*(Average_QRS_Peak Average_Noise_Peak)

where TH is the threshold coefficient. Similarly, the R-to-R interval estimate used in 5 is calculated as the median or mean of the last eight R-to-R intervals.

The beat detector must begin with some initial threshold estimate. In order to make an initial estimate, the maximum peaks are detected in eight consecutive 1-second intervals. These eight peaks are used as the initial eight values in the

QRS peak buffer, the initial eight noise peaks are set to 0, and the initial threshold is set accordingly. The eight most recent R-to-R intervals are initially set to 1 second.

In practice, you will find that it tends to place the events not at the R wave peak, but rather between the R and S waves.
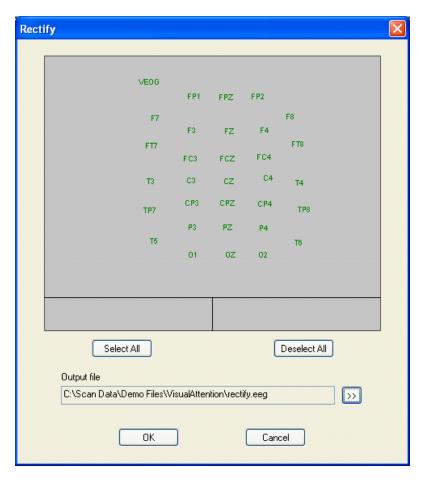

There is a "warm up" period at the beginning of the CNT file where no events are placed (8 beats), then you should see events inserted for each detected QRS complex.

Our experience thus far with the common domain QRS Detection method is that it is very effective in detecting the QRS complex in routine EKG recordings; however, it tends to become less accurate with BCG (which it was not designed to detect).
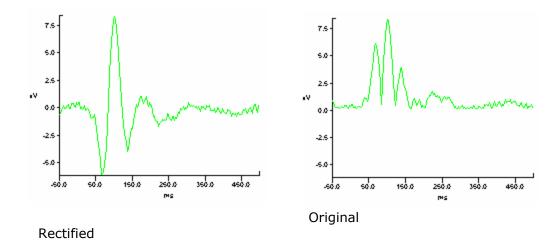
2.4.42 Rectify

Rectify (EEG, AVG; time domain) - The Rectify transform is a simple "absolute value" operation: all positive waveform values are left unchanged, and all negative waveform values are inverted to their corresponding positive values. This transform can prove useful for electromyographic (EMG) recordings.

After retrieving your EEG or AVG file, click the Rectify option from the Transforms list.

Select the channels that you want to be rectified, and, for EEG files, enter an output file name. With AVG files, the transform is performed in place.

Rectified

Original

2.4.43 RespWin

RespWin (CNT) - RespWin was originally a DOS based utility program that was used to associate responses with specific stimuli, such as in the case where there are

intervening stimuli between the target stimulus and the response. It has now been implemented in SCAN 4.3 and subsequent versions.

The RespWin (Response Window) procedure performs an offline analysis of behavioral data in an event (.evt) file that consists of a stream of stimulus and response events. The user defines a response window and one or more paired subsets of stimuli that correspond to target events and associated distractor events. A hierarchy of rules is applied to resolve ambiguities in forming associations between stimuli and responses. Hits, correct rejections, false alarms, and misses are tallied, and a nonparametric signal detection analysis is given. Reaction times are computed for each stimulus-response association.

To run RespWin, data typically will have been collected using ACQUIRE in conjunction with the STIM system. The hardware enables the STIM PAD responses to be transmitted to a SCAN system running continuous acquisition, regardless of the state of the STIM computer. As a consequence, the response stream of events is entirely separate from the stimulus stream of events. The RespWin program operates on an event file (containing the stimulus and response event stream) that must be created in the EDIT module of SCAN.
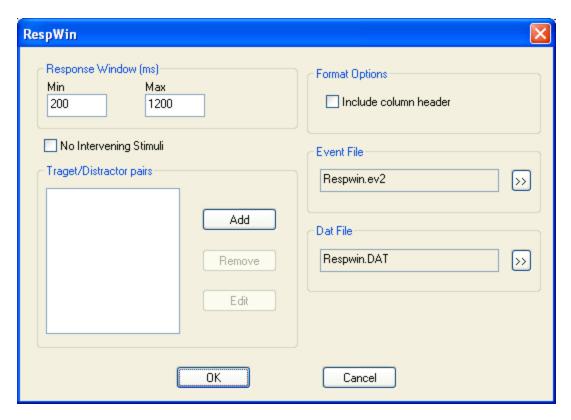
Response events from the STIM PAD are coded as follows: button #1 is coded as 1, button #2 is coded as 2, button #3 is coded as 4, and button #4 is coded as 8.

🗎 Note

If you have Stim[2], and are using the Mouse or Keyboard for the Response Device, please see the section entitled **Stim2 Response Devices** [7].

The *digitization rate* is required in order to compute reaction times. This is obtained automatically from the CNT file. Note that the precision of the reaction time measure computed in this way is dependent on the digitization rate used. For example, with a digitization rate of 250Hz, reaction times will be measured in units of 4ms.

Retrieve a CNT file, and select the RespWin transform to see the following dialog box.
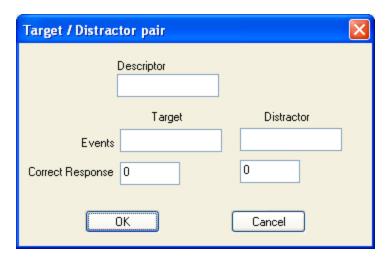
The **Response Window Minimum** is the minimum time after a stimulus event that a response event can be associated with it, and the **Response Window Maximum** is the maximum time after a stimulus event that a response event can be associated with it.

The **No Intervening Stimuli** field should be disabled if it is possible for a response to a stimulus to occur *after* an intervening stimulus has occurred, e.g., if a sequence such as S1-S2-R1 is possible, where R1 is a response to stimulus S1. To block this possibility, enable the **No Intervening Stimuli** field.

The **Target/Distractor pairs** correspond to the subtasks that the subject will be concurrently performing. Thus, a selective attention task would have just one target/distractor type, but a *divided* attention task would have two or more target/distractor types. Each target/distractor type has associated with it: a *description* string for identification purposes, a definition of the *target*, a definition of the *correct response to the target*, a definition of the *distractor*, and a definition of the *correct response to the distractor*. Click the ⬚ Add ⬚ button to create the target/distractor pairs using the following dialog box.

Enter a **Descriptor** to identify the pair. A *target event* is a subset of stimulus codes that require the same response. A *distractor event* is a subset of stimulus codes that require a different (possibly null) response compared with the associated target event. Subsets of stimulus codes are specified in a manner using commas and dashes, where necessary, as in 1-5, 10. You may have multiple target/distractor event pairs. A divided attention task, for example, would require the specification of at least two target/distractor event pairs. *In a two-choice task that does not use the target/distractor framework, you may just arbitrarily assign one choice to the "target" and the other to the "distractor".*

Correct target and distractor responses must be single integers that fall within the specified response code range. A response code of 0 indicates a "null" response (i.e., the correct response is no response).

 Note
The logic of the analysis procedure detailed below is predicated on the assumption that all target and distractor events are defined as disjoint subsets; also, it is assumed that each target/distractor pair will be assigned distinct responses. However, neither of these conditions are explicitly checked by the program. All stimulus codes that are not assigned to some target or distractor event are classed together as "extra stimulus" events; it is assumed that only the null response is appropriate for these extra events.

STIMULUS-RESPONSE ASSOCIATION RULES. The stimulus-response association rules listed below are centered around the following definition of a subset of stimuli that is associated with each response. For each response r, let S[r] be the subset of all stimulus events such that: (i) each stimulus in S[r] is defined as a target or a distractor event; (ii) r is contained within the response window of each stimulus in S[r]; and (iii) each stimulus in S[r] has not already been associated with some other (non-r) response. The following rules are followed in associating stimuli with responses:

General Rules:

Rule 1. If the response r is not defined as a correct response to any possible target or distractor event, then it is tallied as an "undefined response", and no further rules apply (i.e., no attempt will be made to associate it with any stimulus).

__Rule 2__. If S[r] is an empty set, then the response r is tallied as an "extra response", and no further rules apply.

__Rule 3__. If S[r] is not an empty set, then the response r will be associated with exactly one target or distractor stimulus in S[r] (unless rule 8 applies). The following rules determine which s will be associated with r, in the order of priority listed. That is, the first association rule that is satisfied will be the rule that actually gets applied, and no further rules will apply.

Determination of hits, correct rejections, false alarms, misses, and confused responses:

__Rule 4__. **Hit**: If r is a correct response to any target stimulus in S[r], then r is associated with the earliest such stimulus, and is tallied as a "hit" to that target/distractor pair.

__Rule 5__. **Correct Rejection**: If r is a correct response to any distractor stimulus in S[r], then r is associated with the earliest such stimulus, and is tallied as a "correct rejection" to that target/distractor pair. (Note that this rule will not apply unless some distractor event requires a non-null response, as in a choice reaction-time paradigm).

__Rule 6__. **False Alarm**: If r is defined as the correct response to some target event that is not represented in S[r], but an associated distractor event is in S[r], then r is associated with the earliest such distractor event, and is tallied as a "false alarm" to that target/distractor pair.

__Rule 7__. **Miss**: If r is defined as the correct response to some distractor event that is not represented in S[r], but an associated target event is in S[r], then r is associated with the earliest such target event, and is tallied as a "miss" to that target/distractor pair. (As is also the case for rule 5, note that this rule will not apply unless some distractor event requires a non-null response.)

__Rule 8__. **Confused response**: If none of the above rules apply for an individual response r, then it must be the case that: (i) multiple target/distractor event pairs have been defined, as in a divided attention task, and (ii) r is an appropriate response to a target/distractor event pair that is not represented in S[r]. For example, in a visual-auditory divided attention task, r may be the appropriate response to a visual stimulus, but S[r] may contain only auditory stimuli. In this case, r is tallied as a "confused response", and is not associated with any stimulus.

Calculation of Summary Tallies:

__Rule 9__. Rules 1 through 8 exhaust all possibilities for each individual response. After each individual response has been considered in sequential order, computations 10 through 13 are made, where applicable.

__Rule 10__. **Hits**: In the unusual (but possible) case where the correct response to a target event is defined to be the null response, then "hits" to that target will be computed as follows: hits = total target events - misses (where misses are tallied according to rule 7; note in this case that rule 3 would not apply).

__Rule 11__. **Correct Rejections**: In the (not unusual) case where the correct response

to a distractor event is defined to be the null response, then "correct rejections" with respect to that distractor are computed as follows: correct rejections = total distractor events - false alarms (where false alarms are tallied according to rule 6; note in this case that rule 4 would not apply).

Rule 12. **False Alarms**: In the unusual (but possible) case considered in rule 10 where the correct response to a target event is defined to be the null response, then "false alarms" are computed as follows: false alarms = total distractor events - correct rejections (where correct rejections are tallied according to rule 5; note in this case that rule 6 would not apply).

Rule 13. **Misses**: In the (not unusual) case considered in rule 11 where the correct response to a distractor event is defined to be the null response, then "misses" with respect to the associated target event are computed as follows: misses = total target events - hits (where hits are tallied according to rule 4; note in this case that rule 7 would not apply).

Rule 14. **Undefined Stimuli**: All stimuli that are not defined as either target or distractor events are tallied as "undefined stimuli". Note that no responses are ever associated with undefined stimuli.
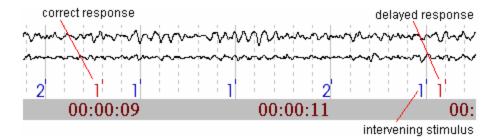
📄 **Note**

Occasionally, the response device may produce response doublets to what was intended by the subject as a single button press. These doublets can be identified as having response codes of the same type that occur within the response window minimum. In this case, the RespWin program ignores the second response code and tallies it as a "doublet response".

Format Options. Enable the **Include column header** formatting option if you want the column header information exported to the output files. (If you are exporting the results into another application, you may wish to exclude the header information).
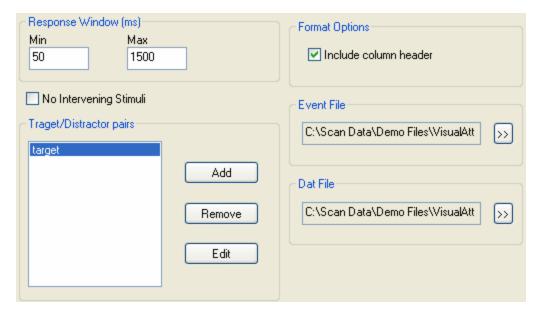
Event File and .dat File. The output of the RespWin program consists of two files: a new .evt file that contains reactions times for stimulus events that were associated with non-null responses, together with correct/incorrect information. Hits and correct rejections are coded with a 1 in the accuracy field, whereas misses and false alarms are coded with a 0 in the accuracy field. The associated response code is placed in the response field (with null responses coded as 0). No response events are included in the output event file, and only stimulus events that have been classified as targets or distractors are included. A second output file which has a .dat extension provides the summary statistics. The above-mentioned tallies are listed, together with average and standard deviation RTs for all target and distractor events having non-null responses. For each target, the hit percentage is defined as the number of hits divided by the total number of target events. For each distractor, the false alarm percentage is defined as the number of false alarms divided by the total number of distractor events. If hit and false alarm percentages are not identically 0% or 100%, Grier's A' (sensitivity) and B" (bias) will be computed (Grier, JB, 1971: Nonparametric indexes for sensitivity and bias. *Psychol. Bull.* 75:424-429).

Using RespWin. We will demonstrate the use of RespWin with a simple example. In the following data file, the subject's task was to click the #1 response pad button whenever he saw the stimulus with a type code of 2 (in this case, the "rare" stimulus

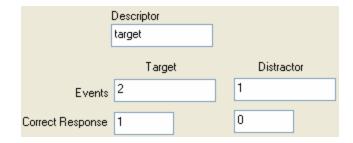in a P300 paradigm). In the section shown, the subject responded after a subsequent stimulus was presented.

The "1" response, albeit delayed, was to the previous "2" stimulus, and the "1" stimulus is now intervening. We want to associate the responses only with the "2" stimuli. As it appears now, the delayed response will be associated automatically with the first stimulus before it. We can use RespWin to associate the response with the correct stimulus.

The RespWin display would appear as shown.

The **Minimum** Response Window was set at 50ms to exclude anticipated responses (i.e., where the subject is trying to time a rapid response to the stimulus without evaluating the stimulus). The 1500ms **Maximum** allows legitimate responses to be recognized up to 1500ms, even though that is in the next trial. **Intervening Stimuli** are expected (so leave unchecked).

The Target/Distractor pair dialog box appears.

In this example, the Target events are type "2", with a correct response of "1". The Distractor type code is "1", and no response is expected ("0"). With more complex paradigms, just add additional target/distractor pairs.

The event file that is created shows the corrected association. The response that was shown as event #15 (before RespWin), is associated with the correct stimulus event, and the latency is computed. (The output .ev2 file contains only the stimulus-response pairs).

The summary output file contains information similar to the following.

```
Event                        Result
----------------------       ------
Undefined Responses          0
Extra    Responses           0
Confused  Responses          0
Undefined Stimuli            0

target:
Total    Targets             3
Total    Standards           10

Hits                         3
Average RT for Hits          800.0
Std Dev RT for Hits          346.4
Misses                       0
Percent of Hits              100.0

False Alarms                 0
Correct Rejections           10
Percent of False Alarms      0.0

Grier's A' (sensitivity)     0.924
Grier's B" (bias)            0.448
```
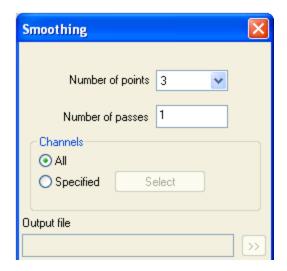
📄 **Note**

Response locked averaging can be accomplished more easily with the Epoch transform. In the original version of RespWin, the output event file from was used for making *stimulus-locked* epochs (and subsequent stimulus-locked averages).
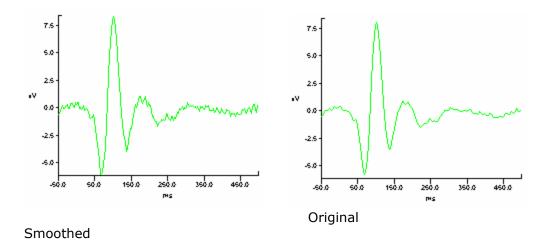
2.4.44 Smooth Data

Smooth Data (AVG, EEG; time domain) - Averaged data files may be smoothed, that is, a given data point may be averaged with adjacent points to create a smoother waveform. After retrieving the data file, click Smooth Data from the Transforms list. You will see the Smoothing display.

The **Number of points** sets how many adjacent data points are averaged (must be an odd number, at least 3). The **Number of passes** is the number of times the smoothing operation is performed.

Channels - Select the **All** radio field to apply the smoothing to all channels. To apply the transform to selected channels, click the **Specified** field, and then click the **Select** button. You will then see the standard screen through which you may select or deselect electrodes.

Click the [>>] button to select a folder and enter an output file name (EEG files only), then click OK to proceed. The transform will be applied. Save the file if you wish to keep the changes. Below is the *vep.avg* demo file where the **Number of points** was **3** and the **Number of passes** was **5**.
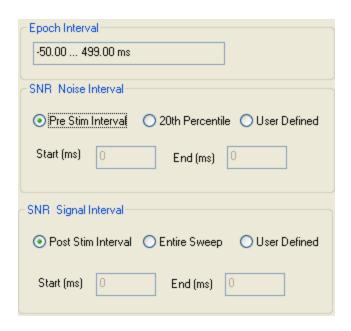
Original

Smoothed

2.4.45 SNR

SNR (AVG; time domain) - The Signal to Noise Ratio (SNR) computations require some preliminary explanation. The SNR is always computed, whether you apply the SNR transform or not. It will attempt to compute the best SNR possible, given the data. SNR is computed in different ways depending on whether there is a prestimulus interval.

Retrieve an AVG file, *right click* between windows, and select the **View SNR Values** option. You will see SNR values - even if you did not apply the SNR transform or average the file with the **Compute SNR** option enabled. These are the "default" SNR values, and they are computed in one of two ways. If there is a prestimulus interval in the data file, then the variance of that interval is used to compute noise and the variance of the poststimulus interval is used to compute signal. If there is no prestimulus interval, then the Mean Global Field Power (MGFP) is computed, arranged by voltage, and the 20th percentile is taken for the SNR estimate (this is the same as with CURRY).
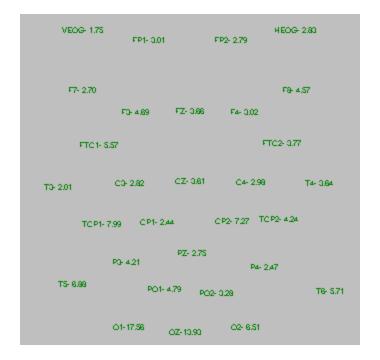
When you apply the SNR transform to the AVG file, you can use the options in the dialog box to select the interval for the signal and noise, and the SNR is computed from the MGFP.

The SNR transform computes "noise" over a specified interval, "signal" over a specified interval, and then the ratio of signal over noise. "Signal" and "noise" are defined as the variance among data points in the selected interval. The SNR then is the ratio of the variance (signal) over the variance (noise).

You can specify the interval to use for the noise and signal. Typically, you would use the pre-stimulus interval to estimate the noise, and some or all of the post-stimulus interval to estimate the signal. You also have the options to use the 20th percentile for the Noise estimate (the median of the GFP is determined and the 20th percentile of that is calculated), the Entire Sweep for the Signal estimate, or a User Defined interval for either or both. You would not want to use the same interval for both, as that will result in SNR values of 1 for all channels.

For time domain AVG files, enter the desired values and click OK. Then click the *right mouse* button between electrode displays, and select the option. You will see the SNR values for each channel.

The Overall Noise level and Highest SNR are displayed.

| Overall Noise [uV] | 0.217 | Highest SNR | 17.5638 |

Click the Save to ASCII... button to save the values to an ASCII file (.dat extension). The electrodes labels can be displayed or not.

2.4.46 Sort Sweeps

Sort Sweeps (EEG, time and frequency domain) - The Sort Sweeps option will create a new EEG file that contains only the sweeps you designate. After retrieving your EEG file, select the Sort Sweeps option from the Transforms list. The Sorting Criteria display will appear. This is the same display that appears during, for example, Averaging (see above for details). Set the criteria that you wish according to the sweep numbers, trigger type codes, response codes, and so forth. Click OK and you will see an output file display. Click the ⟩⟩ button, and enter a file name and set the path (the .eeg extension will be added automatically). Click Save, and a new multiple window display will appear with the first sweep of the new epoched file.

2.4.47 Spatial Filter

Spatial Filter (CNT, EEG, AVG; time domain) - The Spatial Filter transform removes and/or retains signals in spatial subspaces of the full measurement space in the context of a control signal. The spatial dimension of the full measurement space equals the number of channels. The dimension of a subspace to be removed (e.g., artifacts) or retained (e.g., ERP components) is usually much smaller than the full measurement space dimension. The "control signal" refers to a reference sample of EEG, and it is represented by a covariance matrix estimated from the reference sample. The purpose of the control signal is to take into account natural spatial correlations in the data. If a control signal is not specified, the control signal is assumed to be spatially identical (equal variance across channels) and independent (zero covariance between channels).

The Spatial Filter transform can be put to several uses. For example, it can remove volume conducted artifacts, such as eye blinks and eye movements, while minimizing distortions to the brain generated activity. This provides an alternative to the more traditional ocular artifact reduction transform, which may attenuate brain responses in the frontal leads. Secondly, it can implement the method of signal space projection, which has been used to "extract" neuronal sources [Tesche CD, Uusitalo MA, Ilmoniemi RJ, Huotilainen M, Kajola M, Salonen O (1995): Signal-space projections of MEG data characterize both distributed and well-localized neuronal sources. *Electroencephalogr Clin Neurophysiol* 95: 189-200]. As a final example, it can perform the spatial SNR transform that "sharpens" or "focuses" ERP maps by reversing natural correlations found in a reference EEG sample [Pflieger ME and Nakada T (1999+): The spatial resolving power of high-density EEG: An assessment of limits. In: T. Nakada (ed.), *Human Higher Function I: Advanced Methodologies*, to appear].

Input and Output. Input to the Spatial Filter transform consists of a representative file

to be spatially filtered, which can be any time domain data format (AVG, EEG, or CNT). In addition, the user must supply at least one of the following: (1) a compatible LDR (linear derivation) file that specifies signals of no interest to be removed, such as ocular artifacts; (2) a compatible LDR file that specifies brain signals of interest to be retained; and (3) a compatible LDR file that specifies the covariance matrix for a suitable control EEG signal. The Spatial Filter transform generates an output LDR file that subsequently can be applied (via the linear derivation transform) to any compatible time domain data format (AVG, EEG, or CNT) that was acquired in the same recording session for an individual subject. In addition, if an output data file is specified (AVG, EEG, or CNT), the computed linear derivation is automatically performed as part of the Spatial Filter transform itself. The spatially filtered output consists of (a) the original data channels after removal of signals of no interest (e.g., artifact) and/or (b) derived channels added for signals of interest (e.g., "P300 channel") or for signals of no interest (e.g., "blink channel"). The spatial SNR transform may optionally be applied.

The working data file (input) from which the output LDR file is produced may be either a time domain average AVG file, an epoched EEG file, or a continuous CNT file. The only requirement is that the working file should "represent" the acquisition parameters of any subsequent files to be spatially filtered. The Spatial Filter transform does not directly modify the working data file. In a typical application, the working data might be an ocular artifact calibration file containing subject blinks and eye movements. The LDR file resulting from the Spatial Filter transform could then be applied to remove ocular artifacts from an experimental data file for the same subject and the same recording session. Of course, it is also possible to estimate the artifacts from the same data file that will subsequently be corrected.

To start the Spatial Filtering process—e.g., as an artifact reduction procedure—there must be some initial way for approximating the spatial topographies of the components to be *removed*. In typical practice, this can be achieved by identifying the onset of events (such as blinks) that are associated with the components. One start method is to use the voltage threshold transform to mark the blinks (or other events) in a continuous CNT file; epoch with respect to the blinks; average the blinks; and finally perform a Spatial SVD on the average to extract the blink topography. The latter operation produces an LDR file that specifies the component(s) to be removed.

Similarly, the user may specify a linear derivation LDR file that lists spatial components that should be *retained* (e.g., brain generated components obtained via the Spatial SVD transform). These components may be specified out of concern for "throwing out the baby with the bath water" during artifact reduction; or they may be specified as signals of interest to be specially derived, e.g., as a preparation for single trial analysis. In other words, the Spatial Filter can "filter out" something unwanted—or it can focus on something of particular interest—or both.

A typical method for obtaining a linear derivation LDR file for a control signal is to start with a continuous CNT file that contains only clean EEG while the subject is in an alert eyes fixated state (for example). The Spatial SVD transform is applied to the clean EEG sample to derive a data covariance matrix, which is saved as an LDR file for the control signal.

Each of the removal, retention, and control LDRs is optional; however, at least one must be specified. Any pair or all three may be specified.

In the interactive mode of operation, retrieve a CNT, EEG or AVG file, and select the Spatial Filter option from the Transform list. The following display will appear.

The display is divided into several sections, and these are described below. The Spatial Filter transform uses up to 3 different LDR files in its computations, and will output a single LDR file, as well as a transformed data file. The LDR files you select - Removal, Retention, and Control - have very different effects on your data file.

Removal LDR: Unwanted signals - Use the Browse button to select the LDR file that is used to approximate the topographies for each component to be removed. This file is typically created from the Spatial SVD transform, or from some other source analysis program that outputs a matrix file that could be reformatted into an LDR file. In Ocular Artifact Reduction, this would be the LDR file derived from the file with prominent blink artifacts (see example below). The Edit button, in this as well as the icon from the Toolbar, is used to access the Montage Editor, where the LDR file may be modified, as desired (refer to the Montage Editor appendix for more details). The Removal LDR, when used alone (i.e., without the Retention or Control LDRs), is appropriate for instances in which you wish to remove a component(s) without regard for retaining any other signals. For example, you could use it alone if you wanted to remove blinks without regard for the EEG that might be subtracted in the process.

Retention LDR: Signals of interest - Use the Browse button to select the LDR file that lists the components to be retained, typically the phase-locked brain signal (EEG). Again, this will typically be the output LDR file from the Spatial SVD program, or other source analysis program that outputs a matrix file that could be

reformatted into an LDR file. The Retention LDR file might be selected as the only LDR file to be used in single trial applications.

Control LDR: Background activity data matrix - In comparison to the Retention LDR immediately above, the Control LDR should be a preferred method for retaining the ongoing EEG activity that may otherwise be lost in the Ocular Artifact Reduction transform. The LDR file that should be selected is one created in the Spatial SVD program, where the Include Skipped channels option is enabled (in the event that the VEOG channel was designated as a Skip channel), and where you selected Data Matrix instead of Components for the Output LDR file. The output LDR file is really a covariance matrix (where the diagonals are the variance measures). The uses are described in more detail below.

Output Spatial Filter LDR - Enter the name of the output LDR file that will be created by the Spatial Filter.

Reconstruction of Original Channels - These options are used to select various methods used in the reconstruction of the wanted and unwanted signals. Different ones will become active depending on which type(s) of LDR files you select. The more common permutations are described below.

> *Reconstitute the original channels* - When enabled (the default and most common choice) the Spatial Filter will be applied to the original channels. No new channels will be derived unless these are selected in the Derivation of Signal Channels section below. If this is deselected, the filter will not be applied to the original channels, but it is still possible to derive the unwanted channels and/or signals of interest depending on the selections in the Derivation of Signal Channels section.

> *Remove unwanted signals* - When enabled, the Spatial Filter will remove the unwanted signals (default setting). This option is active only when you have selected a Removal LDR.

> *SNR transform* - When enabled, SNR, in this capacity, functions as a sort of feature enhancement routine. Channels with prominent signals (such as the P300 component) will show an enhancement of the signals, whereas those channels with less prominent signals will tend to be flattened.

> *Project signals of interest only* - When enabled, this option will estimate the activity to the signals of interest (such as source dipoles), and project them back to the scalp. It retains the wanted signals only. This option is active only when a Retention LDR has been selected. If a Removal LDR has also been selected, the unwanted signals will have been taken into account when estimating the signals to be retained, i.e., the unwanted signals will have been "implicitly" removed.

Include skipped channels - Enable this field if you want channels that have been designated as Skip channels to be included in the analyses.

Derivation of Signal Channels - These options allow you to designate whether new channels will be derived for unwanted signals or signals of interest. The options are active when you have retrieved a Removal or Retention LDR.

Derive channels for unwanted signals - Enable this option if you want new derived channels for the unwanted signals to be displayed.

Derive channels for signals of interest - Enable this option if you want new derived channels for the signals of interest to be displayed.

Output File - Click the ⟩⟩ button and select a folder, then enter an output file name. When you have made all your selections, click OK to apply the transform.

Removing Ocular Artifact - One of the more common applications of the Spatial Filter is in the removal of ocular artifact. Below are three methods for removing ocular artifact based on the Spatial Filter and Spatial SVD.

VEOG Correction - Method 1

Let's say you wish to use the linear derivation approach with the Spatial Filter Transform to remove blink artifact both offline and online. Ideally, you would first acquire data from a subject while he/she was intentionally producing eye blinks, then generate the artifact LDR file from this recording, and apply the final output LDR file to the experimental recording. It is possible, however, to accomplish the same result using the actual experimental recording, providing there are enough good blink examples in it. Let's imagine the worst case, and assume that you have acquired a single experimental recording, in *continuous mode*, and that there is a sufficient number of blinks to warrant removal (as opposed to simple sweep rejection). We'll use the *viscpt.cnt* file. It is assumed for this demonstration that you have a basic understanding of the operation of the other EDIT transforms. The basic steps are:

1. **Construct an average artifact file**
2. **Perform the Spatial Singular Value Decomposition (SVD)**
3. **Apply the Spatial Filter Transform**
4. **Apply the Linear Derivation (offline or online)**

Construct an average artifact file. Retrieve the *viscpt.cnt* file.

📄 **Note**
If the file had been acquired with a High Pass filter setting of DC, you would need to perform the DC drift correction (under Transforms*) before continuing.*

📄 **Note**
If you have recorded the VEOG channel such that its blinks are inverted with respect to the EEG channels, you can still use the Spatial Filter transform - the results will be identical. (The Ocular Artifact Removal transform will also produce identical results regardless of whether the blink channel is inverted or not; make sure the Trigger direction, Positive or Negative, is set correctly).
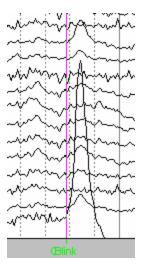
📄 **Note**
The band pass filter settings must be the same for the VEOG channel as for all other EEG channels when you are performing the LDR VEOG correction (use Filter *under* Transforms*, if needed).*

📑 **Note**

The viscpt.cnt *file has one bad channel (P3) - set it as a* BAD *channel. You might also wish to designate the VEOG channel as an* artifact rejection *channel, and deselect the other channels that had been set as* artifact rejection *channels.* Do this from the **Channel Attributes** section under Overall Parameters.
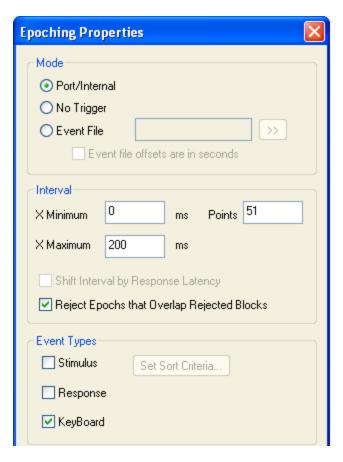
View the *viscpt.cnt* file using the control icons. Using the **Mark Block** option, go through the file and **Reject** bad sections of the file. There are about 5 or 6 obviously bad sections.

The next step is to create an AVG file that "captures" the blink artifact. One way to do this is to insert Function Key events at the approximate same beginning point for about 10-20 good blinks (an easier way using **Voltage Threshold** is described in the Script section). Step into the file until you see a good blink. Then click the **Add Mark** icon 🜂 on the Toolbar. Position the cursor at the beginning of the blink, and press a function key from the keyboard. The text is not relevant. Repeat this procedure for 10-20 good blinks.
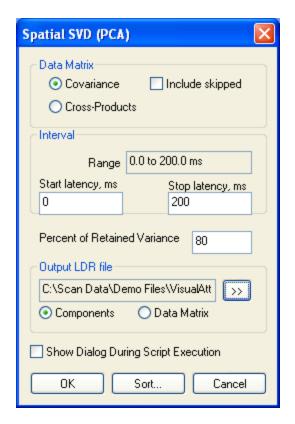
If there are any other function key events in your file, these should be removed. The blue triggers from STIM are OK (don't remove them).

Next, we want to epoch the file around the function key events only. Select the Epoch File option under Transforms, and designate the **Port/Internal Mode**, an Interval of **0-200**ms (to capture the main part of the blink), and **Keyboard** Event Types (only).

Click OK to continue. Enter a file name of "Artifact", and the .eeg extension will be added automatically. When completed, you will see a new multiple window display containing the artifact-laden file. Step through the file to make sure all the sweeps contain good blink artifacts, then average the file (making sure it has the "focus"). Call the new file "Artifact" again - the .avg extension will be added automatically.
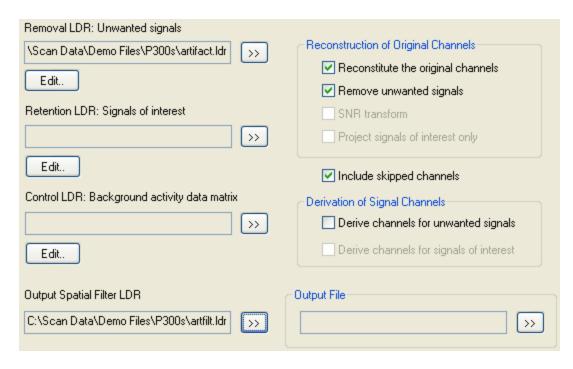
Perform the Spatial Singular Value Decomposition (SVD). Now we want to apply the Spatial SVD to the *artifact.avg* file. Select **Covariance** for the Data Matrix, with **Include skipped** channels enabled (to include the skipped VEOG channel). Use the **0-200** for the Interval, and enter **80** for the **Percent of Retained Variance** (to insure that only one component will be detected).
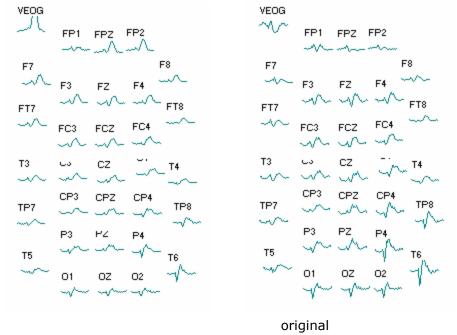
Enter "Artifact" for the output LDR file name (the .LDR extension will be added automatically), and select **Components** for the type of output. Then click OK to continue.

Take a moment to look at the *artifact.ldr* file using, for example, Windows Notepad (or the Montage Editor). Note that the channels having the largest multipliers are from the VEOG and frontal sites (excluding P3, which is a BAD channel).

Apply the Spatial Filter Transform. The next step is to apply the Spatial Filter. The Spatial Filter may be applied to CNT, EEG or AVG files. For this example, it may be easier to work with an AVG file. Take the original *viscpt.cnt* file, epoch it, and average the epochs (in this example we are not interested in the Rare or Frequent responses - average them all together). When you are finished, make sure the "focus" is on the AVG file, then select the Spatial Filter transform. In this example we will illustrate the simplest method for removing the blink artifact. That is, simply removing the artifact without retaining any of the EEG that may be subtracted in the process. On the Spatial Filter display, click the Browse button on the Removal LDR line, and select the *artifact.ldr* file created above from the Spatial SVD. Under **Reconstruction of original channels**, enable both options. The original channels will be reconstructed without the unwanted artifacts. Leave disabled the **Derive channels for unwanted signals** option under Derivation of Signal Channels. If enabled, this will create new, derived channels that will display the unwanted activity that was removed. Enter "artfilt.ldr" for the Output Spatial Filter LDR file. Then enter a file name for the output AVG file - call it *vis-spatfilt* (the .avg extension is added automatically). Click OK to proceed.

When the process is completed, you will see a new multiple window display with the corrected data. The blinks have been effectively removed in all the channels.

original

corrected

For comparison's sake, you might want to process the original *viscpt.cnt* file using the Ocular Artifact Reduction techniques under Transforms, and see the differences between methods (they are typically very subtle).
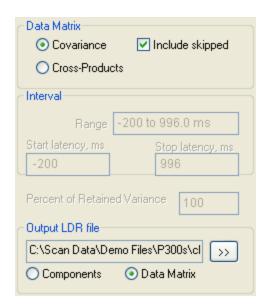
In our experience thus far, we have seen that this approach is very effective in

removing VEOG artifact. However, legitimate EEG signal may be removed from the anterior-most channels as well as the artifact. Actually, this is to be expected. This simplest variation removes artifact without attempting to preserve legitimate EEG. Retaining the EEG is accomplished in the second method (below), which, based on our experience, is recommended over the first method. The first method is provided by itself as an illustration of the technique, as well as for possible instances in which its application may be sufficient, and perhaps even preferable.

VEOG Correction - Method 2
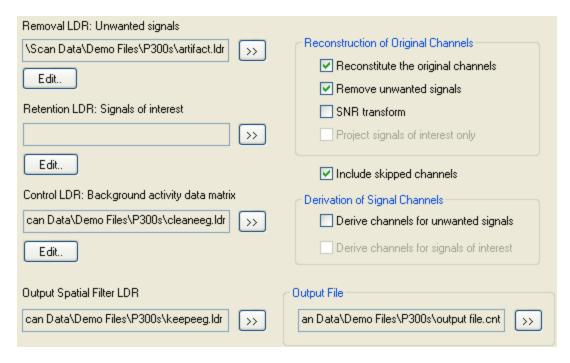
One of the criticisms of the point-by-point subtraction procedures (such as the Ocular Artifact Reduction offered under Transforms) is that legitimate EEG activity recorded from the VEOG channel might also be subtracted from the EEG channels. For example, anterior beta activity could be reduced if it is present in the VEOG channel and anterior EEG channels. In the previous example, we subtracted the VEOG artifact activity, but made no effort to retain any coincident EEG activity. This can be accomplished with a few extra steps in the process.

Construct an artifact-free block. At the beginning of the procedure above, we created an artifact-laden average file. For this example we also need to construct an artifact-free continuous file. This may be accomplished by saving artifact-free blocks of the continuous file to a new continuous file. Retrieve the *viscpt.cnt* file, and go through the file using the **Mark Block** option to save sections of clean EEG to a new CNT file. Save the blocks to a *.cnt* file called *cleaneeg*. Save about 30-60 seconds worth. Remember to click the **Close Segment file** option under File when you have finished saving blocks to the file.

Perform the Spatial Singular Value Decomposition (SVD). Go through the steps described above with the Spatial SVD to get the *artifact.ldr* file, if you have not done so already. For the clean EEG file, we will perform the Spatial SVD on the *cleaneeg.cnt* file created in the previous step. Retrieve the *cleaneeg.cnt* file, and select Spatial SVD from the Transforms list. Select **Covariance**, enable the **Include skipped** channels (to include the VEOG channel), leave the **Percent of Retained Variance** at **100** (this is not relevant because of the next setting), and select **Data Matrix**. The LDR file that is produced when you select Data Matrix is really a covariance matrix with all channels included. Then click OK to proceed. The output will be the data matrix LDR file, which you may view in Notepad or the Montage Editor.
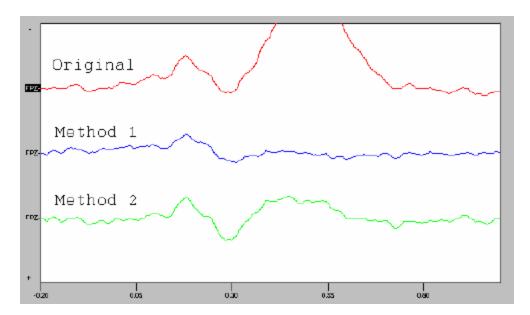
Apply the Spatial Filter Transform. Return the "focus" to the *viscpt.avg* file that you used in the "Apply the Spatial Filter Transform" section above, and select the Spatial Filter transform. For the Removal LDR, select the *artifact.ldr* file that we created in the first variation above. Skip the Retention LDR, and for the Control LDR, select the *cleaneeg.ldr* that you created in the step above.

Under Reconstitution of Original Channels, select the first two options. These will reconstruct the original signals with the artifact removed. The SNR option should be disabled. If enabled, this will tend to enhance the prominent features and flatten the less prominent ones. Under Derivation of Signal Channels, you may enable or disable the option as you prefer. If enabled, you will see derived channels for the unwanted signals (leave disabled for this example). Enter a file name for the output LDR file - call it *keepeeg* (the .avg extension will be added

automatically). Click OK when the Linear Derivation screen appears. Then enter a file name for the AVG file - call it *keepavg* (the AVG extension will be added automatically). Click OK to proceed. A new multiple window display will appear with the corrected file.

If we look at FPZ for the three AVG files - the original viscpt, the result of the first method, and the result of the second method - we can see that both methods are effective in removing artifact. The second method appears to retain more of the original waveform while still removing the artifact.

Online VEOG correction. In the above example the VEOG correction was performed offline on an existing data file. In SCAN 4.3 and newer versions, however, you can perform the correction online. To do so, you should first record a continuous data file containing intentional blink activity, horizontal eye movements, or other artifacts to be removed. Go through the steps described above in Variation 2 to obtain the final output LDR file. Rather than apply it to the existing data file, apply it to the online continuous file during acquisition, as explained in the ACQUIRE manual.

VEOG Correction - Method 3

In the previous sections, we describe two methods for removing VEOG artifact using the Spatial Filter. The first simply removes the blink artifact, while the second removes the blink artifact while preserving the genuine EEG signals. The method below is a third alternative that uses the SNR (Signal-to-Noise Ratio) feature of the Spatial Filter transform (this requires SCAN version 4.2, or newer software). In essence, the SNR procedure is used to identify large signal strength components (artifact) from the normal signal strength background (genuine EEG signals). The Spatial Filter is used to remove the artifact components and retain the genuine EEG signals. (While these examples focus on VEOG artifact, the Spatial Filter may be used to remove undesired artifact, such as ballistocardiogram, from recordings made in the MR bore, as well. See also the EKG Noise Reduction transform, described in the MagLink RT manual).

In the larger perspective, there are four conceptual steps in this procedure (not

necessarily performed in this order):

(A) Spatially normalize and decorrelate the data via the SNR transform (using the clean/outside EEG for the Control LDR).

(B) Apply the Spatial SVD transform on the SNR-transformed data containing artifacts to identify the artifact components.

(C) Remove artifact components (e.g., those with SNR greater than a user determined value, using the Spatial Filter without a Control LDR).

(D) Perform an inverse SNR-transform linear derivation to restore the data to potential (microvolt) units.

In theory, the process treats the clean/outside EEG as if it were "noise". Everything that looks like clean/outside EEG will be normalized with SNR values not too far from 1 (these are similar to standard deviations). The activity that is spatially different from this (e.g., artifacts) should show up as components with SNR certainly greater than 1 (although you could pick a higher threshold, such as 2). This provides a relatively objective way to deal with all artifact components. The artifacts are removed in "SNR space", and then the corrected data are transformed back to the original "potential space".

There are at least 2 practical issues to deal with: 1) in all steps until the final result, you should avoid writing linear derived data back to CNT or EEG formats, as these integer formats can lose precision and/or clip (this is accomplished by using Script files for some operations); 2) in step B above, there are currently unresolved concerns regarding whether or not to use time-locked artifact averaging to obtain the artifact-laden data file (for now, use either a CNT or EEG file with concentrated artifact, or else AVG files that have been appended).
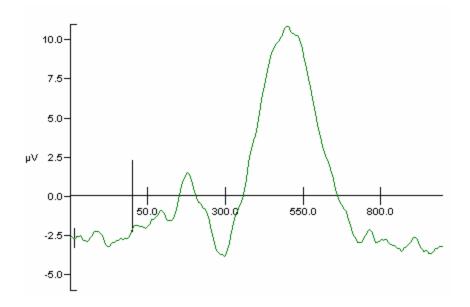
To use the Spatial Filter and SNR procedure, you will need a sample of clean EEG (such as one without eye blinks, or one recorded outside the MR bore), and another sample that contains the artifact (with blinks, or inside the bore). Continuous (CNT) files are recommended.

In the example below, we will use the *viscpt.cnt* demo file, which contains good examples of VEOG blink artifact. To a copy of that file we added some high voltage spikes to represent an additional source of artifact. We created a frontal topographical distribution for the spikes (as opposed to a constant amplitude at all sites). The blinks, therefore, are examples of artifact you might have to deal with in any recording, while the spikes represent, in an analogous way, an additional artifact source (such as one encountered in the bore). The goal is to remove both types of artifact, while preserving the original signals.
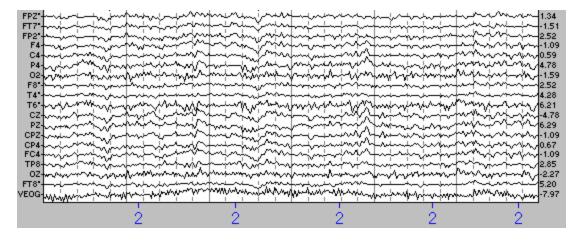
The following steps were taken:

1. Retrieve the original CNT recording (with blinks, but no spikes). If your file was recorded with a high pass filter setting of DC, you should perform a DC Drift correction first. Apply any other offline filtering at this point, if desired. If you have any Skipped channels that you want to include in the analyses, it would be good to designate them as regular channels now. Reject any blocks that may be bad.

For later comparisons, go ahead and Epoch the file, and then Average the file in the Time Domain. (We disregarded the different stimulus type codes for this demonstration; all the sweeps were averaged together). Below is the resulting average for FPZ, with the prominent blink artifact around 500ms.

Now we need to create a new file that has only clean sections of EEG. Use the **Mark Block** / **Save Block** option to create a new "clean" EEG file, and then retrieve that file. Below is a sample of the "clean" file.
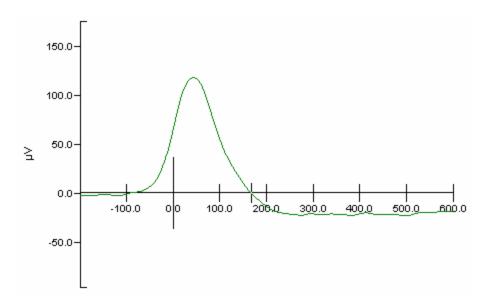
Now select the **Spatial SVD** transform, select **Covariance**, and the **Data Matrix** option. Enter a file name for the output LDR file (e.g., *Step 1 LDR*). The LDR file will be used as the Control LDR, that is, the background activity data matrix that we wish to preserve.

2. For this step it does not matter which data file you use (we used the same CNT file as in the previous step). Select the **Spatial Filter**, and enter the LDR file from **step 1** as the **Control LDR**. Enable the **SNR transform** option (the inverse SNR transform LDR, which will have the same name with "_inverse" appended, will be created automatically). Enter the output LDR (such as, *Step 2 LDR*) and CNT file
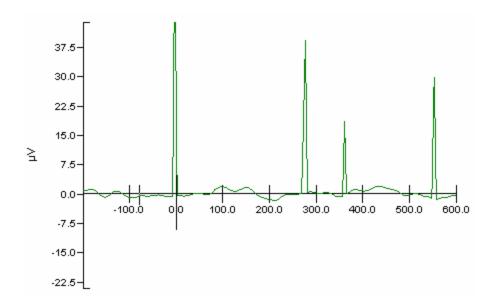
names (if you are using CNT files). The output LDR file is the one we will use in the next step. This spatially normalizes and decorrelates the data via the SNR transform.

3. We now need a CNT or EEG file that has concentrated artifact in it. There are different ways to create this. For example, you could take the CNT that has the artifacts and **Save Blocks** of the artifacts into a new CNT file. (You should first perform the DC Drift correction, any additional filtering, and rejection of bad blocks, as you did in Step 1 with the clean EEG file). Depending on the nature of the artifact, you might be able to use the Voltage Threshold option to place events automatically at the beginning of the artifact, and then create an epoched file using those events.

In this example, since there are two distinct artifacts (blinks and spikes), we did the following. We used the Voltage Threshold option to set triggers for the blinks, we then Epoched around the blinks (-200 to 600ms), and averaged the blinks together. Below is the average of blinks at FPZ.

The spikes had a lower peak voltage than the blinks, so we used Save Block to create a new CNT file with spikes, but no blinks. We then used the Voltage Threshold option to set triggers for the spikes, and then Epoched and Averaged the file as with the blinks. That average for FPZ is shown below.

We then made a simple Script file where we Inputted one AVG file (blinks), then used the Append Sweeps option to add the second AVG file (spikes) to create a new EEG file containing two sweeps (one blinks and the other spikes). In instances where there are multiple artifacts to be removed, it is necessary to have the artifacts contained in the same CNT or EEG file. The above steps are a simple way to create such a file (note that the sweep durations for the AVG files must be the same).

After creating the concentrated artifact file, make a **Script** file (this must be done in Script mode to avoid integer formats that may lose precision or clip the data), using it as the **Input File**. The next transform in the Script tree will be **Linear Derivation**, where you select the SNR transform LDR (created in **step 2** - not the inverse LDR file). Enter an output CNT file name (if you are using CNT files; this file will not be used). The last step in the Script should be the **Spatial SVD** transform. Select the **Covariance** option. Specification of **Percent Retained Variance** is an option that you may wish to vary (we used **95** in order to see most of the components). Enter, for example, *Step 3 LDR* for the output LDR file. Then execute the Script file.

The Spatial SVD option performs a Principle Component Analysis to determine the major components that comprise the signals. The Transform Report will show the number of components, the fraction of variance accounted for, and the SNR value (or "mag", for magnitude). At this point, you need to decide which components to include in the subsequent analyses. The magnitude (SNR values) should be greater than 1, but by how much? In this example, only two components emerged.

```
Input<--blinks and spikes.eeg - 2 epochs read from D:\New viscpt\blinks and spikes.eeg
Linear derivation - Applied D:\New viscpt\step 2.ldr
Spatial SVD - COMP1 frac=0.914312, mag=9.432320
Spatial SVD - COMP2 frac=0.073956, mag=2.682617
Spatial SVD - Linear derivation written to D:\New viscpt\step 3 conc arts.ldr
```

You could easily have more than two. There is no absolute rule for which components to use. In our example, we ran the analyses with just COMP1 and again with both COMP1 and COMP2. With COMP2 omitted, the spikes were still

there. In this case, COMP1 reflected the blinks and COMP2 reflected the spikes. With different files and different artifacts, you may need to experiment a little to determine which ones to omit. From the files we have analyzed, it appears now that a good cutoff is a "mag" value between 1.5 and 2, especially where the variance percentage is very low (less than 1%, perhaps) for the remaining components.

To remove the unwanted components from the LDR file, retrieve the file in Notepad or other text editor. Delete the components as desired and modify the top line accordingly. The two numbers on the top line are the number of new channels and the number of existing channels. The number of new channels should be changed so it is the same as the number of components. An example from a different file is shown below, where four components were kept, and the top line has been modified accordingly.

```
4  16
                     1             2             3             4
      COMP1      0.07233       0.25975       0.00895      -0.03278
      COMP2     -0.05943      -0.34618       0.14515       0.18845
      COMP3      0.10355      -0.27072       0.21629       0.29080
      COMP4      0.14291       0.39142      -0.18073      -0.15818
```

4. Now retrieve either CNT file (it does not matter which one). The next step is to design a **Spatial Filter** LDR using the result of step 3 as the **Removal LDR** (do not include a Control LDR). Enter output file names for the LDR (such as, *Step 4 LDR*) and CNT files (if you are using CNT files; all we need is the output LDR file). The output LDR file is the one that will be used to remove the unwanted artifact.

5. Finally, we need to make another **Script** file. The **Input File** is the data file to be *corrected* (not the concentrated artifact file). The next step in the Script tree is to select the **Linear Derivation** transform, and select the SNR transform LDR file generated in **step 2** (not the inverse one). Then, select the **Linear Derivation** transform again, and enter the result of **step 4** to remove the artifact components. Select the **Linear Derivation** transform for a third time, and select the *inverse* SNR LDR that was generated in **step 2** to restore the data to potential (microvolt) units. Lastly in the Script file, create an **Output File** to save the results to a new file. (Note: In all linear derivations, it is OK to leave the units as <default>; the final result will be microvolts, even though intermediate values are SNR.) Execute the Script file.
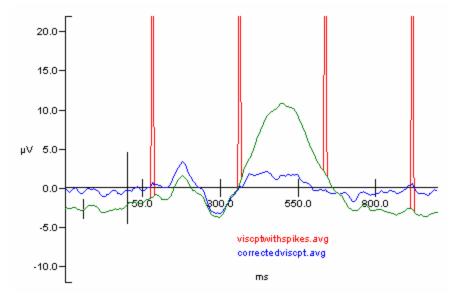
Now retrieve the original artifact-laden CNT file and the final output CNT file from step 5 to compare the effects visually (displays scales are slightly different between files).
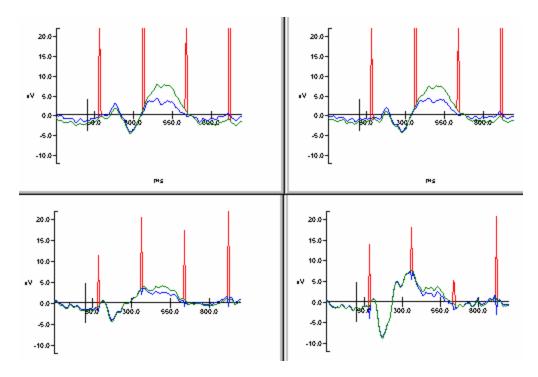
Original with blink and spike artifact   Same section after SNR correction
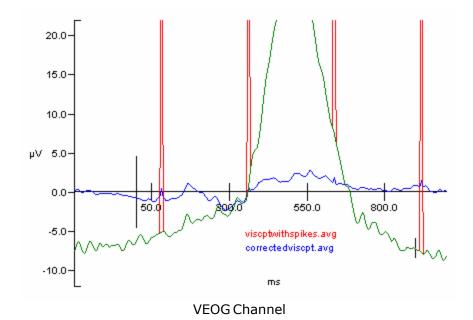
Epoch the final output CNT in the same way as you did the original clean EEG file in step 1, and compute the average file (again, we combined all the trigger types). In the figure below, the green waveform is from the original viscpt file (FPZ), with averaged blink artifact around 500ms. The red waveform is the identical file with spikes added (the rest of the red line is hidden behind the green line). The blue waveform is the same file after the blinks and spikes were removed using the SNR method.
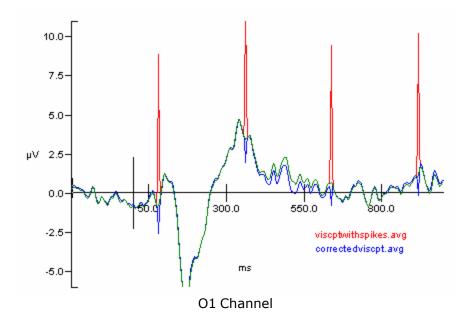
Similar results from F3, F4, P3 and P4 are shown below.

Lastly, we'll take a close up look at some of the channels (VEOG and O1). You can see in the VEOG channel (blue) that not quite all of the spike artifact was removed, while the spikes were slightly over-corrected in the O1 channel (next figure).

viscptwithspikes.avg
correctedviscpt.avg

VEOG Channel

O1 Channel

In most of the channels, the spike removal looked perfect, but there were a few channels that showed minor under-corrections or over-corrections. The spikes were artificially created, with relatively high voltages. They may or may not provide an accurate estimate of what you will find with genuine data.

While we have been focusing on blink and spike artifact, the same method can be used for other undesired artifact, such as, ballistocardiogram (BCG). This is the artifact occasionally seen in recordings made in the MR bore, due to micro-movements associated with the heart beat. In test files we have analyzed in our facility, the SNR procedure has worked very well in recordings where there is simple BCG. That is, where the BCG artifact appears as repeated heart beat artifact that does not vary appreciably during the recording. In other files, where the BCG artifact appears as a more complex waveform that varies in its morphology or spatial distribution during the course of the recording (suggesting that there may be more than one source accounting for it), the procedure has been less successful. We also suggest using the EKG Noise Reduction routine that is included with the Maglink RT system.

In summary, spatial filtering using the SNR method appears to be a useful technique for removing unwanted components in the EEG, while retaining other components of interest. In the above example, the method was used to remove two independent sources of artifact with near perfect results. We should emphasize that it is better to avoid artifact, rather than to try to remove it in post-hoc processing.

Additional SNR Information - SNR values of 1 are equal to the noise level in the raw, unaveraged EEG. Values greater than 1 indicate a signal strength greater than the noise level. Thus, the SNR values displayed in average (AVG) files are scaled for single trials. This convention allows comparison of SNR values across files that have differing numbers of sweeps. The single-trial SNRs are the "common denominator" across files. However, as the number of trials increases, the actual SNR values for the final average also increase, according to the following equation:

$$\text{SNR (final average)} = \text{SNR (single trial) x SQRT(\# Trials)}.$$

For example, a peak single trial SNR of about 1.3 converts to approximately 8.3 {1.3 x SQRT(41 sweeps)} for the final average. In other words, it's a very strong signal. However, in a single sweep of EEG, the signal would be only marginally greater than noise.

You may have noticed that there are final output LDR files created each time you do the Spatial Filter. These are used in the computation of the Output AVG file. Once created, however, you may find it is faster, especially with files having large numbers of channels, to apply these LDR files to other data files using the Linear Derivation transform. Doing so assumes that the other data files were recorded from the same subject under like recording conditions. You can also automate much of the procedures with Batch files.

Some important final notes. Based on the experimentation we have completed, the Spatial Filter approaches appear to result in final averaged files that are very similar to those obtained with the alternative method of Ocular Artifact Reduction, with more genuine signal being retained. Also, the final LDR file can be used during online acquisition. This will give an indication of the quality of the recordings that you can achieve after final processing, and also allow clearer online evaluations. The VEOG channel is corrected with the LDR approach (that is, the VEOG activity is removed from the VEOG channel, as well); whereas, it is not corrected with the Ocular Artifact Reduction routine. After calculating FFT analyses on the various epoched files, we have seen that there is more activity in the 1-20Hz range (albeit only slightly) with the LDR approach than with the Ocular Artifact Reduction routine. This suggests that, as has been stated before, the Ocular Artifact Reduction routine may be removing genuine EEG along with the VEOG artifact. We did not see this in every file tested.

We wish to emphasize that the examples above do not represent the only methods, nor necessarily the best ones, although they gave good results in our testing. We are presenting these approaches, with as much guidance as we can offer, but there is much to be investigated further. For example, one might ideally record eye movements in a separate recording, go through the above steps, and generate a final LDR file that could be used in subsequent experimental recordings with that same subject. What may be critically important in doing this, however, is the similarity between the VEOG artifact generated "intentionally" and the artifact that occurs spontaneously. Intentional blinking could be more pronounced and pervasive, affecting more posterior sites, for example, and there could then be an overcorrection at these sites. This is something we have not investigated. Also, one might wish to record vertical and horizontal eye movements and place these in the "artifact" file to be removed. We expect that the horizontal movements would appear as a separate component, and that both may be removed while still retaining the EEG.

Since the Spatial Filter and its SNR option are relatively new features, having many options in the ways they can be implemented, we request any helpful information you wish to provide based on your experiences. We would greatly appreciate hearing from you, and receiving a copy of the files you are using.

Lastly, we would like to point out that while the above examples have dealt with the removal of unwanted VEOG artifact, this is just one possible use of the LDR

feature. Various electrophysiological components may be identified, quantified, removed, etc. This is a powerful technique, and we will be interested in hearing from you regarding novel implementations of it.

2.4.48 Spatial SVD

Spatial SVD (CNT, EEG, AVG; time domain) - The Spatial Singular Value Decomposition (SVD) transform can be applied to any time domain file type (AVG, EEG, or CNT). This transform generates spatial component topographies, fraction of total variance explained by each component, and a linear derivation file for deriving component time series. (See also the PCA/ICA capability, described in the Toolbox manual).
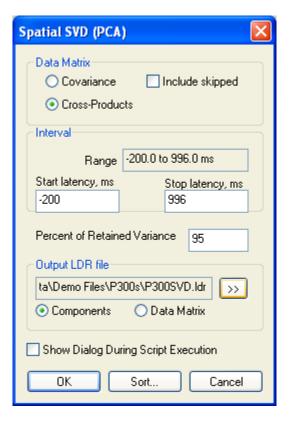
The Spatial SVD transform is equivalent to spatial PCA (principal component analysis) without rotation of components. A series of spatial components – i.e. unit magnitude channel vectors or topographies — are derived such that the first component accounts for a maximum of the temporal variability in the data; the second spatial component is orthogonal to the first and accounts for a maximum of the residual temporal variability; etc. Spatial SVD is a linear decomposition which produces "statistical sources" for the data. The rationale for making a linear decomposition is based on the rationale for performing a full-fledged biophysical source analysis, i.e., the quasi-static approximation for volume conduction in biological media (Plonsey, 1969) implies that transmission from brain sources to measured scalp potentials is instantaneous and linear. All of the statistical sources considered together span a "signal space" that corresponds to the biophysical projection of the brain source signals to the scalp. However, there is not in general a 1-1 correspondence between individual spatial SVD components and brain sources. In particular, note that the spatial SVD components are mathematically required to be mutually orthogonal, whereas the biophysical projections of actual brain sources to the scalp are not orthogonally constrained.

Using Spatial SVD - The easiest way to explain the uses of Spatial SVD is with an example. We will take the *P300.eeg* file, perform the SVD, create and retrieve the output LDR file, and apply it to the files made from the *P300.eeg* file. (If you followed the example with the P300 file in the SCAN Tutorials, you will have created the .AVG files already).

Start by retrieving the *P300.eeg* file. Perform the Baseline Correction, if desired. The main thing is to perform the Ocular Artifact Reduction transform to remove the VEOG blink artifacts. Otherwise, the largest component in the PCA will be the blinks. Refer to the Tutorial or the Ocular Artifact Reduction section above for a discussion of the VEOG reduction routine. Call the corrected EEG file *P300VEOG.eeg* . Be sure to change the "focus" to the *P300VEOG.eeg* file for the next operations (or close the other .eeg files).
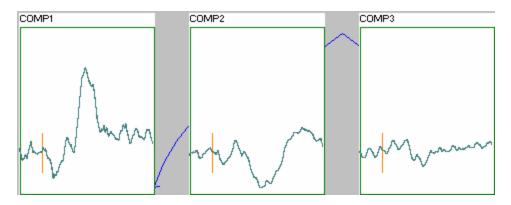
Next, create averages from the *P300VEOG.eeg* file based on Type codes of 1 (the frequent responses; call it *P300freq.avg*) and on Type codes of 2 (the rare responses; call it *P300rare.avg*), as described in the Tutorial. (Note that there is

a ⬚ Sort... button on the Spatial SVD display. This accesses the Sorting Criteria display used in other transforms to select the sweeps that you wish to use).
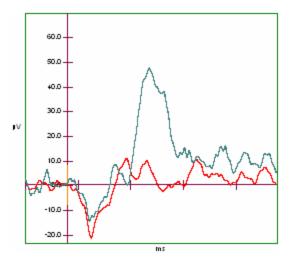
With the "focus" on the *P300VEOG.eeg* file, select Spatial SVD from the list under Transforms. Since there could easily be an offset relative to the baseline for the P300 component, select the **Cross-Products** option (Covariance disregards any offset). Leave the **Include Skipped** field unchecked. When enabled, this option will include in the analyses any channels that you have designated as Skip channels. Leave the Interval set for the entire range, and set the **Percent of Retained Variance** to **95**. Use the file name of *P300SVD.ldr* for the Output LDR file, with the default **Components** button enabled. This means that the output LDR file will have the weights for constructing the principle components topographies. If Data Matrix is checked, the LDR file will contain the data matrix itself (either a covariance matrix or a cross-products matrix, depending upon which was selected above). The standard Sorting options are accessed from the Sort button. If you are sorting by responses, please see the section entitled "**Some notes about response codes** [100]" for some important information. Then click OK. A progress bar will track the SVD calculations, as the LDR file is being computed.
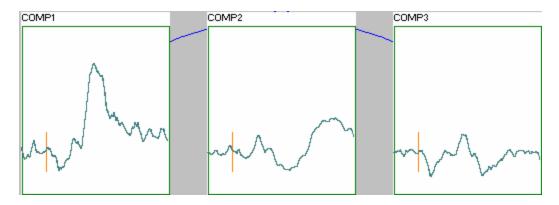
Now, retrieve the *P300rare.avg* file that was created above. Select Linear Derivation from the Transforms list of options. In the Linear Derivation screen, use the Browse button to select the *P300SVD.ldr* file. Enter a file name for the output AVG file - call it *P300rare-SVD.avg*, then click OK. The first 3 components are shown below.

These are the components that account for nearly all of the "energy". (Since we used Cross-Products in the SVD calculations, the program does not compute variance, per se, but rather variance without subtracting the means). The P300 portion of COMP1 could be used to determine a "global" P300 latency. For interest, repeat the same steps with the *P300freq.avg* file, and compare the two. The P300 related differences are fairly obvious.

You can obtain similar results by calculating the SVD using the *P300rare.AVG* file, rather than the *P300VEOG.eeg* file. Retrieve the *P300rare.avg* file, and select Spatial SVD from the Transform list. Select **Cross-Products** and **95%**, as above, and enter a new file name for the Output LDR File - *P300rare.ldr*. After the calculations are completed, switch the "focus" to the *P300rare.avg* file again, and select Linear Derivation from the Transforms list. Select the *P300rare.ldr* file. Enter a file name for the Output AVG file - *P300SVD-rare.avg*, and click OK.

Notice that the first component is very similar to that created in the *P300rare-SVD.avg* file above.

Another use for the Spatial SVD is in the identification of features in single sweeps. In the above example, start with the *P300VEOG.eeg* file and perform the Spatial SVD. Then return the focus to the *P300VEOG.eeg* file, and select Linear Derivation. Select the same *P300SVD.ldr* file used before, and click OK. Enter an output .eeg file name. When the calculations are completed you will see a new multiple window display with the single sweep results (step through the file as with any .eeg file). If you average this file, sorting for Type 2, you will obtain the same results as we did in the *P300rare-SVD.avg* file above.
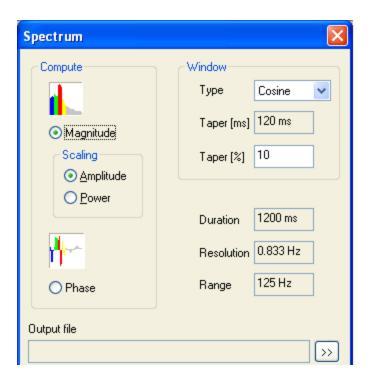
See also the Spatial Filter section for further examples of the Spatial SVD, especially regarding the use of the Data Matrix option.

2.4.49 Spectrum

Spectrum (AVG; time domain) - Time domain average waveforms consisting of a power-of-2 number of points (e.g., 64, 128, 256, 512, 1024, 2048, etc.) can be Fourier analyzed to obtain an amplitude (i.e., root power) spectrum at each electrode. If your average waveform consists of a non-power-of-two number of points, use the **Spline fit** transform first (see below).

Forward FFT is the Transform used for computing FFTs with single-sweep EEG files (see above). Keep in mind that computing the spectrum of an averaged waveform will not be the same as computing the average spectrum from the single sweeps. Waveform averaging in the time domain reduces the power of all non-time-locked activity such as ongoing EEG. Thus, the spectrum of an average waveform consists primarily of power from the time-locked signal (event-related potential), plus a contribution from the power of the residual noise. On the other hand, the average of single sweep spectra will not differentiate between time-locked and non-time-locked contributions. Thus, an average spectrum will typically be dominated by the ongoing EEG activity (since the non-time-locked activity usually dominates the time-locked activity on single sweeps).

After retrieving your AVG data file, click on Transforms. Click on Spectrum and the spectral options dialog box will appear. The display consists of two main sections, and an information section.

Compute - There are two computational options: Magnitude and Phase.

Magnitude - The Magnitude spectrum computes the amplitude or power as a function of frequency. Two Scaling options are supported: Amplitude and Power. The **Amplitude** option takes the square root of the power spectrum to express the units in microvolts. (Amplitude is not precisely the square root of Power; different scaling and compensations for windowing effects are used). Amplitude is an approximate measurement of the baseline to peak amplitude (rather than peak-to-peak). (The measurement would be precise if you were analyzing a pure sine wave, with starting and ending points at zero, where no windowing was needed). The **Power** option computes a standard power spectrum (adapted from the Cooley-Tukey method) with values expressed in microvolts squared. The results of a Spectrum transform using the Amplitude option are shown below.

Phase - The Phase spectrum transform computes the phase angle of a waveform as a function of frequency using the Fast Fourier Transform. Phase angle is displayed in degrees, ranging between -180 and 180 degrees. This is the complement of the Magnitude transform, which computes the amplitude or power as a function of frequency. The phase spectrum is particularly useful for analysis of steady-state evoked responses. In the application, phase is a sensitive measure of lag. See below for an example of the Phase display.

Window - You may select to Window the data to control spectral leakage.

Window type - The window type field determines whether a Cosine, Hamming, Hanning, Parzen, Welch, or Blackman is employed. The differences between these various windows are subtle.
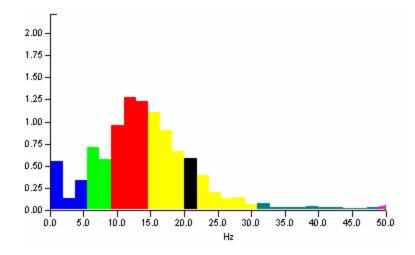*Taper [ms]* - This field displays the length of the taper in ms (X% of the Duration, where X is the Taper [%] entered below).

Taper [%] - The window length determines the extent of taper at the beginning and at the end of the epoch.

General Information - The remaining informational fields display the Duration of the current sweep(s), the Resolution (width of the frequency bins), and the highest frequency in the Range of frequencies (half the AD rate).

Output File. Use the [>>] button to access the dialog box to enter an output file name and to select a folder.

For illustration purposes, retrieve the *vep.avg* file, and use the Spline Fit transform to allocate 512 points (to achieve the required power of 2). Compute the Magnitude, with Scaling set to **Amplitude**, and a **Cosine** Window with a **10%** taper. Enter a file name and folder. When you have entered the desired settings, click OK. After the computation is complete, you will see a new multiple window display with the results of the FFT. To reduce the frequency range of the display, go to the **Frequency** section under Overall Parameters. Set the Display **Stop** time to, for example, 50Hz, and click OK. The result will appear similar to the following.

This is the power spectrum at OZ. Note that the standard EEG frequency bands (delta, theta, alpha, beta) are displayed as a series of colors. You can change these colors by selecting the colors item located in the **Options** → **Multiple Window Settings** → **General** → **Frequency Bands**).
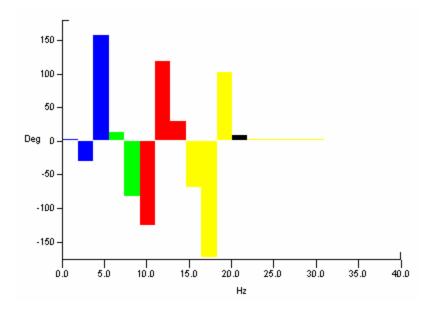
📄 **Note**
On occasion, you may wish to change the frequency resolution, that is, the width of the frequency bins. This can be accomplished by changing the epoch duration at the time the CNT file is epoched; the longer the duration, the narrower the frequency bins (or the greater the frequency resolution).

Calculation of **Phase** is very similar. Still using the spline fitted *vep.avg* file, again select the Spectrum option under Transforms, and enable the ⊙ Phase option. Enter a file name in the Output File display (the AVG extension will be added automatically), and click OK.

The Y-axis displays degrees from 180 (top) to -180 (bottom). The X-axis is in Hz. For this example, we reduced the X-axis display Stop frequency to 40Hz.
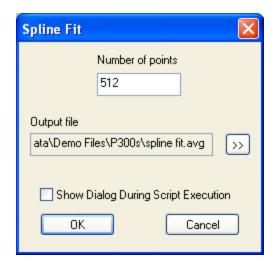

📄 **Note**

Only selected frequencies are displayed. As the FFT power approaches zero, the Phase angle becomes essentially meaningless. Therefore, Phase is displayed only for those frequency bins where their power exceeds 5% of the total FFT power. (The total power includes all channels that are not designated as Bad or Skipped channels, and all frequencies).

What does it mean when there is, for example, a phase value of 50 degrees at a given frequency bin? A pure cosine wave, for each given frequency, is used as the reference waveform. If you imagine a cosine wave with an amplitude of 1, then the amplitude at 0 degrees will be 1. At 90 degrees, the amplitude is zero. At 180 degrees, the amplitude is -1. At 270 degrees, it is back to 0, and then 1 at 360 degrees. The Phase value is the number of degrees that your data waveform is shifted in relation to the cosine reference. Let's say that your observed EEG waveform has the characteristics of a sine wave. At 0 degrees, the amplitude is 0, at 90 degrees the amplitude is 1, at 180 degrees it is 0, at 270 degrees it is -1, and at 360 degrees the amplitude is back to 0. In relation to the cosine, the Phase of the sine wave would be shifted 90 degrees in the positive direction. (Technically, it could also be -270 degrees, but Phase is limited to $\pm$ 180 degrees). Phase is calculated for each frequency bin. Phase calculations are used, for example, where you are interested in interhemispheric relationships among steady state evoked potentials.

2.4.50 Spline Fit

Spline Fit (EEG, AVG; time domain) - Spline Fitting fits an existing waveform to a new, specified number of points. This is essential if you, for example, recorded data with a number of points other than a power of 2, and then wish to do an FFT or coherence analysis (both require the number of points to be power of 2). Or, you may

wish to combine two or more data files that differ only their number of points (same number of channels, same labels, same start and stop times for the epoch interval). Spline Fitting can then be used to force a different number of points on to the same waveform. As a general rule, you should only spline *down* to the nearest power of 2. For example, if you 300 data points, you should spline down to 256, not up to 512.
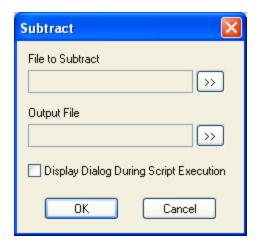
After retrieving your EEG or AVG file, select Spline Fit from the Transforms list. The Spline Fit window will appear, displaying the current number of points. Enter the

desired number of points, use the [>>] button to access the dialog box to enter an output file name and to select a folder, and click OK. A new multiple window display will appear with the new number of points.

2.4.51 Subtract

Subtract (AVG, time and frequency domain; EEG, time domain) - The Subtract option computes the difference between two like files, and displays the results as a difference waveform. The files must have the same number of electrodes, the same labels, the same start and stop points for the epoch, and the same number of points. With EEG files, the reference AVG file is subtracted from each sweep in the EEG file.

With prior versions of SCAN, it was possible to subtract COH files. Since that is not a valid operation without first transforming the COH values (using, for example, Fisher's z), we recommend instead that you export the COH files to ASCII, import them into a statistical package, and perform the transformation and subtraction there.

After retrieving a .dat file, select the Subtract option from the Transforms list. You will see the Subtract display. Use the [>>] button to select the comparison file and the output file. Then click the OK button. A new multiple window display will appear containing the difference waveforms.
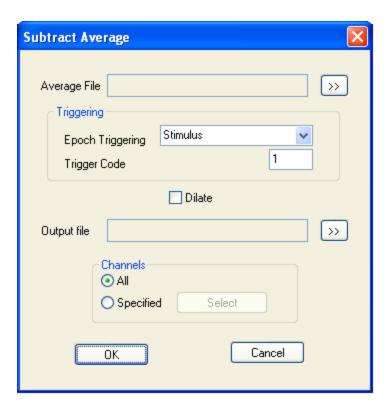
2.4.52 Subtract Average

Subtract Average (CNT) - The Subtract Average transform lets you subtract an AVG file from sections in a CNT file. For example, if you have an averaged EKG or BCG artifact, you can subtract that average from detected artifacts in the CNT file. To use the transform, you must first have stimulus or response events placed for the artifact sweeps. The events can be placed using the **Voltage Threshold** transform, the **QRS Detection** transform, or manually using **Insert Multiple Events**.

Subtract Average was split out from the EKG Noise Reduction transform to allow you more control in its use. Part of the EKG Noise Reduction transform involves creating a rolling average, and then subtracting that from subsequent artifact sweeps. The Subtract Average transform is similar in that an averaged artifact is subtracted from detected artifact sweeps. The average file, in this case, is not rolling - it is based on whatever sweeps you use to create the average.

Note
The Correlate Peaks, QRS Detection, and Subtract Average transforms perform many of the same operations contained in the EKG Noise Reduction transform. They were create as separate transforms to allow more flexibility in their use (and to make them available in the regular SCAN software; whereas, you need a Toolbox license to have access to the EKG Noise Reduction transform). An example using the transforms is presented just below.

Selecting the transform displays the Subtract Average dialog screen.

Average File. Select the AVG file that will be subtracted from each designated event in the CNT file. Generally, the AVG file is one created by Epoching and Averaging sweeps from the CNT file. The events should be place first using the **Voltage Threshold** transform, the **QRS Detection** transform, or manually using **Insert Multiple Events**.

📄 **Note**

When you epoch the CNT file, you should use Start and End times just as if you were using the EKG Noise Reduction transform. That is, select an End time that overlaps slightly with the next R wave peak. In most cases, Start and End times -200 and 1200ms should work well for EKG reduction.

Triggering. Triggering uses either **Stimulus** or **Response** events. There is no Voltage Threshold option, as there is with the EKG Noise Reduction algorithm. Select the type of event, and enter the **Trigger Code**.

Dilate. A given artifact sweep may vary from the average artifact by overall amplitude - it may be somewhat larger or smaller than the average artifact. Enabling this option will direct the transform to fit the average to the current sweep by using a multiplier to dilate or constrict the average waveform until a best fit is obtained. On a per channel and per trigger basis, data points in the average waveform are scaled according to a minimized RMS value. The final subtraction will avoid over- or under-correction that may otherwise occur.

Output file. Enter a name for the new CNT file that will be created.

Channels. You can have the correction applied to **All** channels, or only **Specified** ones. In the latter case, select Specified and select the channels to be included
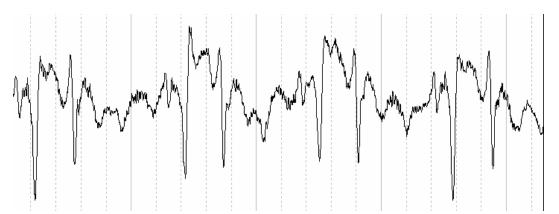
(green) or excluded (red).

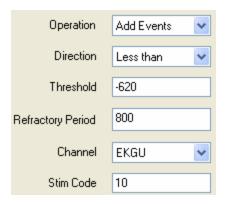### Example Using Correlate Peaks, QRS Detection, and Subtract Average

As mentioned, these new EKG/BCG reduction transforms are, for the most part, contained within the EKG Noise Reduction transform. Our experience has been that, in some cases, especially with BCG, it is more effective to apply the steps independently, where you have more control over the parameters, and can see better what parts are not effective enough. Also, we have added some additional methods. We will demonstrate with a CNT file that contains considerable BCG artifact (the steps for EKG reduction are similar).
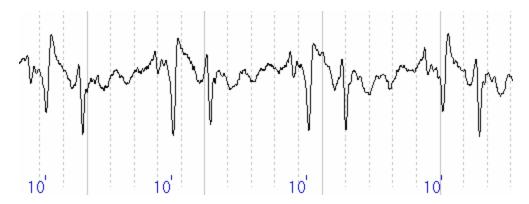

1. The first thing we need to do is add event marks for the peaks of each artifact. There are at least three ways to do this: the Voltage Threshold transform, the QRS Detection transform, and manually.

    a. **Voltage Threshold**. If we look more closely at the EKGU channel, we see that there are two peaks for each heartbeat. The first is likely the R wave.

Looking through the file, it appears that a threshold of about -620μV may work. We enter the parameters as displayed to have the Voltage Threshold transform insert the events (type 10). The Refractory Period will block out other peaks that reach the threshold.

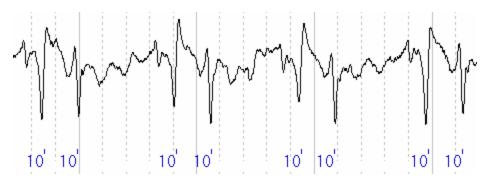|	
Operation	Add Events
Direction	Less than
Threshold	-620
Refractory Period	800
Channel	EKGU
Stim Code	10

Looking again through the file, the events were placed correctly in all instances, with no false positives or false negatives.

b. **QRS Detection**. Had the Voltage Detection not worked, we might then try QRS Detection to insert the trigger events. You need only select the artifact channel and enter the Type code to insert.
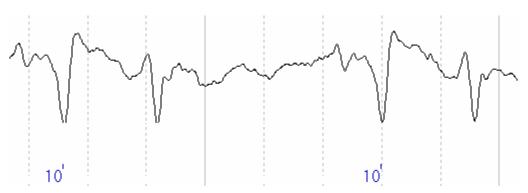
In this file, QRS Detection inaccurately placed events at all peaks. Averaging those sweeps and then subtracting the average would lead to very unacceptable results.

The QRS Detection method is based on an automatic QRS detection algorithm, and works very well for regular EKG recordings. However, with BCG, it is not always too effective.
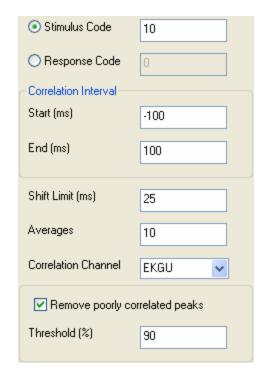
It is also possible - with any of the above methods - to filter the trigger channel first to make the peaks easier to detect. Assume you filter the trigger channel and have placed the events accurately using one of the above methods. Now, if you want to perform the correction using the original data, you will need to transfer the events from the filtered file to the original file. You can do this by selecting the **Event File** transform to create a text file that contains the event types and positions. You can then import that event file using the Import Event File transform (see **Import Event File** [133] above). You will then have the same events in the original file, and you can proceed to the next step.

c. **Manually insert the events**. If no other way will work well enough, you can use the 1 icon to **Insert Multiple Events**. Display a few seconds at a time to facilitate placements at the peaks (better temporal resolution). The Correlate Peaks transform will correct small errors by alignment by waveform correlation rather than event placement.

Manual placement can be very effective, albeit time-consuming.

2. Once you have placed the events, the next step is to correct the placements based on waveform correlations, rather than by simply aligning the events, using the **Correlate Peaks** transform. Enter the stimulus (or response) code marking the peaks. The Correlation Interval has been described above. It is the actual interval in the most recent artifact sweep that will be correlated with the same interval in the average artifact. It typically encompasses the R wave, although it can be a different interval (-100 to 100ms about the events was used in this example).

The Shift Limit is imposed to minimize the possible correlations that will be computed (+25 points was used). Ten sweeps will be averaged to create the average artifact. Sweeps that do not reach a correlation of .90 will be excluded from the average.

You probably will not notice any difference after applying the correction. The events were repositioned as needed to maximize the correlations.

3. The next step is to create the averaged artifact that will be used in the correction. In the EKG Noise Reduction transform, this will be a rolling average. In the current steps, we will use a single average based on the entire recording. **Epoch** the CNT file *only* for the artifact events that were entered (type 10 in this example). For X Minimum and X Maximum, we recommend -200 to 1200ms in most cases for EKG. It does not matter that the maximum extends into the next artifact (in fact it is recommended). For BCG, it may take more experimentation to find the best times, and it may work better if there is no overlap with the next artifact.

Now that you have the epoched file, you can reject any remaining sweeps that are aberrant, perform baseline correction, detrending, etc. as needed. Filtering is not recommended at this point.
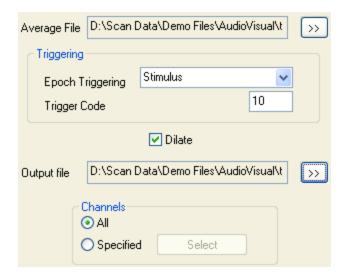
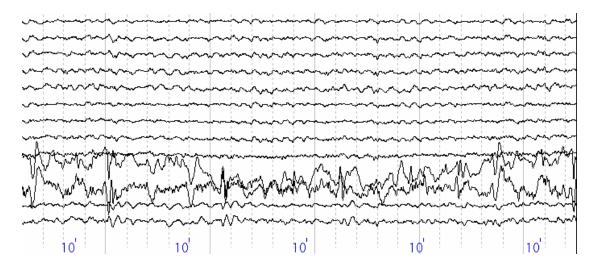Then average the artifact sweeps.

📄 Note
The EKG Noise Reduction transform uses a rolling average. That is to allow for variations in the heart beat that can occur over time. The assumption is that a given EKG pulse will be more similar to the N beats that precede it than to the average of all heart beats in the file. In the preceding step, we averaged all the heart beats in the file, knowing that the subtraction may be less than perfect.

4. Now that we have an average artifact AVG file, the final step is to subtract that waveform from each section about the events in the original CNT file. This is the purpose of the **Subtract Average** transform. Select the file to be subtracted, select whether the CNT file events are stimulus or response types, and enter the type code. The Dilate option was selected to correct for beat to beat amplitude variability. Enter an output file name, and apply the corrections to all or selected channels.

You will then see the corrected CNT file.

The steps have significantly reduced the BCG artifact. In general use, we recommend that you try the EKG Noise Reduction transform first, and then try the individual steps if that is not successful enough. The individual steps allow you to observe better what is happening with a difficult file, and thereby suggest parameters or other steps that may be more effective.
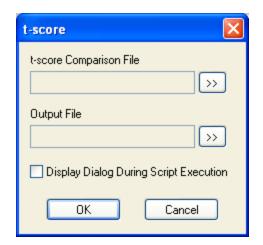
2.4.53 t-score

t-score (AVG, time and frequency domain) - This option calculates t-tests for each electrode over time for waveform data and over frequency for spectral data. Student's t for two distributions that are thought to have the same variance but different means is computed as the difference between the means normalized by the standard error of the difference of the means (Sd):

$$t = (mean1 - mean2) / Sd$$

Where $Sd = sqrt((var1*(n1-1) + var2*(n2-1) / (n1+n2-2))(1/n1 + 1/n2))$.
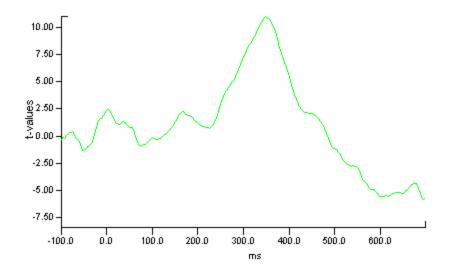
Follow these steps to compute t-scores between two comparable group data files. The two group data files must have the same number of electrodes, the same electrode names, the same epoch start and stop time points, and the same number of points.

1. Select the first of the two groups that you wish to compare. Since you will be subtracting group 2 from group 1, give some thought to which file you retrieve first. For example, if you are comparing P300 RARE and FREQ group averaged recordings, you should recall the RARE group first. Otherwise, the t-scores will have negative values during the P300 component, and the maps will show a significant decrease during the P300 component.

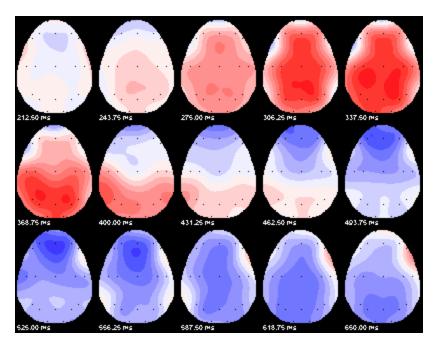2. Next, select t-score from the Transforms list, and see the t-score display.

3. Select the comparison file using the browse button ⟩⟩, and the Open File utility display that is accessed. Then click OK.

4. Use the ⟩⟩ button to select a folder and enter an output file name, then click Save, and you will see a new multiple window display containing the t-score waveforms.

Shown below is the result of the t-score operation between auditory P300 RARE and FREQ group data waveforms. T-scores have been computed for each point at all electrode sites. The results for the PZ electrode are displayed.

Large positive t-values are found over the 250 to 400ms interval as well as negative values from about 530 to 700ms.

5. Note that you may map the t-score data just as you map other data files. Please refer to the Mapping sections below for details (the .map file must agree with the data file in terms of channel labels). A 2D Cartoon displaying the t-scores throughout the P300 and N400 components will appear similar to the following:
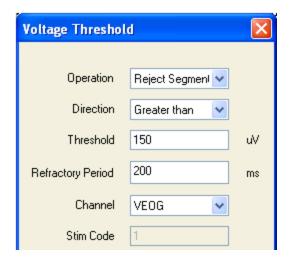

📄 **Note**

The t-score option will not be active on the Transforms list if variances have not been saved for the comparison file. Variances across individuals are automatically saved when group averages are created. Thus, for a comparison of two group averages, the **Compute Standard Deviation** *option under Average need not have been toggled on when the individual averages were made. However, the t-test comparison of two individual average waveforms does require that the*

variability across sweeps be computed. The **Compute Standard Deviation** *option must be turned on when creating individual averages. The statistical validity of comparisons between two average files created from a single subject is left up to the user to determine.*

2.4.54 Voltage Threshold

Voltage Threshold (CNT) - The Voltage Threshold option allows you to insert event markers into a CNT file on the basis of a detected voltage in a specified channel, and to reject sections of a CNT where detected voltages exceed a specified threshold.

Retrieve a CNT file and click Voltage Threshold on the Transforms list. The Voltage Threshold display will appear. (The *viscpt.cnt* file was used below to illustrate this feature).

Operation - The operation field allows you to select **Add Events** or **Reject Segments**. **Add Events** will add triggers to the CNT file where the voltage threshold is met. **Reject Segments** will reject segments of the CNT throughout the span where a designated channel exceeds the threshold.

Direction - The options are: **Greater than**, **Less than**, and **Absolute value**. In the first two options, a trigger will be placed when the voltage at the designated Channel is Greater than the Threshold, or Less than the Threshold. In the first case, think of that as a positive voltage that exceeds the positive Voltage Threshold. In the latter case, think of that as a negative voltage that is less than a negative Voltage Threshold. The Absolute value option will result in a trigger when the threshold is exceeded in either the + or - direction. In this instance, the threshold MUST be a positive number.
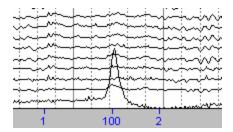
Threshold - Enter the voltage threshold in μVs.

Refractory Period - Once a threshold criterion is met, the Refractory Period determines the length of time that must pass before the next trigger may be detected. This is to prevent the insertion of multiple triggers during a burst of EMG, for example.

Channel - The pull-down menu will display a list of all your channels. Select the one that is to be monitored for the voltage threshold.

Stim Code - This field lets you specify the trigger type code that will be inserted at each detected event.
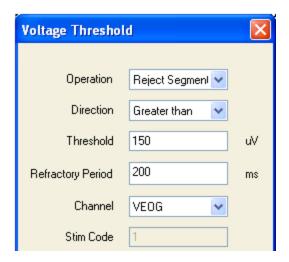
We will illustrate the **Add Event** option by having Type codes of 100 entered into the *viscpt.cnt* file at every point where the voltage on the VEOG channel exceeds 250μVs (with a refractory period of 500ms just to make sure that multiple events are not entered for the same blink). In other words, we will add triggers near the peaks of the more prominent blinks. Enter the values and click OK.

The events will be added to the CNT file. Step through it until you see a prominent blink - it will have a type code of 100 beneath it.
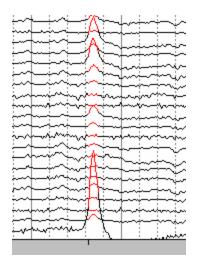

Note that these types codes may now be treated just like any other stimulus trigger type codes from STIM. You may create epoch around them, include them in an event file, and so forth.

The other option with Voltage Threshold is to use it to reject segments in the CNT file. Using the same original *viscpt.cnt* file, select Voltage Threshold, and enter the settings as shown.
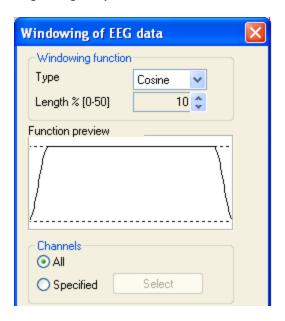

This will result in the automatic rejection of those segments of the CNT file where the positive voltage from the VEOG channel exceeds 150 μVs, with a 200ms refractory period. Click OK, and locate a blink. The span of the peak part of the blink will be rejected in all channels (changed to red).

2.4.55 Window

Window (EEG, AVG; time domain) - The Window transform applies a window taper to single-sweep epochs. Application of a window can be useful to minimize edge effects.

After retrieving your EEG or AVG file, select Window from the Transforms list. Select the type of windowing function from the pull-down list (Cosine, Blackman, Hanning, Hamming, Parzen or Welch), and the enter the extent of the taper. The effects of the various filters and taper length are displayed in the Function preview region. You may window All channels, or just Specified channels (click the Select button and select the channels from the montage diagram).

Enter a file name and path, and click OK when you are ready to proceed. A new multiple window display will appear containing the windowed data.
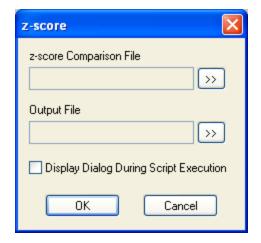
2.4.56 z-score

z-score (AVG, time and frequency domain) - The z statistic is used to determine how many standard deviations from the mean a given value happens to fall. For example, you can use z-scores to compare an individual's EP measures to a group distribution of the same measures. In EDIT, z-scores are computed for each electrode over time for waveform data and over frequencies for spectral data. The formula used for calculating z-scores is:

$$\frac{(\text{working file mean} - \text{comparison file mean})}{(\text{standard deviation for working file})}$$
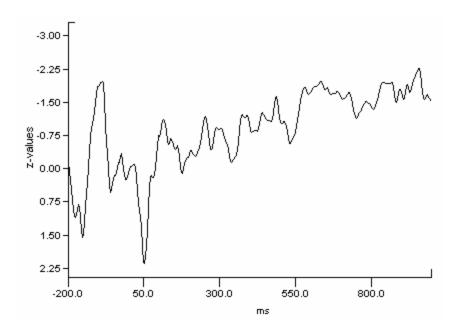
Follow these steps to compute z-scores.

Retrieve either the group average file or the individual's data file (the order does not matter). *Note: when you average the individual's sweeps, you must have the* **Compute Standard Deviation** *option disabled.*
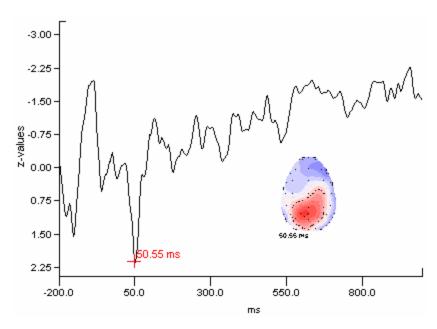
After retrieving either file, select z-score from the Transform list of options. You will see the Z-score display. Click the Browse button ⟩⟩ to access a Select Data File utility. Select the other file for the comparison, and click Open.

Enter a filename and path, and click the OK button. You will then see a new multiple window display containing the z-scores for each time point and from each channel.
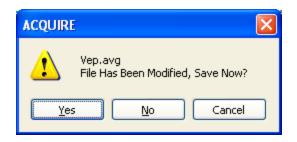
The z-scores may be mapped as with any AVG file, as shown.

📄 **Note**
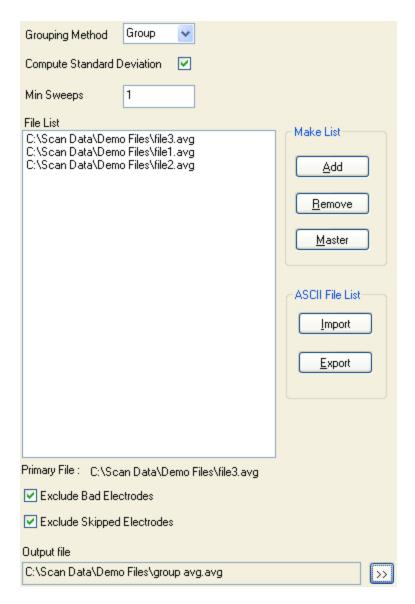
When you close a data file (or close EDIT) following a Transform or other operation that may cause a modification to the data file, you will see a message asking if you want to save the change. Click Yes to save the file with the modification, No to close the file without the modification, or Cancel to cancel the closing of the file.

2.4.57 Group/Individual Avg

Group/Individual Avg (AVG, time and frequency domain) - The
Group/Individual Average option allows you to create a group average from individual
AVG data files. This is one of the few options in which you do not need to retrieve the
data files first (in fact, you should not retrieve them first - you cannot include any
open files). Click the Group/Individual option from the Transforms list. You will see the
Group Averaging Properties display appear.

Grouping Methods - There are two Grouping Methods: Group and Individual. The **Group** method computes an average based on a grouping variable, where each subject in the average is represented by one file. Therefore, it also calculates and stores the number of individuals within the average. When using the Grouping method, it is NOT necessary for the individual averages to have been formed with the **Compute Standard Deviation** option enabled (in the Averaging transform). The variance is created across individual AVG files to get the grand variance.

The **Individual** method computes weighted data averages based upon the number of trials or sweeps in each data file. For example, if two files are averaged together, and one file comprised three times as many trials as the other file, then values in the first data file would be multiplied by a factor of three. Then the files would be summed and divided by two (the number of files in the average). This utility primarily should be used to average several data files associated with the same individual. Since this average takes into account the total number of trials per waveform, the resulting average is the same as if the data were collected and averaged in one contiguous session.
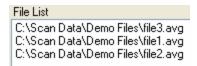
When using the Individual method, it IS necessary for the individual averages to have been formed with the **Compute Standard Deviation** option enabled (in the Averaging transform). The variance is created for each AVG file, and then combined to get the pooled variance across epochs.

Compute Standard Deviation - The Compute Standard Deviation field determines if the standard deviation is saved along with the group or individual average. *Note: If you intend to use the t or z statistics, be sure to enable this option when you create the group.*

Min Sweeps - The minimum # sweeps field determines the minimum number of sweeps that a given file must contain to be included in a group average.

The next step is to select the files to use in the average.

Make List - Click the [Add] button to access the Select Data Files display. If the data files are all in the same folder, you can use the standard Windows keyboard options to select multiples (*Ctrl+left mouse*; *Shift+left mouse*). The selected files will be displayed in the File List.

File List
C:\Scan Data\Demo Files\file3.avg
C:\Scan Data\Demo Files\file1.avg
C:\Scan Data\Demo Files\file2.avg

Use the [Remove] button to remove an unwanted file from the list (highlight the file, then click the button).

The [Master] button is used to designate a single file as the determining file for inclusion of Skipped channels (see the Exclude Skipped Channels section below). In previous versions of EDIT, the *first* file was automatically selected as the "master" file. In SCAN 4.3, you can select *any* file to be the Master file. Highlight the file to be considered the primary file, and then click the [Master] button.

Import List from ASCII - The Import from ASCII option lets you retrieve a .dat file that you saved using the Export to ASCII option (see below).

Export List to ASCII - It may be convenient in some circumstances to save a list of files that you wish to average together. For example, you may wish to average a group of files, and at a later date, add (or delete) more files to the group. The Export to ASCII option will create a .dat file that contains a list of the files and paths that are displayed in the File List. After Importing the ASCII list, you may add (or delete) files to the list, thereby avoiding the need to recreate the original list.

Exclude Bad Electrodes - When enabled, activity in any of the channels marked Bad, in any of the data files, will be excluded from the group average. If you leave it disabled, the activity in the Bad channels will be included in the group average. If there are any Bad channels in common across data files, the group average will

indicate this by displaying the electrode labels for those channels in red. After retrieving the group averaged AVG file, click between the electrode displays with the *right mouse* button and select the ⎡View N Values⎤ option. You will then see a display showing how many sweeps were averaged for each channel. With Group Averaging, this will be the total number of files minus the number of files with Bad channels. With Individual Averaging, this will be the total number of sweeps across files, minus the number of sweeps in files where the channels were Bad. For example, if you had File1 with 100 sweeps and no Bad channels, File2 with 200 sweeps and no Bad channels, and File3 with 300 sweeps with one Bad channel at FZ, then the "View N Values" count for FZ, in the final average, would be 300 (600 Total sweeps minus 300 with no accepted sweeps from FZ).

Exclude Skipped Electrodes - When enabled, activity in any of the channels marked Skip, **in the Primary data file only**, will be excluded from the group average, and those channels will not appear in the group average. The same Skipped channels in subsequent data files will also be Skipped - there will be no group averaged data displayed (or calculated) for the channels that are Skipped in the first data file. Different Skipped channels in subsequent data files will be ignored. The rationale for this is that you typically decide which channels are to be Skipped before acquisition begins. For example, you may want to Skip an EKG channel. Skipped channels in a group average, therefore, should be the same channels across data files, so the first data file is used as a template for the remaining data files. Bad channels, on the other hand, are channels that go bad during acquisition, or may be determined to be bad in the offline analyses. These may easily vary from file to file, and are therefore treated in a different way, as described above.

If you leave Exclude Skipped Channels disabled, the activity in the Skipped channels will be included in the group average, and the channel will be displayed.

Use the ⎡>>⎤ button to enter a file name for the averaged data file, and click Save. A new multiple window display will appear with the averaged waveforms.

2.4.58 User Defined
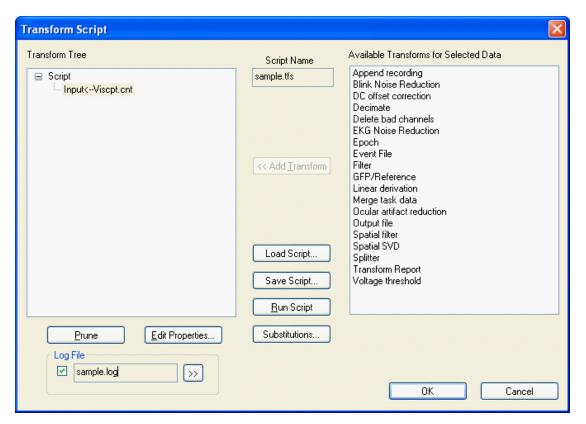
User Defined - The User Defined option allows you to select a data file first, then select a Script file to apply to that file (see the Script section below for scripting details). Retrieve a data file, then click the User Defined option. An Open File display will appear, allowing you to select a .tfs (script file) you have already created. After selecting the file, it will then be applied to the data file. Notice in Scripting, described below, that one of the options under Input File, "Files of type", is for a Neuroscan Setup File (.ast). Selecting the setup file allows you to create the script without specifying a data file. Then, when you subsequently retrieve the data file, you can apply the script to that file by using the User Defined option. This allows you to apply one script to multiple files without inputting the file name for each (assuming they all were acquired with the same setup file). Note also that you can create an .ast file from a data file (under Edit), if you don't have the .ast file.

2.4.59 Script

Script (CNT, EEG, AVG, COH) - Script files are useful when you have a repeated sequence of operations that are performed on your data file(s). Rather than performing each operation manually, you can create script files to automate many of the operations. Aside from saving time and reducing the monotony, script files also insure that the same operations are performed in the same way, and in the same order for all data files used. Beginning with SCAN 4.2, BATCH files based on Tool Command Language (Tcl) are possible, and in many cases preferred over Scripting. BATCH files let you do much more and are more flexible. For an introduction to Tcl BATCH files, please see the Tcl BATCH Tutorial (distributed as a PDF file in the *\Scan4.5\Pdf* folder), and the Tcl BATCH manual for complete details.

Scripting is accessible at any time in EDIT. However, a script file cannot retrieve a data file if you have the data file already open. Be sure to close any data files that will be included in the script program (see the User Defined option above for a way around this).

Click the Script option at the bottom of the Transforms list, and the following screen will appear.

The field on the left hand side displays the script "tree" as it grows, and the field on the right shows the operations that are available for a given step in the script sequence. When you first start the script routine, there is only one option available - **Inputfile**. Select **Inputfile** by clicking it. Note that the <kbd><< Add Transform</kbd> button becomes active. Click it, and you will see the standard Open File utility.

You may also double click on a transform to add it and display its properties automatically. Select the type of file from the pull-down "Files of type" menu, and then select a file. For example, select the *viscpt.cnt* demonstration file (in the *\Scan Data\Demo Files\VisualAttention* folder), but do not open it just yet. We will use it to demonstrate some of the operations shortly.

Notice that one of the options under "Files of type" is for a Neuroscan Setup File (.ast). Selecting the setup file allows you to create the script without specifying a data file. Then, when you subsequently retrieve the data file, you can apply the script to that file by using the User Defined option, described above. This allows you to apply one script to multiple files without inputting the file name for each.

Output Files in Scripting. Many of the transforms seen in point-and-click mode contain lines for the output files. These lines are basically ignored in Script mode. Instead, you will need to specify the output file using the option in the list of script commands, as described in the examples below and in the Script tutorial (in the SCAN Tutorial manual).

Display Dialog During Script Execution - You have likely noticed by now that most of the Transform screens described above have an enable/disable field at the bottom called ☑ Display Dialog During Script Execution . When enabled, the screen will appear while you are executing the script file. This provides an opportunity for you to make modifications to the operations while the script routine is running. Generally, it is preferable to leave it disabled, so the that Script file will run without the need for user intervention. Leave the field disabled, and open the *viscpt.cnt* file.

⊟ Script

The Transform Tree displays the first branch   Input<--Viscpt.cnt , and the Available Transforms for that type of file are listed on the right side of the display.

Append recording
DC offset correction
Delete bad channels
Epoch
Event File
Filter
GFP/Reference
Linear derivation
Merge task data
Ocular artifact reduction
Output file
Spatial filter
Spatial SVD
Splitter
Voltage threshold

If you select any of the transforms, you will see the same dialog screens that are described above. Select the options that you want to use in the script file in the same way you would for manual execution. A typical next step might be to Filter the *viscpt.cnt* file. Select the **Filter** transform, and then click the << Add Transform button. You will then see the same Filter screen described in that section above. Set the parameters as desired, and click OK. (The final script file we are creating

will be displayed below).

A note about Scripting with CNT files. Most of the operations performed on a CNT file contain an option for the Output CNT file. The Output file is always created, but it may not be one you wish to save. If you do not want the interim files saved as separate files, the easiest thing to do is to use the default file name for the Output CNT file (such as *FILTER.cnt*). The next step will use that file, and any transformations will be made to the file. If you want an interim file to be saved, use the Output File option listed on the right-side list of options above.
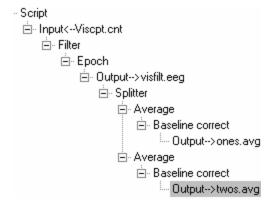
Exception with Ocular Artifact Reduction. The Ocular Artifact Reduction transform is a terminal operation. That is, no further operations may be performed on a file after the reduction has been performed. It is necessary to retrieve the transformed file in a second script file, and continue subsequent transforms with it.

Continuing with the example, let's say that after Filtering the *viscpt.cnt* file (and using the default Output File name), we then wish to Epoch the file. Click the **Epoch** option, then Add Transform, and select the settings as desired. For this step, we will want to create and save the epoched file (.eeg file). Select the Output File option, click Add Transform, and enter a file name.

After epoching, the next step might be to Average the sweeps using the two type codes in the file. In other words, we want to perform more than one operation on the same file in the same script (two sorted averages using the same .eeg file). The **Splitter** option allows you to do this. It serves as the junction point for the branches in the tree. It should be placed just after the "parent" file, or, in this example, just after the Epoch option (see final tree below). With the Splitter in position, we can now create the sorted averages.

Select the **Average** option, and use the **Sort Criteria** button to select the Type Codes of 1. Let's then perform a **Baseline Correction** on the final AVG file, and give it an Output File name. Then highlight the Splitter option in the tree, and click the Average option again. Sort this time for Type Codes of 2. Select Baseline Correction again, and then the Output File option for the second AVG file.
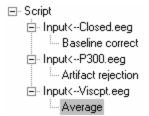
The final Script file should look like the one below.

```
-- Script
  ⊟-- Input<--Viscpt.cnt
     ⊟-- Filter
        ⊟-- Epoch
           ⊟-- Output-->visfilt.eeg
              ⊟-- Splitter
                 ⊟-- Average
                    ⊟-- Baseline correct
                       ┊---- Output-->ones.avg
                 ⊟-- Average
                    ⊟-- Baseline correct
                       ┊---- Output-->twos.avg
```

Remember to save your Script files using the **Save Script** button. Click **Run Script** to execute the Script file, but still remain within the Script editor. If you click OK, you will exit Scripting. If you made any changes, you will be asked if you want to

save them. Click Cancel to exit the editor without running the Script file.

Using Multiple Files in a Single Script. It is possible to specify more than one file in a single Script. Select Input File, then Add Transform, then select a data file, as above. To add an additional file, click the line, and you will see the Input File line again. Click it again followed by Add Transform and select another file. You can add transforms to each data file branch.
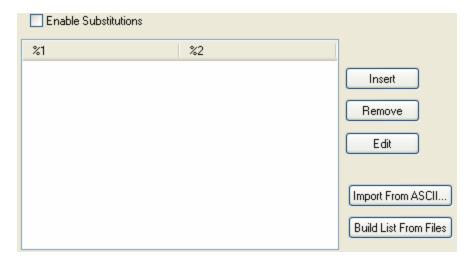
```
□ Script
    □ Input<--Closed.eeg
        └ Baseline correct
    □ Input<--P300.eeg
        └ Artifact rejection
    □ Input<--Viscpt.eeg
        └ Average
```

Substitutions - The Substitutions option lets you use character strings to perform the desired set of operations on multiple data files. This is a useful and powerful option if you plan to use script files extensively in your analyses. However, using it to its full extent requires some preplanning for your choice of file names. Let's look at a couple of examples that will illustrate its operation.

First, it is important to understand that 1) the Substitutions option is only used with the Input and Output File options, and 2) you need to define the list of files prior to creating the script that will use them.

Let's say you have 5 .eeg data files called *exampA.eeg* through *exampE.eeg*. Note that the file names have in common "examp", and the only thing that differentiates them is the final letter. That is the character "string" that we will substitute (the string can have any number of characters). The first step is to make a list of the characters to be substituted. Select Script from the list of Transforms. When the Transform Script display appears, click the ⬚ Substitutions... button, and see the following display.

```
☐ Enable Substitutions

  %1                    %2
                                          [ Insert ]

                                          [ Remove ]

                                          [ Edit ]


                                          [ Import From ASCII... ]

                                          [ Build List From Files ]
```
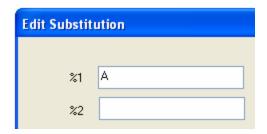
The are two string lists that you may use (%1 and %2). The general idea is to make one or two lists of characters that will be substituted wherever you place

%1 and/or %2 in the Input or Output File statements.

Click the ☑ Enable Substitutions field. (The Substitution information is saved automatically with the Script file. The Enable field allows you to use or not use the Substitutions, even when the information is saved with the Script file).

Click the [Insert] button, and see the Edit Substitution display. (This is the same display the you may later alter by clicking the [Edit] button).

Edit Substitution

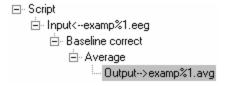%1 [A   ]

%2 [   ]

For this example, we will be using the **%1** substitution list only. Since the first file we will be using has an "A" as its only unique character, enter an "A" in the %1 field, and click OK. An "A" will appear in the %1 column. Repeat these steps to enter B, C, D and E (Insert, B, OK, and so forth). Then click the OK button on the Substitution List display, and you will be back at the Transform Script display.

Select the Input File option, click the [<< Add Transform] button, and select the first file. In this case, it is the *exampA.eeg* file. Now click the [Edit Properties...] button. The Input File display will appear, and we want to modify the file name. This is where you replace the uniquely occurring file name characters, that is, the strings that you listed in the Substitution list, with "%1". In this case, the "A" in the File Name line should be replaced with "%1". The path and file name would read C:\Scan4.1\Demo\examp%1.eeg . Then click the Open button. You will see the modified file name in the Transform Tree display Input<--examp%1.eeg .
You are telling the program to run the Script file using all files, in the specified directory, beginning with "examp", and ending with A-E. Now, go ahead and select whatever additional Transforms you wish to perform. When you get to the Output File name, include "%1" to add the A-E characters to the Output File names. The final Script file might appear as the following one.

```
⊟ Script
  ⊟ Input<--examp%1.eeg
    ⊟ Baseline correct
      ⊟ Average
        └ Output-->examp%1.avg
```

Then Save the Script file (if desired). Click the Run Script to run the Script file. You will see it cycle through for each file that has been retrieved.

When completed, you will see a **Transform Report**. The report can be saved as a .log file using the **Log File** field (see below).

```
Input<--examp%1.eeg - 10 epochs read from C:\Scan4.1\Demo\exampA.eeg
Baseline correct - Completed
Average - 10 Sweeps Accepted, 0 Sweeps Rejected
Output-->examp%1.avg - Results written to C:\Scan4.1\Demo\exampA.avg
Input<--examp%1.eeg - 10 epochs read from C:\Scan4.1\Demo\exampB.eeg
Baseline correct - Completed
Average - 10 Sweeps Accepted, 0 Sweeps Rejected
Output-->examp%1.avg - Results written to C:\Scan4.1\Demo\exampB.avg
Input<--examp%1.eeg - 10 epochs read from C:\Scan4.1\Demo\exampC.eeg
Baseline correct - Completed
Average - 10 Sweeps Accepted, 0 Sweeps Rejected
Output-->examp%1.avg - Results written to C:\Scan4.1\Demo\exampC.avg
Input<--examp%1.eeg - 10 epochs read from C:\Scan4.1\Demo\exampD.eeg
Baseline correct - Completed
Average - 10 Sweeps Accepted, 0 Sweeps Rejected
Output-->examp%1.avg - Results written to C:\Scan4.1\Demo\exampD.avg
Input<--examp%1.eeg - 10 epochs read from C:\Scan4.1\Demo\exampE.eeg
Baseline correct - Completed
Average - 10 Sweeps Accepted, 0 Sweeps Rejected
Output-->examp%1.avg - Results written to C:\Scan4.1\Demo\exampE.avg
```

Since there are two possible substitution lists that may be used, we could have, for example, entered a different string list under the **%2** column, and specified that in the Output File name C:\Scan4.1\Demo\examp%2.avg .

%1	%2
A	vvv
B	www
C	xxx
D	yyy
E	zzz

The files ending in A-E are retrieved, transformed, and saved as vvv through zzz (see the section of the Transform Report below).

```
Input<--examp%1.eeg - 10 epochs read from C:\Scan4.1\Demo\exampA.eeg
Baseline correct - Completed
Average - 10 Sweeps Accepted, 0 Sweeps Rejected
Output-->examp%2.avg - Results written to C:\Scan4.1\Demo\exampvvv.avg
Input<--examp%1.eeg - 10 epochs read from C:\Scan4.1\Demo\exampB.eeg
Baseline correct - Completed
```
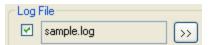
As you can see, this simple procedure can be used to rename files, even if no other Transforms are applied.

The Remove button is used to remove an entry from the list (highlight the entry, then click the Remove button). The Edit button is used to modify existing entries (highlight the entry and click the Edit button). In some circumstances, it may be easier to create your substitutions list from a text editor, rather than using the steps described above. You may do that as long as you save the file as a .txt file. Then click the Import From ASCII... button, and select the .txt file. You may select a number of files at once to add to the list

by clicking Build List From Files . An Open File utility will appear. Use the *Ctrl+Mouse* click combination to highlight multiple files. After clicking OK, these will appear in the %1 column.
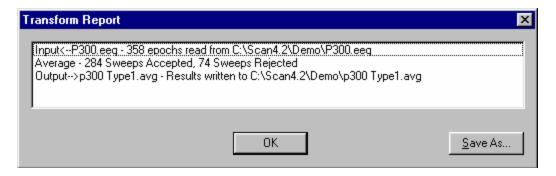
Editing options. While you can use the Edit Properties... button to make changes on a Transform display, it is not possible to modify the Script file itself - aside from pruning (deleting) a limb of the tree. That is, it is not possible to delete a single operation from within a tree, nor to add a step within a tree. For this reason, we encourage you to construct your Script file on paper first, then create it in the Script screens. Instead of highlighting a selected transform and then clicking the Edit Properties... button, you can just click the *right mouse* button on the transform to go directly to the properties display.

Log Files. You can create a record of the script file operations by enabling the **Log File** option from the main Script window. Use the Browse button to set the path and file name. The summary information is written to a text file (with a .log extension), which can be reviewed with a text editor.
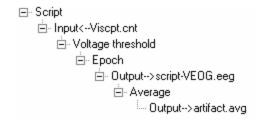
```
Input<--P300.eeg - 358 epochs read from C:\Scan4.2\Demo\P300.eeg
Average - 284 Sweeps Accepted, 74 Sweeps Rejected
Output-->p300 Type1.avg - Results written to C:\Scan4.2\Demo\p300 Type1.avg
```

You also have the option to save the results of the Transform Report (same information) from the Transform Report screen using the Save As button. The Save As utility window will appear, and you may specify the file name and path (.log extension).
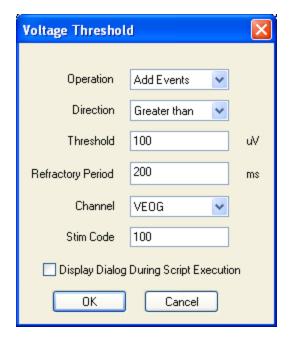
Sample Script. An example of the application of Scripting was alluded to above in the Spatial Filter section in the identification of blink sections for use with the Ocular Artifact Reduction routine. In that example, we described how to place Function Key events at the beginning of the blinks. This can be automated considerably by using the Voltage Threshold transform in a Script file. The Script file would appear like the following one (using the *viscpt.cnt* demo file).

```
□ Script
  □ Input<--Viscpt.cnt
    □ Voltage threshold
      □ Epoch
        □ Output-->script-VEOG.eeg
          □ Average
            ⌐ Output-->artifact.avg
```

Start by retrieving the *viscpt.cnt* file, and then apply the **Voltage Threshold** transform. This is used to add event marks in a designated channel (VEOG, in this case), whenever a voltage threshold is met (100μV in a positive direction, in this example).

A type code of 100 was specified for the events. The Voltage Threshold display should appear as follows.

Voltage Threshold

Operation	Add Events
Direction	Greater than
Threshold	100 uV
Refractory Period	200 ms
Channel	VEOG
Stim Code	100

☐ Display Dialog During Script Execution

[OK]   [Cancel]

In the next step, epochs of 0-200ms are created around the type codes of 100. (Be sure to set the Sort Criteria Type field to 100). An Output .eeg file is created, and then averaged. The averaged file is then save as *artifact.avg*. This will create a perfectly suitable artifact-laden file on which you could then apply the Spatial SVD, as described in the Spatial Filter section above. Of course, you could also continue the Script file further and do the Spatial SVD in it.

Cartesian/Polar Coordinates (EEG, AVG, COH; script mode only) - The Cartesian Coordinate Transform applies especially to complex data, such as after computation of a Forward FFT, and is a complement to the Polar coordinates transform. That is, the Polar coordinates transform reverses the Cartesian coordinates transform, and vice versa. The Cartesian representation of complex data stores the real part as the first coordinate, and the imaginary part as the second coordinate. Note that real time domain data can also be viewed as complex, with the understanding that the imaginary part is identically zero. In

addition to frequency domain complex data, this transform anticipates an increasing role for treating complex time series in the future (e.g., complex demodulation). This transform has no effect if the data are already represented in Cartesian coordinates. Note that, as of this writing, the AVG format does not currently store complex data, but the first coordinate (real part) only; however, both EEG and COH formats support full complex data.
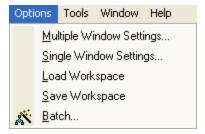
The Polar coordinates transform also applies especially to complex data, such as after computation of a Forward FFT, and is a complement to the Cartesian coordinates transform. That is, the Cartesian coordinates transform reverses the Polar coordinates transform, and vice versa. The polar representation of complex data stores the magnitude (square root of real part squared plus imaginary part squared) as the first coordinate, and the phase angle (arctangent of imaginary part divided by real part) as the second coordinate. Note that real time domain data can also be viewed as complex, with the understanding that the imaginary part is identically zero. In this case, the magnitude (first coordinate) equals absolute value (rectification), and the phase angle is 0 degrees for positive values and 180 degrees for negative values. In addition to frequency domain complex data, this transform anticipates an increasing role for treating complex time series in the future (e.g., complex demodulation). This transform has no effect if the data are already represented in Polar coordinates. Note that, as of this writing, the AVG format does not currently store complex data, but the first coordinate (magnitude) only; however, both EEG and COH formats support full complex data.

Executing Scripts from Outside SCAN. You may execute script files from an external batch file (.bat file) using the following command:

Acquire.exe /EditMode /Script=c:\Scan Data\Demo Files\sample.tfs.
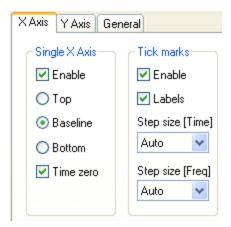
2.5 Options

The Options fields allow you to set a variety of personal preferences used in the display windows, such as, colors, axis labels, etc. You may also save and later recall size and position information for the data windows you open. All of the settings are saved in "Workspace" files (.aws extensions).

```
Options  Tools  Window  Help
         Multiple Window Settings...
         Single Window Settings...
         Load Workspace
         Save Workspace
    ✳    Batch...
```

2.5.1 Multiple Window Settings

Multiple Window Settings... - Clicking on the Multiple Windows Settings option displays a dialog box containing 3 option tabs: the X-Axis, the Y-Axis, and General.

X-Axis - The X-Axis page is divided into 2 regions: Single X-Axis and Tick marks.

Single X-Axis - Click on the **Enable** field to display the x-axis in the multiple window display for averaged or epoched files. Select whether you would like the axis to appear at the **Top**, the **Baseline**, or **Bottom** of the waveform display. Click on the **Time Zero** box to have a vertical line drawn at time zero.

Tick marks - Click on the **Enable** field if you would like tick marks displayed on the x-axis. Enable **Labels** if you would like labels to appear under the tick marks. Under the **Step size** options (Time and Freq) you may select the interval between successive tick marks. The Time domain steps are in ms, and the Frequency domain steps are in Hz. Click the pull-down arrow indicator and select the desired option (range is from 0.1ms to 100 seconds under the Time field, and .5Hz to 10kHz under the Freq field; or, select **Auto** to let the program place the marks automatically).

When you are satisfied with the settings, click the **Save As** button to add the information to the workspace file, then click on **OK** to continue. Click **Cancel** to leave the page without applying any of the selections.

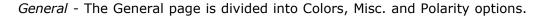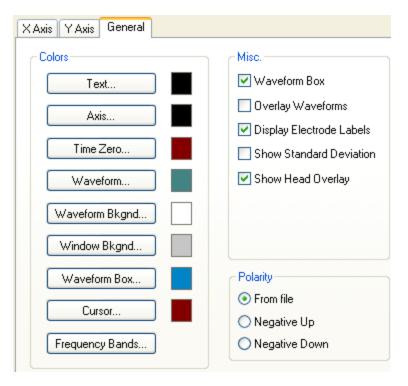*Y-Axis* - The Y-Axis page is divided into 3 regions: Single Y-Axis, Tick marks, and Scaling.

Single Y-Axis - Click on the **Enable** field to display the y-axis in the multiple window display. Select whether you would like the axis to appear at the left end of the x-axis (click **Adjust left**), the right end of the x-axis (click **Adjust right**), or intersecting with the zero point on the x-axis (click **Time zero**).

Tick marks - Click on the **Enable** field if you would like tick marks displayed on the y-axis. Enable **Labels** if you would like the labels to appear beside the scale. Under the **Step size** option you may select the interval between successive tick marks. Click the pull-down arrow indicator and select the desired option (range is from $0.01\mu V$ to $100mV$; or, select **Auto** to let the program place the marks automatically).

Scaling - Select whether you would like the scaling to be **Linear** or to use a ***Logarithmic*** scale.

When you are satisfied with the settings, click the **Save As** button to add the information to the workspace file, then click on **OK** to continue. Click **Cancel** to leave the page without invoking any of the selections.
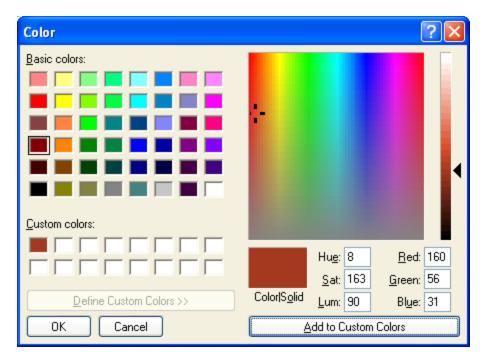
General - The General page is divided into Colors, Misc. and Polarity options.

Colors. Under the Colors section you may specify the color for various display features, including Text, Axes, Time Zero, Waveform, Frequency Bands, Waveform Background, Waveform Box, and Window Background. Selecting any of these *except* the Frequency Bands option, will display the basic color palette consisting of 48 options. Click on the desired color, then click **OK** to invoke the color.

📄 **Note**

The Text color will determine the color of the electrode labels. When selecting the Text color, bear in mind that Bad channel labels will always appear in red, and Skipped channel labels will always appear in black, regardless of the color you select for the Text.
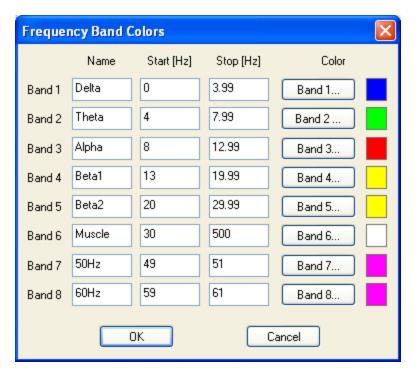
If you would like to create your own custom color, click the **Define Custom Colors>>** bar. An extension to the color palette will appear. In the large color screen, catch the reticule with the mouse, move it around the spectrum, and see the corresponding color in the Color/Solid box below. Notice also the intensity bar on the far right. Catch the triangular indicator with the mouse, and slide it up and down to vary the intensity of the color in the Color/Solid box. When you have decided on a color, click the **Add to Custom Colors** bar, and the color will be repeated in one of the Custom boxes on the original Color screen. Create as many customized colors as you wish.

Notice that each of the display features options will bring up the color palette with the custom colors you have created. To select one of the custom colors, click on the box, then click **OK** to invoke the color for the display feature you had selected.

The Frequency Bands option is the only exception to the other Colors options. Clicking this option displays the Frequency Band Colors window. With this feature you may 1) label up to eight EEG frequency bands, 2) define the start and stop frequency limits for up to eight EEG frequency bands, and 3) select a color for each frequency band. Note that these settings apply only to the Online Frequency Analysis you selected under **Overall Parameters → Frequency** section.

The default frequency band names are Delta, Theta, Alpha, Beta1, Beta2, Muscle, 50Hz and 60Hz; however, you may rename these as you desire.

You may also redefine the frequency limits of each band. Keep in mind that the actual frequency resolution will be determined by the **Points** value you selected under **Overall Parameters** → **Frequency** section*, and the AD rate. For example, 256 points, with a sampling rate of 1000Hz, gives a frequency resolution of approximately 3.9Hz. Therefore, while you might define, for example, Alpha as 8.0 to 12.99Hz, the actual Start and Stop values may be closer to 7.8Hz and 11.7Hz. With 1024 points, the actual Start and Stop points are approximately 7.84 and 12.74, respectively. The program will round the Start and Stop points you enter, but realize that these are not the exact values that are calculated. Notice also that you may have overlapping frequency bands. For example, the 60Hz band is completely encompassed by the EMG band.

Lastly, you may define the colors for each band by clicking on the corresponding button in the **Color** column. The color palette will appear, as described above. Select the desired color and click **OK** to continue.

Misc. - In the miscellaneous field you may select additional display options.

Waveform box. This field toggles the Waveform Box on and off. This is the

line box that surrounds the electrode display. The color is controlled by the Waveform Box color button.

Overlay Waveforms. The Overlay Waveforms option applies to epoched files. Enable it, and as you step through the EEG file, you will see successive sweeps overlain on the previous sweeps.
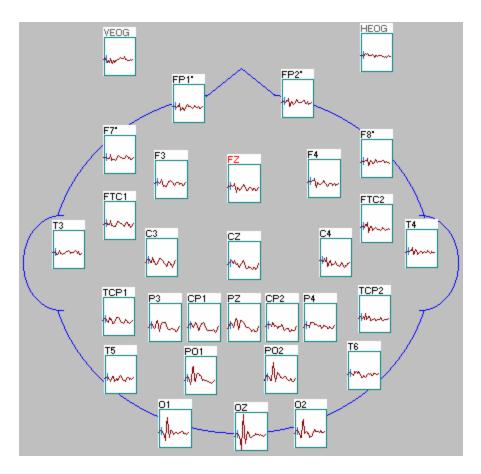
Display Electrode Labels. This option will toggle the display of the electrode labels (in the upper left hand corner of the displays).

Show Standard Deviation. This field toggles the display of the Standard Deviation for averaged data files, assuming the sweeps or files must have been averaged with the Compute Standard Deviation option enabled. When averaging single sweeps, that option is found on the Averaging transform display, in the Options section. When group averaging AVG files, the Compute Standard Deviation option is found on the Group Averaging Properties display.

Show Head Overlay. When enabled, this option will display the head overlay.
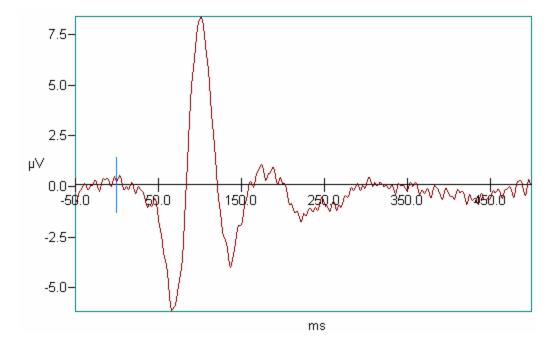
Polarity. These fields allow you to set the polarity when the file is retrieved. You can set it for **From File** to use whatever polarity setting is saved with the data file. Or, you can select **Negative Up** or **Negative Down** to override the data file and present the polarity the way you want.

Illustrations of Display Parameters - The following figures are presented to simplify the parts of the display that may be controlled independently using the settings described above. Shown is a multiple window display.

The gray area between the electrode displays is set by the **Window Background** color control. The white area within the displays is controlled by the **Waveform Background** control. The black electrode label color is set by the **Text** control. The gray color for the VEOG and HEOG channels indicates that these are **Skipped** channels. The red color for the FZ label indicates that this was set as a **Bad** channel. Labels that have an asterisk have been designated as **Artifact rejection** channels. The dark green box around each electrode display is the **Waveform Box** . The color of the waveforms is set by the **Waveform** control. The blue head shape is the **Head Overlay**. Zooming in on a channel gives the following display.

The positions of the x and y axes are controlled by the **Single X Axis** and **Single Y Axis** buttons (such as, the Top, Baseline, and Bottom options for the X axis). In the example, the X-axis is set for **Baseline**, and the Y-axis is set for **Adjust Left**. The Tick Marks controls toggle the tick marks on and off, toggle the tick mark labels on and off, and set the interval between the tick marks. The vertical blue line on the x-axis around 0 μVs is the **Time Zero** mark. This is seen on all of the channels in the multiple window display.
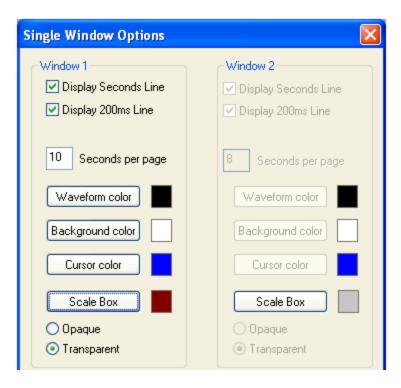
📄 Note
For printing purposes you may want to have all white backgrounds.

When you are satisfied with the settings, click on the **Save As** button to add the information to the workspace file, or to create a new workspace file (you may want to have more than one workspace file depending on the operations you routinely perform; the *.aws* extension is added automatically). Click **OK** to continue, or click **Cancel** to leave the page without applying any of the selections.

2.5.2   Single Window Settings

Single Window Settings... The Single Window Options dialog box allows you to set parameters for the single window displays. These include whether or not you wish to show the **Seconds Lines** and the **200ms Lines** in the display. You may also select the color for the Waveforms, Background, Cursor (text in the scale tool), and Scale Box (background for the scale tool). Clicking any of these buttons will access the Color field used before (see the description under General under the Multiple Windows Settings for details). You also have the option to make the background of the **Scale Tool** transparent or opaque. The Scale Box color will have no effect if the background is Transparent. If you have two CNT files open, you may enter independent settings for it. Click **Save As** to store the setting you have entered in the .aws (workspace) file, then click **OK** to continue.

The "Window 2" fields are used in ACQUIRE when you are displaying two single windows (the second one is grayed out in EDIT).

2.5.3   Load Workspace

The options that you have selected above are stored in a workspace file (.aws extension). The workspace file also stores the sizes and positions of the various windows that you have opened. You may save and recall different "workspaces". Use the Load Workspace option to retrieve a workspace file that you have previously created. Selecting the option will display the standard Open File utility from which you may select a workspace file. EDIT will retain the most recent workspace file, and apply it the next time you run the program. The workspace file that is being used is displayed on the right side of the Status Bar (if your screen resolution is too low, you may not see this).

2.5.4   Save Workspace

The Save Workspace option is used to save the Options you have selected above, as well as the sizes and positions of the data display screens you have opened. You may wish to have several different workspace files, depending on the operations you are performing. When you have the settings and displays in a way that you would like to retain, click Save Workspace. Use the standard Save As utility to enter a file name and path (the .aws extension is added automatically).

2.5.5   Batch

This option displays the **Autorun** feature dialog screen for use with BATCH files. Please refer to the Tcl Batch Commands manual for details.

2.6 Tools

The Tools option accesses several utility routines.

Waveboard - This option is used to open the Waveboard. The Waveboard is used to display waveforms from the same file, or different files. You can also launch the Waveboard from the Toolbar icon 📋. Please see the Waveboard appendix at the end of this manual for a complete description.

Mapgen - In prior versions, Mapgen was a stand-alone routine, accessed from the Program Launcher. It is now accessed from EDIT. Mapgen is used to create or modify .map files. Please refer to the Mapgen manual for complete details.
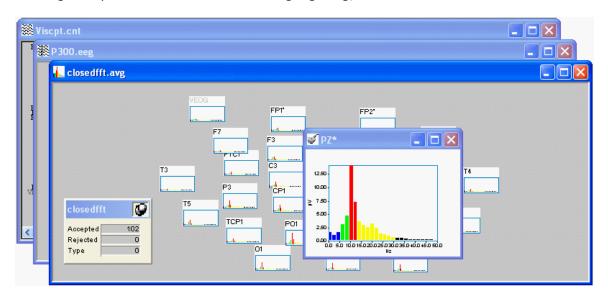
MATLAB - If the MATLAB software package is installed on your computer, and you have a Toolbox license, SCAN 4.5 allows you to export data to MATLAB and import them back to EDIT. You should use MATLAB 6; MATLAB 5 will work, but some of the functionality related to bringing the graphics windows is not supported. Note that trigger information is *not* exported along with the EEG data in the CNT files. Please refer to the Toolbox manual for details.

MS Excel - This option is used to open the MS Excel program (Toolbox license required), and export data files directly to it. Please refer to the Toolbox manual for details.
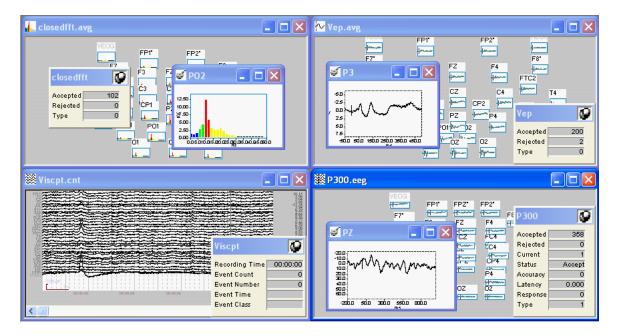
2.7 Window

The Window option accesses the standard options in Windows for arranging multiple displays on the screen.

Cascade - Selecting Cascade aligns the windows in a stack of overlying "cards", with the edges exposed to allow access for highlighting, as shown below.

Tile Horizontally - Tile Horizontally will automatically arrange windows in a horizontal manner, stretching from one side of the screen to the other, top to bottom. With
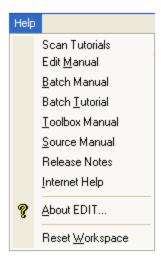
multiple window displays (e.g., more than 3), however, the Tile Horizontally, or Tile Vertically option will arrange the window displays in an well-organized fashion, as shown below:

Tile Vertically - Tile Vertically will automatically arrange windows in a vertical manner, stretching from the top of the screen to the bottom, side by side. With multiple window displays, however, the Tile Vertically, or Tile Horizontally option will arrange the window displays in a well-organized fashion, as shown above.

2.8   Help

The Help section contains several options: Manual access options, Internet Help, About EDIT and Reset Workspace.

Scan Tutorials - This manual contains several tutorials to introduce you to acquisition and analysis in SCAN.

Edit Manual - Clicking this option will open the EDIT manual in PDF format. If you are looking for a particular detail, we suggest checking for it in the Table of Contents.

BATCH Manual - This selection will give you immediate access to the Tcl Batch Commands manual in PDF format.

Batch Tutorial - This option access the Tcl Batch Tutorial manual, which is a good place to begin to get introduced to Batch commands.
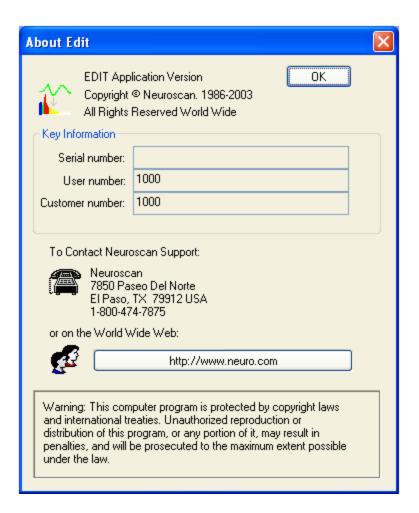
Toolbox Manual - This selection accesses the manual for Toolbox, containing details for EKG Noise Reduction, Blink Noise Reduction, PCA/ICA, etc.

Source Manual - Clicking this option will open the SOURCE manual in PDF format.

Release Notes **-** Clicking this option displays the latest release notes document, in which the new features are summarized.

Internet Help - Clicking the Internet Help option will take you directly to the Scan Help section on our web site. From there, you may jump to the Support section, or send an e-mail to the Technical Support department.

About EDIT - The About EDIT option will display the current version of the *acquire.exe* file (which contains both the online ACQUIRE and offline EDIT modules), as well as information about your serial number, etc.

Reset Workspace - This option provides a quick way to restore the workspace file (.aws extension) to its default settings. Corrupted workspace files have been encountered occasionally in the SCAN 4.0 software (mainly in ACQUIRE), and this option provides an easy way to restore the workspace file. If you were not directed to this option by Technical Support, it is advised that you do not use it.

3   Toolbar Icons

Listed below are all the icons that appear on the Toolbar. Not all functions are available for each type of file (for example, you can not go to the next rejected sweep when you are displaying an average data file). When applying these, make sure that the desired display screen has the "focus".

File Open, Save, and Update Changes - The first two are typical icons for opening new files or saving displayed files. Each opens a utility screen in which you can select the desired folder, file, or enter a file name. The Update Changes can be

used in cases where you have modified a data file, and wish to save it using the same file name. In some circumstances, that could not be done in prior versions of SCAN because the file was already open (in both point and click and BATCH modes). The Update Changes button will preserve the modifications with the open data file when you close it. When you wish to update the open file, click the icon and you will be asked to verify that you want to overwrite the existing file. (Update changes does not function with COH files).

History Window 📊 - The History field displays a list of the most recent Transform commands in BATCH form that have been executed. A text version of the History is written automatically to the *History45.txt* file, which may be found in the default file storage folders for XP and Vista.

```
OPENFILE {C:\Scan Data\Demo Files\P300s\P300.eeg}
EXPORTAVG_EX2 {C:\Scan Data\Demo Files\P300s\ASCII file.dat} POINTS T T T T F F F T F F F { FP1 FP2 F3 F4 C3 C4 P3 P4 O1 O2 F7 F8 T3 T4 T5 T6 CZ FZ PZ O
OPENFILE {C:\Scan Data\Demo Files\P300s\ASCII file.dat}
EXPORTAVG_EX2 {C:\Scan Data\Demo Files\P300s\ASCII file.dat} POINTS T T T T F F F T F F F { FP1 FP2 F3 F4 C3 C4 P3 P4 O1 O2 F7 F8 T3 T4 T5 T6 CZ FZ PZ O
EXPORTAVG_EX2 {C:\Scan Data\Demo Files\P300s\ASCII file.dat} POINTS T T T T F F F T F F F { ALL }
OPENFILE {C:\Scan Data\Demo Files\P300s\ASCII file.dat}
EXPORTAVG_EX2 {C:\Scan Data\Demo Files\P300s\ASCII file.dat} POINTS T T T T F F F T F F F { ALL }
```
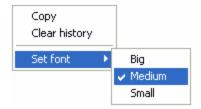
Right click inside the History box and you will see options to Copy the text (for use in BATCH files), Clear the window, and change the font size.

```
Copy
Clear history

Set font        ▶    Big
                   ✓ Medium
                     Small
```

Display Scale Controls ⬆ ⬇ ↕ - These options Increase, Decrease, or Autoscale the data as displayed in the screen. Applying them has no effect on the stored data. The first one increases the display scale, the second decreases the display scale, and the third one autoscales the displayed data using the maximum and minimum displayed data points.

Decelerate/Accelerate Display 〜 〜 - These options are used with continuous data files to vary the number of seconds displayed on the screen. More displayed seconds has the effect of Decelerating the playback, and fewer displayed seconds has the effect of Accelerating the playback. You can also use the + and - *keys* on the keyboard (by the calculator pad) to Decelerate and Accelerate the display). You can also use the *right mouse* button option, Set seconds per page , to set the number of seconds displayed.

Show Next/Previous Display Page 📄↓ 📄↑ - From the **Edit → Channel Layout** window, in either ACQUIRE or EDIT, you have the option to assign electrodes to additional display pages. The icons will be active if you have created additional pages. Use them to step through the Next or Previous pages.
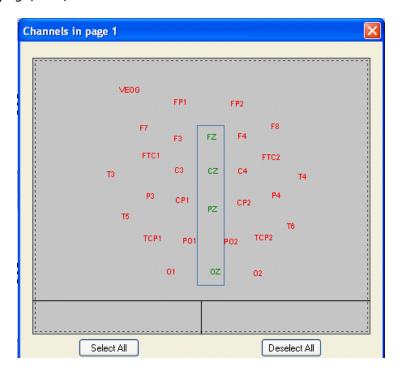
Typically, you will create the additional display pages in ACQUIRE so that they will

already be present when you retrieve the files in EDIT. However, it is also possible to create display pages in EDIT.

The Display Page feature allows you to assign electrode channels to additional screen display pages. To do this, click the up arrow button at the end of the Page field. The field will display a 1 and the [Assign Channels] button will become active. The screen behind the **Channel Layout** screen will be empty. Click the **Assign Channels** button, and see the Channels in Page 1 display. Double click on the individual electrode labels (so they turn green), to add them to the first additional display page, and/or use the [Select All] and [Deselect All] buttons.

Click OK when you are through, and you will see the selected electrode displays. Size and position them as desired. Through this process you can assign electrodes to any display page you wish. You may assign the same channel to more than one display page (for example, you might want the artifact channel to appear on each display page). Use the down arrow button to get back to the original display page. Repeat these steps to assign electrodes to one or more display pages. Then click OK to exit. Resave the data file to make the changes permanent. Now step through the Display Page icons to see the additional pages.

Grid Display (Display only) ⊞ - Selecting this option displays the multi-channel electrode windows in a grid form, ignoring any positioning that has been performed. Click the icon again to return to the original display layout.

Baseline On/Off (Display only) ⊥ - The Baseline option centers the waveforms within the allocated display region for each channel. This is for display purposes, and has no effect on the stored data.

Invert Polarity (Display only) ⋎ - Clicking this icon inverts the displayed waveforms. It does not affect the stored data. You can set EDIT to always read files with negative up or down (or as it was recorded in the original file) from the General tab under Options (on the Main Menu bar), then Multiple Window Settings.

DC Correction **DC** - The DC Correction is only available for continuous data files recorded with a SynAmps, with a high pass filter setting of DC, and after you perform the DC Offset Correction transform. The icon will let you toggle between the corrected and uncorrected waveforms.

Zoom In/Out ⊕ ⊖ - These options are active when you enlarge an electrode display in a multiple window display. To use, click the icon, then drag a rectangle around the area on the waveform that you want to enlarge. Release the mouse button to see the "zoomed" area. Click the Zoom Out icon to return to normal size.

Mapping Options ⋏ ⊗ ⋏ - There are several ways in which you can map your data from EDIT. These include: 2D Mapping, 2D Cartooning, Spectrum Mapping, and 3D Mapping (see the next section for details). Not every type of mapping is available for every type of data file. You can tell which types are possible by seeing whether the icon is grayed out or not.

Launch Waveboard 🖬 - Clicking this icon launches the Waveboard program that is used to display waveforms from different files, measure and mark components, and so forth. Please refer to the Waveboard Appendix for complete details.

Launch Montage Editor ✎ - This option launches the Montage Editor, which is used to create and modify montage files and Linear Derivation files. The Montage Editor is also accessed from the Edit button that appears on several screens, including the Linear Derivation display. The Montage Editor is described in complete detail in the Montage Editor Appendix.

Launch PCA/ICA program 🎆 - PCA/ICA allows you to perform Principle and Independent Component Analyses (and requires the Toolbox license). It can be used online in ACQUIRE or offline in EDIT. Please refer to the Toolbox manual for operational details.

Launch SOURCE program 🔲 - The SOURCE program performs a variety of source reconstructions (and requires a SOURCE license). Please refer to the SOURCE manual for operational details.

Print 🖨 - This option opens the standard Print utility screen (refer to the Print section under Files for more details).

Display Status Window ⓘ - From time to time you may "lose" the Status boxes seen in the data displays. Should this happen, click the ⓘ button to restore them.

Replay Control buttons ⬅✓ ✗ ⬅ ➡ ✗ ➡✓ - These buttons are used to move through the continuous or epoched files. The two buttons in the middle will step forward or backward one sweep in epoched files, or one display page in continuous files. (The *right* and *left arrow keys* on the keyboard perform the same function). The two buttons adjacent to the middle two are used only for epoched files. The red x's on the buttons are used to indicate rejected sweeps. Clicking these buttons will jump forward or backward to the next rejected sweep (and will be grayed out if there are not any). The outermost pair of buttons are also used only with epoched files. The green check marks are used to indicate accepted sweeps. Clicking these buttons will jump forward or backward to the next accepted sweep (and will be grayed out if there are not any).
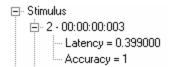
Scan Control Buttons ◀◀ ◀▶ ▶▶ - These buttons are used for the automatic replay, or scanning, of a continuous or epoched file. The outer buttons will start the scanning either forward or backward through the file. The middle button will stop the scan. The speed of the scan is controlled with the Speed Scan Interval, under the View button on the Main Menu bar (see that section of the manual above for details).

Sweep Status Indicators ✓ ✗ - As you step through an epoched file, one of these two buttons will be "pressed" to indicate whether the sweep has been tagged as Accepted or Rejected. You can change the status of the sweep by clicking the other button.

Go to Event/Sweep ↻ - This button has slightly different functions depending upon whether you have retrieved a continuous or an epoched file. For continuous files, clicking this button displays the Go To Event window.

The display will show all of the events that are in the continuous file. These include, Stimulus, Keypad (or Response), Reject, Accept, Keyboard, DC Correction and Segment events. Where events are detected, there will be a + sign by the type of event. Clicking it shows a list of the times within the continuous file where these events occur. For example, if there are stimulus events, these will be listed individually. If you have Merged the Behavioral Data file (.dat file) from STIM (described under Merge Data File), the Latency and Accuracy information will be displayed.

Under Reject and Accept, the times points listed are the beginnings of a new rejected or accepted region. DC corrections are listed, as are Stop/Start points in the continuous file (under Segments). In other words, this is a listing of the contents of the Event File (described above), that allows you to jump to any event that is in the file. Highlight the event, click OK, and you will be taken to that point in the continuous file.

The Go To button functions in a slightly different way with epoched files. When you click the Go To icon, a Go To Sweep display will appear. The total number of sweeps in the file is displayed, and you may enter the number of the desired sweep in the field. Then click OK to go directly to that sweep.

Go To Time ⏰ - The Go To Time icon is active with CNT files only. After retrieving the file, click the icon, and you will see the following display.

The total recording length of the file is shown at the top. Enter the Hours, Minutes and Seconds for the desired time point, and click OK. You will be taken to that point in the data file.

Note that you may move the sweep control Toolbar as a single unit. This can be useful when, for example, you are reviewing sweeps manually to select those to accept or reject. Click the left mouse button on the Toolbar, between the active icons, and drag it to a new location.
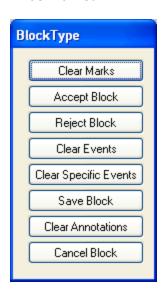

You can also drag it to the side the of the upper Toolbar, creating one long Toolbar. To return it to its original location, drag it to a position partially on top of and slightly below the original Toolbar and drop it.

📄 **Note**

The next three Toolbar icons - Mark a Block, Place a Marker, and "Delta" - are used with continuous files only. They may only be used one at a time. When one option is active (icon is "depressed"), the others will not be active until you deselect the depressed one.

Mark a Block 🗖 - The Mark Block is used with continuous files to mark a section of the recording. Once marked, it can be rejected, accepted, saved, and so forth. After retrieving the CNT file, click the Mark Block icon. Position the mouse at the beginning of the section of interest in the CNT file, and click the left mouse button once. Then

position the mouse at the end of the section of interest, and click the left mouse button again. The following list of options will appear. If the block you wish to designate extends beyond the display you are seeing, use the forward or backward arrows on the Toolbar to step to the next screen(s). When you click the mouse the second time, the entire block will be marked.
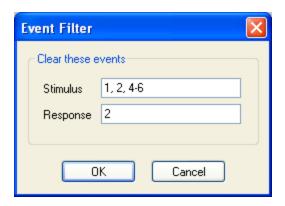

Clear Marks - If you had made any Marks (including Keyboard Function Key events), using the Place Mark option from the Toolbar 🢁∿, this option may be used to remove them. Use the Mark Block function to delineate the section from which you want the Marks removed, then select Clear Marks.

Accept Block - This option allows you to accept a block that had previously been rejected.

Reject Block - Clicking this option will cause this block to be excluded during the epoching process. After clicking the button, you should see the block turn red in color.

Clear Events - This option will remove any stimulus, response, or keyboard event markers that appear in the continuous file. *Note: When you save or close the continuous file, you will be asked whether you wish to save the modifications you have made. If you save the file with the modifications, these deletions will be permanent. We recommend you always work with a copy of you data file so the original will remain intact.*
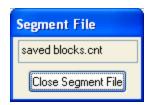
Clear Specific Events - This option allows you to remove selected stimulus and/or response events within a marked block. Use the Mark Block operation to delineate a block of data, and select the Clear Specific Events option. The following dialog box will appear.

Enter the stimulus and/or response type codes to be removed, and click OK. The type codes will be removed within the designated block.

Save Block - This option is used to save a designated block(s) of continuous data to a new CNT file. Follow these steps to save blocks from an original CNT file to a new CNT file.

1. Retrieve the original CNT file.

2. In the original CNT file, use the Mark Block option to select a section of the CNT file that you want to save to the new file. When you click the mouse button the second time, to indicate the end of the block, you will see the option list above. Select Save Block, enter a file name and select a folder, click OK and the block will be written to the new file. You will also see the Segment File window.

3. Repeat the Mark Block / Save Block steps to save all the sections you wish. The blocks will be written to the same new CNT file.

4. When you are finished, click the Close Segment File option to close the new CNT file. Alternatively, you may close the original CNT file and that will close the new CNT file as well. To retrieve the new "segment" CNT file, you must first close it using either method.

5. When you retrieve the new CNT file, there you will see "SS" (Stop/Start) event markers that indicate the end/beginning of each block you saved.

Clear Annotations - If you inserted any Annotations, you may remove them from the block you designate.

Cancel Block - Selecting this option exits the option screen without making any changes. The beginning and ending points of the block are not retained.

Place a Mark 〽 - This option is used to place event marks in a CNT file using the function keys from the keyboard. To use it, first retrieve a CNT file, move to a section where you would like to add an event mark, and click the Add Mark icon. Move the mouse to a position in the file where you would like to add the event mark, and press a function key. You will see a comment added at the bottom of the display.

The marks that are displayed are the default ones shown in the Events Key section in ACQUIRE. You may reassign these, as desired. To do so, click the *right mouse* button inside the single window display to get the Properties option, then select Overall Parameters, and then the Events tab. This is the same screen that you see in ACQUIRE. To change the Text associated with a function key, you should first highlight the line with the function key and [Remove] it. Then position the mouse cursor in the Hot Key field, and press the desired function key (e.g., F6). Then type the text you want in the Text field, and click the [Add] button. Then click the Save As button to save the changes (to the .ast file), and click OK. When you use the Add Mark option and press that function key, you should see the new text.

You may treat these Marks as regular events, that is, you can create epochs around them during the epoching process, or Go To the Events. To epoch around the keyboard events, select Keyboard in the Event Types section of the Epoching Properties display under the Epoch file transform.

Of course, you can select Stimulus, Response and Keyboard events at the same time, if you wish. The type codes that are used correspond to the function keys in the following way. The F1 function key is reserved by Windows for calling Help files, and the type codes begin with a code of 0. Therefore, F2 has a type code of 0, F3 has a code of 1, F4 is 2, and so forth up to F12 (type code of 10). These are the codes you will see in the Go To Events list (under Keyboard), when you create an Event File, and when you Epoch the continuous file.

Type Annotation **A** - You may add annotations to a CNT file by clicking the Type

Annotation icon. Position the mouse/vertical line where you want the annotation to be added, and click the left mouse button. You will then see the Enter Annotation display.

Type the text that you wish to enter in the top line, and click OK. You will then see an A' at the bottom of the CNT file where the text was added. Position the mouse over the A' and you will see the comment in a Tool Tip box. The Playback Status box will display the time of the event, and the class of the event.
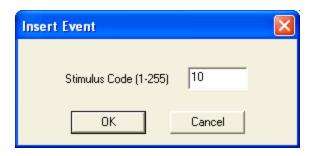

The larger field in the Enter Annotation display, below the line where you enter the text, will display an inventory of text lines that you have entered in the setup file in ACQUIRE (under the Events tab). You can add more lines to the inventory by clicking the *right mouse* button inside the single window display, and selecting Properties, then Overall Parameters. Click the Events tab, and enter an annotation, and click the Add button. Save the setup file. These comments will then be available on the Enter Annotation screen above.

Measure interpeak amplitude (Delta) △ - This option is use for measuring the amplitude change ("Delta"), between two points on the waveforms in EEG and AVG files (enlarge a window to full size). After clicking the icon, position the mouse at the initial point for the peak measurement, then click and hold the left mouse button. When you now move the mouse cursor around the display screen, you will see the change in amplitude displayed in either a Tooltip that moves with the mouse (EEG and AVG files), or in the Delta column at the right side of the display (CNT files). This is the change in time (AVG and EEG) and amplitude (all types) between the initial and the current mouse positions.

Insert Stimulus Event 1⤶ - This button is active with continuous data files only. It allows you to enter a user defined type code at selected places in the CNT file. Click

the icon and the displayed window will appear. Enter the desired type code (1-255) and click **OK**. Then click the CNT file at whatever point(s) you want to insert the events. Click the icon again to stop inserting events. You can access the same window using *Ctrl+V*, although in this case you must position the mouse cursor first, then press *Ctrl+V*. Enter the type code and click OK. A single event will be placed at the mouse position.

3.1 2D and 3D Mapping

Note

The maps that are used for all types of 2D Mapping must correspond to the data files you are mapping. The .map files are created in MapGen. The labels must match exactly the labels you used in the setup file in ACQUIRE. You may rename the electrodes in EDIT to make the data file match the map file, if needed. You may have fewer electrodes in the .map file than in the data file, as long as the labels match. If you are using conventional labels, the internal mapping scheme in EDIT will map all recognized electrodes automatically, in which case you do not need a .map file.

Interpolation - Maps are created using either of two interpolation algorithms:
1. Global interpolation method
2. Local interpolation method

The SCAN software uses both methods, with the Global method selected as the default method.

The Global interpolation method uses all electrodes to calculate values at any given point; whereas, the Local interpolation uses the 1-4 nearest electrodes in the calculations. There are advantages and disadvantages to both methods.

The advantage of the Global method is that it provides smoother maps. The disadvantage is that it may take longer to produce them. The time for the calculations is proportional to the number of electrodes. Conversely, the advantage of the Local interpolation method is that the time for calculations is not dependent on the number of electrode channels (neighboring electrodes can be found once and then stored). The disadvantage in that the maps may not be as smooth as with the Global method.

The influence of any electrode on the interpolated potentials is affected by weighting functions. There are many choices of weighting functions, starting from the simplest linear functions up to complex spline and polynomial functions. The Local method of interpolation uses reciprocal distance weighting of 1-4 nearest neighbors to provide backward compatibility with previous versions of SCAN software. The number of nearest neighbors is specified in MapGen when the .map

file is made. However, Global interpolation is now the default used in SCAN 4.1+.

The Global interpolation function $g(x,y)$ has the form

$$g(x,y) = \mathbf{w}(x,y)^t \mathbf{W}^{-1} \mathbf{v}$$

where $g(x,y)$ is the globally interpolated value at map coordinates x and y; $\mathbf{w}(x,y)$ is a column vector (n-dimensional, n = number of channels) of inverse distance squared weights of the map coordinates with respect to electrode locations; $\mathbf{W}$ is a symmetric matrix (n-by-n) of inter-electrode inverse distance squared weights; and $\mathbf{v}$ is a column vector (n-dimensional) of the actual potential measurements across all channels. The "t" superscript denotes the transpose operation. Thus, a column vector of dimension n ($\mathbf{v}$) multiplied by a square matrix of dimension n-by-n ($\mathbf{W}^{-1}$) multiplied by a row vector of dimension n ($\mathbf{w}(x,y)^t$) yields a globally interpolated scalar potential value ($g(x,y)$).

The ith component of the weights vector $\mathbf{w}(x,y)$ is given by

$$w_i(x,y) = ((x\text{-}x_i)^2 + (y\text{-}y_i)^2 + a)^{-1}$$

where x_i and y_i are coordinates of the ith electrode, and a is a positive constant added to avoid singularity in the expression when $x=x_i$ and $y=y_i$. In this implementation, a is set to the average inter-electrode distance. Intuitively, one may draw an analogy between the form of this weighting function and Coulomb's inverse distance squared law for the force between a pair of electrostatic charges.

Each element of the symmetric matrix $\mathbf{W}$ is computed as

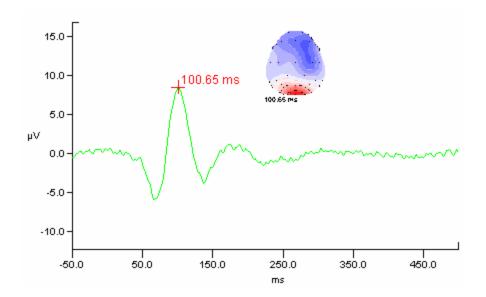$$W_{ij} = ((x_i\text{-}x_j)^2 + (y_i\text{-}y_j)^2 + a)^{-1}$$

where i and j index electrodes. The inverse of $\mathbf{W}$ is not directly computed in this implementation; rather, a speed-optimized Gaussian elimination routine is used to compute $\mathbf{W}^{-1}\mathbf{v}$.

2D Mapping - 2D Mapping will display individual data points on a flat 2D map. To map your data, click on the 2D Mapping icon. If it is grayed out, and you have retrieved a multiple window display (EEG or AVG) file, you need first to enlarge one electrode display to its full size within the data display (and, if need be, click the mouse inside the display). This does not have to fill the entire display screen for EDIT.
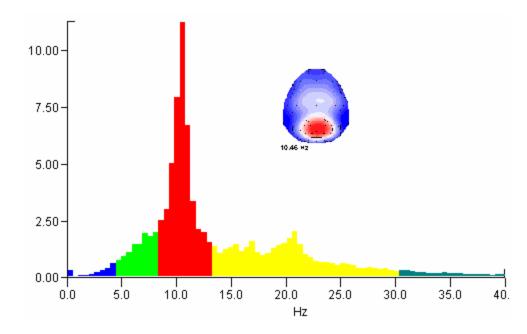
After clicking the 2D Mapping icon, you will see an external map display as well as an additional map in the data screen. Move the mouse cursor in the full size electrode display. If the colors in the map do not change, or if the topography does not look correct, that means that the .map file does not match the data file. Refer to the Load MAP file option below.

> *Placing 2D Maps* - You may place a 2D map directly on the waveform display by positioning the mouse cursor near the point you wish to map, so that the additional "head figure" appears with the mouse cursor. Position the hash mark
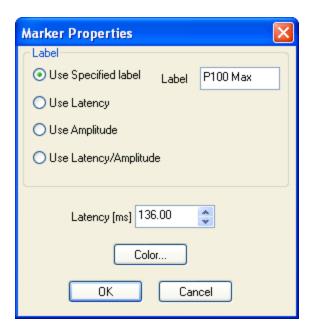
on the point you wish to map, click and hold the left mouse button down, and drag the rectangular shape to a clear area on the display. Release the left mouse button, and a 2D map will be "dropped' at the position.

Frequency domain files may be mapped in a similar way.

Note that you may reposition the 2D map by grabbing it with the left mouse button, and dragging it to a new location. You may edit the Marker by clicking the *right mouse* button near the cross-hair marker. You then have the option to Delete the marker, or access the Edit Properties. If you select Edit Properties, you will see the following:

The Label can be a string you enter, or you can use the Latency, Amplitude, or Latency/ Amplitude as the label. You may also change the latency of the selected point to a new latency, and you can change the color of the label (click Color button to access standard palette display).
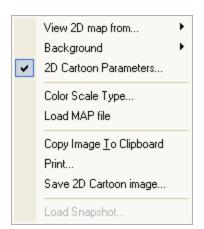
Right mouse button options when clicking on a placed 2D map - Click the *right mouse* button on one of the maps you have just placed, and see the Delete

option. The latency of the map you selected is displayed Delete map '102.00 ms' . If you have multiple maps displayed, this will make sure you are deleting the correct one.

Right mouse button clicking on the 2D maps, cartoons, and spectrum displays. The options listed below are shown when you click the *right mouse* button within the 2D map or 2D cartoon displays.
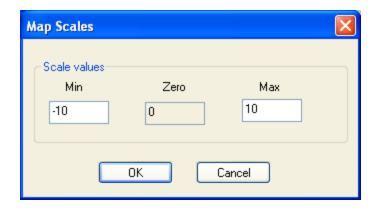
2D map   2D cartoon

Scale min/max values... - This option allows you to change the values on the map scale. Click it to see the Map Scales display. Enter the desired Min and Max values, and click OK.

Color Scale Type... - This option allows you to select from among several color schemes that may be used with the 2D Maps (refer to the 2D Mapping description above for complete details).

Load MAP File... - Use this option to select a different .map file (refer to the 2D Mapping description above for more details).

Show Electrodes - This option toggles on or off the display of the black dots corresponding to the electrode locations, as they were placed in the map file when it was created in MapGen.

Show Electrode Info - When enabled, this option will display the values at each electrode position on the map when the mouse is positioned over the electrode.

Use Local Interpolation - Selection of this option will use the Local Interpolation method to generate the maps. Maps are created using either of two interpolation algorithms - Global interpolation method and Local interpolation method - as described at the beginning of this section.

Use Map Tracking - When enabled, the 2D maps that appear when you click the 2D Mapping icon will "track" the position of the mouse as you move it along the waveform. When disabled, the maps will not track the mouse position.

Use 3D Mapping - This option activates the 3D Mapping option. Please refer to the 2D Mapping section above for operating details.
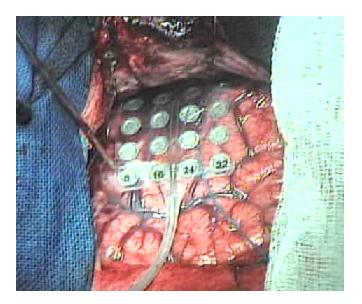
Copy Image to Clipboard - Selecting this option will copy the 2D map image to the Windows Clipboard (as a bitmap file). From there you may Paste it into other Windows applications, such as Word.

Print - The option accesses the standard Print screen, and may be used for printing the 2D map directly.
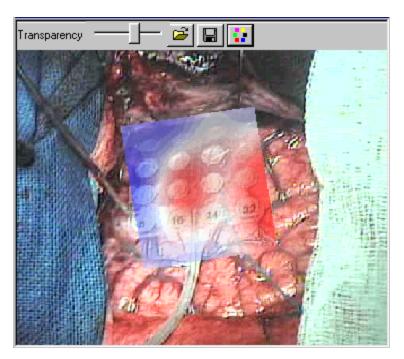
Save Image As... - This option accesses the standard Save File screen which may

be used to save the 2D map as a metafile.

Load Snapshot - This option allows you to load a BMP file and then superimpose a 2D map on top of the BMP image. (This has been an option in ACQUIRE since 4.2, where you can use a digital camera or a BMP picture, and show the 2D map changes in real time). One application would be to superimpose EP data recorded from a cortical grid on a BMP picture of the grid in place.
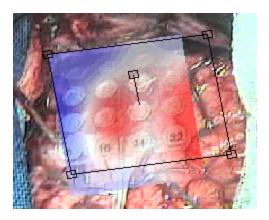

A 2D map can be positioned directly over the grid to show the potential distribution.

To generate a display such as the one above, you will need first to create a 2D map in the desired shape. Please refer to the MapGen manual for complete

directions. Basically, you need to create a small shape in blue (about the size of a quarter), import it in MapGen, and then place the electrodes on it. The output is a .map file that can be selected from within EDIT.

Set up the 2D map display as usual, *right click* on the map display, and select the Load Snapshot option to load a BMP file. You will see the map superimposed on the BMP, with a control box.

Use the control box corners as you would any other window to resize and reposition the 2D map. Grab/drag the center box to rotate the image. Use the Toolbar icons to make the map display more or less transparent, to load a different file, to save the image as a BMP file, and to change the Color of the control box lines.

Left click inside the map part to display the control lines; click outside the map display to hide the control lines.

View 2D Map From... - When selected, this option allows you to select views from the Top, Right or Left sides. In the EDIT program there is an internal default mapping template containing 77 electrodes with top, left and right views. If your data file uses a subset of these electrodes, the program will map the data file from the different perspectives. If your data file uses different labels (or numbers), then you will need to create the map files you wish to use in MapGen.

Background - When selected, you have the option to use the Default (black) or Inverted (white) background on the Cartoon display.
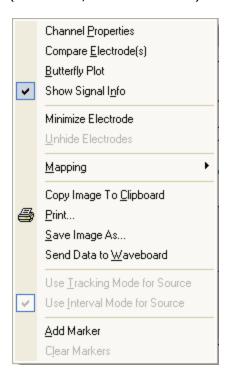
2D Cartoon Parameters... - Enable/Disable the Parameters option (check mark will appear/disappear) to open close the 2D Map Cartoon Parameters display. (Refer to the 2D Cartooning explanation above for more details).

Save 2D Cartoon Image... - This option opens a Save As... utility in which you may enter a file name, designate a path, and Save the cartoon image as a Windows Metafile (the .wmf extension is added automatically).

Right mouse button Mapping options within the electrode display - Click the *right mouse* button on the electrode display to access a more complete list of options.
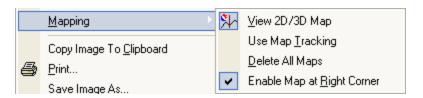
The list will vary depending on whether you clicked in a minimized or maximized electrode display. Both are shown below (minimized, then maximized).

Channel Properties
Compare Electrode(s)
Butterfly Plot
✔ Show Signal Info
Minimize Electrode
Unhide Electrodes
Mapping ▶
Copy Image To Clipboard
🖨 Print...
Save Image As...
Send Data to Waveboard
Use Tracking Mode for Source
✔ Use Interval Mode for Source
Add Marker
Clear Markers

Channel Properties
Butterfly Plot
Maximize Electrode
Hide Electrode
Unhide Electrodes
Mapping ▶
Clear Markers

Most of these are explained below in the section called *Right mouse button clicking inside the electrode displays*, but the following are relevant to 2D mapping.

> *Mapping* - This option displays a secondary menu that has the various mapping options.

Mapping ▶	View 2D/3D Map
	Use Map Tracking
Copy Image To Clipboard	Delete All Maps
🖨 Print...	✔ Enable Map at Right Corner
Save Image As...	

> *View 2D/3D Map* (EEG, AVG) - This option will be active when you enlarge an electrode display to mid- or full-size. You may enable or disable 2D Mapping from this line. It may be accessed more easily from the Toolbar icon . Refer to the 2D Mapping section above for mapping details.
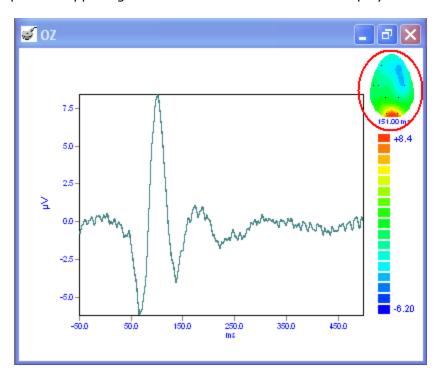>
> 📄 **Note**
> *When you are placing 2D maps and Adding Markers at the same time, it will be necessary for you to disable temporarily the 2D Mapping (otherwise you will drop a map when you want to drag the Marker). The 2D Mapping toggle is useful in this instance so you don't lose the maps you have placed.*
>
> *Use Map Tracking* - If this option is enabled, then the 2D map will change as you move the mouse in the waveform display. Disabling it will let you

select a single point (click a point and it will be mapped).

Delete All Maps - Click the Delete All Maps line to delete all maps. You may also disable the 2D Mapping feature by clicking View 2D Maps (so the check mark does not appear).

Enable Map at Right Corner - This option is used to display or remove the 2D map in the upper right hand corner of the waveform display.

Printing/Saving the map and waveform display - From the same right button menu you have the option to Copy Image to Clipboard, Print the display, or Save Image As... a Windows Metafile.
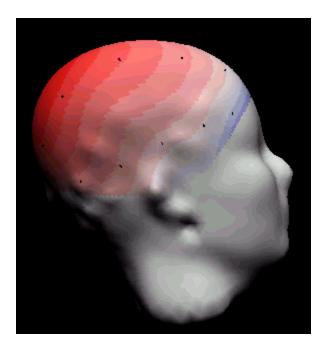
Selecting the Copy Image to Clipboard feature will copy the display to the Windows Clipboard as a bitmap (BMP) file. From there it is easily inserted into other Windows applications, such as Word, using the Paste option. Selecting Print opens the standard Print display, described above under Files. Selecting the Save Image As... option opens a Save As utility to save the display as a Windows Metafile (the .wmf extension is added automatically).

Mapping on a 3D head shape - The EDIT program can map your data on a "stock" 3D head. If you have difficulty running the 3D mapping option, try changing the Colors field on your **Windows Display Properties** → **Settings** display to High Color (16 bit) or True Color (32 bit). The 256 colors setting is insufficient.

To map your data on a 3D head shape, you should first retrieve an AVG file, enlarge an electrode display to full size (such as CPZ), and then click the 2D Mapping icon . (In this example, we are using the P300rare.avg file created from the *P300.eeg* demo file). Click the *right mouse* button on either of the 2D maps that appear when you select 2D Mapping. Select from the list of options. You will see a 3D head appear. Position the mouse at the peak of the P300 component waveform, at about 386ms. (Move the cursor straight up away from the waveform to allow you to retain the time point while continuing to move the mouse). The selected time point will be mapped on the 3D head.

You may now position, resize, and spin the display, as desired. For example, position the mouse within the 3D display, hold the left mouse button down, and move the mouse on a level, horizontal line, back and forth. You will see the head rotate with it. Similarly, you may move the mouse vertically (while holding the left button down), and tilt the head toward or away from you. Hold the left mouse button down and move the cursor all around, and the head will follow in all directions.
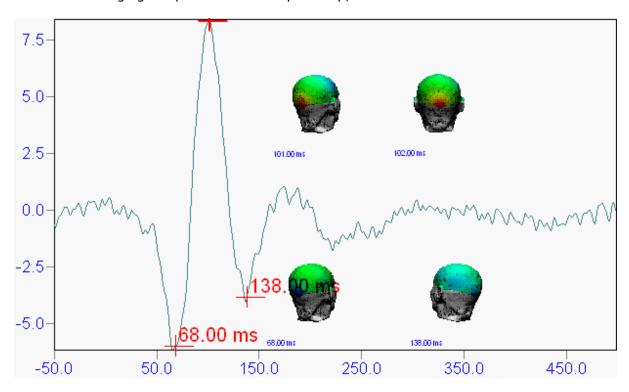
Now, position the cursor in the middle of the display, hold the *right mouse* button down, and move the cursor up and down. Moving it up makes the head shape smaller; moving it down makes it larger. To spin the head, hold the left mouse button down, and move the cursor rapidly across the display, releasing the button after it travels a short distance. The head will begin spinning on its own. If it spins too fast, move the mouse at the same time to slow it down (smaller heads also spin faster than larger ones). To stop it, grab the head with the left mouse button, and move it slightly. This will stop the rotation. While the head is spinning, you may use the *right mouse* button to change its size.

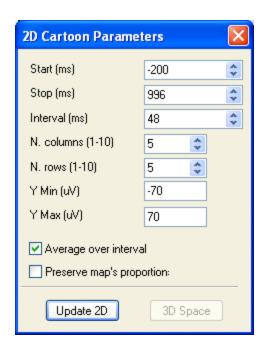If you *right click* again on that head shape, you will see that the list of options

has changed slightly. You now have the option to Load 3D Head File . This will let you select the .tri file that corresponds to that subject (assuming you have digitized the electrode positions and head shape in 3DSpaceDx or 3DSpace). 3D mapping uses the same .map file, or internal mapping scheme, that is used in 2D mapping. The 2D map is stretched around the 3D head. If all of you electrodes are not mapped, you will likely need to create a .map file (in MapGen) where the labels match those in your data file.

You can change the scaling of the map on the 3D head by using the up and down arrows on the Toolbar.

Note that you can use 3D heads to map various points on the waveforms, changing the position from map to map, if desired.

2D Cartoon - 2D cartooning creates a series of maps with a user defined starting point, stopping point, and averaging interval. Retrieve your data file, and click the 2D Cartoon icon from the Toolbar. You will see two additional windows appear. The first is the 2D Cartoon Parameters display. The fields are explained below:

Start/Stop (ms) - The Start and Stop fields are used to specify the beginning and ending time points for the section to be cartooned.

Interval - Interval is the averaging interval. Maps will be created every X ms, based upon the average of the data points within that interval. The interval value must be a multiple of the "dwell" time (the total number of ms divided by the number of points). For example, an epoch from 0 to 1000ms, with 500 points, will have a dwell time of 2ms. The Interval is therefore a multiple of 2. If you enter a value that is not a multiple of the dwell time, the program will select the nearest acceptable value automatically.
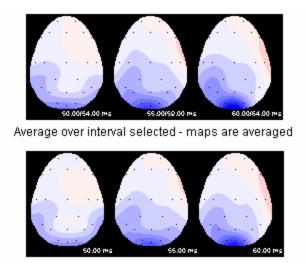
📄 **Note**
If you encounter problems when you change the interval (such as, the 2D Update button appears not to work), try entering the desired Start and Stop times, then change the N Columns and N Rows fields until you get the desired interval (they are interrelated).

N columns (1-10) and N rows (1-10) - These two fields allow you to set the maximum number of maps per row and per column to be displayed in the 2D Cartoon display. Up to 100 maps may therefore be presented. The values that you enter here will supercede the Stop point entered above. For example, if you select 5 columns and 10 rows, that will generate 50 maps. If the Interval is 2ms, then 50 maps times 2ms equals a total span of 100ms. The program will begin mapping at the Start point, and then map the 50 maps, covering the next 100ms, regardless of the Stop time.

Y Min (μV) and Y Max (μV) - These fields set the mapping scale for the cartoon. A smaller range will result in a more colorful map.

Average Over Interval - If you select this option, all of the data points in the interval will be averaged to create a single map. If you do not select it, the maps will be based on only the single time points indicated.
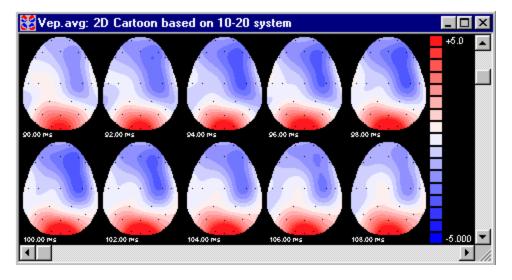
Average over interval selected - maps are averaged

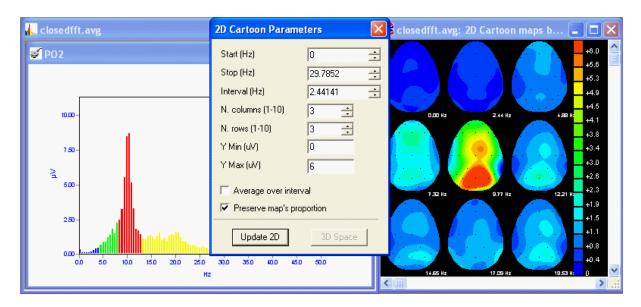Average over interval not selected - maps are single time points

Preserve map's proportion - When enabled (check mark appears), all the maps will stay the same size and proportion when you resize the 2D Cartoon window. That may result is the need for scrollbars to see all of the maps. When disabled, the maps will change in proportion in order to display all the maps created, regardless of the size of the 2D Cartoon display.

2D Cartoon - When you have made all the changes desired, click the Update 2D button to apply the changes.

When the above settings are used with the *vep.avg* file, the following cartoon will appear (90-110ms section).

Frequency domain files may be mapped in a similar way. Retrieve a frequency domain file, enlarge one electrode display to full size, then click the 2D Cartoon icon. Set the parameters as desired, and click the Update 2D button. Below are results from the *closed.avg* file, with maximum power in the alpha frequency range.

Right mouse button options in cartooning - Additional options may be accessed by clicking the *right mouse* button within the 2D Cartoon window.

View 2D Map From... - When selected, this option allows you to select views from the Top, Right or Left sides. In the EDIT program there is an internal default mapping template containing 77 electrodes with top, left and right views. If your data file uses a subset of these electrodes, the program will map the data file from the different perspectives. If your data file uses different labels (or numbers), then you will need to create the map files you wish to use in MapGen.

Background - When selected, you have the option to use the Default (black) or Inverted (white) background on the Cartoon display.

2D Cartoon Parameters - Enable/Disable the Parameters option (check mark will appear/disappear) to open close the 2D Map Cartoon Parameters display.

Color Scale Type... This option allows you to select from among several color schemes that may be used with the 2D Maps (refer to the 2D Mapping

description above for complete details).

Load MAP File... Use this option to select a different .map file (refer to the 2D Mapping description above for more details).
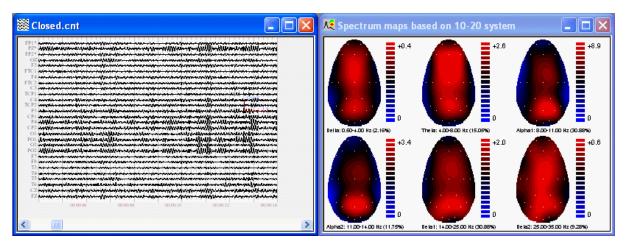
Copy Image to Clipboard - This option will copy the cartoon maps to the Windows Clipboard (as a BMP file). From there you may Paste it into other Windows applications, such as Word.

Print - The Print option accesses the standard Print screen, as described above under Files.

Save 2D Cartoon Image... - This option opens a Save As... utility in which you may enter a file name, designate a path, and Save the cartoon image as a Windows Metafile (the .wmf extension is added automatically).

Spectrum Mapping - Spectrum mapping will generate a series of power spectrum maps corresponding to predefined frequency bands. Since the Transform must compute an FFT prior to mapping the data, the number of points must be a power of 2 (e.g., 256, 512, etc.).

For an example, retrieve the *closed.cnt* file, and then click the Spectrum Mapping icon. The maps will appear using the internal default mapping template containing 77 electrodes from the 10-20 system, and extended placements (see the 2D Mapping section for more details). It will map whatever data channels there are that match the internal default mapping template. To use a different map file, *right click* on the maps, and select Load Map File to select a file that is compatible with your data file (the .map file, created in MapGen, must have the same electrode labels as seen in the Channel Assignment list. There may be fewer electrodes in the .map file, but not more). The display will look similar to the following one. Note that as you step through the CNT file, the maps will change accordingly. If you accelerate or decelerate the continuous display, the maps will change according to what appears in the single window display.

This example uses a CNT file, but you can also compute the Spectrum Maps for EEG and AVG (time and frequency domain) files.
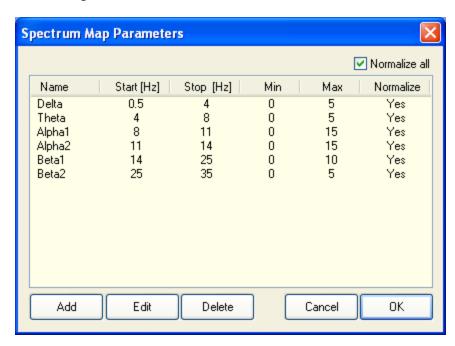
Right mouse button options with spectrum mapping - If you click on the spectrum

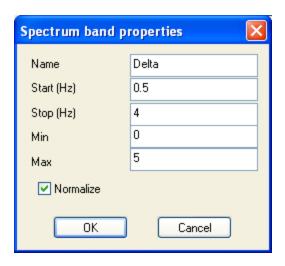maps with the *right mouse* button, you will see the following list.

View 2D map from...   ▶
Background   ▶
✔ 2D Cartoon Parameters...
Color Scale Type...
Load MAP file
Copy Image To Clipboard
Print...
Save 2D Cartoon image...
Load Snapshot...

With the exception of Band Parameters, these options are discussed above.

Band parameters... - The Band Parameters screen lets you select frequency ranges for the maps, their labels, scale settings, etc. Selecting the options will display the following screen.

Spectrum Map Parameters

☑ Normalize all

Name	Start [Hz]	Stop [Hz]	Min	Max	Normalize
Delta	0.5	4	0	5	Yes
Theta	4	8	0	5	Yes
Alpha1	8	11	0	15	Yes
Alpha2	11	14	0	15	Yes
Beta1	14	25	0	10	Yes
Beta2	25	35	0	5	Yes

Add   Edit   Delete   Cancel   OK

For each frequency band, you see the name, the Start and Stop limits (in Hz), the Min and Max display limits (in μVs), and a column called Normalize.

Normalize, when toggled Yes, will automatically scale each map according to the minimum and maximum voltages. When toggled No, the maps will be scaled according to the Min and Max values you enter in the Spectrum Map Parameters display above. You may set all the bands as Normalized, or not, by clicking the Normalize All field. You may modify any of the settings for an individual frequency band by double clicking the left mouse button on the band name, or by highlighting the band and clicking the Edit button. You will then see the Spectrum Band Properties screen. Edit the properties as desired, then click OK. Notice the Add and Delete buttons on the Parameters screen. The Add button will display the properties screen above, in which you may enter the name and settings for each new spectral map. To Delete an existing band, highlight it with the left mouse button and click the Delete button.

4   Context Menus

Depending on the type of data file being displayed, there are different options that are accessible when you click the *right mouse* button. Clicking the *right mouse* button inside an electrode display gives a different list of options than clicking it between the electrode displays. There are also *right mouse* button options when you click on the 2D map and 2D cartoon displays. Many of these have been described above, and all are detailed below for convenience.
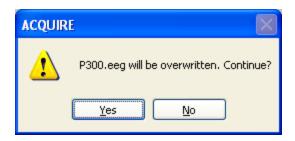
4.1   Right mouse button clicking between the electrode displays

If you click the *right mouse* button between the electrode display windows (multiple window displays), you will see a menu list with the following options. In general, when you select an option after clicking *between* the electrode displays, all channels will be affected. The list below is seen with AVG files; EEG files will have most but not all of the same options.

Save As... - Selecting this option allows you to save the file as a new data file. A Output File display will appear in which you may enter the new file name and path designation.

Update Changes - Selecting this option allows you to apply changes to whichever data file has the "focus". In prior versions, certain operations could not be applied because the file was open, and you had to save the file with a different file name.

Beginning with SCAN 4.3, you can update the changes in the open file. The changes will be saved when up close the file (if you choose to save them). When you select the Update Changes option, you will see a confirmation message. The option does not function with COH files.

Copy Image to Clipboard - The multiple window display will be copied to the Windows clipboard, with file information included. This can then be Pasted into other Windows applications.

Print... - Selecting the Print option opens a standard Print display screen. Set the options as desired, and click OK.

Save Display Image... - This option allows you to save the image as a Windows

metafile. A Save As screen will allow you to enter a file name and path (the .wmf extension will be added automatically).

Properties - The Properties option will take you to the same screens used in ACQUIRE to create the setup file and acquire the displayed data. Some of the fields are shown for informational purposes, and others may be changes to modify the displayed data file.

> *Overall Parameters* - Selecting this displays the Amplifiers, Channel Attributes, and Epochs sections from the Overall Parameters option in ACQUIRE. Please see the section under *Edit* above for a more complete description of these fields and how they may be used in EDIT.

> *Channel Layout* - Selecting this option displays the Channel Layout screen used in ACQUIRE. You can use it here in much the same way to reposition and resize the electrode displays, create additional display screens, import and export electrode position information, and so forth.

> *Channel Assignments* - This displays the Channel Assignment screen from ACQUIRE. It can be used to rename an electrode, if desired, but cannot be used to reorder the physical channels.

> *Subject...* - This displays the Subject screen with any information that you entered in ACQUIRE as part of the data acquisition. Refer to the ACQUIRE manual for more details about the Subject screen.

Transforms (CNT, EEG, AVG, COH) - This is an alternative route to the Transforms menu list that is accessed from the Main Menu bar. The transforms are described in more detail above.

Send Waveforms to Waveboard - Selecting this option will send all of the waveforms to the Waveboard. Refer to the Waveboard manual in the Appendix section below for complete details of its operation.

MS Excel - This option is used to export CNT, EEG and AVG files to Excel. It assumes you have Excel installed and that you have a license for the Toolbox. For details, see the description above under Tools (on the Main Menu bar).

Clear Markers - This option will Clear all Markers that you placed with the Add Marker and Peak Detection options.

Marker Report - If you have Added several Markers to an EEG, AVG or COH file, this option will create a text file list of the Markers.

With an EEG file, select the Marker Report option, and the EEG file will appear to be having a seizure as the sweeps are rapidly searched for Markers. At the end of the search, an Output File utility display will appear in which you may enter a file name and path (the .dat extension will be added automatically). The resulting file will look something like the following (from Notepad):

```
Sweep Number      Channel Marker  Latency  Amplitude
2         FCZ     New     302.325581      22.060547
7         FCZ     New     277.906977      22.763672
21        FCZ     New     525.581395      4.833984
31        FCZ     New     400.000000      33.662109
31        FCZ     New     400.000000      33.662109
38        FCZ     New     368.604651      47.900391
```
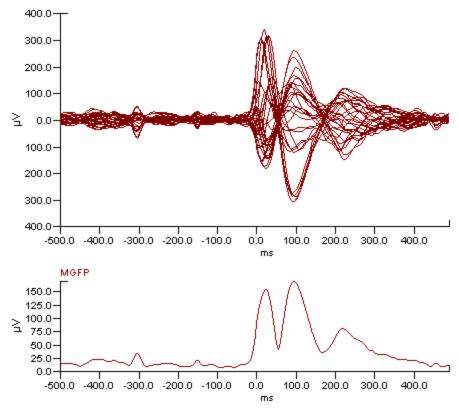
Similarly, multiple Markers made in an AVG file will produce a Marker Report similar to the following (frequency domain files will have appropriate labels):

```
Sweep Number      Channel Marker    Latency         Amplitude
1         OZ      P100 component  100.711744      8.308467
1         OZ      N70 component   65.480427       -6.153495
```

Show Markers - This toggles On and Off the display of the markers you have placed with the Add Marker option described below. When toggled Off (no check mark), the markers will not be displayed. Toggle it On to display them again. This is in contrast to the Clear Markers option, which will permanently remove the markers.

Load 3D Electrode positions (CNT, AVG, EEG, COH) - This option is used to add measured 3D electrode position data to the data file. The information is contained in the .3dd file created in 3DSpaceDx, and is used in the SOURCE program. Clicking the option displays the Open File utility window, from which you may select the .3dd file. The file must be from the subject whose EEG data you are viewing in EDIT (otherwise the electrode positions will be only approximations).

Butterfly Plot (AVG, EEG) - Selecting this option will superimpose all channels together, plus calculate the Mean Global Field Power for the displayed epoch. The data will be redisplayed as shown below.
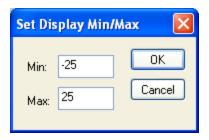
▤ Note

MGFP should not be used with the .avg file results obtained from Event Related Band Power - the results will not be valid.

Deselect the option (or just close the window) to return to the original display.

Set Display Min/Max (EEG, AVG, COH) - This option allows you to set the minimum and maximum display limits (without going through **Properties → Overall Parameters → Epochs** to set them). Selecting the option displays the following screen, in which the minimum and maximum values may be entered.
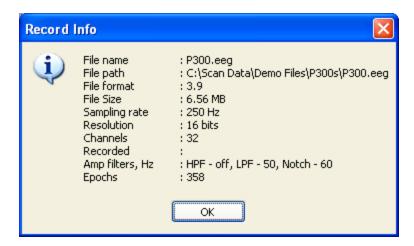
Add Display Filter / Remove Display Filter - The Add Display Filter option accesses the Filter dialog screen, from which you may apply a digital or analog filter to the displayed data only. The Remove Display Filter option returns the displayed data to their prior state.

Add Linear Derivation / Remove Linear Derivation - The Add Linear Derivation option lets you select and apply an LDR file to the displayed data. Click the
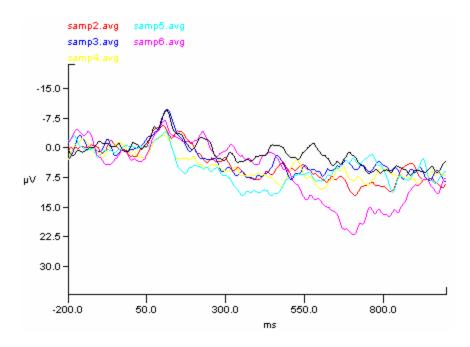
Remove Linear Derivation option to remove the derived changes.

Unhide Electrodes - If there are any hidden channels in the data file, these can all be unhidden by selecting this option.

Record Info - Clicking this option displays miscellaneous information about the data file.

Load Comparison File (AVG) - Selecting this option accesses an Open Files utility display through which you may select files to be overlain upon your original file. The comparison files must have the same number of channels, electrode labels, start and stop times for the epochs, and number of points. You can overlay up to at least 20 additional files. These can be selected at the same time by using *Ctrl+Mouse* click on each of the desired files in the Select Data Files display. Comparison files will be given different colors so you can differentiate them from each other and the original file. When you zoom into one of the electrodes, a color-coded legend will appear at the top of the display. Shown below are 5 files superimposed on one original one.

Right mouse button options - If you click on one of the electrode labels at the top with the *right mouse* button, you will see the displayed list of options.
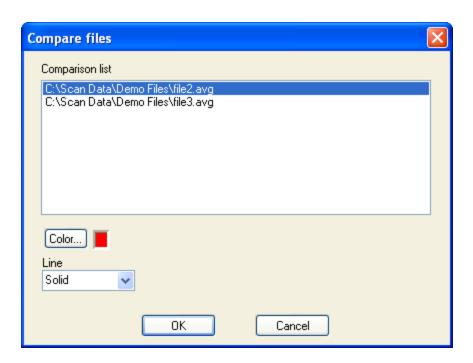

Change color... - This opens the standard color palette. Select a different color, or create you own with the Define Custom Colors>> button, and click OK to apply the new color.

Delete file - This option allows you to delete a single file from the display. You will be prompted for verification before the file is removed.

Delete All Comparison Files (AVG) - Select this option to delete all of the comparison files that have been overlain.

Comparison File Options. This option becomes accessible after you load a comparison file. Clicking it displays the following window.

The Comparison list will show all the comparison files you have selected. Highlight one, then select the Color and Line style for that file. Then highlight the next file and make any modifications, and so on. The new styles will be seen when you enlarge one of the electrode displays.

View SNR Values - The Signal-to-Noise Ratio (SNR) values for each channel may be viewed with this option, as well as the overall noise level and best SNR value.
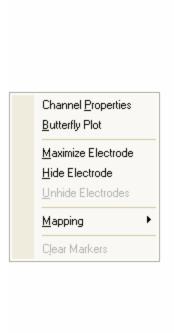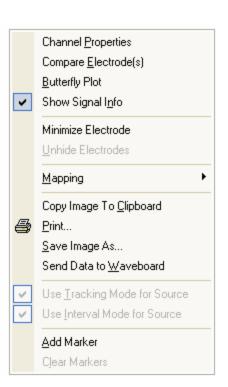

View N Values - When viewing an averaged data file, the N Values will display the number of cases that were used to construct the average.

View Impedance Values - The last impedance values that are present when you are running the impedance routine are saved with the data file. *Right click* between electrode displays and select the View Impedance Values option to see the saved values. You then have the option to save the values to an ASCII file, if desired.

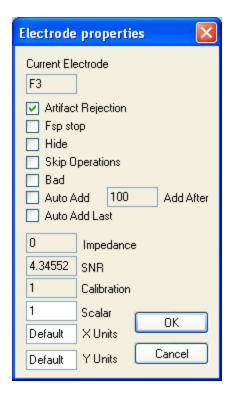## 4.2   Right mouse button clicking inside the electrode displays

Clicking the *right mouse* button within an electrodes display brings up additional options. These will vary depending on the type of file, and whether the display is minimized or maximized (shown below). In general, when you select an option after clicking *inside* an electrode display, only that channel is affected.
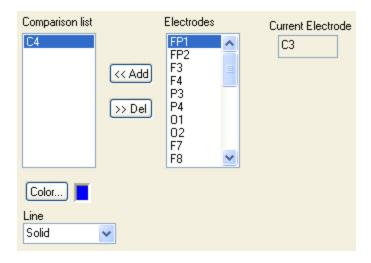
```
                                          Channel Properties
                                          Compare Electrode(s)
                                          Butterfly Plot
                                     ✔    Show Signal Info

                                          Minimize Electrode
                                          Unhide Electrodes

              Channel Properties          Mapping                    ▶
              Butterfly Plot
                                          Copy Image To Clipboard
              Maximize Electrode     🖨    Print...
              Hide Electrode              Save Image As...
              Unhide Electrodes           Send Data to Waveboard

              Mapping              ▶  ✔   Use Tracking Mode for Source
                                     ✔   Use Interval Mode for Source
              Clear Markers
                                          Add Marker
                                          Clear Markers
```

The first list of options above appears when click inside a *minimized* electrode display. All of these are also present when you click inside a maximized display, except for the Hide Electrode and Maximize Electrode options. Additional options are possible after the display is *maximized* (partially, or completely). All are described below.
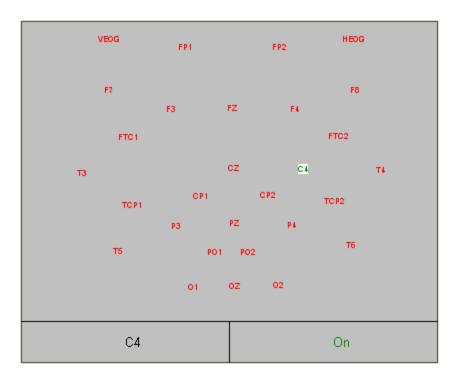
Channel Properties (CNT, EEG, AVG, COH) - Selecting the Channel Properties option gives access to the Electrodes properties screen. This has the same fields of information that are contained in the Channel Layout and Channel Attributes screens seen in ACQUIRE (under *Edit*). With CNT files, the Electrode Properties display is accessed by clicking on the desired electrode name (from the column of labels on the left side of the display). You may modify the settings as desired.

Compare Electrode(s) (EEG, AVG, COH) - The Compare option allows you to superimpose electrodes from the same data file. For example, if you want to compare C3 and C4, click the *right mouse* button inside the C3 display (enlarging it first is typical), and select the Compare Electrode(s) option. The following display will appear (shown in two parts).

The Current Electrode is displayed in the top left field. The additional electrodes are listed in the Electrodes column, and shown in the montage on the right side of the display. Highlight the C4 electrode from the list and click the << Add button, or simply click it from the montage display.
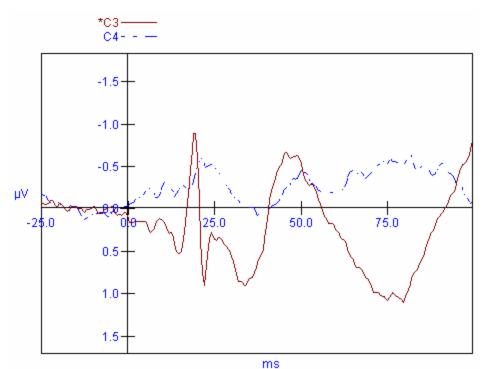
C4 will appear in the Comparison list. Note that you may change the colors of the comparison electrode by clicking the Colors... button. This displays the standard Colors selection display.

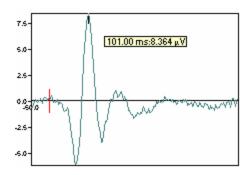The line style may be changed by clicking the Line field pull-down menu.

When you have entered the electrodes to be compared, click OK, and you will see the selected electrodes super-imposed on the original one.

You can remove selected electrodes from the Comparison list by highlighting them and clicking the ⟩⟩ Del button.

Butterfly Plot (AVG, EEG) - This is the same option as described above under *Right mouse button clicking between the electrode displays*.

Show Signal Info - If enabled, you will see a Tooltip box with latency (or Hz) and amplitude information for each data point as you move the mouse inside the waveform display. Disable the option to suppress the Tooltip.

Maximize / Minimize Electrode. Select Maximize Electrode to enlarge the display to full size; select Minimize Electrode to return it to the original minimized size.

Hide / Unhide Electrodes - The Hide Electrode option will "hide" the selected electrode display (it does not delete it from the data file). The Unhide Electrodes option will redisplay all previously hidden electrodes.

Mapping - This option displays a secondary menu that has the various mapping

options.

View 2D/3D Map (EEG, AVG) - This option will be active when you enlarge an electrode display to mid- or full-size. You may enable or disable 2D Mapping from this line. It may be accessed more easily from the Toolbar icon . Refer to the 2D Mapping section above for mapping details.
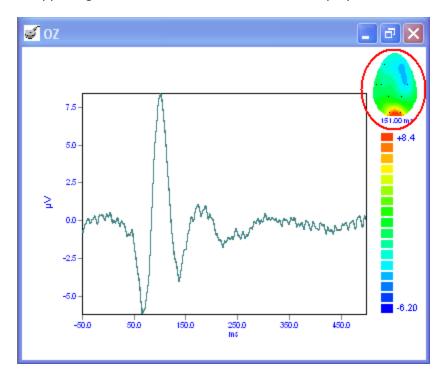
 Note
When you are placing 2D maps and Adding Markers at the same time, it will be necessary for you to disable temporarily the 2D Mapping (otherwise you will drop a map when you want to drag the Marker). The 2D Mapping toggle is useful in this instance so you don't lose the maps you have placed.

Use Map Tracking - If this option is enabled, then the 2D map will change as you move the mouse in the waveform display. Disabling it will let you select a single point (click a point and it will be mapped).

Delete All Maps - Click the Delete All Maps line to delete all maps. You may also disable the 2D Mapping feature by clicking View 2D Maps (so the check mark does not appear).

Enable Map at Right Corner - This option is used to display or remove the 2D map in the upper right hand corner of the waveform display.

Copy Image to Clipboard - This option copies the contents of the display to the Windows Clipboard (as a bitmap file). From there, you may Paste it into other Windows applications, such as Word.

Print (EEG, AVG, COH) - Print accesses the standard print screen for printing the displayed images (see also Print under Files above).

Save Image As ... (EEG, AVG, COH) - Use this option to save the electrode window display as a Windows metafile. Metafiles can be inserted into a variety of Windows application software. For example, save an electrode display as a metafile (.wmf extension added automatically), and add it to a Word document by selecting Insert, then Picture, then From File, and selecting the electrode file.

Send to Waveboard (EEG, AVG, COH) - This option allows you to send selected waveforms to the Waveboard. The waveforms will always be sent to Waveboard1.
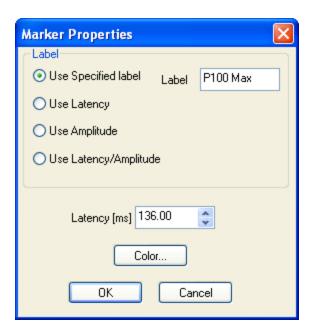
Use Tracking Mode for Source - This option will be unavailable unless you are using the SOURCE program (see the SOURCE manual for details).

Use Interval Mode for Source - This option will be unavailable unless you are using the SOURCE program (see the SOURCE manual for details).

Set Coherence Reference (COH files only) - Coherence is a correlation-like measure that is calculated between one electrode and all the other electrodes. When you retrieve a COH file, one of the electrodes will appear by default as the Coherence Reference. It will have dotted lines connecting it to all other electrodes, and they will contain the coherence values. Set Coherence Reference allows you to switch the coherence reference to a different electrode. Click the *right mouse* button inside the electrode that you wish to have as the reference, and select Set Coherence Reference.

Add Marker (EEG, AVG) - This option allows you to mark a point on the waveform and add text. For frequency domain files, you must have the "line" option, rather than a histogram. Enlarge an electrode display to full size, then click the *right mouse* button inside the display, at the point where you want the marker to appear. Click the [Add Marker] option. You will see the Marker Properties display appear. Enter the desired text in the Label field (or use the amplitude and/or latency options), enter the latency where the Marker should be placed (if you want a different one), and change the color of the text, if desired. Then click OK.

The Mark will appear in the display. Using the left mouse button, grab the cross hair that appears at the beginning of the Mark, and drag it to the desired location.
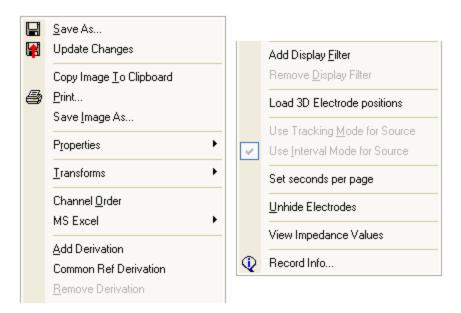
To change the label, click the *right mouse* button on the cross hair, and you will see a small option list. Delete will delete the marker. Click Edit Properties, and you will see the same Marker display shown above. You may then modify the text and color, as desired. If desired, you can click *between* electrode displays and select the Marker Report option. This will create a .dat file (ASCII) that has the marker information.
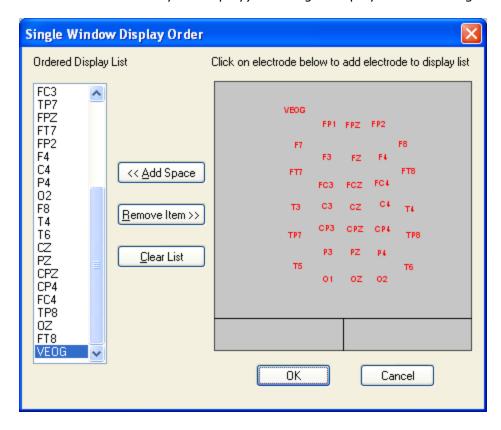
Clear Markers (EEG, AVG, COH) - Selecting this option will remove any markers you have placed.

4.3   Right mouse clicking on a Single Window Display

When you click the *right mouse* button on a single window display, as when viewing CNT files, you will see a slightly different list of options. Those not described above are listed below.

Channel Order - This option allows you to reorder the sequence of channels on the CNT file display. (The same option may be selected from the Single Window Order button on the Channel Layout display). Clicking it displays the following screen.

The current order of channels is in the left side column. To remove a channel from the list, just highlight it and click the Remove Item >> button. *Note: this removes the channel from the list, not from the display. There will always be the same number*

of channels displayed; this option will only alter the order. To reorder the display completely, click the [Clear List] button. Then click the channel labels in the montage display in the order that you want them to appear. As you rebuild the list, you might want to separate the channels with spaces. Click [<< Add Space] to leave a space between the channels as you select them. If you omit some channels, they will be added at the bottom of the single window display. Click OK when you are through to see the new ordering. To save the CNT file with the new order, click Save As under File. You will then have the option of either overwriting the existing file, or creating a new one.

Add Derivation - Add Derivation allows you to apply an LDR transform to the CNT file. (You will need to create a matching LDR file first using the Montage Editor; please see that Appendix at the end of this manual). The applied LDR is for display purposes only. Use the Linear Derivation transform, on the list of Transforms, to apply and save the changes, if desired. *Note: if you use Add Derivation, the additional display pages will be disabled.*

Common Ref Derivation - Selecting this option will compute as display the data with common average reference.

Remove Derivation - Click this option to remove the applied LDR transform.

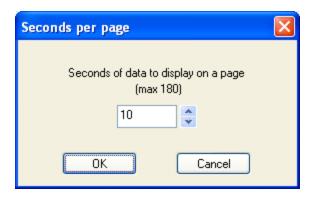*Add Display Filter* - Clicking this option displays the Filter screen. Enter the settings as desired, click the [Apply To All Selected Channels ->] button, and click OK to apply the filter to the displayed CNT file. The filter will affect the display only. Use the Filter transform to apply and save the filtered data.
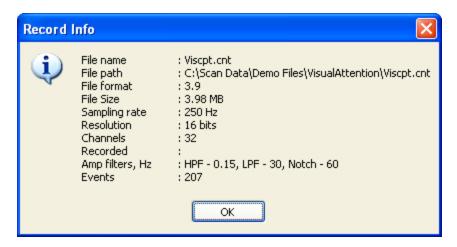
Remove Display Filter - Clicking this option removes the effects of the Add Display Filter option.

Load 3D Electrode positions - This option is used to add measured 3D electrode position data to the data file. The information is contained in the .3dd file created in 3DSpaceDx, and is used in the SOURCE program. Clicking the option displays the Open File utility window, from which you may select the .3dd file. The file must be from the subject whose EEG data you are viewing in EDIT (otherwise the electrode positions will be only approximations).

Set seconds per page - This option in used in place of the Accelerate and Decelerate icons on the Toolbar to change the number of seconds displayed per page. Click it to see the "Seconds per page" dialog box, in which you may enter the number of seconds you want to be displayed (up to 180 seconds).
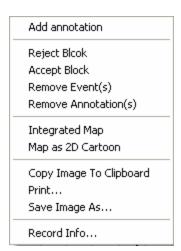
Record Info - Clicking this option displays information about the CNT data file.

4.4   Click-dragging with the right mouse button in a Single Window Display

If you click the *right mouse* button on a CNT file, hold it, then drag and release it, you will see the option list below.
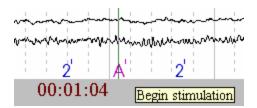
The section you created is a block that can be used in several ways.

Add Annotation. Select this option and the following screen will appear. From the text line, you may enter a text string.

The comment will be added to the CNT file at the bottom, in the middle of the block, and appear with a letter. Move the mouse over the letter to see the annotation. The annotation can be removed using the Remove Annotation(s) option.

Accept Block / Reject Block. You can use this method to mark or unmark blocks of data in the CNT file. The other method is to use the Mark Block icon from the Toolbar. Marked blocks will be omitted during epoching (unless you deselect the Reject Epochs that Overlap rejected Blocks option in the Epoching Properties dialog screen).

Remove Event(s) / Remove Annotations(s). After delineating a block, you may then remove the events and annotations in the block.
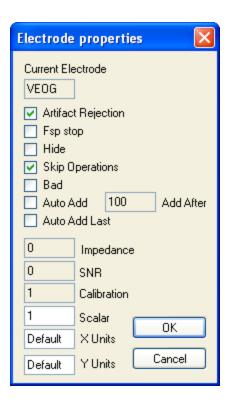
Integrated Map. Delineate a block of data, select this option, and you will see that block of data mapped with a 2D map. All of the points for each channels are summed, and it is the integrated sums that are mapped. Over a large block of EEG, therefore, the map will tend to be all zeros, as the summed values tend toward zero. Map a small block, containing, for example, a spike or a blink, and the map will reflect the distribution.

Map as 2D Cartoon. Delineate a block of data, select this option, and you will see that block of data mapped with a 2D cartoon (see 2D cartooning for details).
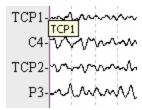
The remaining options - Copy, Print, Save, etc. - have been described elsewhere, and are largely self-explanatory.

4.5   Clicking the electrode labels in the Single Window display

Clicking the *right mouse* button on an electrode label displays the Electrode Properties dialog box. You may modify any of the active (non-grayed out) settings.

If you move the mouse over the electrodes labels, you will see a Tool Tip displaying the electrode label. This is useful in files with many channels where the electrodes labels may be hard to read.
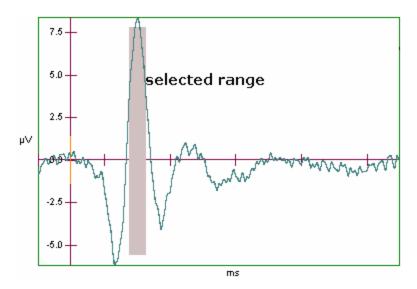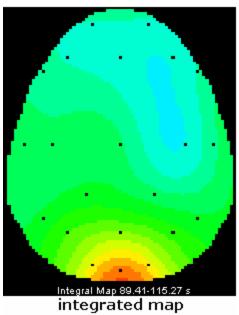
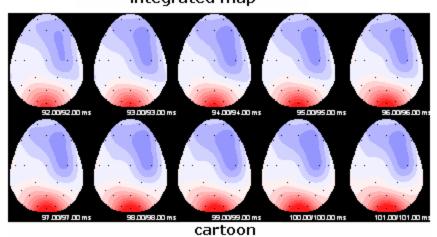## 4.6 Click-dragging with the right mouse button in a Multiple Window Display

If you click the *right mouse* button on an EEG or AVG file, hold it, then drag and release it, you will see the option list below.

These have the same functions as described above. **Integrated Map** will create a 2D map based on all of the data points in the selected range. **Map as 2D Cartoon** will display the maps in the selected range in a 2D Cartoon.

selected range

Integral Map 89.41-115.27 s

integrated map

cartoon

5   Summary of Keystroke Commands

The following keystrokes are used in the EDIT program.

Basic Operations

Open Data File	*Ctrl+O*
Save As	*Ctrl+S*
Print	*Ctrl+P*

Display Options

Accelerate Display	*+ key* (CNT files)
Decelerate Display	*- key* (CNT files)
Increase Scaling	*Up arrow*
Decrease Scaling	*Down arrow*
Next Display Page	*Page Up*
Previous Display Page	*Page Down*
Baseline Correction	*Ctrl+B*
Invert Polarity	*Ctrl+I*
Move Backward	*Left arrow*
Move Forward	*Right arrow*
SpeedScan backward	*Alt+left arrow*
SpeedScan forward	*Alt+right arrow*
SpeedScan stop	*Spacebar*
Move through CNT file	*Mouse wheel*

Accept/Reject Sweeps (EEG files)

Accept sweep	*Insert*
Reject sweep	*Delete*

6   References

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7   Appendix A - Waveboard

The Waveboard is a handy utility program that may be used to display, annotate, and measure data from individual channels. It may be used as a stand-alone program, or it may be called from the ACQUIRE or EDIT programs. Its main features include:

- The display of Multiple Window data from channels selected from the same or different data files.

- Time and frequency domain files can be displayed on the Waveboard.

- The ability to mark time points for each channel (latency and amplitude).

- The ability to place one or two cursors to show latency and amplitude measurements and differences between them.

- Movable and adjustable X and Y measurement scales.

- Style and color modifications for each channel.
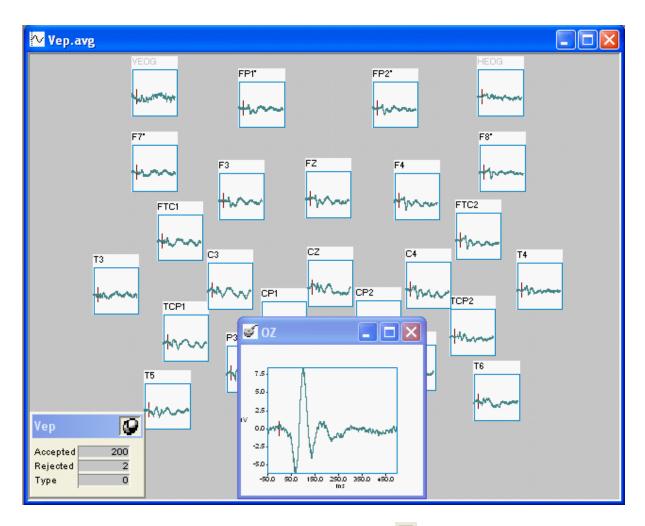
7.1   Waveboard Tutorial

Step 1 - Starting the Waveboard. The *waveboard.exe* program may be run as a stand-alone program by double-clicking on in the Scan4.5 folder. More commonly, you may launch the program by clicking the Waveboard icon from the Toolbar in ACQUIRE or EDIT. The Waveboard is used with the Multiple Window Displays (when collecting or retrieving single sweep data or on-line averages), and not with the Single Window Display (the continuously scrolling EEG).

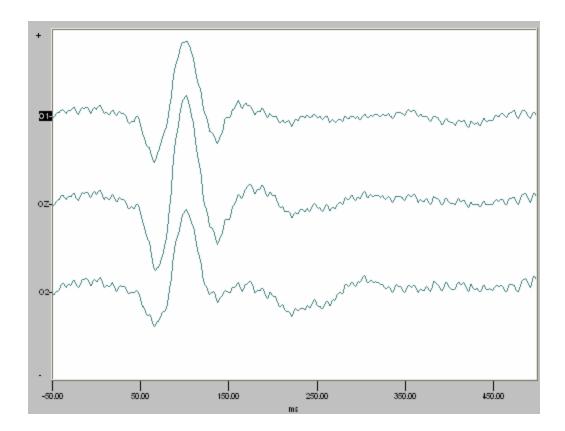For this demonstration we will use the *Vep.avg* demonstration file that is in your *\Scan Data\Demo Files\Veps* folder. Launch the EDIT program from the Program Launcher, and click **File → Open data file**, or click the **Open Data File** icon . Set the Files of type pull-down menu to AVG files, then go to the *\Scan Data\Demo Files\Veps* folder and double-click on the *Vep.avg* file. The data file will appear similar to the following.
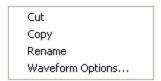
Now click the Launch Waveboard icon from the Toolbar 🖻 , and minimize the Waveboard display.

Step 2 - Copying data to the Waveboard. Let's copy O1, OZ and O2 to the Waveboard. Position the mouse cursor on the O1 display, enlarge it to mid- or full-size, and click the

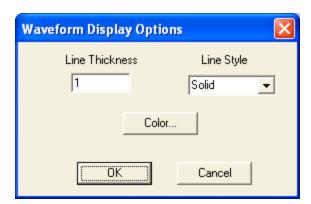*right mouse* button. Select the   Send Data to Waveboard   option.

Repeat the same steps for the OZ and O2 electrodes. Now Maximize the Waveboard display, and maximize the waveform display inside the Waveboard display, if desired. The result will look similar to the following (your background and waveform colors will likely appear different, depending on the settings you selected in the Multiple Window Settings,

under Options). Use the Up and Down arrows ⬇⬆ to scale the data on the display, as

desired, and invert the polarity ⅌ₙ , if desired.

Step 3 - Changing colors. Let's change the colors to make it easier to tell the waveforms apart. Position the mouse over the O1 waveform label, and click the *right mouse* button. You will see the displayed list of options.

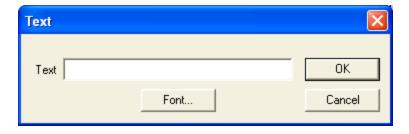Select **Waveform Options**, and see the following display.

As the display suggests, you can change the thickness of the waveform lines, or you can change the style of the line from solid to dots, dashes, etc. For now, just click the **Color**

button, and you will see the standard Windows Color Palette display.

Select a color for the O1 waveform (red). If you don't like any of the displayed color options, click the **Define Custom Colors>>** bar, and select a customized color. Then click OK, and OK again. You should then see the new color for O1. Repeat the sequence to change OZ and O2 to different colors (green and blue).
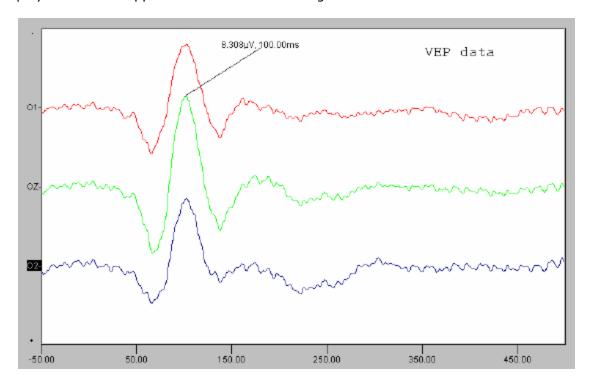
Step 4 - Adding Text. Now, let's add some text. Click the Add Text icon , and click the left mouse button in the approximate area where you want to add the text. The Text display will appear.

Click the mouse in the text field, and enter something like "VEP data". You can change the font style, size, and other characteristics by clicking the **Font** button. Then click OK. The text will appear. You may reposition it by clicking and holding the left mouse button over the text to "grab" it, and drag the text to a desired location. Release the mouse to place it there. You can also click the *right mouse* button over the text. You will see a small option list which you can use to **Delete** the text or **Edit** the text. If you select **Edit Text**, you will get the same Text window as shown above.

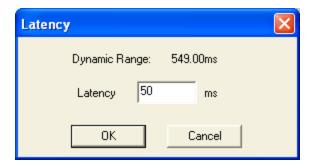*Step 5 - Measuring Points*. Now let's measure amplitude and latency of the peak of the P100 component at OZ. Click the Add Marker icon , and then position the cross-hair at the P100 peak at OZ. Hold the left mouse button down, and drag the amplitude and

latency values to a clear place on the display, then release the left mouse button to place it there. If you wish to change the placement, position the mouse over the measurements, and click and hold the left mouse button. You can then grab and drag the measurement information to a desired location. The indicator line will stay attached. Your display should now appear similar to the following.
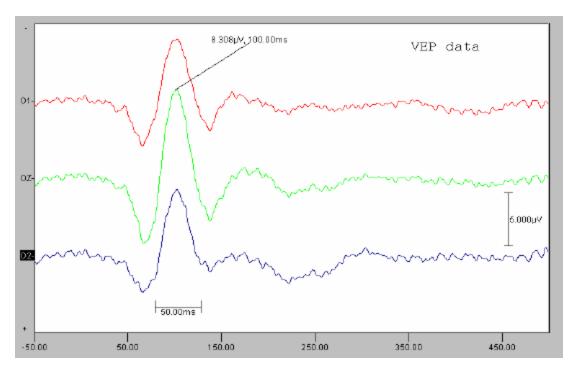

Step 6 - Adding Scale Tools. Now, let's add the Latency and Amplitude Scale Tools for precise measurement of latency and amplitude. Click the Latency Bar icon from the Waveboard Toolbar. You will see the x-axis scale tool. Click on it one time with the left mouse button, and a rectangle will appear on one end . By grabbing the rectangle with the left mouse button, you can extend or reduce the length of the scale tool. Alternatively, click on the scale tool with the *right mouse* button, and you will see a small option list. Selecting **Delete** will delete the scale tool. Selecting **Set Latency** will display the Latency window, through which you may select the length (in ms) of the tool. The Dynamic Range is the length of the entire epoch, and is the maximum range allowed for the scale tool.

Add the Amplitude Scale Tool (or y-axis tool) by clicking on its icon ⊥. The options for it are directly analogous to the Latency scale. You can reposition the scale tools by grabbing them with the left mouse button and dragging them to a desired location. Your display will now appear similar to the following.

Step 7 - Moving the Waveforms. Note that it is possible to move each waveform up and down on the screen. Grab a channel label (O2) with the left mouse button, and drag it upward. If you want to overlay the waveforms on top of each other (so they have the same position for zero Volts on the screen), you can click and drag them into position, or do it more simply by selecting **Options** → **Overlay All** from the Main Menu bar.
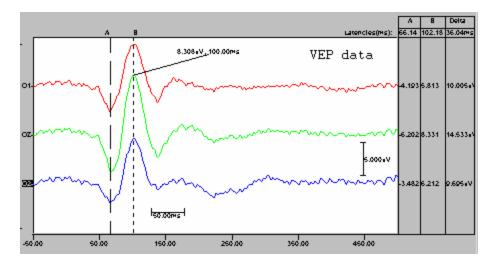

To restore the channels to their original positions, select **Options** → **Raster All**. If you were displaying channels from different data files that had the same labels (such as, OZ from two or more data files), you can select the **Raster w/ Label Matching** option. This will overlay waveforms that have the same labels (see step 10 below).

Step 8 - Using the Cursors. Next, let's do some relative latency difference measurements and some peak-to-trough measurements. Click the Enable Cursor 1 icon | from the Toolbar. You will see a vertical dashed line (Cursor 1) appear with the letter "A" at the top of it. You will also see several columns appear on the right side of the screen. Grab the cursor line with the left mouse button, and drag it back and forth. You will see the latency (in ms) of its current position displayed at the top of the first column, and the

corresponding amplitude values (in μVs) for each of the waveform points. Position the cursor at the peak of the N70 component measured from OZ (about 66ms).

Now enable the second cursor by clicking its icon ▐▐ from the Toolbar. It will have the letter "B" at the top of it. Position it so that it is at the peak of the P100 component.

You will see two more columns of numbers on the right side of the display. In Column B, there is the latency of the second cursor as well as the amplitudes for that time point for each of the waveforms. The third column - Delta - displays the change in latency at the top, and the change in amplitude below for each channel, in relation to the position of the first cursor. This is a quick way to measure latency differences between two points, and the peak-to-trough amplitude differences.
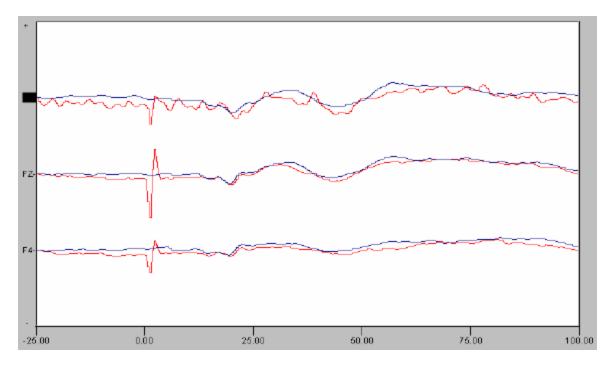
Step 9 - Saving, Printing, etc. You can save the file by clicking **File → Save As**, or by clicking the **Save** icon 🖫 from the Toolbar. Designate a path and file name, then click OK (the .wvb extension will be added automatically). You may then retrieve the file at a later time. You may also **Print** the file directly using the standard Windows printing conventions, or you may **Copy** the display to the Windows Clipboard.

Step 10 - Combining channels from different files. Lastly, one of the more useful aspects of the Waveboard is its capability for combining waveforms from different data files. *Note: The files must have the same epoch durations and number of points to combine them on the same Waveboard display.* In the *\Scan Data\Demo Files\Seps* directory there are two files called *sepblk.avg* and *sepnoblk.avg*. These are somatosensory EP recordings obtained during right median nerve stimulation. The *sepnoblk.avg* file did not use the Deblocking feature of the SynAmps, and the *sepblk.avg* file was acquired with Deblocking. Deblocking blocks acquisition for brief spans of time, and can be used to eliminate SEP stimulus artifact. With the Waveboard, it is very easy to show the effects of deblocking between the two recordings.

Retrieve the *sepnoblk.avg* file in EDIT. The stimulus artifact is very apparent in electrodes F3, FZ and F4. Copy these to the Waveboard, as described above. It is a good idea at this point to change the color of these channels so it will be easy to tell them apart from the *sepblk.avg* data channels. Change the colors as described above.

Now retrieve the *sepblk.avg* data file (it is not necessary to close the first file). Send the

same three channels to the Waveboard. Maximize the Waveboard display, and you will see the data from all 6 channels. Scale the display, as desired. Click **Options** → **Raster w/ Label Matching**. This will overlay the channels with the same channel labels, and provides a convenient way to display data from two (or more) conditions on the same graph. (It is also a nice demonstration of the Deblocking feature of the SynAmps).
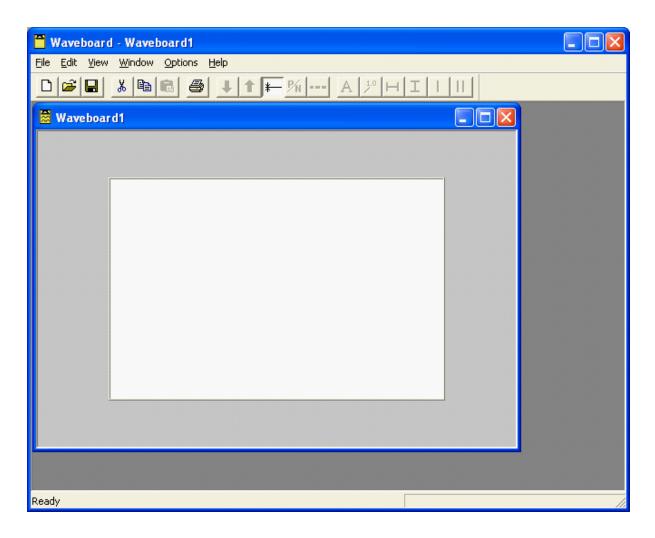

This concludes the Waveboard tutorial. The remainder of the manual describes all of the features of the Waveboard.

7.2   Operating the Waveboard
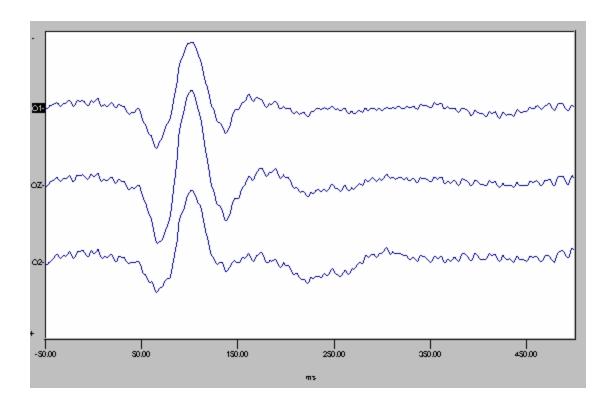
The *waveboard.exe* program may be run as a stand-alone program by double-clicking on Waveboard.exe in the Scan4.5 folder. More commonly, you may launch the program by clicking the Waveboard icon from the Toolbar in ACQUIRE or EDIT. The Waveboard is used with the Multiple Window Displays (when collecting or retrieving single sweep data or on-line averages), and not with the Single Window Display (the continuously scrolling EEG). In ACQUIRE, you can send waveforms to the Waveboard during acquisition, or you can Pause the recording and send the waveforms. You may send time domain or frequency domain data files to the Waveboard.

Starting the Waveboard and Sending Waveforms to it. The basic steps in operation are to start EDIT (or ACQUIRE) first, then click the Waveboard icon . The main Waveboard screen will appear.

There will be an empty Waveboard1 display, which can be enlarged to full size, if desired.

You may send individually selected channels to the Waveboard, or you may send all of them at one time. Click the *right mouse* button anywhere that is NOT in an electrode display window, and you will see a list of options. Select the Send Waveforms to Waveboard option to send all the waveforms to the Waveboard. If you position the mouse within a single, enlarged electrode display and click the *right mouse* button, you will see the option list. Select the Send Data to Waveboard option, and only the single waveform will be sent. Repeat the process for each waveform you wish to send. An example of the Waveboard display might look like the following.
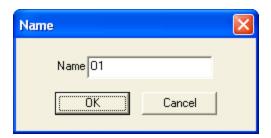
Positioning the waveforms on the display. The waveforms may be dragged up or down to new locations by grabbing the label with the left mouse button (the background of the label will change colors). It is also possible to reposition the waveforms automatically using the **Raster** and **Overlay** options described below under **Options**.

Some right mouse button options. There are some options that are accessible only with the *right mouse* button. Click on a waveform LABEL using the *right mouse* button. The displayed menu will appear.
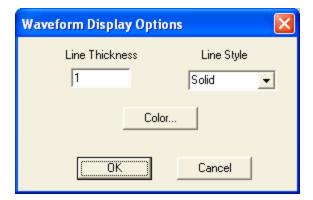
The **Cut** and **Copy** options are fairly standard and self-explanatory, and are described below.
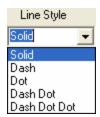
> *Rename*. You may rename the channel easily by selecting the rename option. The Name window will appear with the current electrode label. Type in a new label, and click OK.
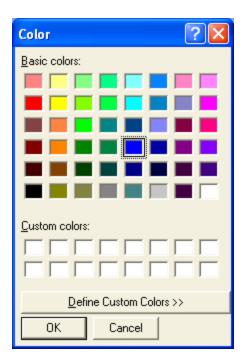
Waveforms Options.... Selecting the Waveform Options line displays the following screen.

The default line thickness is 1, but you can increase the thickness up to a value of 10. The pull-down menu under Line Styles shows the different styles that may be selected for the waveforms.

Note: When changing the Line Styles, the Line Thickness should be set to 1.
You may change the color of the individual waveforms by clicking the **Color** button. The standard Windows Color palette will appear.

Select a color for the selected waveform, and click OK. If you don't like any of the displayed color options, click the **Define Custom Colors>>** bar, and select a customized color. Then click OK, and OK again. Repeat the process to select a new color for each channel, as desired.

Click the *right mouse* button anywhere else, and you will see the following list of options.

Paste. The Paste option will be active if you have previously Cut a waveform from the Waveboard (same function as **Edit → Paste** from the Main menu bar). In combination, the Cut and Paste options may be used to take a waveform from one Waveboard display, and Paste it into another.

Clear All. Selecting this option will permanently delete all Waveboard contents (same function as **Edit → Clear All** from the Main menu bar). You will see a warning asking for verification before the contents are deleted.

Save Display Image... This option opens a standard Save As utility screen through which you may enter a file name, designate a path, and save the image as a Windows metafile (the .wmf extension is added automatically). This is the same function as **File → Save Display Image**.

The majority of the remaining options are accessed from visible options within the Waveboard display. At the top of the main screen, the Main Menu list contains the following options: File, Edit, View, Window, Options and Help.

7.2.1 File

The options under File are standard Windows features, and will be described only briefly. They include New, Open, Close, Save, Save As, Print, Print Preview, Save Display Image, Recent File, and Exit. Fewer options will be displayed if there is no Waveboard file open.

New. New opens a new Waveboard display to which data can be copied. You can access this option more easily from the Toolbar icon ⬜. Note that waveforms sent from EDIT or ACQUIRE will always be sent to Waveboard1. The waveforms may then be copied to a New Waveboard display that you open.

Open. The Open command displays a standard Open File utility. In the Files of type pull-down menu you can select preexisting Waveboard Files (*.wvb), or display all the files in the folder. Only *.wvb files may be opened. This option can be accessed directly from the Toolbar icon 📂 .

Close. The Close command will close whichever Waveboard file has the focus.

Save. The Save command saves the current Waveboard to its existing folder using its same name. If you try to Save a new file, one that has not been saved before, you will get the Save As utility display.

Save As. The Save As command opens a standard Save File utility which may be used to enter a file name and designate a destination folder. The .wvb extension is added automatically when Waveboard files are saved. Save As can be accessed more easily from the Toolbar icon 💾 .

Print. The Print command displays a standard Print window which you can use to select the printer. The Print window can also be accessed from the Toolbar icon 🖨 . Note that the screen image may not match exactly the image that is actually printed. Use the Print Preview option to view the printed output.

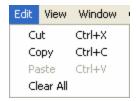*Print Preview*. The Print Preview command will allow you to preview the information that you wish to print.

Save Display Image. This option opens a standard Save As utility for saving the display in a Windows metafile format. Enter a file name, designate the path, and click the Save button to save the file (the .wmf extension will be added automatically).

Recent File. The Recent File area shows a list of recently retrieved *.wvb files. If you wish to recall one of these, you can click the mouse directly on the file (instead of going through the extra steps using **File → Open file**).

Exit. Exits the Waveboard.

7.2.2   Edit

The Edit option opens a menu list of standard Windows options for Cutting, Copying, Pasting and Clearing files.
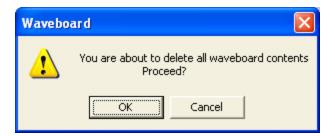
Cut. The Cut command can be used to remove individual waveforms from the Waveboard. Highlight the electrode Label (the background behind it will change colors), then select Cut, and that waveform will be removed (to the Windows Clipboard). Cut may be accessed more easily from its Toolbar icon ✂. You can also click the *right mouse* button on the electrode label to access the Cut option.

Copy. The Copy command will copy a highlighted waveform (label) to the Windows Clipboard. It can be accessed more easily from the Toolbar 📋, and also by clicking the *right mouse* button on the electrode label.

Paste. The Paste command will paste a waveform from the Windows Clipboard to the Waveboard display. It can be accessed more easily from the Toolbar 📋, or by positioning the mouse where you want the waveform to be pasted and then clicking the *right mouse* button.

Clear All. The Clear All command will permanently delete all Waveboard contents. You will be asked for verification before the contents are deleted.

You can access the Clear All command more easily by clicking the *right mouse* button in any free space in the Waveboard display screen.

7.2.3   View

View is used to enable or disable the display of the Toolbar and Status Bar.

Toolbar. The Toolbar contains the icon shortcuts near the top of the main screen. These are described in more detail below.

Status Bar. The Status bar at the bottom of the main screen is used for displaying brief information about icon functions (position the mouse over the icon and read the status bar description). The Status Bar will also display the latency of the mouse position whenever the mouse cursor is positioned within the waveform display.

7.2.4   Window

The Window options include New Window, Cascade, Tile Horizontally, Tile Vertically, and a list of open windows.

New Window. The New Window option creates a new window that has the same contents as a previously opened Waveboard window. It can be used to make modifications to the Waveform display while retaining an original version of the display.

Cascade. Cascade is a standard Windows option that arranges open windows in an overlapping, stacked arrangement.
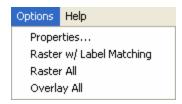
Tile Horizontally. The Tile Horizontally option will arrange the open windows automatically so that the windows span the width of the larger Waveboard window, one above, but not overlapping, another.

Tile Vertically. The Tile Vertically option will arrange the open windows automatically so that the windows span the height of the larger Waveboard window, side by side, but not overlapping, one another.
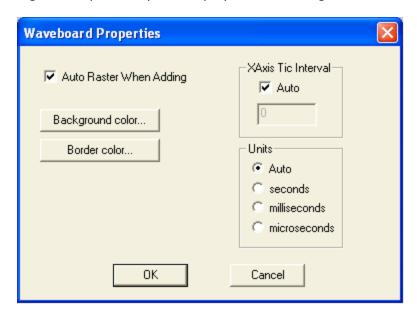
Open Windows List. Lastly you will see a list of the currently opened display windows. You can change the focus to any window by clicking on it from the list (so that the check mark is beside the window). In some instances, where a desired window is hidden completely behind another, this is an easier way to change the focus to the desired window.

7.2.5   Options

Options contains the following choices: Properties, Raster w/ Label Matching, Raster All, Overlay All. Please refer also to the tutorial above for more information and examples.

Properties. Clicking the Properties option displays the following window.

Auto Raster When Adding. It allows you to enable or disable the Auto Raster option when you are adding files to the Waveboard. When enabled (check mark appears), the channels that are added to the Waveboard will be added above or below existing channels (not overlain). When disabled, new channels will be overlain on previously added channels.

Background Color. This option lets you select a color for the background behind the waveforms. Clicking the button shows the standard Color selection display. Select a color and click OK, and the background color will change.

Border Color. This option lets you select a color for the border area around the waveform display. Clicking the button shows the standard Color selection display. Select a color and click OK, and the border color will change.

XAxis Tic Interval. This allows you to set the tic marks along the x-axis of the waveform display. If you select Auto, the tic marks will be placed with an automatically selected interval. Deselect Auto and enter in an interval value (such as 100), and the tic marks will appear every 100ms.

Units. The Units options let you select what units are used for values on the

x-axis. "Auto" will autodetect the best scaling to use, but you may override it by selecting seconds, milliseconds, or microseconds.

Raster w/ Label Matching. When enabled, this option will take all channels having the same label and overlay them. For example, let's say you send O1, OZ and O2 to the Waveboard, from three different data files. If you select the Raster with Label Matching option, you will see the three O1 channels overlain on top of each other, the three OZ channels on top of each other, and the three O2 channels on top of each other.

Raster All. The Raster All option will display all channels that are on the Waveboard in non-overlapping space (none of the channels overlay any other channels).

Overlay All. The Overlay All option will overlay all the channels on the Waveboard. Whatever Baseline Correction computation you made in EDIT will be transferred automatically to the Waveboard.

7.3   Toolbar Icons

The icons on the Toolbar provide quick shortcuts to many of the common operations with the Waveboard, and, in some instances, provide the only means of access to some options.

The first seven icons - New file, Open File, Save As..., Cut, Copy, Paste, and Print are standard Windows icons and are described above. The remaining icons are specific to the Waveboard, and are described below.

Up/Down Display Scale Arrows. The Up and Down arrows are used to vary the display scale of the data displayed in the Waveboard. These alter the display scaling only, and have no effect on the original data file.

Baseline On/Off. Clicking this option centers the waveforms in their allocated regions on the display. It has no effect on the actual data measurements. If you have overlain the waveforms, enabling this option will cause the superimposed waveforms to line up according to the initial data point (which you may not want to do). Generally, you would not use this option with overlain waveforms.
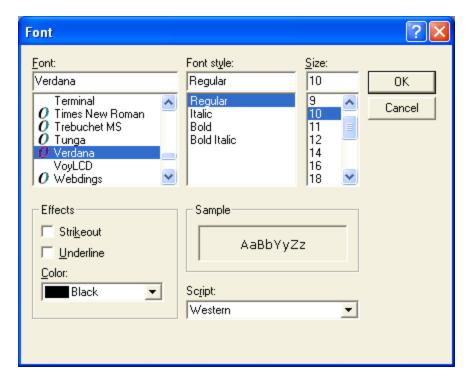
Polarity Reversal. The polarity icon inverts the display polarity (positive up to negative up). This affects the displayed data only, and has no effect on the original data file.

Enable/Disable Zero Indicator. Enabling the option will display a dashed line showing the zero-voltage baseline, as calculated in EDIT.

Add Text. This option allows you to add text to the Waveboard display. Click the icon, and then click the left mouse button in the approximate area on the Waveboard display where you want the text to appear. The Text dialog box will then appear.
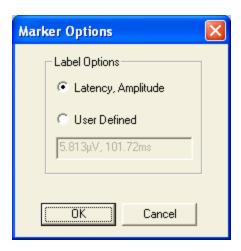
Then enter the text you want to display. If you want to vary the font, style, size, etc., click first on the **Font** button. A standard Font display screen will appear.

After you have entered your settings, click OK.

After you have placed the text on the screen, you may reposition it by grabbing it with the left mouse button, and dragging it to a new location. Click on the text with the *right mouse* button, and you have the option to **Delete** it, or to **Edit** it. If you wish to edit it, click the Edit Text option, and the same Text window shown above will appear.

Add Marker. The Add Marker option allows you to add a marker that displays the millisecond and microvolt values for any point on a waveform. Click the icon, then position the cursor on the point of interest. Then click and hold the left button down, and drag the marker to a clear space and release the button. You can change the position by grabbing the marker with the left mouse button and dragging it to a new location. Click on the marker with the *right mouse* button, and you will see an option list consisting of **Delete**, which will delete the marker, and **Options**. Clicking the Options line displays the Marker Options screen.

The default position uses the Latency and Amplitude values for the marks. You can modify that by selecting the User Defined option. This allows you to enter any text you wish (see Final Output Image below for example).

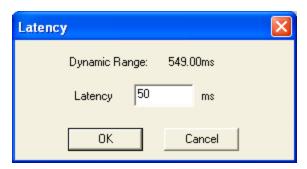*Scale tools*. Next on the Toolbar are the two scale tools. The first displays a scale tool for the x-axis, or latency scale. The second displays a scale tool for the y-axis, or amplitude scale. Click the Latency Bar icon and the latency scale tool will appear. Click on the scale tool one time with the left mouse button, and a rectangle will appear on one end . By grabbing the rectangle with the left mouse button, you can extend or reduce the length of the scale tool. Alternatively, click on the scale tool with the *right mouse* button, and you will see a small option list. Selecting Delete will delete the scale tool. Selecting Set Latency will display the Latency window, through which you may select the length (in ms) of the tool. The Dynamic Range is the length of the entire epoch, and is the maximum range allowed for the scale tool.

Operation of the Amplitude Scale Tool is directly analogous to the Latency scale. You can reposition the scale tools by grabbing them with the left mouse button and dragging them to a desired location. (See the tutorial above for graphical display).

Cursor 1 and Cursor 2. These buttons allow you to move one or two cursors on the Waveboard display to measure latencies, amplitudes, and differences between the cursors on all waveforms. (The second cursor is not active until you place the first one).
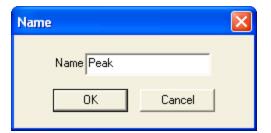
Click the Enable Cursor 1 icon from the Toolbar. You will see a vertical dashed line

(Cursor 1) appear with the letter A at the top of it. You will also see several columns appear on the right side of the screen. Grab the cursor line with the left mouse button, and drag it back and forth. You will see the latency (in ms) of its current position displayed at the top of the first column, and the corresponding amplitude values (in μVs) for each of the waveform points. Position the vertical dashed line at any point on the screen.

Now enable the second cursor by clicking its icon **II** from the Toolbar. It will have the letter "B" at the top of it. Position it at a different point. You will see two more columns of numbers on the right side of the display. In Column B, there is the latency of the second cursor as well as the amplitude(s) for that time point for each waveform(s). The third column - Delta - displays the change in latency at the top, and the change in amplitude below for each channel, in relation to the position of the first cursor. This is a quick way to measure latency differences between two points, and the peak-to-trough amplitude differences. To the right is a sample of the columns of measurements.
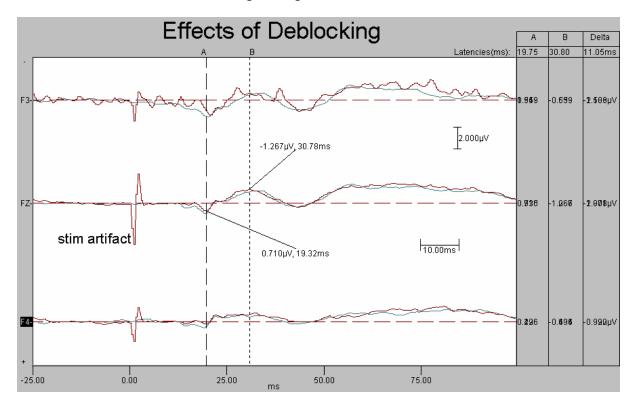
A	B	Delta
120.19	225.00	104.81ms
-0.489	0.728	1.217μV
0.337	1.121	0.784μV
1.612	1.630	0.018μV
0.485	-1.364	-1.849μV

You can change the labels from "A" and "B" by clicking the *right mouse* button on the vertical cursor line.

Name

Name Peak

OK   Cancel

You will see the Name display appear. Click the left mouse button on the text line, and enter the new cursor label. You can rename both cursors.

The Final Waveboard Image. The following display shows an example of the primary features of the Waveboard in a single image.

The numbers in the columns on the right side appear blurred because they are superimposed. (Move the waveforms to separate the numbers).

8   Appendix B - The Montage Editor

The purpose of the Montage Editor is to create and modify Linear Derivation (.ldr) and Montage (.mnt) files. Before discussing the Montage Editor, it may be helpful to present some basic information about Linear Derivation files. Montage files are discussed in more detail below.

Linear derivation files in SCAN 4.3+ allow you to perform a variety of online and offline analyses with a high degree of flexibility. All of the online analyses - plus more extensive applications - may be performed offline in the EDIT module. The purposes of the next section are to acquaint you more fully with the concept of linear derivation files, and to provide some examples of *.ldr* files that will illustrate their uses.

LDR Bipolar Montage and "Composite" Channel Derivations

Perhaps the easiest way to introduce the basic concept of linear derivation is to look at a simple linear derivation file that converts linked-ear reference recordings to a bipolar montage.

16 20

	Fp1	Fp2	F7	F8	F3	F4	T3	T4	C3	C4	T5	T6	P3	P4	O1	O2	Fz	Cz	Pz	Oz
Fp1-F7	1.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F7-T3	0.0	0.0	1.0	0.0	0.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T3-T5	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T5-O1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0
Fp1-F3	1.0	0.0	0.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F3-C3	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C3-P3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
P3-O1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0
Fp2-F8	0.0	1.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F8-T4	0.0	0.0	0.0	1.0	0.0	0.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T4-T6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T6-O2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	-1.0	0.0	0.0	0.0	0.0
Fp2-F4	0.0	1.0	0.0	0.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F4-C4	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C4-P4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.0	0.0
P4-O2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	-1.0	0.0	0.0	0.0	0.0

Linear derivation files will have *.ldr* extensions, and may be created, reviewed and edited with the Montage Editor, or a standard text editor, such as Notepad. In a text editor, the first line will consist of 2 numbers: "16 20" in this example. This indicates that you will be creating 16 new channels from the existing 20 channels that are recorded. This is the essence of the linear derivation approach - *to create new data channels from weighted linear combinations of existing channels*.

Let's say that you are recording 20 channels using the standard 10-20 montage placements, and that you are using a linked-ears reference for each. The next line in the .ldr text file (when viewed with a text editor) contains electrode labels for the standard 10-20 system. These do not have to be in any particular order, but they do have to agree in number and label with the information contained in the corresponding setup file that was created in ACQUIRE. The first column contains the labels of the *new* channels that you are creating. The labels are created manually.

The numbers in the cells are *multipliers,* or scaling factors*,* for the data in the original file

that you are acquiring, or have already acquired. The original data points for each channel are multiplied by the corresponding *multiplier*, and the data in the newly derived channels are simply the *linear sums* of these "weighted" values. For a simple conversion to a bipolar channel, for example, Fp1-F7, the data points from the Fp1 channel are multiplied by "1", the data points for the F7 channel are multiplied by "-1", and data points from all other channels are multiplied by "0". All of the data values for a single time point are then summed linearly across channels, and the result is the difference between Fp1-linked ears and F7-linked ears, or Fp1-F7. The remainder of the bipolar conversion is then simply a matter of placing the 1 and -1 multipliers in the appropriate columns. (A simple way to do this is described below).

Another example of a simple linear derivation is to create "composite" regional channels, that is, a single channel that is derived from several channels in one region. Using the same recording channels as above, we might create 4 derived channels representing the Front, Back, Left and Right regions, as follows:

```
4 20
         Fp1 Fp2  F7   F8   F3   F4   T3   T4   C3   C4   T5   T6   P3   P4   O1   O2   Fz   Cz   Pz   Oz
Front   .125 .125 .125 .125 .125 .125 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0 .125 .125 0.0  0.0
Back    0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0 .125 .125 .125 .125 .125 .125 0.0  0.0 .125 .125
Left    .125 0.0 .125 0.0 .125 0.0 .125 0.0 .125 0.0 .125 0.0 .125 0.0 .125 0.0  0.0  0.0  0.0  0.0
Right   0.0 .125 0.0 .125 0.0 .125 0.0 .125 0.0 .125 0.0 .125 0.0 .125 0.0 .125 0.0  0.0  0.0  0.0
```

Notice that the first line was changed to indicate that 4 channels will be created (seen in the text editor, not in the Montage Editor). Eight channels were selected for each of the Front, Back, Left and Right derived "composite" channels. The multiplier is therefore 1/8, or .125. You can use "1s" for the multipliers if you wish - fractions were used in order to maintain the same microvolt scaling as in the original recording. Using "1s" as the multipliers would increase the derived channel amplitudes by a factor of 8.

For more information about Linear Derivation, please refer to the Linear Derivation, Spatial SVD, and the Spatial Filter transforms described in the EDIT manual. With this brief introduction to the basic premise of the LDR files, we will move on to discuss ways to create and edit them, as well as Montage files.
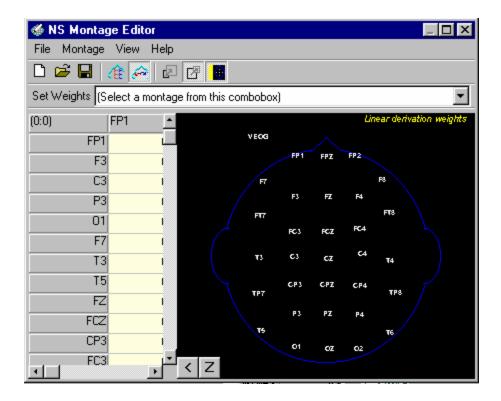
8.1   The Montage Editor

The Montage Editor provides a useful means for creating and editing Montage (.mnt) and

Linear Derivation (.ldr) files. It may be accessed most easily from the Toolbar icon in EDIT and ACQUIRE, and also from several of the Transforms in EDIT, including Linear Derivation, Ocular Artifact Reduction, Coherence, and Spatial Filter. Any Transform that pertains to LDR or MNT files that shows an Edit.. button will access the Montage Editor.

Let's begin by starting the EDIT program and retrieving the *P300.eeg* file from the *\SCAN DATA\Demo Data\P300s* folder. Click the Montage Editor icon from the Toolbar.

Overview of the Montage Editor. Let's look superficially at the basic sections and functions of the Montage Editor. Note first that the electrodes are arranged on the Head Contour display in the same positions as in the data file that was retrieved. The electrode

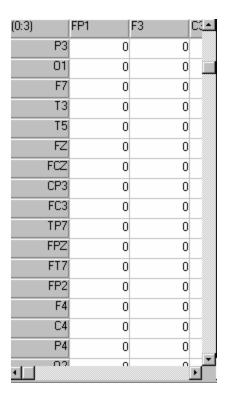labels and position information is retrieved automatically when you open the Montage Editor.

The Main Menu bar `File  Montage  View  Help` in the Montage Editor has four options: File, Montage, View, and Help. Nearly all of the operations tha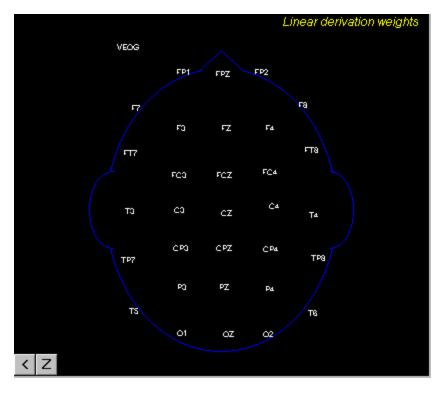t are listed in these pull-down menus may be accessed more easily from the Toolbar icons , and the features will be described in that section below. If you prefer keyboard controls rather than the mouse, you may access the Main Menu bar options using the standard conventions. For example, press alt-f from the keyboard to access the File pull-down menu, then press the capitalized letter to select one of the options.

Set Weights - The next section on the display, labeled as "Set Weights", provides a list of LDR or MNT files that has been created and stored in the last directory that was accessed. Click the pull-down menu at the far right side of the field to see the list. Whether you see MNT or LDR files depends on which type of file you have chosen to edit. This is typically done using the Toolbar icons, as discussed below.

The section on the left hand side of the screen displays a text matrix of the LDR or MNT file.

(0:3)	FP1	F3	C3
P3	0	0	
01	0	0	
F7	0	0	
T3	0	0	
T5	0	0	
FZ	0	0	
FCZ	0	0	
CP3	0	0	
FC3	0	0	
TP7	0	0	
FPZ	0	0	
FT7	0	0	
FP2	0	0	
F4	0	0	
C4	0	0	
P4	0	0	
02	0	0	

The large display area on the right hand side of the screen displays the Head Contour with the current montage, using the electrode label and position information from whatever file you have retrieved.
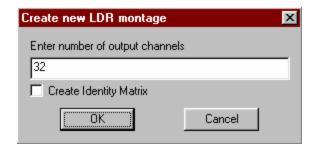
Toolbar icons - Now, let's look at the basic functions accessed from the Toolbar icons.

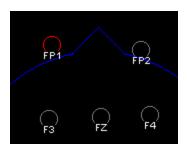Notice also there are two additional icons in the lower corner of the Head Contour display area.

Create New Montage - This option will remove any current contents from the displayed MNT or LDR file, allowing you to create a new montage from scratch. This will not affect the saved MNT or LDR file (as long as you don't overwrite the existing file).

When you click the icon, you will see the following display.

You will be asked to enter a number for the number of output channels that you want to create. You will also be asked if you wish to Create an Identity Matrix. If you enable this option, an LDR file will be created that has 1's going down the diagonal, with all other cells set to 0. The output file will be the same as the original file (the number of input and output channels must be the same). This is useful in cases where, for example, you want to create a new file that has fewer channels. Just delete the channels that you don't want from the y-axis list - the 1's are already in place along the diagonal (see below for instructions on deleting output channels). If you elect to create an identity matrix, you will see loops appearing for each of the output channels on the Head Contour display.
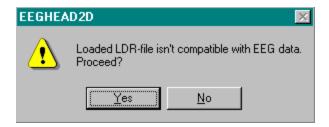
Note: if you enable the Create an Identity Matrix option, it will remain enabled the next time you enter the Montage Editor.

Open Montage File - This option allows you to open an existing MNT or LDR file. If you have selected the Edit Bipolar Montage icon , the Open File list will show MNT files. If you have selected the Edit LDR File icon , you will see a list of LDR files.

Note:The Montage Editor program is accessed after you have retrieved a data file. If

you want to retrieve an LDR file that does not match the data file, select the file using Open Montage File. You will then see the following message.
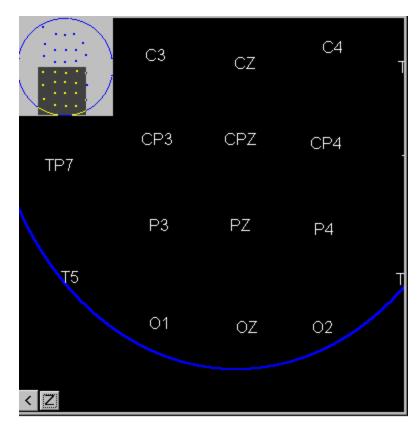
Click Yes to continue, and the new LDR file will be retrieved.

Save Montage File ⊟ - This option allows you to save a MNT or LDR file. A Save File utility window will appear, allowing you to enter a file name and path (the .MNT or .LDR extension will be added automatically).

Edit Bipolar Montage - This option allows you to edit a bipolar montage. An example of this process is presented below.

Edit LDR File - This option allows you to edit an LDR file. An example of this process is presented below.

Zoom In - This option allows you to zoom in on the Head Contour display. When

selected, you will see a diagram in the upper left hand corner of the display, with a darker shaded region. Using the left mouse button, grab and drag the shaded region to a new location. That location will be shown in the zoomed display. This is particularly useful when you are working with files that have large numbers of electrodes. *Note: Double-clicking the left mouse button in an area will also zoom into that area.*

Zoom Out - The Zoom Out icon will return the display to the original size (see Zoom In above).

Show Head Contour - This button toggles the Head Contour display on and off.

Full Size Display - Clicking this option will enlarge the electrode display to the full screen size, and will hide the text portion of the display. Clicking it again will return to the split display.
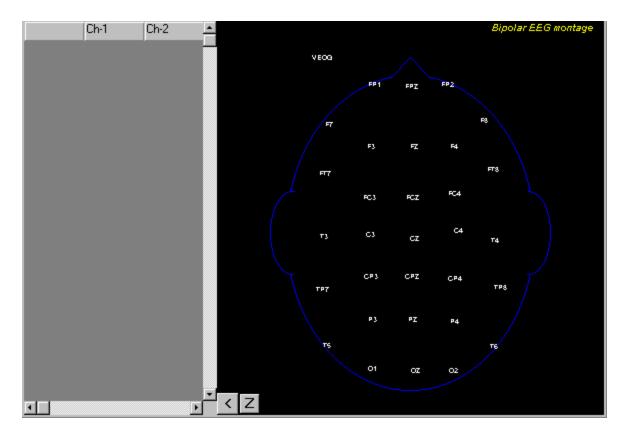
Zoom Display - The Zoom Display button performs the same function as the Zoom In and Zoom Out icons.

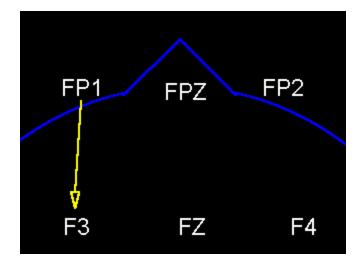## 8.2 Creating and Editing a Bipolar Montage

The following steps illustrate the procedure for creating and editing a bipolar montage. The result of these operations will be a bipolar MNT or LDR file. MNT files are used only with the Coherence transform. The LDR file can be used any time you want to apply the Linear Derivation Transform.

The first step is to retrieve a data file for which you would like to create a bipolar montage. For this demonstration, retrieve the *P300.eeg* file in EDIT. Then click the Montage Editor icon . Click the Edit Bipolar Montage icon , if needed. You will see a display similar to the following:
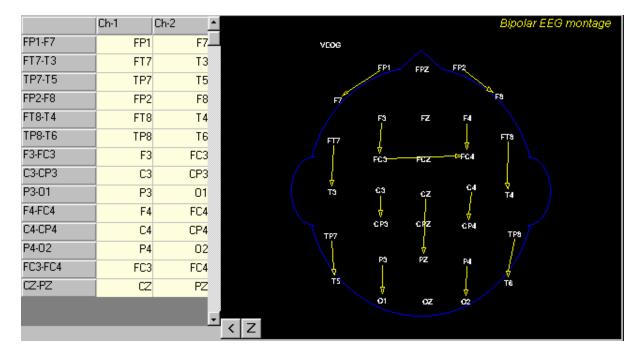
To create a bipolar channel from the original linked ears recording, the basic process is a subtraction of one monopolar channel from another monopolar channel. In other words, to create the bipolar FP1-F3 channel, the program subtracts F3-A1/A2 from FP1-A1/A2. The user interface for this instruction is very simple. Click and hold the left mouse button on FP1, and drag the resulting arrow to F3, and release the mouse button. The arrow will attach itself to F3.

The creation of the new channel will be listed in the text display on the left hand side of the screen.

	Ch-1	Ch-2
FP1-F3	FP1	F3

Now go back and create as many bipolar channels as desired. Your final bipolar montage might appear similar to the following.

As you draw the lines for the bipolar montage, you will see the channels being added to the text matrix on the left side of the screen. Continue creating the desired bipolar channels.

Now, let's say you mistakenly created a channel, and you would like to delete it. In the above example, let's delete the FC3-FC4 channel. Position the mouse on the FC3-FC4 label, and click the right mouse button. You will see a small option window with the Delete Channel option.

Select it and you will see a window confirming your desire to delete the channel. Click Yes to delete it.

If you want to start over from scratch, select the Create New Montage option under File.

To save the bipolar montage, click the Save Montage File icon 💾. A Save As utility window will appear allowing you to enter a file name (e.g., P3-bipolar). Click the pull-down arrow at the end of the "Files of type", and select whether you want to save the file as an .MNT or .LDR file.

```
Bipolar Montage Files (*.mnt)            ▼
Bipolar Montage Files (*.mnt)
Linear Derivation Files (*.ldr)
```
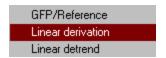
📄 **Note**

If you are creating a bipolar montage for display purposes, or any other purpose aside from selecting channels for the Coherence transform, save the file as an LDR file - not an MNT file. The LDR file is used in most instances.

Then enter a file name and path (the .MNT or .LDR extension will be added automatically). The next time you enter the Montage Editor, and click the Edit Bipolar Montage icon, you will see the MNT file listed in the Montage pull-down display.

```
Montage │P3-bipolar.mnt                    ▼
        │ visbipolar.mnt
FP1-F3  │ P3-bipolar.mnt
```

The bipolar montage that you have created can be applied in the calculation of Coherence. An option on the Coherence screen allows you to select an .MNT file. Coherence will be calculated for those channels only. (If you want to try this with the *P300.eeg* file, you must first perform a Spline Fit where you force the number of points to be a power of 2. To see the results in the final Coherence display you will need to set one of the bipolar electrodes as the Coherence Reference using the *right mouse* button. See the Coherence description in the EDIT manual for more details).
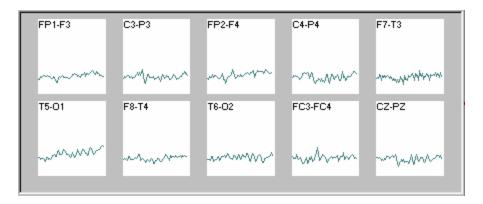
The *bipolar LDR* file can be applied anytime the Linear Derivation option is available on the Transform or Script options list. For example, save the bipolar montage created above *using the LDR file type*, and exit the Montage Editor. With the *P300.eeg* file still displayed in EDIT, select Linear Derivation from the Transform menu.

```
GFP/Reference
Linear derivation
Linear detrend
```

When the Linear Derivation display appears, use the ⟩⟩ button to retrieve the LDR file.

LDR File

c:\scan4.2\demo\p300bipolar.ldr   >>

Edit..
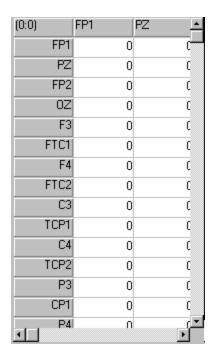
Click the [OK] button to continue. The LDR file will be applied and you will see the derived bipolar channels.

| FP1-F3 | C3-P3 | FP2-F4 | C4-P4 | F7-T3 |
| T5-O1 | F8-T4 | T6-O2 | FC3-FC4 | CZ-PZ |

For those familiar with earlier versions of SCAN software, the Linear Derivation feature is now used to display your data as bipolar channels, rather than having separate bipolar options.
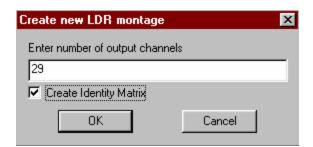
8.3   Creating and Editing an LDR File

This section will demonstrate how to create and edit Linear Derivation files. Perhaps the simplest illustration of an LDR file is one used to create a new data file that has fewer channels than the original file. To illustrate this, retrieve the *closed.cnt* file from the *\Scan Data\Demo Data* directory, and click the Montage Editor icon from the Toolbar. In the Montage Editor, click the Edit LDR Montage icon , if needed. The Head Contour display will have no links, and the LDR text display, on the left, will have all zeros. Let's take a closer look at the LDR text display. Unclick the Head Contour icon .

(0:0)	FP1	PZ	
FP1	0	(	
PZ	0	(	
FP2	0	(	
OZ	0	(	
F3	0	(	
FTC1	0	(	
F4	0	(	
FTC2	0	(	
C3	0	(	
TCP1	0	(	
C4	0	(	
TCP2	0	(	
P3	0	(	
CP1	0	(	
P4	0		

In the upper left hand corner of the matrix you will see (0:0). This is the cell identifier. Each cell in the matrix may be identified by its row and column number (row, col). The numbers correspond to whatever cell is in the top left corner of the section of the matrix being displayed.
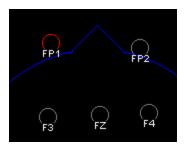
All of the electrodes are listed across the top of the matrix, as well as down the left side of the matrix. The arrows and sliding buttons will let you look through the entire matrix. The channels across the top are the existing channels. The channels going down the left side are the new channels being created. The numbers within the matrix are the LDR weights. Each data point for each existing channel is multiplied by the respective weight, and the weighted data points are then summed linearly and written to a new channel in a new data file.

In the simplest example, let's create a new data file that contains only the four midline channels. The easiest way to do that is to create an Identity Matrix, and then delete the unwanted channels. Click the Create New Montage icon ⬜, and enable the Create Identity Matrix option.

Create new LDR montage   ✕

Enter number of output channels

`29`

☑ Create Identity Matrix

[OK]   [Cancel]

Click OK, and you will see a text matrix that has the same output files as input files, with 1's running down the diagonal. Notice that the Head Contour display will show loops at each electrode (click the Show Head Contour icon 🔵, if needed, to see the display).

This is to signify that the electrode is linked to itself.

The Identity Matrix could have been created manually by creating an output file with 4 channels, and then clicking on the labels in the Head Contour display. Clicking a label once with the left mouse will cause the loop to appear, and simultaneously will write a 1 in the corresponding cell. It is also possible to enter the 1 in the desired cell in the text matrix. That will cause the loop to appear on the Head Contour display at the corresponding electrode site.

If saved at this point, the LDR file would create an output file that was identical to the input file. Now go down the column of electrodes labels on the left, and do a combination Ctrl + Left Mouse click on all the ones you want to delete (they will all be highlighted). Then click the right mouse button on one of the highlighted labels, and click the
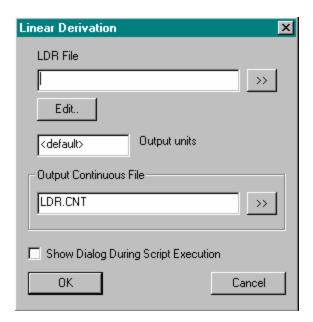
Delete selected channel(s)   option to delete the channels. In this example, it would have been slightly easier to have highlighted all the channels at once (by highlighting the top label, then using the Shift + Left Mouse click on the bottom label), and then deselecting the 4 channels to be retained.

Conceptually, we want to preserve the original data from a given channel. The weight for that channel should therefore be 1, and the weights for all the other channels should be 0. When summed linearly, the result will be no change to the original data. The final matrix should appear as follows (shown in part).
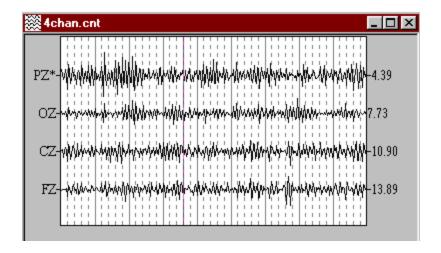
(0:0)	FP1	PZ	FP2	OZ	F3
PZ	0	1	0	0	
OZ	0	0	0	1	
CZ	0	0	0	0	
FZ	0	0	0	0	

Click the Save Montage File icon 💾 , enter a file name (the LDR extension will be added automatically), and click Save. Then close the Montage Editor.

Back in EDIT, make sure the *closed.cnt* file has the focus, then select Linear Derivation from the list of Transforms. Use the Browse button >> to select the LDR file that you just created. Enter a file name for the Output CNT file, and click OK.

You will then see the Linear Derivation progress bar track the execution of the transform. Since this is a CNT file, you will need to retrieve it. The resulting file will contain the 4 channels.
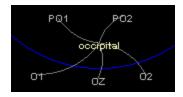

8.4   Creating New Channels

In some instances you might wish to create an entirely new channel based upon some combination of existing channels. For example, you could create a linear combination of the occipital channels in the *VEP.avg* demo file. Retrieve the *VEP.avg* file, and go into the Montage Editor. Click the right mouse button anywhere on the list of output channel labels. Select Insert channel , and enter a channel name, such as "occipital". You will see the new label on the column of output labels.

You will also see a cursor and a tooltip box instructing you to place the new label as desired. Position it in the posterior area of the Head Contour display. If you then apply the LDR file to create a new data file, retrieve that file, and enter the Montage Editor, you will see the electrode label.
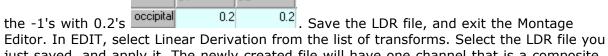

Now, delete all of the other channels in the output label column, leaving only the "occipital" channel. That row will have all zeros. Create links from each of the 5 surrounding electrodes to the new "occipital" one.
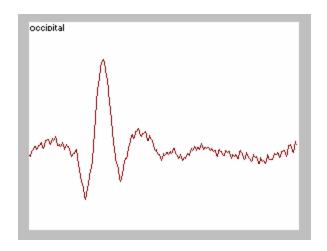

This will place "-1s" in the PO1, PO2, O1, OZ and O2 columns. In the text area, replace the -1's with 0.2's . Save the LDR file, and exit the Montage Editor. In EDIT, select Linear Derivation from the list of transforms. Select the LDR file you just saved, and apply it. The newly created file will have one channel that is a composite of the 5 channels.

8.5   More Complex LDR Files

So far, we have been dealing with simple LDR files that can be created in the Montage Editor. In practice, you may be using more complex LDR files that are created as output files from some of the Transforms in EDIT, such as the Ocular Artifact Reduction, Spatial SVD, Spatial Filter, and so forth. Let's take a look at an LDR file created from the Ocular Artifact Reduction transform.

Below is a section from the lower right hand part of the output LDR file created when the *P300.eeg* file underwent Ocular Artifact Reduction.

```
0.00000     0.00000     0.00000     0.00000    -0.08171
0.00000     0.00000     0.00000     0.00000    -0.08478
1.00000     0.00000     0.00000     0.00000    -0.12742
0.00000     1.00000     0.00000     0.00000    -0.06659
0.00000     0.00000     1.00000     0.00000    -0.07214
0.00000     0.00000     0.00000     1.00000    -0.11770
0.00000     0.00000     0.00000     0.00000     1.00000
```

The column on the far right is from the VEOG channel. The other columns are from some of the EEG electrodes. Throughout the file, along the diagonal, are 1's. These are the cells where the existing channels intersect with the new channels to be created. If there were no numbers in the VEOG column, the LDR file would have no effect when applied. In other words, the artifact subtraction is based solely on the values in the VEOG column. These values are the linear transmission coefficients computed in the Ocular Artifact Reduction transform, and will have the highest values at the frontal channels. Note that they are all negative numbers (with the exception of the lower right hand 1.0, which is the intersection of the input and output VEOG channel).

It should therefore be apparent how the subtraction part of the artifact reduction works, when using an LDR file. For any given EEG channel, the weight is 1, so the data points for it are unchanged. The points for the VEOG channel are multiplied by the transmission coefficient (i.e., reduced proportionally to the covariance of the artifact in each channel). When summed linearly, that proportion of the amplitude at the VEOG channel is subtracted from the amplitude at the EEG channel (because it is a negative number). Since this is an LDR file, it may be applied to other files from the same subject (assuming the data were acquired under comparable conditions).

A more complex LDR file is created when you perform a Spatial SVD transform on a data file. The picture below is a section of the LDR file created when applying the Spatial SVD to the *P300.eeg* file.

	FP1	F3	C3	P3	O1
COMP1	0.43699	0.20500	0.10985	0.06828	0.02145
COMP2	-0.23946	0.00472	0.15519	0.23956	0.22382
COMP3	0.19567	-0.16845	-0.19916	0.02746	0.29918
COMP4	0.10058	0.10182	0.21074	0.22823	0.22688
COMP5	-0.10222	0.01744	0.07632	0.10142	0.13528
COMP6	-0.14268	0.13720	0.00018	-0.10605	0.24251
COMP7	0.05690	0.19437	-0.00590	-0.19876	-0.26663
COMP8	-0.00500	-0.01628	-0.09789	-0.07939	0.13721
COMP9	-0.09013	-0.09859	-0.07059	0.00165	-0.05779
COMP10	-0.07622	0.01450	0.30376	0.01816	-0.42444

As you can see, the LDR files can get fairly complex. In this example, COMP1 is the first component detected in the Principle Components Analysis, and it is the component that accounts for the largest amount of variance. If you look along the row for COMP1, you will see that some channels have relatively larger weights. These are the channels where COMP1 is most clearly distributed. The LDR is essentially preserving the activity from those channels where the component is most evident (larger weights), and minimizing the activity from those channels where the component is less evident (smaller weights). When summed linearly, the result is the clearest, single waveform depiction of COMP1. As with the Ocular Artifact Reduction LDR file above, you may apply the SVD LDR file to a different, but comparable data file.

The Montage Editor can be used to modify these LDR files. For example, you may rename, delete, or insert output channels using the right mouse button options described above. You can, of course, modify the values contained within the cells, however, we do not recommend doing so unless you have a thorough understanding of the effects it will have on your data.

9 Appendix C - Header

Structure of Data Headers

Neuroscan average (.AVG), coherence (.COH), compressed spectral array (.CSA), epoched EEG (.EEG), and continuous EEG (.CNT) files all share the same header structure. An SET setup file created in the ACQUIRE module is basically a header structure without data; the more recent AST setup files do not contain the 3.0 style headers that are in the other files. (You can export your AST file as a SET file, if needed; the AST format is proprietary, and not published).

The header consists of two parts: general, and channel-specific. The general part contains information that applies to all channels (such as digitization rate, pre-trigger interval, etc.), whereas the channel-specific part contains information which pertains to particular channels (such as electrode label, calibration factor, etc.). The size of the general part of the header is currently 900 bytes, and the size of the channel-specific part of the header is 75 bytes per channel. A C coded file called SETHEAD.H lists the full details of these header structures (may be downloaded from the www.neuroscan.com web site). Partial details of these structures are given below.

Beginning with version 4.1, a footer of varying length is appended to all data files. This contains information that is used by EDIT. Users can safely ignore this information. However, one is cautioned not to use the file size in determining the amount of waveform data contained in the file.

The information below does not include the 32 bit format as used with *SynAmps²*, which is proprietary.

A C language structure called ELECTLOC for the electrode specific part of the header is defined below (see the SETHEAD.H file for details concerning the "reserved space"):

```
/* STRUCTURE FOR INDIVIDUAL ELECTRODES        */
typedef struct
{
  char lab[10];          /* Electrode label; last byte NULL   */
  char reserved1[5];     /* reserved space                    */
  short n;               /* # observations at each electrode  */
  char reserved2[30];    /* reserved space                    */
  short baseline;        /* baseline offset in raw ad units   */
  char reserved3[10];    /* reserved space                    */
  float sensitivity;     /* channel sensitivity               */
  char reserved4[8];     /* reserved space                    */
  float calib;           /* calibration coefficient           */
} ELECTLOC;
```

The structure for the general part of the header is called SETUP, and is defined below. (For full details regarding the "reserved space", please refer to the SETHEAD.H file.)

```
/* STRUCTURE FOR GENERAL PART OF ERP HEADER */
typedef struct
{
  char        rev[12];        /* Revision string                   */
  char        type;           /* File type AVG=1, EEG=0            */
  char        id[20];         /* Patient ID                        */
  char        oper[20];       /* Operator ID                       */
  char        doctor[20];     /* Doctor ID                         */
  char        referral[20];   /* Referral ID                       */
  char        hospital[20];   /* Hospital ID                       */
  char        patient[20];    /* Subject name                      */
  short       age;            /* Subject Age                       */
  char        sex;            /* Subject Sex Male=M, Female=F      */
  char        hand;           /* Handedness Mixed=M,Rt=R,lft=L     */
  char        med[20];        /* Medications                       */
  char        category[20];   /* Category                          */
  char        state[20];      /* Subject wakefulness               */
  char        label[20];      /* Session label                     */
  char        date[10];       /* Session date string               */
  char        time[12];       /* Session time string               */
  char        reserved4[115]; /* reserved space                    */
  short       compsweeps;     /* #  sweeps                         */
  short       acceptcnt;      /* # accepted sweeps                 */
  short       rejectcnt;      /* # rejected sweeps                 */
  short       pnts;           /* # points per waveform             */
  short       nchannels;      /* # active channels                 */
  char        reserved5[3];   /* reserved space                    */
  char        variance;       /* Variance data included flag       */
  unsigned    short rate;     /* D-to-A rate (Hz)                  */
  double      scale;          /* scale factor for calibration      */
  char        reserved6[111]; /* reserved space                    */
  float       dispmin;        /* display minimum                   */
  float       dispmax;        /* display maximum                   */
  float       xmin;           /* epoch start in seconds (neg)      */
  float       xmax;           /* epoch stop in seconds             */
  char        reserved7[351]; /* reserved  space                   */
  long        NumSamples;     /* # samples in continuous file      */
  char        reserved8[18];  /* reserved space                    */
  long        EventTablePos;  /* offset to the event table         */
  float       ContinousSeconds; /* # seconds displayed per page    */
  long        ChannelOffset;  /* Block size of one SynAmps channel */
  char        AutoCorrectFlag;/* Autocorrect of DC values          */
  char        DCThreshold;    /* Auto correct of DC level          */
} SETUP;
```

A fragment of C code to read the header of a file might look like the following:

```
#include <stdio.h>
#include <stdlib.h>
#define    N_ELECT  64
#include "sethead.h"

ELECTLOC *channel[N_ELECT];
SETUP erp;       /* variable to contain header info    */
FILE *fp;        /* file pointer                       */
```

```
        short i;

        /* open file */
        fp = fopen("test.eeg", "rb");

        /* read general part of header */
        fread(&erp, sizeof(SETUP), 1, fp);
        /* read channel-specific part of header */
        for (i=0;i<erp.nchannels;i++)
        {
                channel[i]=(ELECTLOC*) malloc(sizeof(ELECTLOC));
                fread(channel[i],sizeof(ELECTLOC), 1, fp);
        }
```

At this point, the erp structure contains all of the header information. The procedure for reading the header would be the same for .CNT, .AVG, .EEG, .COH, and .SET files.

Actual data begins immediately after the header for .EEG, .AVG, and .CNT files. Thus, the offset to the beginning of data is 900 (=sizeof(SETUP)) + 75 (=sizeof(ELECTLOC)) * erp.nchannels bytes.

.AVG Data. Average data is stored as 4-byte floats in vectored format for each channel. Each channel has a 5-byte header that is no longer used. Thus, after the main file header, there is an unused 5-byte header followed by erp.pnts of 4-byte floating point numbers for the first channel; then a 5-byte header for channel two followed by erp.pnts*sizeof(float) bytes, etc. Therefore, the total number of bytes after the main header is: erp.nchannels * (5 + erp.pnts*sizeof(float)). To scale a data point to microvolts, multiply by the channel-specific calibration factor (i.e., for electrode j: channel[j]->calib) and divide by the number of sweeps in the average (i.e., channel[j]->n);

.COH data. Coherence data is the result of a pair-wise comparison between electrodes. Immediately following the data header is a comparison directory. This directory consists of a square matrix of offset numbers that point to the location of the coherency spectrum. It appears immediately after the data header. Here is a code fragment to read in the coherence directory:

```
        // These declarations should appear at the
        // the top of file
        long ** CoherenceDirectory;
        short int i;
        short int size;

        // Allocate memory and read - be sure to add protection

        // for memory and read errors in your code!
        size=sizeof(long)*erp.nchannels;
        for( i=0;i<erp.nchannels;i++)
        {
                CoherenceDirectory[i]=(long)malloc(size);
```

```
            fread(CoherenceDirectory[i], size, 1, fp);
      }
```

To access the coherency spectrum use the following code:

```
      // declaration should appear at the top of your code
      // row and column defines the electrode pair
      short row;       //first electrode
      short col;       //second electrode
      float *real;     //holds real component
      float *imag;     //holds imaginary component


      // Allocate memory
      real=(float*)malloc(sizeof(float)*erp.pnts);
      imag=(float*)malloc(sizeof(float)*erp.pnts);

      // Note - only non zero Directories are valid
      // Main diagonal comparisons (row=col) are not valid
      // This example selects a comparison of electrode # 1 with #
2
      row = 1;
      col = 2;

      // Note - the extra 8 bytes added to the offset below is
used
      // to skip over a small unused header
      fseek(fp, CoherenenceDirectory[row][col]+8,SEEK_SET);

      // Read in real array
      fread(real, sizeof(float)*erp.pnts, 1, fp);

      // Read in imaginary array
      fread(imag, sizeof(float)*erp.pnts, 1, fp);

      // To compute the coherence spectrum use the following code
      // Note - results are placed in real array
      for (i=0;i<erp.pnts;i++)


      {
            real[i]=real[i]*real[i]+imag[i]*imag[i];
      }

      // To compute the coherence phase use the following code
      for (i=0;i<erp.pnts;i++)
      {
            real[i]=atan2(imag[i]/real[i]);
      }
```

.EEG Data. There are erp.compsweeps sweeps of data in an .EEG file. Each sweep of data consists of a sweep header followed by the EEG data. The sweep header could be characterized by the following structure:

```
typedef struct
{
    char  accept;           /* accept byte          */
    short ttype;            /* trial type           */
    short correct;          /* accuracy             */
    float rt;               /* reaction time        */
    short response;         /* response type        */
    short reserved;         /* not used             */
} SWEEP_HEAD;
```

After the sweep header, data is stored as 2-byte integers in multiplexed format; i.e., letting J=erp.nchannels and I=erp.pnts, the data points are as follows: data point #1 for channel #1, data point #1 for channel #2, . . ., data point #1 for channel #J; . . . ; data point #I for channel #1, data point #I for channel #2, . . ., data point #I for channel #J.

To scale a data point to microvolts for channel j, first subtract off the amplifier DC offset (if any) found in the variable channel[j]->baseline. Then multiply by the sensitivity (channel[j]- sensitivity) times the channel-specific scale factor (channel[j]->calib) divided by 204.8.

.CNT. Data are stored as 2-byte (short) integers after the main header in continuous multiplexed format. Thus, the first data scan consists of erp.nchannels points (= 2*erp.nchannels bytes). The second data scan likewise contains erp.nchannels points (= 2*erp.nchannels bytes), etc., until the beginning of the event table is reached. (NOTE: With old ACQUIRE versions prior to 4.0 a different continuous format was used if you are using *SynAmps* with your SCAN system. Please see below for a description of the *SynAmps* continuous file format).

Scaling of .CNT data to microvolts is identical to scaling of .EEG data — see above.

Following this data is the event table. The event table begins at a file offset that is given (in bytes) by the erp.EventTablePos variable. The following C definitions are used for the event table:

These are some preliminary definitions:

```
#define BYTE char
#define UBYTE unsigned char
#define WORD short
#define UWORD unsigned short

typedef enum
{
    TEEG_EVENT_TAB1=1,        //Event table tag type
```

```
        TEEG_EVENT_TAB2=2
}
TEEG_TYPE;
```

This structure describes a tag type 0 in a continuous file:

```
typedef struct
{
        TEEG_TYPE Teeg;
        long Size;
    union

        {
            void *Ptr;    // Memory pointer
            long Offset;  // Relative file position
                          // 0 Means the data start immediately
                          // >0 Means the data starts at a
                          // relative offset
                          // from current position at the end
                          // of the tag
        };
} TEEG;
```

This structure describes an event type 1 in a continuous file:

```
typedef struct
{
  UWORD StimType; //range  0-65535
  UBYTE KeyBoard; //range  0-11 corresponding to function keys+1
  UBYTE KeyPad:4; //range  0-15  bit coded response pad
  UBYTE Accept:4; //values 0xd=Accept 0xc=Reject
  long Offset;    //file offset of event
} EVENT1;
```

This structure describes an event type 2 in a continuous file (it contains additional information regarding subject performance in a behavioral task):

```
typedef struct
{
  EVENT1  Event1;
  WORD    Type;
  WORD    Code;
  float   Latency;
  BYTE    EpochEvent;
  BYTE    Accept;
  BYTE    Accuracy;
} EVENT2;
```

At the beginning of the event table is a TEEG ("Tagged EEG") structure that is defined in the SETHEAD.H file. Following this structure is the event table proper. Currently, there are two types of event tables — the first with a minimum of event information, and the second with additional behavioral information. The Teeg variable in the TEEG structure

indicates the type of event table.

Version 4.0 and earlier:
A raw data file (that has not been merged with a behavioral data file) is always of type 1. Depending of the event table type, the structure for each event is either EVENT1 or EVENT2.

Version 4.1 and later:
In previous versions, event tables contained Type 1 events until the file was merged with behavioral data from STIM. Beginning with 4.1, ALL events are of Type 2 regardless of whether these files have been merged with behavioral data.

The number of events in the event table can be calculated by dividing the size variable in the TEEG structure by sizeof(EVENT1) (or sizeof(EVENT2), as the case may be). The events (of structure EVENT1 or EVENT2) immediately follow the TEEG structure.

.CNT (SynAmps). The following applies to files created with ACQUIRE versions prior to 4.0. For files created with ACQUIRE version 4.1 and later see above (excluding *SynAmps*[2]).

When using *SynAmps* for continuous files, data are sent in a blocked rather than multiplexed format. Data are sent from the *SynAmps* in the following format:

Block 1

$$X_{1,1} \quad X_{1,2} \quad X_{1,3} . . . . X_{1,N}$$
$$X_{2,1} \quad X_{2,2} \quad X_{2,3} . . . . X_{2,N}$$
$$X_{3,1} \quad X_{2,2} \quad X_{2,3} . . . . X_{3,N}$$
$$X_{M,1} \quad X_{M,2} \quad X_{M,3} . . . . X_{M,N}$$

Block 2

$$X_{1,1} \quad X_{1,2} \quad X_{1,3} . . . . X_{1,N}$$
$$X_{2,1} \quad X_{2,2} \quad X_{2,3} . . . . X_{2,N}$$
$$X_{3,1} \quad X_{2,2} \quad X_{2,3} . . . . X_{3,N}$$
$$X_{M,1} \quad X_{M,2} \quad X_{M,3} . . . . X_{M,N}$$

Where X is a 16 bit integer, N refers to a data point and M the number of channels. Data are typically sent in blocks of N data points channel-by-channel. The size in bytes of one channel block is stored `erp.ChannelOffset` located in the SETUP structure (see above). To read these files you should allocate a buffer the size of `erp.ChannelOffset` and read each bock channel-by-channel. Since data is recorded continuously, you will need to concatenate each channel block into a continuous stream keeping track of channel alignment. Events are stored in an identical manner to the 100 and 330kHz modules (see above).

3DSpace .TRI file format
Below you will find the description of the TRI file format as used in the 3D Space program. The TRI file contains the description of a triangulated head surface. The description uses C/C++ variables to describe elements.

Each file starts with a header, which looks like this:

Long ID (should be 100003, or 100004. (or 100002))
Short Filetype (=2 for triangle file)
short revision
float electrodethickness
float electrodediameter

BYTE reserved[4080]

Then the facet and vertex information follows:
short number_of_facets
short number_of_vertices

Then for **all** the facets give by number_of_facets:

the centroid (centre of facet) x,y,z coordinates (unit vector) and it's length are writen as four **floats**.

Then follows the facet vertex coordinates for **all** vertices (given by number_of_vertices):

four **floats**: x, y, z, (normalized) and it's length

Then for **all** the facets (give by number_of_facets):

the three vertices that belong to this facet. These are three **shorts**, and are index values to the proper vertice as listed above (largest number is given by number_of_vertices).

Then the number of electrodes follows:

(**unsigned short**) number_of_electrodes

Then for **all** electrodes (given by number_of_electrodes):

char label[10] (label of electrode, max 9 chars + \0)
short key (normally = 'e' for electrode)
float x, y,z (position)
unsigned short ix (electrode index number)

Frequency domain EEG file format

For each sweep of data, there is a sweep header that is identical to that described on Page 6 above.

At this point there is a difference. After the sweep header, the frequency domain data for each sweep has the following format:

for each channel (erp.nchannels):

for each frequency bin (erp.pnts):

real value of the FFT stored as a 4-byte float;

for each frequency bin (erp.pnts):

imaginary value of the FFT stored as a 4-byte float;

The data have been scaled to microvolts prior to the FFT, and it is these results which are stored to the file.

Information for Scan 4.3 and More Recent Data Files

Reading 32 bit CNT files. There is no way to determine from a data file if it is a 16 or 32

bit file; you must know this a priori.

The header in 4.3+ data files is the same as in earlier versions: 900 byte setup followed by 75 bytes per channel. The end of the data is encoded in the NextFile parameter.

Number of points can be computed as follows:

nEndOfData = Setup.NextFile
HeaderSize = 900 + 75 * nChans
nPoints = (nEndOfData-HeaderSize)/(nChannels*4)

Note: the 4 represents 4 bytes per sample (32 bit).

Data are in multiplexed format (same as before).

UvperLSB is computed as:

UvperLSB = elect_tab[i].sensitivity/204.8f;

Note: the *SynAmps*[2] does not have programmable gain like the *SynAmps*. It will always be either .0298023 μV/bit for DC recordings, and .00014827 μV/Bit for AC recordings.

There are no calibration factors to apply for *SynAmps*[2] data. Calibration values are applied BEFORE the data are stored.

Additional files are available to help construct code for reading the 32bit structure. Contact Technical Support for additional information.