SCAN 4.3 - Vol. II

EDIT4.3

Offline Analysis of Acquired Data

Document number 2203, Revision D

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*These transforms require Tool Box 2003.

*These transforms require add-on software components.

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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 online/offline EKG, BKG 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
- ☐ Relative power computations
- ☐ 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

This manual is divided into two sections. The first section will present a series of tutorials that will guide you through some common types of post-acquisition processing. These tutorials correspond approximately to the setup tutorials described in the ACQUIRE manual. Data sets have been collected for some of these examples and will be used to illustrate the capabilities of EDIT. The second half of the manual - *Operating EDIT* - will describe in detail each of the commands and features of EDIT.

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Post-acquisition processing examples

This section illustrates the use of EDIT with previously acquired data sets. These data were acquired using approximations of the setup files generated in the ACQUIRE manual and will be presented in a tutorial format. Explanation of individual commands will be brief. Please refer to the *Operating EDIT* section below for a complete description of all features of this module. The following example data sets will be processed:

- ☐ An online average - Pattern-shift VEP
- ☐ Single-sweep processing - Auditory P300
- ☐ Epoching a continuous file - Visual sustained attention task
- ☐ Spectral analysis - A continuous EEG recording
- ☐ 2D and 3D Mapping in EDIT
- ☐ Script files in EDIT

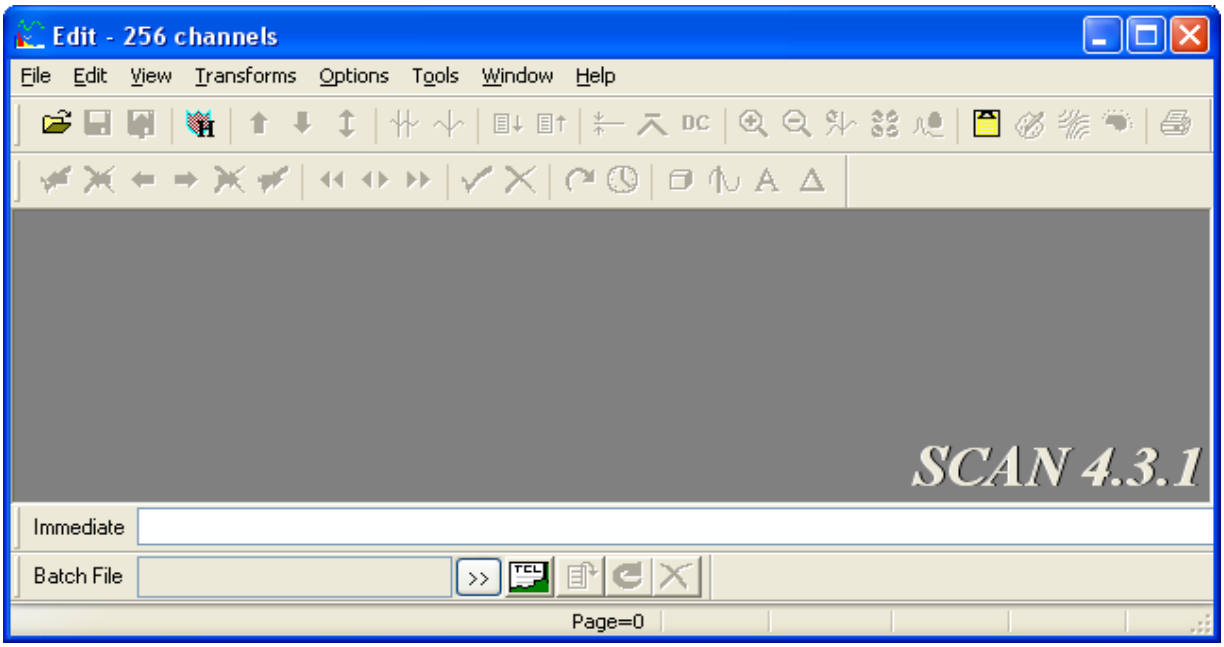
Online average - Pattern-shift VEP

This section illustrates some of the processing steps that can be performed on averaged (AVG) files with the EDIT module. A 30 channel recording to a reversing checkerboard pattern will be used as an example data set.

The visual evoked potential (VEP) to a checkerboard-pattern shift is one of the most widely employed neurophysiological measures. A checkerboard-pattern stimulus consist of a series of black and white checks that reverse their position at a specified rate. It is a popular stimulus because it generates a large and clearly defined series of responses at specific electrode sites. The most prominent responses are a negative peak at 70 ms (N70) and a positive peak at 100 ms (P100). Since the initial demonstration of delayed responses of these components in patients with multiple sclerosis (Halliday, McDonald, Mushin, 1973), the test has seen wide spread clinical application in neurology and ophthalmology.

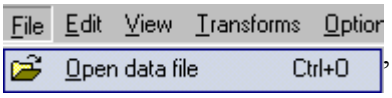
Click the EDIT icon From the Program Launcher (not present with Windows NT).

You will see the main screen in EDIT appear.



Then follow these steps to retrieve the VEP data file:

Step 1 - Loading a data file. Click on the File\Open data file option



, or, click the Open data file icon . A standard Open File utility will appear. At the bottom of the screen is the "Files of type" line. Click the down arrow and select the Neuroscan Average File (*.avg) type. Go to the Scan4.3\Demo\Veps folder, and retrieve the Vep.avg file. If the lines appear flat, click the up arrow a few times to increase the display gain, or use the autoscale icon to scale the waveforms according to the largest and smallest values on the display. You should then see the VEP average waveforms. If you are used to seeing positive voltage up (or down), click the polarity invert icon to invert the waveforms, if needed. The colors in your file may be very different to those shown below. These are controlled by the options on the General tab, under *Options* on the Main Menu bar, then Multiple Window Settings (described in more detail below).

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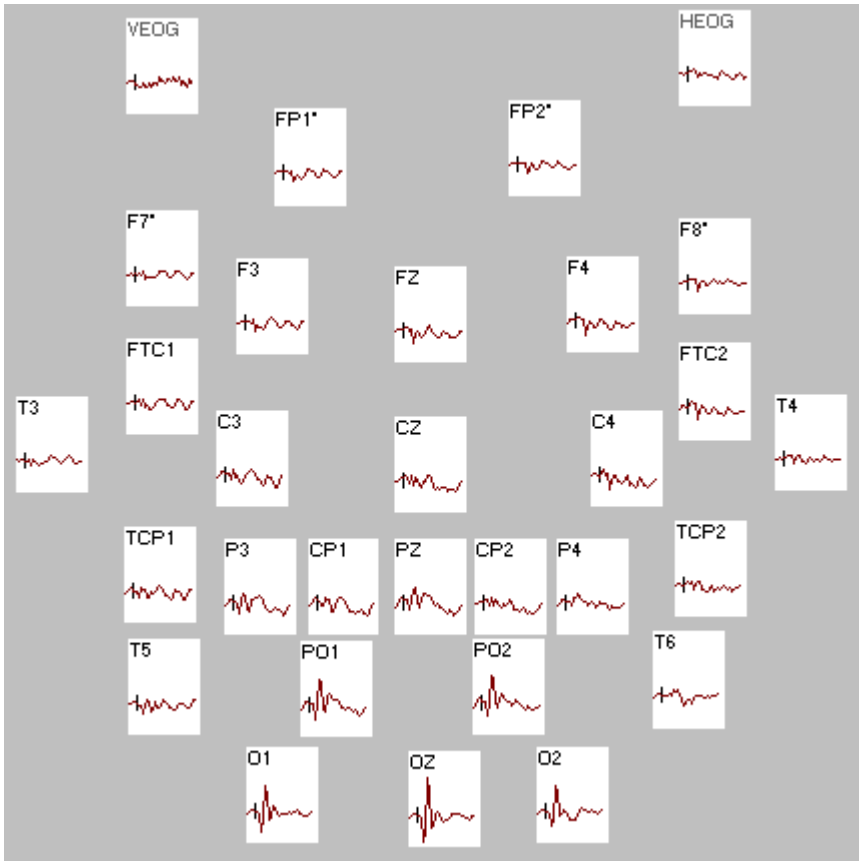
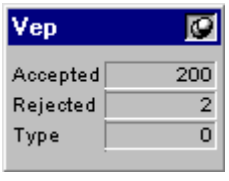
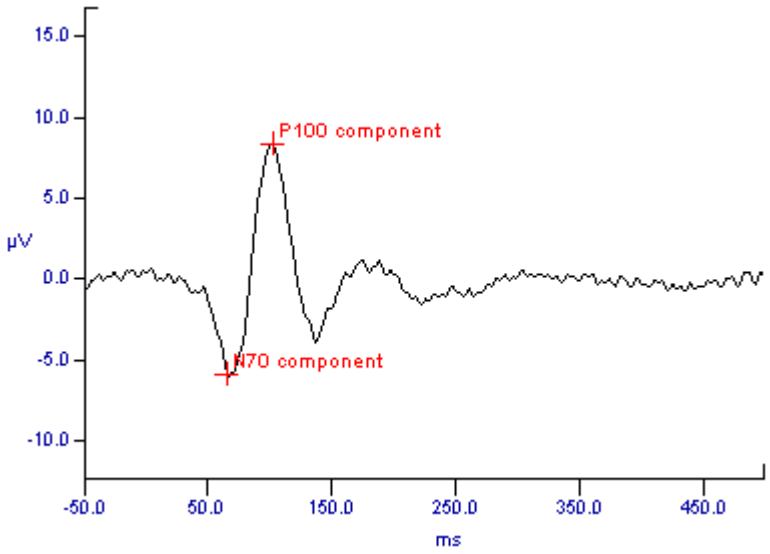


This average was collected from a normal 26 year-old male with 20/20 vision. Checkerboard reversal occurred at a rate of 1 per second. The most noticeable feature of this recording is the prominent response at the occipital leads O1, O2, OZ, PO1 and PO2. This is the VEP generated to the reversing pattern. Note there is also a small Status box, that contains information about how many sweeps were accepted and rejected (the Type field is explained in the *Operating EDIT* section, and is not relevant for this demonstration).



Next, double-click on the channel labeled Oz**.** This will "Zoom in" to this channel and display the waveform shown below. AutoScale the display ↕, if needed.

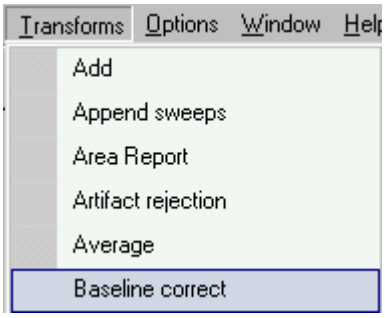


The first clearly identifiable peak is N70. In this subject, the peak occurs at 67ms and is marked as such in the display. The next peak is the P100 response which occurs at approximately 100ms. The labels were added with the Add Marker option, described below.

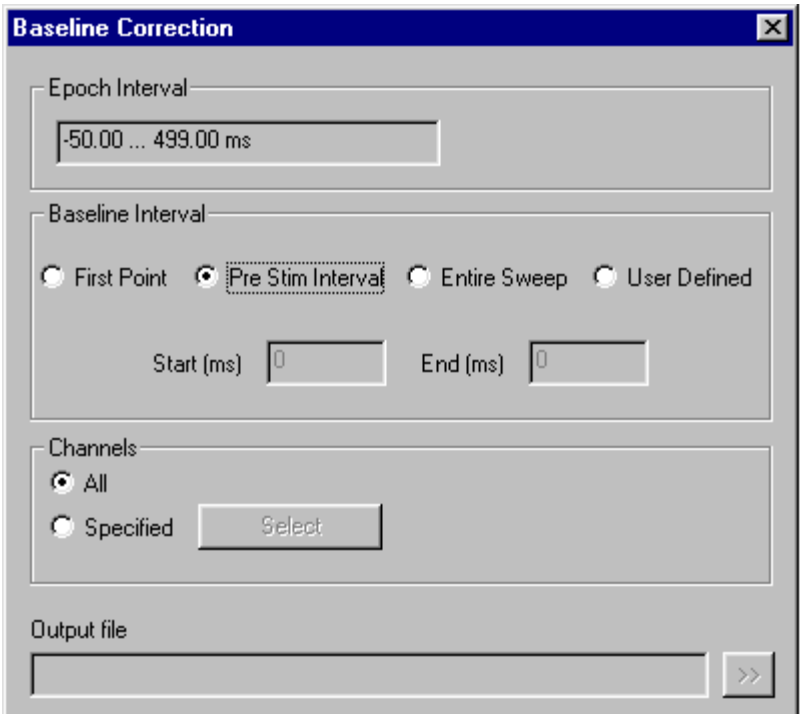
Now that we have an averaged file loaded, we can explore some of the various processing capabilities of EDIT. The primary purpose of EDIT is to change or transform a data set. Under normal circumstances a data file is loaded and then transformed in some manner. The transforms available depend on the type of file you have retrieved, and the possibilities are located under the Transforms menu. You may also access the Transforms menu by positioning the mouse between the electrode displays, and clicking the right mouse button. A menu will appear with the Transforms option.

Step 2 - Transforming the data. Click on the Transforms menu item and a list of the options that are available for the type of file will appear. A complete description of the Transforms may be found in the *Operating EDIT* section of the manual below. For now, we will just use a few of them.

Step 3 - Baseline Correction. Baseline Correction computes the baseline offset for each channel and then removes the offset from the working data file. Click on Transforms from the Main Menu, and select the Baseline Correction option.



The Baseline Correction window will appear. The Epoch Interval is displayed on the top line (the start and stop time points of each sweep).



In the Baseline Interval region, select the Pre-Stim Interval, which, in this example, is -50 to 0 ms. This means that for each waveform the mean DC value will be computed using the prestimulus interval. This value will then be subtracted from all points within the waveform. In the Channels region, select All to apply the correction to all channels. With AVG files, the Output file line is grayed out (see the grayed out Browse button >>). This is typical of many of the transforms that may be applied. With AVG files, the transform is applied "in place", meaning that the changes are applied directly to the AVG file. Save the file if you wish to keep the changes. With epoched, or *.EEG files, you must use the Browse button to create a new output file.

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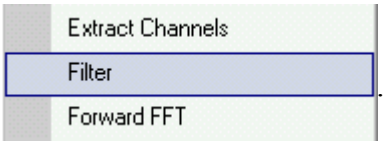
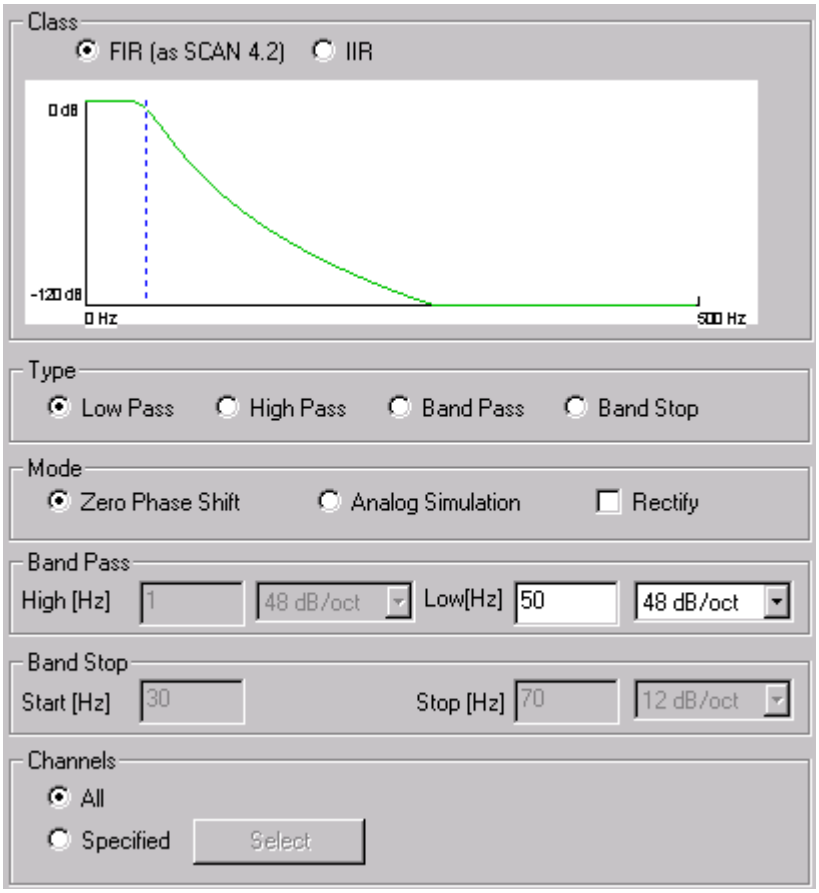
Click OK, and the Baseline Correction will be made to the displayed file. When you close the file, you will be asked if you want to save the changes - you can overwrite the existing file or create a new file with the modifications (do not save the file yet).

Step 4 - Filtering. The VEP file was collected with a band pass of 1 to 100 Hz in a noisy (60Hz) environment. We can remove the unwanted noise by digitally filtering the data with a low pass filter set below 60Hz. The digital filter in EDIT is a zero-phase shift type which has the advantage of not producing a latency shift in the major components of the waveforms. Click on Transforms from the Main Menu, and select the Filter option 

. The Filter display will then appear. Select the FIR class, Low Pass for the Type of filtering, Zero Phase Shift Mode, and enter 50 for the low pass frequency cutoff. Select 48 from the pull down menu for the filter slope.



The filter display at the top shows graphically the current filter transfer function. Under Channels, select All. (The Output File line is grayed out for AVG files). Then click the OK button to apply the filter transform.

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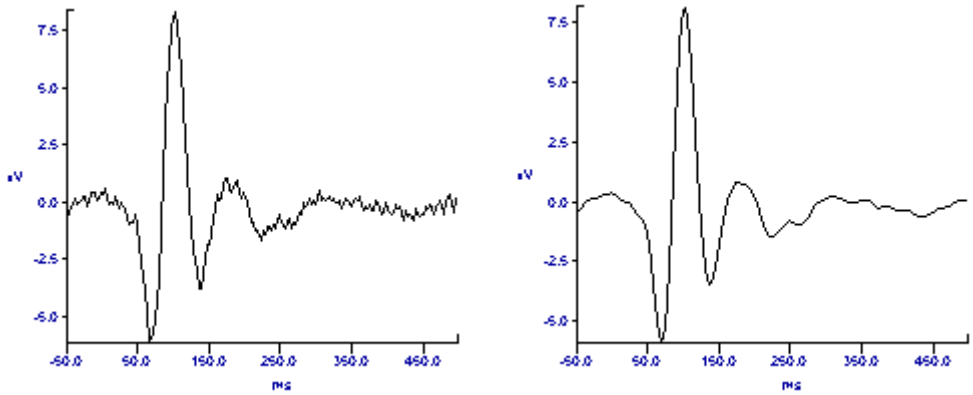
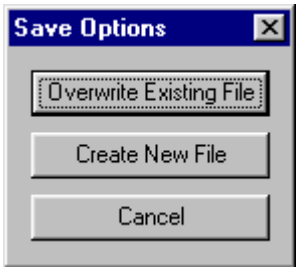
You can examine the effects of the filtering by zooming in on an electrode, such as OZ. To zoom in on an electrode, click once on the waveform to activate the window, or click twice to enlarge the window to its full size. Shown below are the effects of filtering. The unfiltered waveform is on the left and the filtered waveform is on the right.



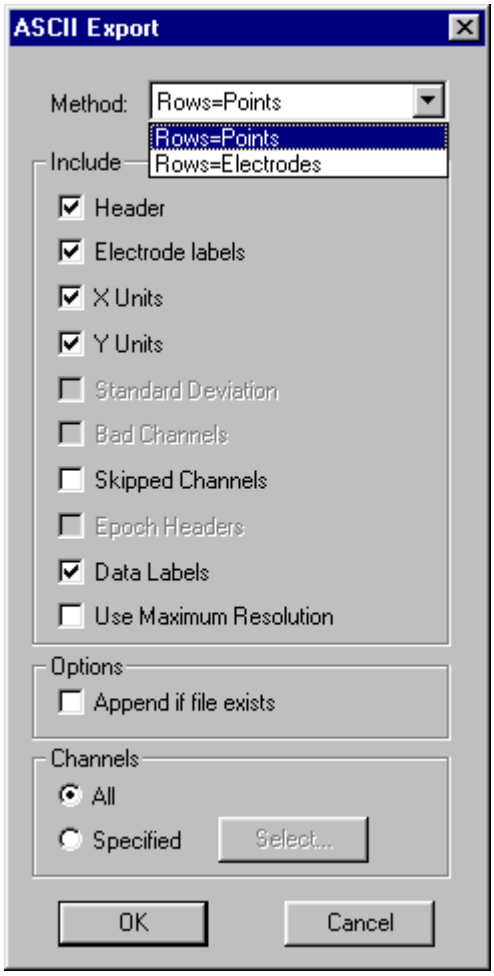
Unfiltered Filtered

Step 5 - Exporting the file in ASCII. Lastly, we'll export the final filtered file in ASCII format. Most of the files created in SCAN 4.2 (and later versions) 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.

To export the filtered VEP file to ASCII, make sure the desired file has the "focus", then select the Save As... option under File. You will have the option of Overwriting the Existing File, or to Create a New File. Select the Create New File option.



On the Output File display, click the pull down menu on the Save as Type line, and select ASCII File (*.dat). Enter a file name, specify a path, and click Save. You will see the following display.



These options are discussed in detail in the *Operating EDIT* section below. For now, select the Rows=Points Method, and click OK. The resulting file may be viewed in WordPad or Notepad (depending on the size of the file). A section of the ASCII file is shown below.

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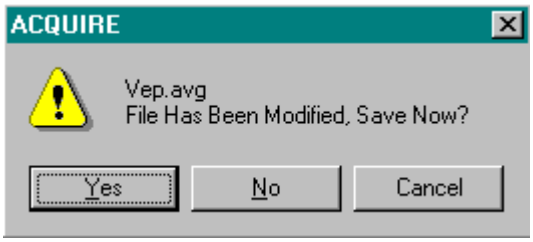
```
[Electrode Labels]
[      FP1]  [      FP2]  [       F3]  [       F4]  [       C3]
[Electrode XUnits]
[ Default]   [ Default]   [ Default]   [ Default]   [ Default]
[Electrode YUnits]
[ Default]   [ Default]   [ Default]   [ Default]   [ Default]
[Average Data]
    +0.1587     +0.0366     -0.0699     -0.3246     -0.5715
    +0.1726     +0.0681     -0.0511     -0.2664     -0.5296
    +0.1863     +0.1019     -0.0313     -0.2007     -0.4826
    +0.1979     +0.1359     -0.0118     -0.1299     -0.4323
    +0.2057     +0.1676     +0.0060     -0.0569     -0.3810
    +0.2084     +0.1947     +0.0205     +0.0149     -0.3311
    +0.2050     +0.2154     +0.0309     +0.0825     -0.2850
    +0.1955     +0.2287     +0.0370     +0.1431     -0.2444
    +0.1804     +0.2343     +0.0389     +0.1949     -0.2107
    +0.1610     +0.2329     +0.0375     +0.2366     -0.1843
    +0.1389     +0.2258     +0.0340     +0.2680     -0.1653
    +0.1161     +0.2147     +0.0301     +0.2896     -0.1530
```

In the Rows=Points format, the electrode labels head each column, and the columns contain the sequential data points.

You may Import the ASCII file by clicking the Open File icon  , setting the Files of Type to ASCII Files, and selecting the DAT file you just created.

When you attempt to close the filtered VEP.avg file, you will have the option to save the file with the modification you made. This display will occur anytime you modify a file, and then try to close it.



If you click Yes, you will have the option again to Overwrite the Existing File, or to Create a New File. Click the latter, and you will see a standard Output File utility, through which you may enter a file name and select a path. If you click No, the file will be closed without saving the modifications. If you click Cancel, you will be returned to the display as it was.

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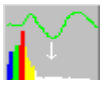
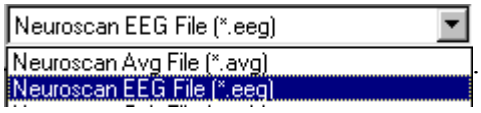
Single-sweep processing - Auditory P300

This section illustrates some of the processing steps that can be performed on single-sweep (EEG) files with the EDIT module. A 32-channel recording made with an auditory P300 paradigm will be used as an example data set.

In the auditory P300 paradigm two different tones of varying frequency are played to the subject. Typically, the two tones of short duration (100 ms) vary in either pitch or loudness. One of the tones is designated as the *infrequent tone*, or "Rare" or "oddball" tone, and occurs with low probability (.15). The other tone is designated as the *frequent tone* and occurs with high probability (.85). The tones are presented at a slow rate (2 second interstimulus interval) to generate auditory evoked potentials that can be easily recorded from the scalp. Evoked responses to these two tones show the well known P300 effect (Sutton, 1965), a large enhanced positivity at vertex peaking near 300 ms to the infrequent tone. In this tutorial you will:

- ☐ Remove baseline offsets from single-sweeps of data
- ☐ Reduce the contribution of ocular artifact
- ☐ Automatically reject artifact sweeps
- ☐ Manually reject artifact sweeps
- ☐ Sort the single-sweeps into separate averages

Step 1 - Loading a data file. After clicking the Edit icon  from the Program Launcher, select the File\Open data file option, or click the Open Data File icon  . A standard Open File utility will appear. At the bottom of the screen is the "Files of type" line. Click the down arrow and select the Neuroscan Epoch File (*.eeg) file type 

. The EEG files contain single sweep data. Select the P300.eeg file from the \Scan4.3\Demo\P300s and click Open (or just double-click the file). The screen will clear and the first sweep of the P300 demo file will be displayed.

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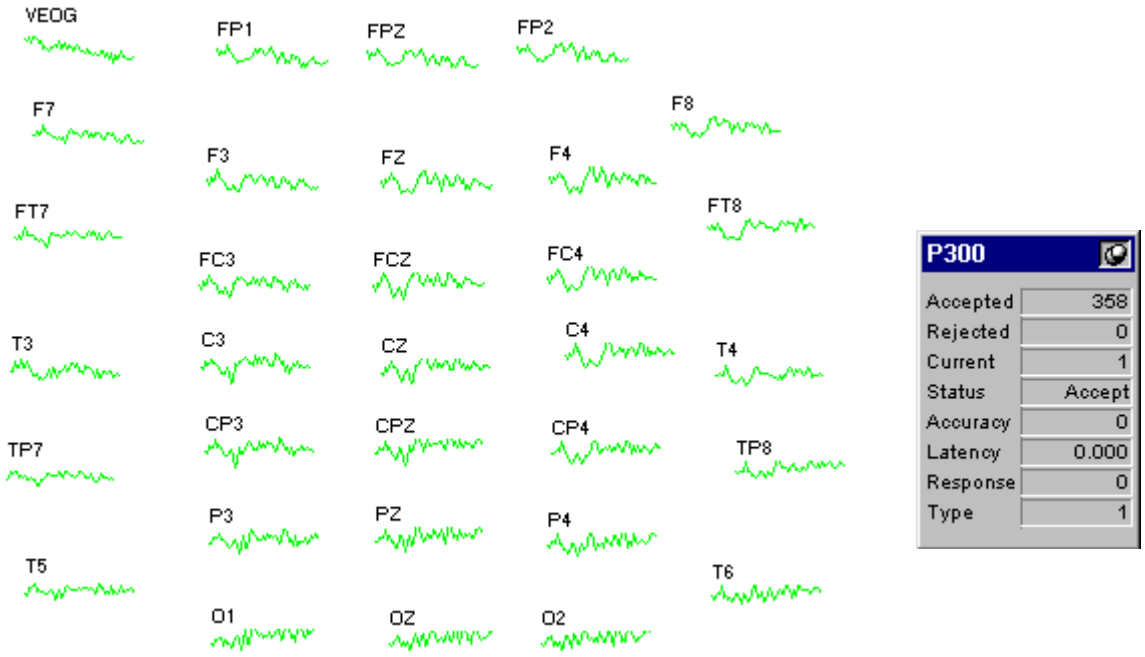


This file was collected from a 25 year-old male with good hearing. Tone pips (20 ms duration, 5 ms rise/fall) were presented via insert earphones every two seconds. A total of 358 tones were presented. Of these 358 tones, 284 were low-pitched (1000 Hz) and 74 were high-pitched (2000 Hz). Single-sweep epochs were recorded from 31 EEG leads and 1 ocular artifact lead to record vertical eye movements. Amplifier gain was 1000 (16-bit resolution on a SynAmps) with a band pass of DC to 50 Hz. Each sample epoch consisted of a 300 point sample, starting 200 ms prior and 1000 ms after stimulus onset.

When the data file appears, notice there is also a small status box. This will contain the Numbers of Accepted and Rejected sweeps in the EEG file, the Current sweep number, and the Status of that sweep (either Accept or Reject). If you had Merged the Task Data with the continuous file, you would see Accuracy and Latency information for each sweep. If you had created epochs on the basis of response triggers, the trigger type would show in the Response field. The Type field shows the stimulus trigger types for each sweep.

You can review the individual sweeps from this file by clicking on one of the Arrow icons located on the Toolbar  . The two middle arrows step through the file sweep by sweep, either forward or backward. The next two with the red "x"s, on either side of the middle arrows, will step to jump the next Rejected sweep, in either direction (if there are no rejected sweeps, these arrows will not be active). The outer two, with the green check marks, will jump to the next Accepted sweep, in either direction. There are also forward and backward SpeedScan buttons  . These will automatically step either forward or backward through the file, sweep by

sweep. The center button stops the SpeedScan. Lastly, there is the Goto button . When clicked, you will see the Goto Sweep window. Enter a sweep number, press OK, and the file will jump to that sweep.

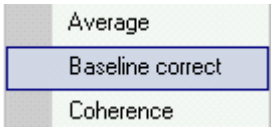
As you step through the sweeps in the file, note that the Current, Status and Type fields in the P300 status box change. Current tells you the current sweep number, Status shows whether the sweep is currently Accepted or Rejected, and Type is the trigger type code. Type will vary between 1 and 2. Sweeps identified by a type code of 1 correspond to the frequent tone and sweeps identified by a type code of 2 correspond to the infrequent tone. You can change the Accept/Reject status of a sweep by clicking on the Accept or Reject sweep buttons on the Toolbar . The remainder of the icon options is explained in the *Operating EDIT* section of the manual.

Step 2 - Baseline correction. The DC level of individual sweeps can be removed with the Baseline Correct option in the transforms menu. To estimate the DC level we will use the prestimulus interval of the epoch. This baseline value will be estimated for individual electrodes for each sweep.

It is also possible to remove the DC level after the average has been created, as in the previous tutorial. However, there are at least two advantages to removing the offset from single-sweeps. First, although offset removal from single sweeps does not affect the averaged waveform, it can affect estimates of variability. By removing the offset from single-sweeps the variability due to offset potentials between each epoch is removed. DC offsets between sweeps can become a significant factor in slow-potential recordings. Second, the automatic rejection algorithm uses voltage excursion criteria and is sensitive to the DC level. More acceptable sweeps can often be obtained if baseline correction is performed before artifact rejection criteria are applied.

Follow these steps to remove the DC level from the P300 file:

Click on Transforms from the main menu bar and a pull-down menu will appear. This menu shows the transforms that can be performed on an epoched file, and a description of each item is provided in the *Operating EDIT* section below. For now, we will look at just a few of them.



Select Baseline Correct , and the Baseline Correction window will appear.

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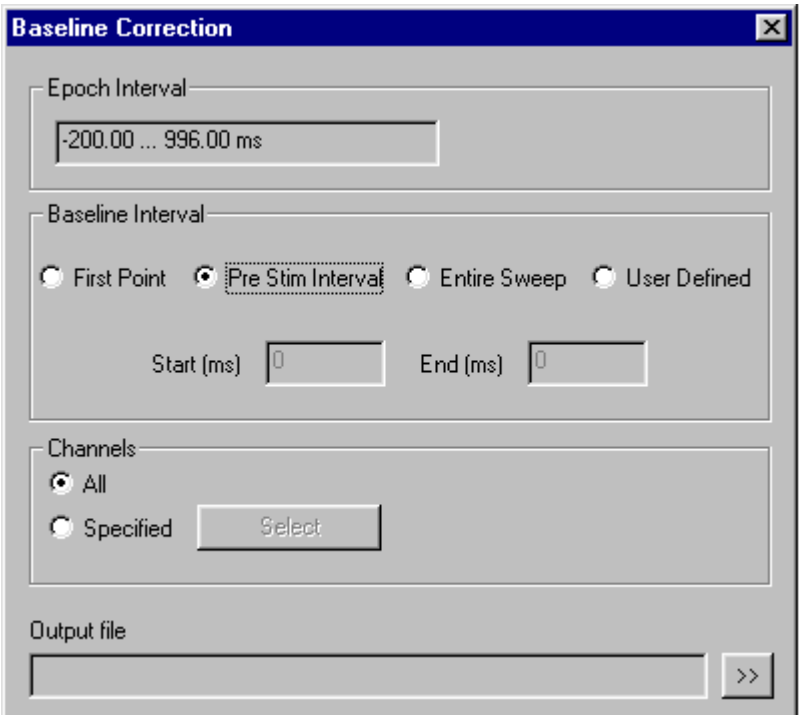

The entire Epoch Interval is displayed on the top line. In the Baseline Interval region, select the Pre-Stim Interval, which, in this example, is -200 to 0 ms. This means that for each waveform the mean DC value will be computed using the prestimulus interval. This value will then be subtracted from all points within the waveform. In the Channels region, select All to apply the correction to all channels. Click the >> button to display the standard Output File dialog box. Select a folder and enter an output file name, click Save, and then the OK button to perform the correction. A progress bar will track the new file as it is being created and saved. When completed, you will see a new Multiple Windows display with the baseline corrected file. Be sure to use this file for the next step.

Note: Use the "Sticky pins" to stick the Status boxes inside their corresponding displays.

Step 3 - Ocular artifact reduction. The artifact generated by eye movements often greatly exceeds the EEG. This is particularly true for frontal, and, to a lesser extent, centrally-placed electrodes. If eye movements are retained in the spectral or evoked potential average, they will greatly distort your results. One strategy for dealing with these eye movements is to visually or automatically reject sweeps of EEG that contain significant eye movements. However, this approach often results in an unacceptable loss of data.

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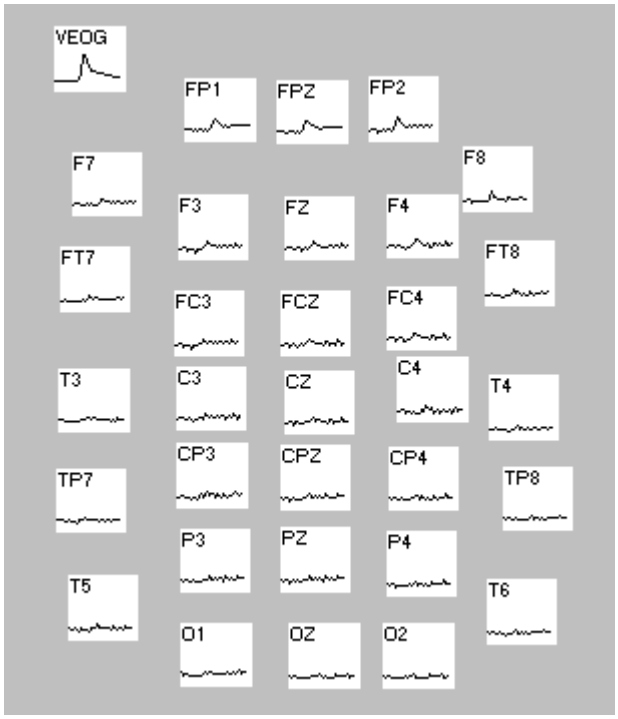
A better solution is to use an eye movement reduction algorithm that can subtract the eye movements from the ongoing EEG. We will apply an artifact reduction transform to improve the EEG before it is submitted to averaging.

Let's review some of the individual sweeps that contain eye movements or blinks. Use the arrow buttons on the Toolbar to move through the individual sweeps of the evoked potential data (or use the arrows keys on the keyboard). The second sweep of the P300 file contains a clear eye-blink, as shown below:



Notice that the blink is most prominent at the VEOG electrode, and then decreases as you move back. As you step through the file, note that these large excursions are found in many of the sweeps. In these sweeps, the electrodes FP1, FPZ, and FP2 are strongly affected, and these artifacts need to be reduced before constructing average waveforms. Find a few sweeps with an eye movement artifact, and note their sweep numbers. We will return to these sweeps after using the eye movement reduction algorithm.

The eye movement correction algorithm proceeds through three steps: 1) the VEOG channel is scanned for the largest eye movement, or blink; 2) an average is constructed from the blinks; 3) the artifact is subtracted proportionally from the raw EEG waveforms.

Click on Transforms, and the Transforms menu will appear. Click on Ocular Artifact Reduction, and the Ocular Artifact Reduction Parameters window will appear.

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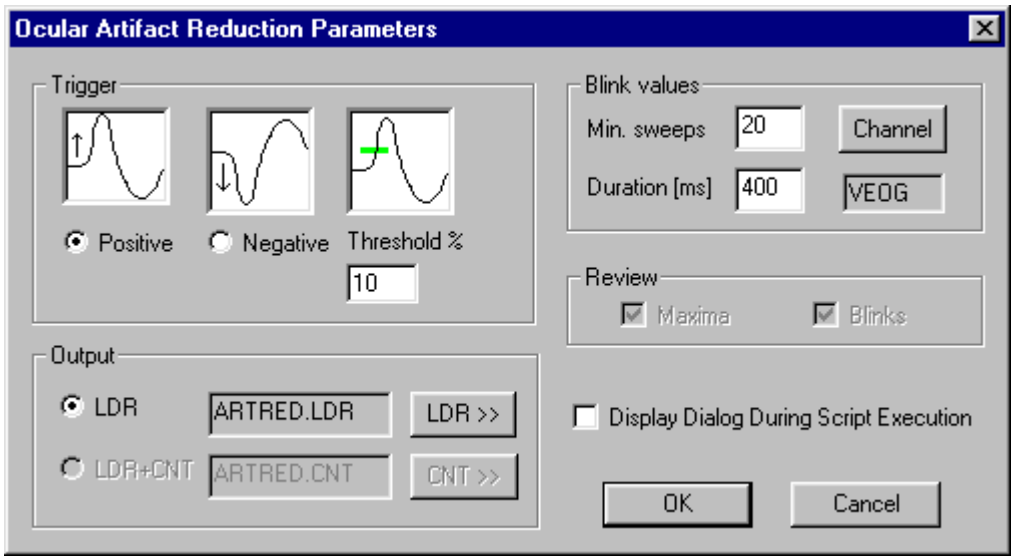

The following is a brief description of each of the fields. (A much more complete explanation of the artifact reduction algorithm is given in the *Operating EDIT* section of the manual). Note: the "default" settings can be entered under the Misc tab in ACQUIRE (Edit \ Overall Parameters). These settings will then be stored with the data files you acquire, and will appear automatically in the Ocular Artifact Reduction Parameters dialog screen.

Trigger - Selecting either of the first two radio buttons determines whether a positive or negative deflection will trigger the onset of an artifact event. The third setting is the Trigger Threshold. This sets the percent deviation from the maximum artifact voltage needed to initiate the onset of an artifact event. (Select Positive and 10% for this demonstration).

Blink Values - The Blink Values area has the following settings:

> *Min. sweeps* - Minimum sweeps sets the minimum number of artifact events needed to estimate transmission weights for ocular correction. Enter 20 for this demonstration.
>
> *Duration* - The sweep Duration field determines in milliseconds the span of the eye blink segment to be used in the average blink artifact. This is explained in more detail in the *Operating EDIT* section below. For now, enter 400.
>
> *Channel* - The Channel field is used to select the blink channel. The electrode label must correspond to an existing electrode name that is assigned to a bipolar vertical or horizontal channel. To change the channel, click the Channel button, and the montage diagram will appear. Click the channel that you desire (typically the VEOG channel), and say OK to return to the parameters screen.

Review - The review settings allow you to select manually the sweep with the maximum voltage and the individual blinks to be used on the average artifact calculation if, and only if, you are using a continuous file. With the P300.eeg, there is no option to review the Maxima and Blinks. Their functions are listed below anyway, for informational purposes.

> *Maxima* - When the Maxima field is enabled, you will have the opportunity to review the maximum voltage that is detected, and then determine whether it is part of a blink or not. This is described in more detail in the *Operating EDIT* section below.
>
> *Blinks* - When the Blinks field is enabled, you will have the opportunity to accept/reject the "blinks" that are detected by the reduction routine. This is described in more detail in the *Operating EDIT* section below.

Output - These fields determine the type(s) of output files to be created. Since we are using the P300.eeg file, the LDR+CNT option is not available. You will have an opportunity to enter a file name for the output EEG file shortly. The LDR+CNT output description is included below for informational purposes.

> *LDR* - When enabled, this option will create an LDR (linear derivation; .LDR extension) file. The LDR file, created in conjunction with the Spatial Filter and Spatial SVD, can be used in place of the Ocular Artifact Reduction routine with other data files from the same subject, assuming the recording conditions are the same (refer to the Ocular Artifact Reduction section in the *Operating EDIT* section of the manual below). Click the LDR>> button to access a Save As... utility display in which you may enter a file name and path for the new file.
>
> *LDR+CNT* - When enabled (assuming you start with a CNT file), this option will create a new .LDR and a new .CNT data file with the artifact transform applied. Click the radio button to enable the option, and then the CNT>> button to enter a file name and path for the new file. Then click the OK button to continue. With EEG files, an Output File display will appear before the transform is applied, allowing you then to create a new file with the transformed data.

When you have entered the desired settings and LDR Output File names, click OK, and the routine will begin. The routine will automatically find the Maximum voltage and average the Blinks. Next you will see an Output File utility display for the corrected EEG file. Enter a file name, specify a folder, and click OK. When the correction has been completed you will need to retrieve the new EEG file.

Note: With EEG files, you will not have the opportunity to see the transmission coefficients or SDs prior to performing the artifact subtraction. You do see these if you are using a CNT file, which is another advantage to recording your data in continuous mode.

Now let's look at the effects of the reduction process. Advance to the second sweep in the file. The Figure below shows the corrected FP1, FP2 and FPZ channels superimposed on the uncorrected

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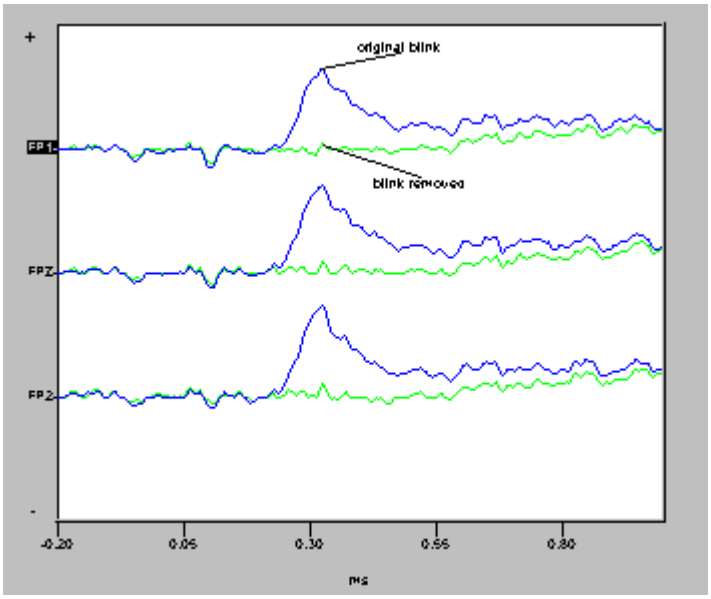

channels. (This graphic was created with the Waveboard feature, described in the Waveboard Appendix in the back of this manual). The algorithm effectively removed the blink artifact. Step through your original and corrected EEG files to see results for several of the sweeps. The blink is still seen in the VEOG channel, which remains unchanged in this process. There are different ways to remove blink artifact while retaining genuine EEG activity. One is described in the Spatial Filter description in the *Operating EDIT* section below, and another uses the Advanced Artifact Reduction plug-in software routines (Gradient/Blink Artifact Removal).

Step 4 - Automatic artifact rejection. Individual sweeps in the designated Artifact Rejection channels that contain voltages exceeding the thresholds you specify, will be automatically rejected using the Artifact Rejection command. In the P300 demo file we are using, the VEOG and most of the fronto-temporal channels were set as Artifact Rejection channels when the data file was recorded (using the Channel Attributes window in ACQUIRE). These channels may be recognized by the asterisk that appears just after the electrode label  Since we have already removed the blink artifact in the step above, it may not be necessary to do Artifact Rejection - a manual review of the sweeps would suffice. However, for the sake of illustration, let's do the Artifact Rejection using a different set of channels that do not include the VEOG channel. (If you include the VEOG channel, there will be about 250 sweeps rejected using +/- 50uV thresholds).

Follow these steps to automatically reject artifact:

Click on Transforms from the Main Menu bar, and then the Artifact Rejection line. The Artifact Rejection window will appear.

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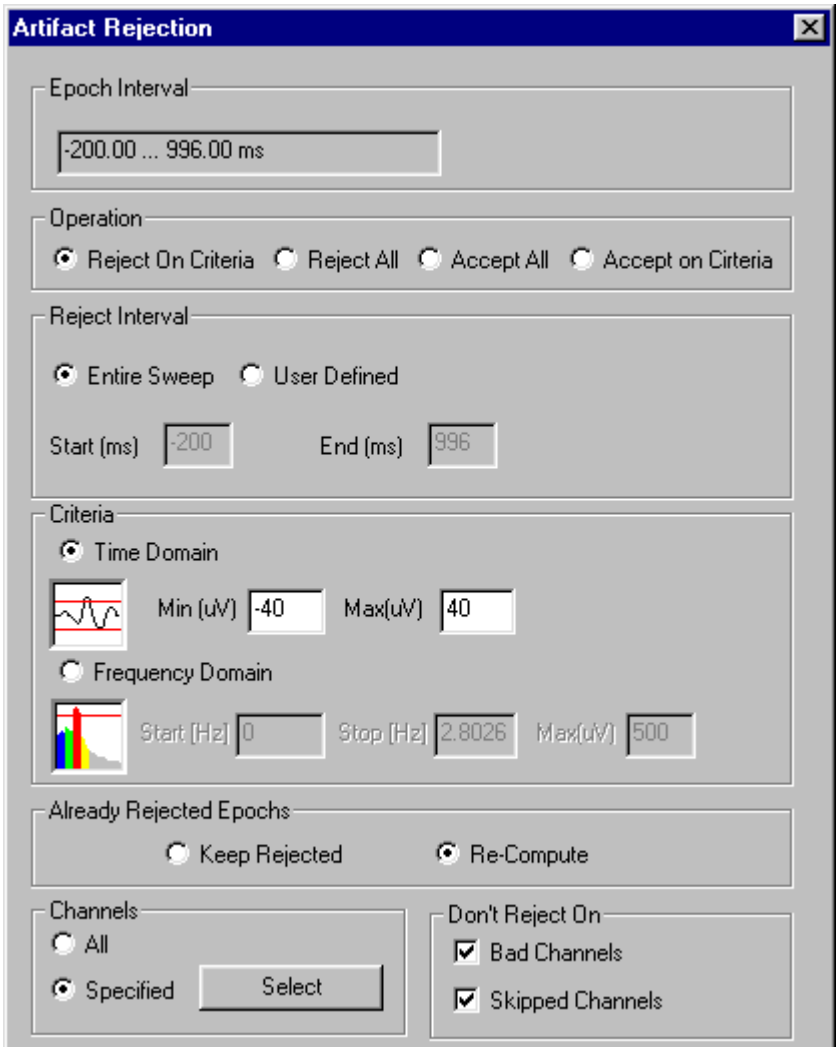

The following is a brief description of each of the fields in this dialog box:

Epoch Interval - This field displays the starting and ending time points of the epochs in the file.

Operation - The Operation field allows you to Reject On the basis of the Criteria you enter below, Reject All sweeps, Accept All sweeps, or Accept on the basis of the Criteria you enter below. Rejecting all sweeps is useful in cases where most of the sweeps are bad, and you wish to accept only a few good ones. Accepting all sweeps can be used to restore all of the rejected sweeps to accepted status. Select Reject On Criteria for this example.

Reject Interval - This section allows you to set the range of the epoch during which the rejection criteria will be applied.

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Entire - When enabled, the entire epoch will be searched for voltages exceeding the amplitude criteria.

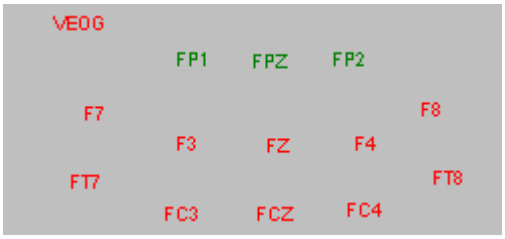
User Defined - When enabled, you may select the time range in which you want the amplitude criteria to be applied. The Start(ms) and End(ms) windows will become active, and you may enter the desired time points.

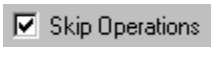
Criteria - Select the Time Domain option, and enter the Minimum and Maximum microvolt values. Any voltages from the Artifact Rejection channels that exceed these limits will result in rejection of that sweep. Enter -40 and 40 for these fields. (The frequency domain option lets you reject sweeps when the amplitude within a specified frequency range exceeds a specified voltage threshold).

Already Rejected Epochs - If you have already rejected some epochs, such as through manual sweep rejection, you can opt to keep these sweeps as rejected by clicking the Keep Rejected radio button. The sweeps will remain rejected regardless of whether they exceed the criteria or not. Select the Re-Compute option if you want the new criteria to be applied regardless of whether any sweeps had been previously rejected (previously rejected sweeps will be accepted if they do not exceed the criteria set above).

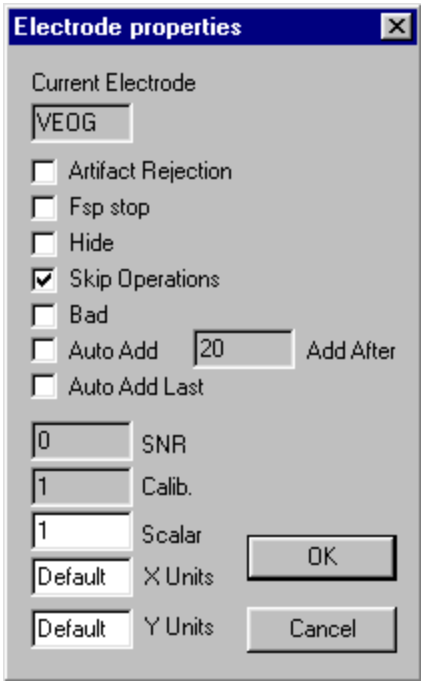
Channels - When the All option is selected, the criteria will be applied to all channels. When the Specified option is selected, the Select button will become active. Click it and you will see a display from which you may select the channels that will be used for artifact rejection. The ones that appear selected are those that were set in the setup file created in ACQUIRE. For this demonstration, select Specified and click the Select button. A montage diagram will appear. Deselect all 

of the channels, then select only FP1, FPZ, and FP2 by double-clicking them (they will change color from red to green). Then click OK. Only these three channels will be monitored for artifact rejection.

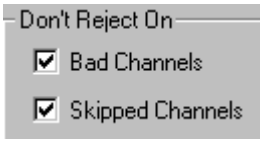


Don't Reject On - In ACQUIRE you had the capability of designating channels as Bad or Skip (you can set them in EDIT as well). The Don't Reject On fields let you remove either or both of these channels from the artifact rejection scan. The VEOG channel was recorded as a Skipped channel - you can recognize Skipped channels because the electrode label will be black, as opposed to whatever color you had selected under Options \ Multiple Window Settings \ General \ Text. You can also click the right mouse button on an electrode display, and select the Channel Properties option. If you right click on the VEOG channel, and you will see the 

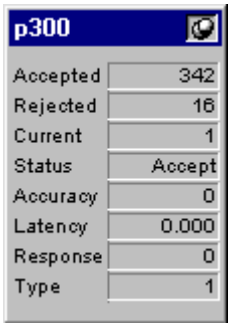
option has been enabled.



For this demonstration, leave both "Don't Reject On" fields enabled on the Artifact Rejection display.



Click OK and the artifact scan will begin. During the scan you will see a progress bar displaying the progression of the scan. After it is complete, the P300 status box will show how many sweeps were accepted and rejected.



Step through the corrected EEG file to see which sweeps are not rejected.

Step 5 - Sorting and construction of averaged waveforms. The last step is to sort the different single-sweep types (1=frequent and 2=infrequent) into separate averages. Follow these steps to construct averaged waveforms:

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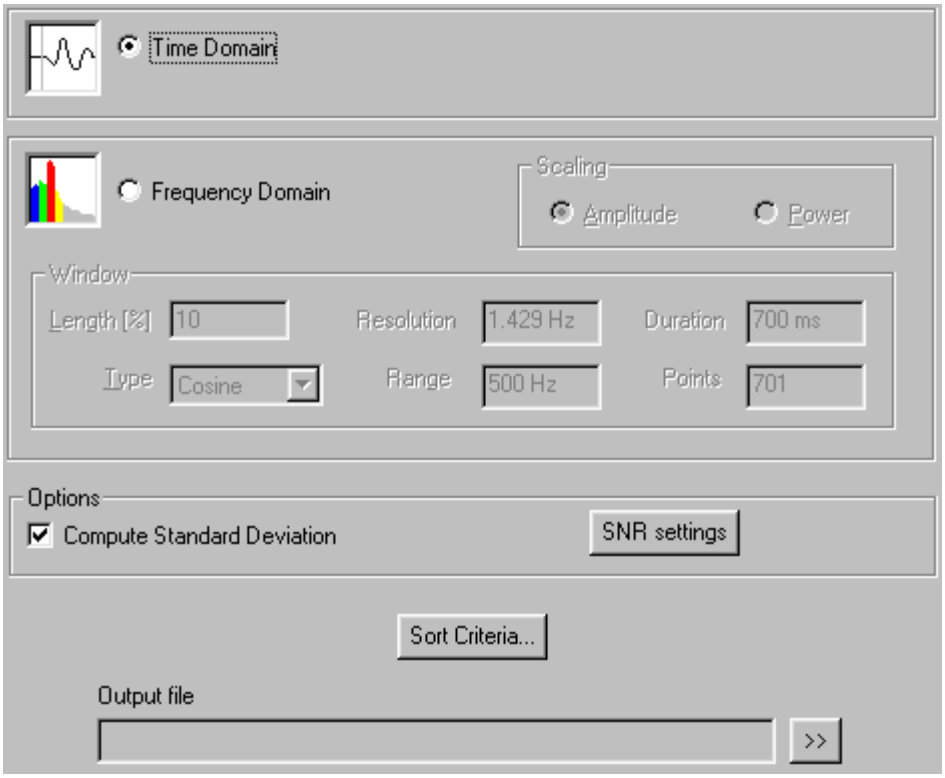
Click on Transforms and transforms pull down menu will appear. Select the Average option, and you will see the Averaging window.



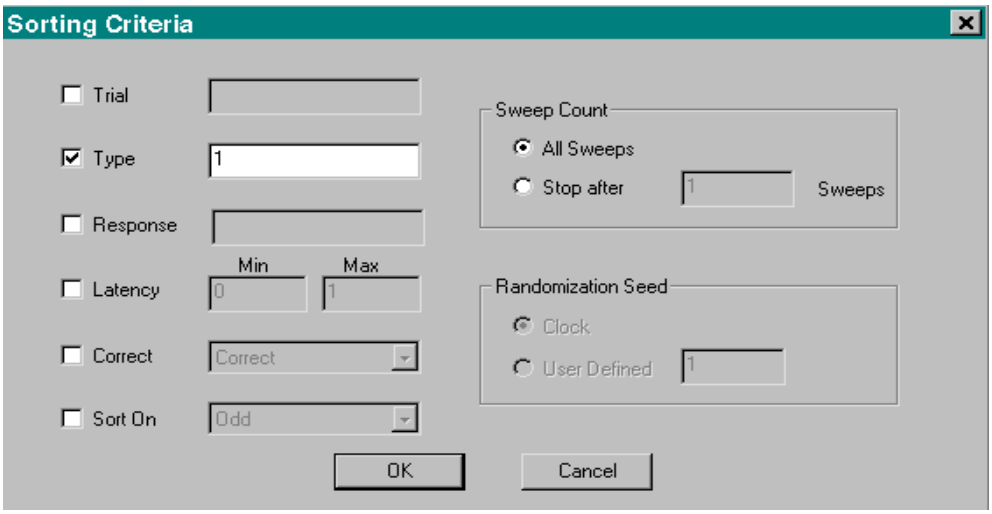
The parameters of this window control the conversion of the single-sweep file to an averaged waveform. The following is a brief description of each of the fields in this dialog box:

Data files are either in the Time domain or Frequency domain. Time domain files consist of amplitude changes over a time span, as in the case of an evoked potential waveform or single-sweep of raw EEG (the x-axis is measured in time). Frequency domain files consist of amplitude changes over a frequency range, as in the case of a file containing FFT spectrum data (the x-axis in measured in Hz). Time domain averages are generated by creating a simple point-for-point averaged waveform. Frequency domain averages are generated by computing an FFT and power spectrum prior to averaging. Since the purpose of this example is to generate an event-related potential waveform, the Time domain option should be selected (the Frequency Domain options will be discussed in the *Operating EDIT* section of the manual). The Options section at the bottom of the screen contains the following choices (these will also be described in more detail in the *Operating EDIT* section).

Compute Standard Deviation - The Standard Deviation (SD) field when turned ON will compute the SD on a point-by-point basis. Disable the option for this demonstration.

SNR settings - This is used in the computation of Signal-to-Noise Ratios (SNR). We will ignore it for now.

Before we begin averaging, we need to set the sorting criteria to select the sweeps of interest. Click the Sort Criteria button Sort Criteria..., and the following window will appear.

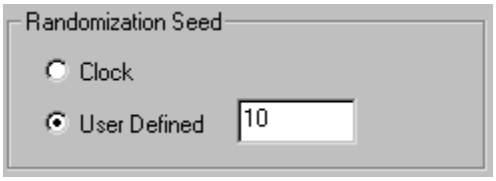


The following is a brief description of each of the fields in this dialog box:

Trial, *Type*, *Response,* and *Latency* - The Trial, Type, Response, and Latency sort fields determine an acceptable range of values for sweep inclusion into the averaged waveform/spectrum. The range is determined on a single line, such as 1-4, or by entering Min and Max latencies in the Latency field.

Correct - The Correct sort field will accept sweeps that have been tagged as correct, incorrect, both, or no response.

Sort On - The Sort On field can be used to select just the odd numbered sweeps, the even numbered sweeps, or a random sampling of sweeps. When you select the Random option, the Randomization Seed area becomes active. There are two choices of methods for selecting random sweeps. The



Clock option uses the PC's clock to select sweeps on a randomized basis. This will give a different set of sweeps each time it is used on the same data file. The User Defined field will accept a number between 1 and 255. Each number is used to generate a unique randomization sequence. The sequence will be preserved, that is, a seed of 10 will always use that same sequence.

Sweep Count - These fields allows you to use All the sweeps in the building of the average, or you can Stop After a designated number of sweeps.

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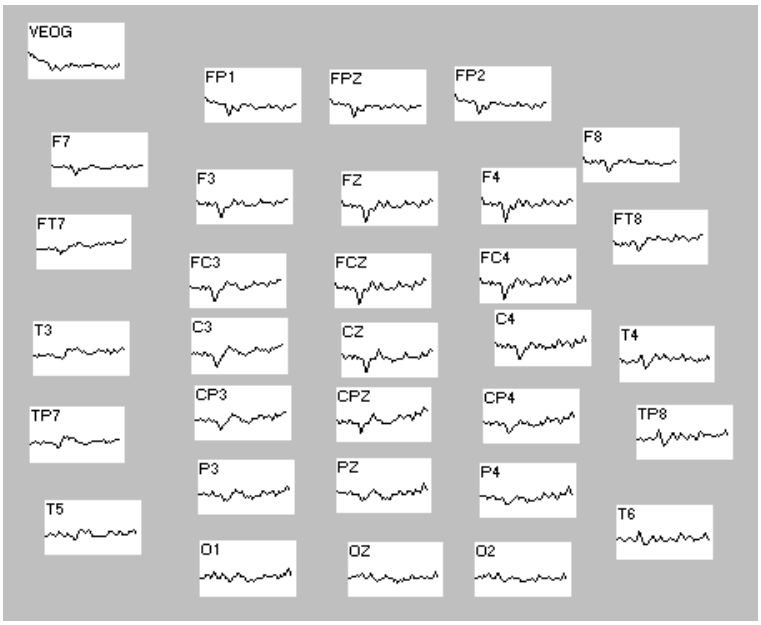
In this example we need to sort on the two different type values. Type values of 1 correspond to the frequent tone. Type values of 2 correspond to the infrequent tone. These two type values are the only ones we need to be concerned with since there were no behavioral responses recorded from the subject.

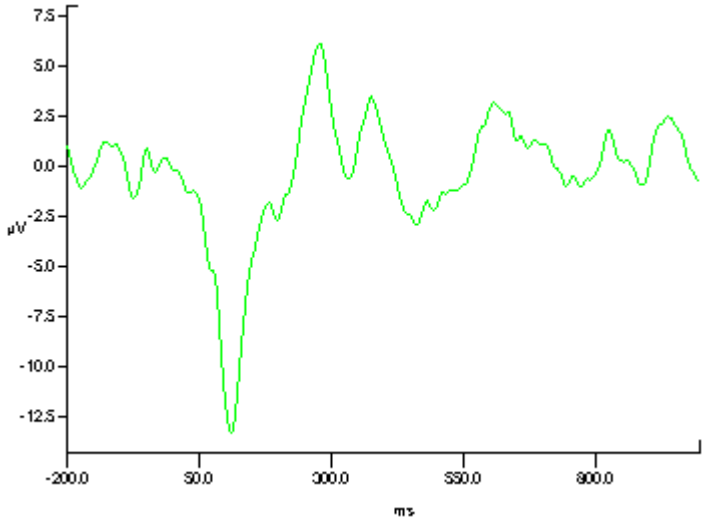
Let's first sort on type 1 to select the sweeps that contain the frequently occurring tone. Click on the Type field (so that a check appears), and enter 1. Your Sort dialog box should match the one shown above.

Next, click OK and the Averaging window will reappear. Click the >> button at the end of the Output file line, and select a folder and enter a file name (FREQ; the .avg extension will be added automatically), then click Save. Click OK to initiate averaging. A progress will track the operation. A second multiple window display will appear containing the averaged waveforms.

The averaged waveforms initially may appear to be low in amplitude. This is because the display is still set to the original scale factor used with the single sweep EEG file. The most convenient method to scale your waveforms is to use the autoscale option located on the Toolbar ↕. Click it and the waveforms will be redisplayed with the new minimum and maximum values shown below.

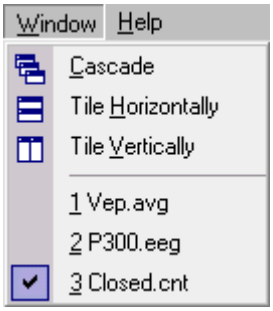


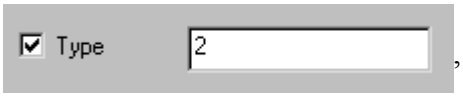
Your screen should now display the above frequent waveform. The FREQ status box will display how many sweeps were accepted. The waveforms display the typical N100 component (sharp negative going wave) that has a maximum distribution near the central electrode sites.



Finally, we need to construct the average for the infrequently occurring or 'rare' tone. Now we need the original single-sweep P300.eeg file to sort on the basis of the 'rare' tones.

You do not need to retrieve the file again. Instead, just switch the focus (so that window is highlighted) to the Multiple Window Display that has the single sweep P300.EEG file. You can also select the desired file from the list under Window on the Main Menu bar.



Next, repeat the process that you used to construct the frequent tone average. Click on Transforms and select Average from the menu. The Averaging dialog box will appear, and click on the Sort Criteria button. Then enter a 2 in the Type field 

, and click OK.

Enter RARE for the output file, and click OK again on the Averaging window. After the averaging process is completed, you will see another Multiple Window Display containing the average waveforms for the RARE sweeps.

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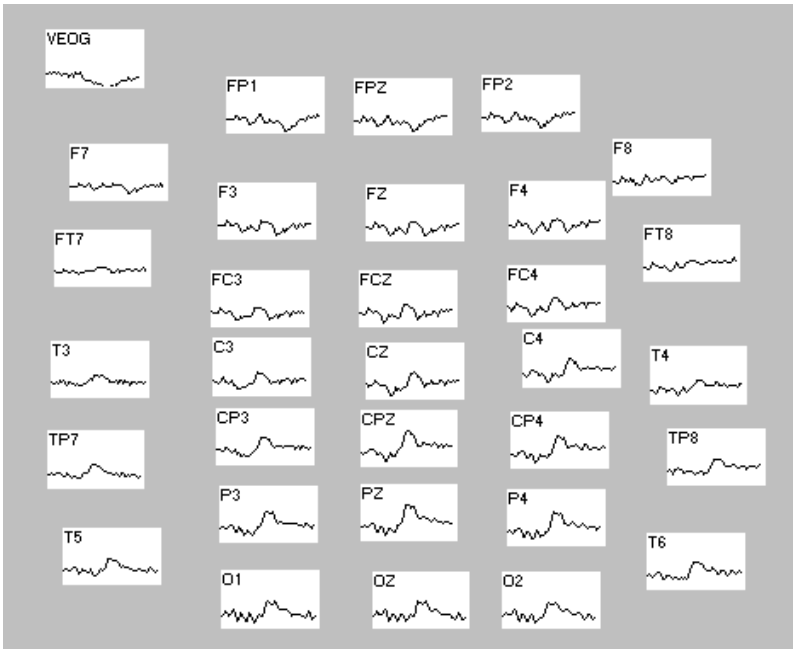


These waveforms show a large positive component peaking between 300 and 400 ms. This is the P300 component elicited by the infrequent tone.

This concludes the P300 tutorial. The essential product of the processing steps are two waveforms. These waveforms are stored in separate files named 'FREQ' and 'RARE'. Please save these files. They will be used in later tutorials for the mapping and statistical operations.

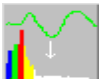
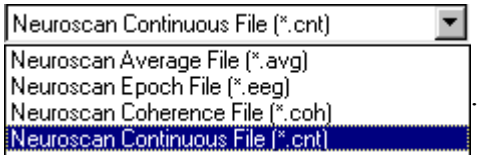
Epoching a continuous file - Visual sustained attention task

This section illustrates processing steps for constructing averages from a continuous data file. A 32-channel recording from a subject performing a sustained visual attention task will be used as an example data set.

The visual sustained task (VISCPT.cnt) was used to generate these data consisted of a series of centrally presented digits (subtending 1 degree of visual arc) ranging from 0 to 9 . The digits were presented for a duration of 100 ms and were separated by a visual noise mask. An interstimulus interval of 2000 ms with a + 100 ms 'jitter' was employed. The subject's task was to identify target (the digit '0') from nontarget (digits 1-9) stimuli. The accuracy and latency to identify targets and non-targets was recorded and saved to a separate behavioral data file.

In this tutorial you will:

- ☐ Review and edit the continuous file
- ☐ Reduce the contribution of ocular artifact
- ☐ Merge behavioral data with the continuous file
- ☐ Create a single-sweep epoch file from the continuous file
- ☐ Remove baseline offsets
- ☐ Automatically reject artifact sweeps
- ☐ Sort the single-sweep data into separate averages

Step 1 - Loading a data file - After clicking the Edit icon  from the Program Launcher, click on the File\Open data file option , or click the Open File icon  . A standard Open data file utility will appear. At the bottom of the screen is the "Files of type" line. Click the down-arrow and select the Neuroscan Continuous File (*.cnt) file type 

. Go to the \Scan4.3\demo\Visual Attention directory and retrieve the Viscpt.cnt by double-clicking it. The Viscpt.cnt demo file will be displayed.

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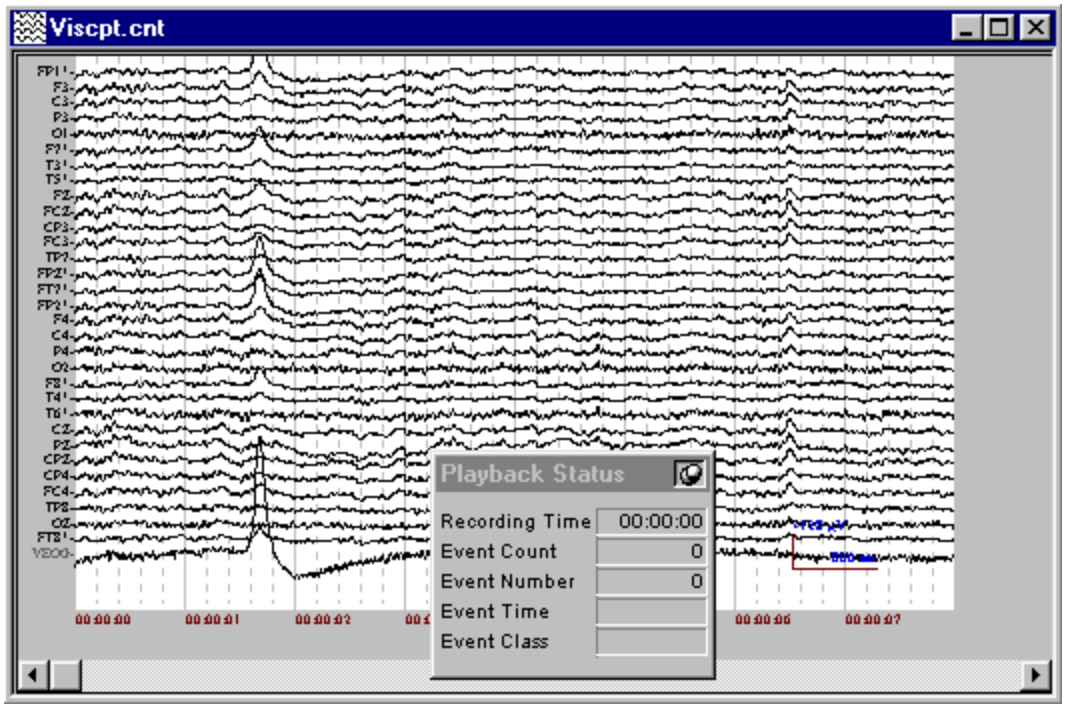


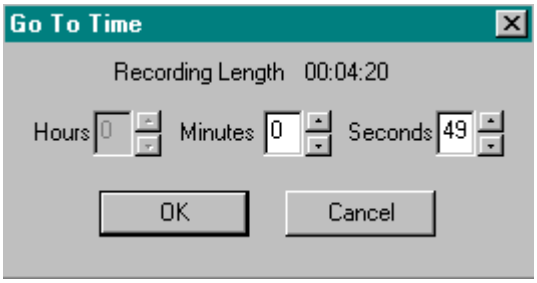
If your display differs from the above, you may need to increase or decrease the display scale using the up and down arrows on the Toolbar, or the autoscale icon. Click the Accelerate or Decelerate Display icons to vary the number of seconds displayed on the screen, or click the right mouse button in the data display, and select "Set seconds per page".

The continuous file was collected from a 25 year-old male recorded from 31 EEG leads and 1 ocular lead to monitor vertical eye movements and blinks. Amplifier gain was 1000 (16-bit resolution on a *SynAmps*) with a band pass of .15 to 30 Hz and was digitized at 250 Hz. The epoch displayed on the screen represents the first epoch of the continuous file. Since the file is continuous, individual sweeps in this display are contiguous.

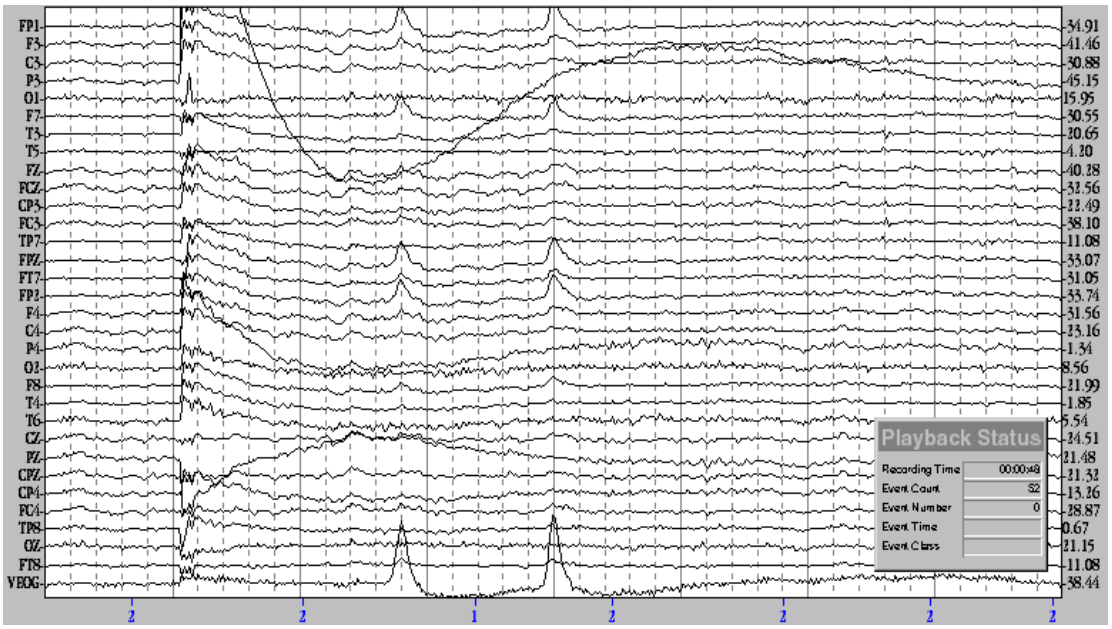
Let's try moving through the file - there are several ways to do this. To move forward or backward by one display page, click the buttons located on the Toolbar, or use the arrow keys from the keyboard. As you move forward or backward, note that the Recording Time indicator in the Playback Status box will increase or decrease. This value indicates the current recording time in hour, minutes, and seconds at the start of the display page. You may also scan automatically through the file by clicking the SpeedScan buttons on the Toolbar. The center button will stop the SpeedScan. You may jump to a desired event or time point in the file by clicking the Goto buttons on the Toolbar. The first option will display the Go To Event screen, from which you can jump to any desired Stimulus, Keypad, Reject, Accept, Keyboard, DC Correction, or Segment event (described in more detail in the *Operating EDIT* section of the manual). The second option opens the Go To Time window, in which you may select a precise time point to jump to.

At the bottom of screen a scrollbar indicator will also move from left to right indicating the current file position . The scrollbar provides a way to move quickly to a different position within the file. To use the scrollbar, click on the rectangle button while holding down on the left mouse button. Drag the rectangle to a new position and release the mouse button. The screen will refresh displaying the new file position. The arrows on the left and right of the scrollbar are used for alignment of the current display page. Each press of these buttons will move the current page by one second.

Step 2 - Reviewing and editing artifact with a continuous file - Let's begin by removing some bad sections of the recording. In this file there are at least six obvious artifact events that should be identified and removed. The first artifact is located 49 seconds into the recording. You can search to this location quickly by clicking on the Go To Time button , and entering "49" in the seconds field, as shown below.



Shown below is the artifact that starts at this point in time.



Other artifacts occur at 0:1:43.2, 0:2:30.5, 0:3:11.0, 0:3:51.0, and 0:4:12.0. You can use the search

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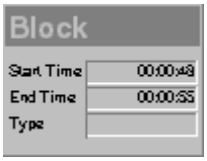
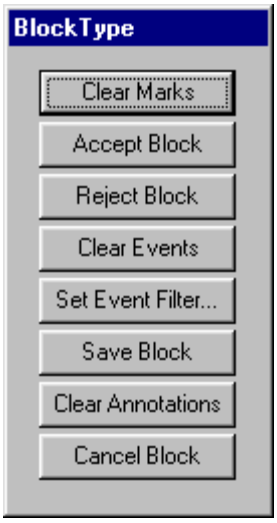
button to move quickly to these locations or you can scan manually or automatically through the file and identify them.

After identifying the onset of the artifact, the next step is to reject the section of data that contains the artifact. This is done with the Mark Block function from the Toolbar. The mouse cursor is now active for marking points in the CNT file, and will allow you to mark the section to be rejected. After clicking the Mark Block icon, click the mouse one time just before the beginning of the artifact, and then again where the artifact resolves. The second click denotes the end of the marked block. You will then see the Start and Stop times written in the Block status box, and the Block Type menu will appear.





Note: If the artifact extends beyond what is displayed in the current screen, you can move the cursor off the waveform display area, click on the page forward arrow, or the right arrow button on your keyboard, and the screen will advance to the next page (or you can increase the number of seconds displayed).

Click the Reject Block option and the screen will refresh showing the marked block in color. *Note - rejected blocks can be accepted again with the Accept block command.*

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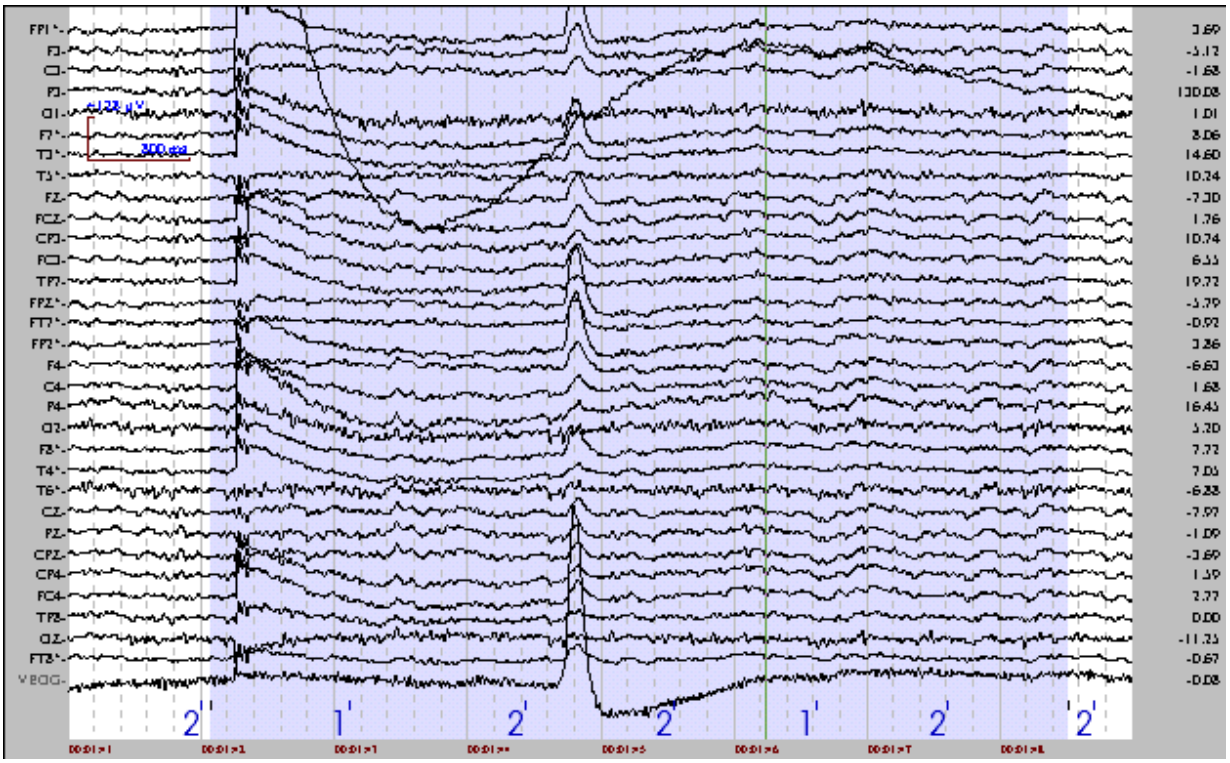

Repeat this step for each of the artifact regions in this file.

Step 3. Ocular artifact reduction - Ocular artifact reduction can be performed with continuous or epoched files. The procedures are similar to those used with the single-sweep epoch files (see previous P300 tutorial). There are, however, advantages to performing ocular correction with a continuous file over an epoched file. First, in a epoch file, a blink or eye movement can occur at any point within the sample epoch. This means that there may be a significant number of artifacts that either start too early or too late with respect to the epoch interval. Second, in an epoched recording it is possible to miss artifacts resulting in fewer sampled eye movements. Since the reduction algorithm becomes more reliable with increasing numbers of samples, a continuous recording that contains additional artifacts will actually improve the quality of the ocular reduction. Third, with continuous files you have the opportunity to review the Maxima, the Blinks, the transmission coefficients, and the Standard Deviations (SDs).

Follow these steps to perform ocular reduction on a continuous file:

Click on Transforms\Ocular Artifact Reduction, and the Ocular Artifact Reduction Parameters window will appear.

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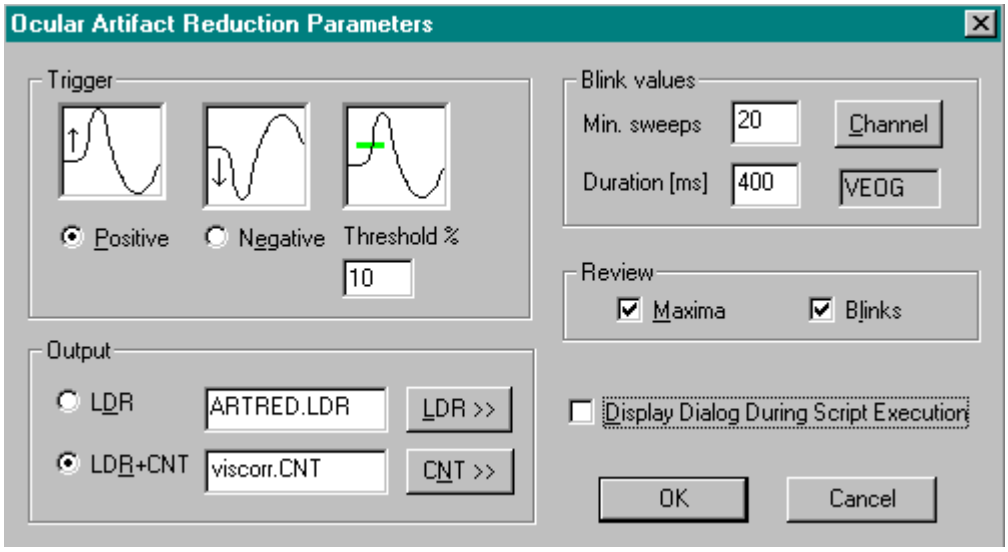
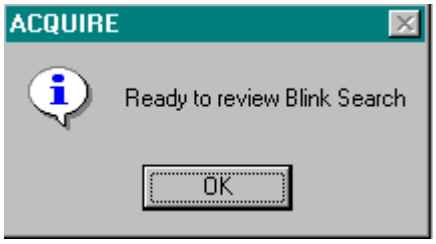


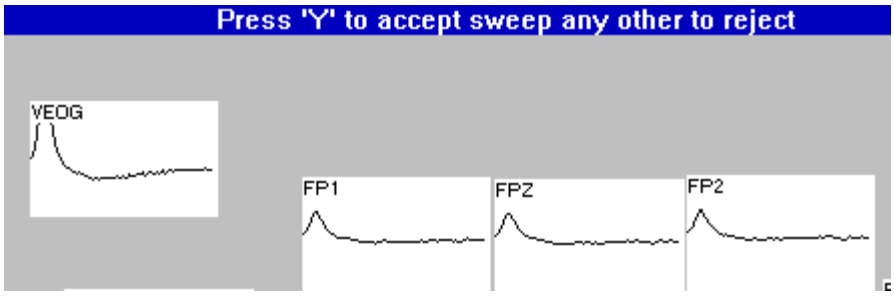
Verify that the values in your ocular reduction dialog box match those shown in the box above, enter a name for the output CNT file, and click OK. You will then see the first sweep, and you will be asked if this looks like a genuine maximum (from the VEOG channel), that is, does it contain the greatest voltage peak for a genuine eye blink (in the VEOG channel). Chances are that this will not be contained in the first sweep. If you say Yes, the program will go 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, if you say "Y", 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. In that case, the Maximum will be detected automatically.

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. You will see a notice saying that the review of the blinks is about to begin.



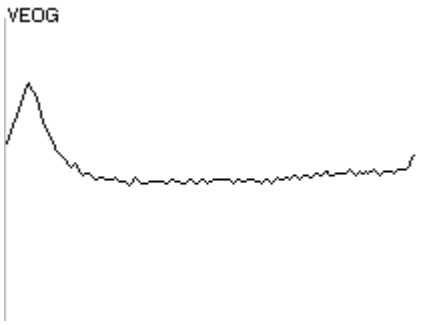
The beginning of the blink artifact is defined as X% of the Maximum voltage, where X is the value you entered for Threshold (under Trigger; typically 10%). With a CNT file, the routine

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.

Hint: With CNT files, the routine will find the first point in the designated channel 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 a duration of about 400ms. The types of blinks to accept are similar to ones shown below. Realize that the Up and Down arrows icons ⬆ ⬇ *can be used for display scaling.*



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 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

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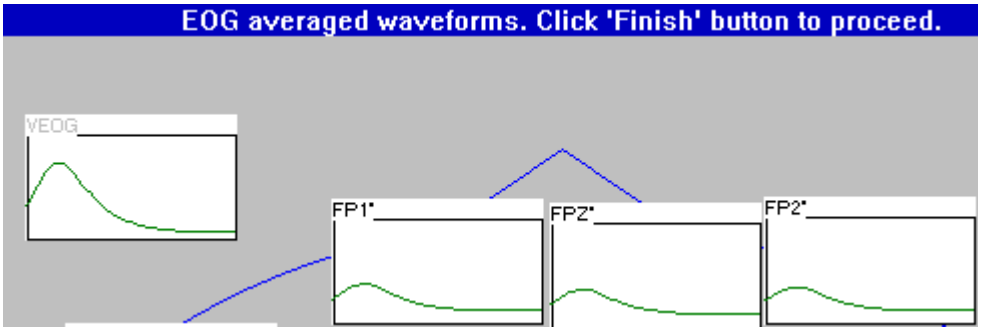
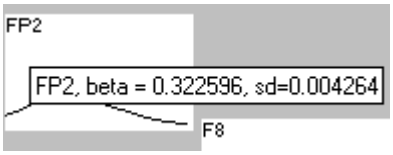
sections will then be included in the average blink artifact. This may result in a less than optimal subtraction of the blink. Generally, if you have a recording with blink artifact that is otherwise clean, the automatic routine will often do as good a job as your manual review.

When averaging is completed, you will see a Multiple Window Display showing the averaged artifact. Vertical eye movements and blinks have a pronounced effect on the frontal electrodes that diminishes as it moves to posterior electrodes. You should see the greatest similarity among the frontal sites, and essentially flat lines at posterior sites.



Viewing the transmission coefficients - To view the transmission coefficients and SDs, point the mouse to an electrode label. The weights and SDs will appear in the form of a Tool Tip.



To see all of the Weights or SDs in a map display, click the Show button in the lower left hand corner 

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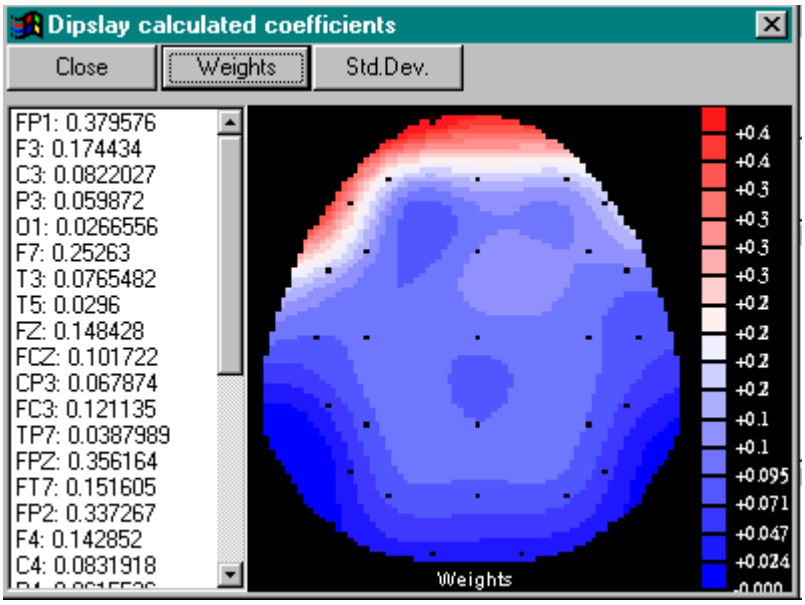

The transmission coefficients are typically much higher in the frontal leads than they are in the posterior leads. This is because the vertical eye movements and blinks spread in an anterior-to-posterior manner. Consequently, much more of the VEOG channel is subtracted from the FP1 and FP2 electrodes 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 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. The large SD is an indication that artifacts other than blinks were averaged, therefore the average is distorted, the coefficients are distorted, and you wind up performing inaccurate subtractions of the artifact.

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

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remove the artifact. If not, click the Abort button to terminate the routine
Finish | Abort | Show .

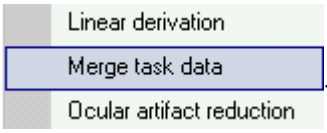
Compare the original file to the corrected one to see the effect of the reduction algorithm.

Step 4 - Merging behavioral data into the continuous file - Continuous files created with SCAN version 3.0 and later can be merged with behavioral data such as stimulus/response codes, latency, and accuracy. The advantage of merging behavioral data into the continuous EEG file is that sorting decisions, based on different performance criteria, are facilitated 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 continuous EEG file.

In the sustained attention task a behavioral data file named VISCPT.DAT was recorded. This file contains 206 trails of trial-by-trial accuracy and latency data. A section of the DAT file is shown below.

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
12	1	2	1	0.272

The VISCPT.DAT can be merged with the corrected continuous file with the following steps.

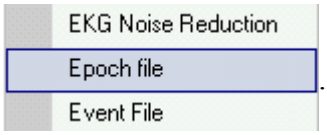
Click on Transforms, and select the Merge Task Data option 

. A Select Task file display will appear, allowing you to select the DAT file. Select the viscpt.dat file, click Open, and the task data will be merged.

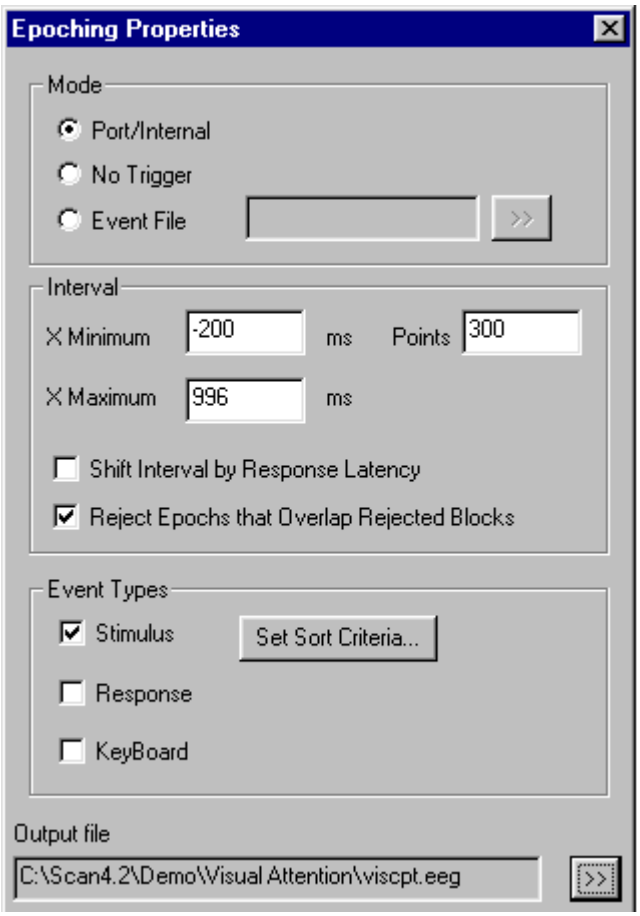
Step 5 - Constructing single-sweep epochs from the continuous file - There are a number of advantages to recording data continuously. First, epoch windows of any size (limited only by memory) can be defined. If, at some later point, you decide to extend or shorten the epoch length, it can be easily done by reconstructing epochs with new values from the continuous file. Second, the epoch frame relative to the event (i.e., length of pre- and poststimulus interval) can be changed at will.

An example of this application might be backward averaging of pre-motor responses. Third, continuous recordings allow for overlapping epochs. There are many instances where it is necessary to examine overlapping epochs as is often the case of complex cognitive tasks. An example of this might be a high-speed sustained attention task in which stimuli and responses occur rapidly.

Follow these steps to construct a single-sweep epoch file:

Click on Transforms and select the Epoch File option 

. You will then see the Epoching Properties window.



The parameters of this dialog box control the conversion of the continuous file to an epoched single-sweep file. The following is a brief description of each of the fields in this window:

Mode - The Mode fields are used to provide information about the source of the events to be used for determining the zero time point of the epochs.

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Port/Internal - These data were acquired with the Port mode, and is the mode used with stimuli from STIM. Select this option for the demonstration.

No Triggers - Use this option for back-to-back epoching (where there are no triggers).

Event File - This option allows you to use an Event File to control epoching.

Interval - These fields set the beginning and ending time points for the epochs.

X minimum - The X minimum field determines the prestimulus interval. The value should be set to -200 in this example.

X maximum - The X maximum field determines the poststimulus interval. The value should be set to 1000 in this example.

# of points - The # of points field determines the total number of points allocated to the current epoch size. Click in the field and the number of points will be calculated automatically.

Shift Interval by Response Latency - This option is used when you want to perform response-locked averaging. When enabled, epochs will be created around the response triggers, rather than the stimulus triggers. Leave it disabled for this example.

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. Enable the option for this example.

Event Types - Select the type(s) of trigger events to be used for epoching. The Set Sort Criteria button allows you to sort specific events to be used for epoching, such as, trigger types within a certain range.

Stimulus - Enabling Stimulus types will create epochs using the stimuli events. Enable the option for this example.

Response - Enabling Response types will create epochs around the Response triggers. Do not enable the option for this example.

Keyboard - Enabling Keyboard types will create epochs using keyboard entered events (as with Function keys). Do not enable the option for this example.

Output file - Click the  button, then select a folder and enter a file name (viscpt.eeg) for the output file (the .EEG extension will be added automatically).

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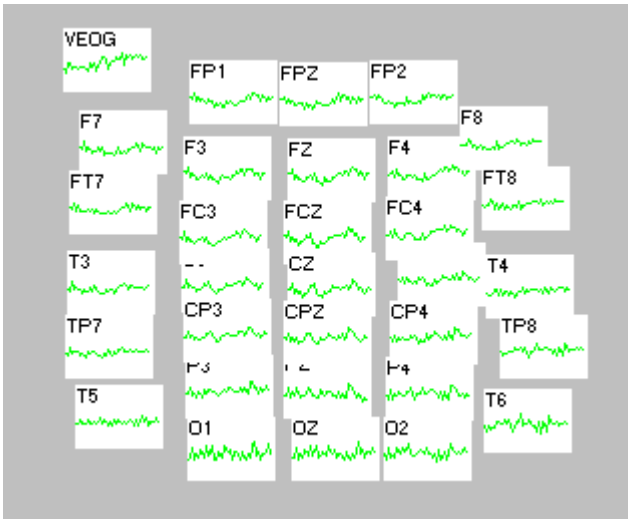
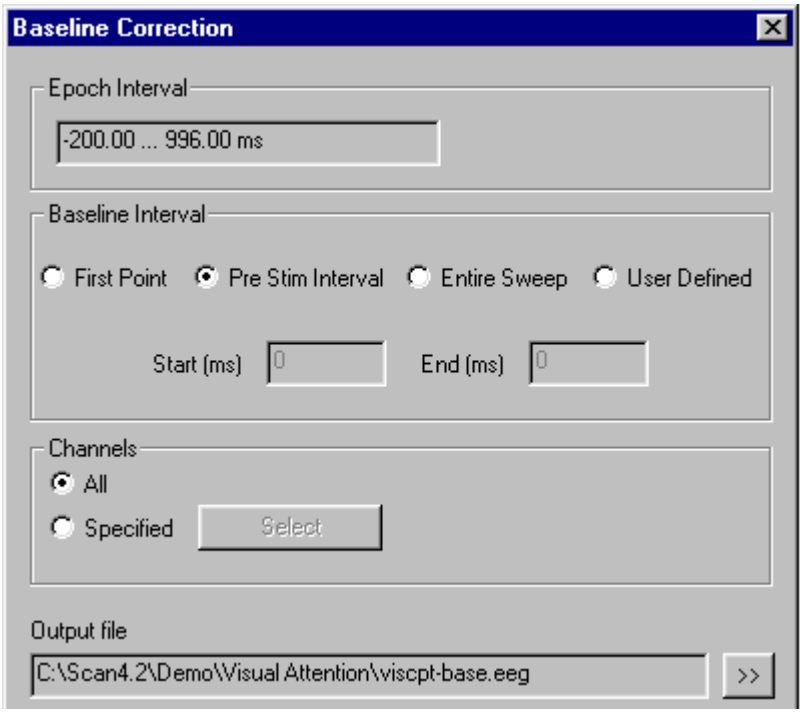
Examine your Epoching Properties screen, make sure it matches the above values, and click OK. The single-sweep file named Viscpt.EEG will be created and individual epochs will be written to it. Upon completion, you will see a new Multiple Window containing the first sweep of the epoched file.



Step 6 - Baseline correction and scanning the epoch file automatically for artifact - Now that we have created an epoch file from a continuous file, we can follow the same steps used to prepare the P300 file in the previous tutorial for sorting and averaging.

Make sure the viscpt.eeg window has the focus, then select Transform\Baseline Correct. The Baseline Correction window will appear.



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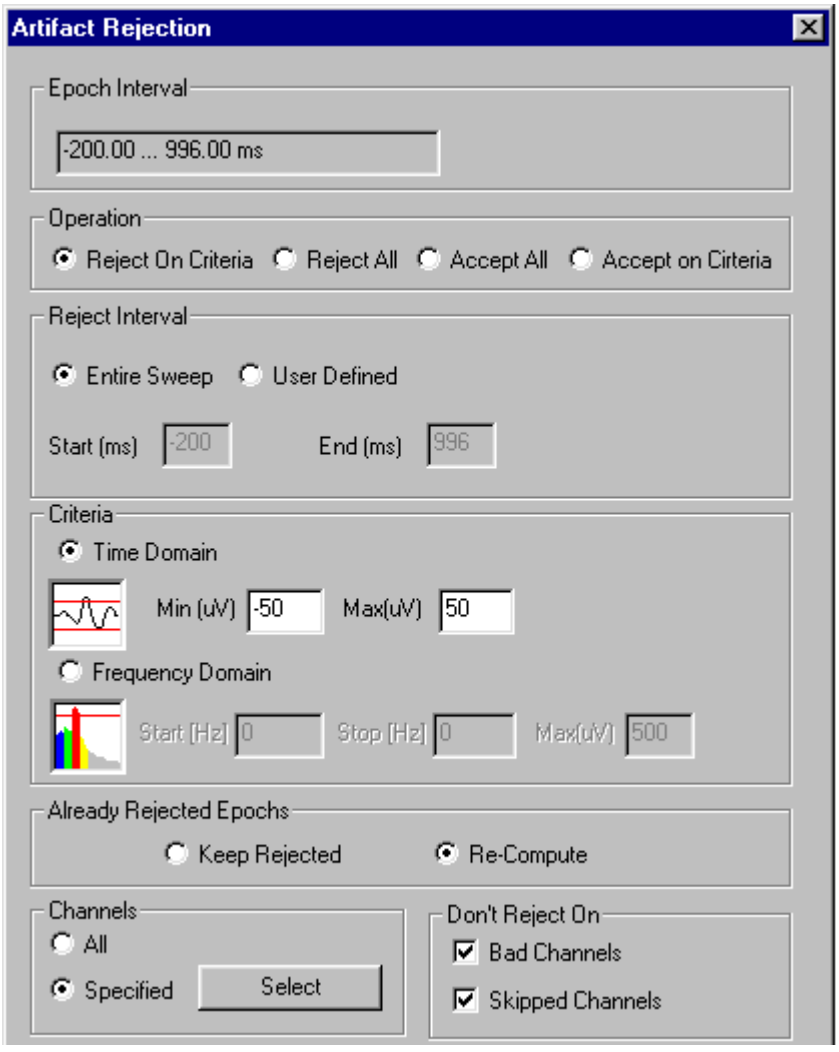
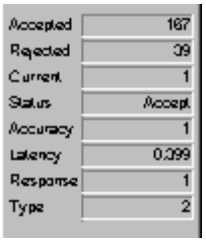
As in the P300 example above, set the Baseline Interval to use the pre-Stim Interval, using All channels, and click OK. Enter a file name and click OK. A bar will show the progress of the transform and new file creation. When it is completed, you will see another Multiple Window Display with the first sweep of the baseline corrected data file.

Next, we will scan automatically for any remaining artifact. Make sure the focus is on the baseline corrected epoched file, and then click Transforms\Artifact Rejection. The Artifact Rejection window will appear. Enter the settings as shown, where we will Reject On the Criteria, use the Entire Sweep,



reject any sweeps with voltages in excess of +/- 50 uVs, Re-compute any sweeps that were rejected already, look at Specified channels (exclude the VEOG channel; see the previous tutorial for how to do this), and not reject on the basis of Bad or Skipped channels. Click OK to begin the artifact scan. A bar will show the progress of the scan. When it is completed you will see the number of accepted

and rejected sweeps in the status box.

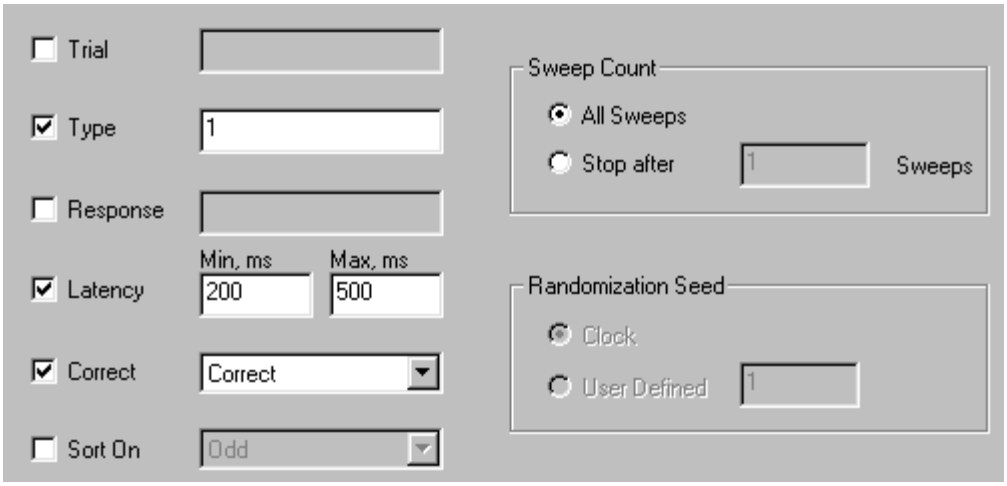


Step 7 - Sorting and construction of averaged waveforms - The last step is to sort the different single-sweep types (1 and 2) into separate averages, much as we did in the P300 example above. Follow these steps to construct averaged waveforms:

Click on Transforms\Average, and the Averaging window will appear. All we are interested in for this example is that it is set for the Time Domain, and the Sort Criteria button.

Before we begin averaging, we need to set the sort criteria to select the sweeps of interest. This is determined by the values in Sort criteria dialog box. To display this dialog box, click the Sort Criteria, and the Sorting Criteria window will appear. These values determine inclusion criteria for the average.

In this example, we need to sort on the different type values corresponding to trial types in the sustained attention task. Type values of 1 correspond to the target stimulus (digit 0). Type values of 2 correspond to the distractor stimuli (digits 1-9). In addition, since this is a behavioral task in which the subject was required to make a decision, we are interested primarily in correct responses that are within a short response interval after the stimulus was presented. Late and incorrect responses may reflect other underlying processes and should be analyzed separately.



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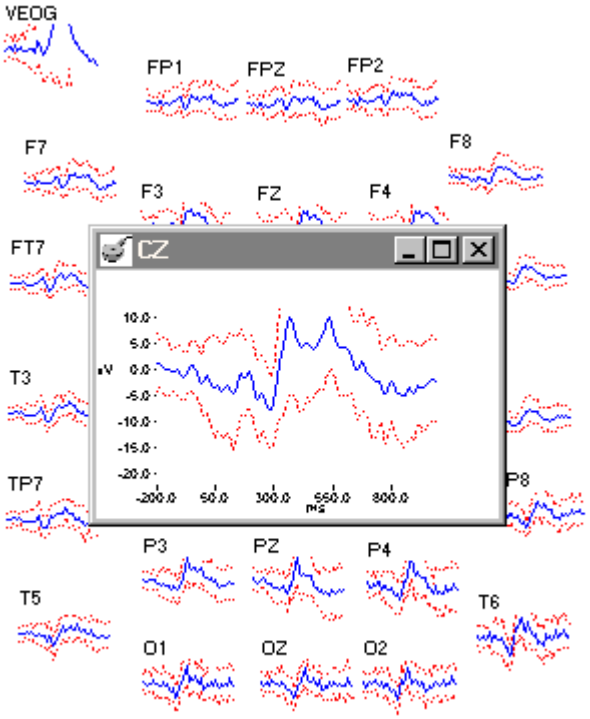
We will average the "target" responses first, so enable the Type field (so that a check mark appears), and enter a 1 in the Type field. To set the latency range, click the Latency field and enter the Min. and Max. acceptable latency values (200 - 500 ms) . Only those sweeps that fall within this range will be accepted. Next, enable the Correct field and select "Correct" from the pull-down menu (if needed). Sweeps that are tagged as correct will be accepted. Set Sweep Count for All sweeps.

Click OK and the Averaging display will reappear. In this example we want the Compute Standard Deviation field ON 

. This means that the standard deviation will be computed and stored for the average.

Enter an output file name (TARGET), and click the OK button to initiate averaging. You will see the progress bar in the center of the screen as the averaging begins. The averaged waveform will appear in a new Multiple Window Display. The averaged waveforms initially may appear to be low in amplitude. This is because the display is still set to the original scale factor used with the single sweep EEG file. The most convenient method to scale your waveforms is to use the autoscale option  located on the Toolbar. Click it, and waveforms for the target stimulus will be displayed with the new minimum and maximum values shown below.



Your screen should now display the above target waveform. The dotted lines above and below the

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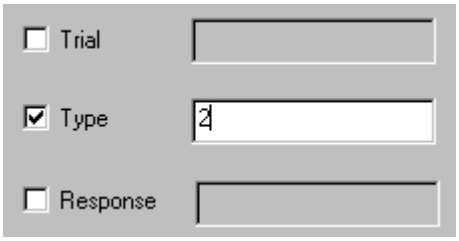
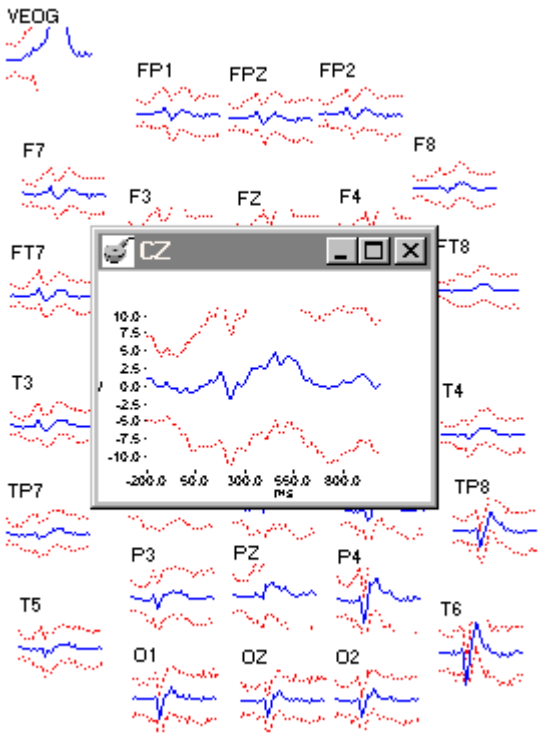
waveforms indicate the +/- 1 SD values. The TARGET status box will show how many sweeps were actually averaged.

Finally, we will construct the average to the distractor stimuli. Switch the focus back to the original single-sweep file window (by highlighting its title bar), and repeat the process that you used to construct the TARGET stimulus average. Click Transforms\Average and the Averaging window will appear. Click on the Sort Criteria button and enter 2 in the Type field. The Latency and Correct fields are not relevant, since the subject made no responses to these stimuli. Your display should match the one shown below. To begin averaging click OK, and the Averaging window will reappear. Enable the Compute Standard Deviation option again, and click OK to begin averaging.



At the completion of the averaging process, you will see a Save File utility. Enter a File Name (DISTRACT), verify the path and click OK. A new Multiple Window Display will appear containing the averaged data. Click the autoscale button to scale the data.



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The waveforms displayed above are the average responses to the distractor stimuli. In this particular subject there is a larger response on the right than left to the distractor stimulus. Also, the large P300 response that was found to the target stimulus is absent. To see the files together, make sure one of the two average files has the focus, and close the other one. Click the right mouse button anywhere in the open average file between electrode displays, and select Load Comparison File. An Open File display will appear, in which you may select the other average file (that you just closed). The second file will be superimposed on top of the first one.

Note: if you save the average file again at this point, the autoscaled values will be saved with the file, and you will not need to autoscale it again the next time you retrieve it.

This concludes the VISCPT continuous file tutorial. The final product of the processing steps are two waveforms. These waveforms are stored in separate files named 'TARGET' and 'DISTRACT'. Please save these files. They will be used in later tutorials for mapping and statistical analyses.

Spectral analysis - A continuous EEG recording

This section illustrates a variety of different types of spectral transforms that can be performed in EDIT. A 32-channel continuous EEG recording with the eyes closed will be converted from the time to the frequency domain in a number of different ways.

In this tutorial you will:

- ☐ Create an single-sweep epoch file from the continuous file
- ☐ Create an ensemble spectral average
- ☐ Create a single-sweep file in the frequency domain
- ☐ Compute the EEG coherence between electrode pairs

We will use a file named closed.cnt as a basic starting point for these different types of transforms.

Follow these steps to retrieve the closed.cnt data file:

Step 1 - Converting from continuous to epochs - Click on File\Open data file, or click the Open data file icon  , and select the Neuroscan Continuous File type.

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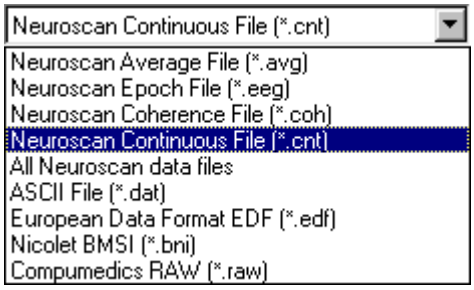
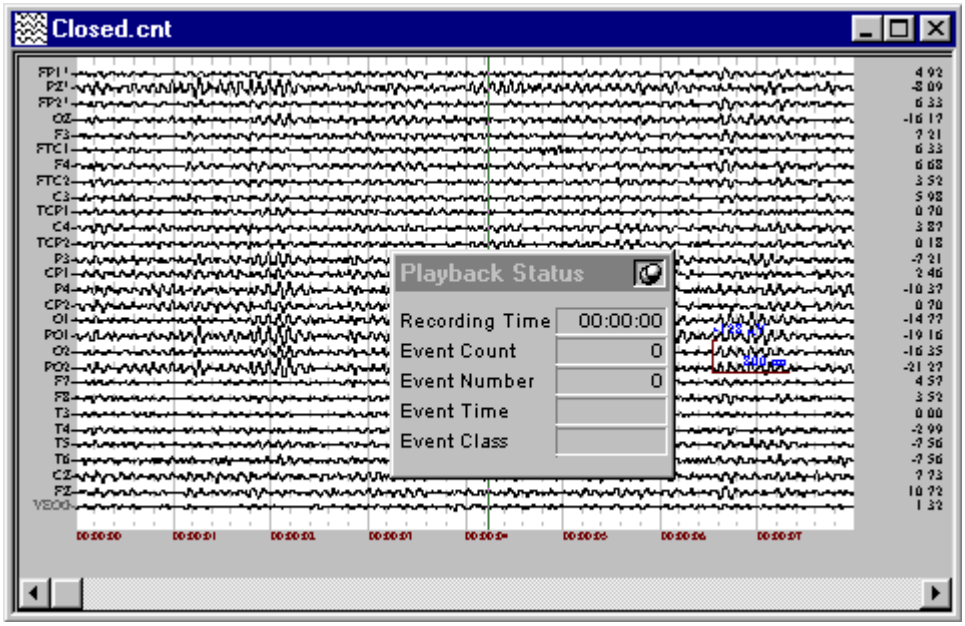


Select the Closed.cnt file from the Scan4.3\Demo\EEGs directory.

The single window display containing the continuous data will appear. Use the Up or Down arrows , or the autoscale icon , as needed to scale the display appropriately.



The closed.cnt file was collected from a 25 year-old male with 28 EEG leads and 1 ocular lead to monitor blinks and eye-movement artifact. Amplifier gain was set at 500 (16-bit resolution on a SynAmps) with a band pass of 1 to 30 Hz and was digitized at 500 Hz. The epoch displayed on the screen represents an 8 second section of the continuous file.

At this point you should go through the ocular correction algorithm and editing that was described in the previous tutorial. This particular file, however, is a short recording that does not contain any obvious artifact. In the interest of expediency we will forego the normal preprocessing steps and immediately convert this file into a single-sweeps epoch file:

Click the Transforms\Epoch File option, and the Epoching Properties display will appear.

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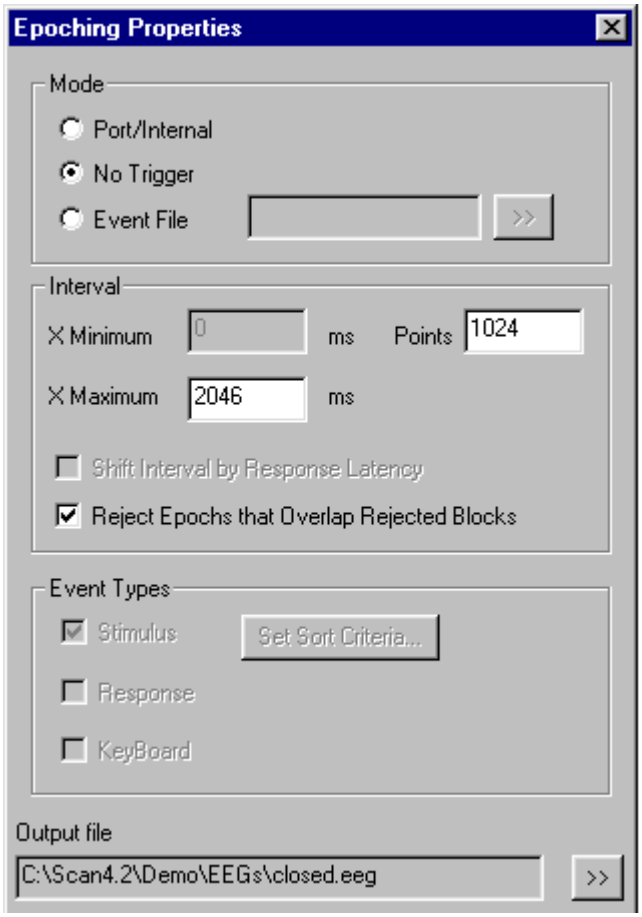
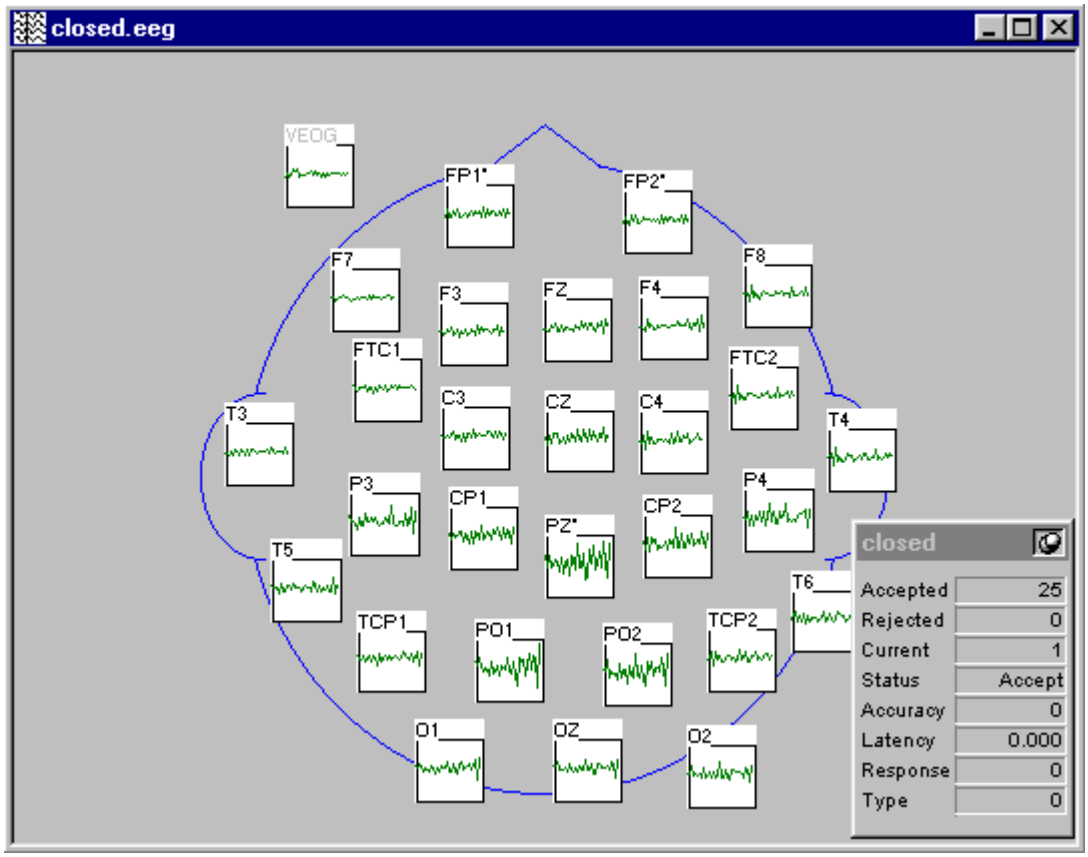


Select the No Trigger mode. This option will create back-to-back epochs with no gaps from the continuous file. Set the number of Points to 1024. We have selected a number of points that is a power of 2. This is a requirement of the Fast Fourier Transform (FFT) used to convert data into the frequency domain. We selected this number so that it would provide a long enough interval (2 sec) to resolve the lower frequencies of the EEG. After entering the Points, click in the X Maximum field, and the end point of the epoch will be computed automatically (based on the A/D rate). Enter a file name for the output file.

Examine your Epoching Properties display to make sure it matches the above values and click OK to begin epoching. A Multiple Window Display will appear showing the first sweep of the epoched file.



This epoched file can now be submitted to a variety of spectral transforms described below.

Step 2 - Ensemble spectral averaging - An ensemble spectral average is created using a series of processing steps. First, time domain EEG epochs are windowed and converted into the frequency domain using an FFT algorithm. Second, power spectral estimates are computed from the real and imaginary results of the FFT. Third, the power spectral estimates are averaged together. Ensemble averaging of spectra generally will improve the accuracy of the estimates of EEG frequency assuming that the EEG spectrum is relatively stable and is not in flux, as is the case of changes in wakefulness. For example, if the power spectrum is computed on a single-sweep, the variability of the estimate will be equal to the estimate itself. Variability decreases proportionally to the number of sweeps in the average. The more sweeps, the better the estimate of spectral composition. If your EEG is relatively stable over a series of discrete epochs, a valid method to estimate EEG frequency content is to average in the frequency domain. Follow these steps to create an ensemble spectral average:

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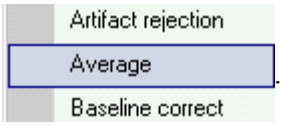
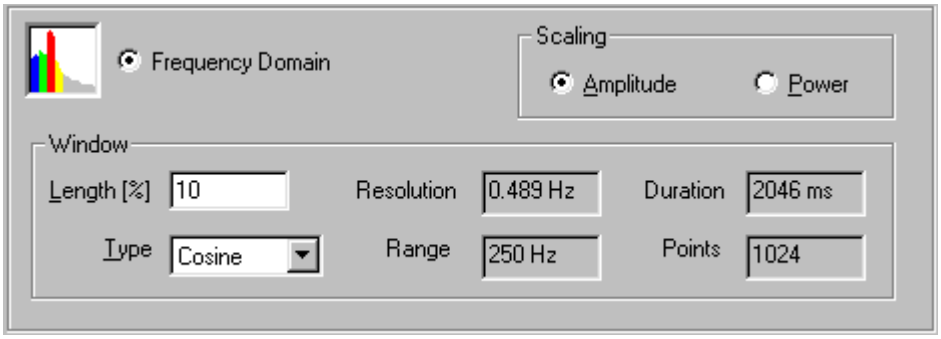
Click on Transforms and select the Average option 

. The Averaging window will appear. Select the Frequency Domain field. This performs the time to frequency mode conversion at the time of averaging. Below is the Frequency Domain section of the Averaging window.



Note there are additional fields for Scaling, Windowing, and some general information.

Scaling - The scaling field determines how the power spectrum is computed. Two options are supported: Amplitude and Power. The Amplitude option takes the square root of the power spectrum to express the units in microvolts. The Power option computes a standard power spectrum with values expressed in microvolts squared.

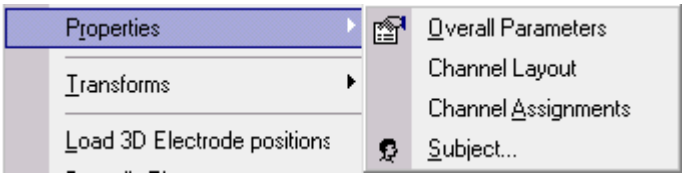
Window - The Window type field is used to taper the ends of the epochs to control spectral leakage. The Window Length [%] determines the extent of the taper (when set to 10%, for example, the beginning and ending 10% of the epoch will be tapered. The Type of windowing determines whether a Cosine, Hamming, Hanning, Parzen, Welch, or Blackman window is employed.

For this example, set the Scaling field to Amplitude, window Type to Cosine, and set the window length to 10%.

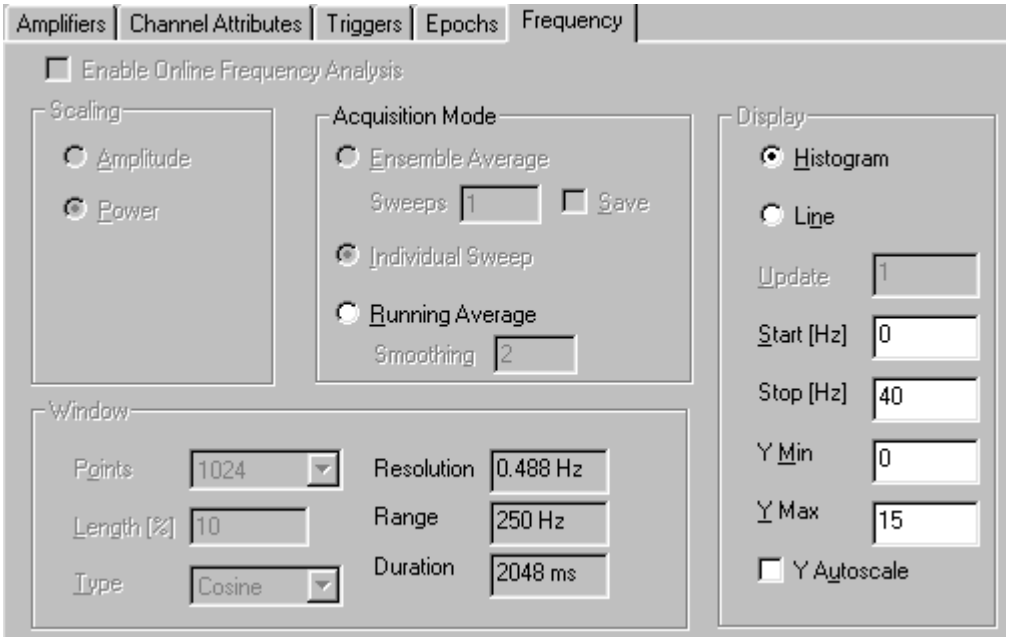
Click OK and a Save File utility will appear. Enter a file name, designate a path, and click Save. You will see a progress bar increment as the transform is applied. *Note - averaging in the frequency domain is slower than in the time domain since an FFT must be computed for each electrode single-sweep waveform for all sweeps.*

Upon completion of spectral averaging, you will see a new Multiple Window Display with the power spectra displayed at each electrode site. The range in frequency of this spectrum will be from 0 to 250 Hz. corresponding to half the sample rate of 500 Hz. (Nyquist sample theorem). The range of this spectrum (250 Hz) is well beyond what is needed for simple EEG and we can narrow the display range by modifying the display range variables located in the acquisition values screen. Follow these steps to narrow the display range from 250 to 40 Hz:

With the right mouse button, click anywhere in the Spectral Data display, except within an electrode channel display. You will see a list of options. Select the Properties option, and you will see a second list of options.



Note that these options are very reminiscent of settings you made when you created the setup file in ACQUIRE. Select the Overall Parameters option, then the Frequency tab. Make the following changes in the Display area.



Instead of the line display, select the Histogram option. Change the Stop field to 40 (to display only the lower frequencies in the spectrum), and change the Y Max. value to 15, to adjust the scaling. Then click OK. You should see something similar to the display below. *Note: The actual data are not affected by these actions, only the display*.

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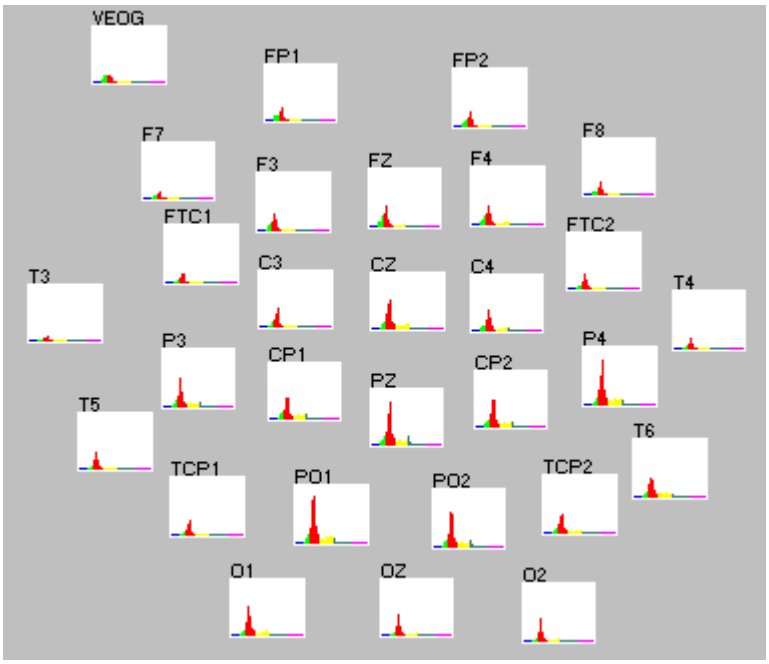
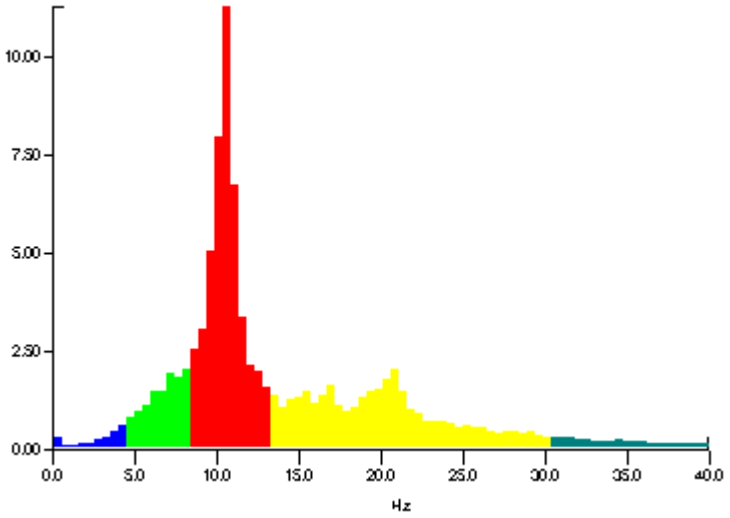


You can examine individual electrodes by clicking on the spectrum just as you have done for waveforms. Try clicking on the Pz electrode display to view the spectrum in more detail. The spectrum will appear as shown below (resize the window as desired).



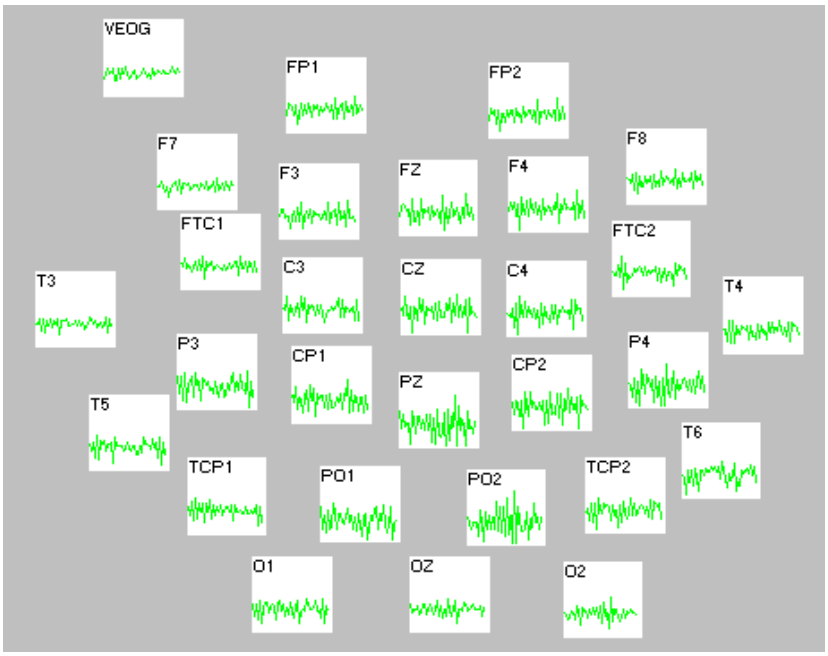
Step 3 - Creating a single-sweep file in the frequency domain - To create a single-sweep frequency domain file an FFT is computed for each individual electrode and sweep. The results are stored in a manner identical to the time domain file version except that data is displayed and stored in

the frequency domain. This transform is useful if you would like to observe changes in EEG spectra over a period of time, such as in a sleep study or an evoked potential following a response.

Follow these steps to convert the closed.eeg single-sweep file from the time to the frequency domain:

Retrieve the closed.eeg file by clicking on File/Open, or click the Open data file icon . Select the Files of type field to Neuroscan Epoched (*.eeg), and select the closed.eeg file.

The first sweep of the epoched file will appear.



Next, click on Transforms and select the Forward FFT option. You will then be asked to provide a name and path for the Output File. Enter these and click Save to create the single sweep FFT file. A progress bar will track the computations, then you will see a new Multiple Window Display with the power spectra for each channel. Use the arrows icons on the Toolbar to step through the file.

The power spectra are computed for the entire frequency range (250Hz in this example). To reduce the display of the frequency range, click the right mouse button between the electrode channel displays, and then select Properties. Click Overall Parameters, and then the Frequency tab. In the Display area, change the Stop [Hz] value to 50, and click OK. The results should look similar to the figure below.

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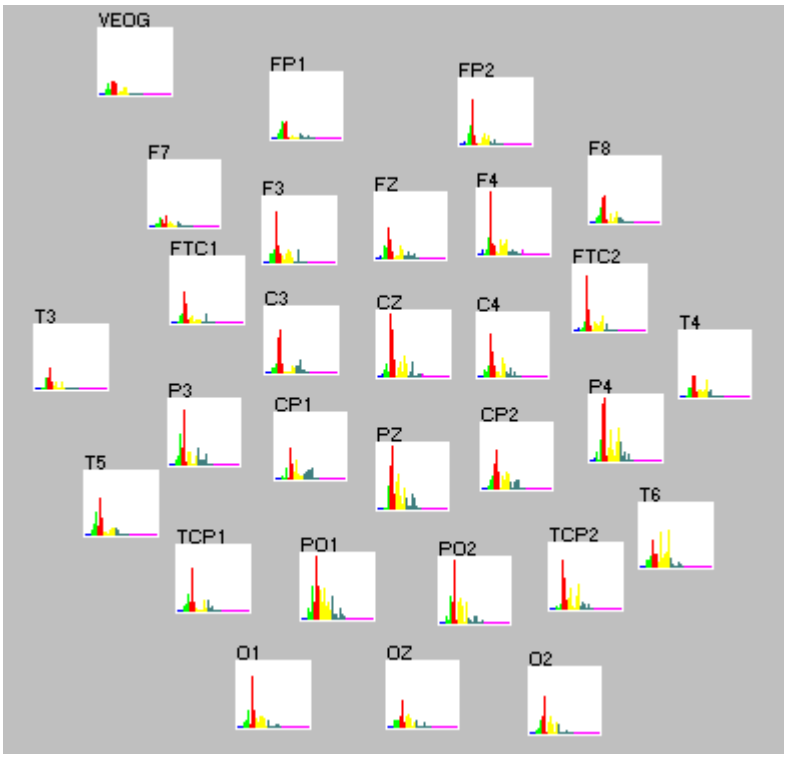
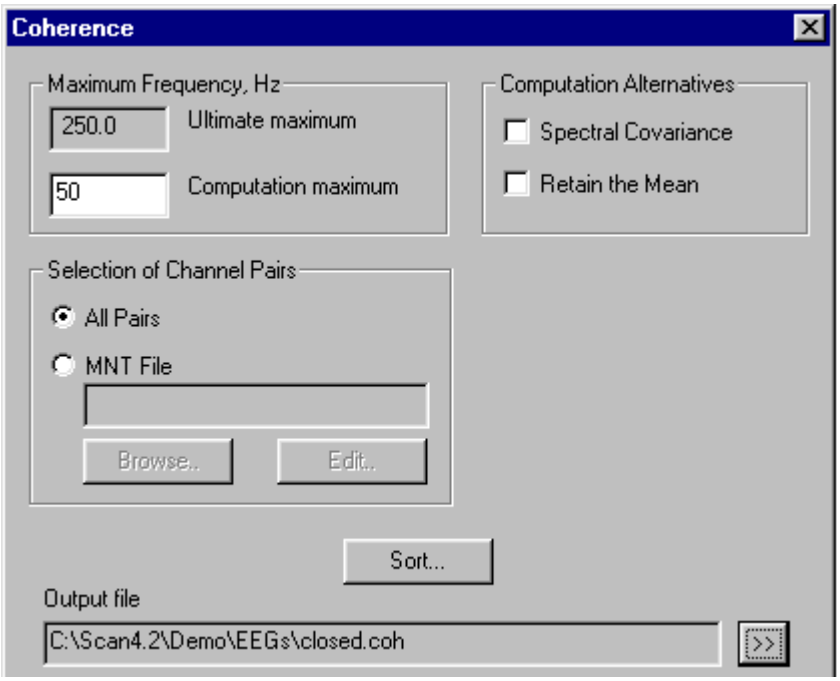


To restore this file to the original time domain file, select Inverse FFT from the Transform list. You will be asked for a file name and path for the restored EEG file. Enter these and click Save. You will then see a new Multiple Window Display with the original wave form data in it.

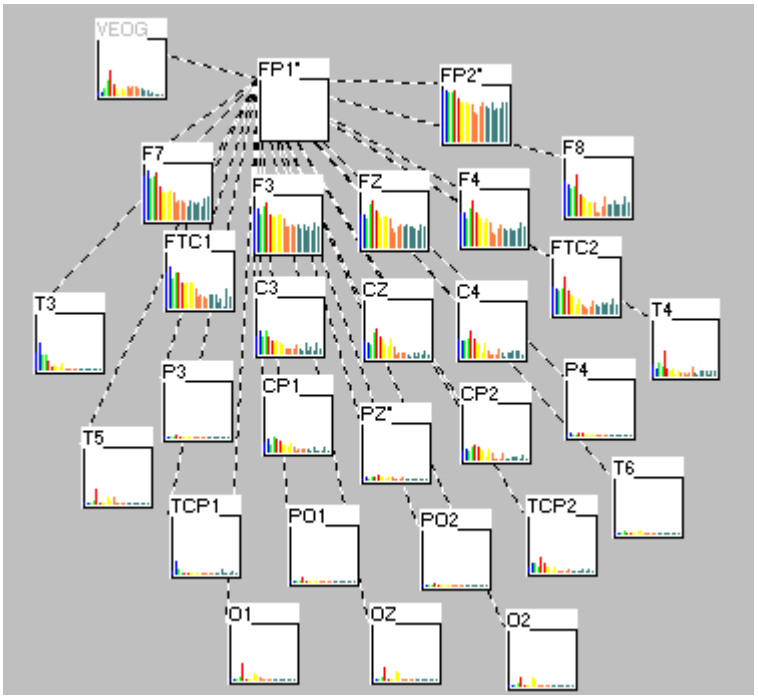
Step 4 - Computing the EEG coherence between electrode pairs - Coherence analysis provides a method to examine relationships between the EEG recorded at different electrode sites. It is well known that some proportion of an EEG signal recorded at one electrode can be dependent on the signals recorded at another site(s). Coherence is a measure of this interdependence. A simplified way to view coherence is that it is the correlation between an electrode pair within the frequency domain. The result of a coherence analysis is a complex correlation spectrum. The complex correlation spectrum, when squared, generates the coherence spectrum which has numbers ranging from 0 to 1. 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 two electrode pairs.

We can illustrate the use of coherence analysis by analyzing our closed.eeg file. Follow these steps to compute a coherence spectrum:

Retrieve the closed.eeg file, and then select the Coherence option from the list of Transforms. The Coherence display will appear.



For this demonstration, we'll use the default values, with one exception. Change the Computation Maximum to 50 (Hz). This will compute coherence up to that frequency, using all pairs of electrodes. Click OK to continue. A progress bar will track the computation, and you will then see a standard Save As display. Enter a file name and designate the folder (the .coh extension will be added automatically). Click Save and you will then see a new Multiple Window Display showing the coherence results.



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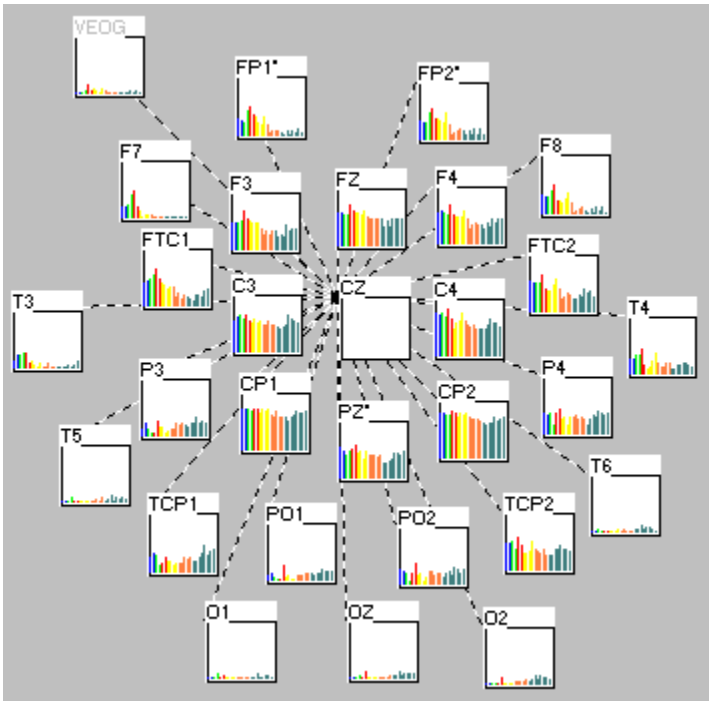
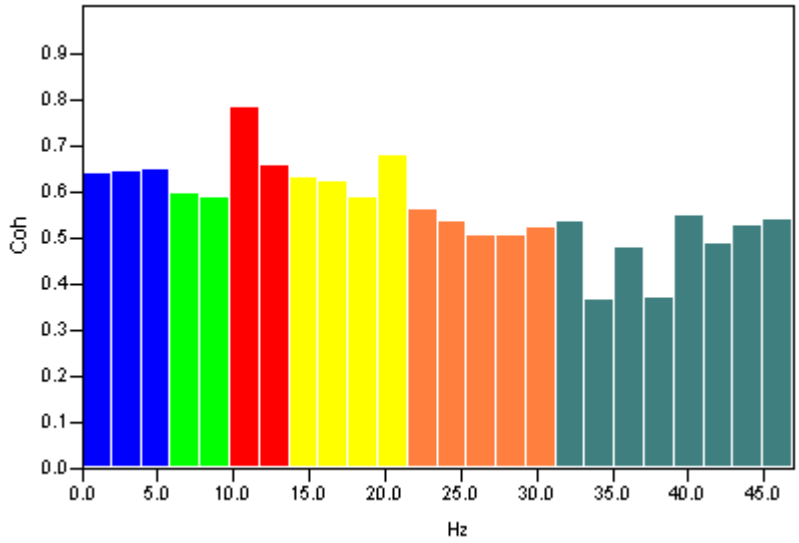
The coherence spectrum is the result of pairwise comparisons between electrodes. To display this relationship in the data, a series of dotted lines are drawn from the current comparison electrode to all other electrodes to which it has been compared. Since we chose the *ALL* option of the electrode pair field, lines have been drawn to all other electrodes from the current comparison electrode. The starting comparison electrode is defined as the first electrode in the electrode table. In this file that electrode happens to be FP1, so lines are drawn from FP1 to all other electrodes. To change to a different electrode, position the mouse over another electrode, such as CZ, and click the right mouse button to access a list of options. Select the Set Coherence Reference option, and you will see dotted lines drawn from CZ to the other electrodes.



As a general rule, coherence values will always be greatest from the electrodes that are closest to the reference electrode.

Now, double-click the left button on an electrode display (such as FZ) to enlarge it to full size.



If your colors look different, these are controlled by settings under the Options menu. Click Options, then the Multiple Window Settings. Click the General tab, and the Frequency Bands button. From this screen you may modify the frequency band limits and colors.

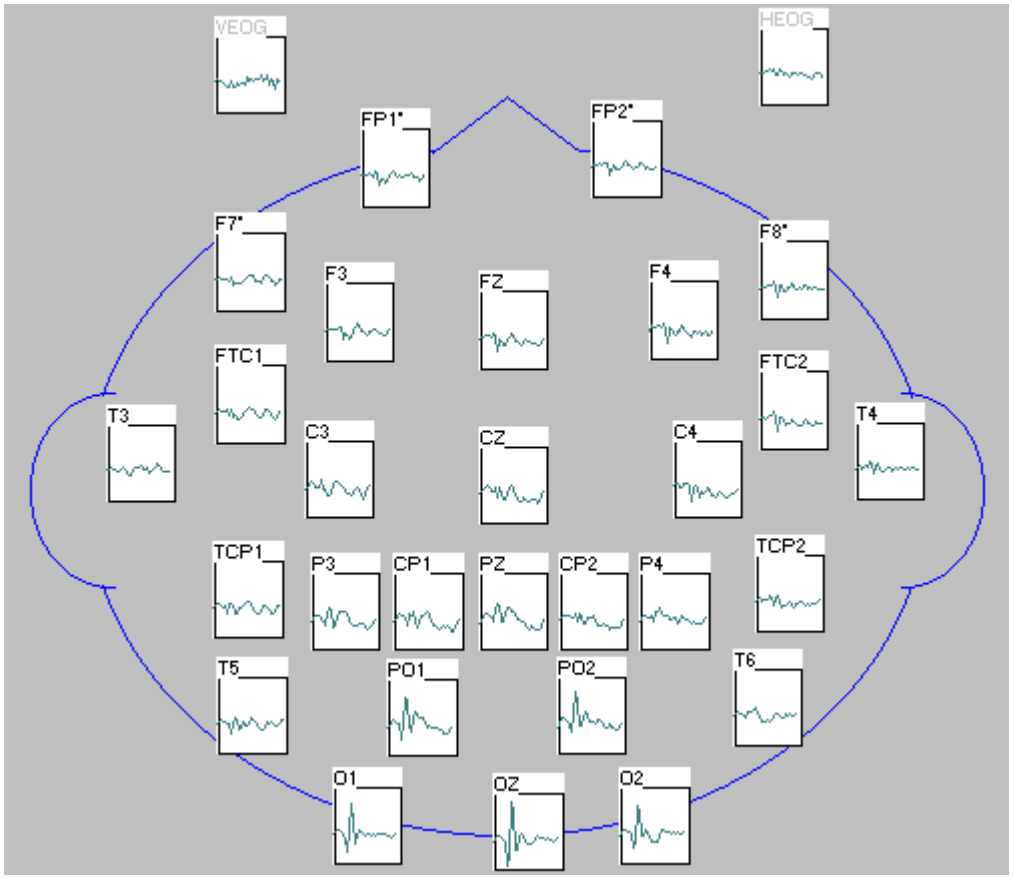
2D Topographical Mapping

SCAN 4.2 (and later versions) includes several ways to map your data. If you are using conventional electrode labels (from the 10-20 and extended system), EDIT will map the data using an internal mapping scheme. If you have different labels, or if you want to modify or create your own mapping template, you should refer to the MapGen appendix at the end of this manual. The mapping features in EDIT include:

- The ability to pick single points on a waveform, and display the data on a 2D map.
- The ability to generate a "cartoon" of maps, that is, a sequence of maps that display data over a specified time range.
- Several choices in the colors scheme used in the 2D maps.
- The ability to map your data on a 3D head shape.

For this tutorial we will touch upon some of the more common aspects of mapping in EDIT. The *Operating EDIT* section below contains a complete description of all of the features. In this example we will use the vep.avg demo file that is contained in the c:\Scan4.3\Demo\Veps directory.

Step 1 - Open the EDIT program by clicking the EDIT icon  from the Program Launcher. Click File\Open data file, and set the Files of type field to Neuroscan Average (*.avg). Go to the \Scan4.3\demo\Veps directory, select the vep.avg file, then click open. The VEP average file will appear.



Double click on the OZ electrode. This will make it a full size window (it must be mid- or full-size to continue). If the waveform is clipped, click the Autoscale icon on the Toolbar  . The result should appear similar to the figure below. (Click the  icon to invert the waveforms, if desired).

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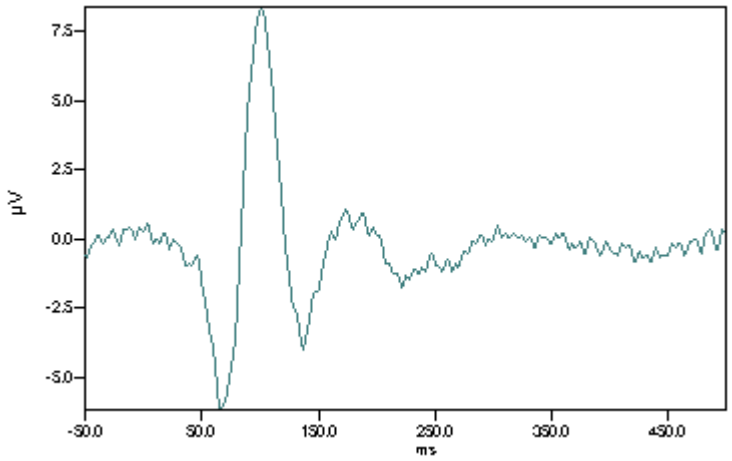
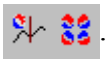
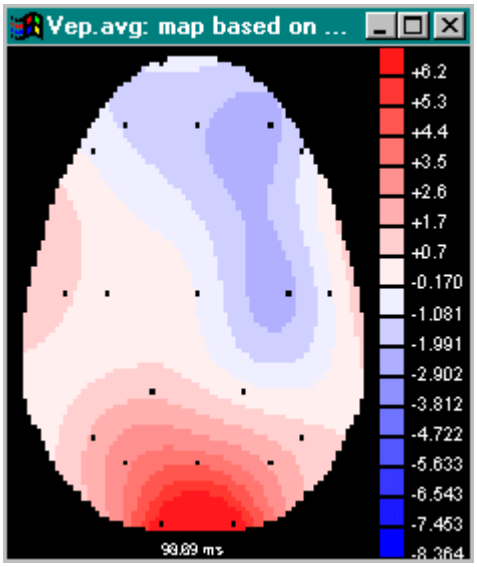


On the Toolbar there are two icons that we will be using with this file  . The first is used for 2D mapping, and the second for 2D cartoons. Click the 2D mapping icon. You will see a color scale appear to the side of the Oz waveform, and the 2D potential map window will also appear. (Click Windows \ Tile Vertical to place the waveforms and map display side by side).



As you move the mouse around in the waveform display window, you will see the map change according to the time point where the mouse cursor is placed. If the map does not change as you move the mouse, right click inside the mapping display, and select the Use Map Tracking option.

The default map file that EDIT uses is an internal mapping template consisting of 77 electrodes from the 10-20 system and extended system. This file does not contain all of the positions used in the vep.avg file; however, it will map the channels that have labels that match the internal mapping template. To map all of the channels, you would need to create a .map file in MapGen (see the

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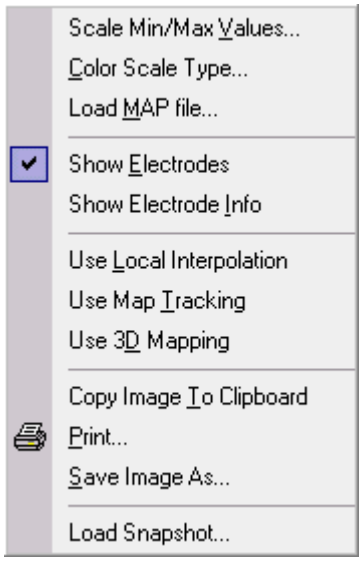
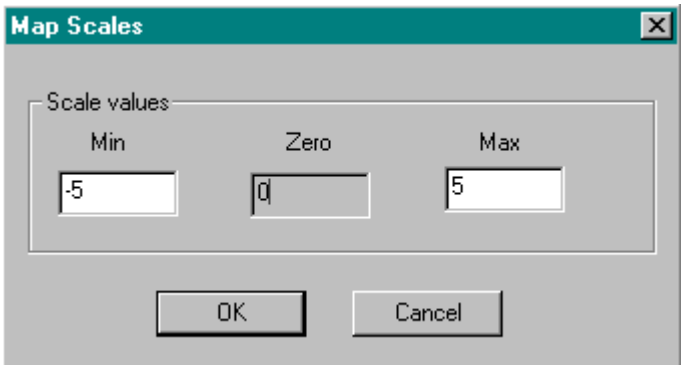
appendix at the end of this manual) where the labels in the .map file match the labels in the data file. There can be fewer channels in the map file, but the labels that you use must match channels in the data file. If you use a different data file that does not match the internal mapping template, you will not see any colors or dots for the electrodes in the 2D potential map display, and see an error message. Using the vep.avg file and the internal mapping template, position the mouse anywhere in the 2D potential map display, and click the right mouse button. You will see the following list of options. Select the Scale Min/Max Values... option. This will allow you to change the scaling of the map to get a better range for the colors.



You will see the Map Scale display. Enter the Min and Max scaling values, as desired. Entering -5 and +5 will give a better display.



The rescaled map will look like the following. You will need to reposition the mouse over the waveform to see the new scaling.

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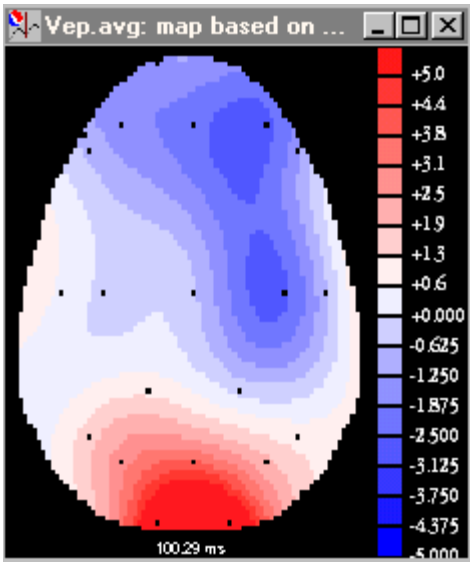
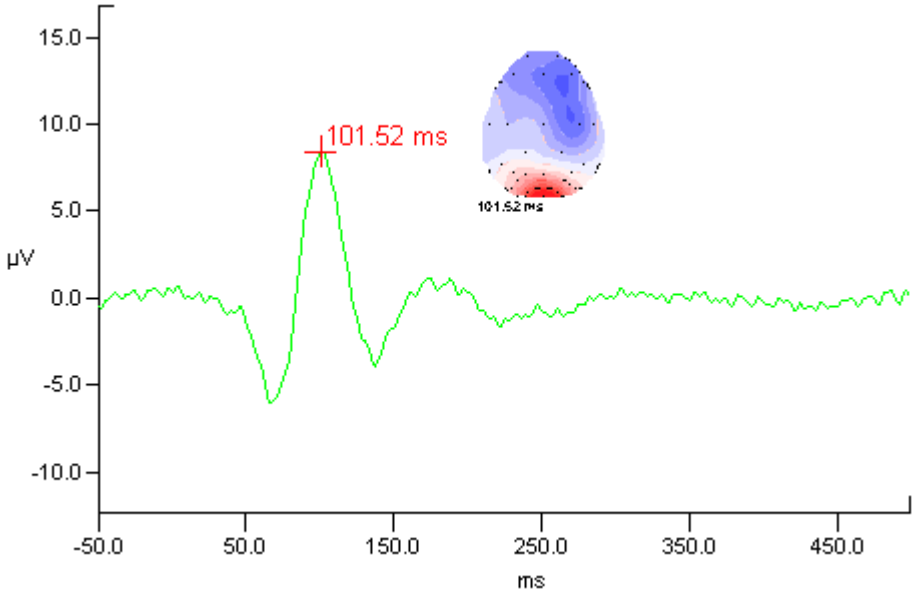


Step 2 - Now move the mouse into the waveform window again. As you move the mouse near the waveform, you will see an additional "head" drawing become part of the cursor. You will also see a vertical hash line appear on the waveform, showing the exact location of the point being displayed.

Now we'll create a 2D map of the peak P100 response. This occurs at approximately 101.5 ms in this subject. Position the mouse at the peak of the P100 component, so the additional "head" indicator appears, and click and hold the left mouse button. A black rectangle will appear. Holding the left mouse button down, drag the rectangle to a clear part of the display, and release the left button. A 2D map will be dropped at that position.



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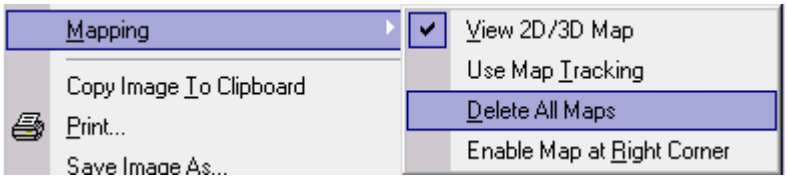
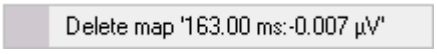
If you scaled the waveform using the Autoscale feature, the top of the millisecond marker will likely be cut off. Click the down arrow on the Toolbar to reduce the display scale. You can map additional points as you desire (up to 25 maps). To remove the maps that you have created, click the right mouse button inside the waveform display, and select the Mapping option.

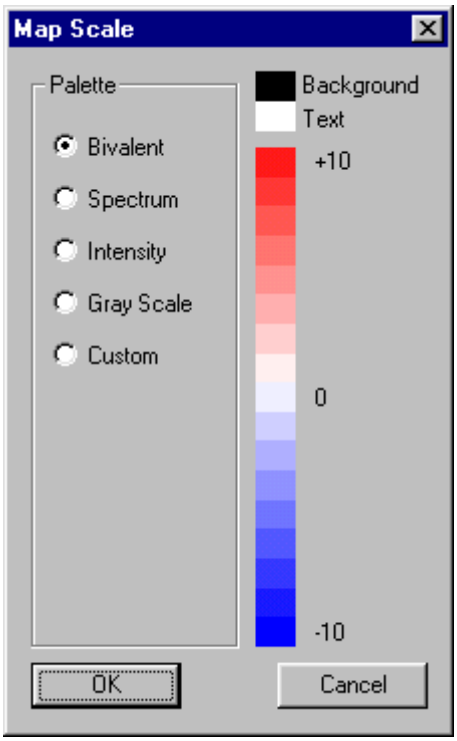


Click the "Delete all maps" option, and the maps will be deleted. To deactivate the 2D mapping feature, click the right mouse button again, and deselect the View 2D/3D map option. Reselect it to reactivate it. To delete a single map, position the mouse over the map and click the right mouse button. The following display will appear. Select the Delete map 'time point'.



Shown above is one color scheme for mapping. There are several others. Change the focus to the 2D potential maps window, position the mouse cursor anywhere in the display, and click the right mouse button to access the menu as shown above.

Click on the Color Scale Type... option, and you will see the following screen.



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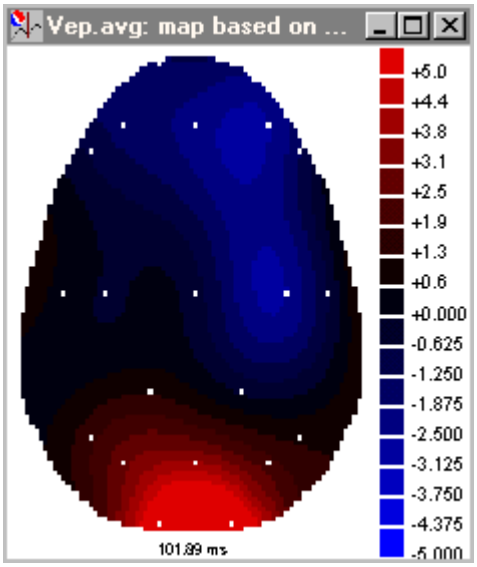
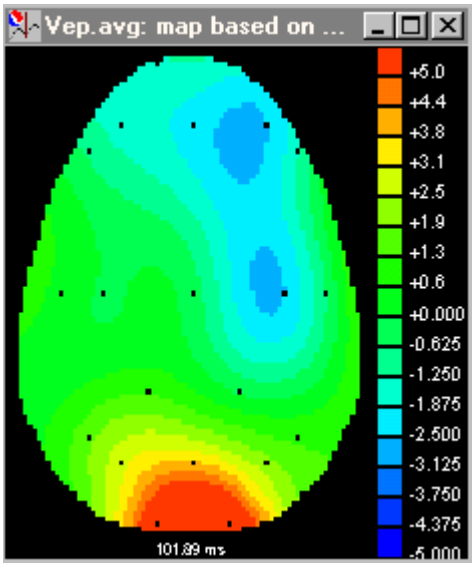
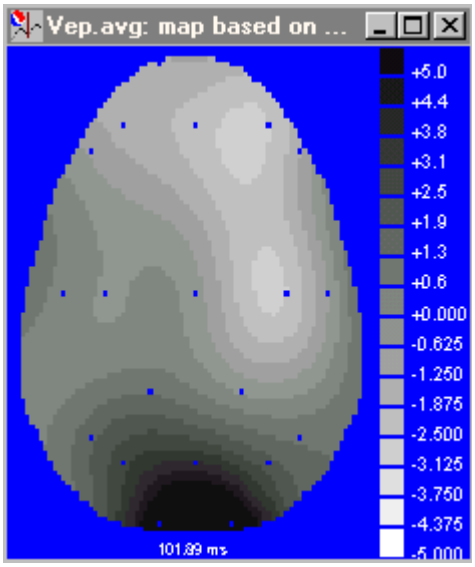
The scheme we have been using is Bivalent (two color; blue to red). Click the Intensity radio button, and click OK. The resulting map will be similar, with black and white being reversed.

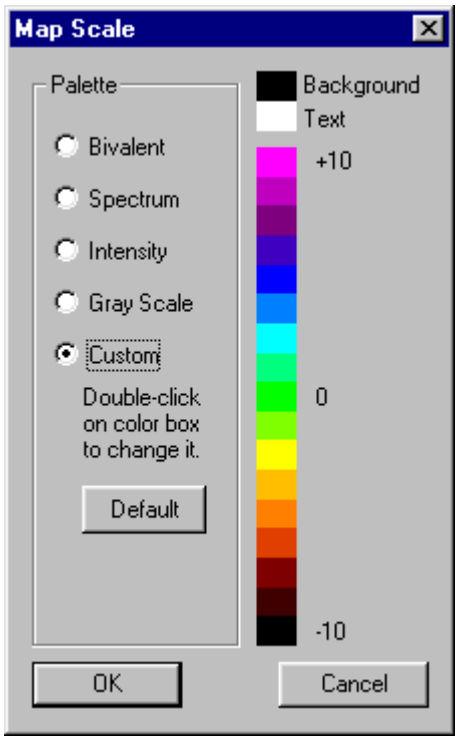


Right click again, and select the Spectrum and Gray Scale options.



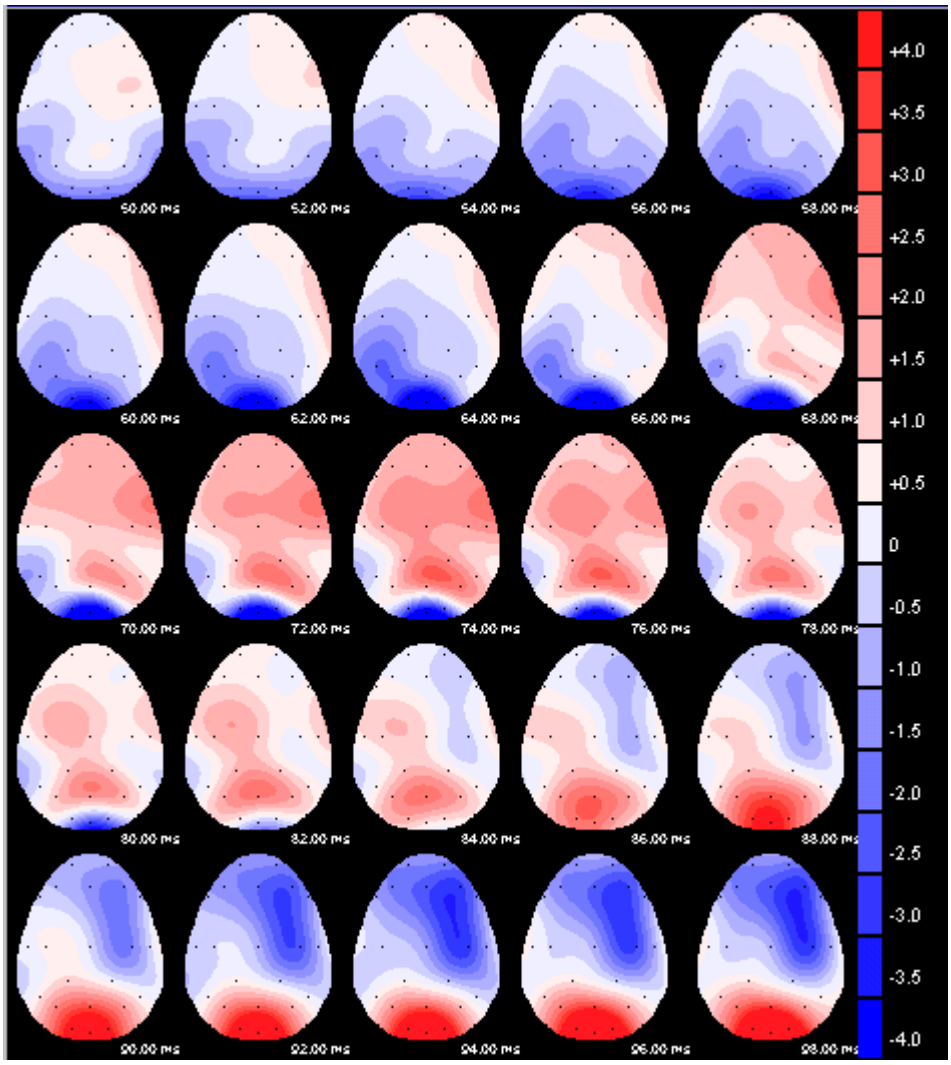


You can create you own color scale by clicking the Custom option. Then double-click any of the colors to see the colors palette, from which you may assign any desired color.



Step 3 - Next, will create some cartoon maps. First, let's clear all the maps so far. Click the 2D mapping icon to close its function, and delete all maps (right click and select Delete all maps). Now click the 2D cartoon icon from the Toolbar. A series of maps will appear based on the default values in the 2D Map Cartoon Parameters display, which also appears.

Set the Start and Stop times in the 2D Parameters display to 50 and 150ms, to capture the most interesting part of the response. Set the Interval to 2ms to create a map for each 2ms span (in this example, the average of the 2 data points - there are data points every millisecond). Set the N Columns 1-10 and N Rows 1-10 to 5 and 10 to display the maps in a 5x10 grid. Set the Y Min and Y Max scaling values to - and + 4.0 uVs. Then click the Update 2D button to make the changes in the maps. The cartoon should like similar to the following:



Note that all of the different color schemes described above may be used with the cartoon maps.

Step 4 - We will now print the screen and save it for other graphics applications. To print the cartoon screen, make sure that screen has the focus, then select Print... from the right mouse menu, or from under File, or click the standard Print icon from the Toolbar. The regular Print window will appear. Note that you have the option to Stretch the output to fit the page. Deselect it if you want the graphic to be displayed in its proportional size.

You may wish to save the image for inclusion in other applications running in Windows. Click the right mouse button in the cartoon display, and select the option called Save 2D Cartoon image... . A Save As... utility screen will appear allowing you to save the image as a Windows Metafile (the .wmf extension is added automatically). Metafiles may be inserted into a variety of document and graphic software packages.

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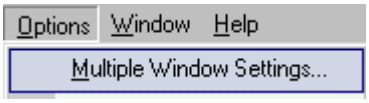
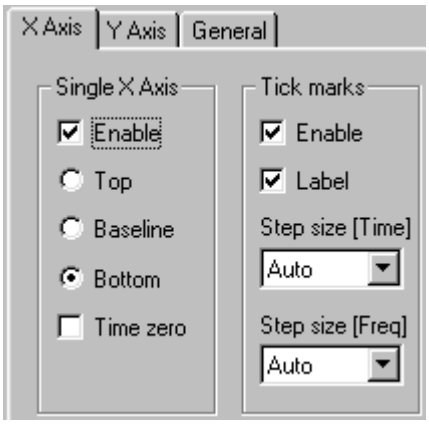
Step 5 - Lastly, this is a good place to discuss some of the display options. These are described in complete detail in the *Operating EDIT* section of the manual. Click the Options button from the main menu bar, and select the Multiple Windows Settings... line.

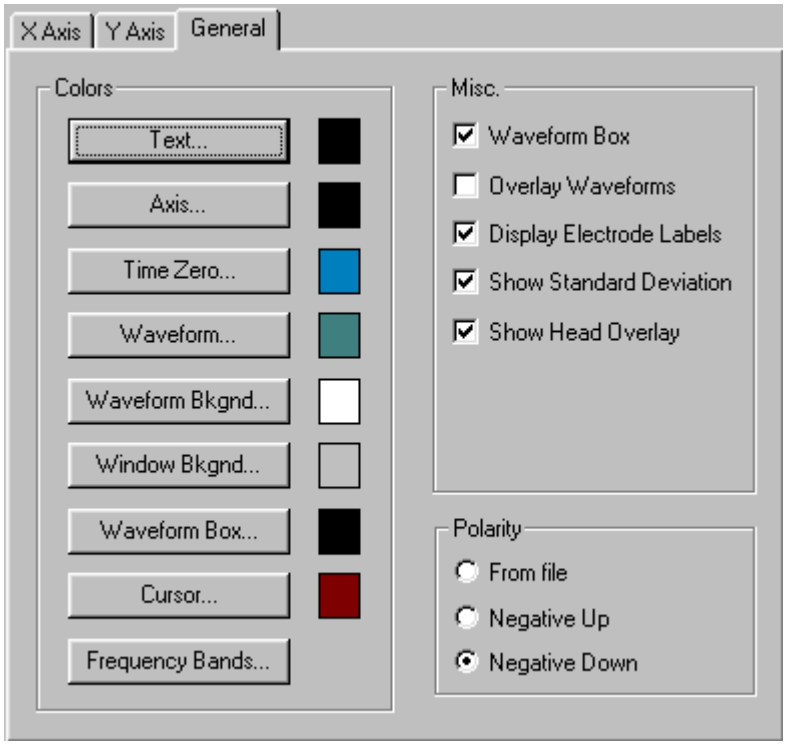


A Multiple Windows Display, in EDIT and ACQUIRE, is the type of display in which each electrode has its own window (e.g., AVG and EEG files). Continuous (CNT) files are displayed in a Single Window Display (all channels are in the same window).

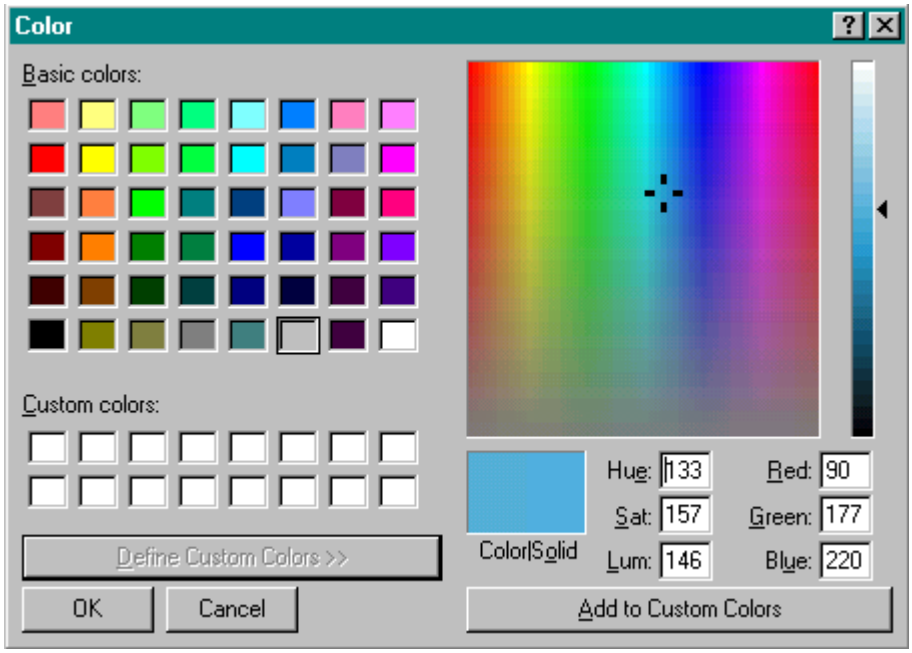
You will see the following screen.



For now, just click on the General tab to access the following options.



In these Colors fields you can select colors for the text, the axes, the windows backgrounds, and so forth. As a quick demonstration, click the Text bar, and a standard color palette will appear (shown with the Custom Color display).



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Select a color, and press OK. If you want to create your own color, click the Define Custom Colors>> bar, and select the color from the spectrum matrix. Click the Add to Customs Colors bar, and click OK. Then go through in a similar fashion and choose colors for the Waveforms, Waveform Background and Window Background. Click the Save As button, and you will see a standard Output File display. The changes you make are stored in the *.aws (workspace) file. Save the changes to the default.aws file, unless you wish to create a new one. Click OK when you are through. The next time you retrieve a Multiple Windows type of file, you will see the color changes. If you save the changes to the *.aws file, they will be applied the next time you enter EDIT.

In the tutorial above we demonstrated some of the mapping features in EDIT. There are additional options to perform Spectrum Mapping and mapping on a 3D head shape. These are described in more detail in the mapping section near the end of this manual.

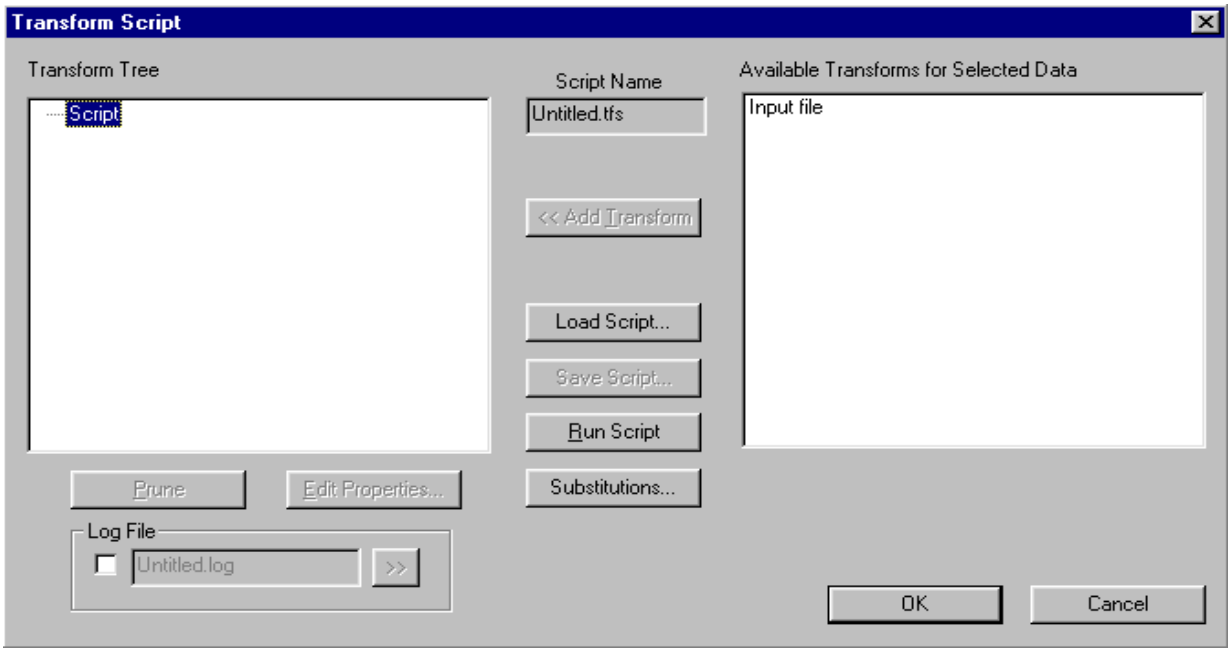
Scripting

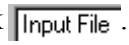
You will likely find when you are processing data files that you repeat the same operations over and over with different files. Beginning with SCAN 4.2, there are two ways to automate processing - Script files and Batch files. Batch files are described in the Tcl Batch Commands manual. In general, Scripts are perfectly adequate for many types of repeated operations. Batch files with Tcl (Tool Command Language) offer almost unlimited flexibility, and are somewhat more complex to master.

In this Script example, we will create a simple Script file that will be used to retrieve a continuous file, and then epoch it. We will then perform a Baseline Correction, refilter it, do an Artifact Rejection, and save the transformed .EEG file.

Open the EDIT program by clicking the EDIT icon  from the Program Launcher. Then click Transforms \ Script... 

. The Transform Script window will appear.



The Transform Tree area will display the Script as we create it. The Available Transforms for Selected Data area will display which transforms can be used at each step along the way. The Script Name field  will display the name of the loaded Script file. To start, click  . It will become highlighted, and the  button will become activated. (Double-clicking an available transform avoid having to click the Add Transform button). Click it and an Open Files utility window will appear. Change the Files of type field to Neuroscan Continuous (*.cnt), and select the closed.cnt file from the \Scan4.3\Demo\EEGs folder. At the bottom of the window, you will see an option called  . This option will appear on most Transform screens. When enabled, it means that a screen will appear during the execution of the script file (leave it disabled for this example). Then click Open. You will see the first step, or branch, of the Tree on the left display, and the next available set of options on the right side.

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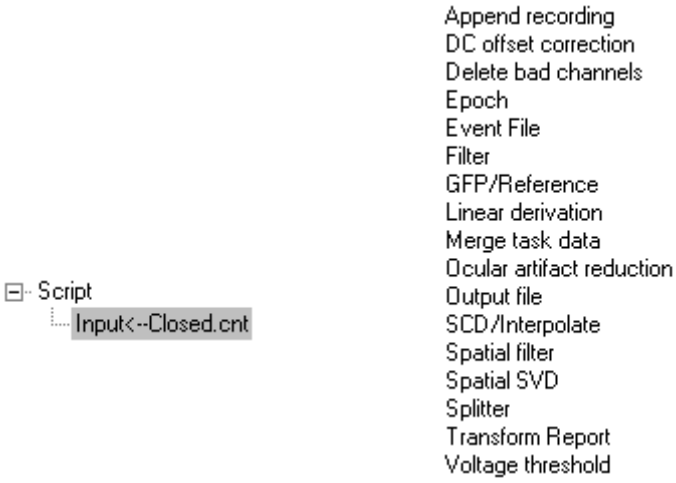
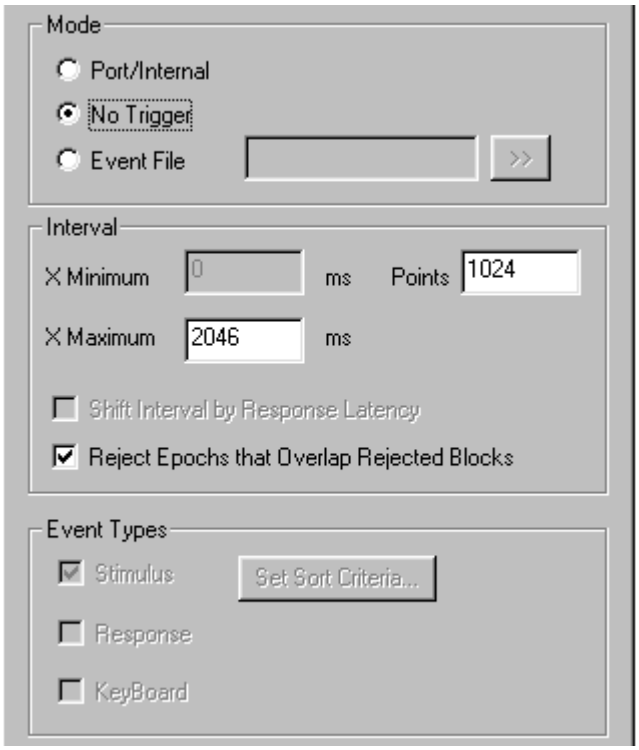
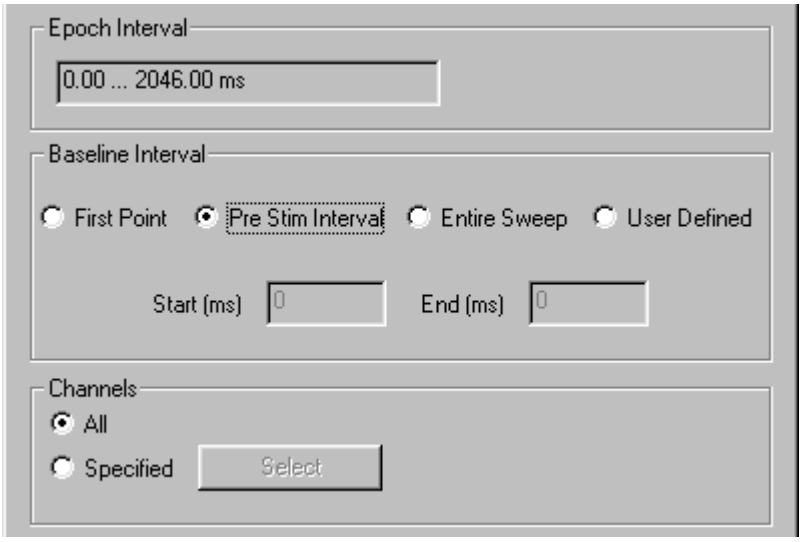


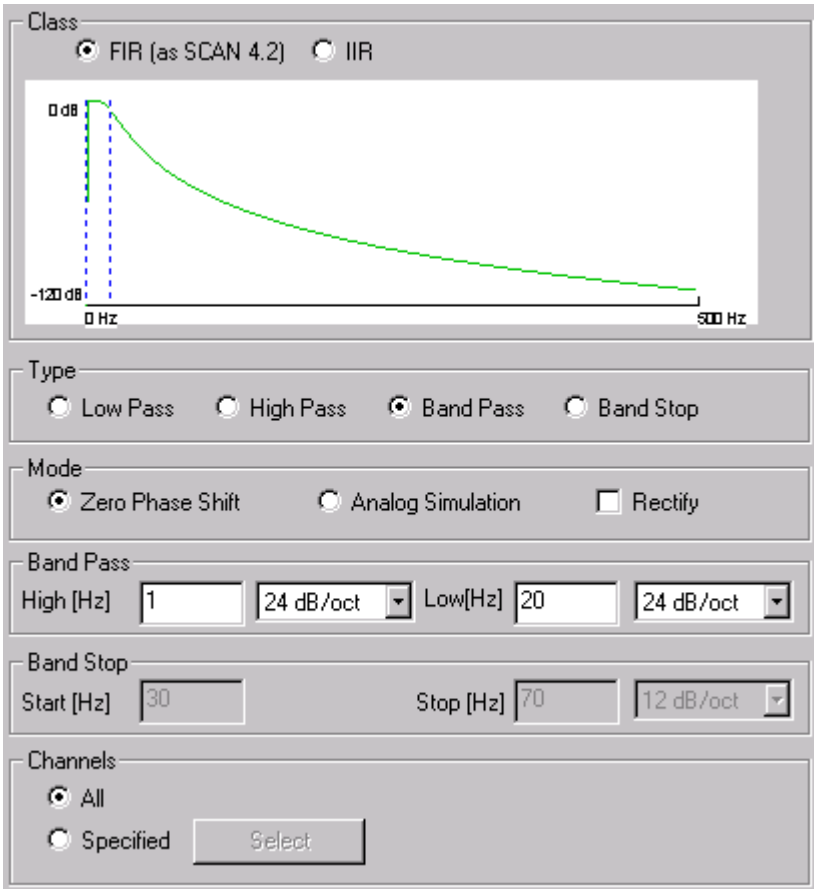
Next, to epoch the file, click "Epoch", then the <<Add Transform button (or double-click Epoch). The Epoching Properties window will appear. As in the previous tutorial where we used the closed.cnt file, set the Mode to "No Trigger", the number of Points to 1024, and then click in the X Maximum field. This will automatically compute the length of the epoch. The output file name is ignored in scripting -you will need to specify the output file in a later step, as described below..



Then click OK, and you will see a new set of options on the right side display. Select the Baseline Correct option, click <<Add Transform, and the Baseline Correction window will appear. Select the Entire Sweep and All channels. (The output file line is, again, ignored).



Then click OK. Now click the Filter option, click <<Add Transform, and the Filter display will appear. The complete options are described in the *Operating EDIT* section of the manual. For the current purposes, select FIR Class, the Band Pass filter Type, the Zero Phase Shift Mode, High Pass filter settings of 1Hz and 24dB, Low Pass settings of 20Hz and 24dB, and All channels. (The output file is ignored). Then click OK.



This will perform a digital band pass filtering between 1 and 20Hz (for demonstration purposes).

Next, click "Artifact Rejection", click <<Add Transform, and the Artifact Rejection window will appear. The options are described completely in the *Operating EDIT* section of the manual. Set the Rejection Window to Reject On Criteria, Entire Sweep, set the Amplitude Criteria to +/- 75 uVs, select Re-Compute under Already Rejected Epochs, All channels, and both fields disabled under Don't Reject on.

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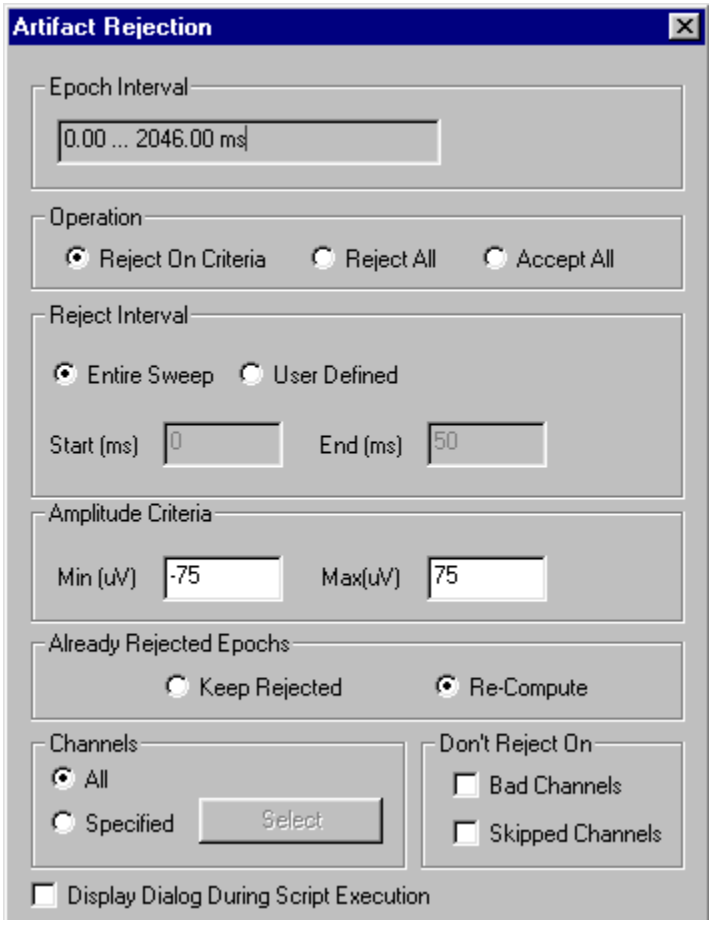

Then click OK. Lastly, click the Output file option, then <<Add Transform. A Save File utility will appear. Enter a file name and path (democlose in this example; the .eeg extension will be added automatically), and click the Save button.

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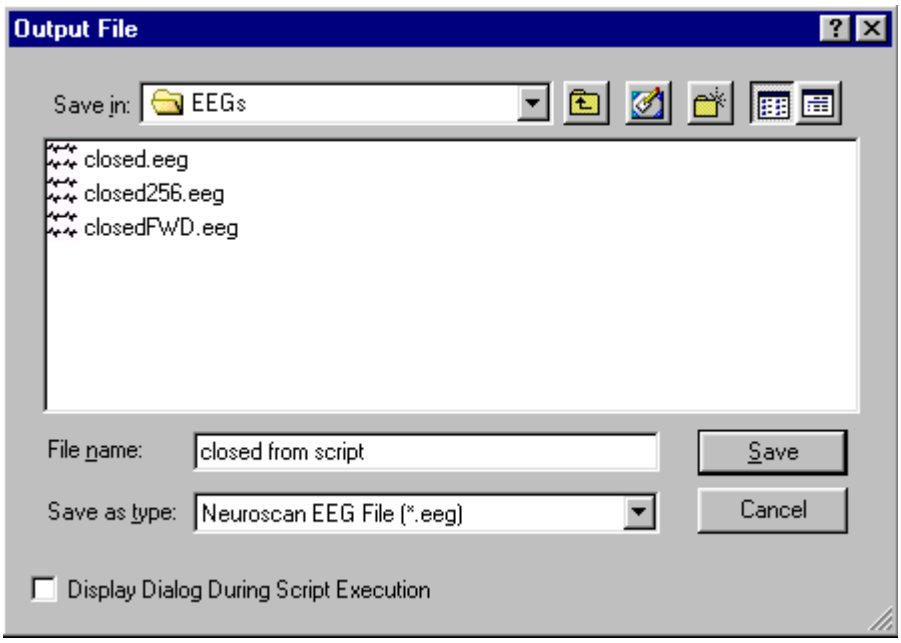
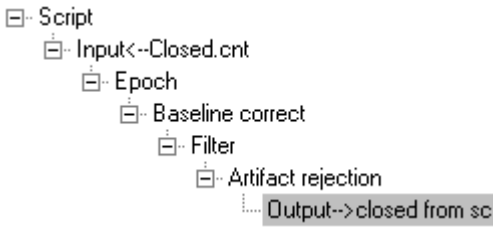


The final script file should look like the following.



Save the script file by clicking the Save Script... button on the script screen, entering a file name (demoscript in this example; the .tfs extension will be added automatically), and clicking the Save button. You may run the script file by clicking either the Apply or the Done button. The difference is that the Apply button will run the script program without exiting the Script window when it is completed. If you click OK, the script program will run and return you to the EDIT main screen.

Click the Apply button to run the program. If we had enabled the Display Dialog During Script Execution option for each screen, you would see the screens appear one at a time while the script program is being executed. This would give you the opportunity to modify the settings as the programs runs. For maximum automation, however, you should leave the option disabled. An incrementing bar will show the progress of the transform process. When completed, you will see a Transform report screen, saying, in this example, how many epochs were made, how many were accepted/rejected, and the path and name of the output file.

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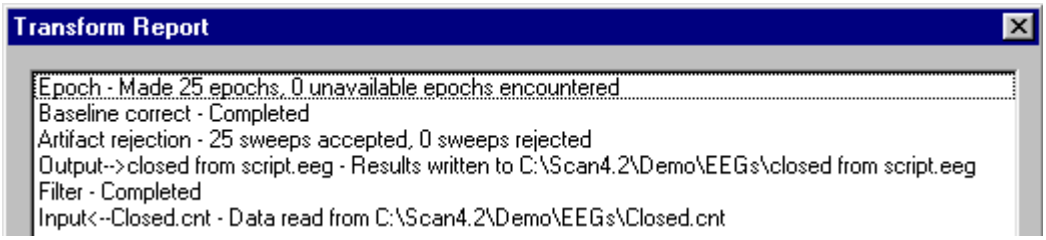
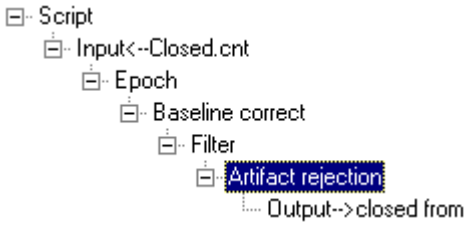


Click OK to continue. You may retrieve the file you created by clicking the File \ Open data file option, setting the file type to .EEG, and double-clicking the file from its folder.

To retrieve a saved script file, click the Load... button from the main script screen.

Let's say we want to modify the existing script file we just saved by decreasing the artifact rejection criteria. Retrieve the script file, then click the Artifact rejection step to highlight it.



Now click the Edit Properties button. You can also click the right mouse button on the transform, and go directly to the properties display. The Artifact Rejection screen will appear, and you may modify the threshold criteria. If you want this file to be stored with a different file name or path, you may modify the Output file line accordingly. Save the new script file, if desired.

The last feature we will discuss here is the Prune function. Pruning will simply remove a branch from the script tree. Highlight a step on the tree, click Prune, and that step as well as everything below it will be removed.

There are other features used with Script files that will be discussed more fully in the *Operating EDIT* section of the manual. Just to mention two of them, you will see the Splitter function appear as an option with many transform operations. This allows you to add branches to the tree. For example, as in the P300 demonstration above, we sorted for the RARE, the FREQuent, or the distractor stimuli. In the script file, you can split the line of operations to allow you to, for example, perform multiple sorted averages within the same file. Another useful feature is the Substitution option. This allows you to run the same script file on multiple data files that you have specified.

This concludes the Scripting tutorial.

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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. It is organized in a left-to-right, and top-to-bottom fashion, as you look at the main screen in EDIT. In other words, the descriptions begin with Files, in the upper left hand corner of the display, progress to the right, with a description of the contents of each pull down menu in a top to bottom fashion.

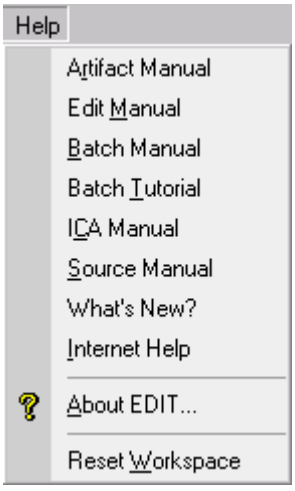
Descriptions of the Toolbar icons are toward the end of the manual. Since people generally tend to use the Toolbar icons more than making selections from the Main Menu item lists, the more complete descriptions of many features may be found in the Toolbar section.

Some features are accessed only when you click on the right mouse button, and you will see several sections where the right mouse button options are listed. Look in the *Table of Contents* to find these sections most quickly.

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.

As a reference document, we have laid out the *Table of Contents* in a way we hope will facilitate your search for specific answers to questions. We recommend you use it as if it were an Index.

This manual (as are all of the SCAN 4.3 manuals) is installed in PDF form on your PC. You may access it from EDIT, by clicking on the Help \ Edit Manual option.



Some differences in EDIT 4.2 (and continued in later versions) - Some minor changes have been made to the transforms in EDIT 4.2, 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 4.2. 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 4.2) 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, 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 an 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 Tcl BATCH manual for more details).

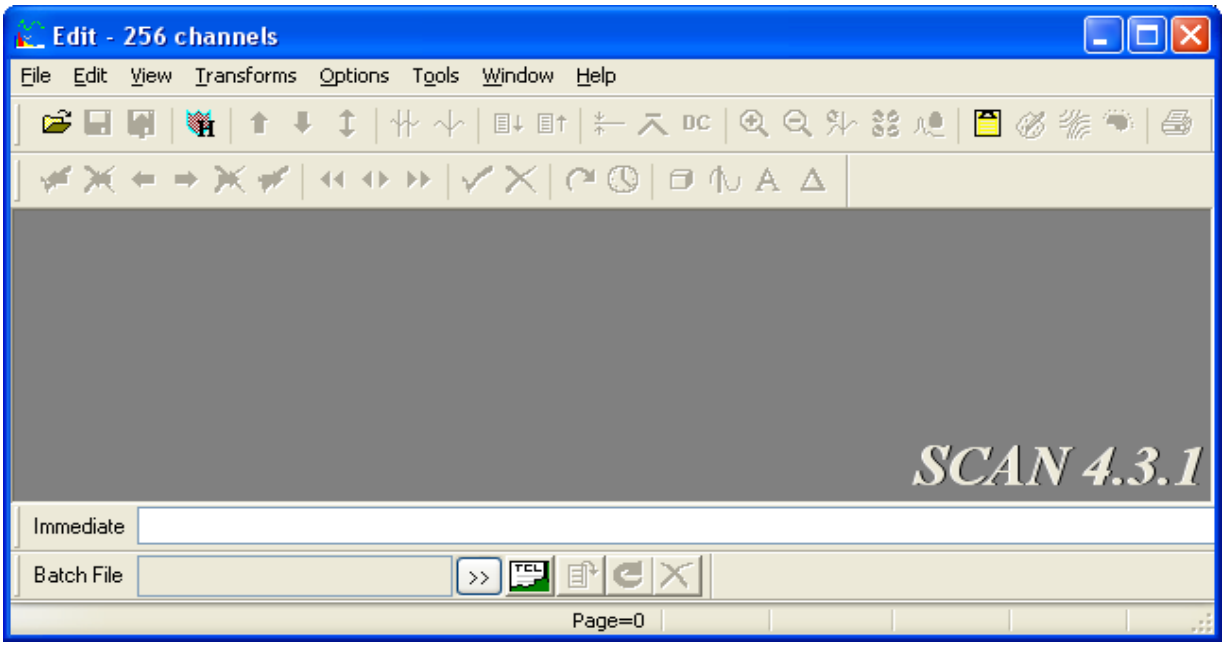
Starting EDIT

Start the EDIT program by clicking first on the SCAN 4.3 icon 

to run the Program Launcher.

Then click the EDIT icon  . You will see a small green triangle appear in the lower 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 triangle is still there, you will need to close and reopen the Program Launcher before reopening EDIT.

The EDIT main screen will appear.



The top line will indicate how many channels your system is set to record and analyze. For example, if you have a 64 or fewer channel system, the line will read Edit - 64 channels.

Next is the Main Menu bar, which consists of File, Edit, View, Transforms, Options, Tools, Window, and Help. Note that some letters are underlined. These options may be selected from the keyboard by clicking Alt + *letter*, where *letter* is the letter that is underlined (e.g., Alt f). When the drop-down menus appear, some of the options will have a letter underlined. In these cases you may select the option from the keyboard by just pressing the letter.

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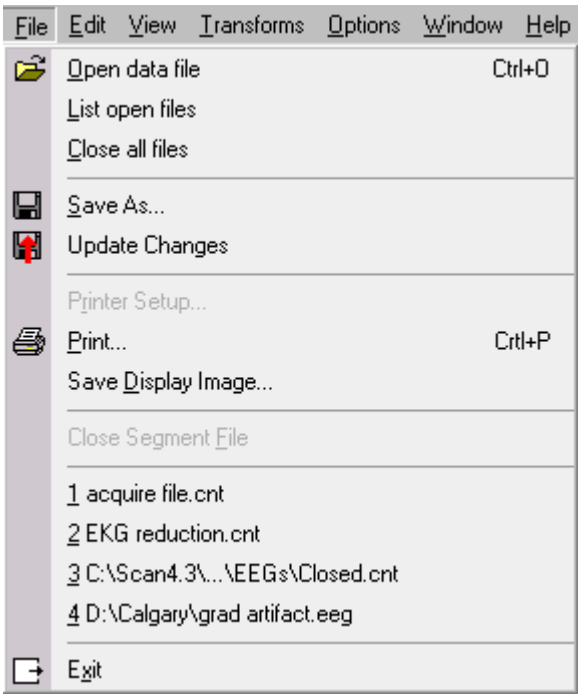
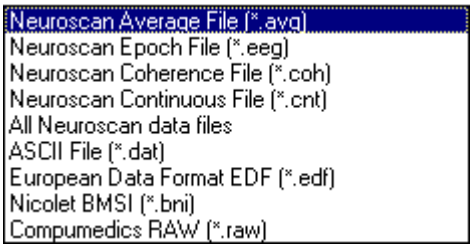
File

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.

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. 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.

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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 AVGs 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). There 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. Behavioral data may be Merged only with continuous files.

All Neuroscan Files - Selecting 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.

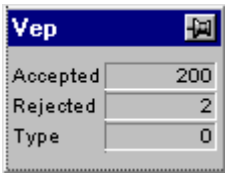
European Data Format EDF (.edf)* - European Data Format continuous files may be imported directly into EDIT.

Nicolet BMSI (.bni)* - Nicolet BMSI files can be opened directly in EDIT (*bni extension).

Compumedics RAW (.raw)* - Compumedics RAW EEG files may be imported directly into EDIT.

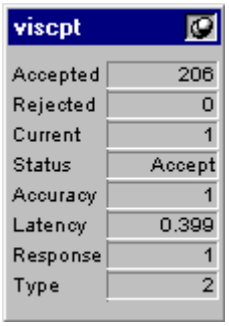
Status boxes - When you retrieve AVG, EEG, or CNT files, you will see a Status box appear. These contain specific file-related information, as follows.

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



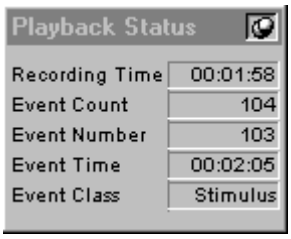
that were accepted into the average file. The Rejected field shows how many sweeps were rejected, or excluded from the average. The Type field will be "0" for AVG files. The % Complete field (where present) displays the percentage of the file that was acquired, as set by the number of sweeps under Epochs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



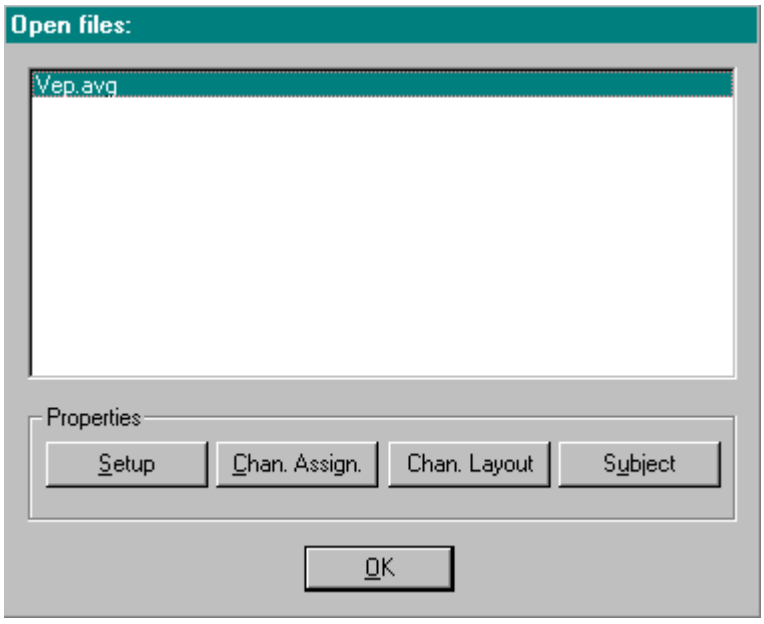
sweeps in the EEG file are tagged as Accepted sweeps. The Rejected field shows how many of the sweeps are tagged as Rejected. These numbers will change as you step through the file and reject bad sweeps. The total of the two will add up to the total number of sweeps in the EEG file. The Current field 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 following one. 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, Time and 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 or class of an event it is.

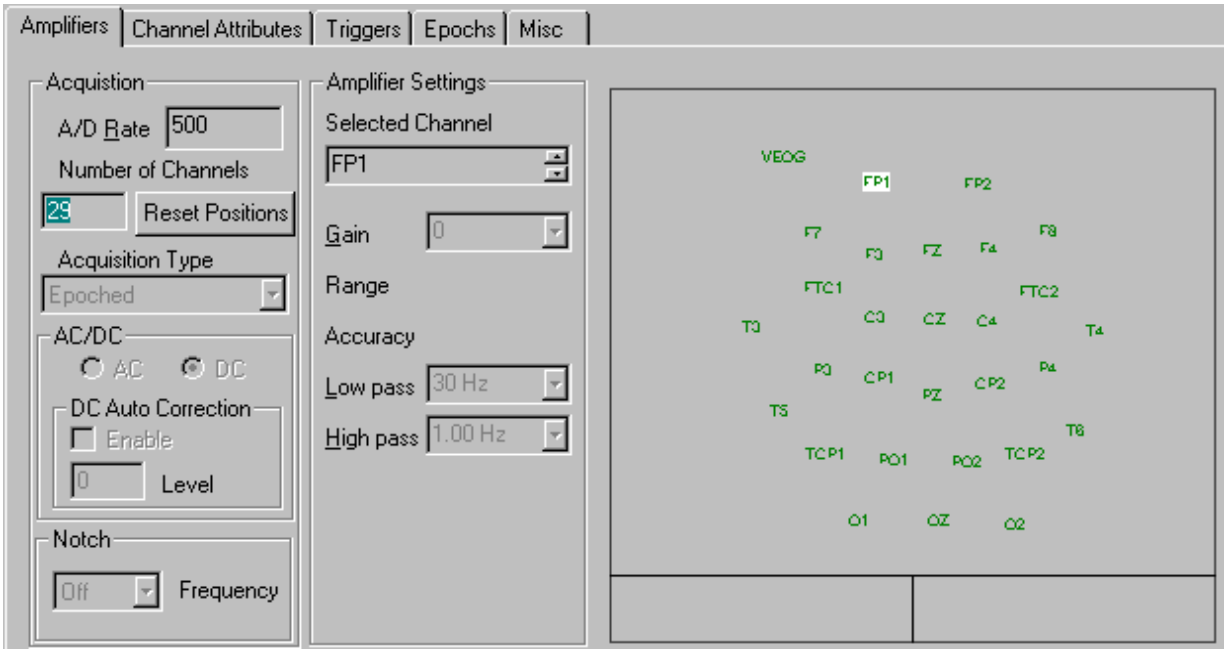
List open files - If you have one or more files open, the *List open files* option can be used to display information about the file contents. Clicking the option opens the following screen.



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. *Note: These same options may be accessed also by clicking the right mouse button between the electrode displays in the data window.*

Setup. The Setup button accesses some of the same screens that you used in ACQUIRE to create the setup file. These include the Amplifiers, Channel



Attributes, Triggers, Epochs, and Misc screens. The Channel Attributes screen will let you make a number of modifications, and these are described in more detail below (and in the ACQUIRE manual). You can also modify the Display settings on the Epochs screen. For example, if you are displaying a frequency domain data file, where the range of frequencies extends to, perhaps, 500Hz, you can reduce the range in the Stop field to something more appropriate for viewing. Additional screens may be available, depending on the type of file you have retrieved.

Chan Assign. 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 to save the change.

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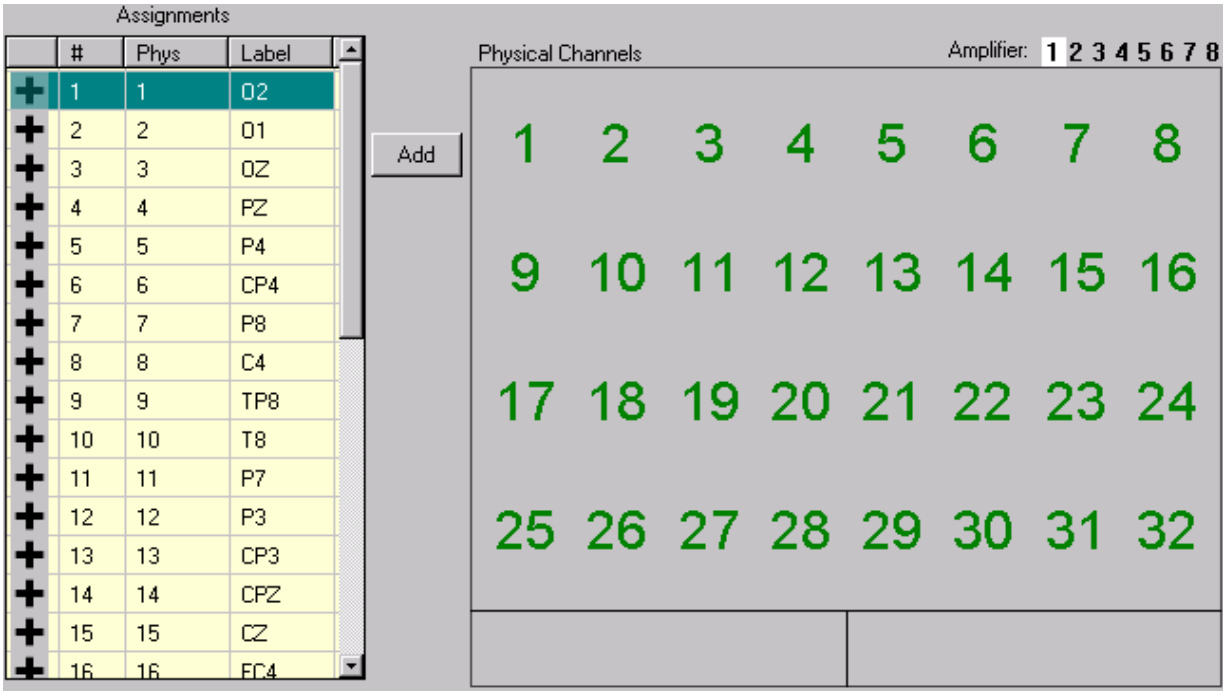
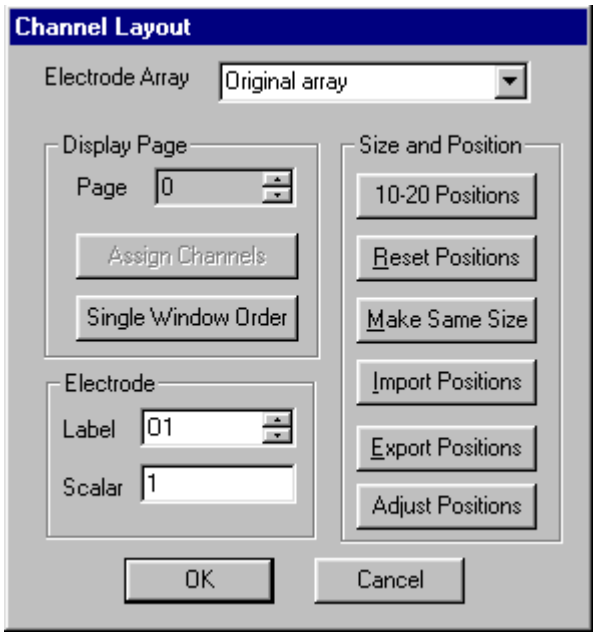
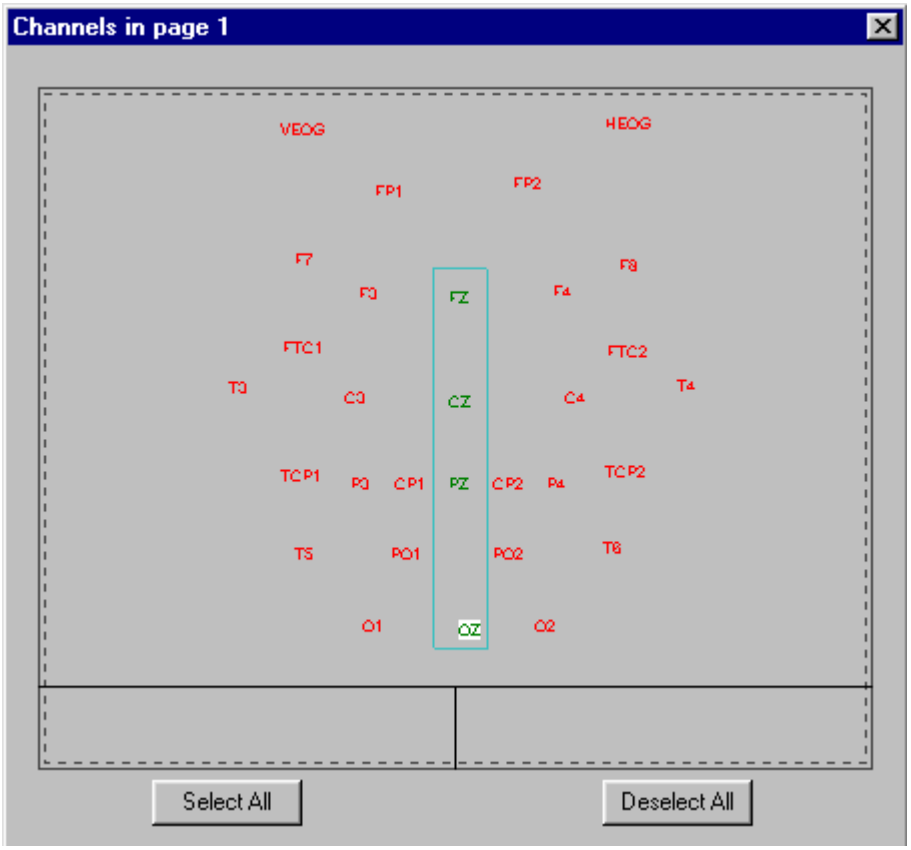


Chan Layout. Clicking this button opens the same Channel Layout display used in ACQUIRE to position the individual channels displays, assign electrodes to display pages, import and export electrode position information, and so forth.



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 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

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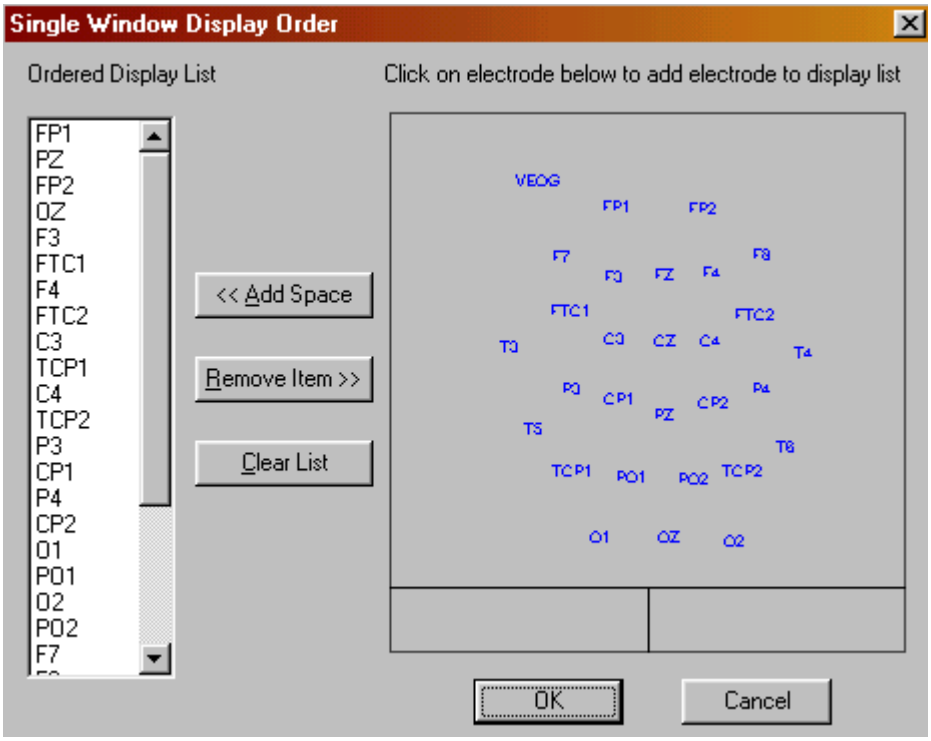
may assign the same channel to more than one display page (for example, you might want the artifact channel to appear on each display page). Use the down arrow button to get back to the original display page. Click OK when you are through, and be sure to resave your setup file if you wish to retain the changes you have made. *Note: if 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 pur-

poses). 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. For example, if the global scale factor is 2 (the number displayed on the Status Bar and affected by the Up and Down arrows on the Toolbar), and the scalar value is 2, then the display will be multiplied by a factor of 4. The scalar setting affects the screen display only, and has no effect on the stored data.

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

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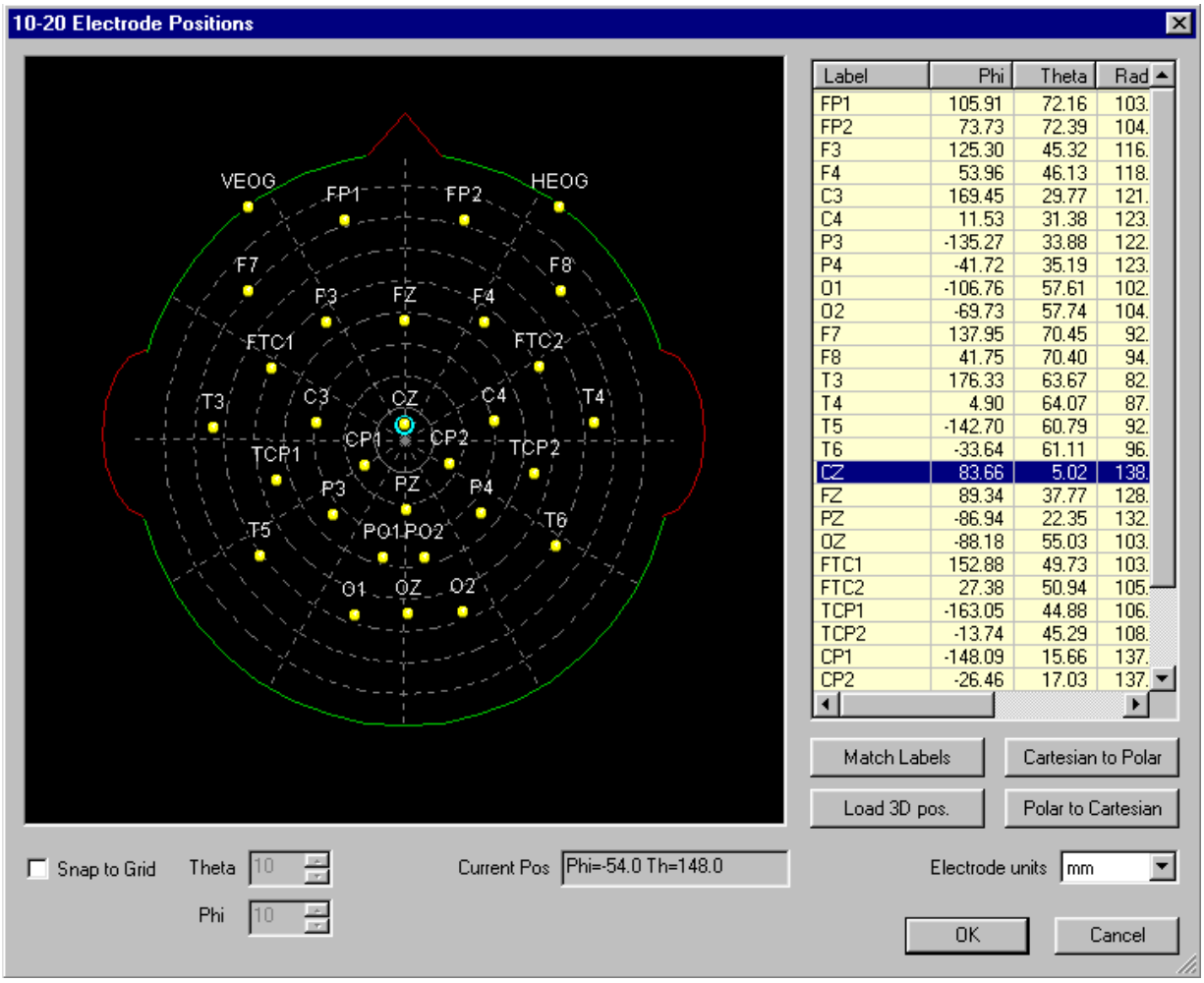
automatically according to the 10-20 system, or from electrode position information contained in the 3DD file created in 3DSpaceDx when the electrode positions were digitized.



Two electrode positioning systems are supported: Cartesian and 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 Polar positioning system uses Phi, Theta and Radius values to express the location of the electrodes, as follows. The center of the display above is (0,0,0). As you move away in any direction from the center of the display,

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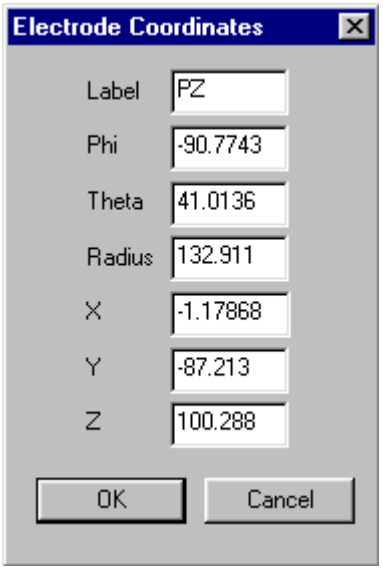
Theta becomes larger (90 at the outer ring). The Phi and Theta values can be read in the lower part of the display 

. Phi is zero all along the line from the center point to the right ear. As you move the cursor up and in a counterclockwise direction, Phi will increase up to 180 (the line from the center point to the left ear). Crossing that line, Phi becomes negative, and increases from -180 to 0 as you continue in a clockwise direction below the x-axis. The Radius is the vector length from zero to the Phi/Theta location, thus pinpointing the electrode position 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
FZ	89.34	37.77	128.13	0.90	78.48	101.27
CZ	0.00	1.11	138.92	-0.00	16.00	138.00
PZ	-86.94	22.35	132.91	2.70	-50.47	122.93

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



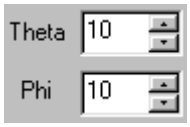
From this screen you may edit the electrode label, and modify the Polar and Cartesian coordinates manually, if desired. Click OK to apply the changes. (If you change the Polar coordinates, click the 

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 

field. You can control the sensitivity

of the "snapping" by the values you enter in the Theta and Phi fields.

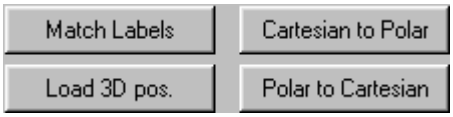


Valid entries for these fields are from .01 to 10 degrees. When theta is set to 10, for example, the moving electrode will snap from one position to the next in discrete 10 degree steps. Similarly, when phi is set for 10, the moving electrode will snap from one position to the next in discrete 10 degree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

The 

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.



The 

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 

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

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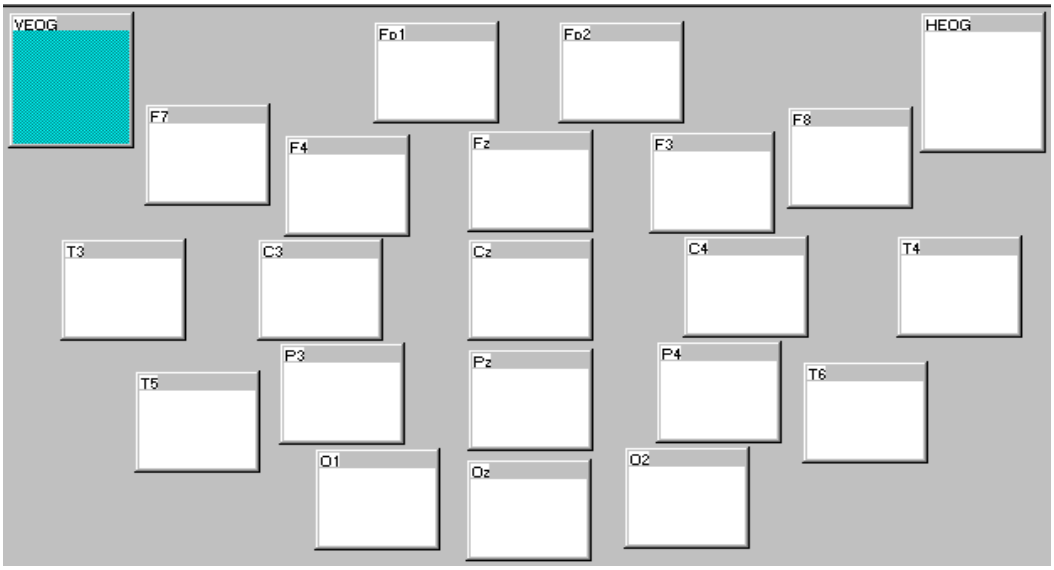
Polar to Cartesian button to compute the Cartesian coordinates automatically. The Cartesian to Polar button will do the converse.

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 Windows 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*

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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 Windows 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 following screen.

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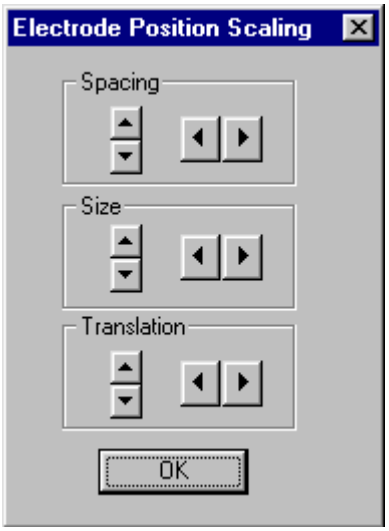

The three groups of adjustments are for Spacing, Size, and Translation. **Spacing** expands or compresses the grouping of the displays either vertically  , or horizontally  . Similarly, the **Size** buttons increase or decrease the size of the electrode displays either vertically or horizontally. The **Translation** buttons will shift the entire grouping of the displays vertically or horizontally.

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

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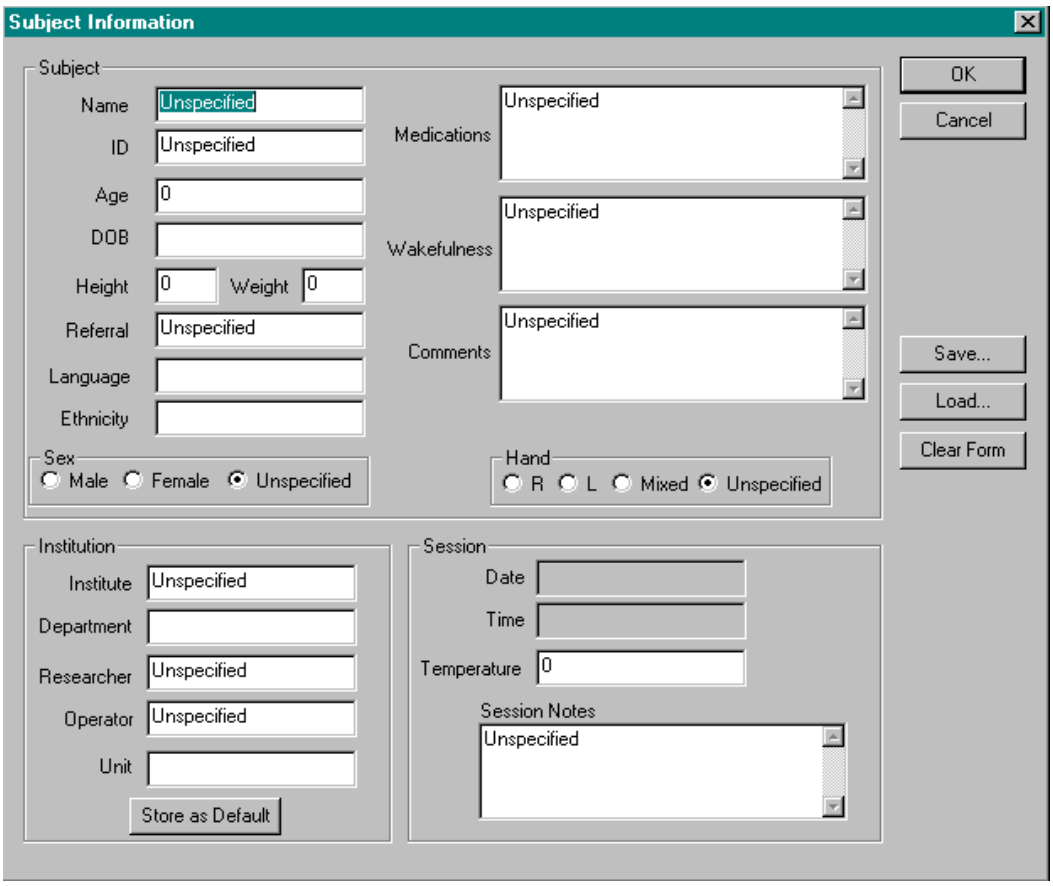
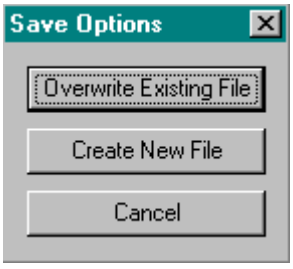


Close all files - Clicking this option will close all open data files in EDIT.

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 a display asking whether you want to modify the existing file, create a new file, or cancel the save.



If you select the Overwrite Existing File option, the changes will be saved to the original file. If you select the Create New File option, you will see a standard Save As... utility. Click the pull-down arrow on the Save as Type line, and 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).

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&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.

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

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.

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.

Close Segment File - The Close Segment File option is related to saving blocks of a CNT file (see the Mark Block, Save Block option 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.

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

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.

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

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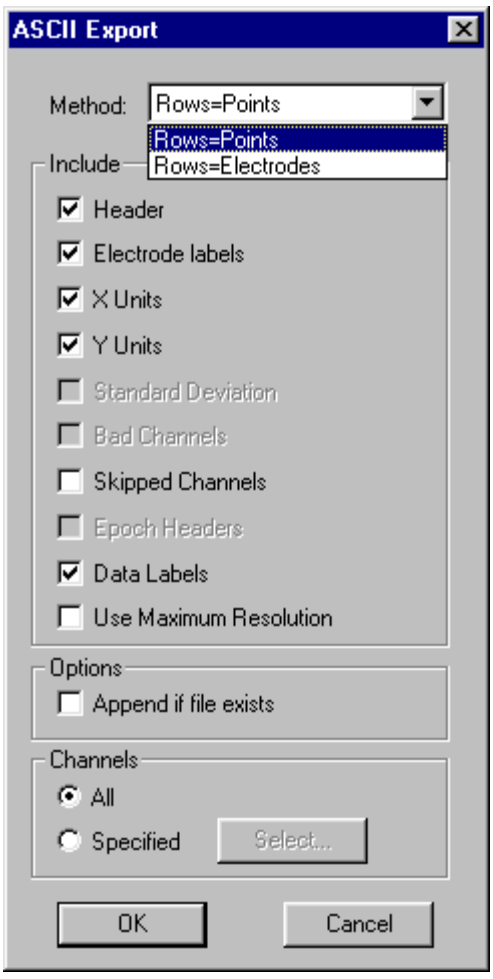
or statistical analysis software. Files created by other acquisition systems, after conversion to ASCII with a compatible structure, may be read into EDIT for analysis. It is also possible to export CNT files using the European Data Format (EDF).

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 electrodes 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 following 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 uVs 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:

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```
[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 - Enable this option if you want to include the Data Labels in the ASCII export.

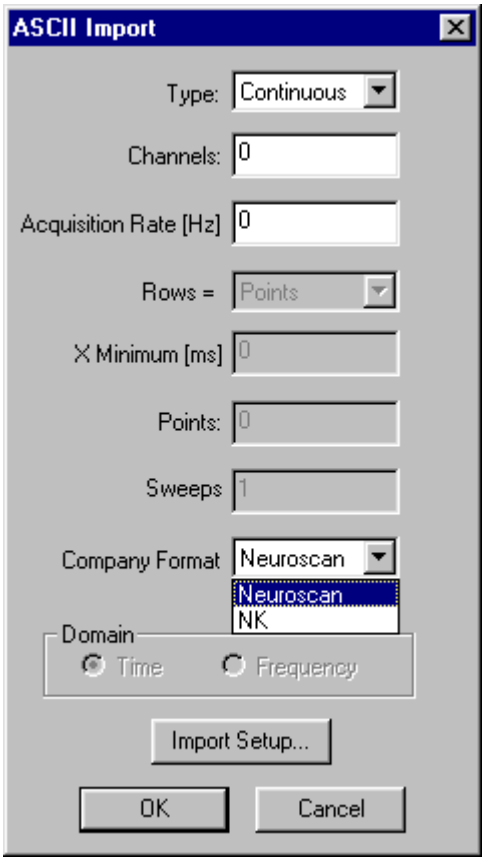
Use Maximum Resolution - Enable this option to export the data points with maximum resolution (up to eight places after the decimal point). Not enabling the option will export values with four places after the decimal point.

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 

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 DAT files will be displayed - not just the data files you have exported. Click OK and the data file will appear. If the header information in the DAT file is incomplete, which may be the case if you are importing a file from some source other than SCAN, you will see the following display.



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 above display. Fill in the missing information and click OK.

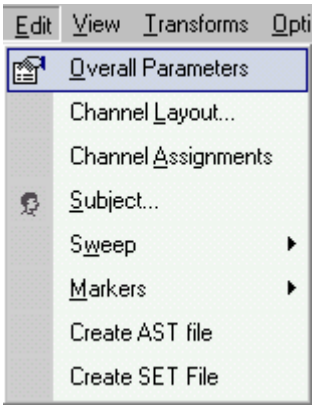
Type refers to the Type of file this is (AVG, EEG, CNT). The number of channels, AD rate, X-minimum (sweep starting point, in ms), number of points, number of sweeps, and Domain should all agree with the ASCII data file. The "Rows = " field refers to the format of the ASCII data file. If the data are 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.

Edit

The Edit option accesses a pull-down menu with the following list of options.



Overall Parameters - Selecting this displays the Amplifiers, Channel Attributes, Triggers and Epochs sections from the Overall Parameters option in ACQUIRE. Additional tabs will be present for certain types of files (such as, coherence files where you will see the Frequency tab as well). You can make a number of changes from the Channel Attributes tab, and you can change the Display settings under the Epochs and Frequency tabs (described below).

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.

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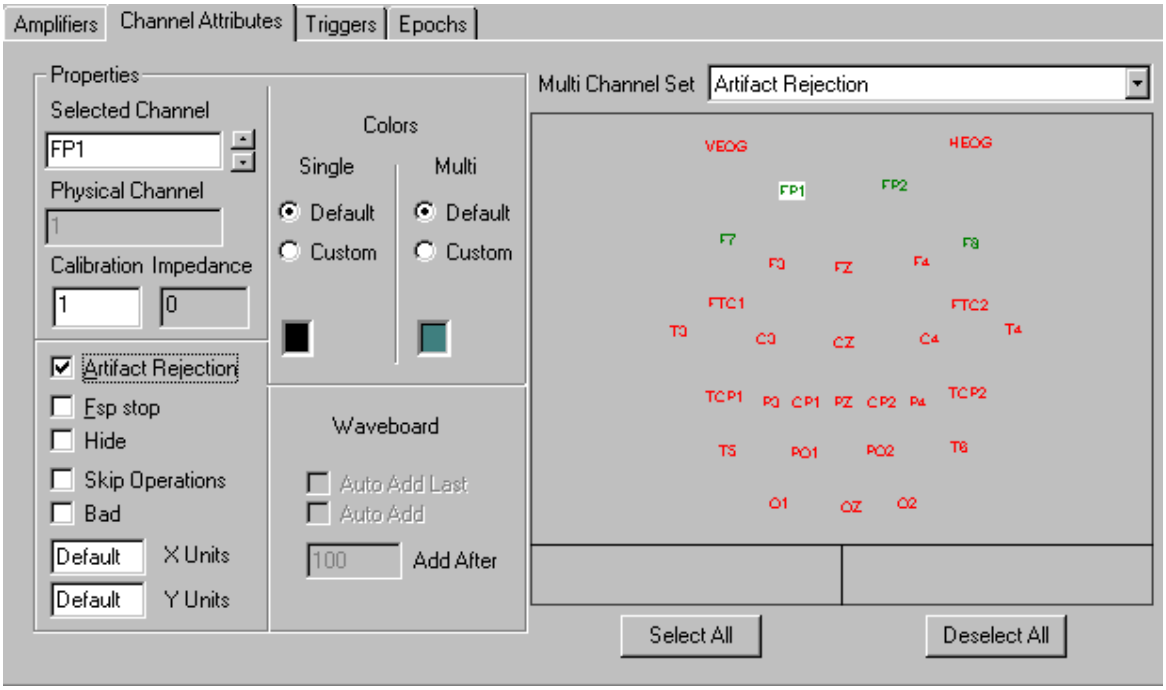
Channel Attributes - The Channel Attributes window is used to set a variety of parameters for individual or all channels. The montage display part of the screen is used to select or deselect the electrode channels that you want to modify, and the other fields are used to select attributes to be applied 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 also use the up and down arrow buttons to step through the electrodes until you reach a desired one. 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 Select All button to select all the channels, and the Deselect All 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 show a check mark, such as Bad).

Selecting multiple channels for a particular attribute. Select the Multi Channel Set attribute to be applied (such as, Auto Add to Waveboard). Then click the Select All button. A check mark will appear beside the attribute (Auto Add). Double click any electrode labels to deselect them, if you do not want the attribute applied to those channels.

Additional Features. Now let's look at the additional modifications that can be made from this window.

Properties. The Properties area displays many of the attributes that may be modified for each channel.

> **Selected Channel**. As demonstrated above, the Selected Channel field will reflect the channel that has been selected when a channel label has been clicked. The up and down arrow buttons can also be used to select a channel. 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. Then click inside the montage display area (not on a label) to see the change.

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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 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. Clicking on the Artifact Rejection

field 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 off-line 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 you selected *All* under the F_{sp} section in Overall Parameters above (under *Edit*), then you need not specify the channels again here. If

you selected *Select* in the section under *Edit* above, then you will need to select the channels individually. Click OK when you have set the channels, and remember to save the setup file under File\Save as. (For more information, see the Fsp Average transform below).

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 off-line 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 off-line 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.

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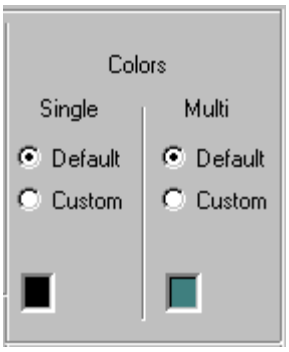
X Units. This option allows you to enter a label for values along the x-axis. You may set the label independently for each channel - the channel that is displayed in the Selected Channel field is the one that you are setting. The *Default* label is "ms". If you change this, and wish to return to the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

Colors. The Colors area allows 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. Click the Custom radio field to access the standard Colors palette, and 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 wave forms to the Waveboard during acquisition. It has no function off-line in EDIT.

Triggers - The Triggers section is shown for informational purposes only. No modifications may be made to it.

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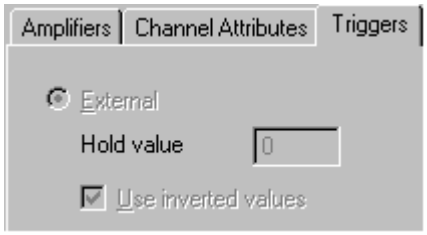
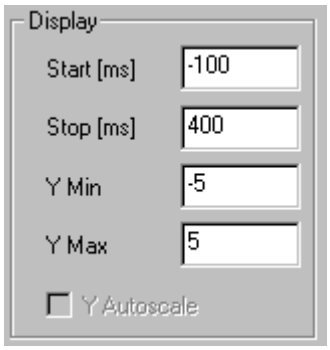
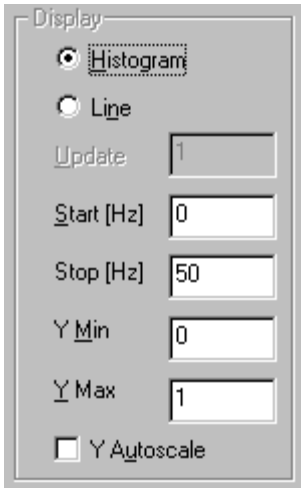


Epochs - The Epochs settings are entered in ACQUIRE prior to acquisition, and, for the most part, cannot be modified in EDIT. The exceptions are the Display fields.



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.



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

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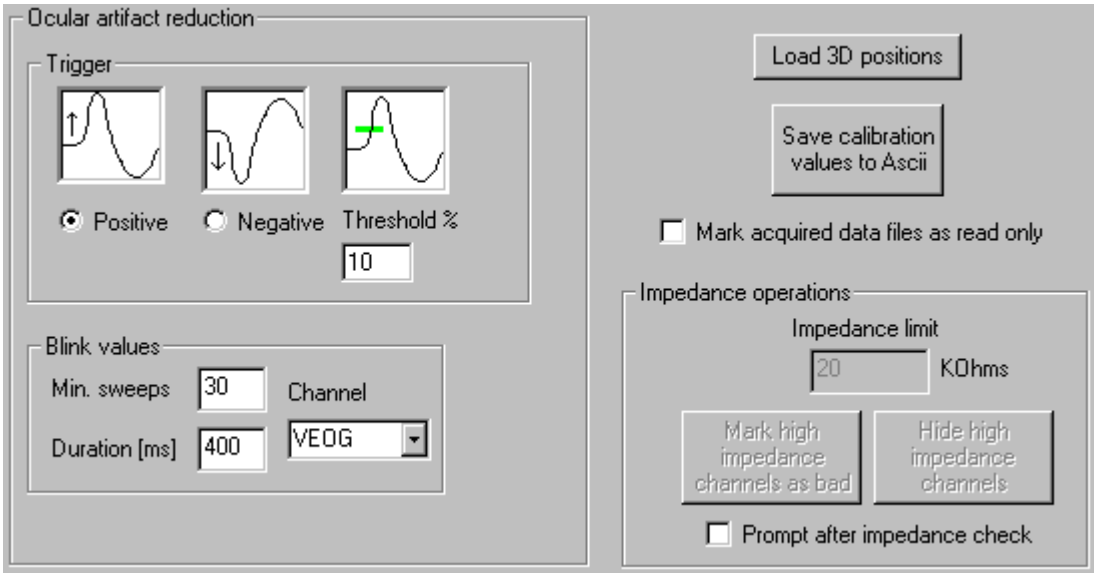
that you may wish to add to the file. Please refer to the Place a Mark section below (and the ACQUIRE manual) for more information.

Misc - The Miscellaneous tab can be used in ACQUIRE or EDIT. It contains the following options when accessed in EDIT.



Ocular artifact reduction. These fields allow you to enter the ocular artifact reduction parameters that will be used when you apply the Ocular Artifact Reduction transform. The values you enter will be applied to subsequent files you retrieve, thus overriding the settings made in the setup file in ACQUIRE.

Load 3D positions. The Load 3D positions button displays the standard Open File utility for selecting a 3DD file from 3DSpaceDx that contains the digitized electrode and PAN positions. The 3DD file must agree with the electrode labels in the ACQUIRE setup file (typically, the ACQUIRE setup file will be used in 3DSpaceDx when the electrodes are digitized).

Save calibration values to ASCII. Clicking this button Save calibration values to Ascii opens the standard Save As utility window. Use it to select a path and to enter a file name (DAT extension added automatically). The calibration values will be stored in this file (and may be reviewed with a text editor).

Mark acquired data files as read only. Enable this option and click Save As to change the file attributes to Read Only. This will protect the file against unintended changes. Disable it and resave the file to remove the Read Only status.

Impedance operations. The only option available in EDIT is to enable/disable the

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Prompt after impedance check field, which can be saved to the setup file in ACQUIRE.

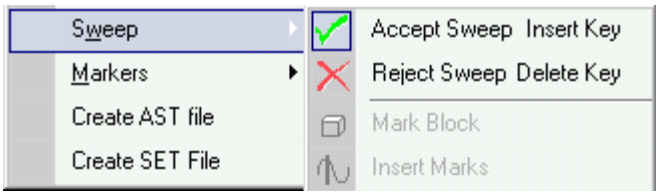
Note that you have the option to use the Save As... button to retain the settings you enter. Changes can be saved to the setup file (.ast file) in ACQUIRE. This is provided for your convenience so you do not have to go into ACQUIRE to modify the setup file.

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, reorder the display of channels in a Single Window display, import and export electrode position information, and so forth. (See the **List Open Files** section above for more details)

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. (See the List Open Files section above, and the ACQUIRE manual, for more details).

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.

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 Reject 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 Accept 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.

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.

Create AST File - This is a very handy option through which you may create a SCAN 4.2 setup file from any 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.

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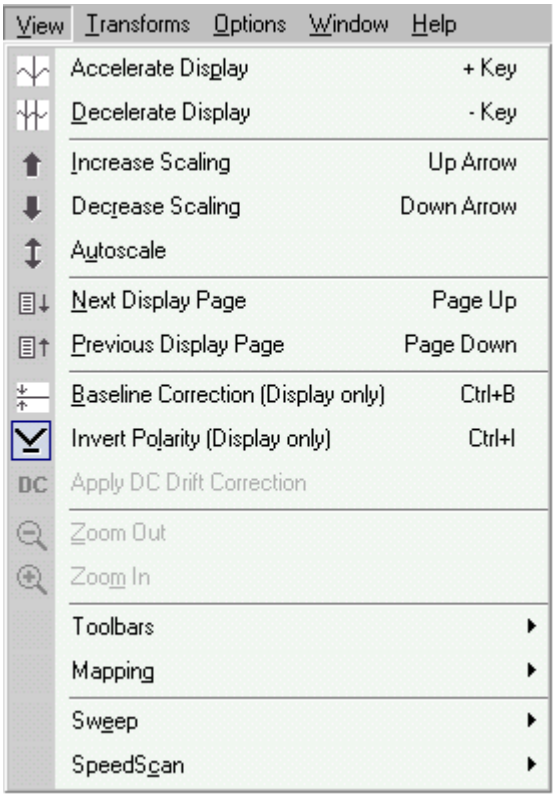
Create SET File - Setup files from SCAN 3.0 used SET extensions. This option allows you to create a *.set file from a SCAN 4.0 - 4.3 data file. There are some older utility or third party programs that still require SET files.

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 (by the calculator pad). You can also use the right mouse button option, Set seconds per page, to select the number of pages 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.

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The - key on the keyboard may be used instead (by the calculator pad). You can also use the right mouse button option, Set seconds per page, to select the number of pages 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 Windows display according to the largest and smallest voltages encountered on a displayed screen. 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 Overall Parameters / Channel Attributes. 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).

Invert Polarity (Display only; all file types) - This option inverts the polarity of the displayed file (does not affect the actual data file).

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.

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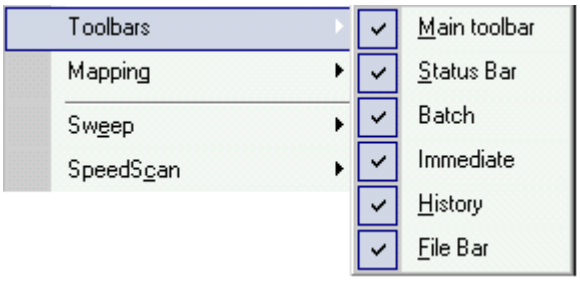
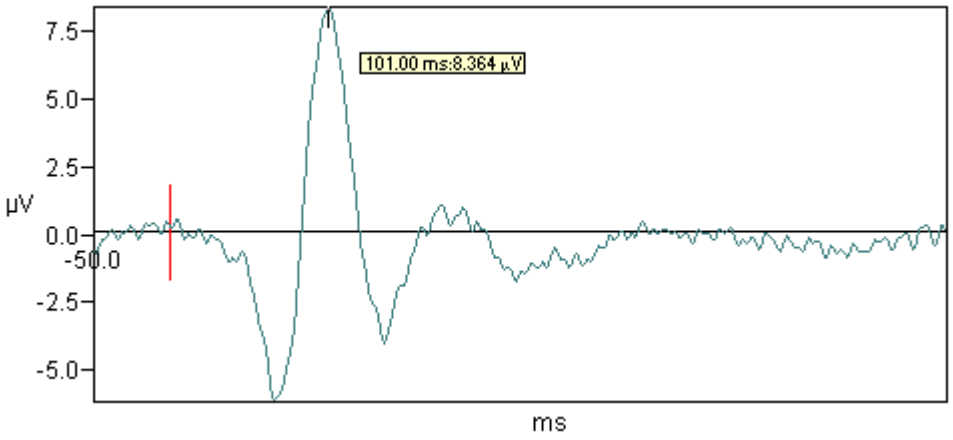


Main Toolbar - Selecting this option (check mark appears) will display the Toolbar icons. The functions of these are described in detail below.

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 five fields that display information when the mouse is positioned inside

a Multiple or Single Window display. The first shows the current Display Page. The second field shows the Display Gain for CNT files only. The next field displays the electrode label. The 4th and 5th 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 Windows 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.



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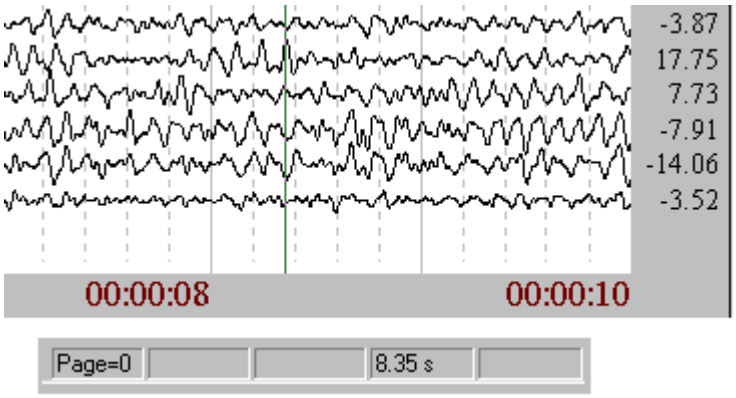
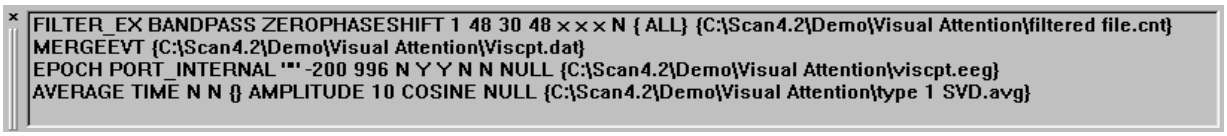
With CNT files, you may read the time point from the Status Bar field, and the voltage for each channel and data point in the column on the right.



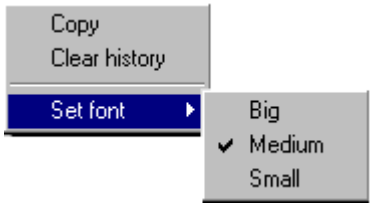
Batch - Selecting this option displays the BATCH Toolbar. The operation of BATCH is described completely in the Tcl BATCH manual.

Immediate - The Immediate Toolbar is used to execute single BATCH commands (see the Tcl BATCH manual for complete details).

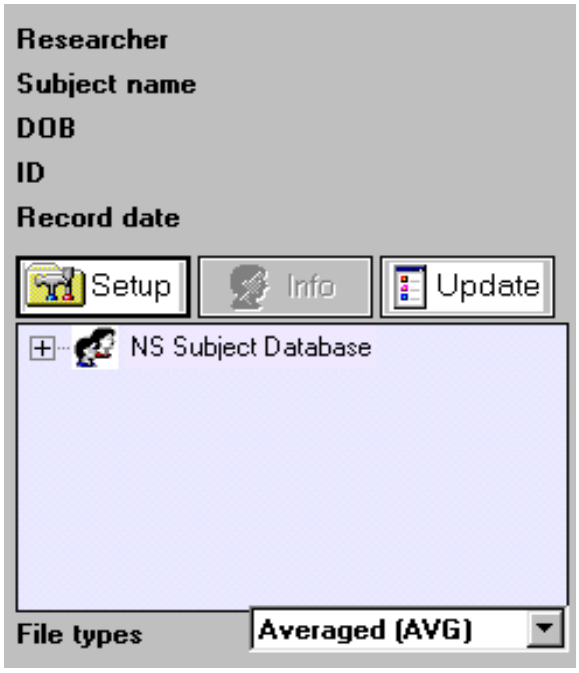
History - The History field displays a list of the most recent Transform commands in BATCH form that have been executed. You may also show or hide the History toolbar using the  icon on the Toolbar.



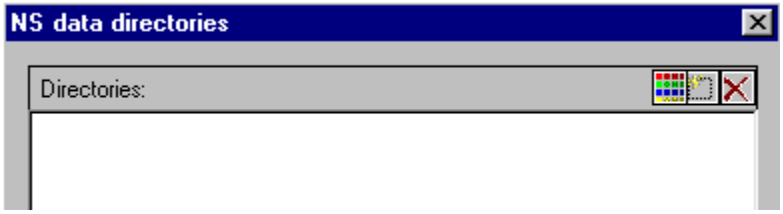
Right-click inside the History box and you will see options to Copy the text (for use in BATCH files), Clear the window, and change the font size.



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 Setup 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.

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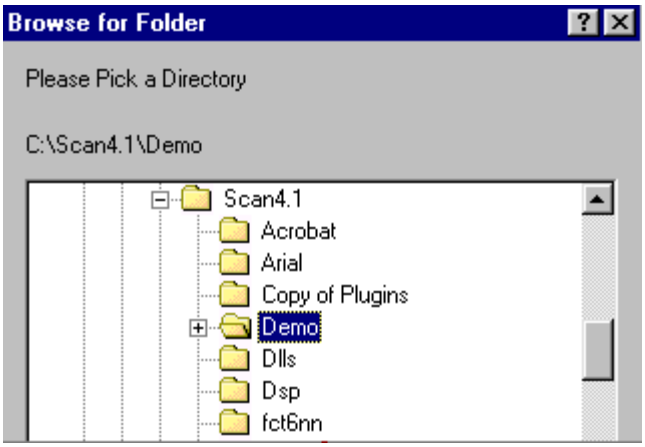
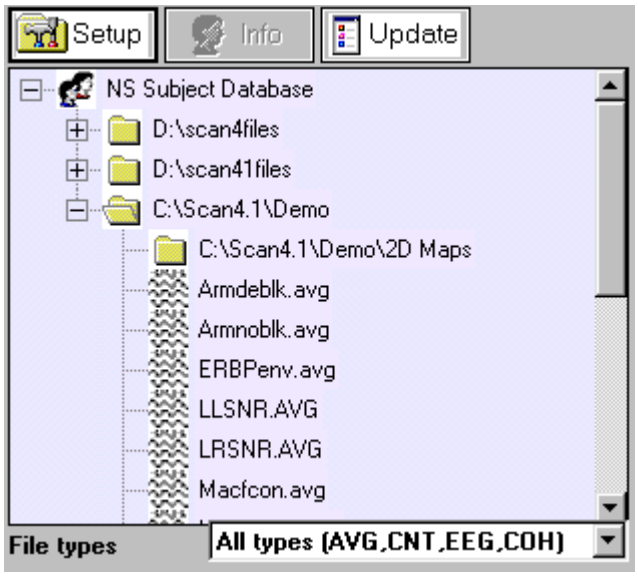


Select a folder that has data files in it, and click the OK button. Repeat the process for all of the data files you want to access. You may select folders from other drives or across a network, as well. Click OK when you are done. The first display will show the file structure.



The tree structure then operates very much like the Windows Explorer program. Note that at the bottom of the display you may select the Type of files you wish displayed.

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 

becomes active. Click this to see the complete Subject Information screen.

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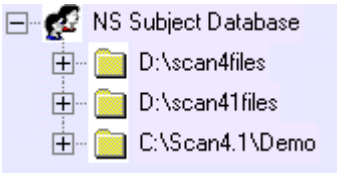
The 

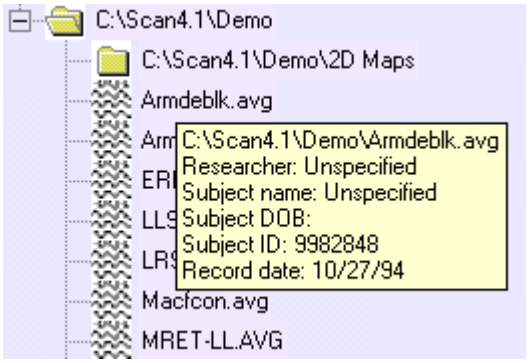
icon is used to update the tree structure. Clicking it will return the structure to the following form.



Notice also on the "NS data directories" screen (after clicking the 

icon), there is an option at the bottom of the screen called 

. If you enable this option, you will see a pop-up window showing some basic file information when you position the mouse cursor on a data file. (Enabling the option may cause some delays on slower PCs).



Deselect the File Bar option to remove the File Bar 

.

Mapping - Selecting the Mapping option opens a second list of options. These are accessed more easily from the icons on the Toolbar 
.

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 mapping 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

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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. Note that 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 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 EEG 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 EEG file.

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

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

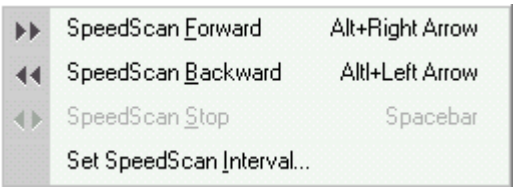
Go To Sweep/Event (EEG, CNT) - Depending on the type of file, this option will allow you to jump directly to a specified sweep number or event in the EEG or CNT files (described in more detail below in the Toolbar section).

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).

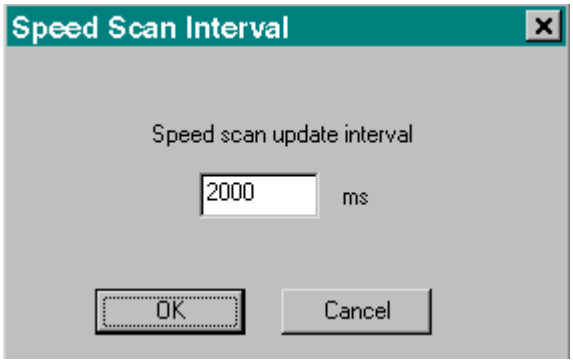


SpeedScan Forward (EEG, CNT) - This option automatically scans through the file in a forward direction. The combination keystrokes of CTRL + right arrow (on the keyboard) perform the same function.

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

SpeedScan Stop (EEG, CNT) - This option is used to stop the SpeedScan.

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 following 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.

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 also that many of the transforms that are available for Time Domain AVG files (evoked potential files) are not available for Frequency Domain AVG files (power spectrum files).

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 have the screen displayed while the Script sequence is being executed. This is described in more detail in the tutorial above and in the Script section below.

Below are the transforms, listed in alphabetical order.

Add (AVG, 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 Add 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

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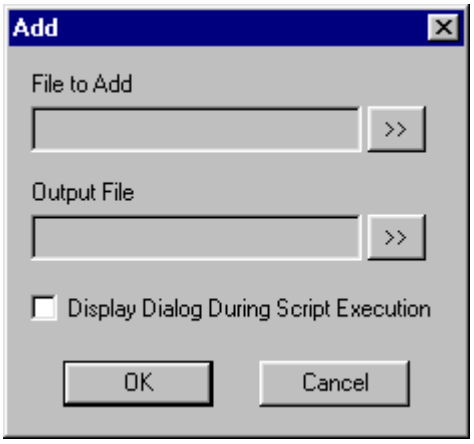

file. Then click the >> button on the Output File line, and enter an output file name. A new Multiple Window Display will appear with the added waveforms.

Append Channels (AVG). 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.

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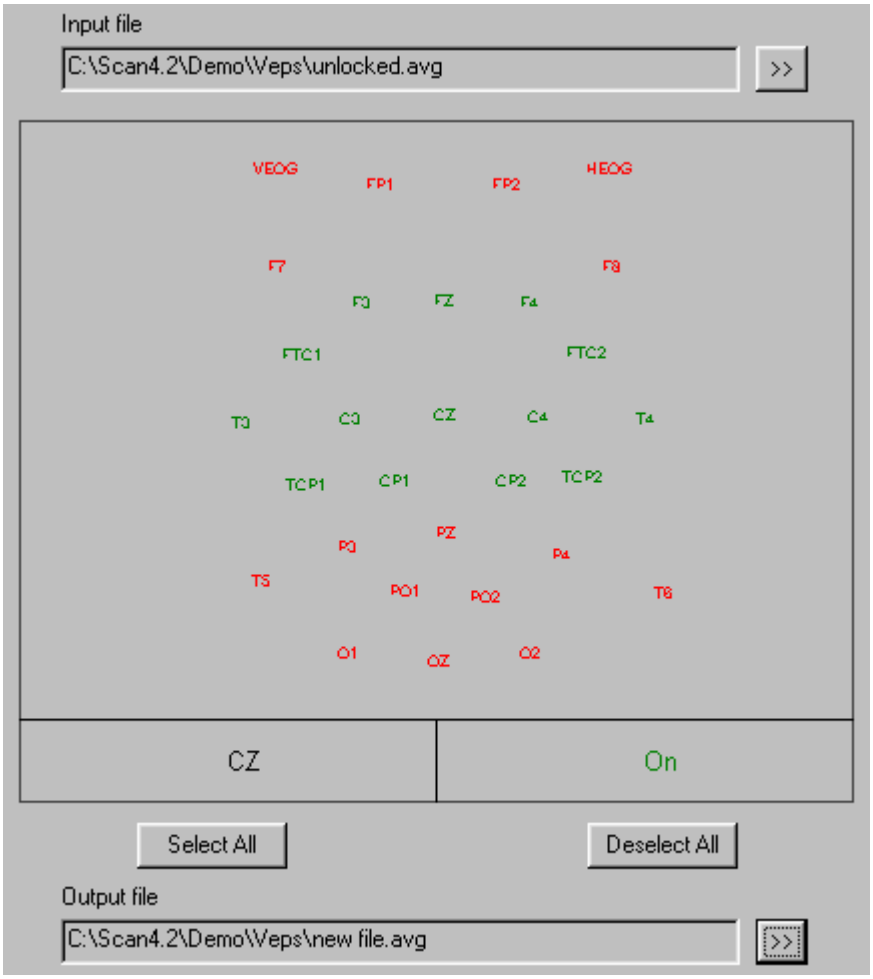

Use the Browse button to select the second AVG file. From that file, you may select the channels that you wish to append to the first file. Enter an output file name, then click OK. You will then see the new file will the original and the appended channels.

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 following

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.

Append Sweeps (EEG). 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.

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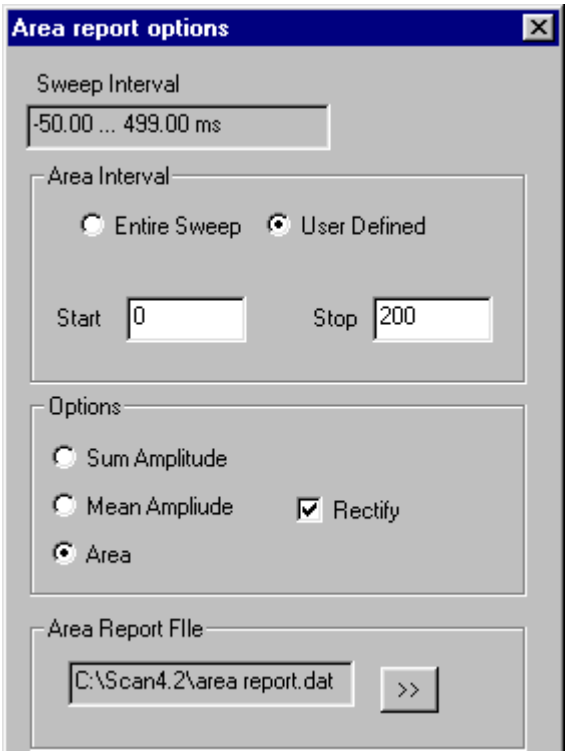
Area Report...(EEG, AVG; time domain). This option is used to create an ASCII file (DAT extension) that will contain the Sum, Mean Amplitude, or Area information for the interval you specify.



The Sweep Interval displays the Start and Stop times for the data file. The Area Interval lets you select the entire interval, 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 all 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
```

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.

Also beginning with SCAN 4.3, you have the option to apply artifact rejection to *CNT* files. This is described shortly.

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

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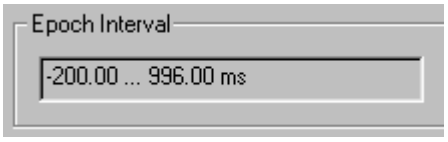
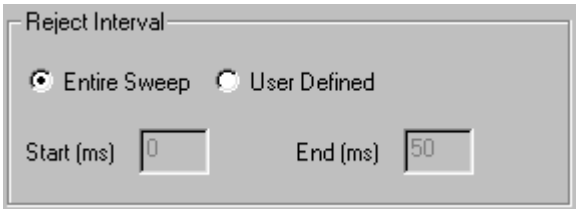
Epoch Interval - The Epoch Interval displays the length of the epoch, as designated in the setup file created in ACQUIRE.



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.

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).



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 uVs). 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 (note: enter the Stop frequency first, as the program will not let the Start frequency be greater than the Stop frequency).

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 (note: enter the Stop frequency first, as the program will not let the Start frequency be greater than the Stop frequency). The rest of the process is the same as with time domain files.

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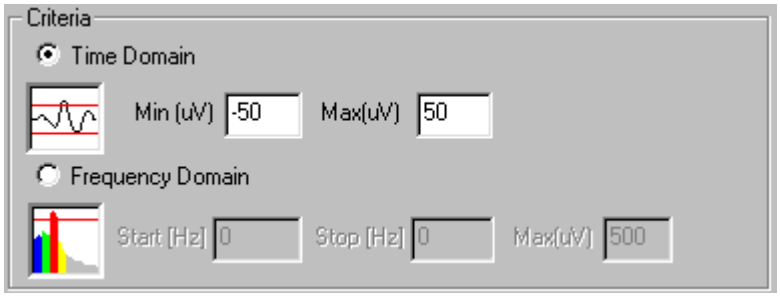
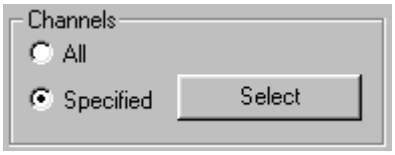


Sweeps that do not meet criteria - If you have already rejected epochs manually, or if you are running the Artifact Rejection routine an additional time, you will have some sweeps that did not meet the rejection criteria. You have the option of retaining these sweeps regardless of whether they meet the 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 alone 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

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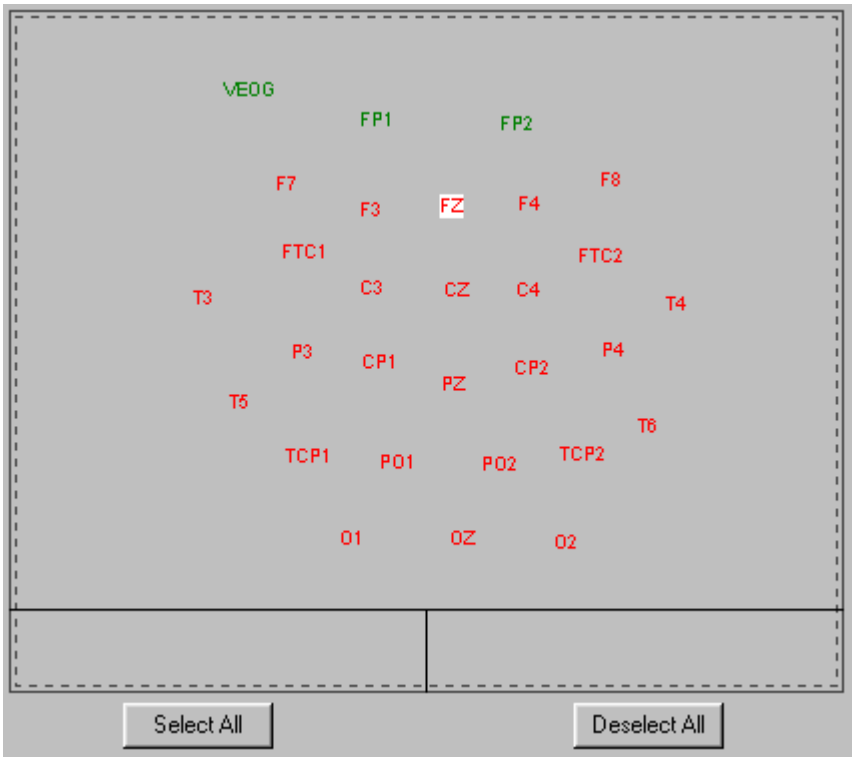

red. Move the mouse over an electrode label, and the fields below the diagram will show the label and the status. Double click on an electrode label to change its status. The Select All button will select all channels for correction; the Unselect All will exclude all channels for artifact rejection.

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

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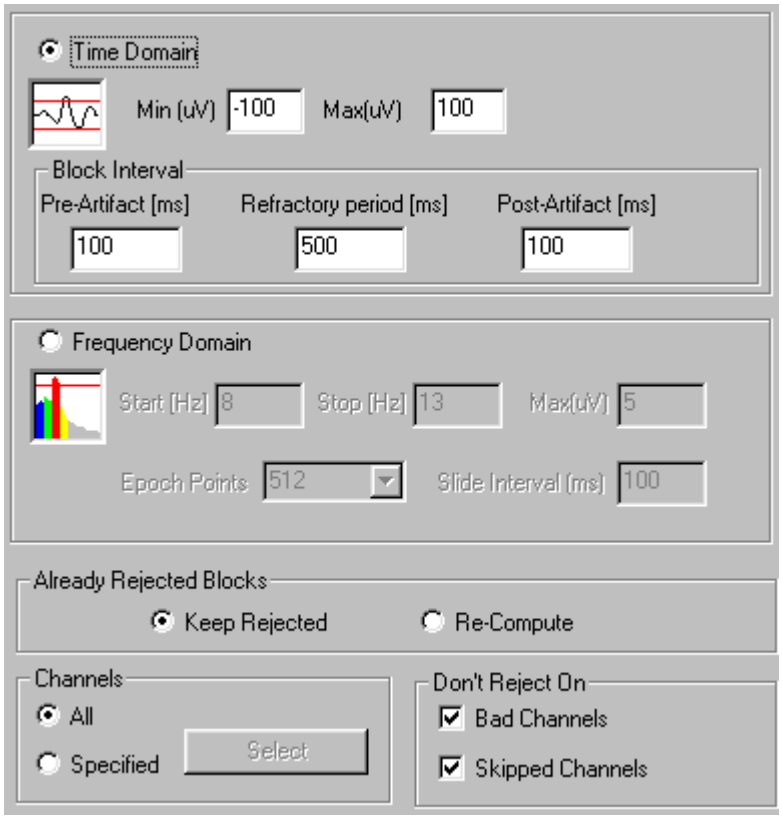
"depressed" button indicates whether the sweep is accepted or rejected. You can, of course, override the settings manually by pushing the alternate button.

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.

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 is a span of time following the artifact during which additional artifacts will not be detected.

For example, the viscpt.cnt was retrieved, and the threshold criteria were set for -100 and 200uV. The Block Interval values were 100, 500 and 100, as displayed above. The regions containing blinks were effectively rejected.

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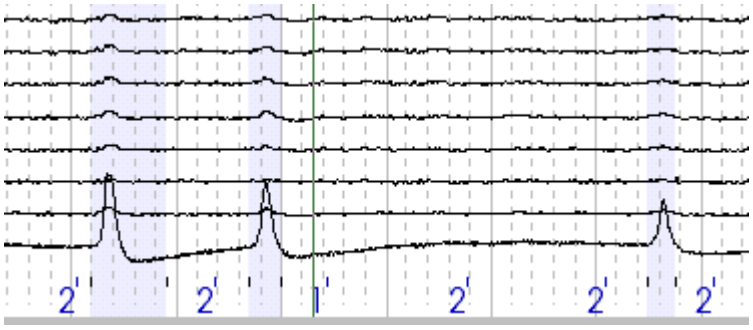
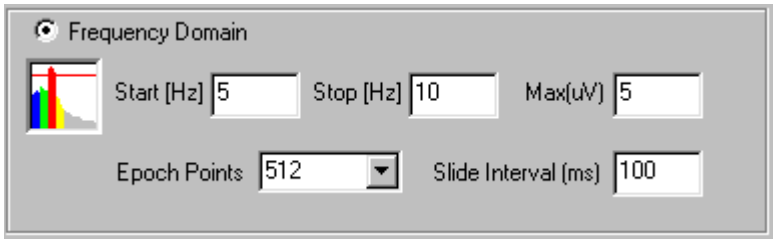


Frequency Domain. Click the Frequency Domain radio field to activate that option.

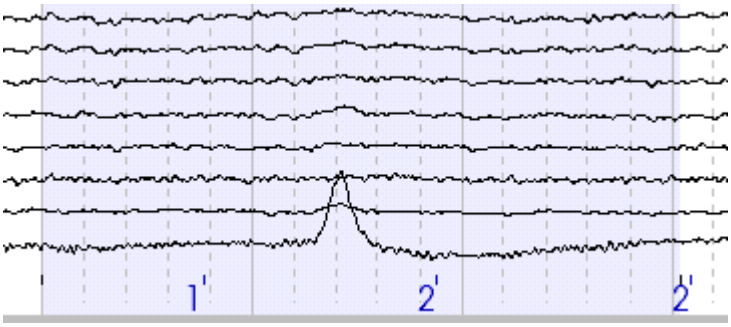


This routine performs a series of FFTs, and then rejects epochs when the power in a specified range exceeds a specified voltage threshold. The span of the epochs is determined by the Epoch Points field, and that will interact with the AD rate used when the file was recorded. For example, if you recorded 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 101-20148ms, and so on.

If the FFT results contain a voltage from the specified channels that exceeds the threshold, 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 is rejected.

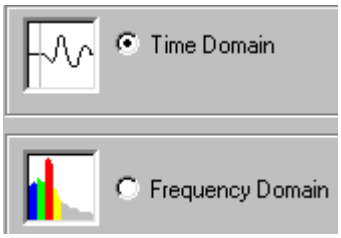


The frequency domain rejection is intended for instances in which you wish to reject sections where there are, for example, periods of drowsiness or sleep (increased theta or delta), or increased EMG that you wish to remove from subsequent analyses.

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 displays 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.

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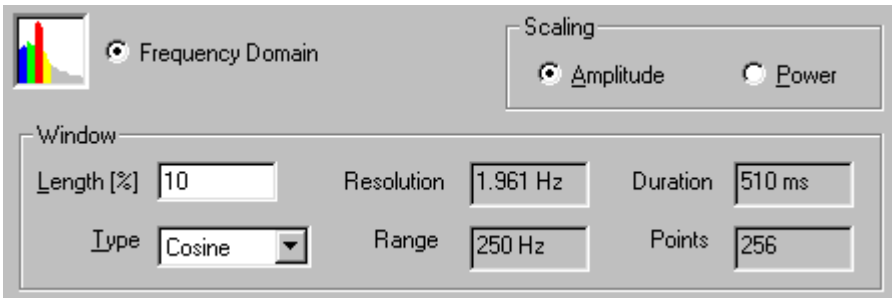

Scaling - Amplitude is computed as a function of frequency, and the results may be scaled in two ways: Amplitude and Power. The Amplitude option takes the square root of the power spectrum to express the units in microvolts. (Amplitude is not precisely the square root of Power; different scaling and 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).

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

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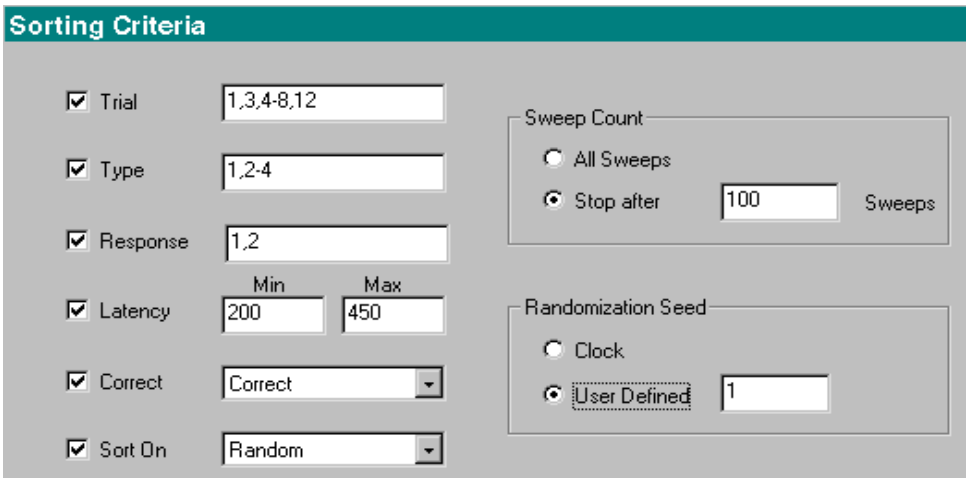
sorting the sweeps to be included. Clicking the Sort Criteria... button displays the Sorting Criteria screen. The screen displays all of the options for sorting the sweeps. If you have multiple sorting options entered, then ALL of the criteria must be met for a given sweep to be included. If an individual 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). For SCAN 3 and SCAN 4.0 users, note that this replaces the vector sort feature.

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**" 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 informa-

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tion 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.

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 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.

Near the bottom of the display you have the choices to Compute the Standard Deviation and/or the Signal-to-Noise-Ratio (SNR is available for time domain files only).

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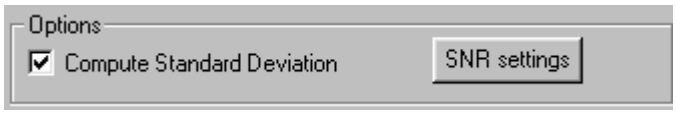
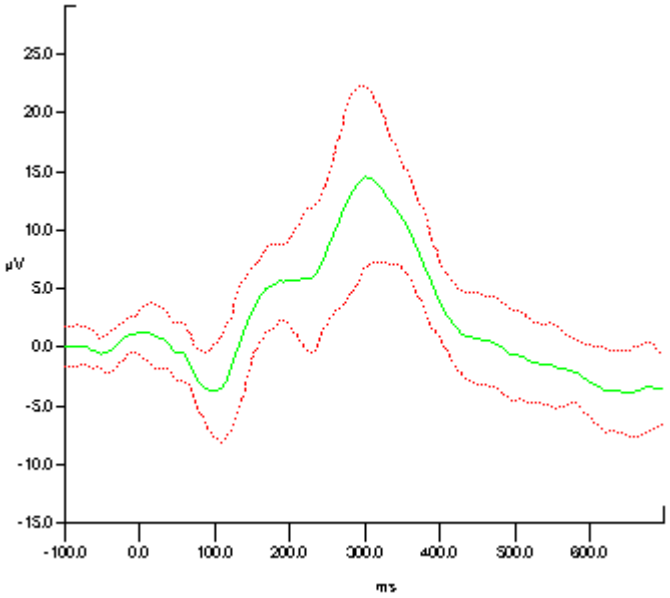


Compute Standard Deviation - The Compute Standard Deviation (SD) field when turned ON will compute the SD on a point-by-point basis for both the time and frequency (as described below) domains. Shown below is a waveform that was averaged with the SD flag set to ON. The dotted lines represent + or - one 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 fro complete details).

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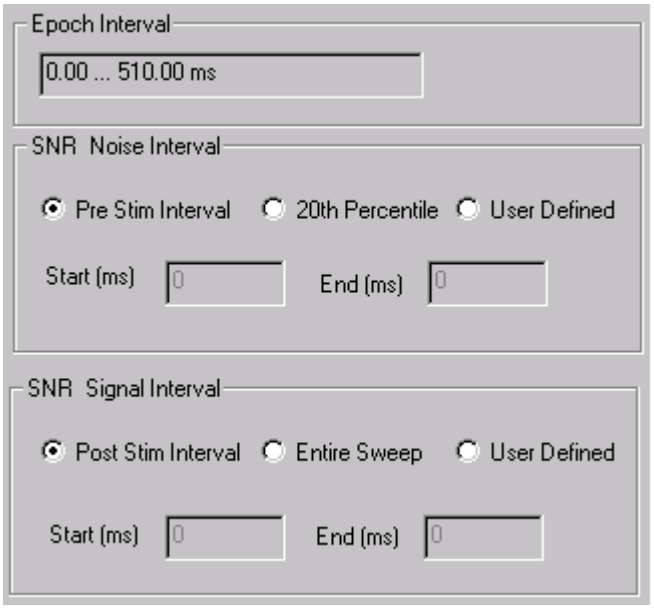

Briefly, for the Noise estimation you can select the pre-stimulus interval (generally used), the value at the 20th percentile (especially if there is no prestimulus interval), or a user defined interval. For the Signal estimation, you can use the post-stimulus interval (generally used), the entire sweep, 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).

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.

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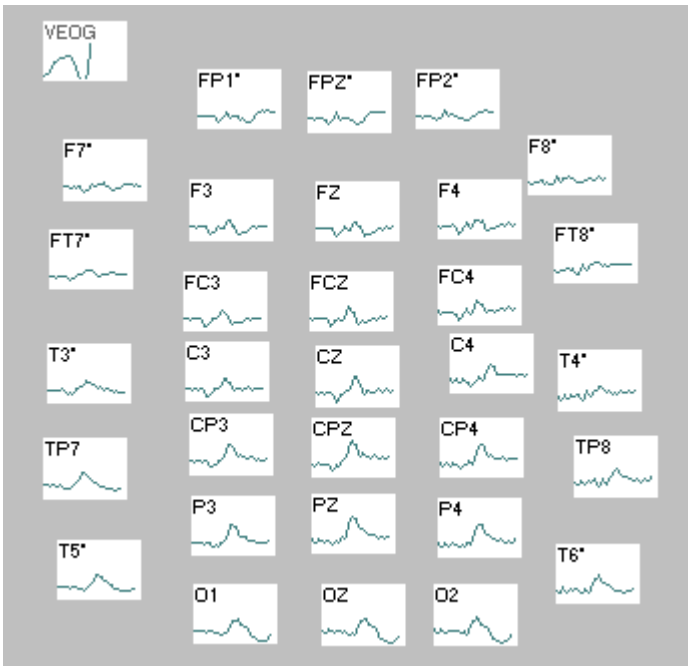
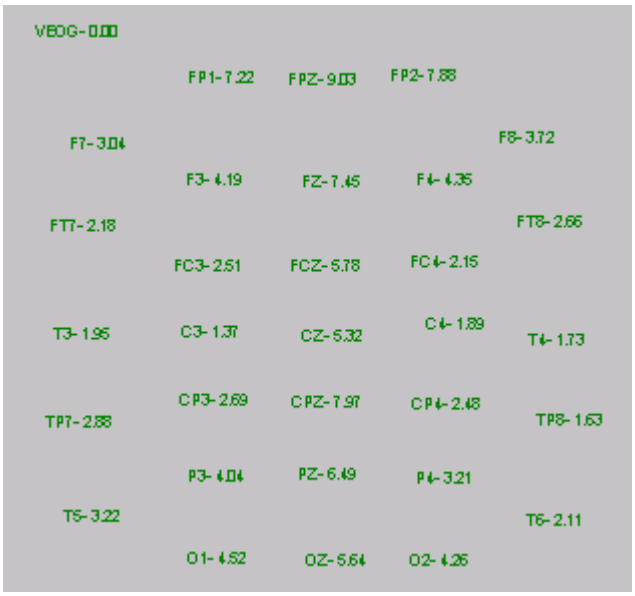


Now let's look at the SNR values that were calculated. For this example, we used the P300.eeg file, corrected for VEOG artifact, and sorted for the Rare responses. Click the right mouse button between the electrode displays, and select "View SNR Values" option. You will see a display with the SNR values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



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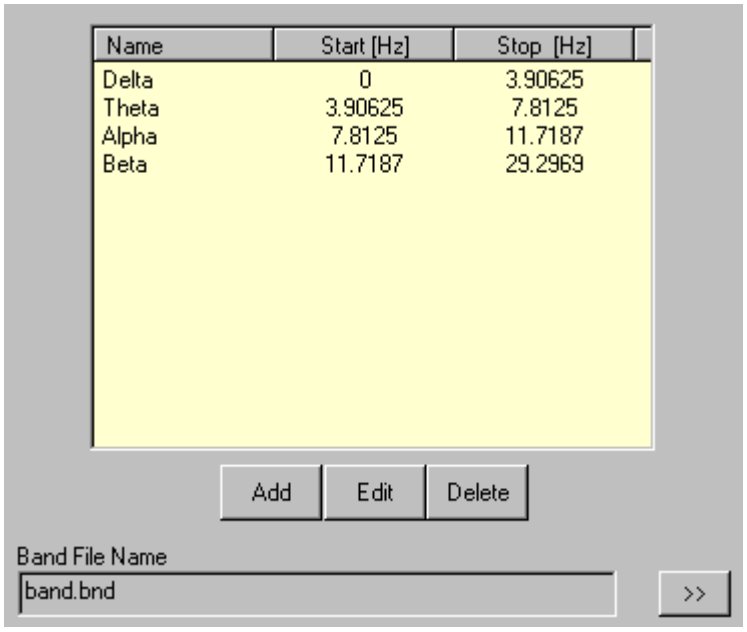
If you enable the Show Labels option, you will see the electrode labels and the SNR values. Note the particularly large SNR values from the centro-parietal sites.

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

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 .bnd 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).

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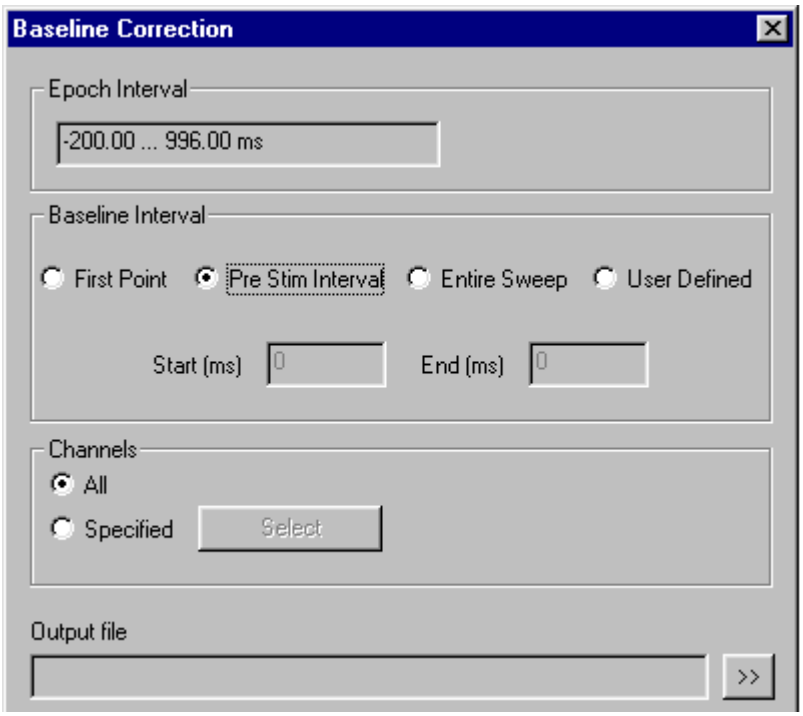
Average spectra within selected bands:

	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

Baseline Correction (EEG, AVG; time domain) - The baseline correct dialog box allows you to modify the D.C. 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 span. The next region gives the options for determining which part of the epoch you want to use for the baseline correction.

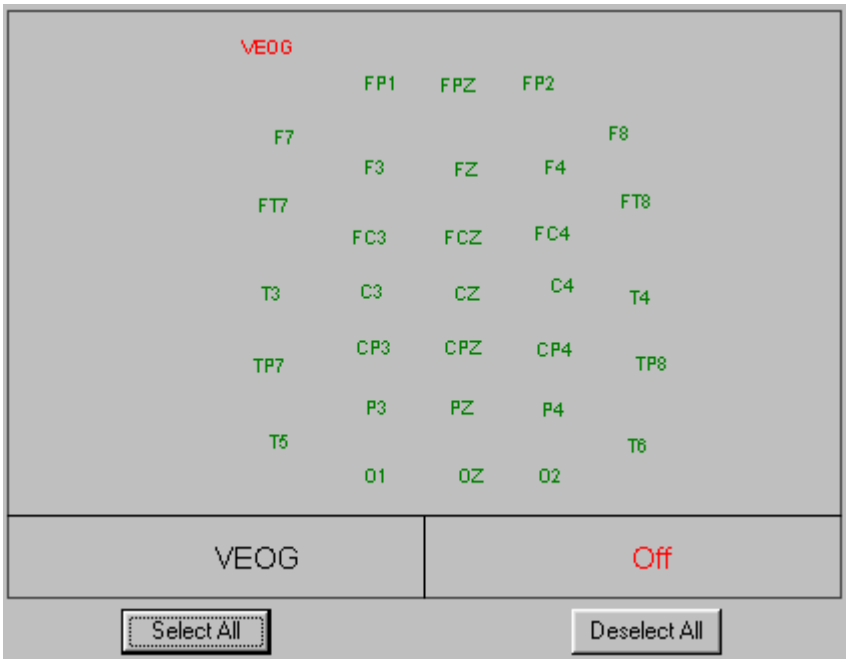
First Point - The First Point option simply uses sets the first data point to zero voltage (the voltage of the first point is subtracted from all data points).

*Pre Stim Interva*l - 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.

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 Unselect All will exclude all channels for correction.

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.

Blink Noise Reduction (CNT) - Blink Noise Reduction is part of the Tool Box 2003 add-on software package. It is designed primarily for the online/offline reduction of VEOG artifact encountered with EEG recordings. You need to be under the maintenance contract in order to access the program (which is contained in the SCAN 4.3 installation CD). For more information, please contact sales@neuro.com or techsup@neuro.com.

Coherence (EEG) - 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:

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

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)

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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.

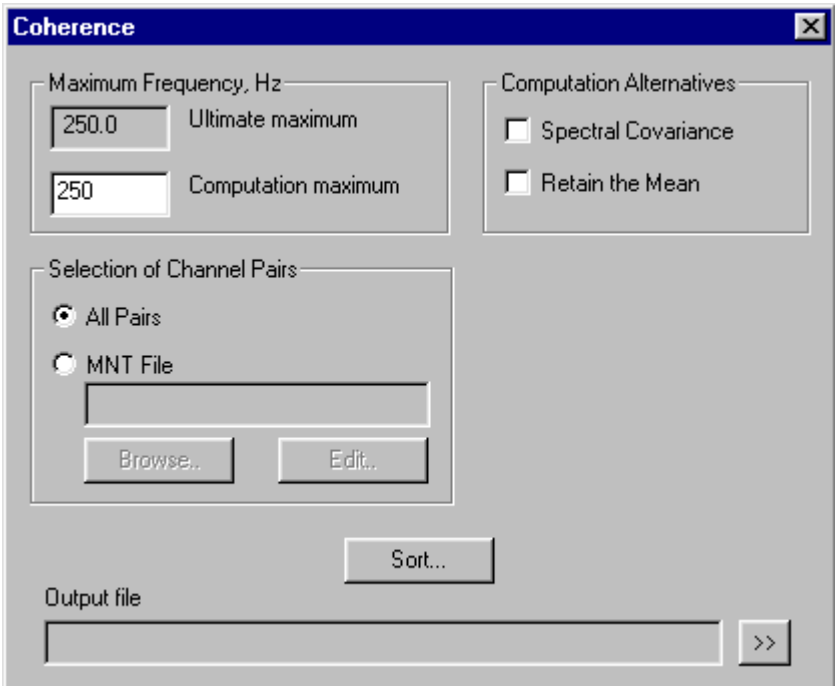
> *Coherence versus Coherency* - You will see that both terms are used, and they have different meanings from each other. Coherency includes phase information. Coherence is a real number, whereas coherency is a complex number. The transform actually computes the coherency spectrum, although only coherence 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 (Event-related COH) 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 unnormalized

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 

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**" 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 Windows display containing the coherence results.

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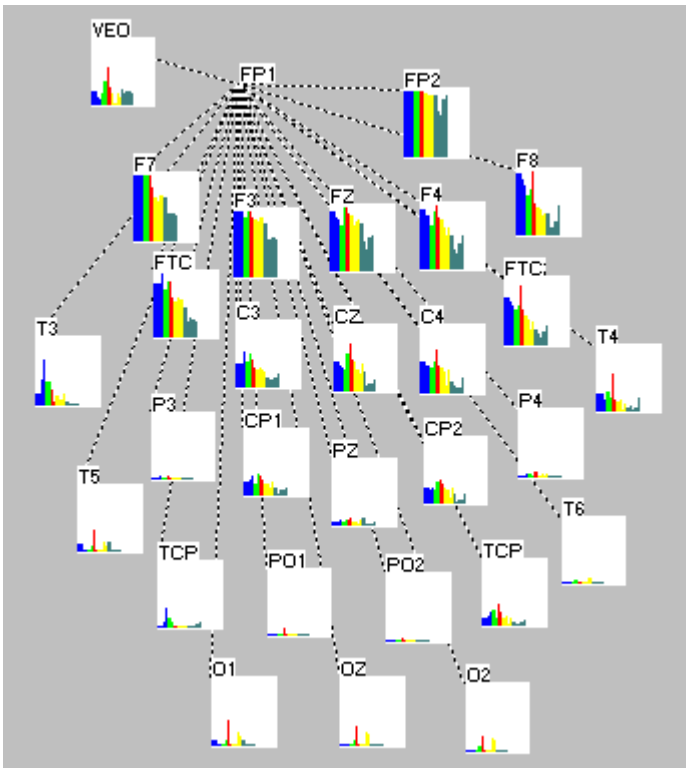
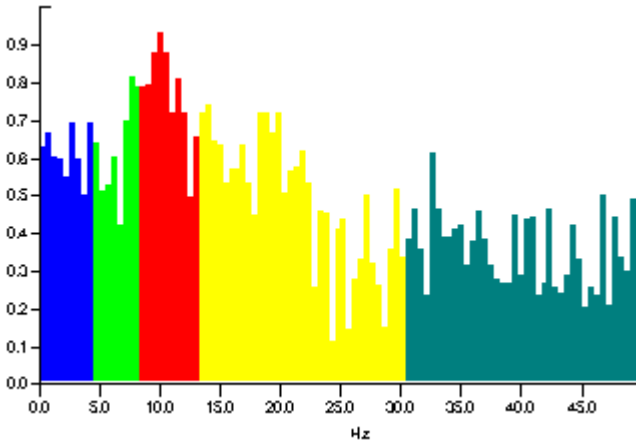


This display shows the coherence values between FP1 and the other electrodes. Zoom into the FZ electrode. You will see the coherence values ranging from 0 to 1.0



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).

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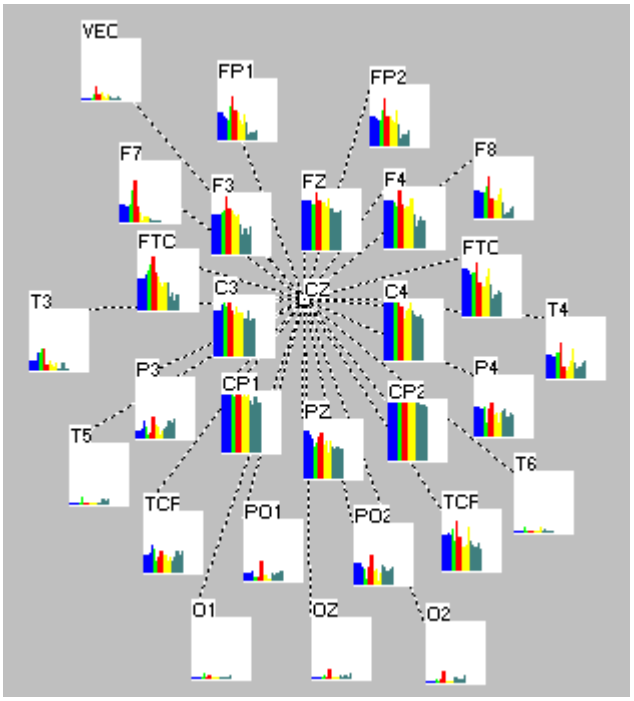
Since we had selected All Pairs above, we can see the coherence values between any given electrode and the remaining ones. To see CZ, for example, click the CZ electrode display with the right mouse button, and select Set Coherence Reference.

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



Note for SCAN 4.3: 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.

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.

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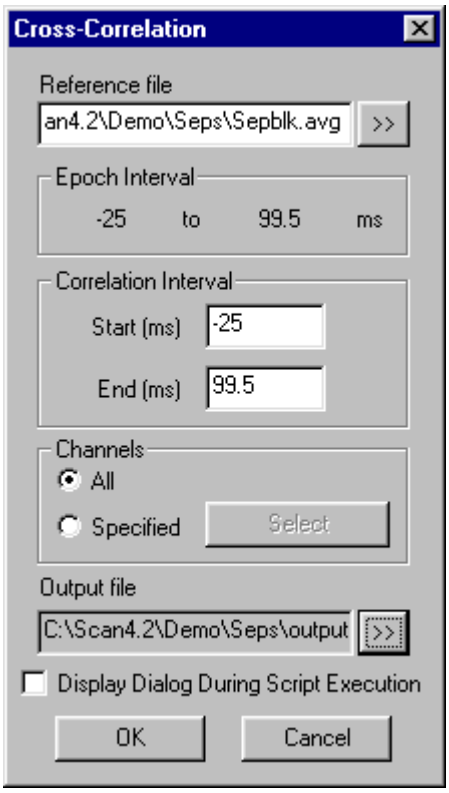

You first need to select a Reference to correlate with the working file. Click the Browse button >>, and select the sepblk.avg file from the Open File utility display. The Epoch Interval area shows the starting and ending time points of the epoch.

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 Windows display containing the cross correlation coefficients. Zoom in on the C3 electrode.

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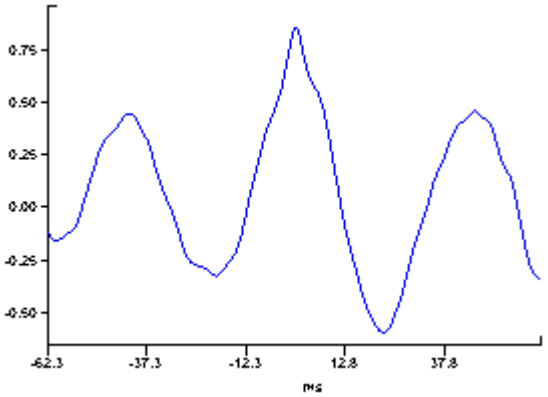
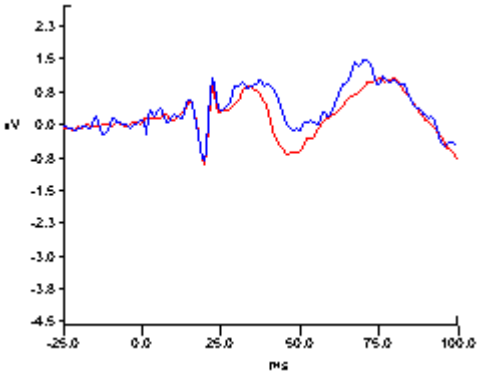


The y-axis displays Pearson's r correlation coefficients. The x-axis is time. The cross correlation statistic computes the correlation between two waveforms at various points in time, in a lagged fashion. That is, correlations are calculated first at time zero, where the two waveforms overlay each other with the same 0 ms 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 0 ms (lagging in the positive and negative directions along the x-axis). Note that the waveform in the display above is essentially symmetric about the 0 ms 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 0 ms 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.

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

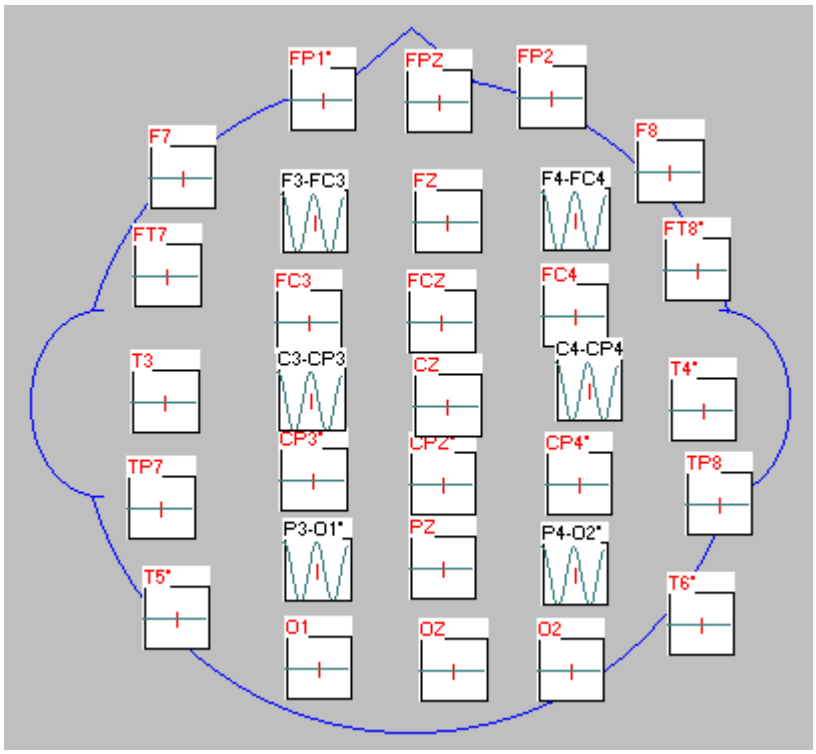


Now, imagine shifting the sepblk waveform (in red) to the right by 22ms, and then recalculating the correlation for the entire epoch (or, rather, the remaining sections that

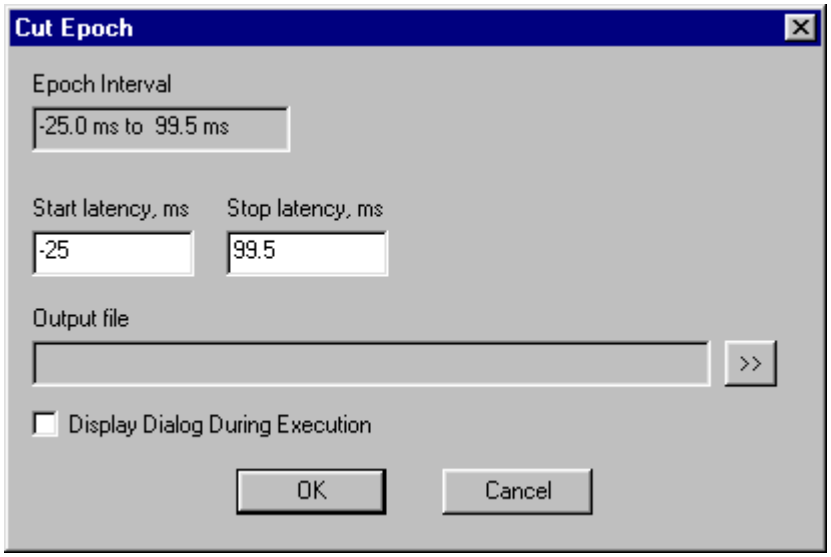
still overlap). You can imagine that the resulting waveforms will be largely out of phase with each other, thus the negative correlation.

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.



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 Laten-

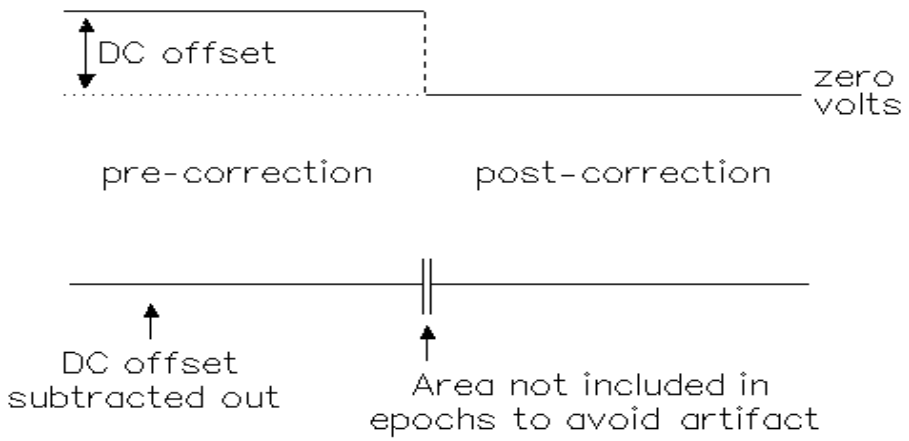
cies (in ms), then use the >> button to enter a file name and designate the path. Click the OK button to apply the transform, then a new Multiple Windows display will appear with the new Start and Stop Latencies.

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 manual. The DC corrections described below may be applied to *recorded* data files.

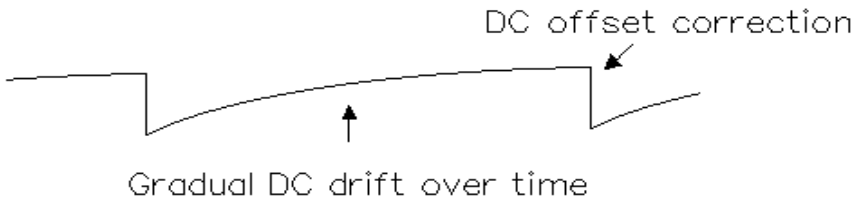
One of the things that we have observed with some regularity since we began offering SynAmps is that users who are accustomed to recording in AC mode are concerned by the drifting waveforms they encounter when first recording with SynAmps using a DC high pass filter. Generally we recommend that users who are not specifically interested in steady state, slow DC potentials should record in AC mode or 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 SynAmps manual. 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 (see below).

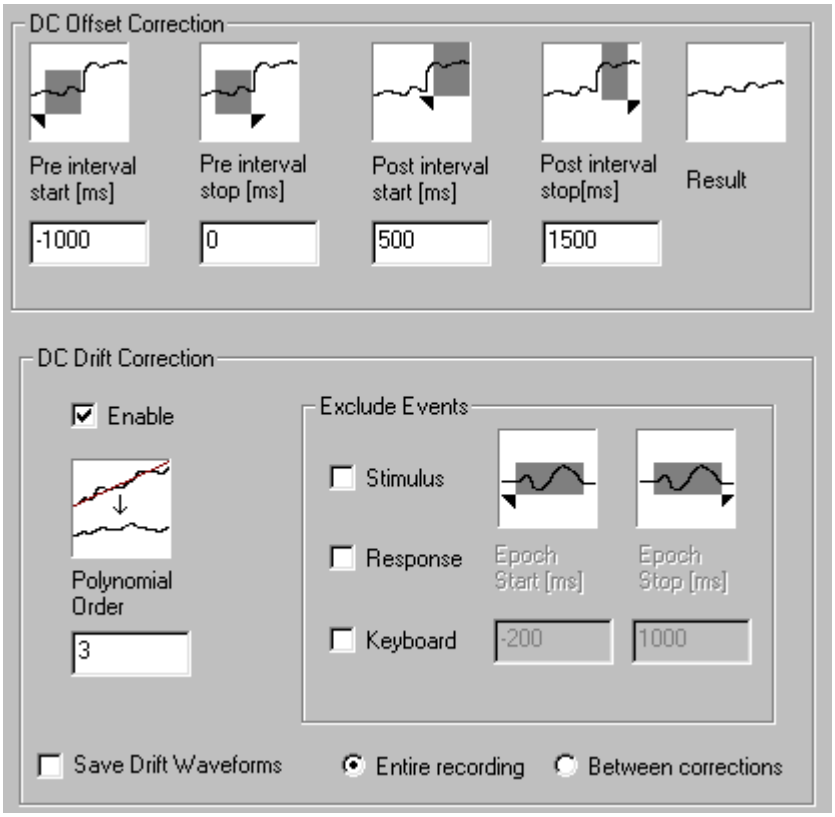


Henninghausen, Heil, and Rosler (1993, *Electroenceph. Clin. Neurophysiol*. 83:199-204) present a method of correcting DC drift for event-related epoched data. The basic principle of the method is to use a low-order polynomial to fit all data points that fall outside time intervals where (slow) event-related 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.

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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 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 some clipping of data toward the end of the file as the signals

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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, $\boldsymbol{a}_k$ for each channel k. The equation to solve is: $\mathbf{B}\mathbf{a}_k = \mathbf{C}_k$, where $\mathbf{C}_k$ 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.

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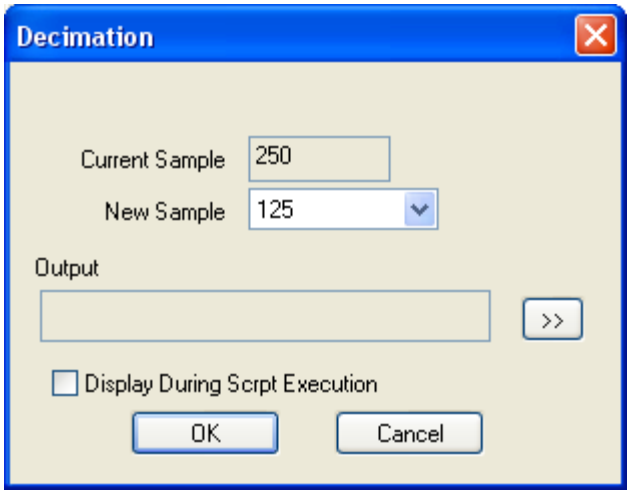
Step 6. Correct the data. Subtract the fitted polynomial function values (for each channel and for each contiguous piece) from the original values for all the time points (including previously excluded points).

Decimate (CNT) - Use this option to decimate CNT files to a lower AD rate. Retrieve the CNT file, select the Decimate transform, and select a New Sample rate from the list of pull-down options. 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 is applied (passed four times) to correct for aliasing. 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.



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. To create the new file, select the Delete Bad Channels option under Transforms, and Save As display will appear.

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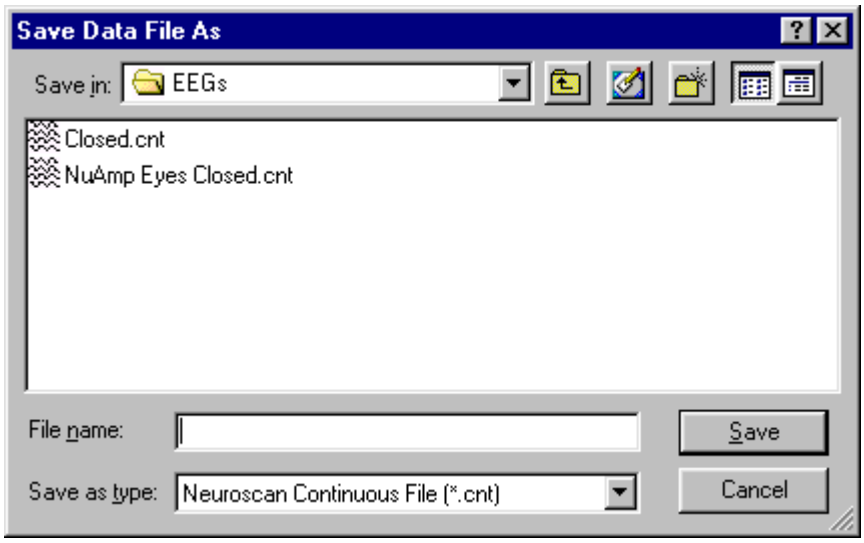
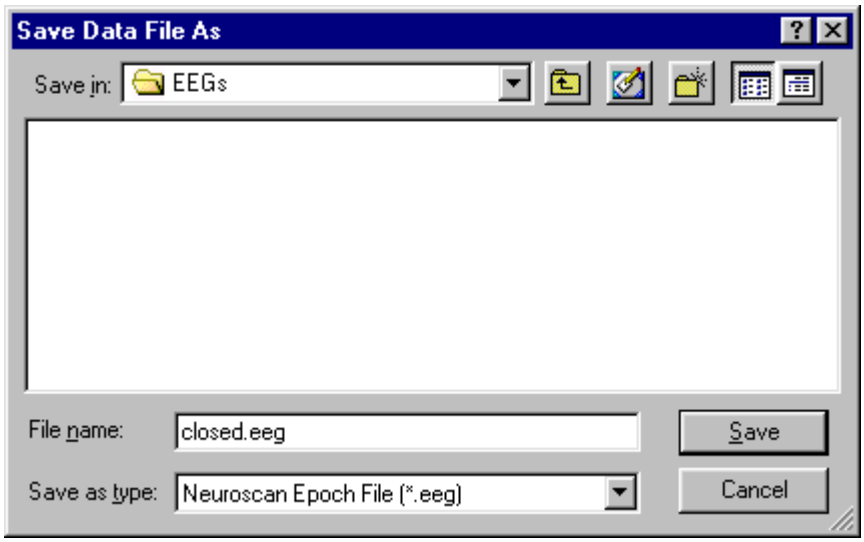


Enter a file name, designate the path, and click Save. A new Single Window display will appear with the "Bad" channels deleted.

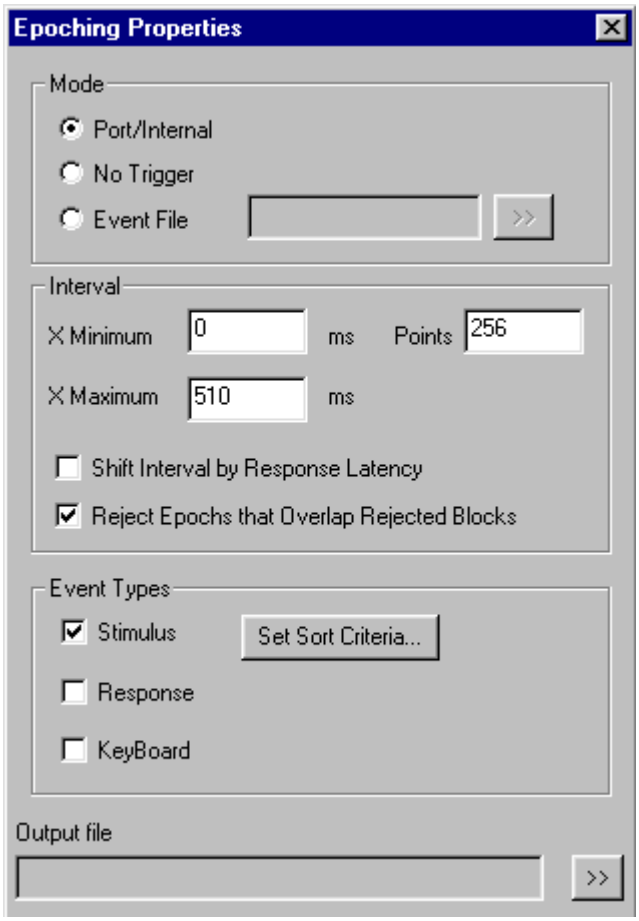
Delete Rejected Sweeps (EEG; time and freq domain) - This option will create a new EEG file containing only the sweeps that have been accepted. After retrieving an EEG file, click Delete Rejected Sweeps under Transforms. The standard Save As... screen will appear. Enter a file name, designate the path,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



EKG Noise Reduction (CNT) - EKG Noise Reduction is part of the Tool Box 2003 add-on software package. It is designed primarily for the online/offline reduction of ballistocardiogram and heart beat artifact encountered with EEG recordings in the MR bore. You need to be under the maintenance contract in order to access the program (which is contained in the SCAN 4.3 installation CD). For more information, please contact sales@neuro.com or techsup@neuro.com.See also the Blink Reduction transform.

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 section describing Spline Fit 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).

Response-locked averaging - It is possible to create averages around the response triggers as well as the stimulus triggers. Greater flexibility is available if you have the behavioral data file (DAT file) created in STIM, or an equivalent file if you are using some other stimulus presentation package. The DAT file should be merged with the CNT file, using Merge Task Data (described below). However, 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.

> *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 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 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 the Sort Criteria option. The program will create epochs around every response trigger that is in the file.

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 Windows 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 overlap any rejected segment?
-would the epoch contain a DC event?

If any of these are true, the epoch will not be created.

Some notes about response codes. You may encounter some confusion when dealing with response 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

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stimulus trigger in the CNT file. Upon re-saving 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 very similar 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 epoch 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 have responses from the 4th button will be averaged. Note: this type of sorting is only possible AFTER a DAT file is merged.

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*.

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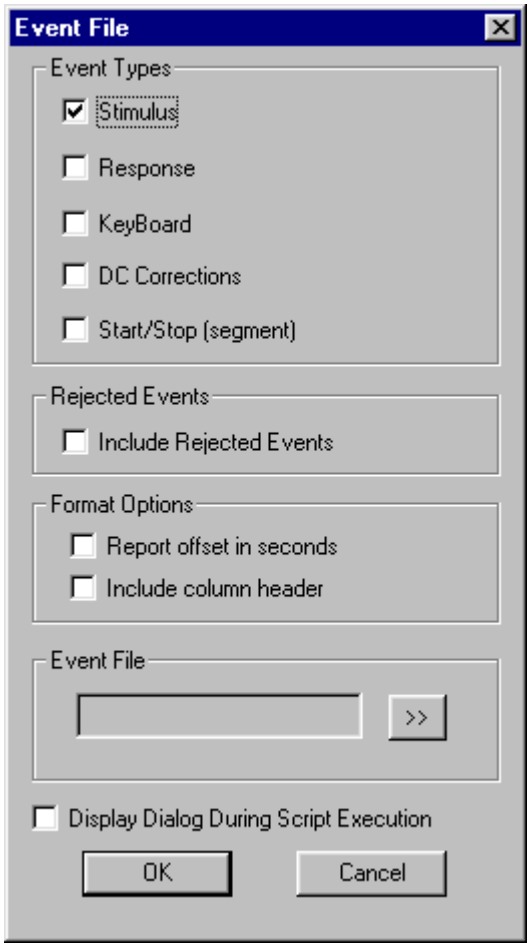
Event File (CNT) - You can epoch a continuous file without first creating an event file (.EVT or EV2). However, using an event file provides more flexibility in epoching a continuous file. Event files are text files that can be modified prior to epoching — either manually with the aid of an editor, or 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 appears as follows.



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 Task file is specified when the event file is created.

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.

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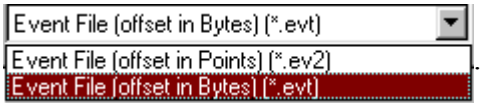
(#)	(type)	(resp)	(acc)	(RT)	(offset)
1	2	1	1	0.3990	3106
2	2	1	1	0.2920	3398
3	2	1	1	0.2510	3715
4	2	1	1	0.2700	3997
5	2	1	1	0.3590	4256
6	2	1	1	0.2950	4588
7	2	1	1	0.2700	4905
8	2	1	1	0.2800	5197
9	1	2	1	0.3900	5514
10	2	1	1	0.2990	5756
11	1	2	1	0.4920	6023
12	2	1	1	0.2720	6319
13	2	1	1	0.2630	6607
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

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.

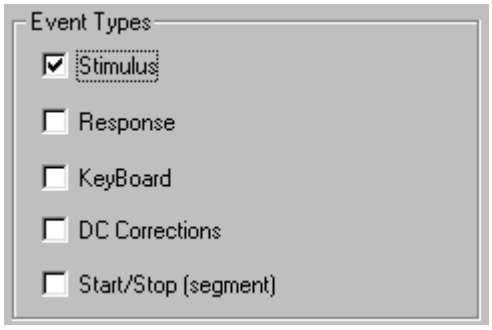
In versions 4.1.1 and later, you will have the option to use either type of event file. When you prepare to run the Event File transform (described in more detail below), and click the

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

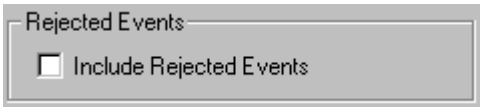


. When you Epoch a CNT file using an existing event file, you will see a similar option for selecting the type of event file that you wish to use.

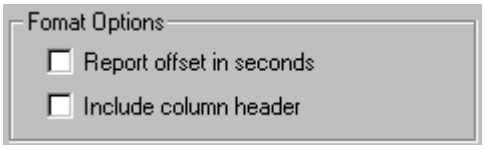
Follow these steps to create an event file: Retrieve the CNT file, and select Event File from the list of Transforms options. Select whether you want to include Stimulus, Response, Keyboard, DC Corrections (appear in the event file with 'DC' in the second column), and Start/Stop events (appear in the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



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



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.



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.

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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).

Using RESPWIN and RESPEVT - The following information pertains to the older DOS version of RESPWIN (see also the RespWin transform that has been included in version 4.3, described below). At the present time, neither RESPWIN (DOS version) nor RESPEVT can use event files with EV2 extensions (this will likely be addressed in the near future). In the meantime, RESPWIN version 2.15 (currently on the ftp site) treats Scan 4.1.0 event files as a special case. In order to interpret EVT files generated by Scan 4.1.0 correctly, you should enter "410" in the "type" field (see the sample PAR file included in the RESPWIN.zip file). The "type" should be set to "1" with 2 exceptions: 1) set to "0" for data collected with Scan 2.0 or prior (and converted with some conversion programs, such as BLCTOCNT); 2) set to "410" for Scan 4.1.0 acquired data.

Event-Related Band Power (AVG, EEG; time domain) – This transform computes power (or amplitude) of induced (and/or evoked) event-related EEG activity in a centered frequency band as a function of time. Power computations are based on magnitude squared (uV^2 units), whereas amplitude computations are based on absolute magnitude (uV 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 0 Hz; and step (2) lowpass filters the spectrum by the half-bandwidth on either side of 0 Hz (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 (uV^2) or amplitude (uV) scaling—alternative scaling options are treated further 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.

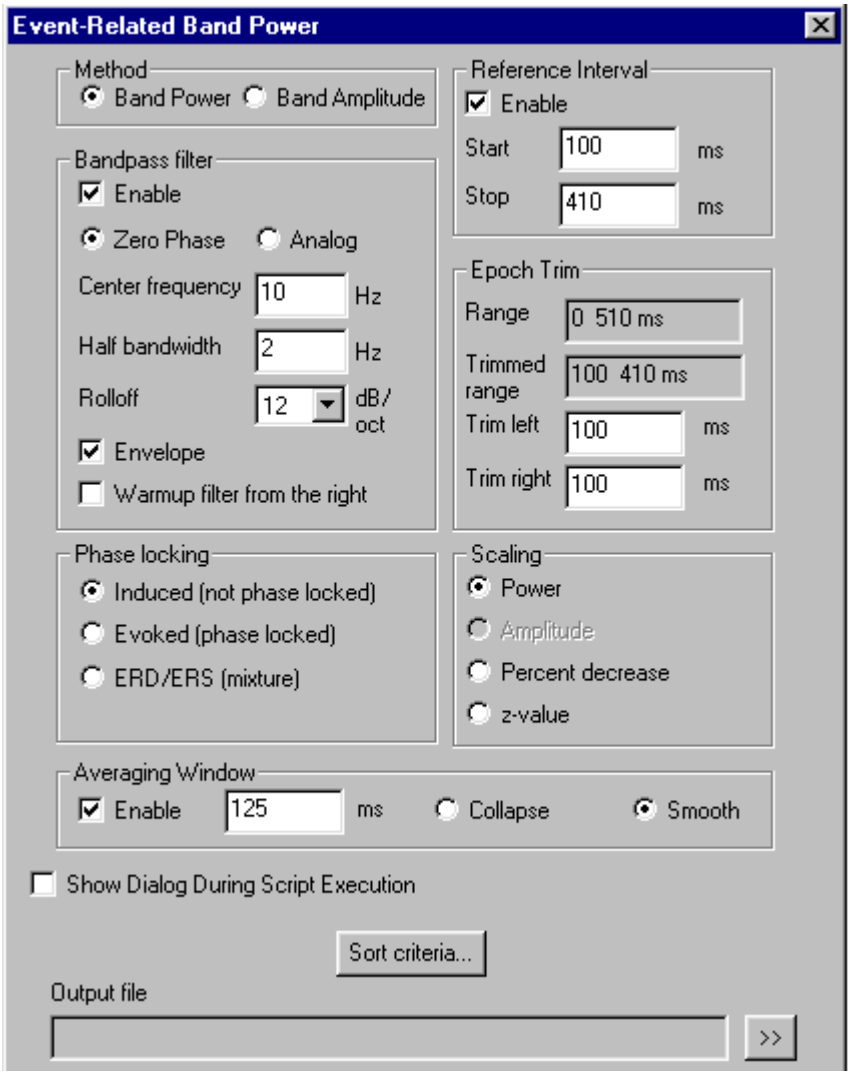
Evoked Band Power equals the magnitude squared of the average in a frequency band of interest, i.e., the power of average evoked oscillatory activity within a specified frequency range.

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). The method of complex demodulation achieves symmetric roll-off and enables computation of the signal envelope. If the data have already been filtered in

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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. However, there are two drawbacks of pre-filtering the continuous data: the continuous filter characteristics are not zero phase (only analog simulation is currently supported), and the envelope option is not available. For this reason, extra features have been added for treating the filter warm-up problem (direction of warm-up, and trimming).

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 10 Hz, and the Half bandwidth is 2 Hz, then the frequency band is 8-12Hz (6 dB down at the ends). In this example, maximum sensitivity is centered at 10 Hz, and the filtered output of a pure 8 Hz (or 12 Hz) 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 3, 6, 12, and 24 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 default. 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, and is 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.

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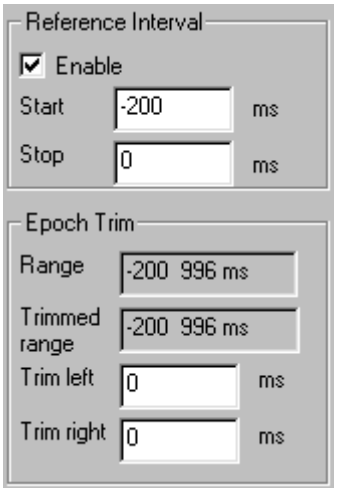
Reference interval - The Reference interval is tied to the Percent decrease option in the Scaling section. When you calculate the Percent decrease, it must be in relation to some other section of the epoch. The Reference interval lets you specify that section.



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.

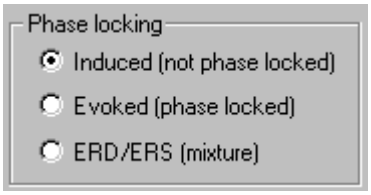
Range – The full available time range of input epochs.

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.

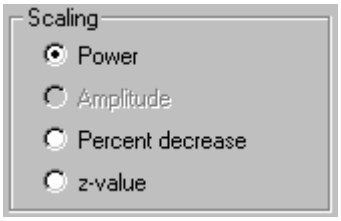


Induced - Induced activity is the non-phase-locked activity that typically dominates the raw recording. As described above, it is computed by removing the contributions from phase-locked activity.

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 uV^2.

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

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 250 ms. If the bandwidth is increased, the averaging window can be made smaller. The default setting disables the averaging window.

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 

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**" for some important information.

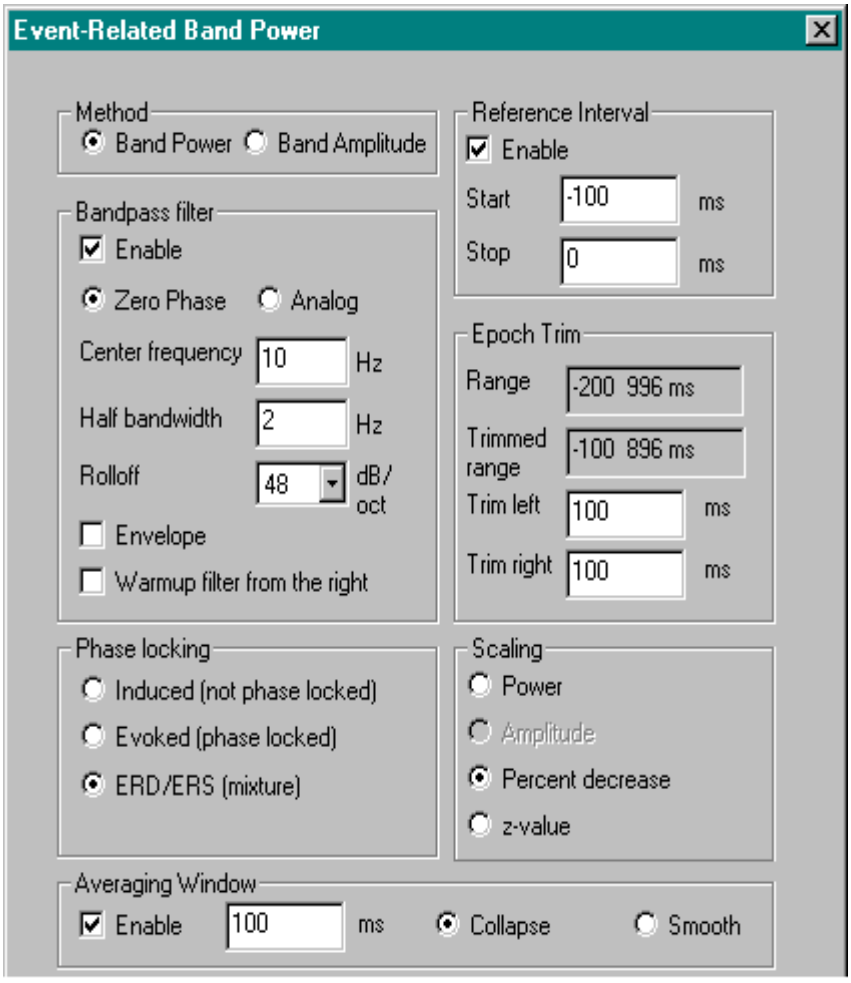
Output file - Click the 

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.

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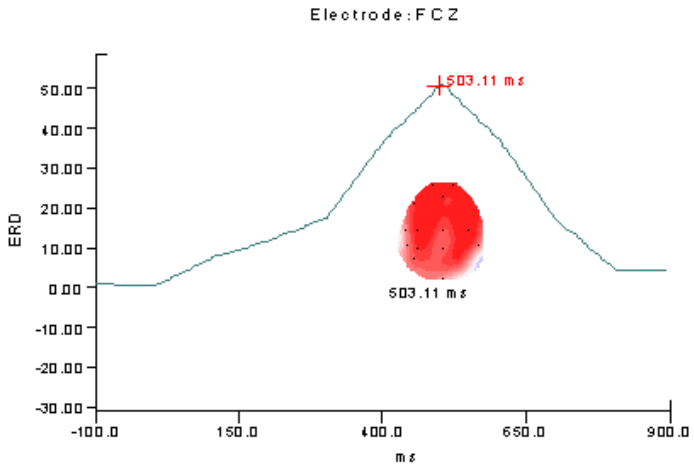

Induced band power - Investigations of Induced band power are increasing in prominence in the literature. They may be replicated here by selecting the following options. Select Band Power or Band Amplitude, Disable the Envelope option, disable the Reference window, select Induced activity, select the 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.

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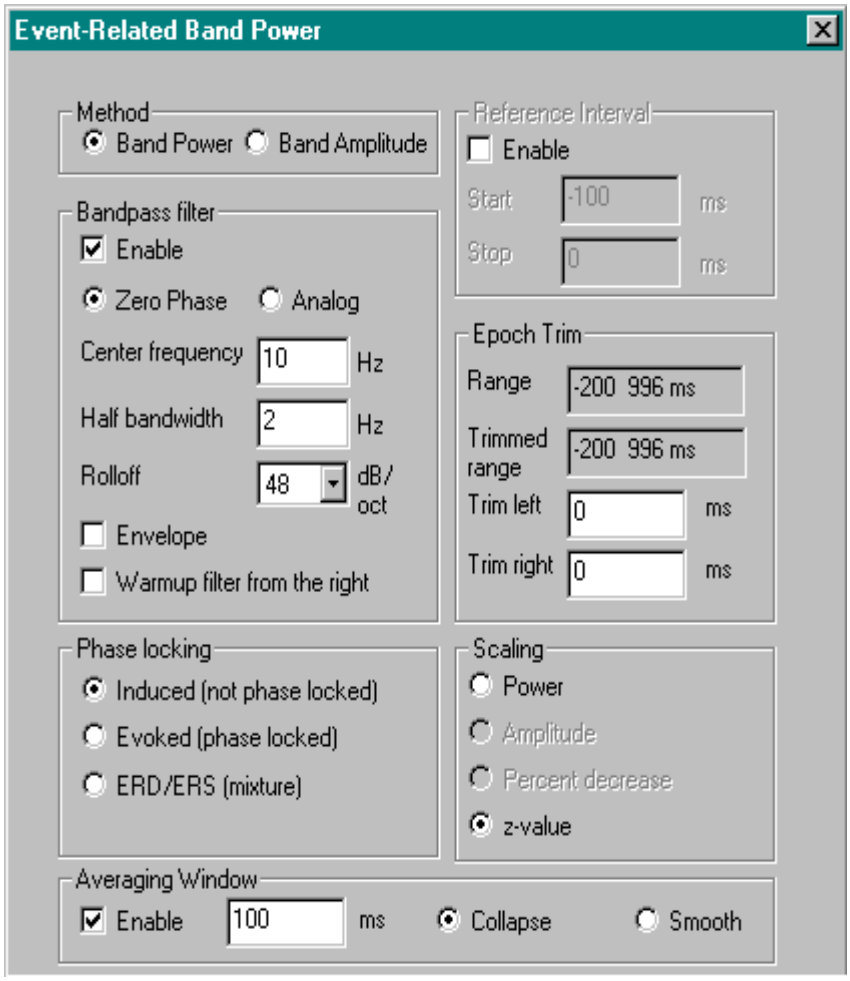
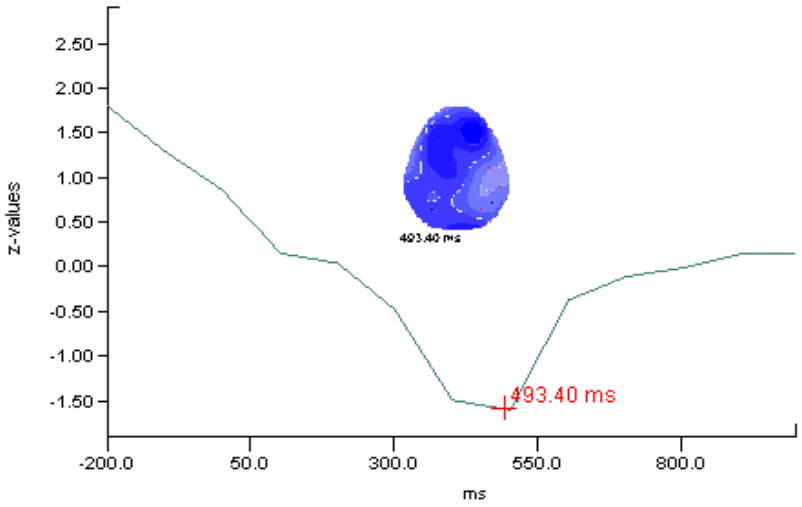
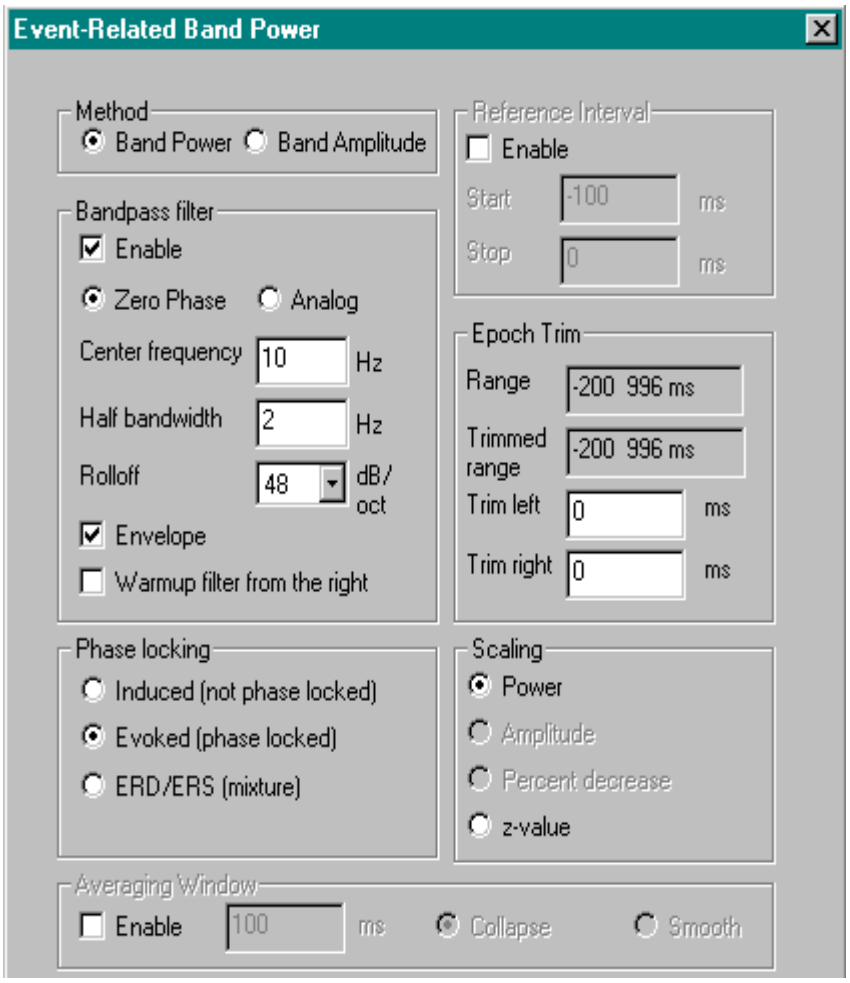


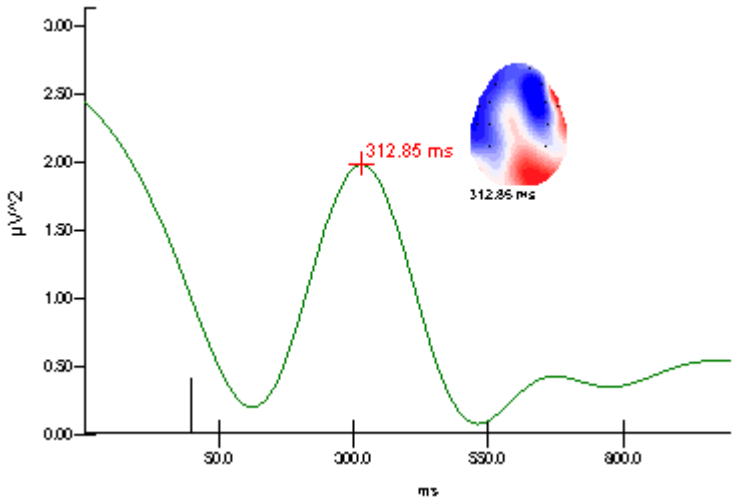
The resulting AVG file would appears as follows.



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

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 10 Hz 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 (Event-related COH) 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.

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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.

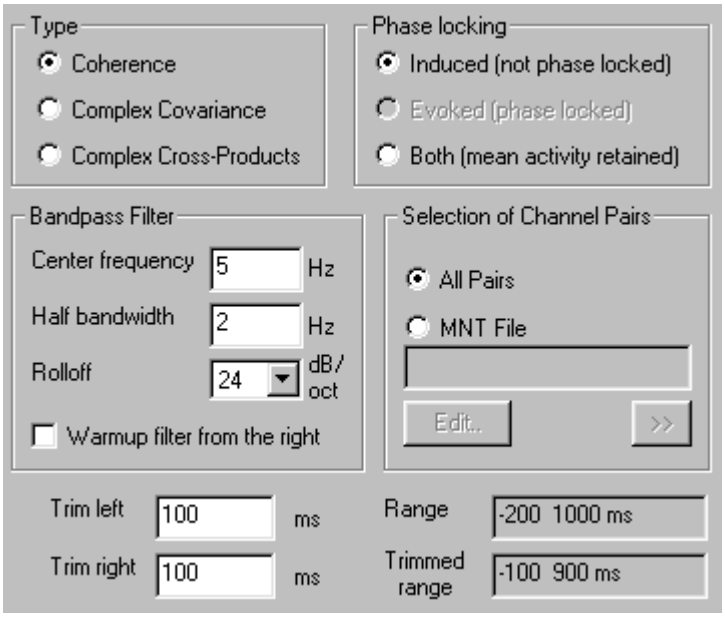
Trim right – Number of milliseconds to trim from the end of the epoch.

Selection of Channel Pairs - This is the same as for the ordinary coherence transform. (Please refer to that section above for more details).

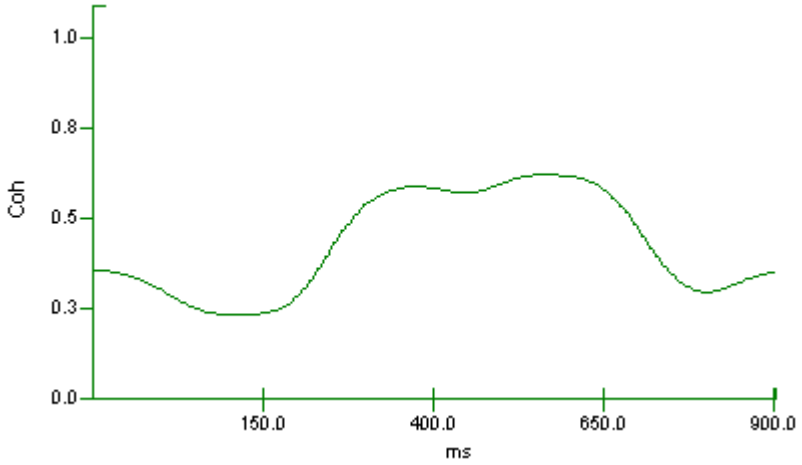
Sort Criteria - The Sort Criteria button displays the regular Sorting Criteria display through which you may select the desired sweeps to be analyzed. If you are using the Response field, please see the section entitled "**Some notes about response codes**" for some important information.

Output file - Click the >> button to select a folder and enter an output file name.

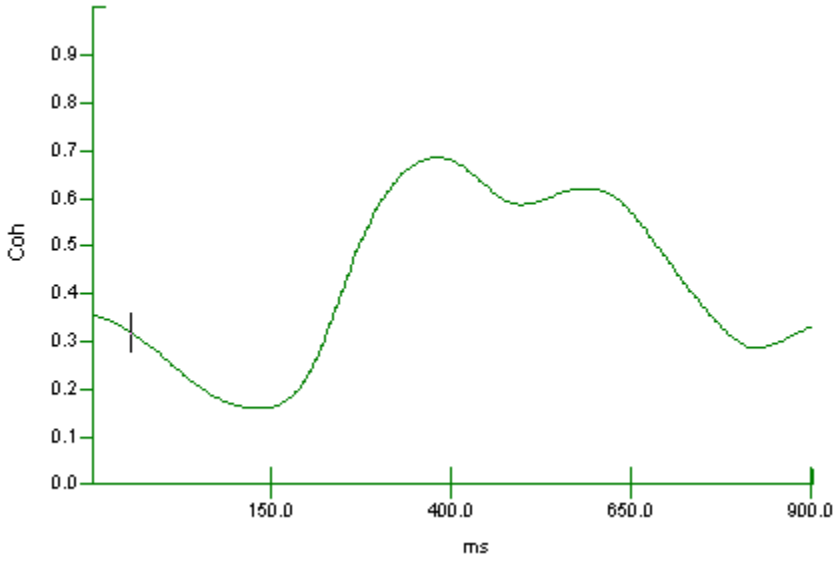
Example. Retrieve the P300.eeg demo file. Note that even though the points are not a power of 2, the ERCoh transform may still be applied. Set the fields as in the figure below. This will be a basic illustration of ERCoh where the mean activity (phase locked) is removed, and the results are normalized 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 is not subtracted out.



Slightly different results emerge when Complex Cross Products, and Evoked phase locking (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.

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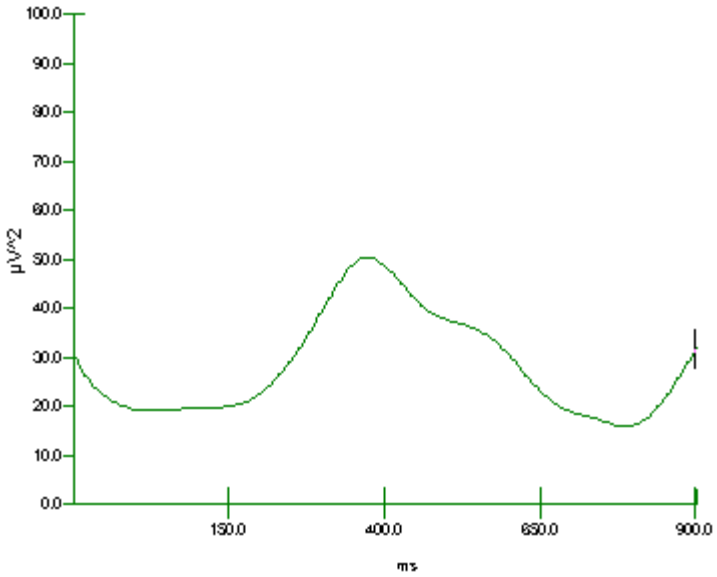
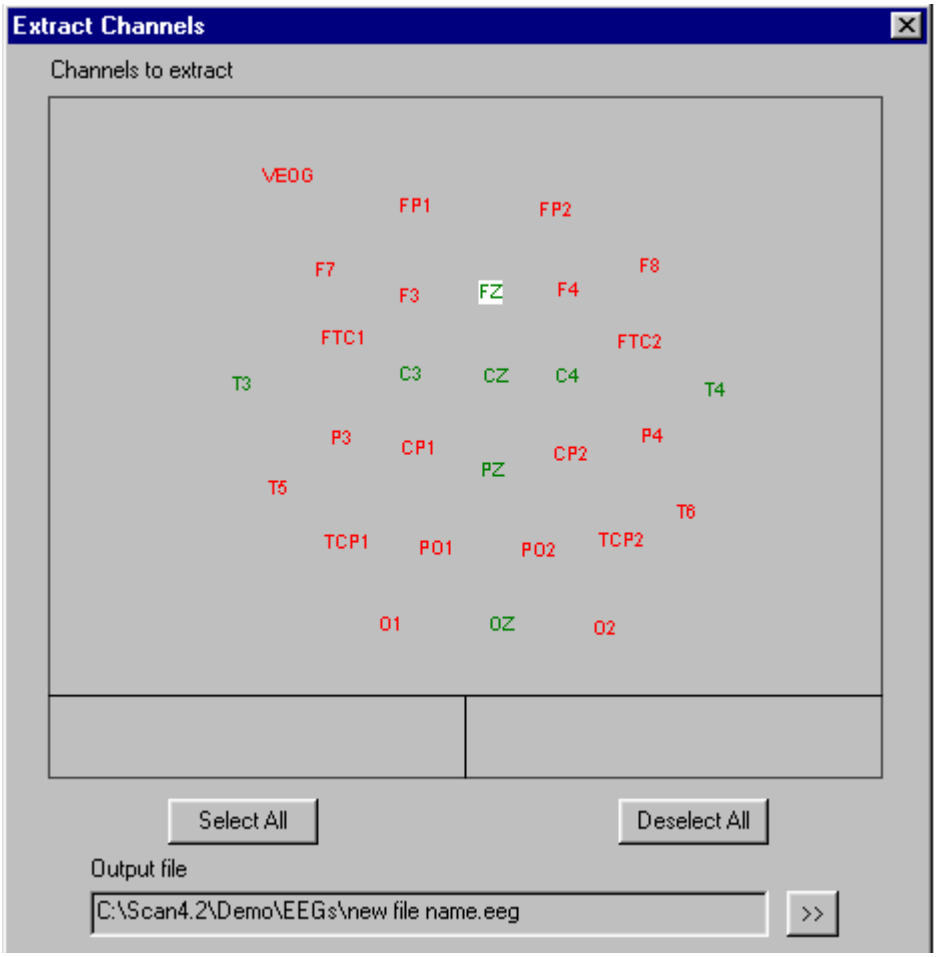


Obviously, there are many ways to vary the ERCoh transform (different methods, frequencies, references, recording conditions, etc.). The above are just a few examples.

Extract Channels (EEG, AVG) - 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 following 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.

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 3 dB 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
	12	24
dB/oct	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 4.3, 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.

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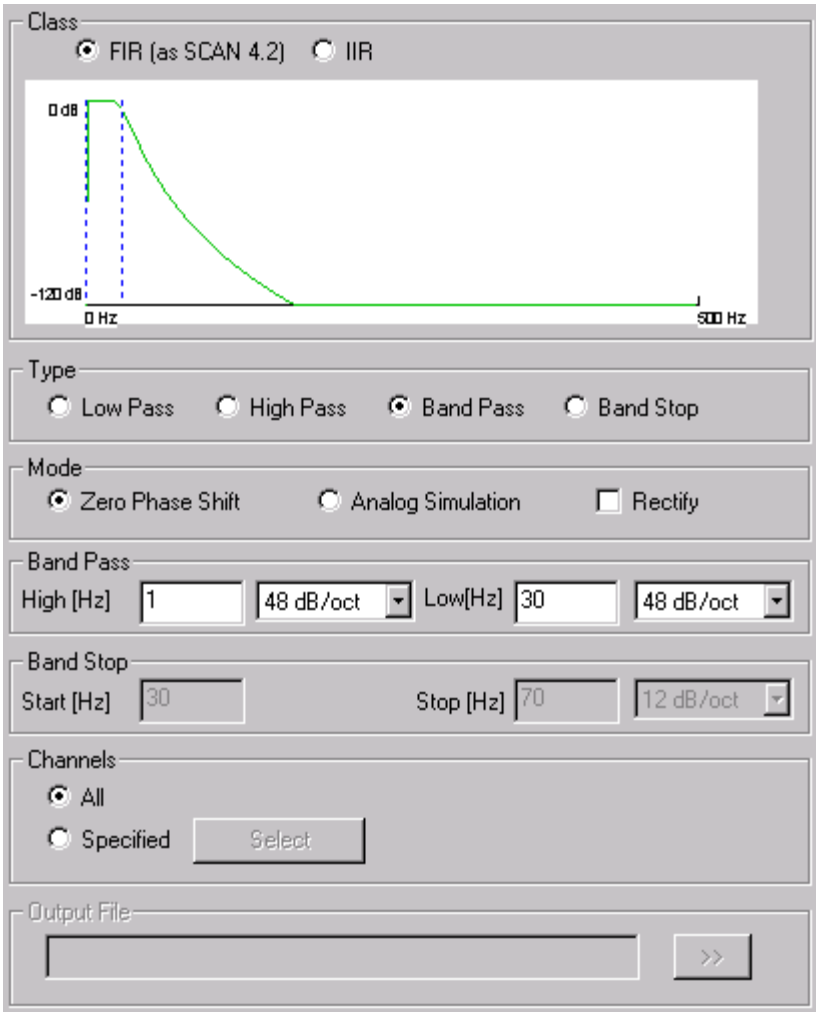

The Filter window is divided into 7 main sections: Class, Type, Mode, Band Pass, Band Stop, Channels, and Output File. The diagram at the top of the window displays the results of the settings you enter.

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 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 filter permits a linear, predictable phase *error* that does not occur with IIR.

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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 less prone to phase mismatches.

Warning: 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 a 20kHz AD file, when using a 24dB slope and a high pass up to 1.3 Hz.

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).

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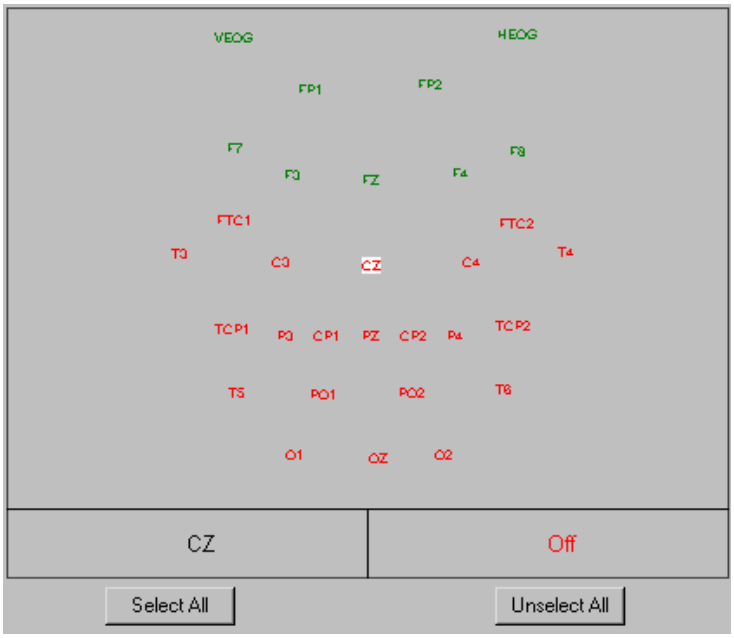
Band Stop - This region will be active if you selected the Band Stop type of filtering above. Enter or select the desired options as described in the Band Pass section above. *Note: Band Stop filtering is basically the opposite of Band Pass filtering. Band Pass filtering affects frequencies primarily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

Channels - This toggle allows you to select individual channels for off-line 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 Unselect 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.

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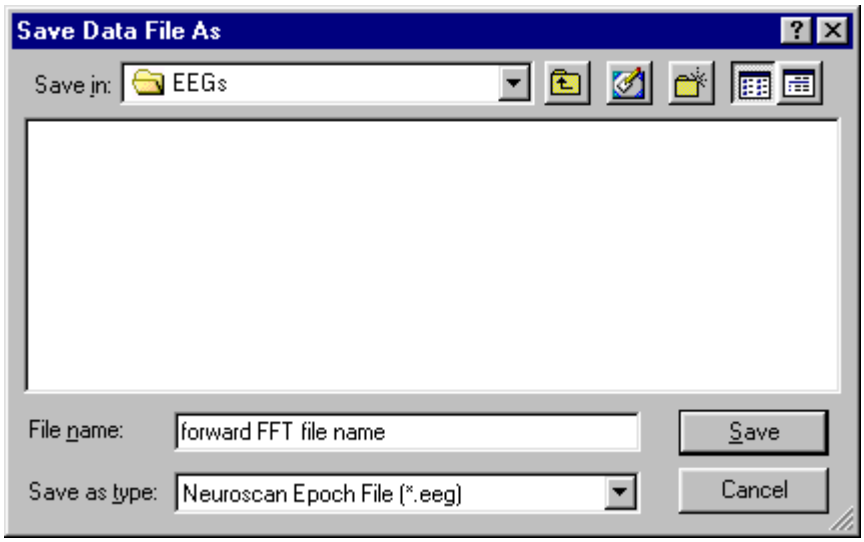
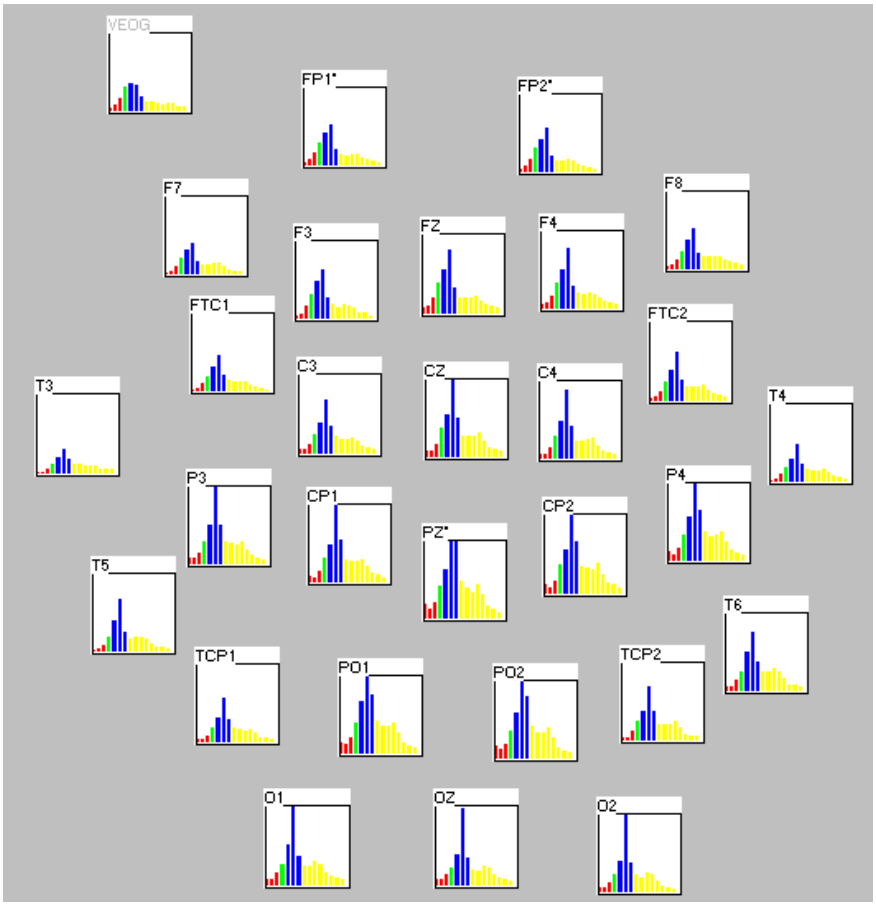
Forward FFT (EEG; time domain) - The Forward FFT option is used to convert time domain data (real or complex) to complex frequency domain data. EEG files converted to the frequency domain via this transform store the full complex information in Cartesian coordinates, although the display shows the amplitude (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 Windows 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, click the right mouse button anywhere between the electrode channel displays, and select the Properties option. Select Overall Parameters and then the Frequency tab. 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.

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 off-line 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.

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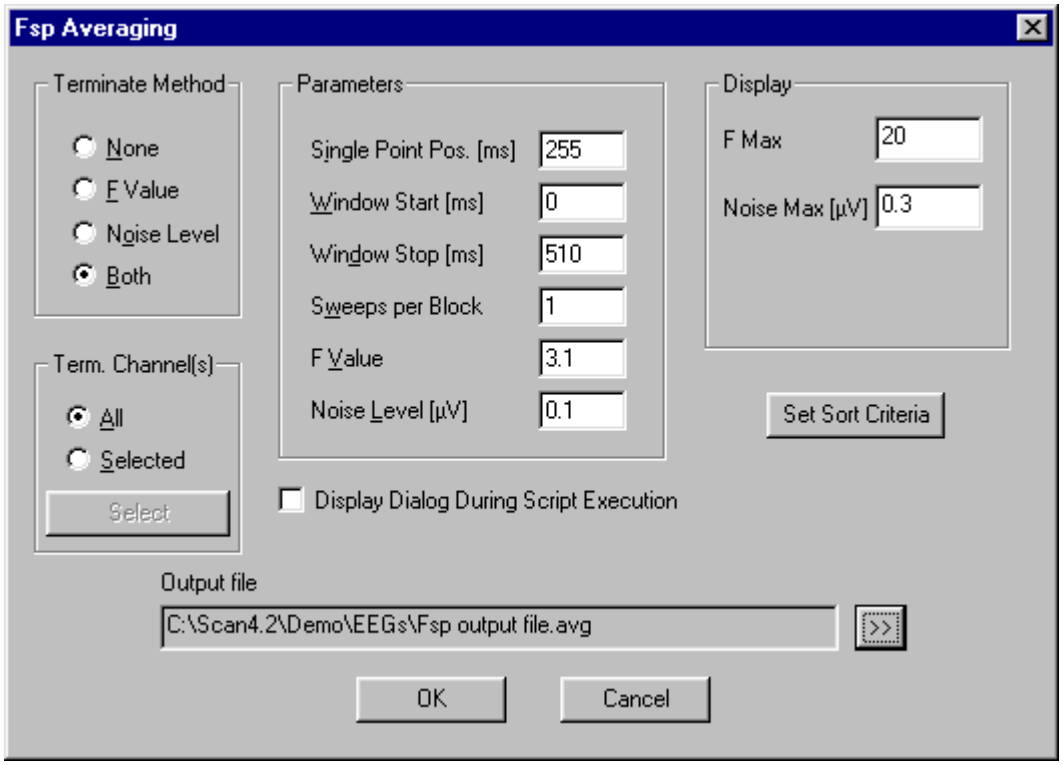

Terminate Method - Select one of the options below if you want to employ an F_{SP} termination method.

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 0.02uV. The noise criterion will terminate the analysis when the terminate method is set to NOISE or BOTH on the designated channels.

Both - Analysis will be terminated if either the F_{SP} or noise criteria are met.

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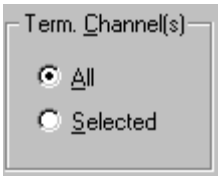
Terminate Channel(s) - The terminate channels fields allow you to specify

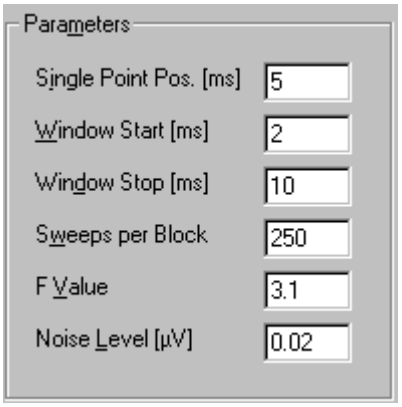


which channels will be monitored for termination criteria:

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 10ms is typical.

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.

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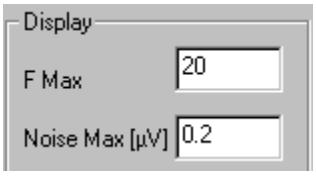
F-Value - Input the desired F value that, when reached, will terminate acquisition. A typical value for the ABR is 3.1.

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

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.

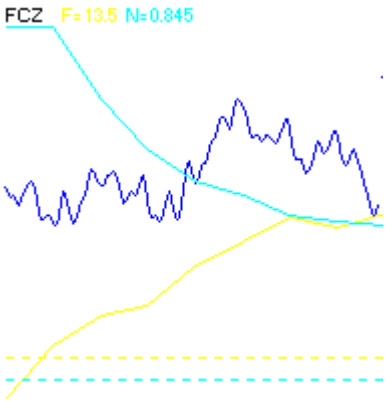


F Max - The F Max sets the upper limit of the range on the F value display. A typical value is 20, although you may go lower for a more sensitive display.

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

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**" 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 will appear with the Fsp results for each channel.



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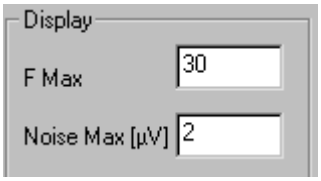
The example above used the viscpt.eeg file purely for demonstration purposes. More typically, the Fsp procedure has been used with ABR recordings. Its applicability to cortical EPs is not well known. The point here is to explain the information in the output file.

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, click the right mouse button anywhere except within an electrode display, and then click the Properties option. Select Overall Parameters. You will now see the same display as described elsewhere for Overall Parameters, with the addition of the Fsp Average tab. Click it, and see the Fsp display screen. 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.

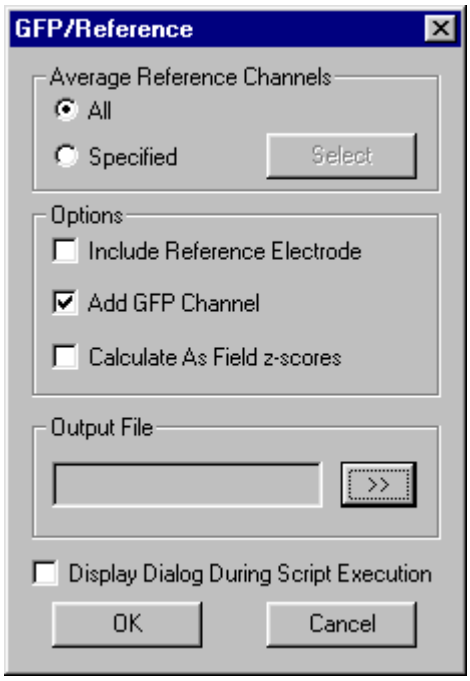
There are two dashed lines. The yellow one is the threshold for the Fsp statistic, and the light blue one is the threshold for Noise. The rising yellow line is the Fsp value that is calculated across the blocks of sweeps. Note that it is superimposed on top of the waveform, but does not correspond to 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.

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 EEG or AVG data file, click on Transforms in the main menu 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.

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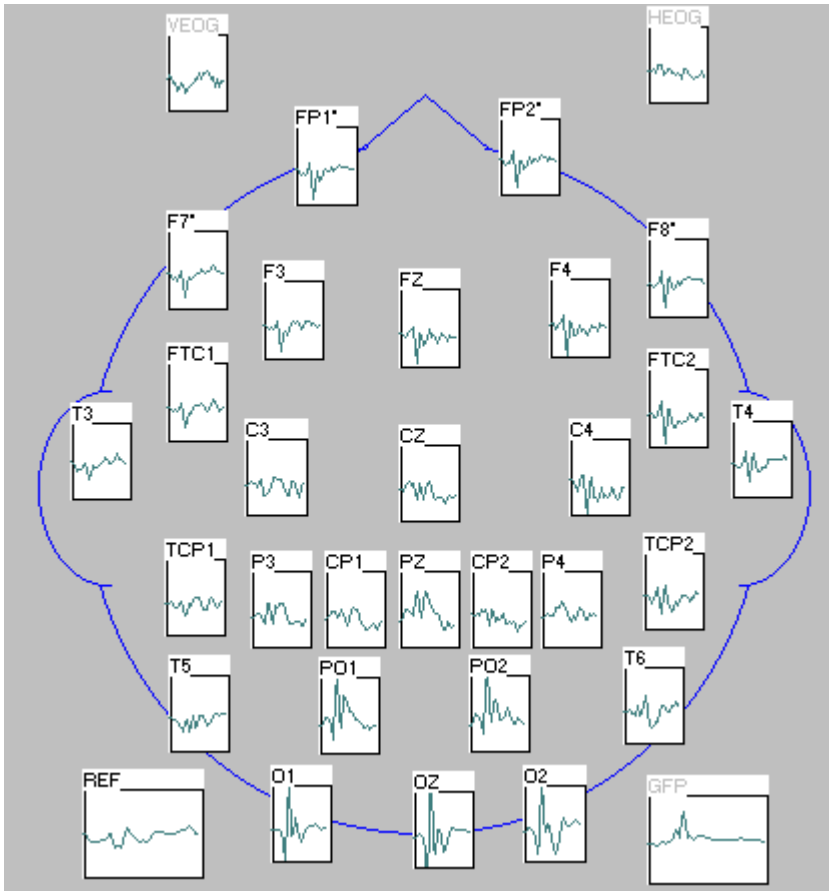
The Add GFP Channel will display a new channel with the GFP results.

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 a movie. 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.

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.

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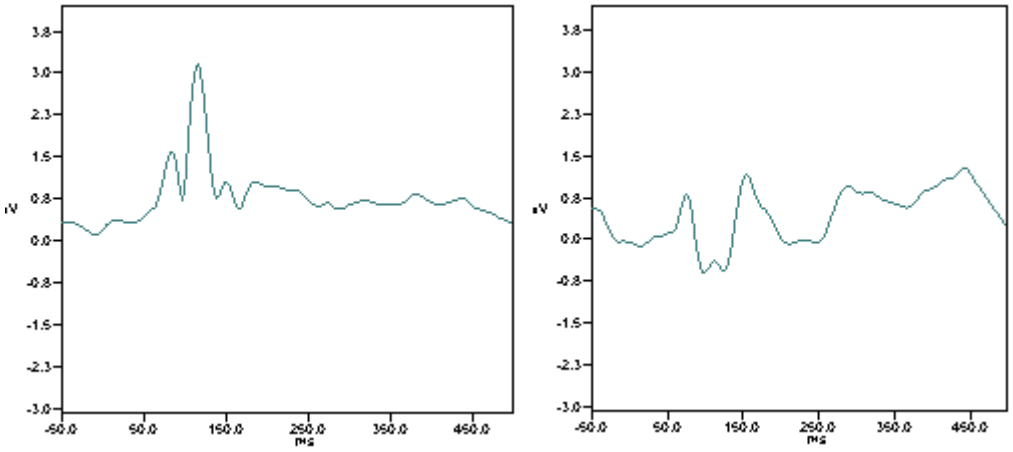
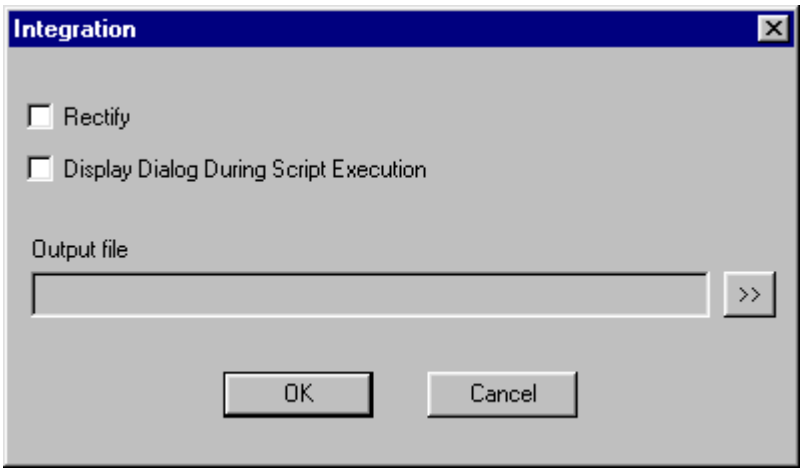


GFP REF

Two maxima are found in this waveform: one at 70 ms the other at 100 ms. The maxima correspond to the N70 and P100 responses located in the occipital leads.

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")

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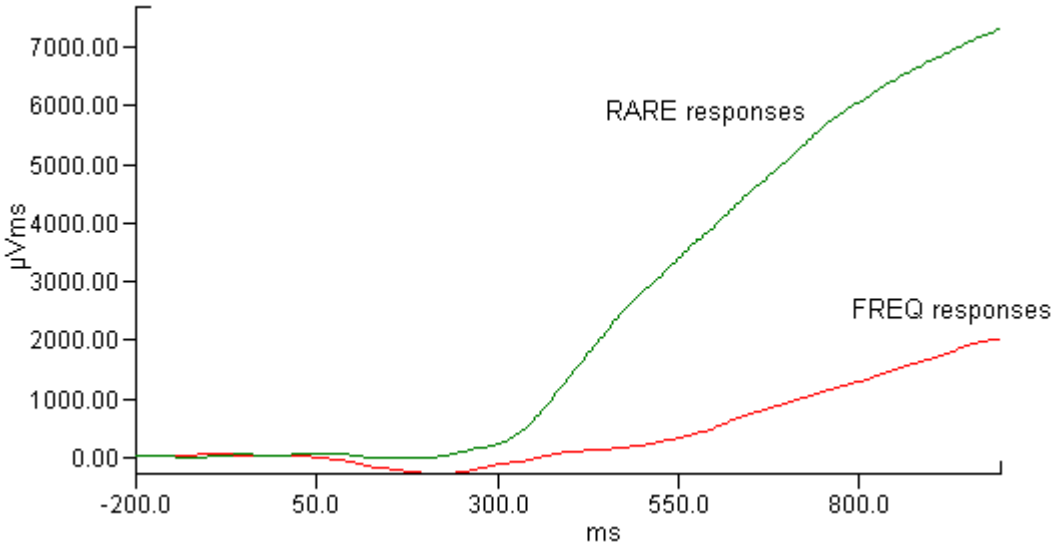
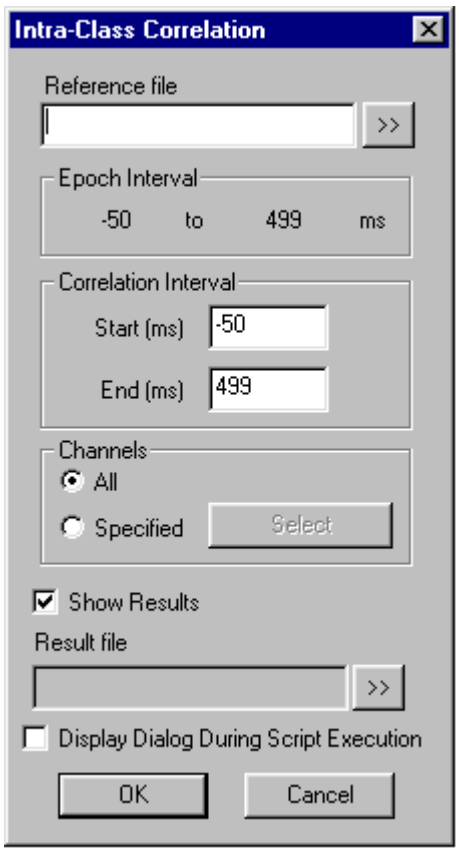
waveform and the frequent (or standard) waveform.



Intra-class Correlation (AVG) - 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 waveshape 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.

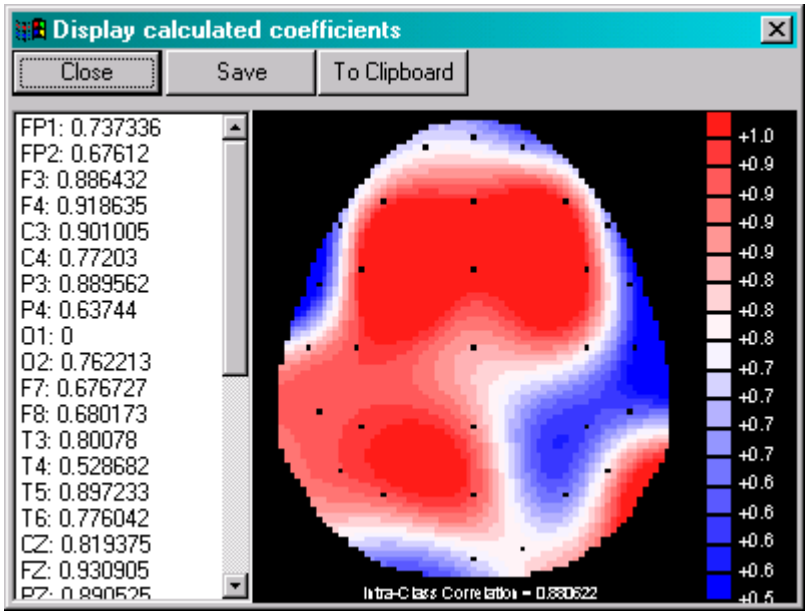
Retrieve your AVG file, and select the Intra-class Correlation option. The Intra-class Correlation display will appear. Click the browse button >>, and an Open Files utility will



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.

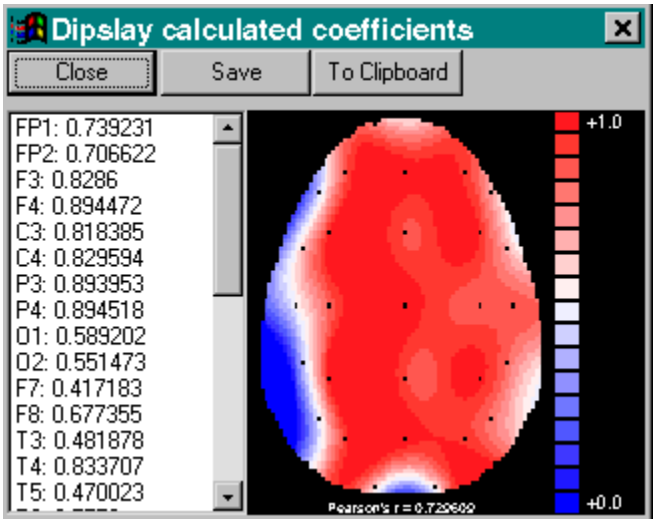


Close - Clicking the Close button closes the coefficient display.

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.

Shown below is the result of an intraclass correlation using the sepblk.avg and sepnoblk.avg demo files, computed over the 10 to 60 ms interval . Since the intraclass correlation statistic is also sensitive to amplitude differences, values are much lower than the Pearson's r statistic, shown below using the same data files.



Inverse FFT (EEG, after Forward FFT) - The Inverse FFT option is available only after you retrieve an EEG file that has had the Forward FFT transform performed. 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 Windows Display with the original wave form data.

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*.

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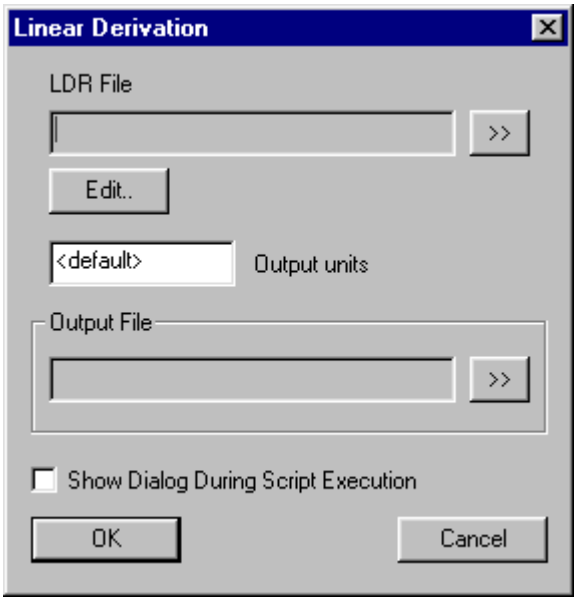
Thus, at each time point, the value of derived channel *i* is computed by adding C_{i1} times the value of recording channel 1, plus C_{i2} times the value of recording channel 2, ..., plus C_{iM} times the value of recording channel M. The resulting N derived channels are saved to a new file.

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.

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 the appendix 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 following 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

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default setting is for microvolts, but you may enter a different option, such as millivolts, by typing it in from the keyboard 

. 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 decimates 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. Lastly we will describe the steps for applying the LDR file created off-line to an on-line acquisition.

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 that Appendix 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 an empty LDR matrix on the left. Unclick the Head Contour icon  to see the full size matrix. 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 conform. Repeat this procedure for all of the nonstandard 10-20 electrodes (FTC1/2, TCP1/2, CP1/2, and PO1/2).

Now we need to add a "1" at the row and column intersection for each electrode in the left side column (leaving "0's" in the columns that are to be excluded). The result in this file will be a string of "1's" down the diagonal (with the exception of VEOG and HEOG). A portion of the matrix is shown below.

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	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

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. Make sure the vep.avg file has the focus, and then select Linear Derivation. Select the LDR file you just created using the Browse button >>, and then enter a file name when the Output File display appears. Click Save, and after a few moments you will see a new Multiple Windows 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** 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:

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	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, just run the reduction routine with the Review options Off, and with no output CNT file - just the LDR file.

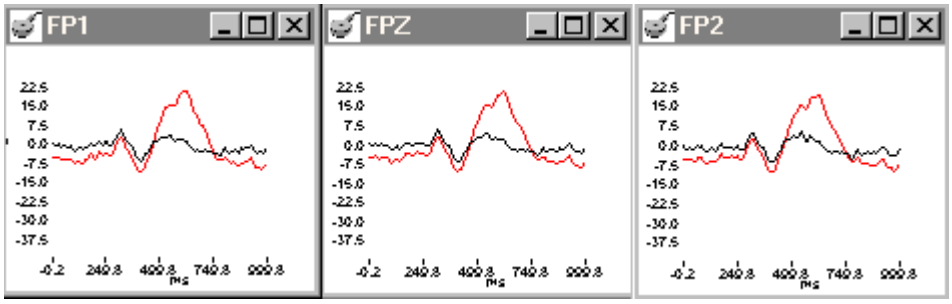
If you look at that output LDR file in the Montage Editor, or with Notepad, you will see that it is a 32x32 matrix of numbers. Across the top are the 32 channels in the data file. Think of these as the input channels. Going down the left side are the same 32 channels. Think of these as the output channels. 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 multiple 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 reduction algorithm (as in the Ocular Artifact Reduction description below).

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. You will first be asked if you want to Modify the Existing Data, or Create a New File. The transform make a permanent change in the data 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 Linear Detrend display will appear.

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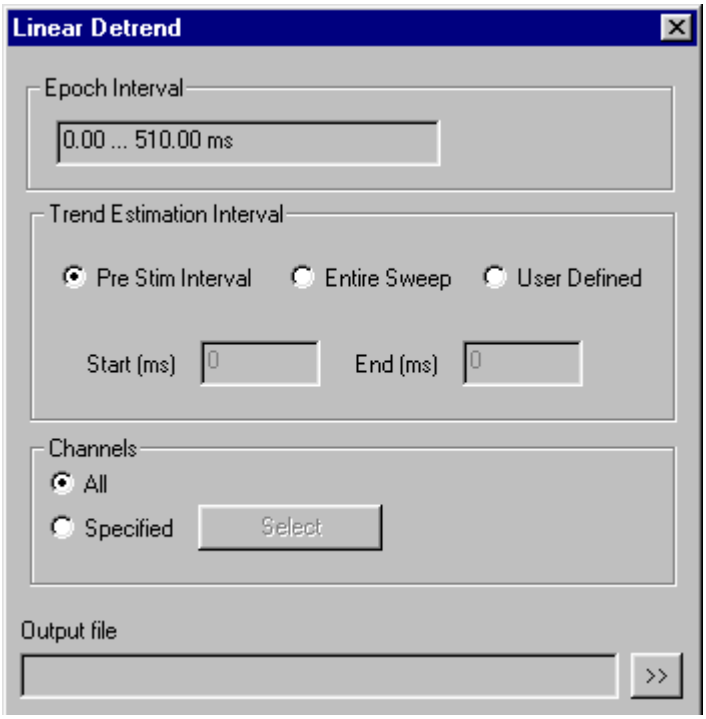

The Epoch Interval displays the epoch span of the data file. The Trend Estimation Interval lets you specify the interval during which the linear component is estimated. In SCAN 3 and 4, the only option was to use the Entire Sweep, and this may work well for most applications. However, you may instead 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 you will see a new Multiple Windows display with the corrected waveforms.

Merge Task Data (CNT) - Continuous files created with SCAN version 3.0 and later can be merged with behavioral data such as stimulus/response codes, latency, and accuracy. The advantage of merging behavioral data into the EEG file is that sorting decisions can be made based on different performance criteria at subsequent processing stages. For

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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 is included in the EEG 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.

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 you will then see an Output file window in which you may enter a file name and path for the transformed CNT file. The merging will then occur, and you will see a new CNT. 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 ScanData\ 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
```


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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 stimpad 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 entitles "**Some notes about response codes**" for more details.

Ocular Artifact Reduction (CNT, 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 multielectrode 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 electrooculogram (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 different method, using the Spatial Filter and Spatial SVD is described in the Spatial Filter section. A further method is available with the Gradient/Blink Reduction plug-in program.

> *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 artifact channel. A percentage of this 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:

$$b = \text{cov}(EOG,EEG)/\text{var}(EOG)$$

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

At the end of stage one, 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 manne*r:

$$\text{corrected EEG} = \text{original EEG} - b \bullet \text{EOG}$$

The 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.

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.

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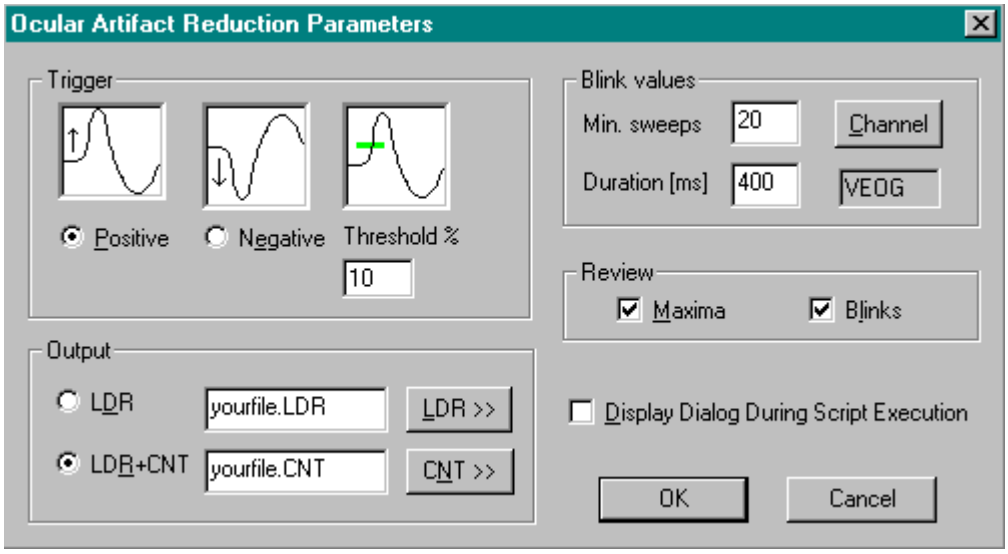

The following is a description of each of the fields:

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 for 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.

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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. The default channel that appears is the first one in your Channel Assignment list. If you plan to make frequent use of ocular artifact reduction, you should place the VEOG channel in channel one (for SynAmps users - remap one of the bipolar channels to appear in the first position on the Channel Assignment list).

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: At the present time, the Review options are available ONLY with CNT files. With EEG files, the maxima determination and blink selection is performed automatically. This is another reason to record your data in continuous acquisition mode.*

When you review the maxima or sweeps, you will see displays with intervals equal to the Duration you set. The peaks from the maxima will be framed in the center of the display.

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*.

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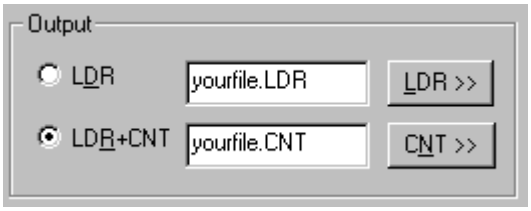
Click on the LDR >> button, and a standard Save As... file will appear. Enter a name, designate the path, and click save to continue.

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

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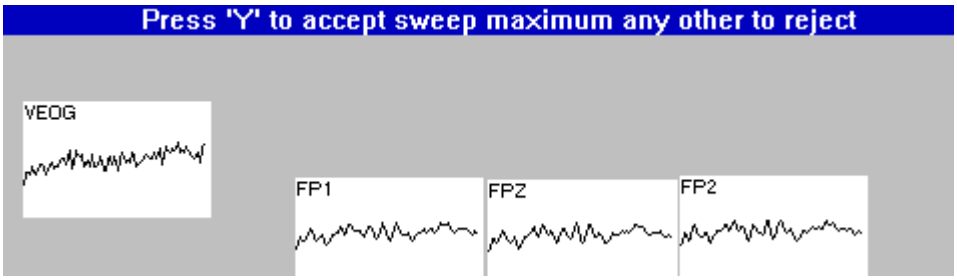
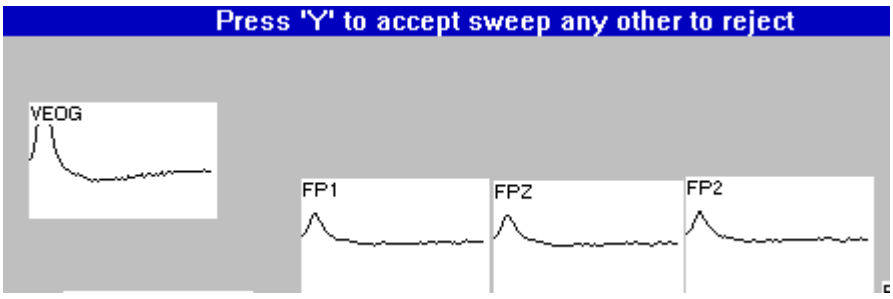


sweep, and will ask if this looks like a genuine maximum, that is, does it contain the greatest voltage peak for a genuine eye blink (in the VEOG channel). Note that you can use the Up and Down arrows to change the display scale  . Chances are that this will not be contained in the first sweep. If you 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.

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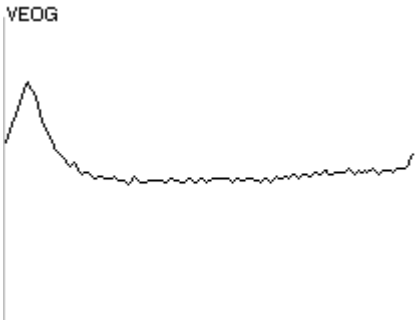
Hint: With CNT files, the routine will find the first point in the designated channels the meets the 10% threshold. When you are reviewing the Blinks, you will have the options to include or exclude the next 50, 200, 400, or whatever your Duration is, in the averaged artifact. The routine will then skip 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, image 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 to 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 arrow controls 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

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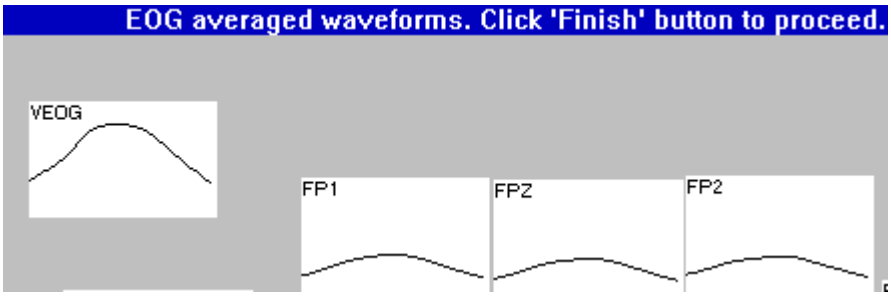
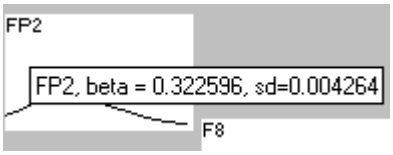
reasons besides blinks, and those sections will then be included in the average blink artifact. This may result in a less than optimal subtraction of the blink. Generally, if you have a recording with blink artifact that is otherwise clean, the automatic routine will often do as good a job as your manual 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 view the transmission coefficients and SDs, point the mouse to an electrode label. The weights and SDs will appear in the form of a Tool Tip.



To see a complete list of the coefficients, the SDs, and the topographical distribution, click the Show button in the lower left hand corner

. 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.

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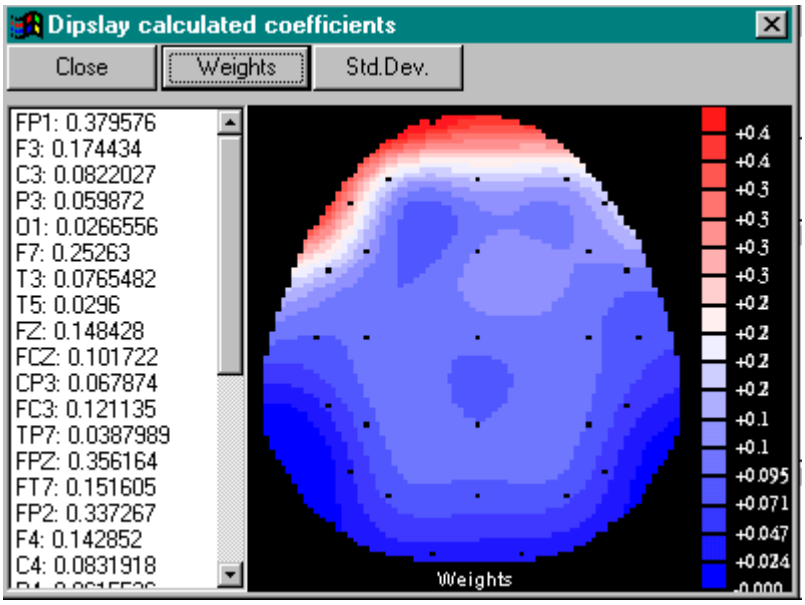

The transmission coefficients are typically much higher in the frontal leads than they are in the posterior leads. This is because the vertical eye movements and blinks spread in an anterior-to-posterior manner. Consequently, much more of the VEOG channel is subtracted from the FP1 and FP2 electrodes 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.

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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 

.

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.

Paired t-score (AVG) - 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 have 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 used for calculating paired-t values is:

$$\frac{\text{(difference scores)}}{\text{(difference score variance/sq root of (n-1))}}$$

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.

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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.

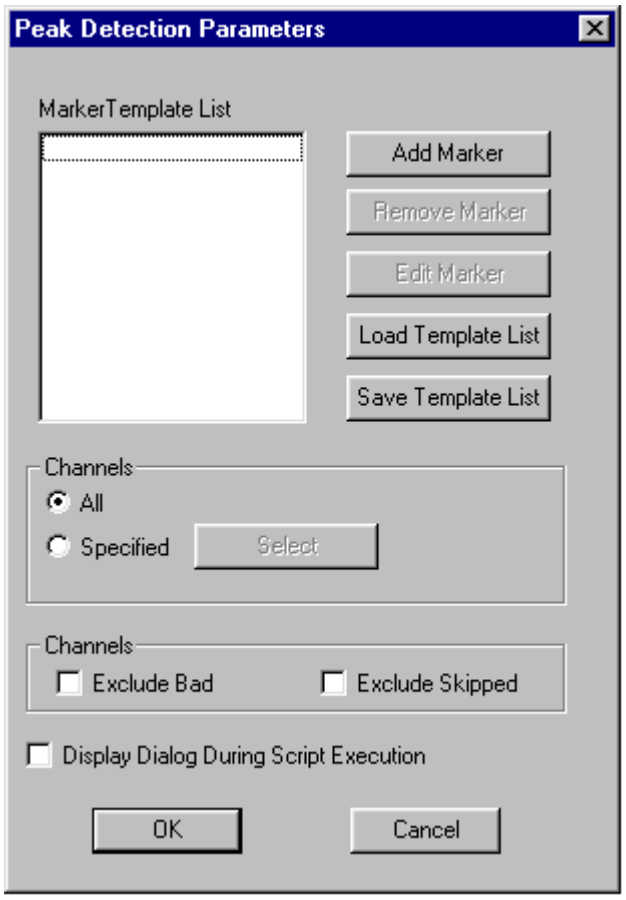
5. Enter a file name and path for the t-score results file, and click OK.

A new Multiple Windows 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.

Peak Detection (AVG, EEG) - 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 from the Demo directory. Then select Peak Detection from the list of Transforms. The following display will appear.



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

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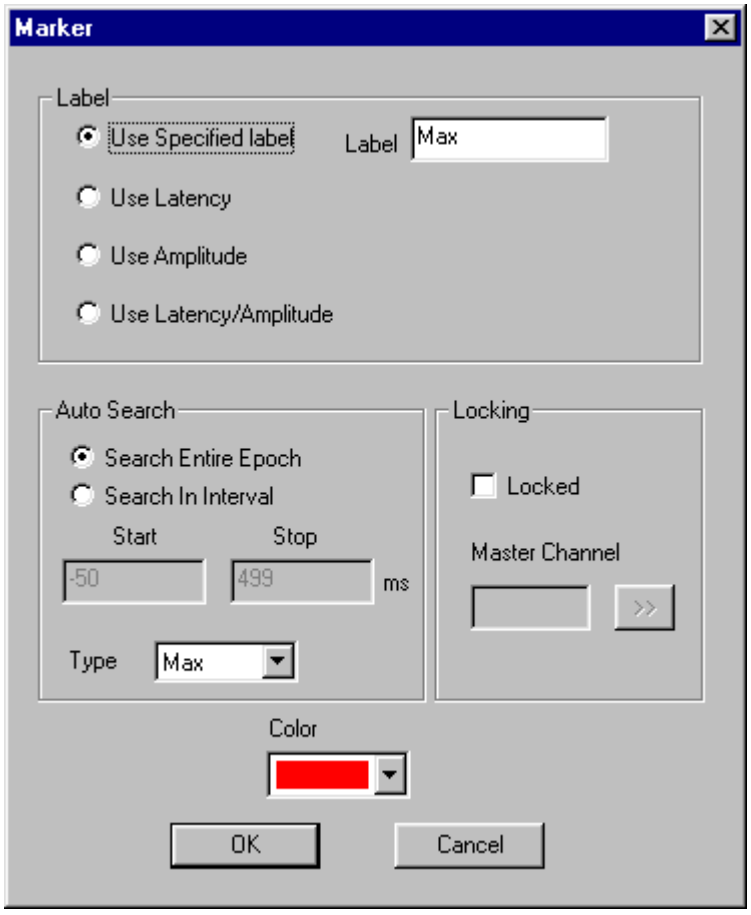

You have the options to use the specified label (the label you enter in the Label field), the latency, the amplitude, or the latency and amplitude. The peak will be marked using the information you select. For example, if you select Use Amplitude, the peak marker will display only the amplitude value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

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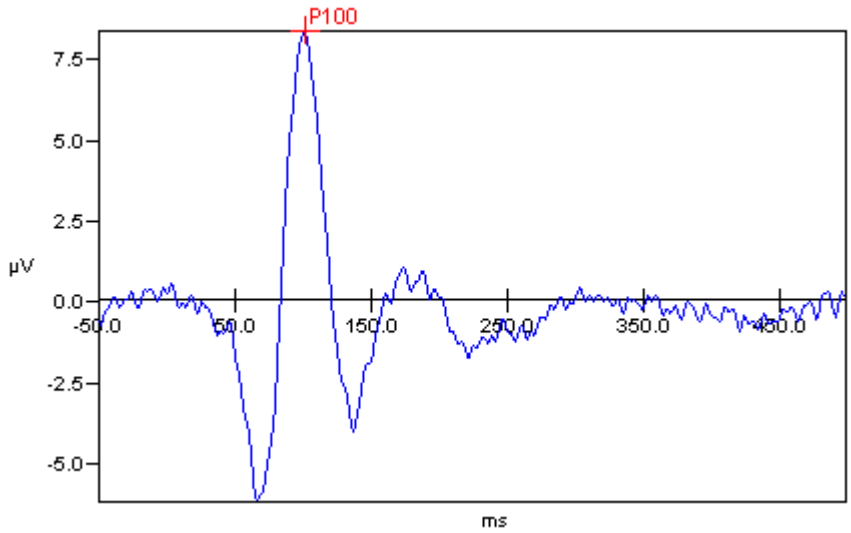
In the Locking area, you have the option to Lock or not lock the search. If you select the Locked option, the Master Channel field will become active. This allows you to select a specific channel for the search. The program will find the peak at that channel, and "lock" the latency for all other channels. 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.

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 Unselect 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.



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Click the right mouse button in the label to see the Delete and Edit Properties screen.

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). Using a text editor, go into the Acquire43.ini (in the Windows folder), and add the following line in the **[STATE]** section:

Scan30Peak=1

When that line appears, the old 3.0 style will be used. If the line is omitted or is set to 0 (Scan30Peak=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 Acquire43.ini file (again in the **[State]** section) controls the type of delimiter used. The SCAN 3.0 software gave a choice of space versus tab

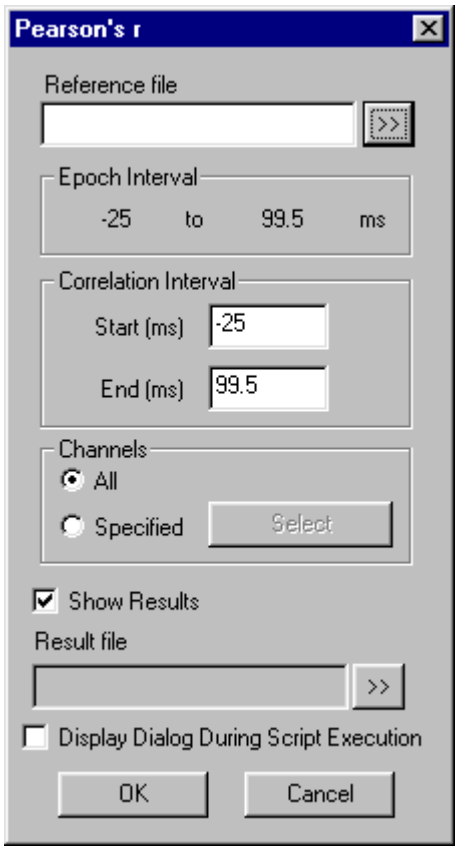
delimited .dat files. Only if the SpaceDelimiter is set to a nonzero value will spaces be used. The default is tabs. This only has an effect if the old style file is being used. The command is:

SpaceDelimiter=1

Again, that command can be ignored if you are using the new format for the DAT files.

Pearson's r (AVG) - 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.



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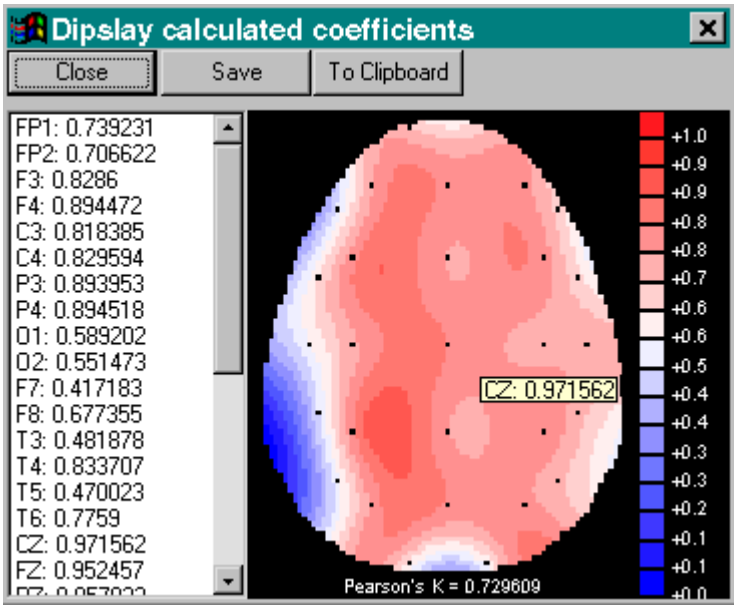
The Epoch Interval displays the span of the epoch. Set the Start and End time points for the Correlation Interval, that is, the interval over which the correlation coefficients will be calculated. Indicate whether you wish to analyze All channels, or Specified channels. Click the Select button to access 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 following screen is displayed.

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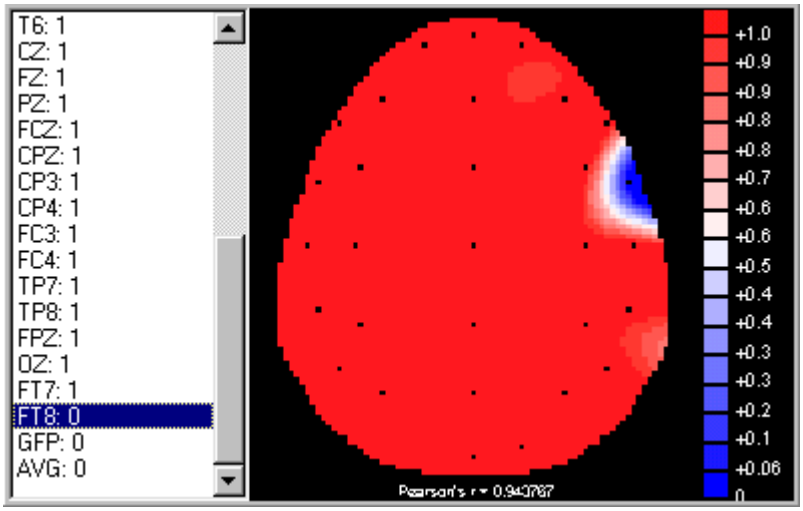
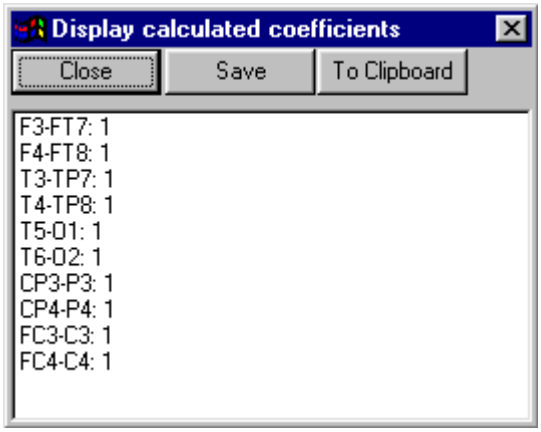
You then have the option of correlating only those channels that have matching electrode labels (the default option), or specifying the pairs of channels using a montage (*.MNT) file. In the first case, you will see zeros for the mismatched channels.

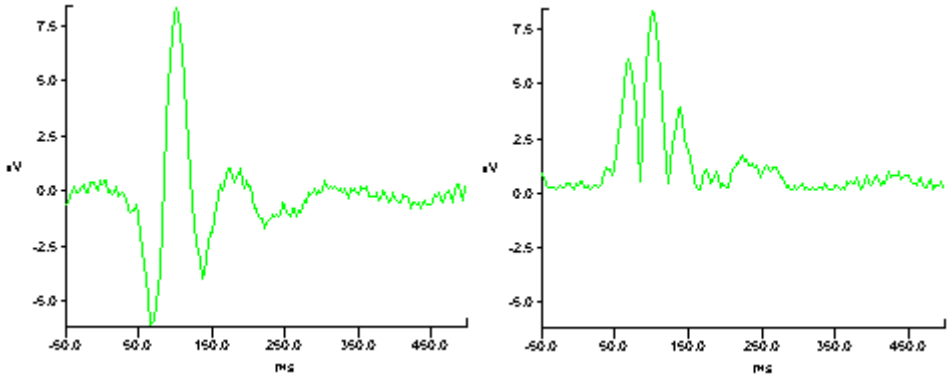


If you use a MNT file, you will see results only for the designated pairs (with labels such as F7-F8, F3-F4, etc.). If you do not already have an MNT file, you may click the Montage Editor button and create one. The resulting file will be a list of the correlation values for the designated pairs.



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. You will be asked if you want to Modify the Existing Data, or Create a New Data File. This will permanently alter the data, so we recommend creating a new data file. A new Multiple Window display will appear with the rectified waveforms. Below is an example of the vep.avg OZ waveform that was rectified.



Original Rectified

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.

The RespWin (Response Window) program performs an off-line 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 AUDIO system hardware and stim-to-scan cable. 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.

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 250 Hz, reaction times will be measured in units of 4 msec.

Retrieve a CNT file, and select the RespWin transform to see the following dialog box.

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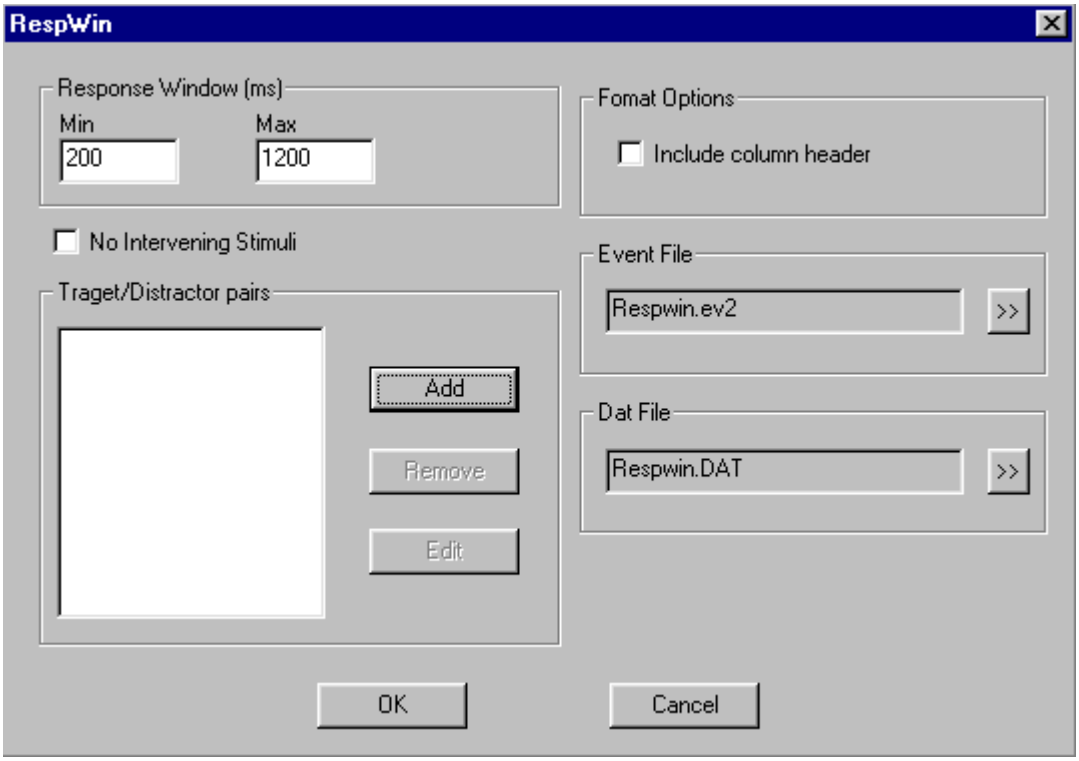

The *Response Window minimum* is the minimum time after a stimulus event that a response event can be associated with it, and the *Response Window maximum* is the maximum time after a stimulus event that a response event can be associated with it.

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 

button to create the target/distractor pairs using the following dialog box.

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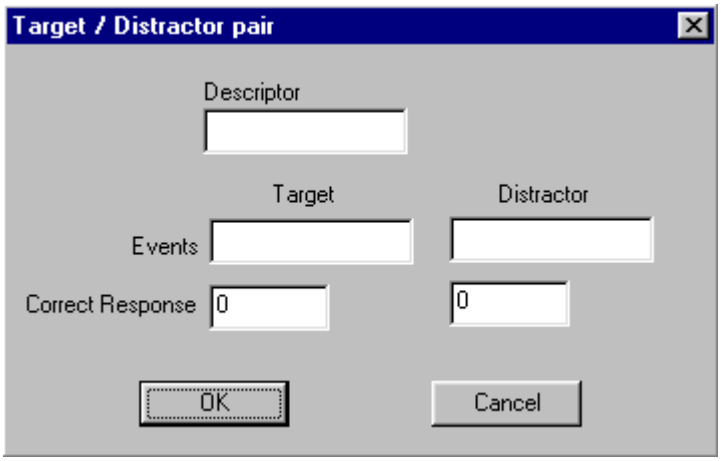

Enter a *Descriptor* to identify the pair. A *target event* is a subset of stimulus codes that require the same response. A *distractor event* is a subset of stimulus codes that require a different (possibly null) response compared with the associated target event. Subsets of stimulus codes are specified 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).

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:

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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.

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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).

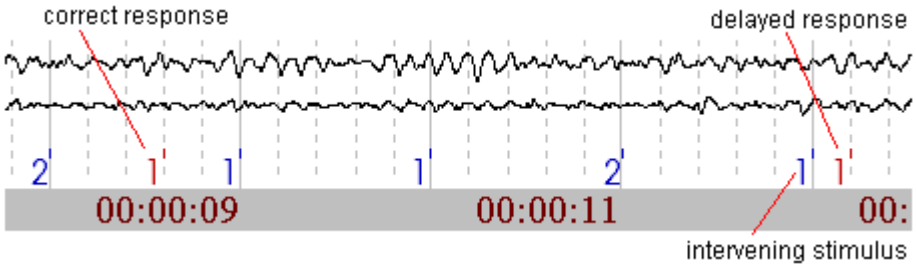
Rule 14. **Undefined Stimuli**: All stimuli that are not defined as either target or distractor events are tallied as "undefined stimuli". Note that no responses are ever associated with undefined stimuli.

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".

OUTPUT. 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

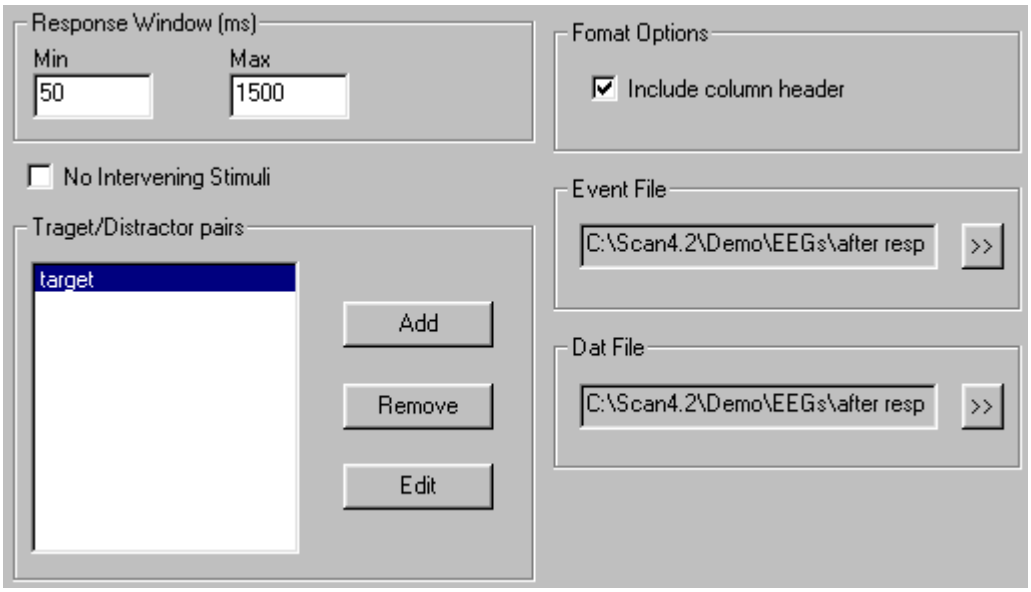
.SUM extension provides the summary statistics. The above-mentioned tallies are listed, together with average and standard deviation RTs for all target and distractor events having non-null responses. For each target, the hit percentage is defined as the number of hits divided by the total number of 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.

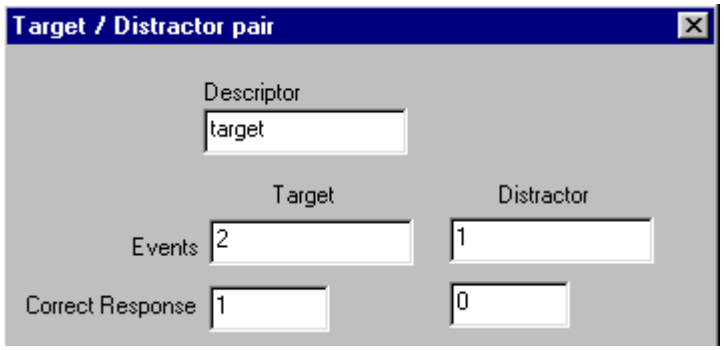


The "1" response, albeit delayed, was to the previous "2" stimulus, and the "1" stimulus is now intervening. We want to associate the responses only with the "2" stimuli. As it appears now, the delayed response will be associated automatically with the first stimulus before it. We can use RespWin to associate the response with the correct stimulus.

The RespWin display would appear as follows.



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 as follows.



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).

before respwin

```
13    2  0   0      0.0000 5500
14    1  1   1    100.0000 6000
15    0  1  -1      0.0000 6100
```

after respwin

```
3     2  1   1   1200.0000 5500
```

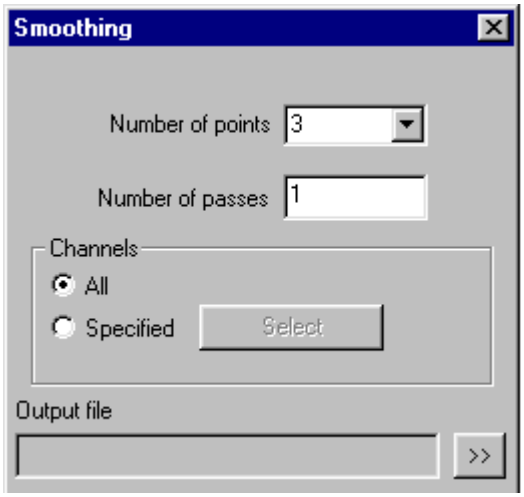
The summary output file contains information similar to the following.

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 on Response-Locked Averaging. 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). An additional utility program called RESPEVT.EXE was applied to RespWin's output event file to create another event file that could be used for making *response-locked* epochs (and subsequent response-locked averages). In the current version of EDIT, this is no longer necessary.

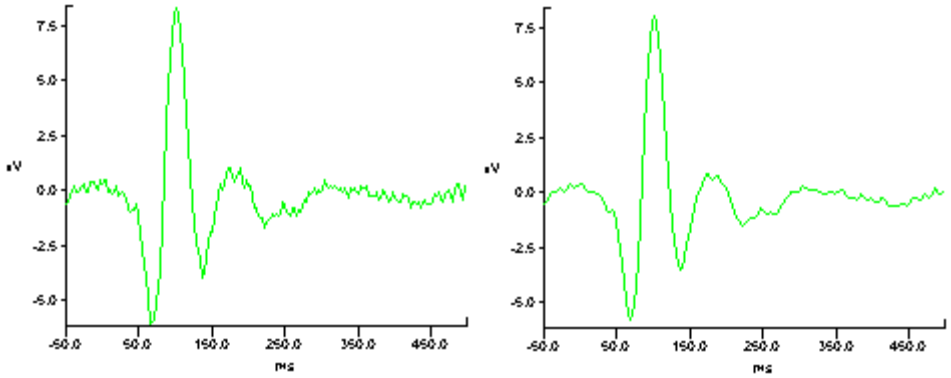
Smooth Data (AVG, EEG; time domain) - Averaged data files may be smoothed, that is, a given data point may be averaged with adjacent points to create a smoother waveform. After retrieving the data file, click Smooth Data from the Transforms list. You will see the Smoothing display.



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

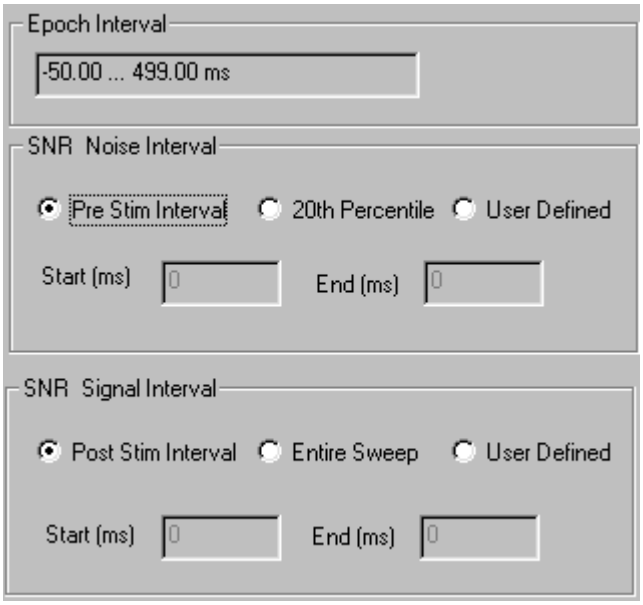
SNR (AVG; time domain) - The Signal to Noise Ratio (SNR) computations require some preliminary explanation. The SNR is always computed, whether you apply the SNR transform or not. It will attempt to compute the best SNR possible, given the data. SNR is computed in different ways depending on whether 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 vari-

ance 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 View SNR Values option. You will see the SNR values for each channel.

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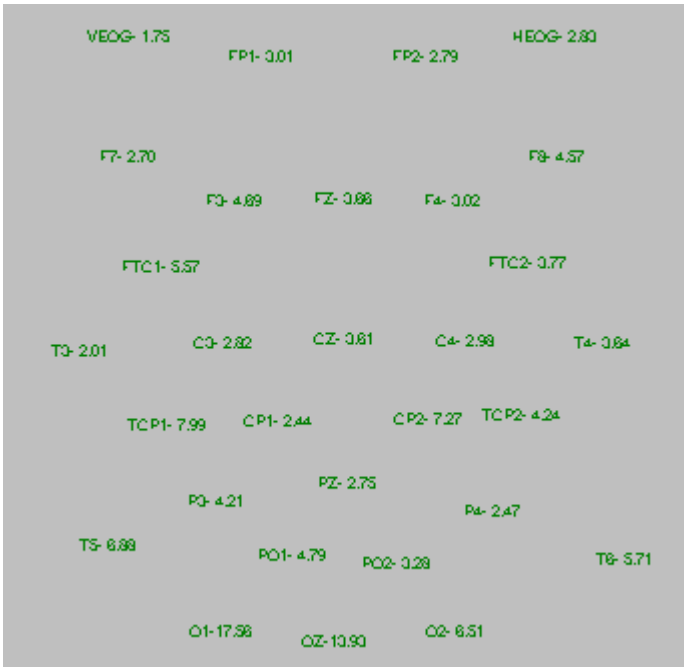

The Overall Noise level and Highest SNR are displayed.

Click the 

button to save the values to an ASCII file (DAT extension). The electrodes labels can be displayed or not.

Sort Sweeps (EEG) - 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 Averaging (see above for details). Set the criteria that you wish according to the sweeps 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 Windows display will appear with the first sweep of the new epoched file.

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.

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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.

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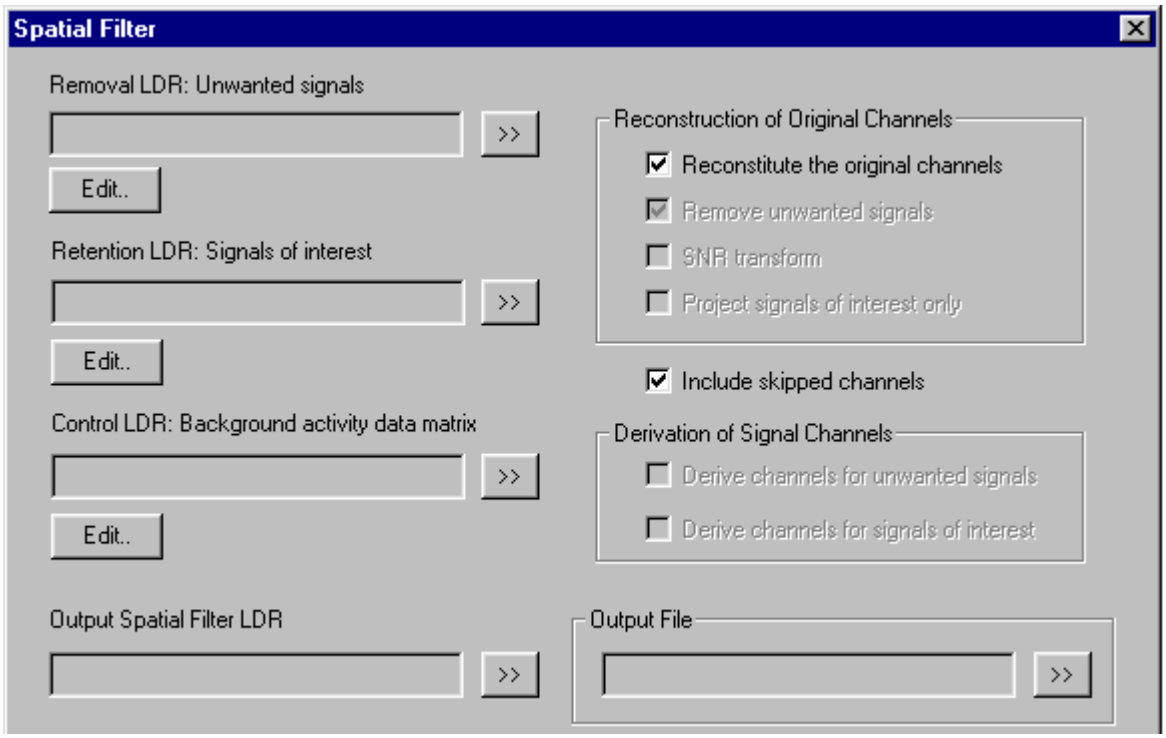

The display is divided into several sections, and these are described below. The Spatial Filter transform uses up to 3 different LDR files in its computations, and will output a single LDR file, as well as a transformed data file. The LDR files you select - Removal, Retention, and Control - have very 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 Edit.. button, in this as well as the other options listed below, 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

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(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

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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 two 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 off-line 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 that should be present in your demo directory. 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 (off-line or on-line)**

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Construct an average artifact file. Retrieve the *viscpt.cnt* file.

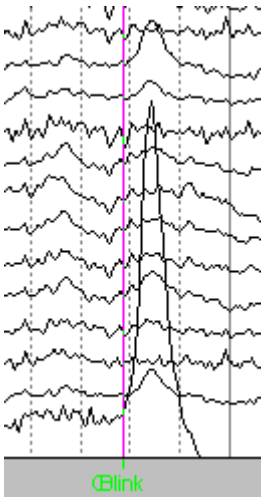
Note1: If the file had been acquired with a High Pass filter setting of DC, you would need to perform the DC drift correction (under Transforms*) before continuing.*

Note2: 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).*

Note3: 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 these by clicking the right mouse button and selecting the Properties option, then Overall Parameters / Channel Attributes. These changes are made on that screen.

View the *viscpt.cnt* file using the control icons. Using the Mark Block option, go through the file and delete bad sections of the file. There are about 5 or 6 obviously bad sections.

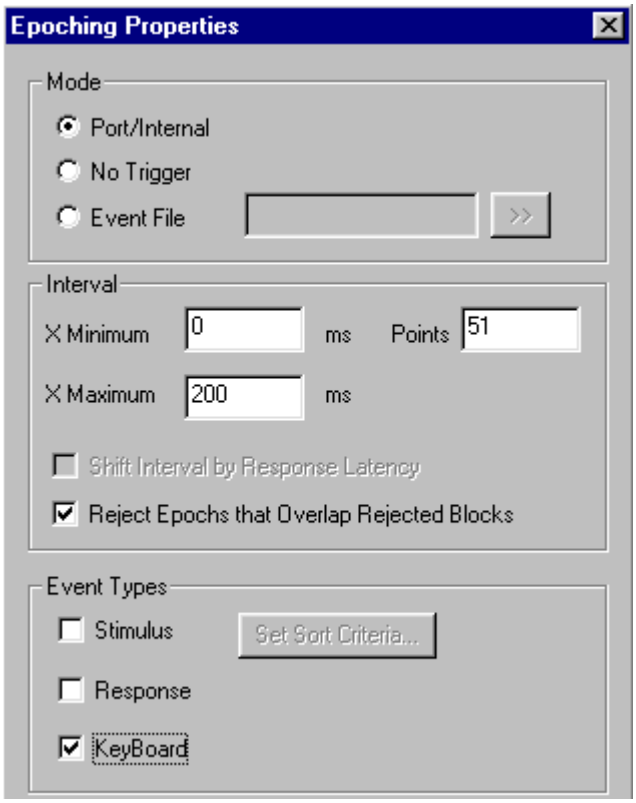
The next step is to create an AVG file that "captures" the blink artifact. One way to do this is to insert Function Key events at the approximate same beginning point for about 10-20 good blinks (an easier way using Voltage Threshold is described in the Script section). Step into the file until you see 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. F5 was used in the example below. 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

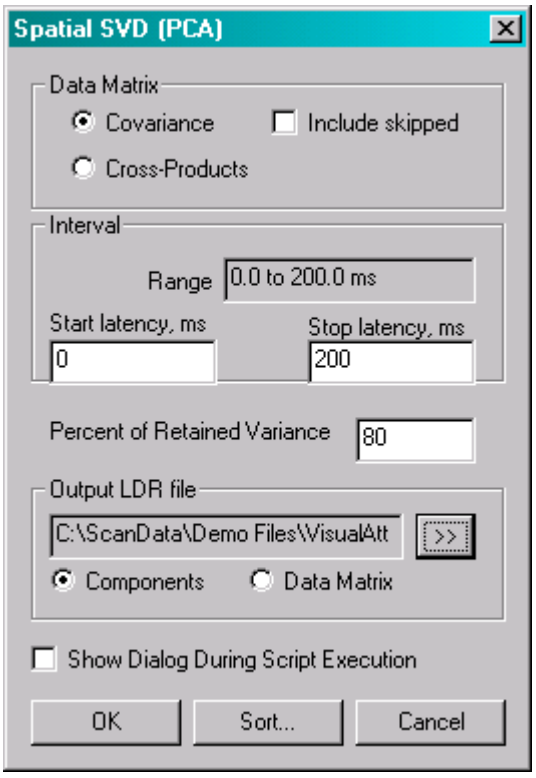
blue triggers from STIM are OK (don't remove them).

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 0-200ms (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 Windows 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 under Transforms. 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

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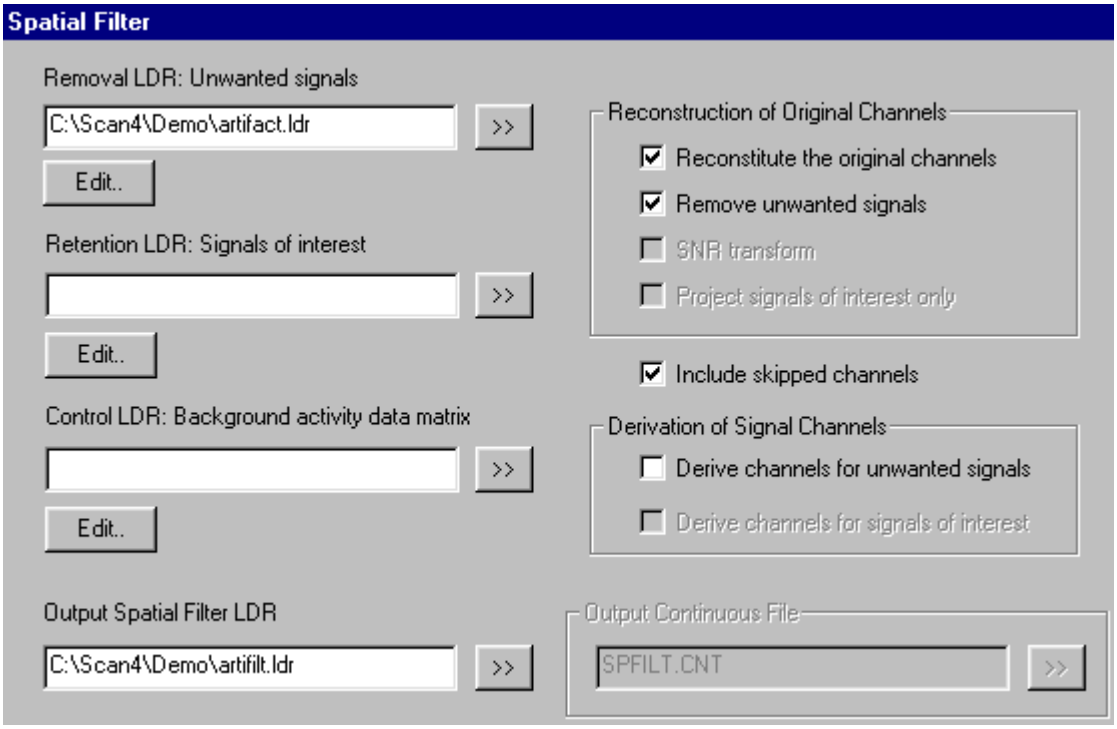
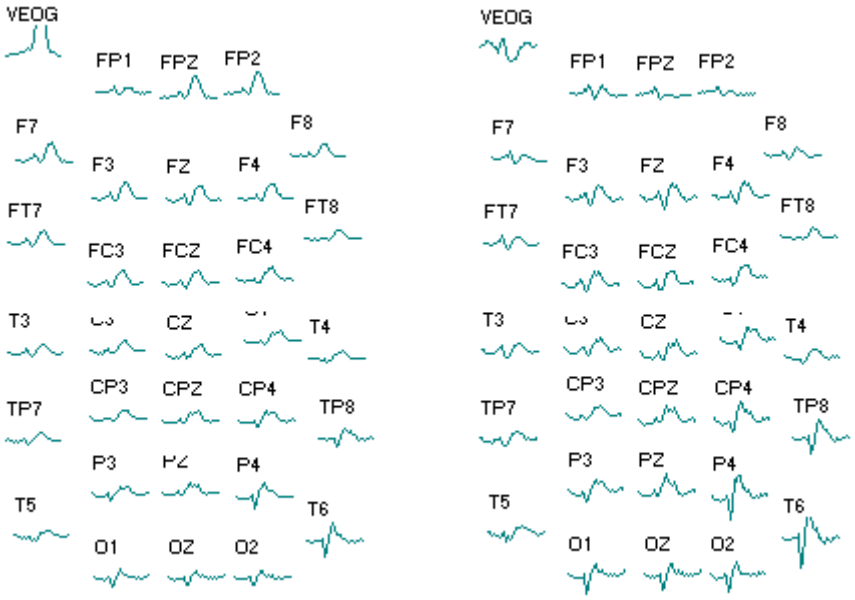
create new, derived channels that will display the unwanted activity that was removed. Enter "artfilt.ldr" for the Output Spatial Filter LDR file. Click OK to proceed. Then enter a file name for the output AVG file - call it vis-spatfilt (the .avg extension is added automatically).



When the process is completed, you will see a new Multiple Windows 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 point-by-point subtraction versus the LDR approach.

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

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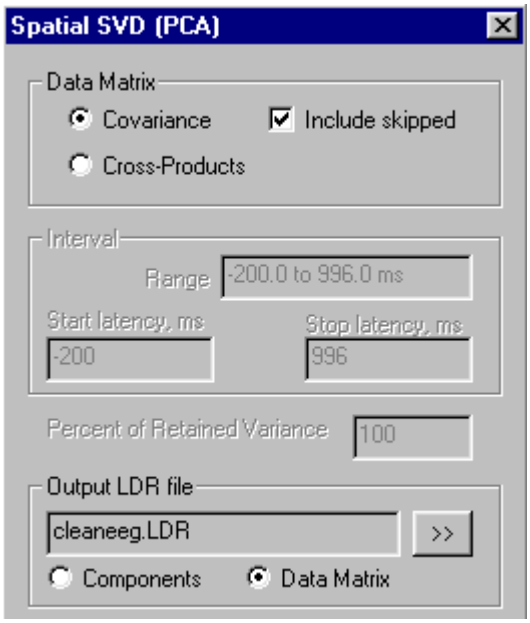
can be accomplished with a few extra steps in the process.

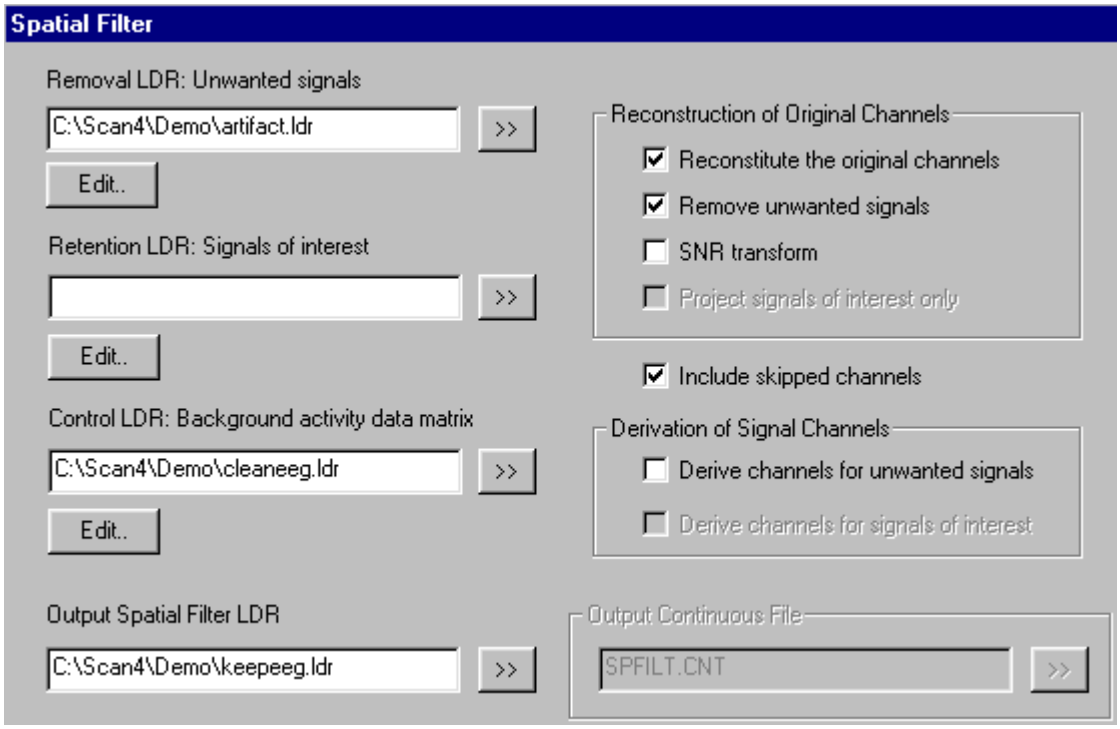
Construct an artifact-free block. At the beginning of the procedure above, we created an artifact-laden average file. For this example we also need to construct an artifact-free continuous file. This may be accomplished by saving artifact-free blocks of the continuous file to a new continuous file. Retrieve 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.



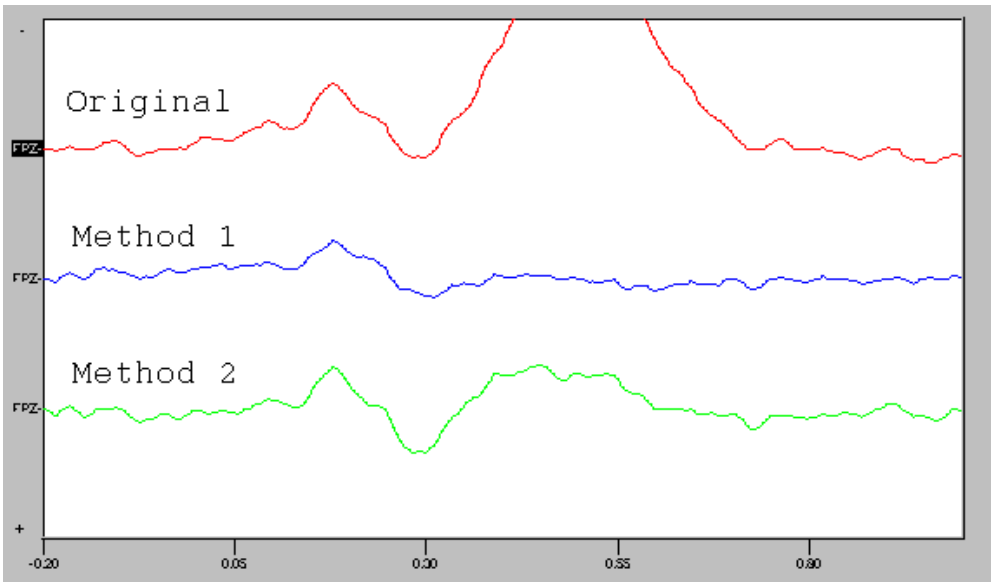
Apply the Spatial Filter Transform. Return the "focus" to the viscpt.avg file that you used in the "Apply the Spatial Filter Transform" section above, and select the

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 to proceed. 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. A new Multiple Windows 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 off-line on an existing data file. In SCAN 4.3, 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).

In the larger perspective, there are four conceptual steps in this procedure (not necessarily performed in this order):

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(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:

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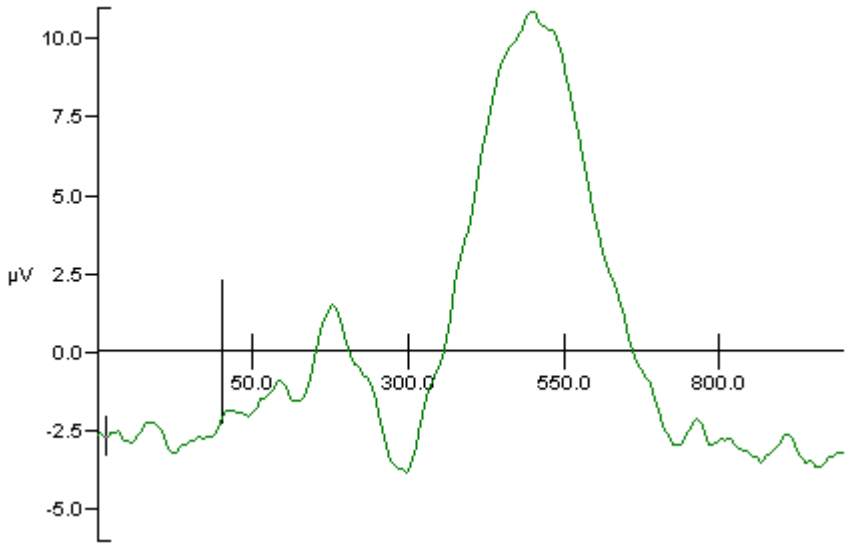
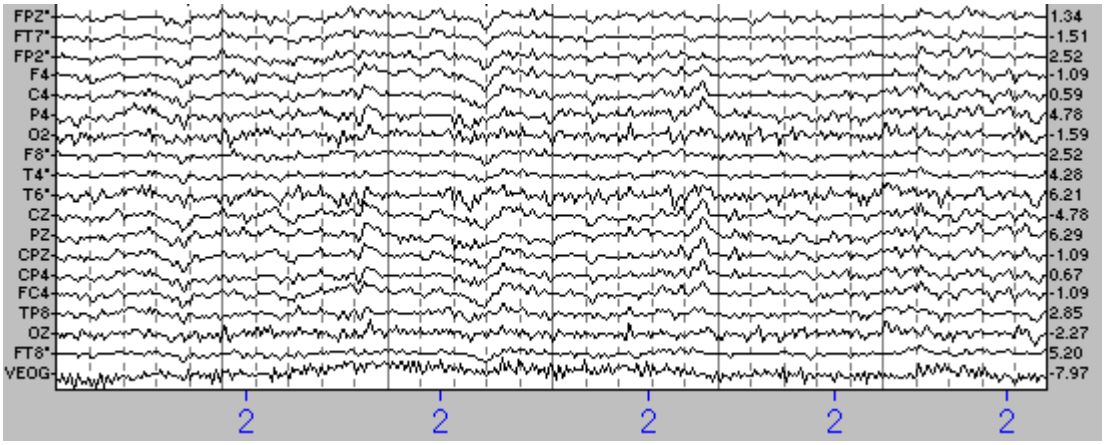
1. Retrieve the original CNT recording (with blinks, but no spikes). If your file was recorded with a high pass filter setting of DC, you should perform a DC Drift correction first. Apply any other off-line filtering at this point, if desired. If you have any Skipped channels that you want to include 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.



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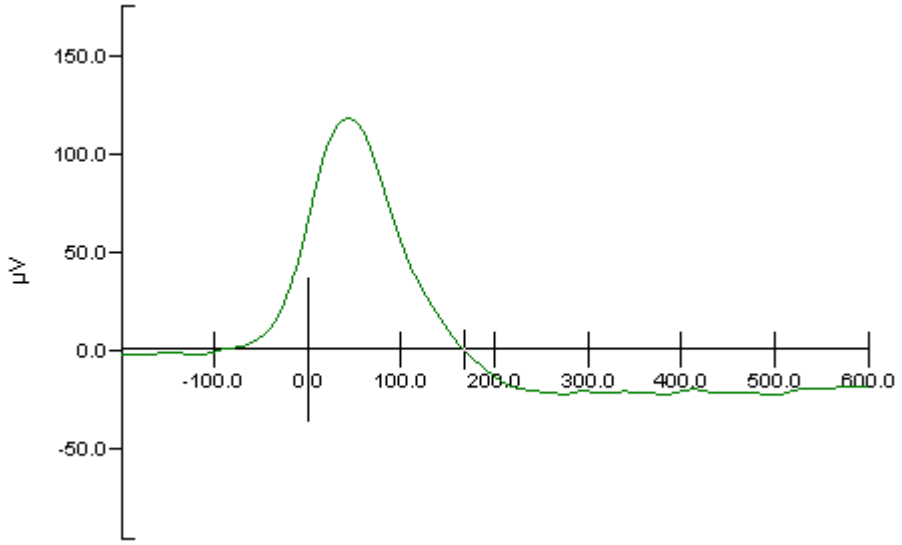
Now select the **Spatial SVD** transform, select Covariance, and the Data Matrix option. Enter a file name for the output LDR file (e.g., "Step 1 LDR"). The LDR file will be used as the Control LDR, that is, the background activity data matrix that we wish to preserve.

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

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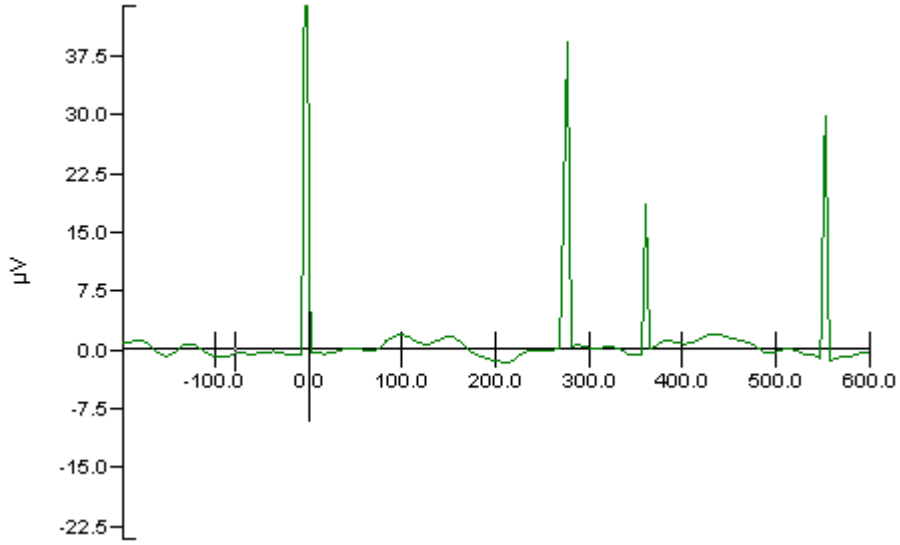
create a new CNT file with spikes, but no blinks. We then used the Voltage Threshold option to set triggers for the spikes, and then Epoched and Averaged the file as we did with the blinks. That average for FPZ is shown below.



We then made a simple Script file where we Inputted one AVG file (blinks), then used the Append Sweeps 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 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.

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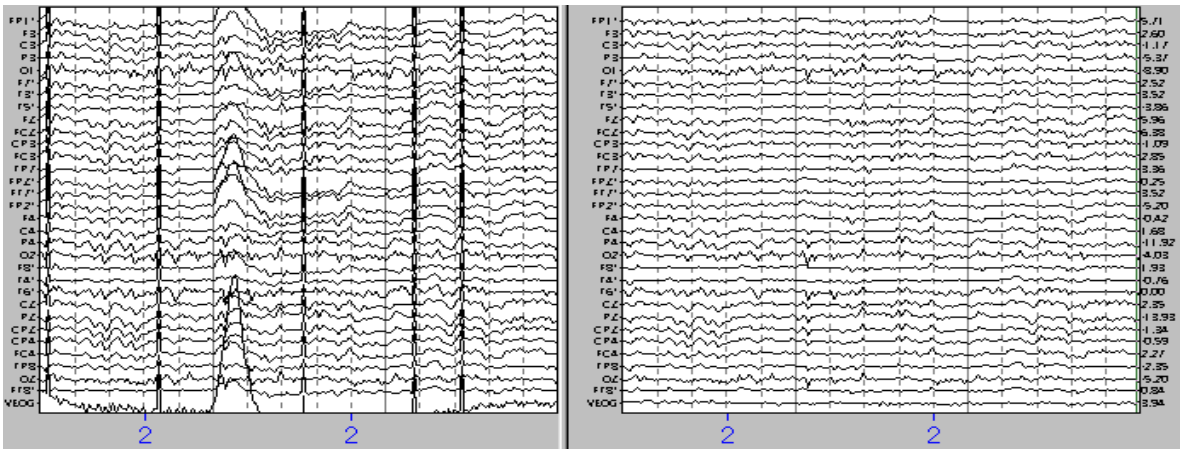
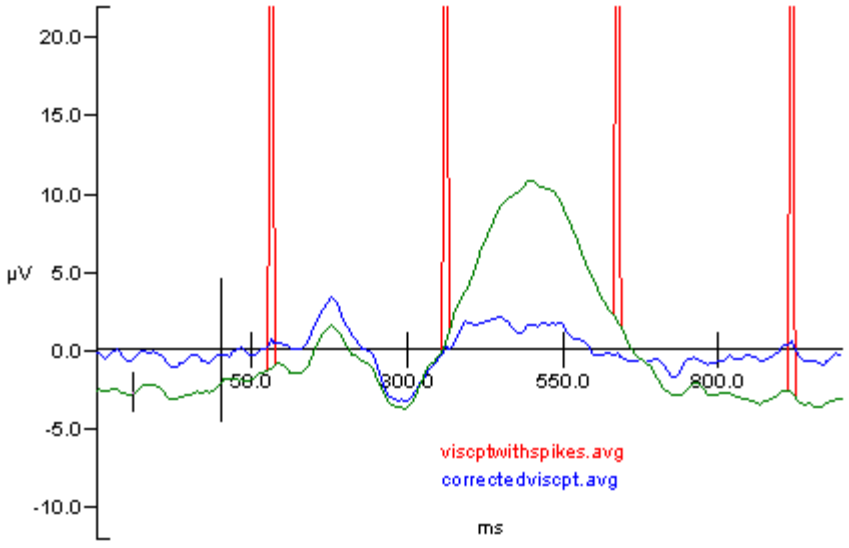
Now retrieve the original artifact-laden CNT file and the final output CNT file from step 5 to compare the effects visually (displays scales are slightly different between files).

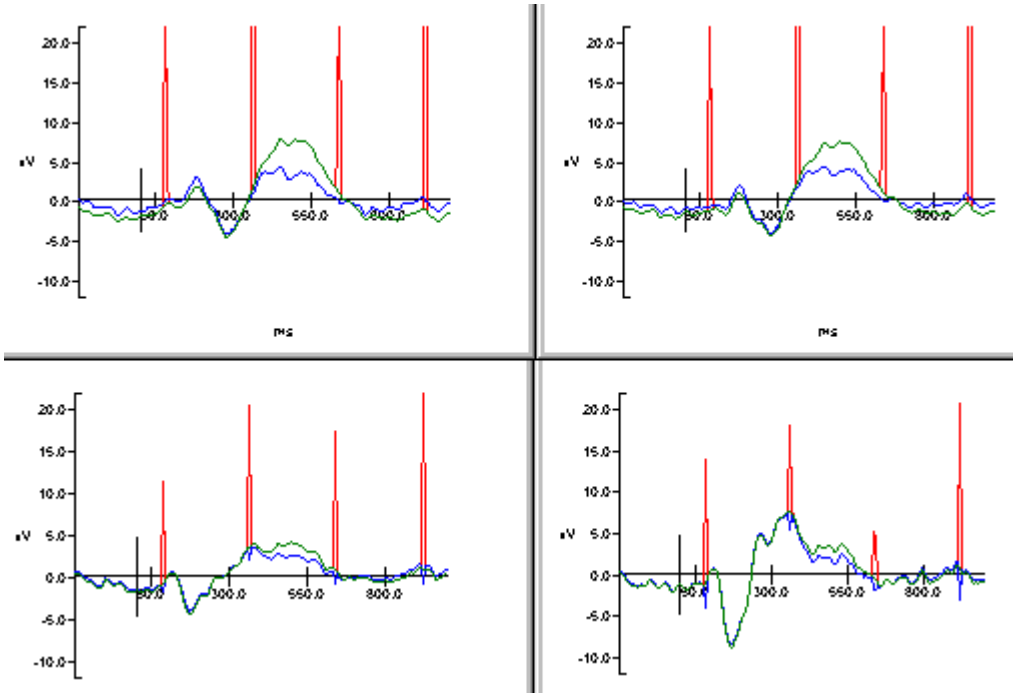


Original with blink and spike artifact Same section after SNR correction

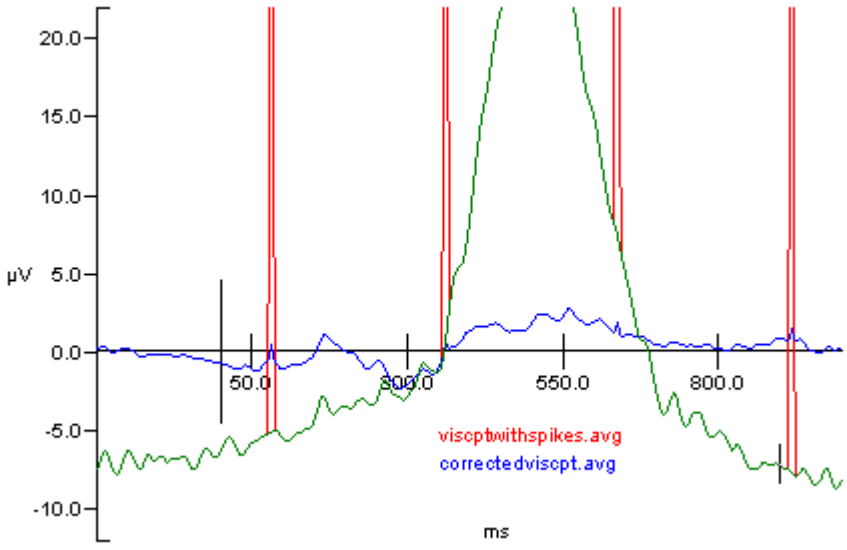
Epoch the final output CNT in the same way as you did the original clean EEG file in step 1, and compute the average file (again, we combined all the trigger types). In the figure below, the green waveform is from the original viscpt file (FPZ), with averaged blink artifact around 500ms. The red waveform 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.



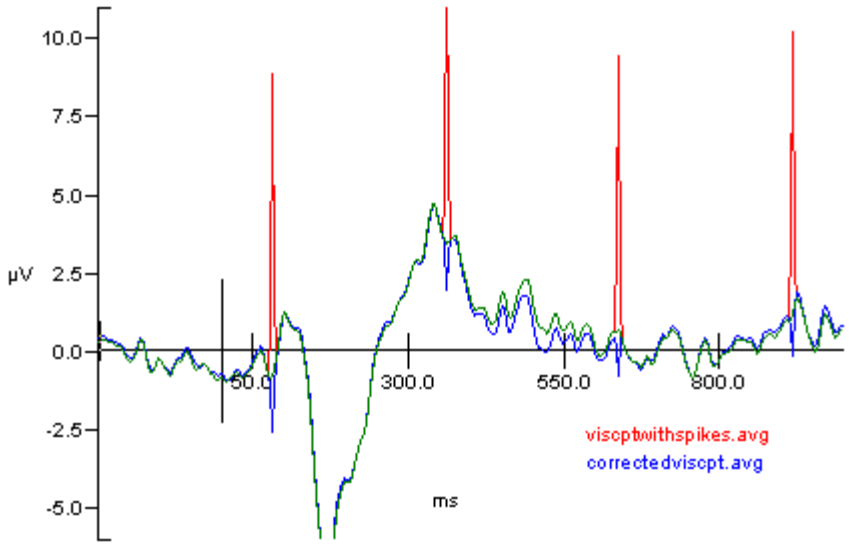
Similar results from F3, F4, P3 and P4 are shown below.



Lastly, we'll take a close up look at some of the channels (VEOG and O1). You can see in the VEOG channel that not quite all of the spike artifact was removed, while the spikes were slightly over-corrected in the O1 channel.



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 (BKG). This is the artifact occasionally seen in recordings made in the MR bore, due to micromovements associated with the heart beat. In test files we have analyzed here, the SNR procedure has worked very well in recordings where there is simple BKG. That is, where the BKG artifact appears as repeated heart beat artifact that does not vary appreciably during the recording. In other files, where the BKG 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 VEOG and EKG Reduction routines that are part of Tool Box 2003 (plug-ins available with SCAN 4.3).

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.

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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:

SNR (final average) = 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.

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.

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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.

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.

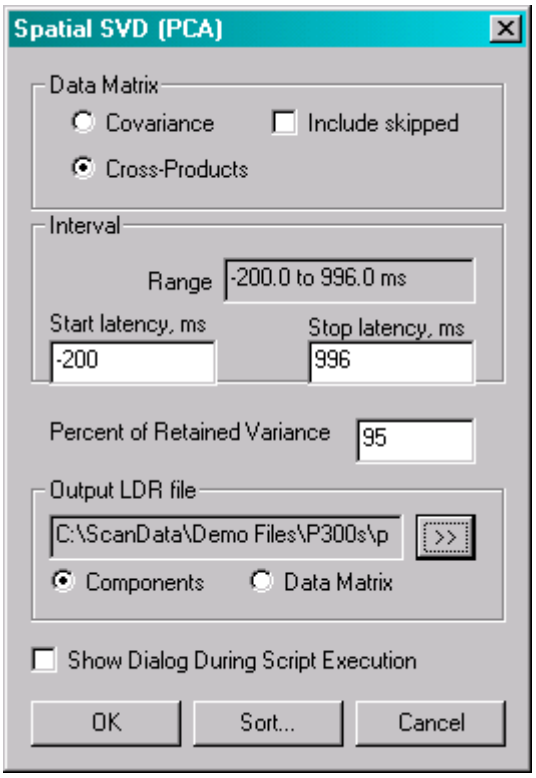
The spatial SVD transform is equivalent to spatial PCA (principal component analysis) without rotation of components. A series of spatial components – i.e. unit magnitude channel vectors or topographies — are derived such that the first component accounts for a maximum of the temporal variability in 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. Let's 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 Tutorial above with the P300 file, 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 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 same 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

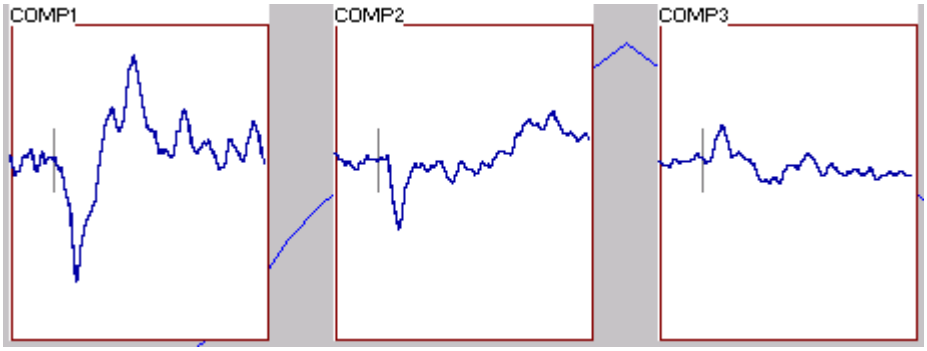


component, select the Cross-Products option (Covariance disregards any offset). Leave the Include Skipped field unchecked. When enabled, this option will include in the analyses any channels that you have designated as Skip channels. Leave the

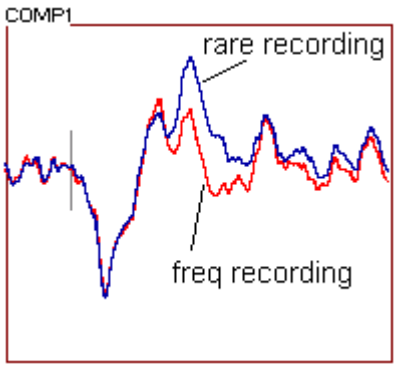
Interval set for the entire range, and set the Percent of Retained Variance to 95. Use the file name of P300svd.ldr for the Output LDR file, with the default Components button enabled. This means that the output LDR file will have the weights for constructing the principle components topographies. If 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**" for some important information. Then click OK.

A progress bar will track the SVD calculations, as the LDR file is being computed.

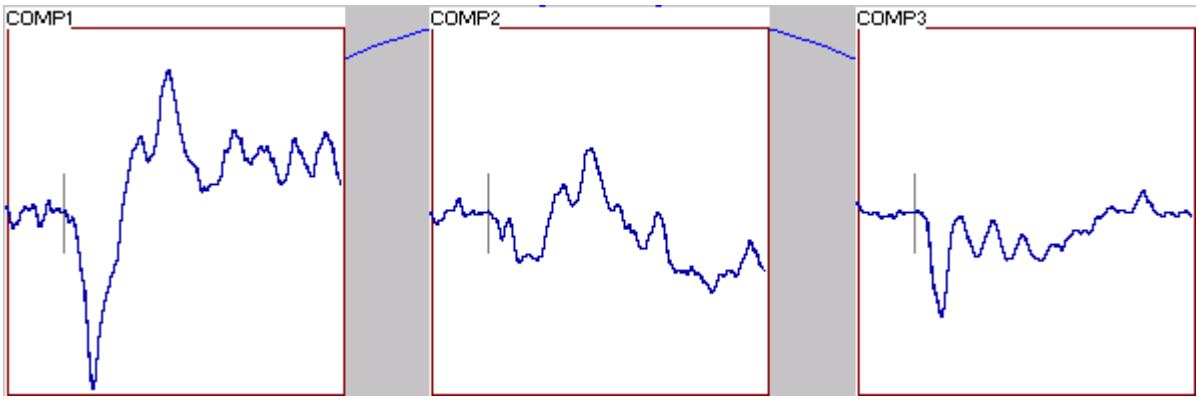
Now, retrieve the P300rare.avg file that was created above. Select Linear Derivation from the Transforms list of options. In the Linear Derivation screen, use the Browse button >> to select the P300SVD.ldr file, and click OK. You will then be asked for a file name for the output AVG file - call it P300rare-SVD.avg. 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, and click OK. Enter a file name for the Output AVG file - P300SVD-rare.avg.



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 Windows 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 file above.

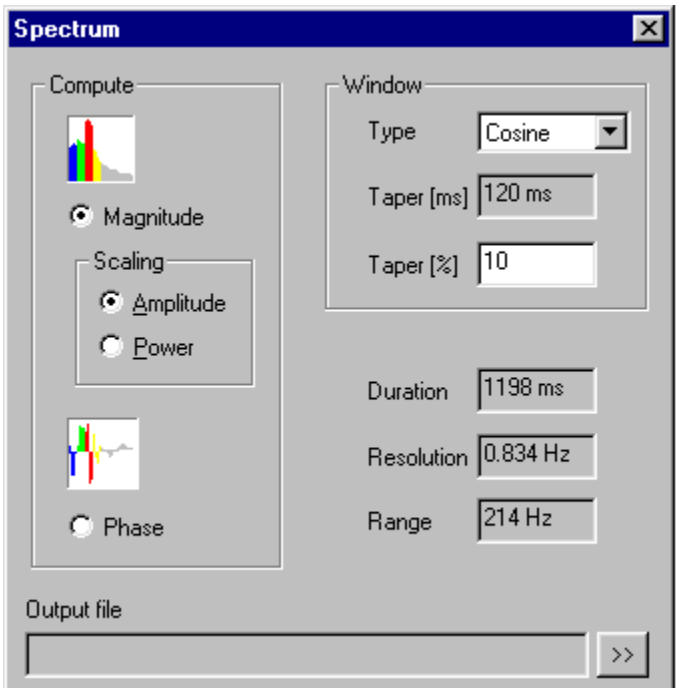
See also the Spatial Filter section for further examples of the Spatial SVD, especially regarding the use of the Data Matrix option.

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 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 as shown below.



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,

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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. When you have entered the desired settings, click OK. After the computation is complete, you will see an Output File utility display. Enter a file name and folder, and click Save. You will see a new Multiple Window Display with the results of the FFT. To reduce the frequency range of the display, click the right mouse button anywhere between the electrode displays, and select Properties, then Overall Parameters, then the Frequency tab. Set the Display Stop time to, for example, 50Hz, and click OK. The result will appear similar to the following.

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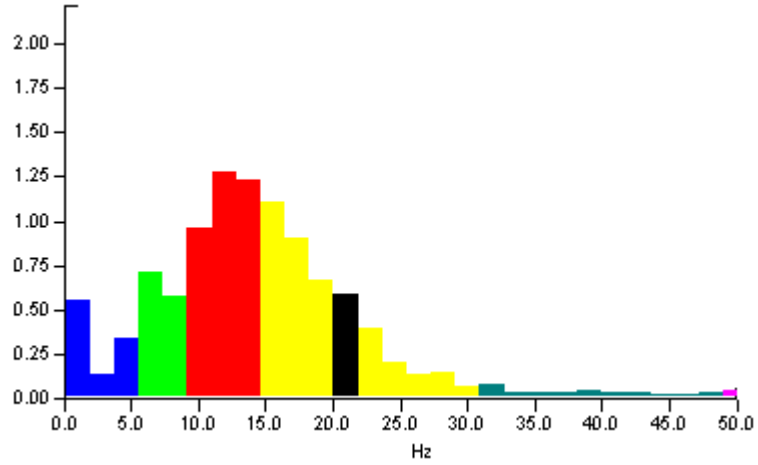
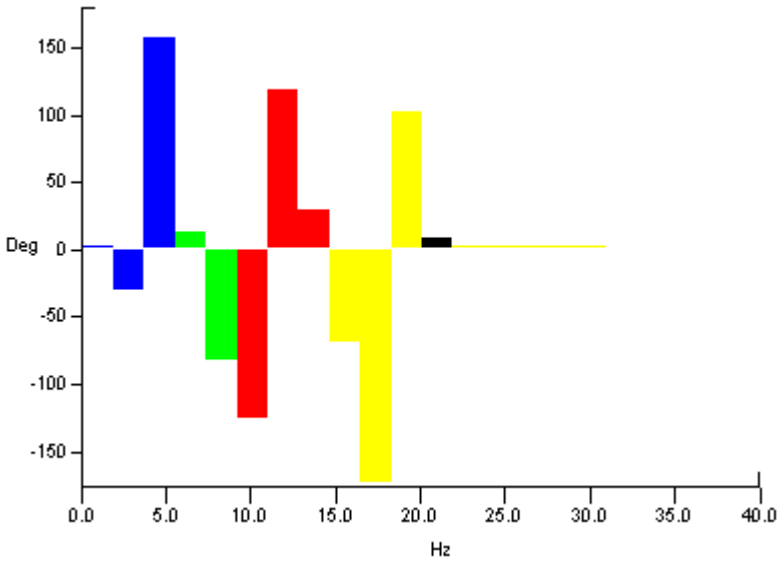


This is the power spectrum at OZ. Note that the standard EEG frequency bands (delta, theta, alpha, beta) are displayed as a series of colors. You can change these colors by selecting the colors item located in the Options menu (under Multiple Window Settings, General, Frequency Bands).

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 

. Click OK, and enter a file name in the Output File display (the AVG extension will be added automatically). Expand the O2 electrode to see the following display.



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The Y-axis displays degrees from 180 (top) to -180 (bottom). The X-axis is in Hz. For this example, we reduced the -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 + 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.

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.

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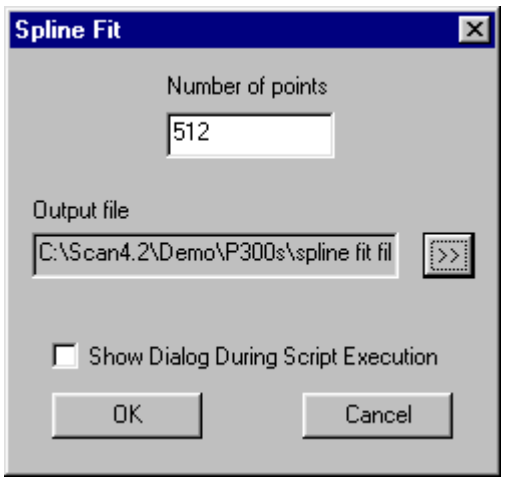
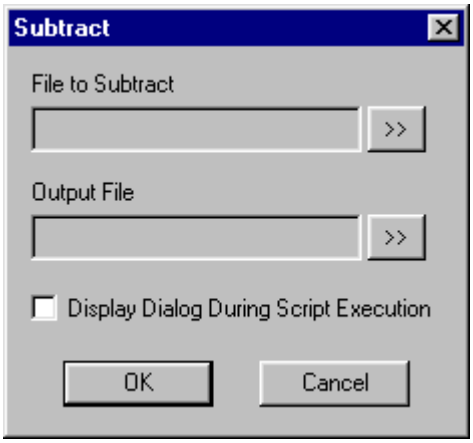


Enter the desired number of points, use the >> button to access the dialog box to enter an output file name and to select a folder, and click OK. A new Multiple Windows display will appear with the new number of points.

Subtract (AVG, EEG) - 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 Windows display will appear containing the difference waveforms.

t-score (AVG) - 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):

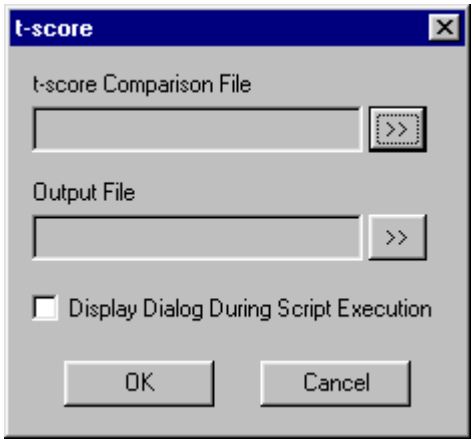
$$t = (mean1 - mean2) / Sd$$

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.

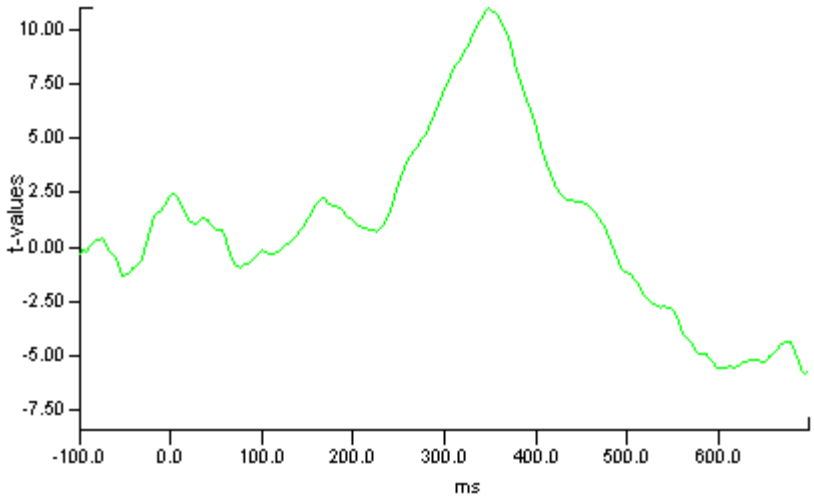
2. Next, select t-score from the Transforms list, and see the following display.



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 and 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 400 msec interval as well as negative values from about 530 to 700 ms.

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:

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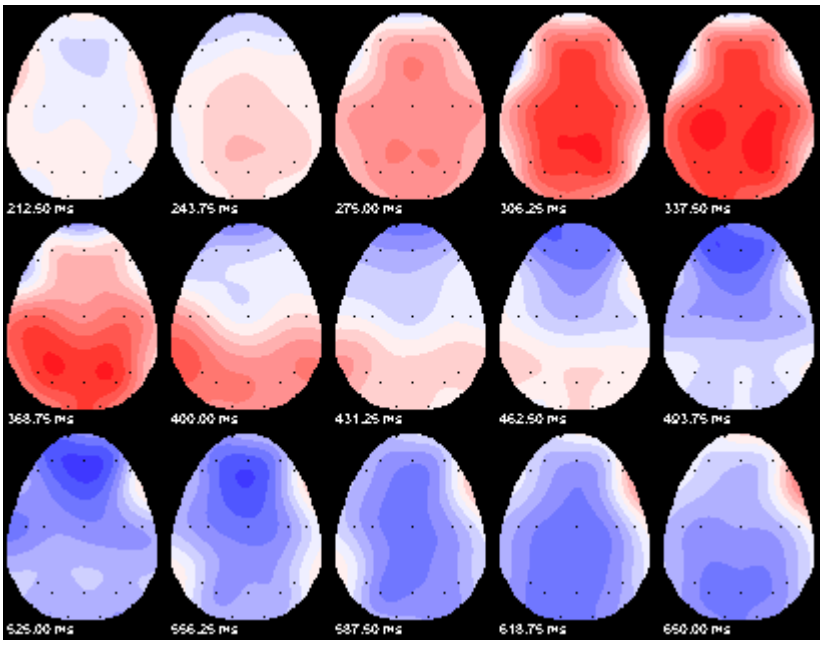
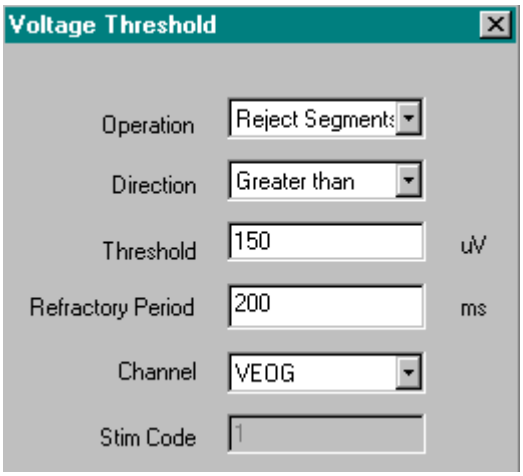


Note - The t-score option will not be active on the Transforms list if variances have not been saved for the comparison file. Variances across individuals are automatically saved when group averages are created. Thus, for a comparison of two group averages, the "Compute Standard Deviation" option under 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.

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 or Absolute value. 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 uVs.

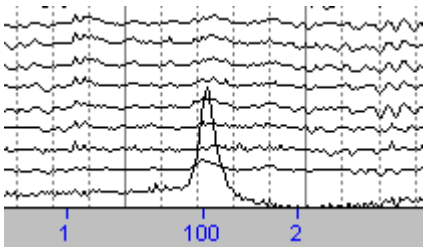
Refractory Period - Once a threshold criterion is met, the Refractory Period determines the length of time that must pass before the next trigger may be detected. This is to prevent the insertion of multiple triggers during a burst of EMG, for example.

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.

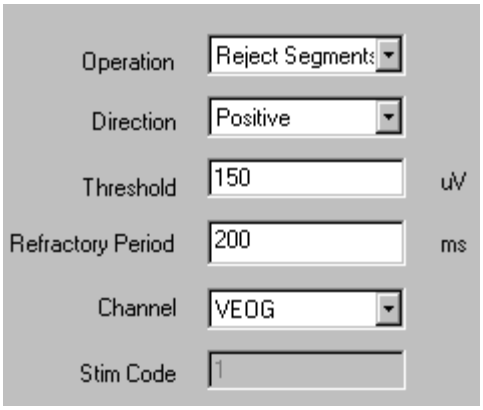
Let's illustrate the Add Event option by having Type codes of 100 entered into the viscpt.cnt file at every point where the voltage on the VEOG channel exceeds 250uVs (with a refractory period of 500ms just to make sure that multiple events are not entered for the same blink). In other words, we'll add triggers near the peaks of the more prominent blinks. Enter the values as shown above, 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.

As mentioned above, 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 below.



This will result in the automatic rejection of those segments of the CNT file where the positive voltage from the VEOG channel exceeds 150 uVs, 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).

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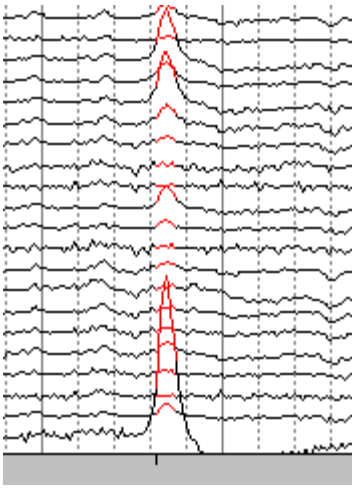
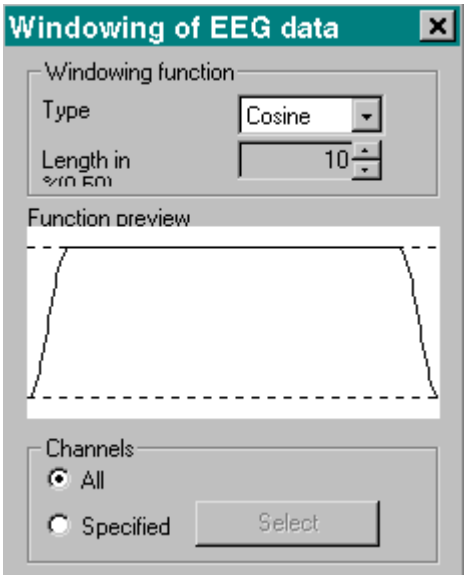


Window (EEG, AVG; time domain) - The Window transform applies a window taper to single-sweep epochs. Application of a window can be useful to minimize edge effects.

After retrieving your EEG or AVG file, select Window from the Transforms list. You will be asked whether you want to Modify the Existing Data file, or Create a New File. Since this permanently alters the data, we recommend that you create a new data file. You will then see the Windowing of EEG Data screen.



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

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channels, or just Specified channels (click the Select button and select the channels from the montage diagram).

Click OK when you are ready to proceed. A Save As... utility will appear in which you may enter a file name (the EEG or AVG extension will be added automatically), and designate the path. Then click Save to continue. A new Multiple Window display will appear containing the windowed data.

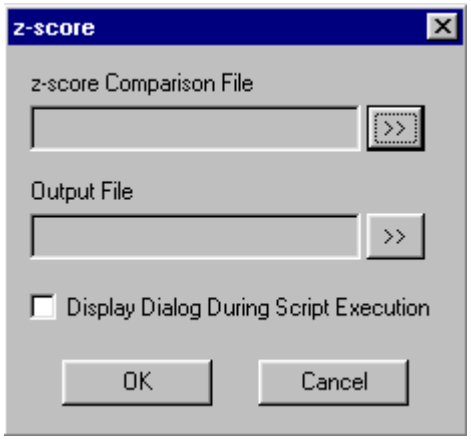
z-score (AVG) - The z statistic is used to determine how many standard deviations from the mean a given value happens to fall. For example, you can use z-scores to compare an individual's EP measures to a normal group distribution of the same measures. In EDIT, z-scores are computed for each electrode over time for waveform data and over frequencies for spectral data. The formula used for calculating z-scores is:

$$\frac{\text{(working file mean - comparison file mean)}}{\text{(standard deviation for working file)}}$$

Follow these steps to compute z-scores.

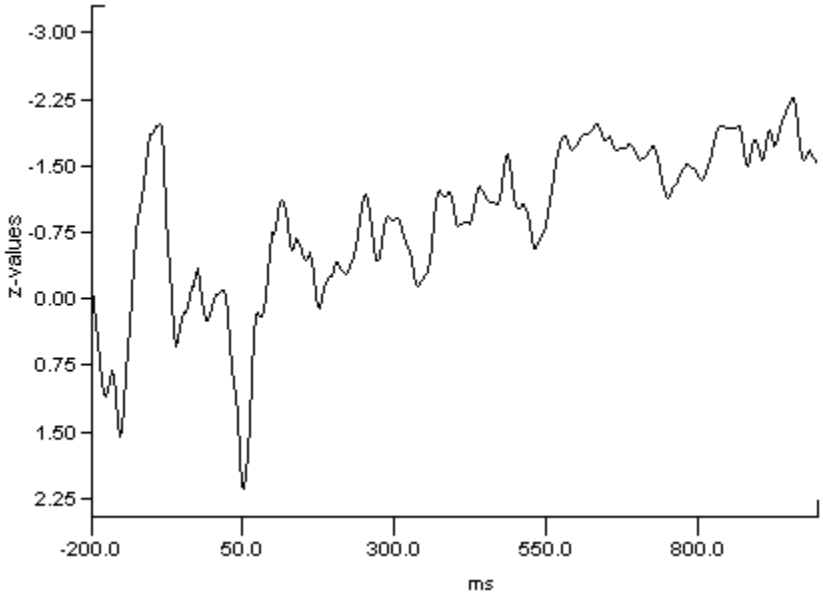
Retrieve either the group average file or the individual's data file (the order does not matter). *Note: when you average the individual's sweeps, you must have the Compute Standard Deviation option disabled.*

After retrieving either file, select z-score from the Transform list of options. You will see the Variance File for Z-score display. Click the Browse button >> to access a Select Data File utility. Select the other file for the comparison, and click Open.

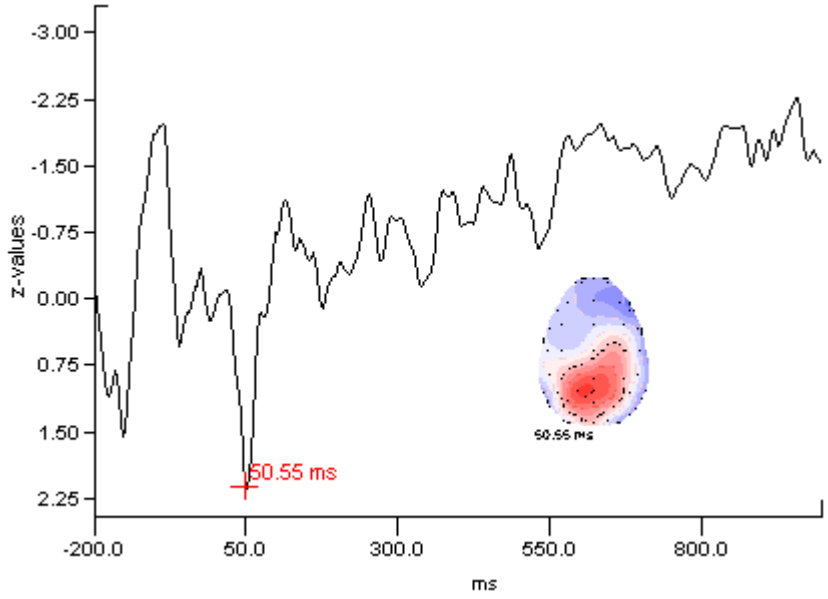


Then click the OK button. An Output File utility will appear in which you may enter a file name and select a folder for the resulting file (the .avg extension will be added automatically). You will then see a new Multiple Window Display containing the z-

scores for each time point and from each channel.



The z-scores may be mapped as with any AVG file, as shown below.



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.

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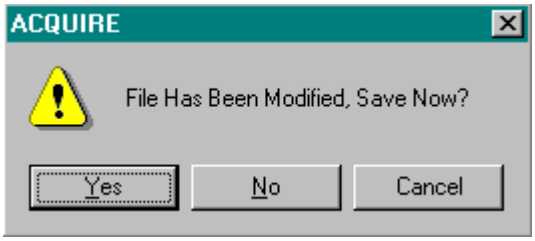
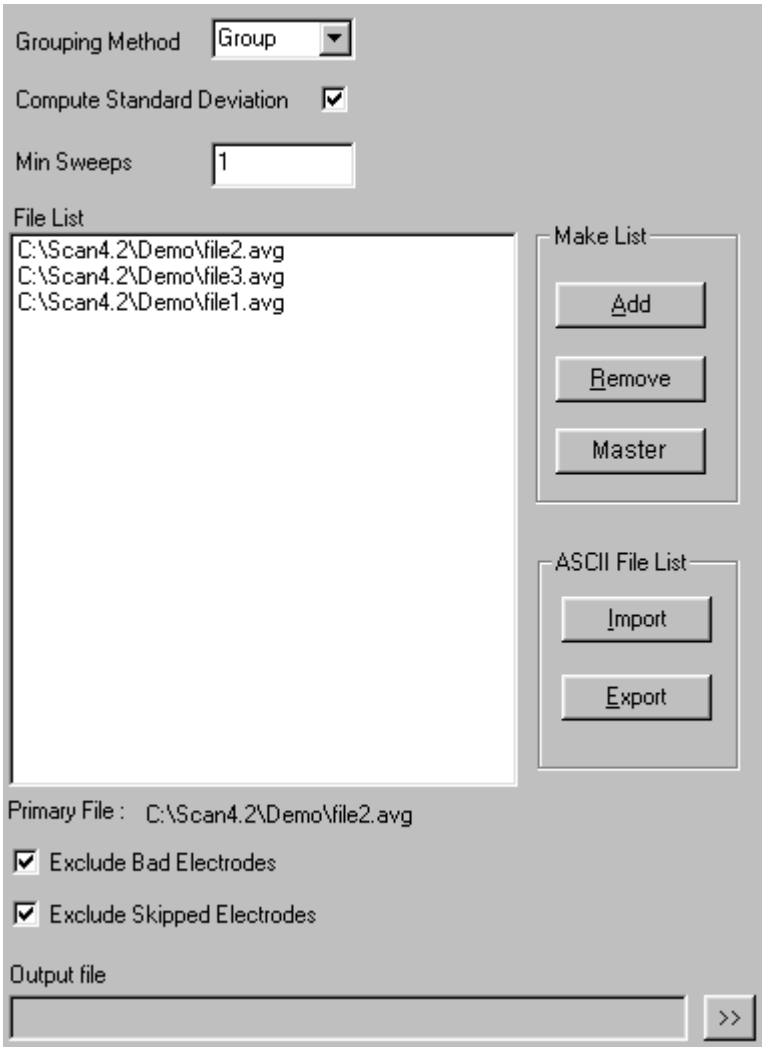


Click Yes to save the file with the modification, No to close the file without the modification, or Cancel to cancel the closing of the file.

Group/Individual Avg (AVG) - 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.

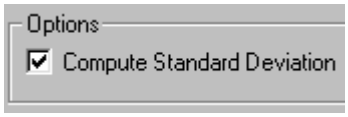


Grouping Methods - There are two Grouping Methods: Group and Individual. The *Group* method computes an average based on a grouping variable, where each subject in the average is represented by one file. Therefore, it also calculates and stores the number of individuals within the average. When using the Grouping method, it is NOT necessary for the individual averages to have been formed with the

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



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 
>
> 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; Ctrl+Shift+left mouse). The selected files will be displayed in the File List.

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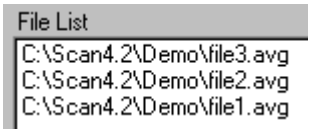

Use the Remove button to remove an unwanted file from the list (highlight the file, then click the button).

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 was 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

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that channel 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 off-line 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.

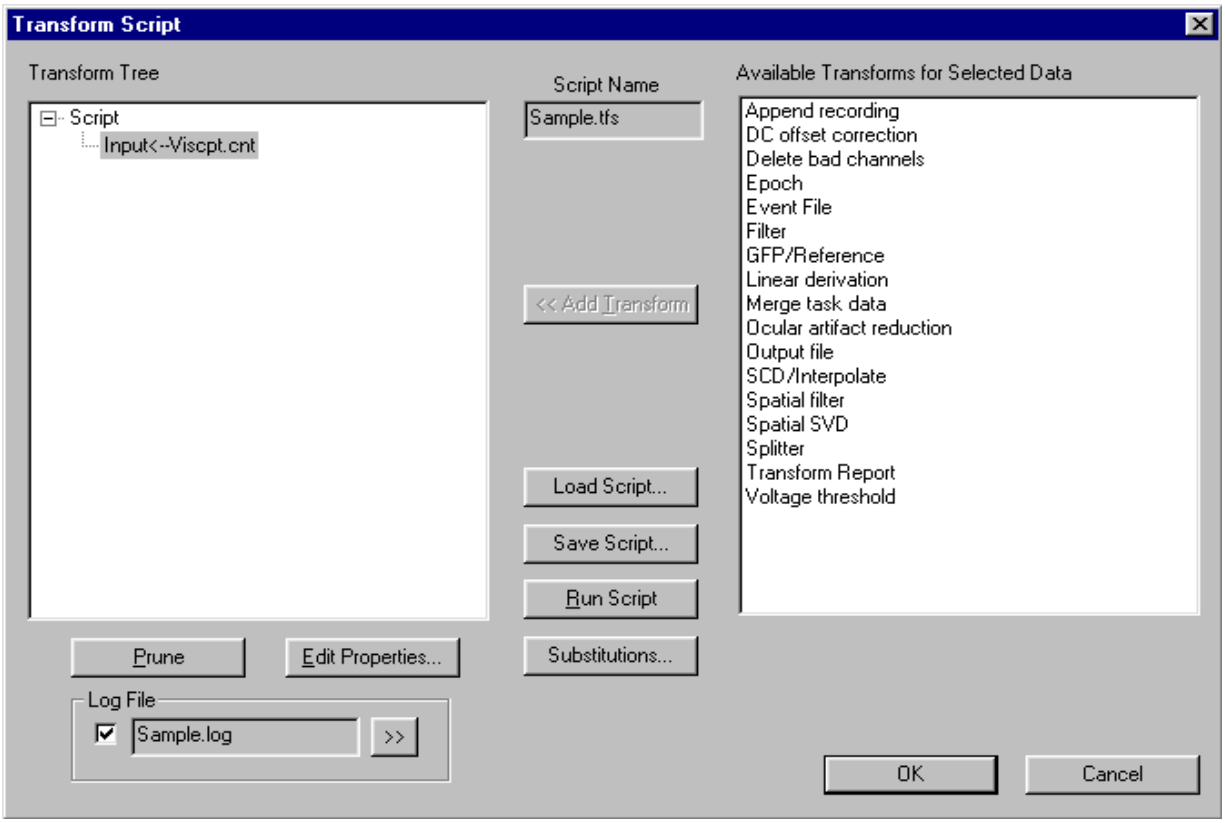
User Defined - The User Defined option allows you to select a data file first, then select a Script file to apply to that file (see the Script section below for scripting details). Retrieve a data file, then click the User Defined option. An Open File display will appear, allowing you to select a *.tfs (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.

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 Scan4.3\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 - Input file. Select "Input file" by clicking on it. Note that the <<Add Transform 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 scan4.3\demo folder), but do not open it just yet. We'll 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

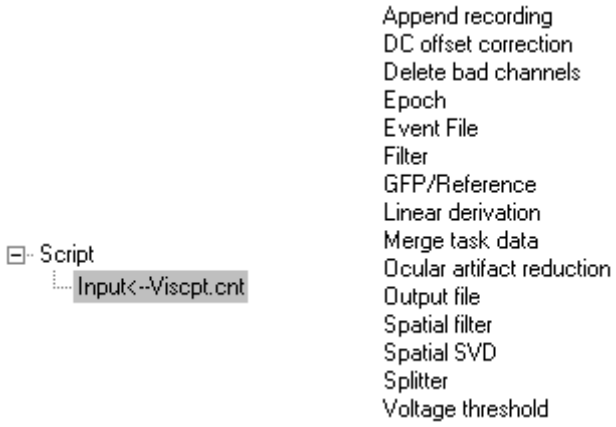
apply one script to multiple files without inputting the file name for each.

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 (earlier in this 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 

. When enabled (check mark appears), 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.

The Transform Tree displays the first branch, and the Available Transforms for that type of file are listed on the right side of the display.



If you select any of the transforms, you will see the same display windows 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 

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

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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.

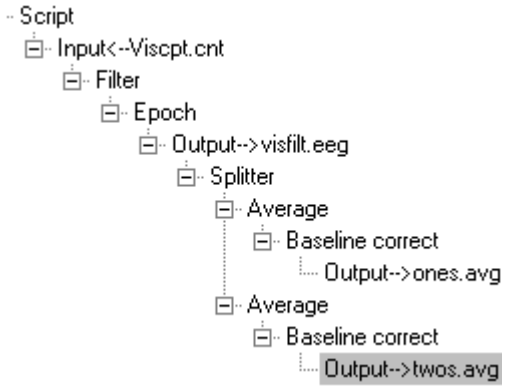
Exception with Ocular Artifact Reduction. The Ocular Artifact Reduction transform is a terminal operation. That is, no further operations may be performed on a file after the reduction has been performed. It is necessary to retrieve the transformed file in a second script file, and continue subsequent transforms with it.

Continuing with the example, let's say that after Filtering the viscpt 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.



Remember to save your Script files using the Save button. Click Apply to execute the Script file, but still remain within the Script editor. If you click OK, the Script

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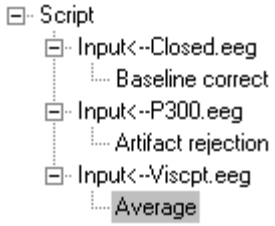
program will be executed, and afterward you will be returned to the main EDIT screen. Click Cancel to exit the editor with running the Script file.

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 Script 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, as shown below.



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.

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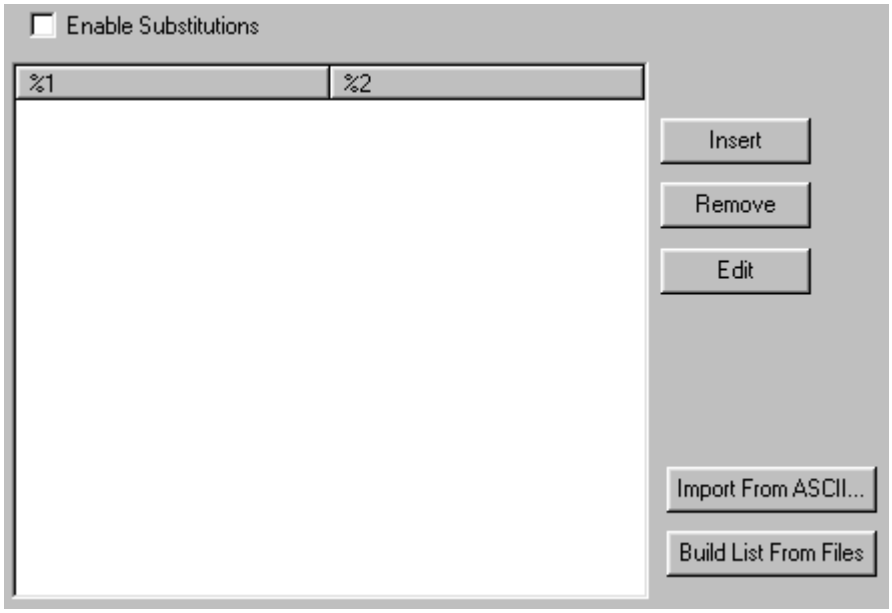
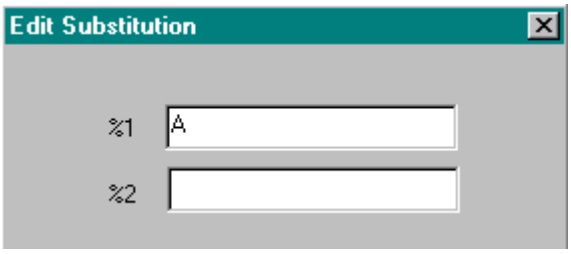


The are two string lists that you may use (%1 and %2). The general idea is to make one or two lists of characters that will be substituted wherever you place %1 and/or %2 in the Input or Output File statements.

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).



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.

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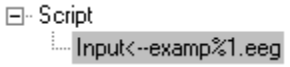
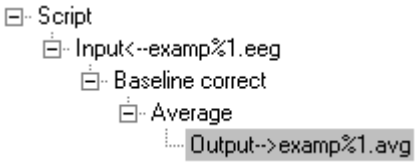
Select the Input File option, click the <<Add Transform button, and select the first file. In this case, it is the exampA.eeg file. Now click the Edit Properties button. The Input File display will appear, and we want to modify the file name. This is where you replace the uniquely occurring file name 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

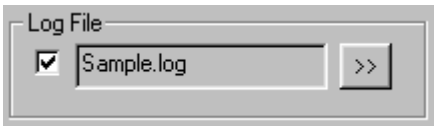


. You are telling the program to run the Script file using all files, in the specified directory, beginning with "examp", and ending with A-E. Now, go ahead and select whatever additional Transforms you wish to perform. When you get to the Output File name, include "%1" to add the A-E characters to the Output File names. The final Script file might appear as the following one.



Then Save the Script file (if desired). Click the Apply 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



field.

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```
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,

%1	%2
A	vvv
B	www
C	xxx
D	yyy
E	zzz

and specified that in the Output File name C:\Scan4.1\Demo\examp%2.avg . 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

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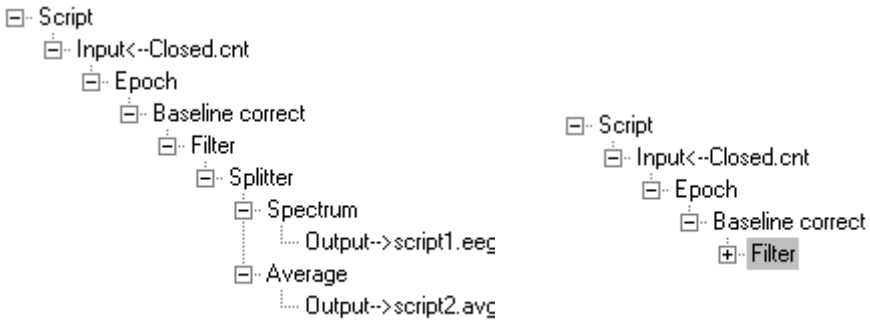
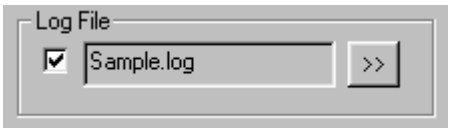
save the file as a .txt file. Then click the Import From ASCII... button, and select the .txt file. You may select a number of files at once to add to the list by clicking the Build List From Files. An Open File utility will appear. Use the Ctrl+Mouse click combination to highlight multiple files. After 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.

Notice that there is a small box with a minus sign ⊟ before each step in the tree. These function in the same way as in the Windows Explorer. Click one of the boxes in your tree, and the minus sign will change to a plus sign. The steps after that point will be hidden. This allows you to simplify the display of more complex tree structures.



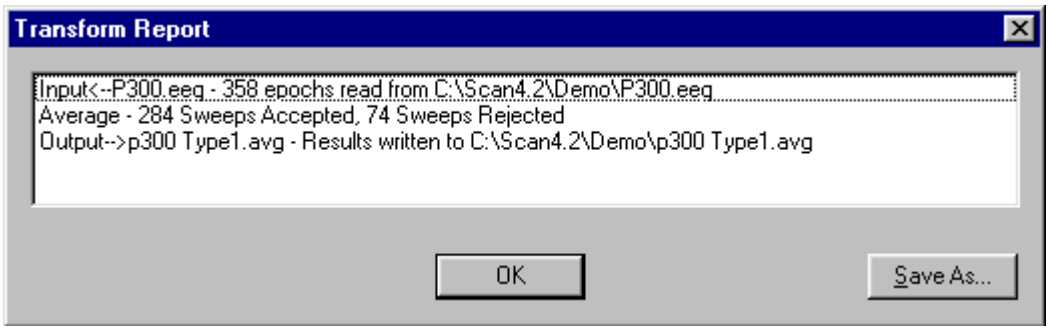
Log Files. You can create a record of the script file operations by enabling the Log File option from the main Script window. Use the Browse button to set the path and file name.



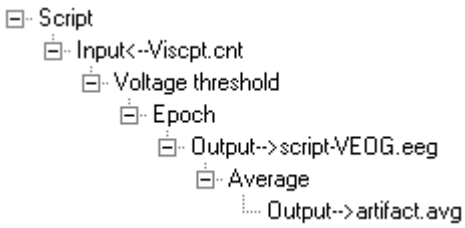
The summary information is written to a text file (with a .log extension), which can be reviewed with a text editor.

```
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. A nice 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).



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 (100uV 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.

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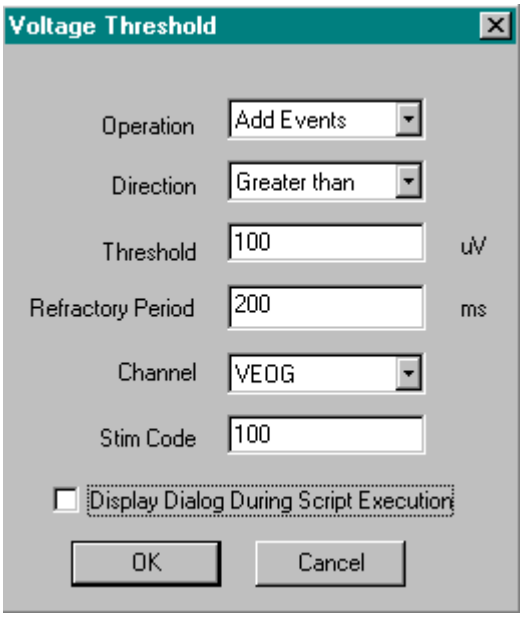


In the next step, epochs of 0-200 ms are created around the type codes of 100. (Be sure to set the Sort Criteria Type field to 100). An Output .eeg file is created, and then averaged. The averaged file is then save as artifact.avg. This will create a perfectly suitable artifact-laden file on which you 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)

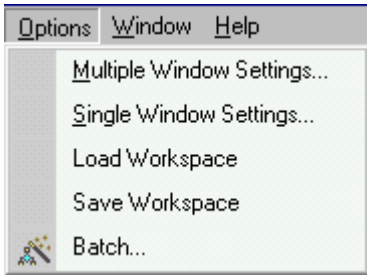
as the first coordinate, and the phase angle (arctangent of imaginary part divided by real part) as the second coordinate. Note that real time domain data can also be viewed as complex, with the understanding that the imaginary part is identically zero. In this case, the magnitude (first coordinate) 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:\scan4.3\demo\sample.tfs.
```

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.



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 3 regions: Single X-Axis, Tick marks, and Scaling.

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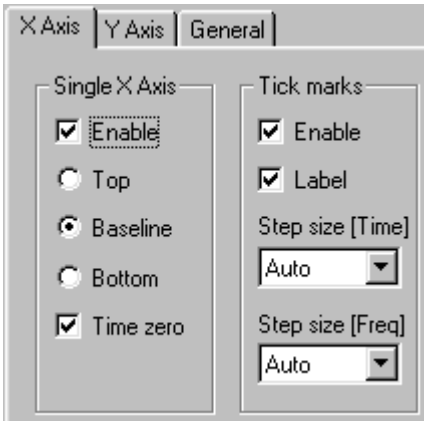

Single X-Axis - Click on the *Enable* field (check mark will appear) to display the x-axis in the multiple windows displays for averaged or epoched files. Next, select whether you would like the axis to appear at the *top*, the *baseline*, or *bottom* of the waveform display. Click on the *Time Zero* 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. Click on the *Label* button 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 on the pull-down arrow indicator and highlight/click the desired option (range is from 0.1 ms to 100 seconds under the Time field and .5 Hz to 10 kHz under the Freq field; or, select *Auto* to let the program place the marks automatically).

When you are satisfied with the settings, click on the *Save As*... button to add the information to the workspace file, then click on *OK* to continue. Click on *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.

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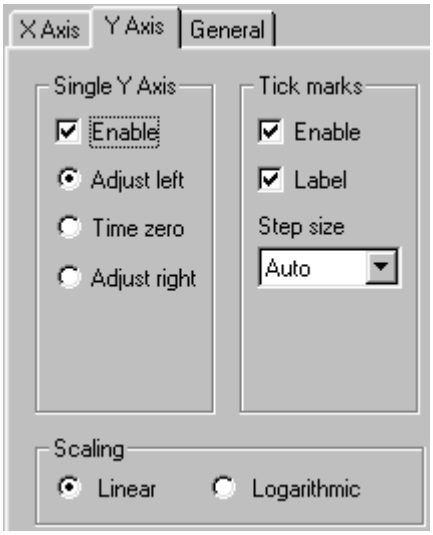

Single Y-Axis - Click on the *Enable* field (check mark will appear) to display the y-axis in the multiple windows displays. Next, select whether you would like the axis to appear at the left end of the x-axis (click *adjust left*), the right end of the x-axis (click *adjust right*), or intersecting 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. Click on the *Label* button if you would like the labels to appear aside the scale. Under the *Step size* option you may select the interval between successive tick marks. Click on the pull-down arrow indicator and highlight/click the desired option (range is from 0.01 uV to 100 mV; or, select *Auto* to let the program place the marks automatically).

Scaling - Select whether you would like the scaling to be *linear* or using a *logarithmic* scale.

When you are satisfied with the settings, click on the *Save As*... button to add the information to the workspace file, then click on *OK* to continue. Click on *Cancel* to leave the page without invoking any of the selections.

General - The General page is divided into Colors and Misc. options.

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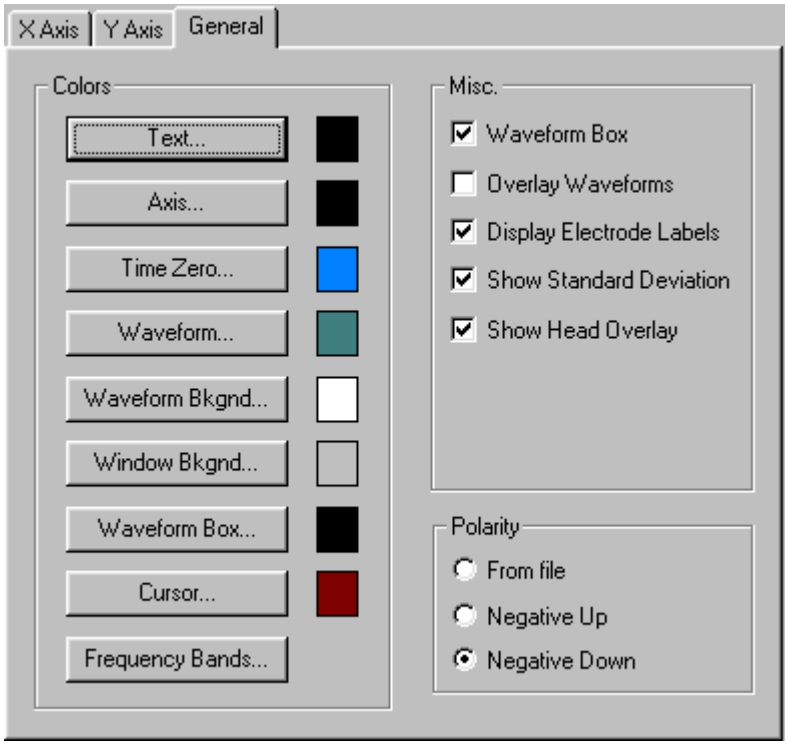
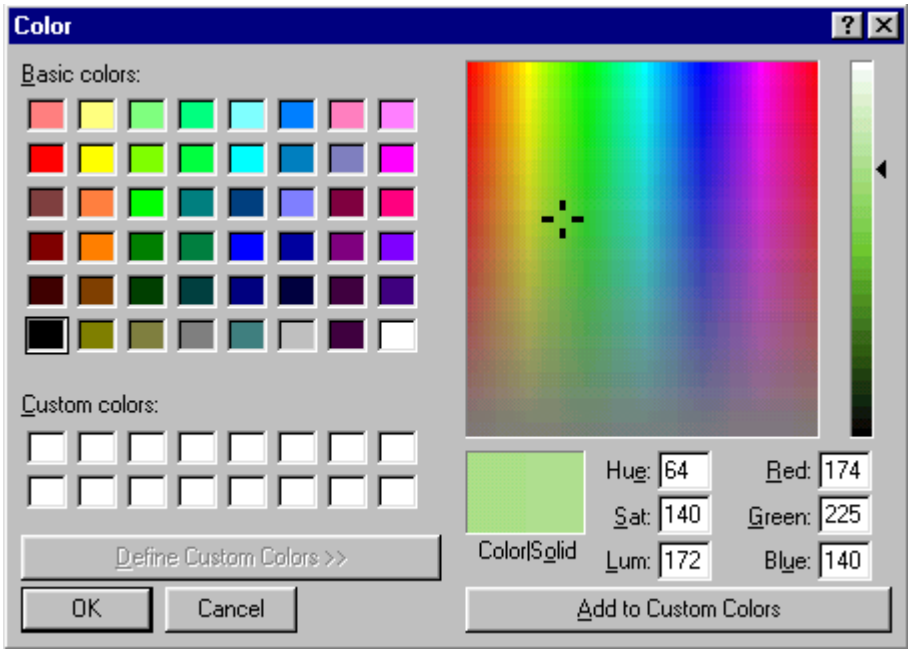


Colors. Under the Colors section you may specify the color for various display features, including Text, Axes, Time Zero, Waveform, Frequency Bands, Waveform Background, Waveform Box, and Window Background. Selecting any of these *except* the Frequency Bands option, will display the basic color palette 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 on 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 on 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 on 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 *Edit/Overall Parameters/Frequency*.

The default frequency band names are Delta, Theta, Alpha, Beta1, Beta2, Muscle, 50Hz and 60Hz; however, you may rename these as you desire.

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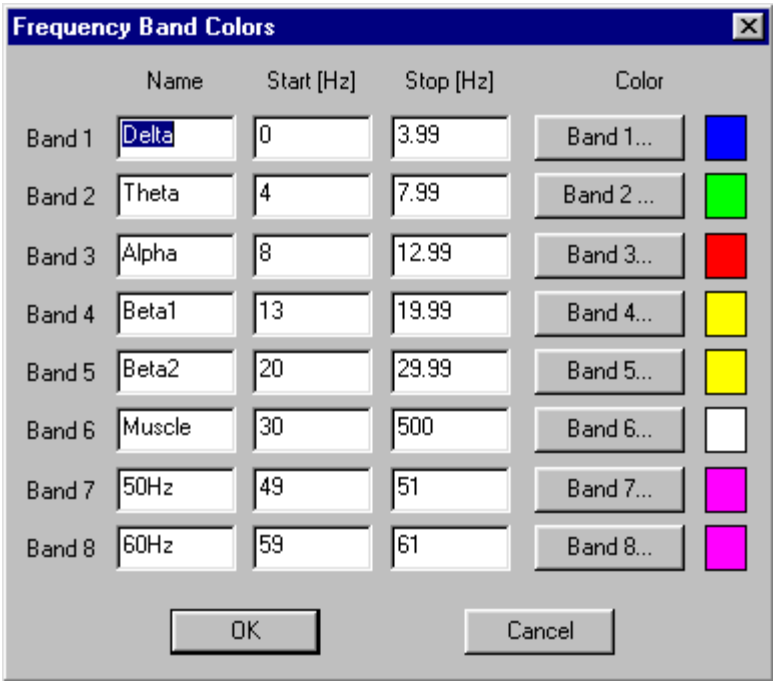

You may also redefine the frequency limits of each band. Keep in mind that the actual frequency resolution will be determined by the *Points* value you selected under *Edit/Overall Parameters/Frequency,* and the AD rate. For example, 256 points, with a sampling rate of 1000Hz, gives a frequency resolution 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.

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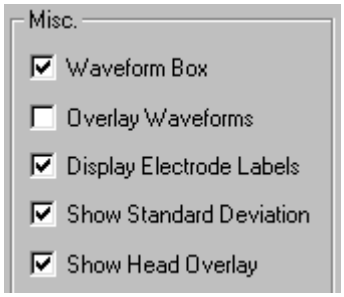


Waveform box. This field toggles the Waveform Box on and off. This is the line box that surrounds the electrode display. The color is controlled by the Waveform Box color button.

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.

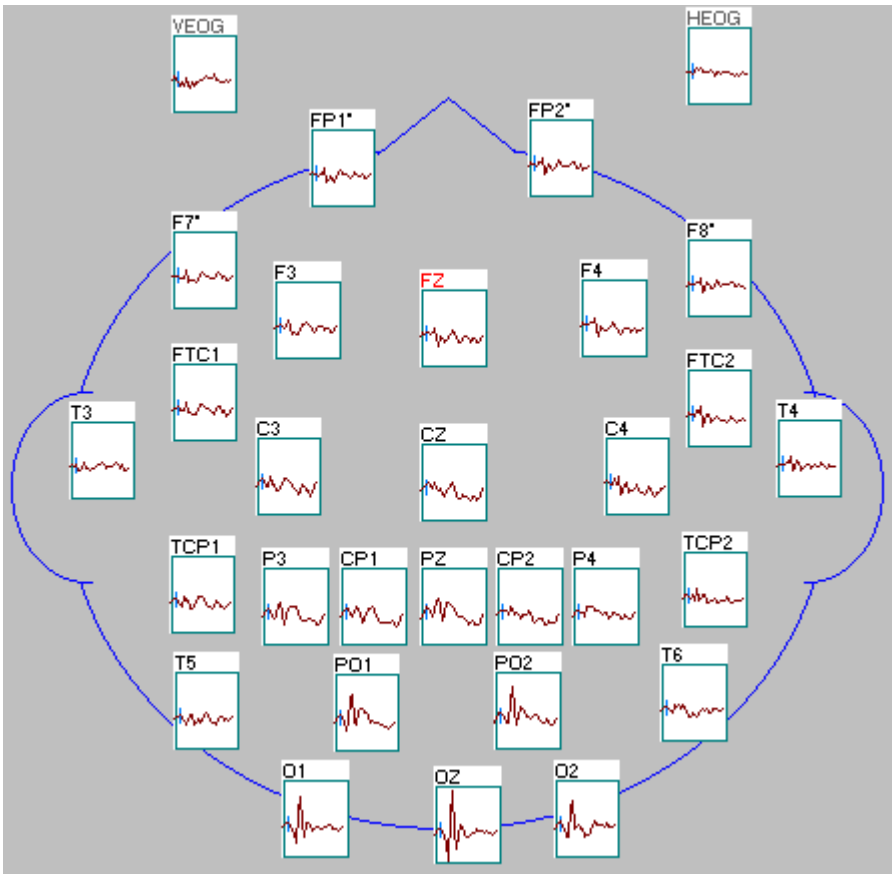
Display Electrode Labels. This option will toggle the display of the electrode labels (in the upper left hand corner of the displays).

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.

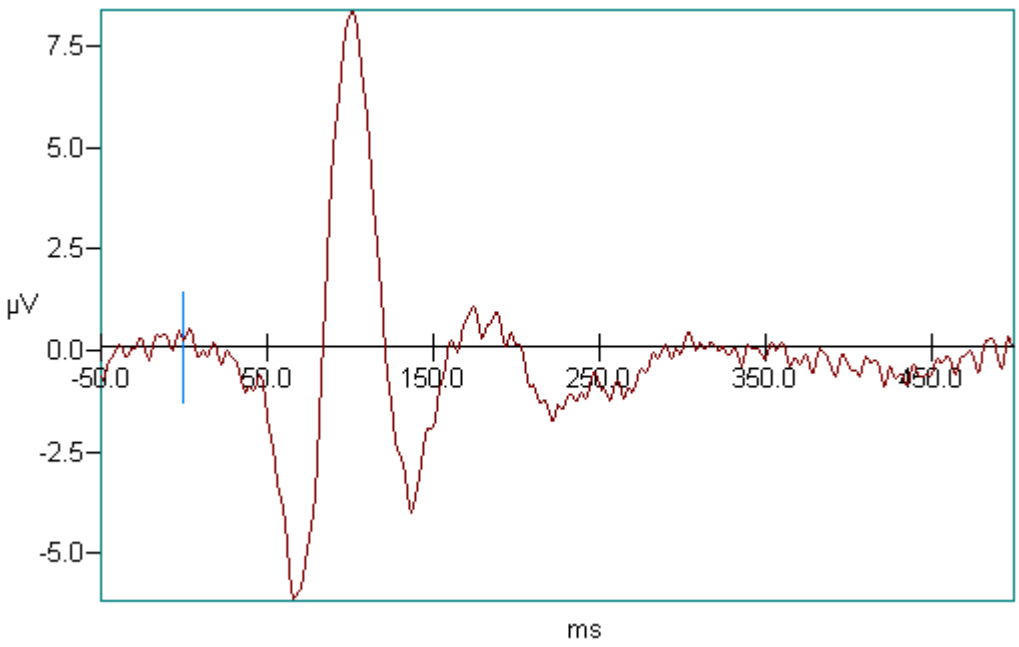
Show Head Overlay. When enabled, this option will display the head overlay.

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 always 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. Below 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; it is toggled on or off by the Waveform Box field. The color of the waveforms themselves is set by the Waveform control. The blue head shape is the Head Overlay. Zooming in on a channel gives the following display.

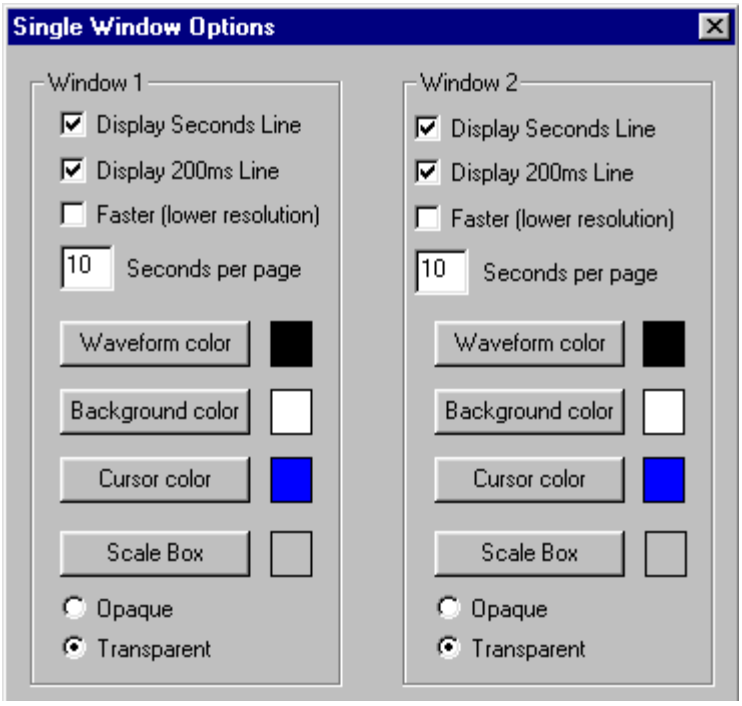


The positions of the x and y axes are controlled by the Single X Axis and Single Y axis buttons (such as, the Top, Baseline, and Bottom options for the X axis). In the above example, the X-axis is set for Baseline, and the Y-axis is set for Adjust Left. The Tick Marks controls toggle the tick marks on 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 uVs is the Time Zero mark (it may be toggled on or off, and the color may be selected). This is seen on all of the channels on the Multiple Window Display (not just when you zoom into one of them).

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 on *OK* to continue, or click on *Cancel* to leave the page without applying any of the selections.

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, as well as a lower resolution option



(check mark will appear when enabled). Faster (lower resolution) displays are useful with the higher sampling rates, as with EMG recordings, in which there may actually be more points than pixels. You may also select the number of seconds per page to be displayed (this may be changed during replay with the accelerate and decelerate icons).

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 on 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).

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).

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).

Batch... - This option displays the Autorun feature dialog screen for use with BATCH files. Please refer to the Tcl Batch Commands manual for details.

Tools

The Tools option accesses several utility routines.

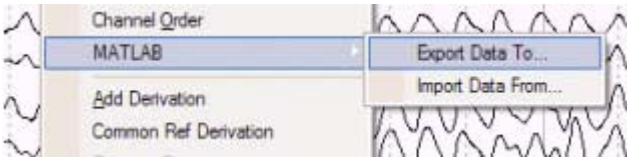
Waveboard - This option is used to open the Waveboard. The Waveboard is used to display waveforms from the same file, or different files. You can also launch the Waveboard from the Toolbar icon  . Please see the Waveboard appendix at the end of this manual for a complete description.

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 license for Toolbox 2003, SCAN 4.3 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. The basic steps are as follows:

1. Load, for example, the CLOSED.CNT file in EDIT.

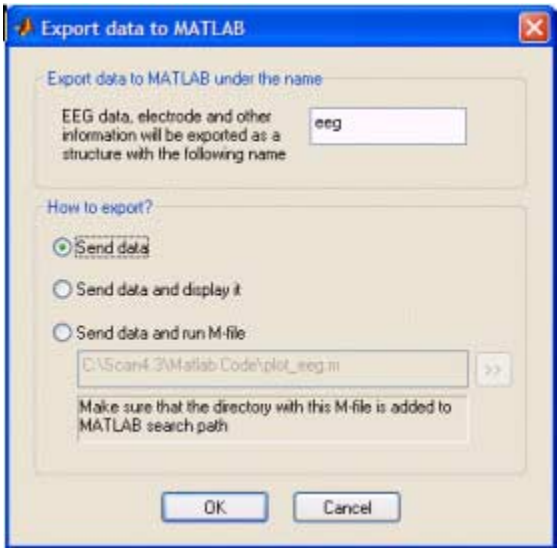
2. From the popup-menu, select the **MATLAB->Export Data To…** menu item.



3. If you have not already activated MATLAB within EDIT, the following dialog appears:

4. Press Yes to activate it. Because MATLAB consists of many modules, it may take several seconds to activate. Typically, it takes 10-15 seconds, and during that loading EDIT warns:

5. After loading, the following dialog screen appears:



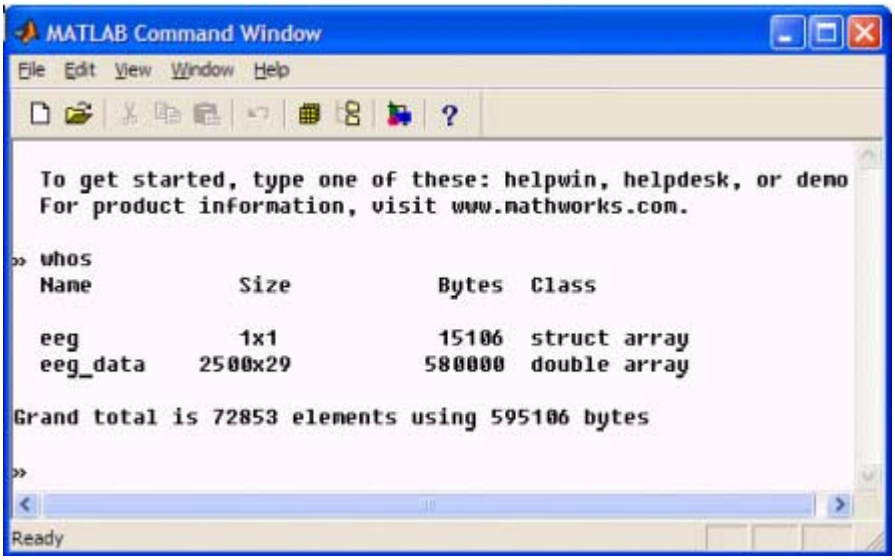
Two types of data will be exported to MATLAB:

- Description structure: its default name is "eeg". You can change this name through the dialog box.
- Matrix with EEG data: with the name "eeg_data". You cannot change the name.

EDIT allows three methods of operation:

- Simply send data.
- Send and display them as a "butterfly" plot.
- Send and run M-file to perform some calculations and/or customize the display.

6. For now, use the default setting "Send data" and press the OK button. Then click "MATLAB command window" at the Windows taskbar (because MATLAB is activated as a separate application, it shows its own button on the taskbar). Type the command **whos** and you will see the following information:



7. It shows that you have structure **eeg** and matrix **eeg_data**. Type **eeg** and MATLAB will show you contents of the structure:

```
>> eeg
eeg =
     path:       'Closed.cnt'
     type:       'EEG'
   vscale:       128
     elec:       [1x29 struct]
```

It includes the name of the file, type (EEG for continuous recording from CNT files and EP for averaged and epoched files), vertical scale in EDIT (usually in µV), and another structure that describes the electrodes. Type **eeg.elec(1)** to see information about the electrodes. SCAN 4.3 sends only electrode names and positions as set in the Channel Layout dialog.

8. Before we continue, you need to configure the MATLAB software as described in the "Export data to MATLAB" dialog:

> Make sure that the directory with this M-file is added to MATLAB search path.

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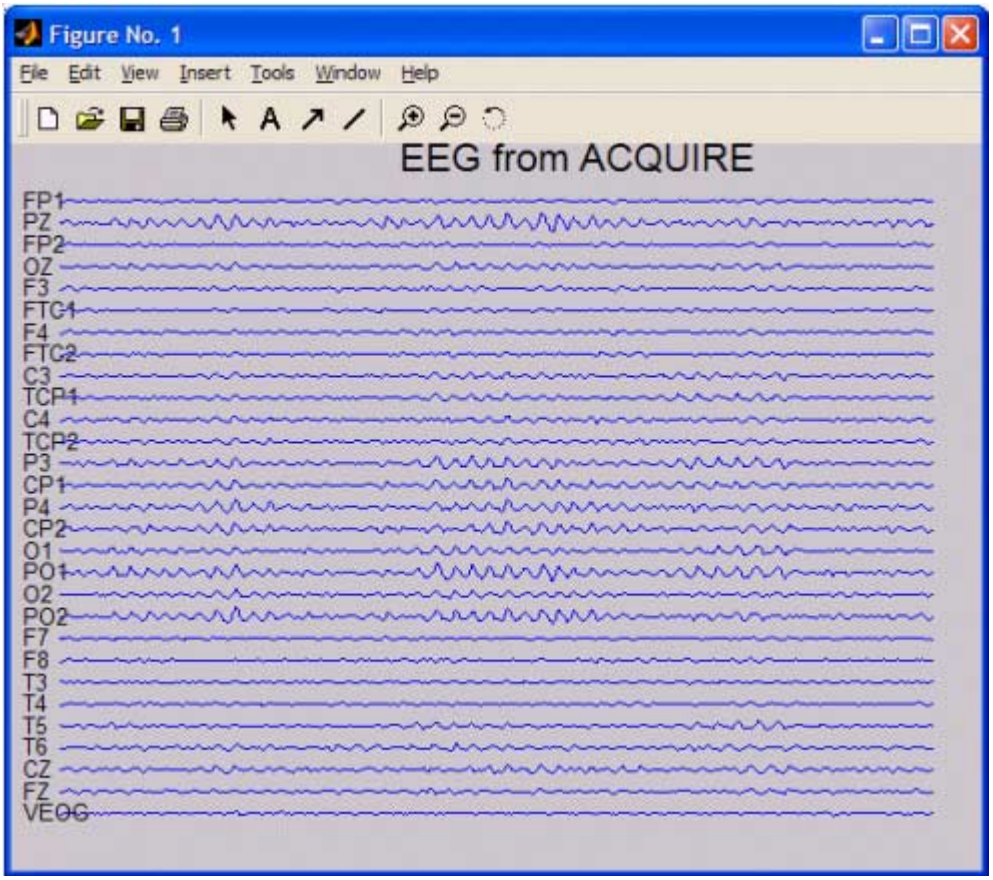
To accomplish that step, select from the "MATLAB Command window" menu "File->Set Path…". Then click on the "Add Folder…" button, navigate to the SCAN 4.3 installation directory (usually C:\Program Files\Neuroscan\SCAN4.3), and select the subfolder "MATLAB Code". Click OK and then Save.

9. Now return to EDIT, again select "Export Data to…", but this time select "Send data and run M-file" option. If you did everything correctly in the previous step, MATLAB will produce the following display:



It shows the electrode names and waveforms.

10. Now we will perform a simple EEG data manipulation. Enter the following commands in the MATLAB command window:

```
>> eeg_data(:,3)=0;
>> t=(0:2499)/500;
>> eeg_data(:,4)=100*sin(2*pi*10*t');
>> plot_eeg(eeg_data,eeg);
```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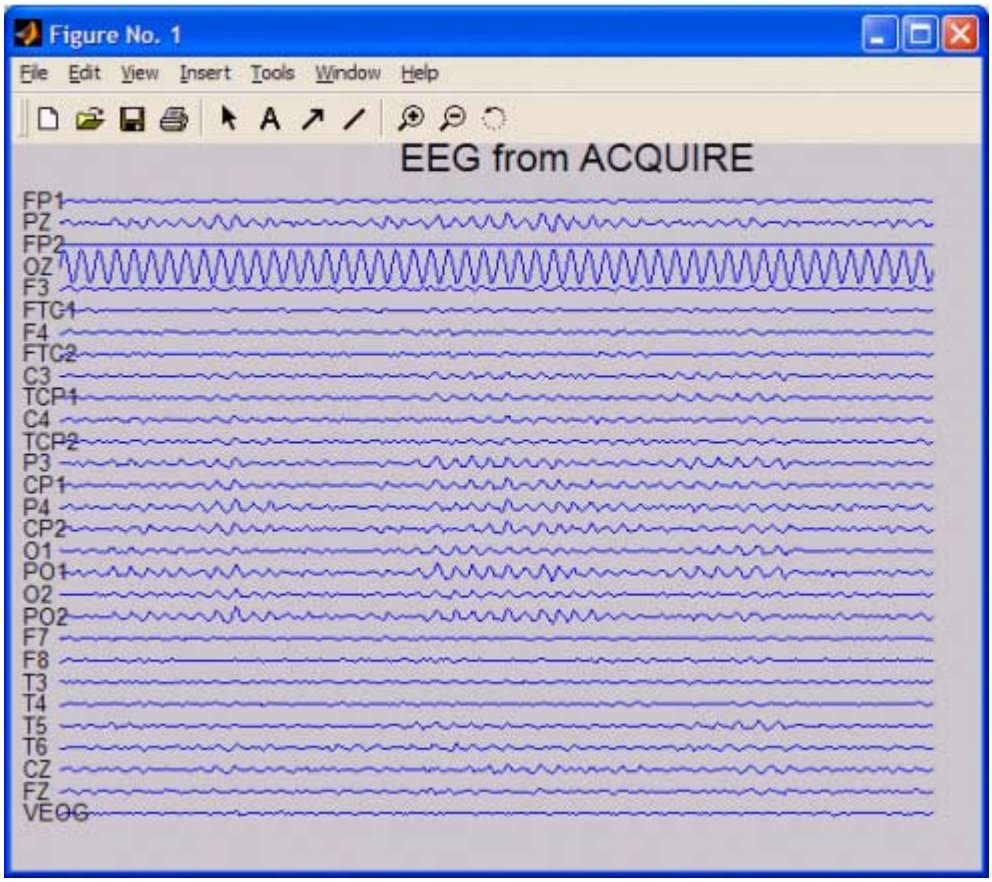
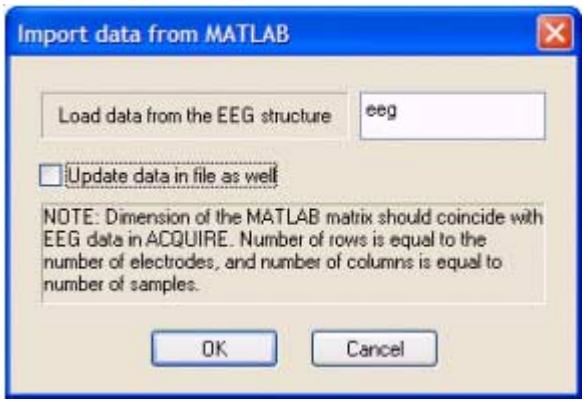
The first line nullifies the signal for the third channel, the following line creates a vector with time information (500 is equal to the sampling rate, and 2499 comes from the fact that we loaded 5 seconds of data 5x500=2500. If you loaded a different file, you will need to make the necessary changes in this code). The third line of this code assigns 10 Hz, 100 µV signal to fourth channel. The final line of code replots the data as shown in the following display:



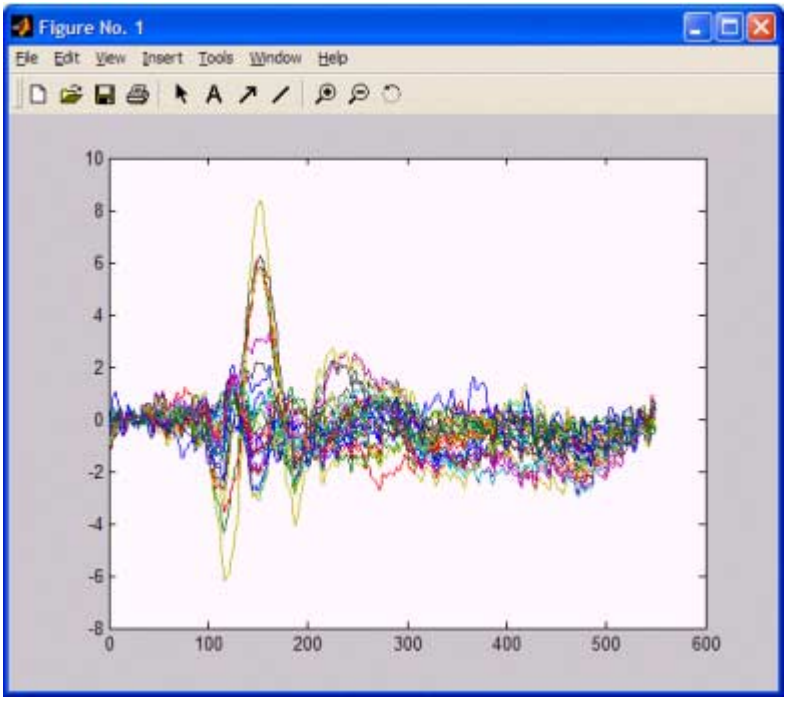
11. Next, we will import that data back into EDIT. Select the **Import Data From...** option from the pop-up menu in EDIT.

12. In the following display, uncheck "Update data in file as well" (otherwise the data will be changed in the CNT file), and click the OK button.



13. The EDIT screen will be updated accordingly.

14. Now load the VEP.AVG file and export it to MATLAB in a similar fashion. Select "Send data and display it". The Butterfly plot will appear.



15. Return to EDIT and export the data again, but this time select the "Send data and run M-file" option. The Topographic plot will appear:

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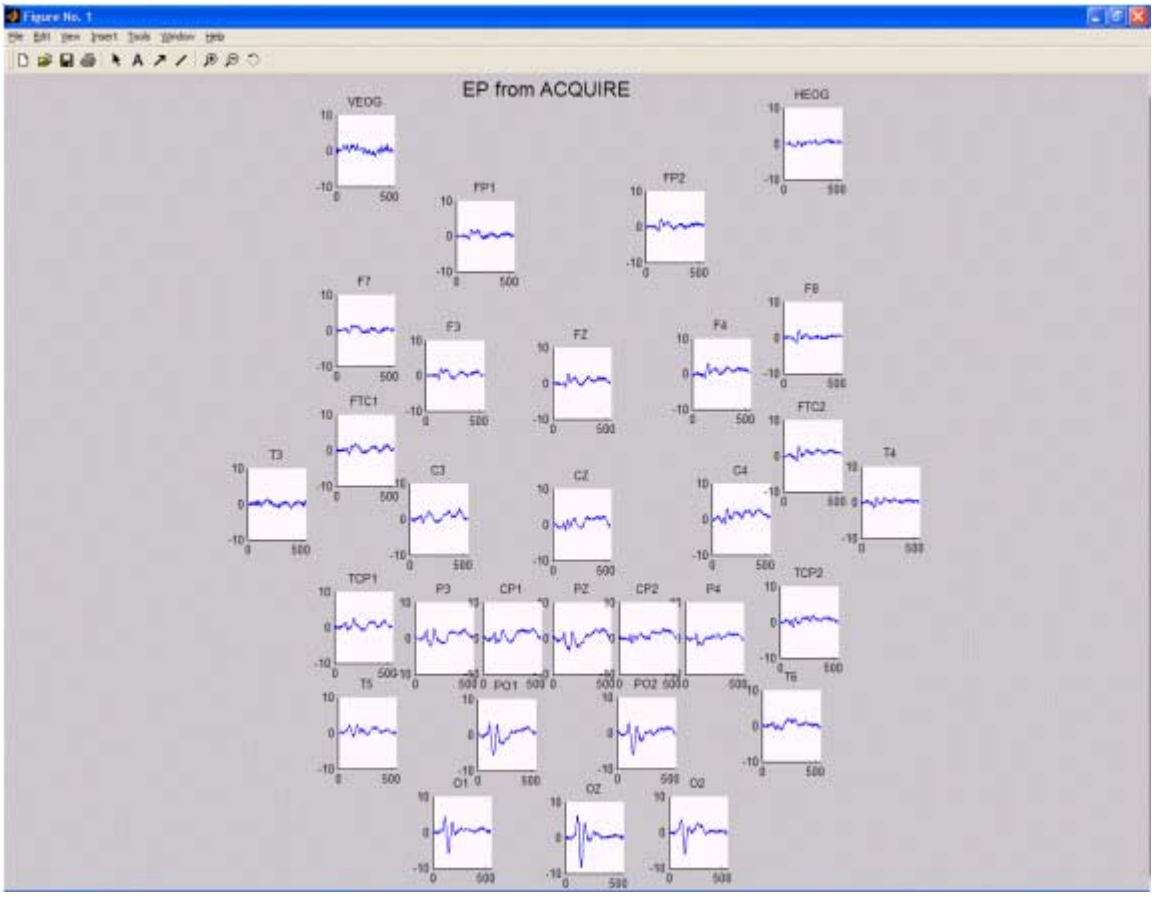


16. Now modify the data as we did in step 10, and import the data back into EDIT. For AVG and EEG files, the option to "Update data in file as well" is hidden.

17. In the MATLAB command window, select "File->Open...". Navigate to the "MATLAB code" folder installed by SCAN 4.3, and open the file **plot_eeg.m**. From this file you can see how the EEG and EP data are plotted.

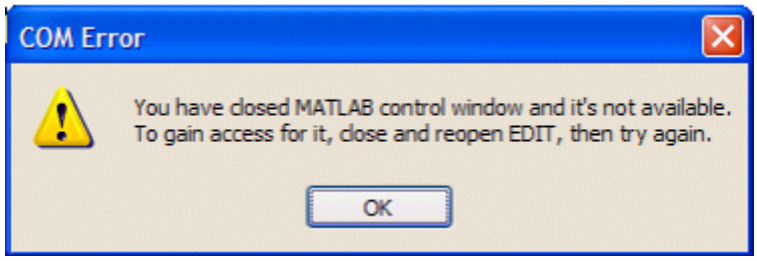
Further suggestions:

1. Activate MATLAB the first time by selecting **Tools->MATLAB...**. The warning displayed in step 4 will appear.

2. This activation of MATLAB needs to be performed once each time you start EDIT.

3. While working with MATLAB from within EDIT, do not close the "MATLAB command window". EDIT will close it automatically after you exit. If you close the

MATLAB command window, then any attempt to export/import data warns:



Perform the steps described above again to reactivate MATLAB. There is no way to reactivate MATLAB until you close and reopen EDIT.

MS Excel - This option is used simply to open the Excel program. For the file transfer function to operate, you must have 1) Excel installed, and 2) a license for Toolbox 2003. To transfer a CNT or AVG file, open the file and right click between electrode displays and then select the Export Data To... option.

You will then see the data in Excel, with a column for each electrode.

Microsoft Excel - Book1

File Edit View Insert Format Tools Data Window Help

L37 -0.0906327813863754

	A	B	C	D	E	F	G
1	FP1	FP2	F3	F4	C3	C4	P3
2	-0.12489	-0.27095	-0.27622	-0.6129	-0.79102	-0.10058	-0.77983
3	-0.07348	-0.24854	-0.29029	-0.58961	-0.7998	-0.14716	-0.81498
4	0.092197	-0.05474	-0.16021	-0.40152	-0.646	-0.02807	-0.68886
5	0.293027	0.196189	0.044578	-0.12115	-0.40298	0.174516	-0.452
6	0.391465	0.350877	0.183445	0.082318	-0.23291	0.304154	-0.25951
7	0.361143	0.35615	0.173338	0.131098	-0.21489	0.294047	-0.21865
8	0.298301	0.322752	0.103465	0.146039	-0.24302	0.246586	-0.23622
9	0.256992	0.301219	0.056004	0.18559	-0.24741	0.236918	-0.23974
10	0.224033	0.294627	0.047215	0.252826	-0.20962	0.270316	-0.21205

Then you can, for example, click the lettered column header to highlight an entire column. Select **Insert**, then **Chart**. Select **line** (without dots on it) as a chart type, and click **Next** twice. Now switch to the Axes tab, and disable **Category (X) axis**. Click **Next** and then **Finish**. You will see the data displayed as a waveform in Excel.

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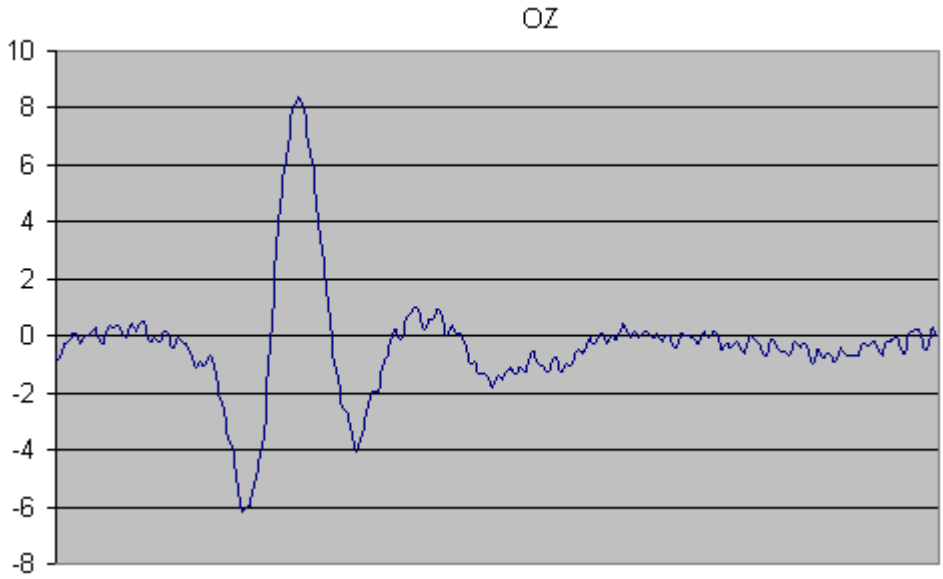


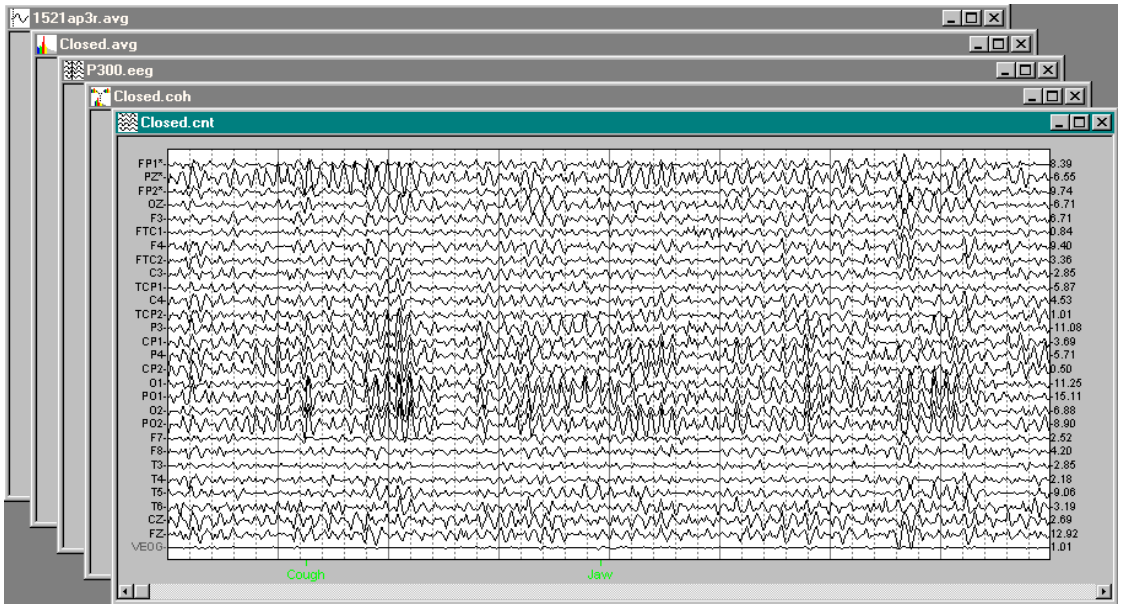
You might then, for example, want to invert the polarity of the file waveform. Right click on the text for the y-axis (a Tootip will display **Value Axis**). Select **Format Axis**, then the **Scale** tab. Enable the **Values in reverse order** option, and click OK. The waveform will be inverted.

Use the full range of options in Excel with the data file. Note that you should not completely close and then reopen Excel in the same session. If you are sending multiple files, leave Excel open while doing so (a limitation of OCX technology).

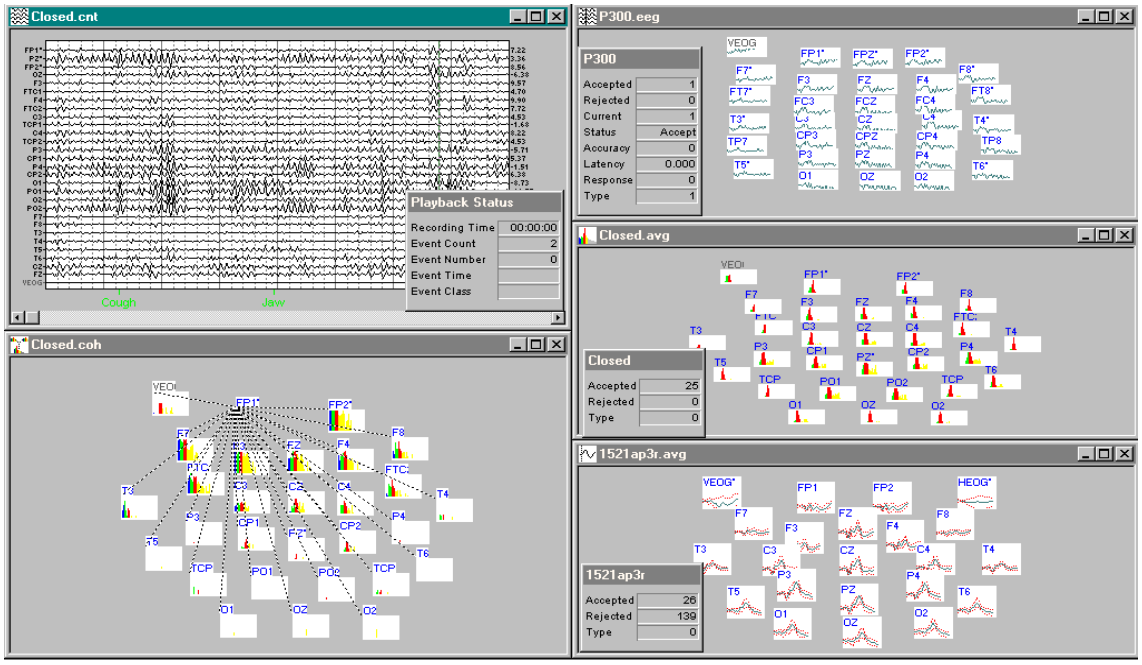
Window

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 windows (e.g., more than 3), however, the Tile Horizontal, or Tile Vertical 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 windows,

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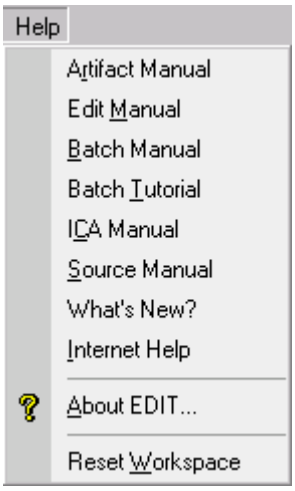
however, the Tile Vertical, or Tile Horizontal option will arrange the window displays in a well-organized fashion, as shown above.

Help

The Help section contains several options: Manual access options, Internet Help, About EDIT and Reset Workspace.



Artifact Manual. This selection accesses the Artifact Rejection routines manual (EKG Reduction and Blink Reduction; described above).

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 to see what page the information is on, and then drag the location rectangle on the right side of the screen. As you drag it, it will display the page number associated with its position in the file.

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.

ICA Manual - This selection accesses the PCA/ICA manual.

Source Manual - Clicking this option will open the SOURCE manual in PDF format (assuming you have the SOURCE software).

What's New - Clicking this option displays the release notes manual, in which the new features of SCAN 4.3 are summarized.

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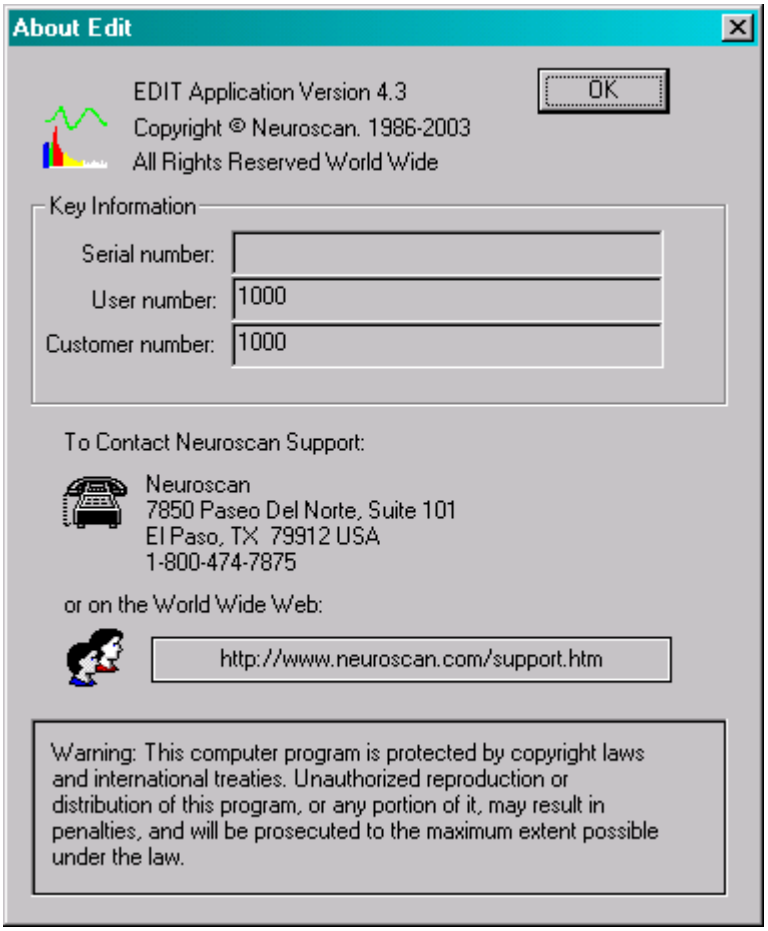
Internet Help - Clicking the Internet Help option will take you directly to the Scan 4 Help section on our web site. From there, you may jump to the Support section, or send an e-mail to the Technical Support department.

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.



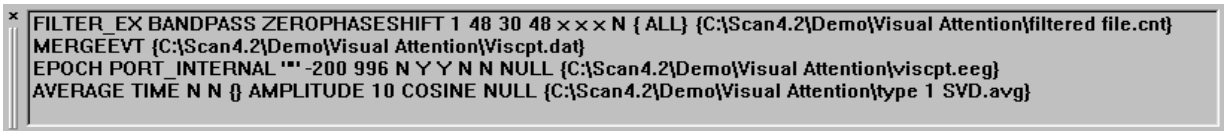
Reset Workspace - This option provides a quick way to restore the workspace file (.aws extension) to its default settings. Corrupted workspace files have been encountered occasionally in the SCAN 4.0 software (mainly in ACQUIRE), and this option provides an easy way to restore the workspace file. If you were not directed to this option by Technical Support, it is advised that you do not use it.

Toolbar Icons

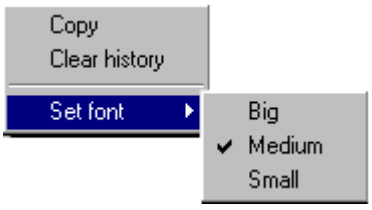
Listed below are all the icons that appear on the Toolbar. Not all functions are available for each type of file (for example, you can not go to the next rejected sweep when you are displaying an average data file). When applying these, make sure that the desired display screen has the "focus".

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&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.



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.



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, 

, to set the number of pages displayed.

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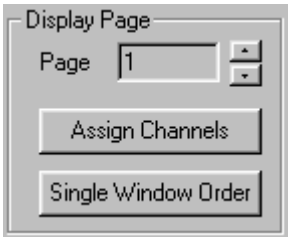
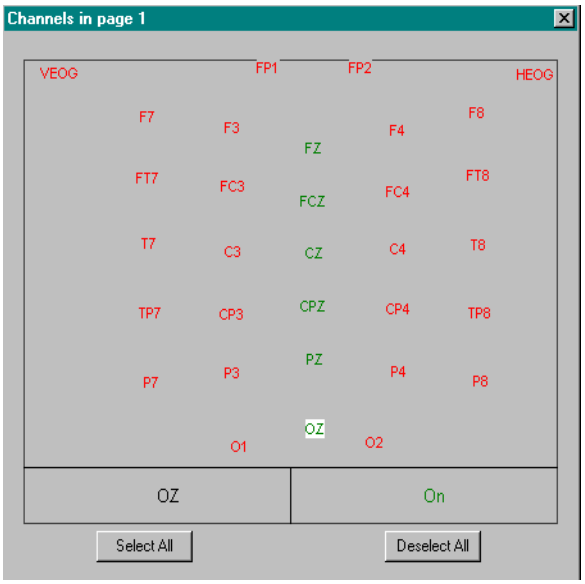
Show Next/Previous Display Page - From the Edit \ Channel Layout window, in either ACQUIRE or EDIT, you have the option to assign electrodes to additional display pages. The icons will be active if you have created additional pages. Use them to step through the Next or Previous pages.

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

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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.

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 

- 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 Windows 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. 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. *Note - to do 2D Mapping with Multiple Windows files you need to first enlarge an electrode to full size to activate the 2D Mapping icon.*

*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 4.3.

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

$$w_i(x,y) = ((x-x_i)^2 + (y-y_i)^2 + a)^{-1}$$

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

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squared law for the force between a pair of electrostatic charges.

Each element of the symmetric matrix **W** is computed as

$$W_{ij} = ((x_i - x_j)^2 + (y_i - y_j)^2 + a)^{-1}$$

where *i* and *j* index electrodes. The inverse of **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 Windows 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. Before we actually place a 2D map on the display, we should examine the options that are accessed with the right mouse button.

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.

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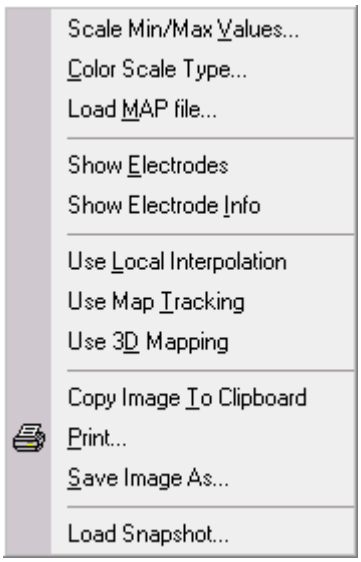
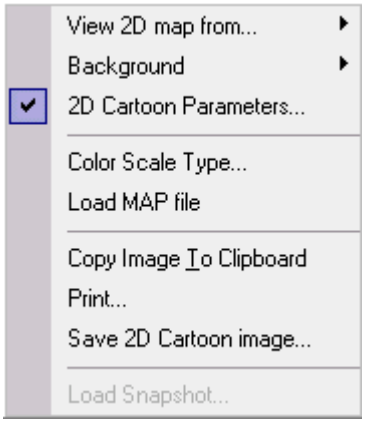
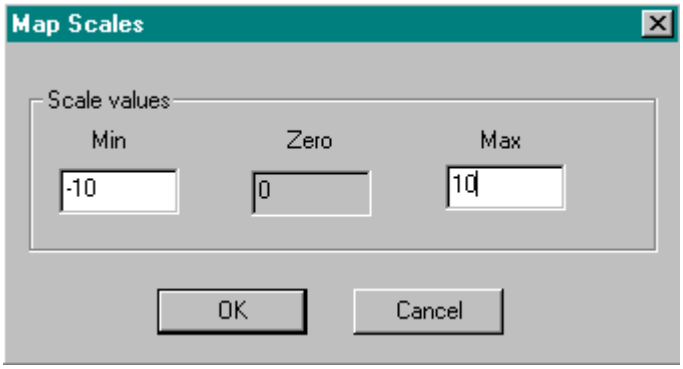




2D map 2D cartoon

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.

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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 access the standard Print screen, and may be used for printing the 2D map directly.

Save Image As... - This option access 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.

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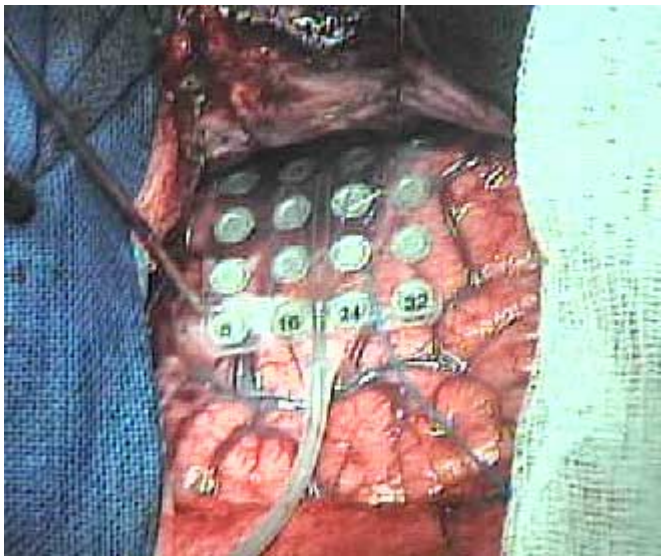
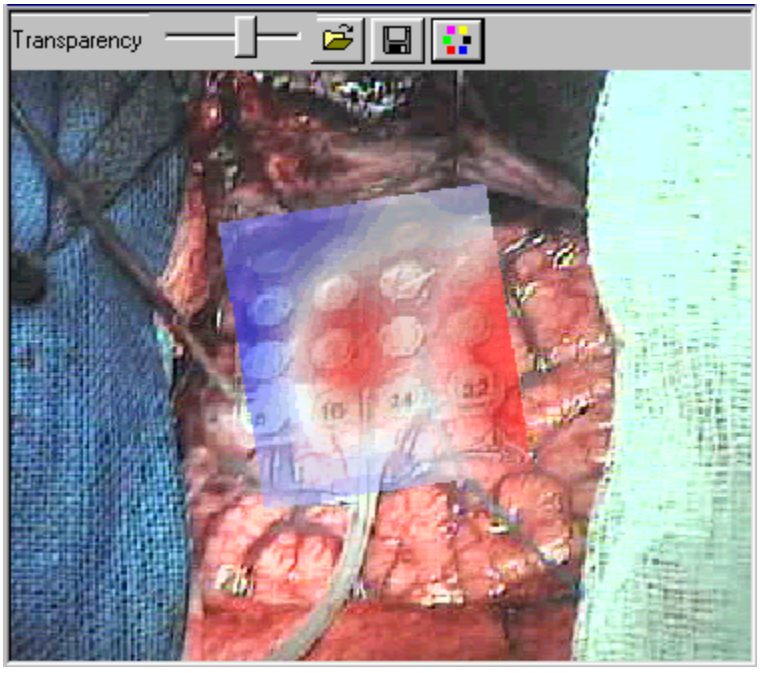


A 2D map can be positioned directly over the grid to show the potential distribution.



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.

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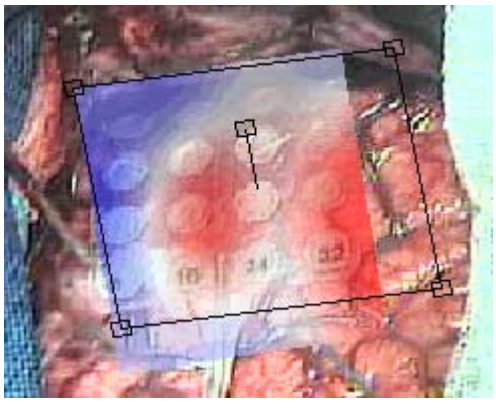
Set up the 2D map display as usual, right click on the map display, and select the Load Snapshot option to load a BMP file. You will see the map superimposed on the BMP, with a control box. Use the control box corners as you would any other



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.

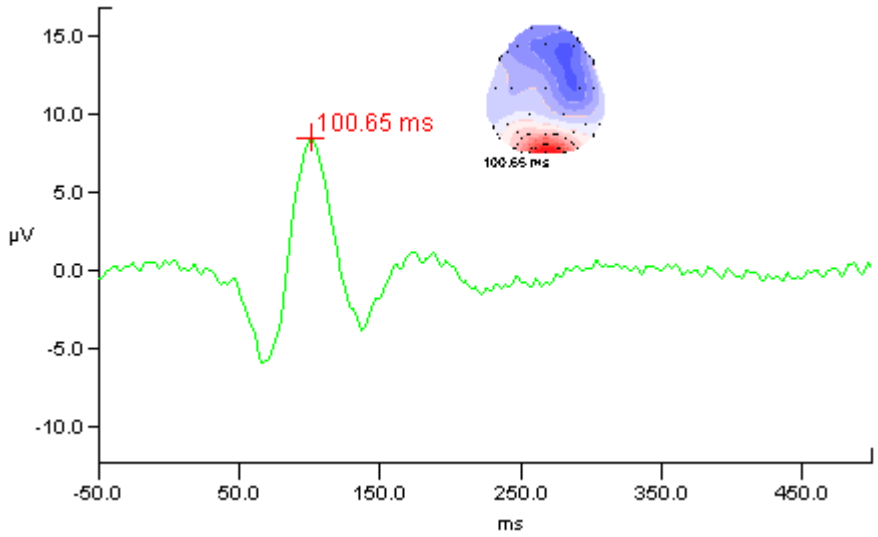
Background - When selected, you have the option to use the Default (black) or Inverted (white) background on the Cartoon display.

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).

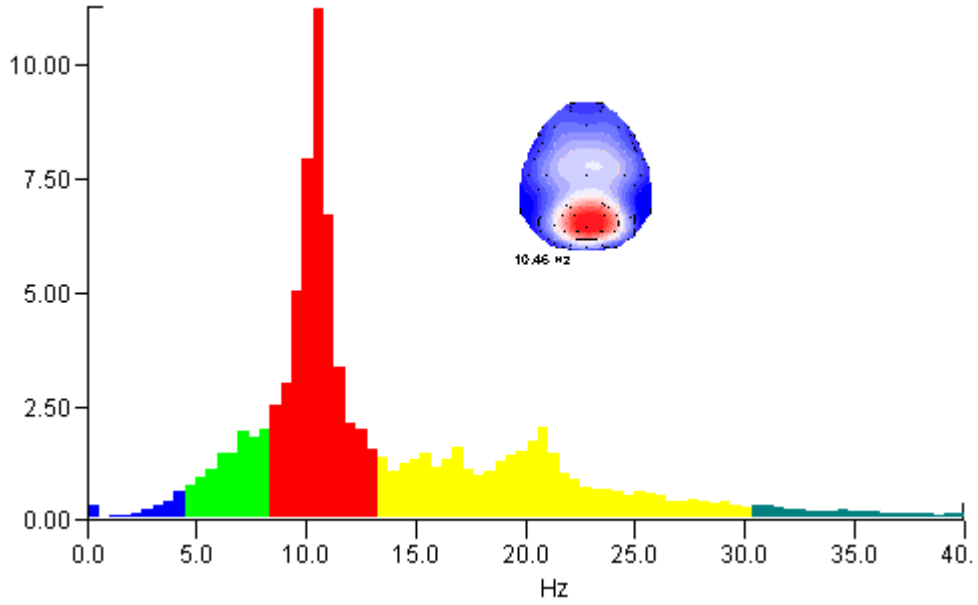
Save 2D Cartoon Image... - This option opens a Save As... utility in which you may enter a file name, designate a path, and Save the cartoon image as a Windows Metafile (the .wmf extension is added automatically).

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.

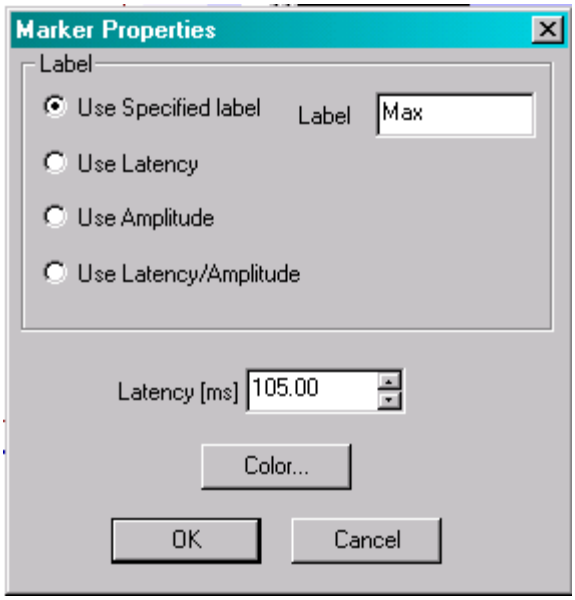


Frequency domain files may be mapped in a similar way.

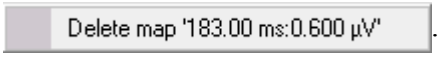


Note that you may reposition the 2D map by grabbing it with the left mouse button, and dragging it to a new location. You may edit the Marker by clicking the right mouse button near the cross-hair marker. You then have the

option to Delete the marker, or Edit the Marker. If you select Edit Marker, 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. Note that the latency of the map you selected is displayed 

. If you have multiple maps displayed, this will make sure you are deleting the correct one.

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).

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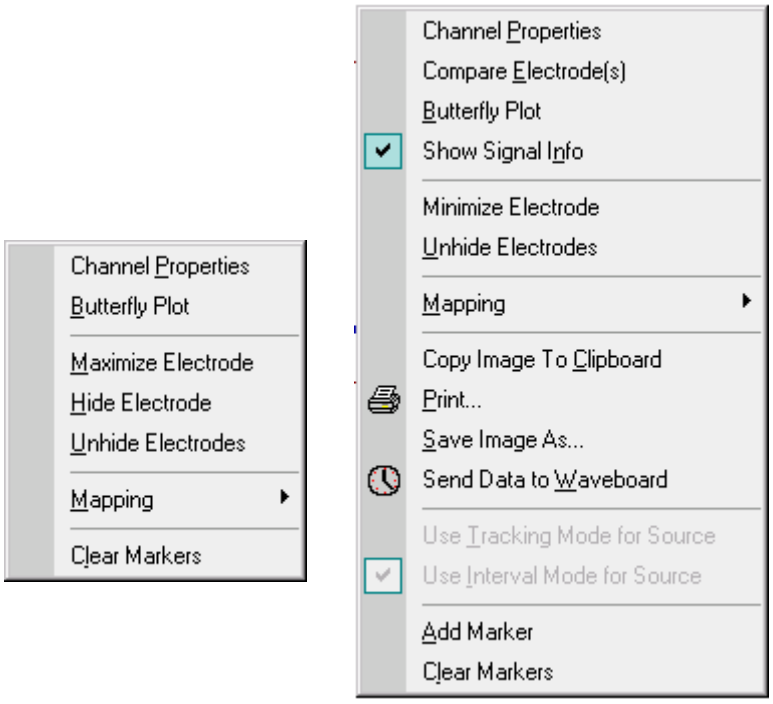
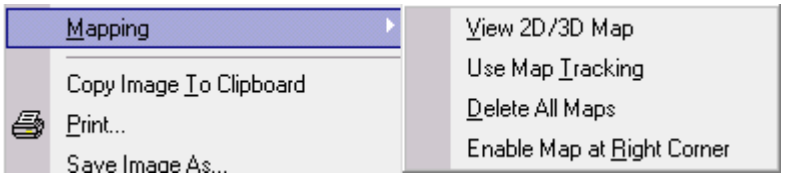


Most of these are explained below in the section called *Right mouse button clicking inside the electrode displays*, but the following are relevant to 2D mapping.

Mapping - This option displays a secondary menu that has the various mapping options.



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.

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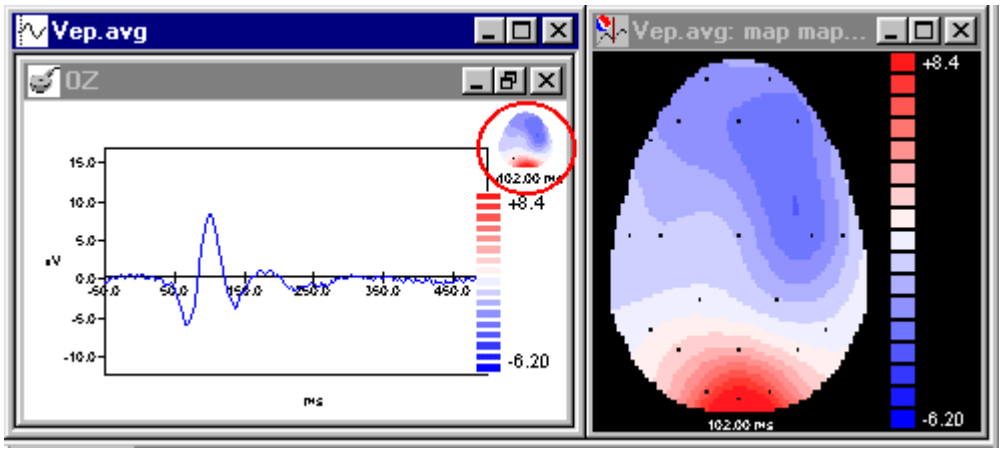
Use Map Tracking - If this option is enabled, then the 2D map will change as you move the mouse in the waveform display. Disabling it will let you select a single point (click a point and it will be mapped).

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.



The display is redundant, since you get the same map in the larger 2D mapping display (on the right), and the smaller 2D map can create confusion when printing a waveform display with multiple maps in it. Uncheck the option to remove the smaller display.

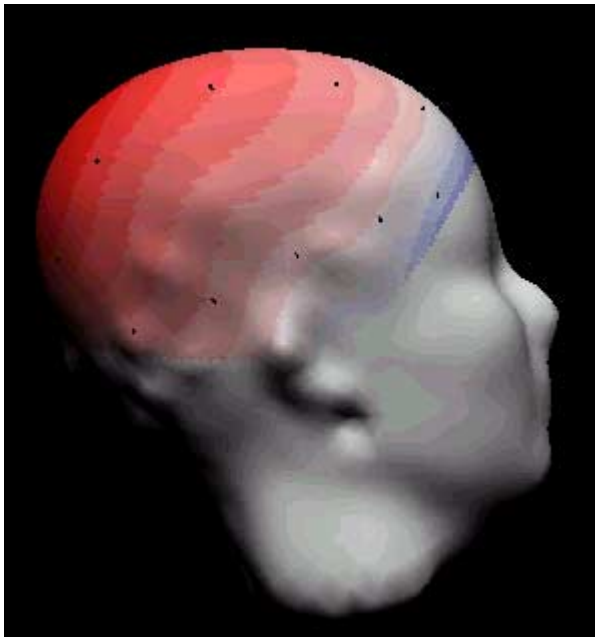
Printing/Saving the map and waveform display - From the same right button menu you have the option to Copy Image to Clipboard, Print the display, or Save Image As... a Windows Metafile. Selecting

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.

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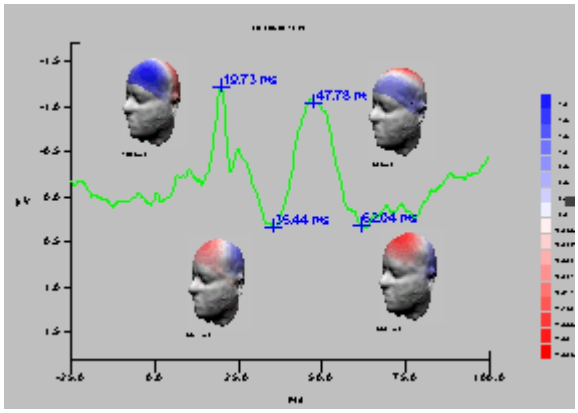
Now, position the cursor in the middle of the display, hold the right mouse button down, and move the cursor up and down. Moving it up makes the head shape smaller; moving it down makes it larger. To spin the head, hold the left mouse button down, and move the cursor rapidly across the display, releasing 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 the Copy Image to Clipboard option to save the 3D maps, and then paste them on the waveform display in, for example, a Word document. This process can be used to create a final graphic which combines 3D maps and the waveform, as follows.



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.

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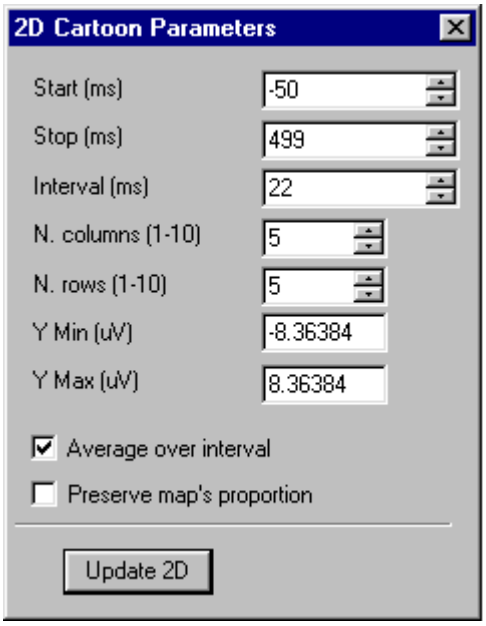
The first is the Cartoon Parameters display. The fields are explained below:



Start/Stop (ms) - The Start and Stop fields are used to specify the beginning and ending time points for the section of the epoch to be cartooned.

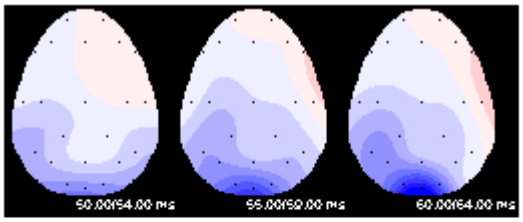
Interval - Interval is the averaging interval. Maps will be created every X ms, based upon the average of the data points within that interval. The interval value must be a multiple of the "dwell" time (the total number of ms divided by the number of points). For example, an epoch from 0 to 1000ms, with 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).

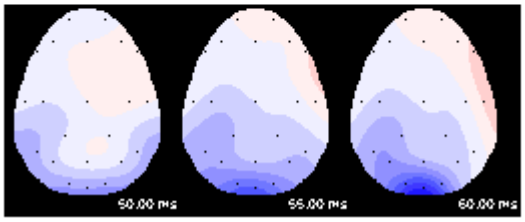
N columns (1-10) and N rows (1-10) - These two fields allow you to set the maximum number of maps per row and per column to be displayed in the 2D Cartoon display. Up to 100 maps may therefore be presented. The values that you enter here will supercede the Stop point entered above. For example, if you 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 (uV) and Y Max (uV) - 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).

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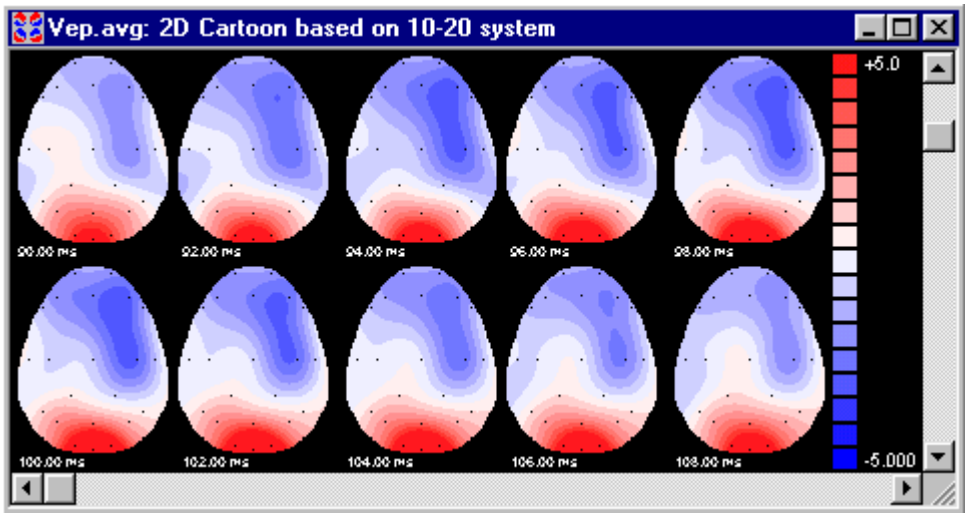
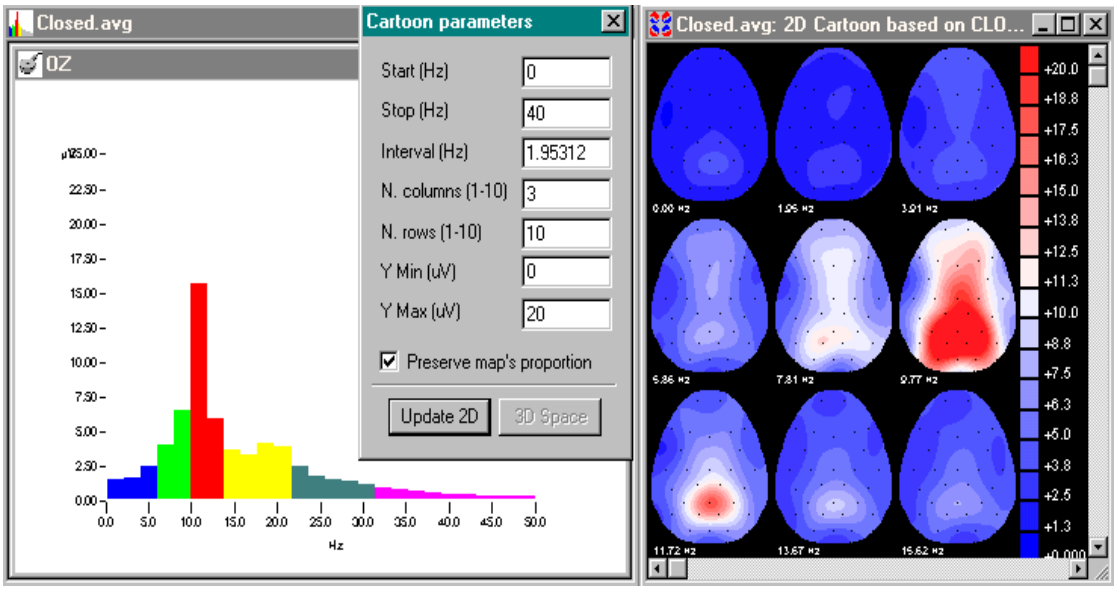


Frequency domain files may be mapped in a similar way. Retrieve a frequency domain file, enlarge one electrode display to full size, then click the 2D Cartoon icon. Set the parameters as desired, and click the Update 2D button. Below are results from the closed.avg file, with maximum power in the alpha frequency range.



Right mouse button options in cartooning - Additional options may be accessed by clicking the right mouse button within the 2D Cartoon window.

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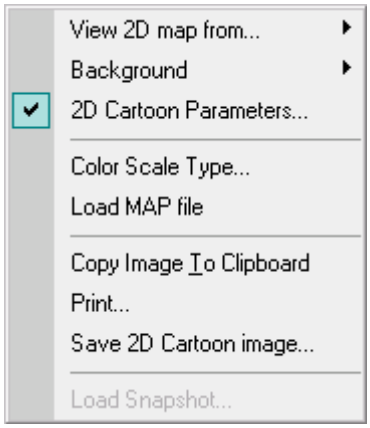


View 2D Map From... - When selected, this option allows you to select views from the Top, Right or Left sides. In the EDIT program there is an internal default mapping template containing 77 electrodes with top, left and right views. If your data file uses a subset of these electrodes, the program will 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.

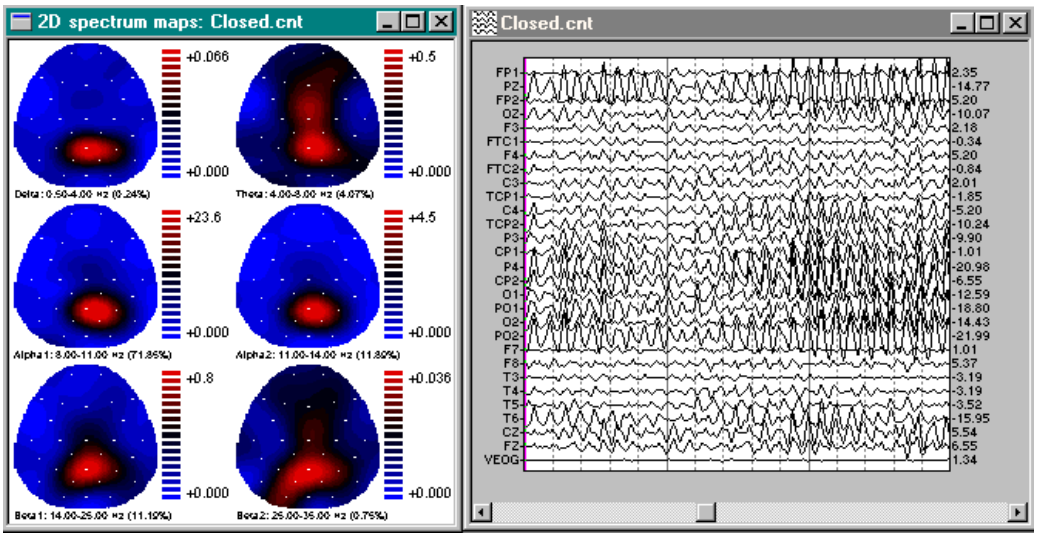
Print - The Print option accesses the standard Print screen, as described above under Files.

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. With an AVG file, you must enlarge an electrode to full size to activate the Spectrum Mapping icon.

Right mouse button options with spectrum mapping - If you click on the spectrum maps with the right mouse button, you will see the following screen.

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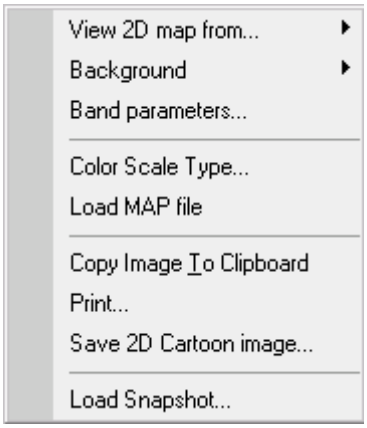
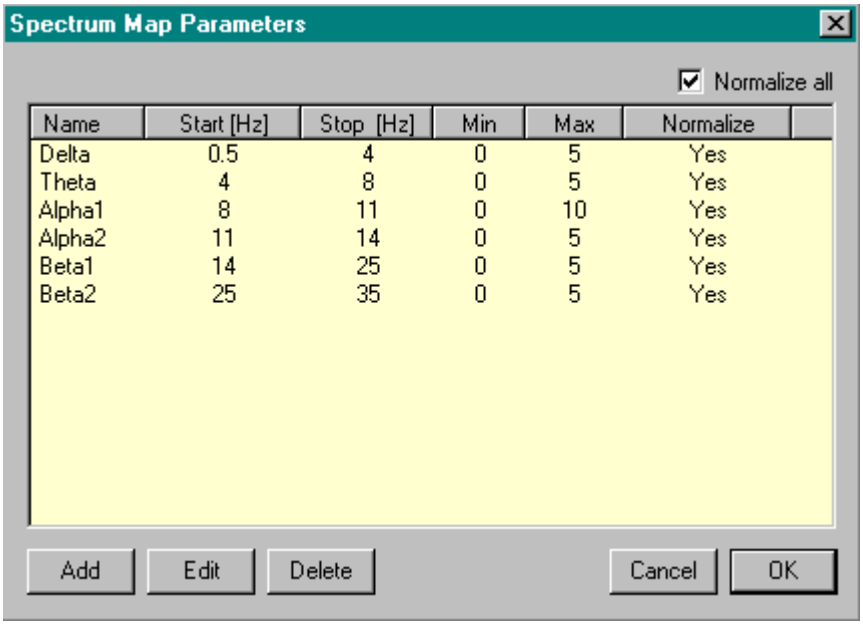


With the exception of Band Parameters, these options are discussed above.

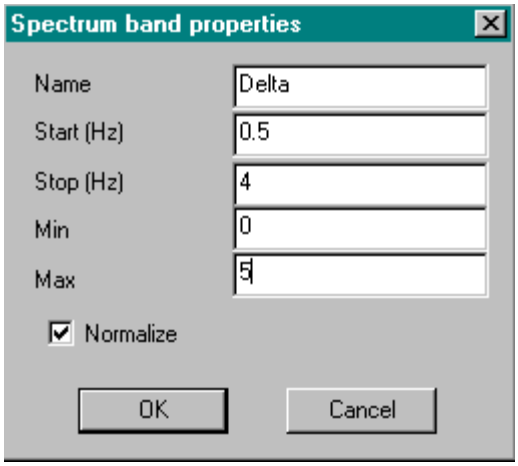
Band parameters... - The Band Parameters screen lets you select frequency ranges for the maps, their labels, scale settings, etc. Selecting the options will display the following screen.



For each frequency band, you see the name, the Start and Stop limits (in Hz), the Min and Max display limits (in uVs), 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.

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 manual in an Appendix below 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 an Appendix at the end of this manual.

Launch SOURCE program. This icon will only be accessible if you have purchased the additional SOURCE plug-in program. If so, please refer to the SOURCE manual for operational details.

Launch PCA/ICA program. PCA/ICA is an additional plug-in program that allows you to perform Principle and Independent Component Analyses. It can be used online in AC-

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QUIRE or offline in EDIT. Please refer to the PCA/ICA manual for operating instructions. The plug-in is installed from the SCAN 4.3 CD; however to access it you need to reprogram your dongle (software lock). You have to be under warranty or a maintenance contract to receive the code to reprogram your dongle. If you are interested in finding out more about PCA/ICA, please see our website (www.neuro.com), or contact techsup@neuro.com.

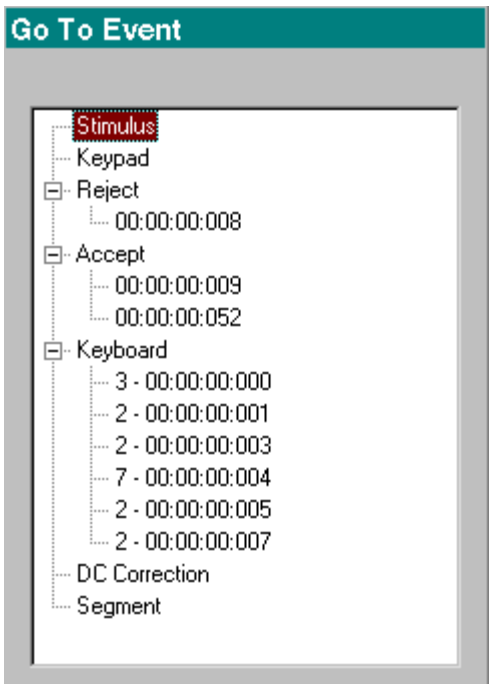
Print  - This option opens the standard Print utility screen (refer to the Print section under Files for more details).

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).

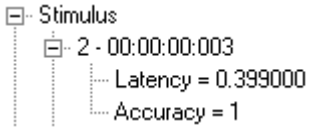
Scan Control Buttons  - These buttons are used for the automatic replay, or scanning, of a continuous or epoched file. The outer buttons will start the scanning either forward or backward through the file. (The combination keystrokes of CTRL + right arrow or CTRL + left arrow, on the keyboard, perform the same function). The middle button will stop the scan. The speed of the scan is controlled with the Speed Scan Interval, under the Options 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.

Goto 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, f 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

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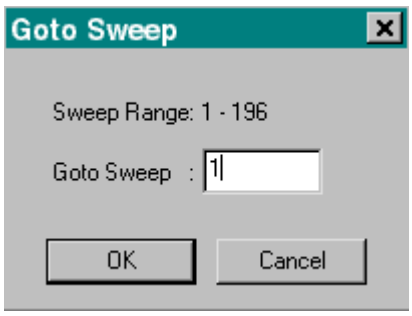
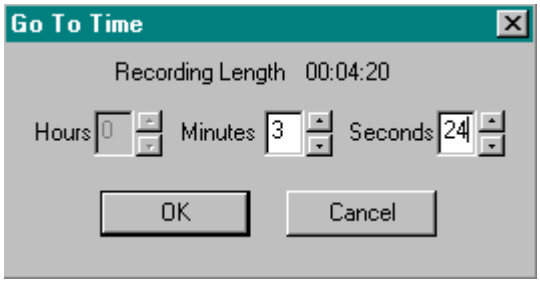


displayed, and you may enter the number of the desired sweep in the field. Then click OK to go directly to that sweep.

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

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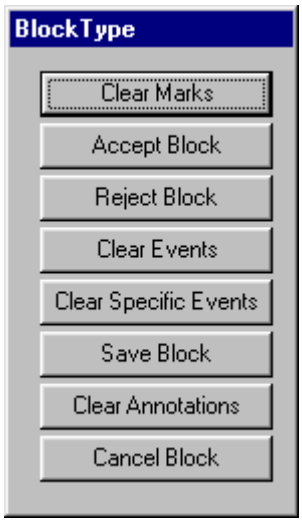
recording. Once marked, it can be rejected, accepted, saved, and so forth. After retrieving the CNT file, click the Mark Block icon. Position the mouse at the beginning of the section of interest in the CNT file, and click the left mouse button once. Then position the mouse at the end of the section 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

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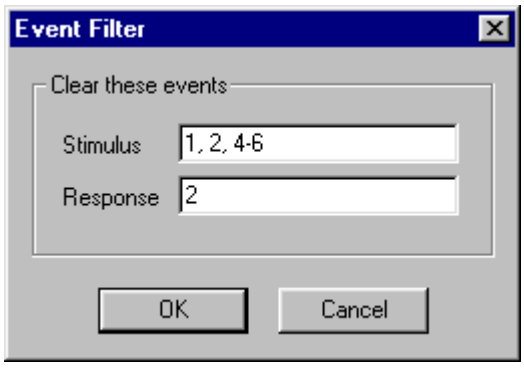
a block of data, and select the Clear Specific Events option. The following dialog box will appear.

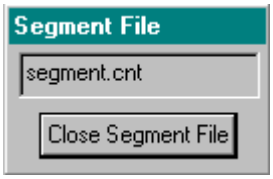


Enter the stimulus and/or response type codes to be removed, and click OK, then Clear Events. The type codes will be removed within the designated block.

Save Block - This option is used to save a designated block(s) of continuous data to a new CNT file. Related to its operation is the *Close segment file* command under 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.



4. 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.

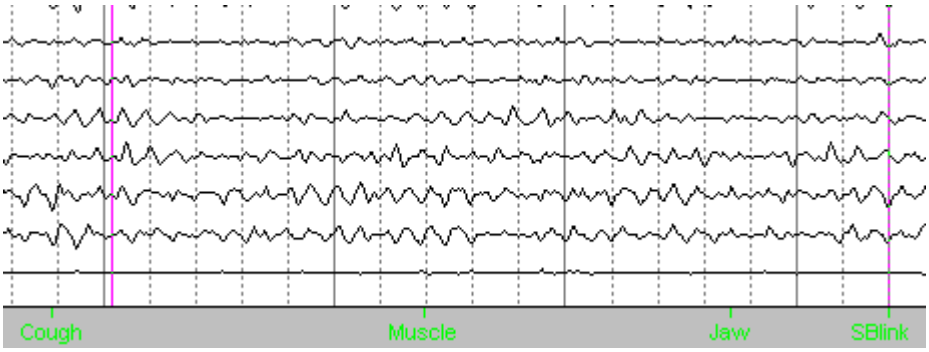
5. When you are finished, click the Close Segment File option to close the new CNT file. Alternatively, you may close the original CNT file and that will close the new CNT file as well. To retrieve the new "segment" CNT file, you must first close it using either method.

6. 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.

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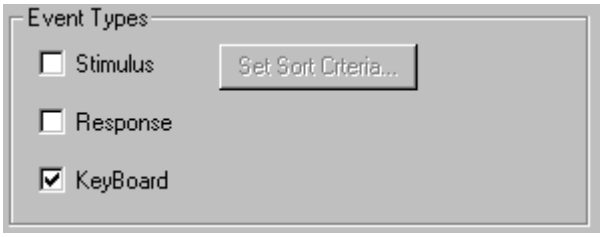
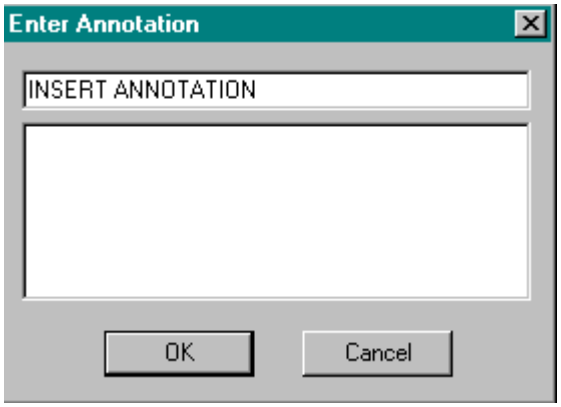
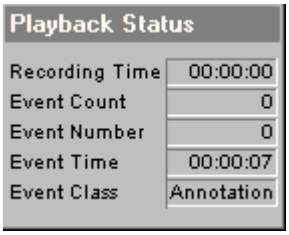


Of course, you can select Stimulus, Response and Keyboard events at the same time, if you wish. The type codes that are used correspond to the function keys in the following way. The F1 function key is reserved by Windows for calling Help files, and the type codes begin with a code of 0. Therefore, F2 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. If you are looking at a Multiple Windows display (EEG or AVG file types), you will need to enlarge an electrode display to full size before the icon becomes active. After clicking the icon, position the mouse at the initial point for the peak measurement, and click the left mouse button one time. When you now move the mouse cursor around the display screen, you will see the change in amplitude displayed in either a small window 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 amplitude between the initial and the current mouse positions.

Some right mouse button options. 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.

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.

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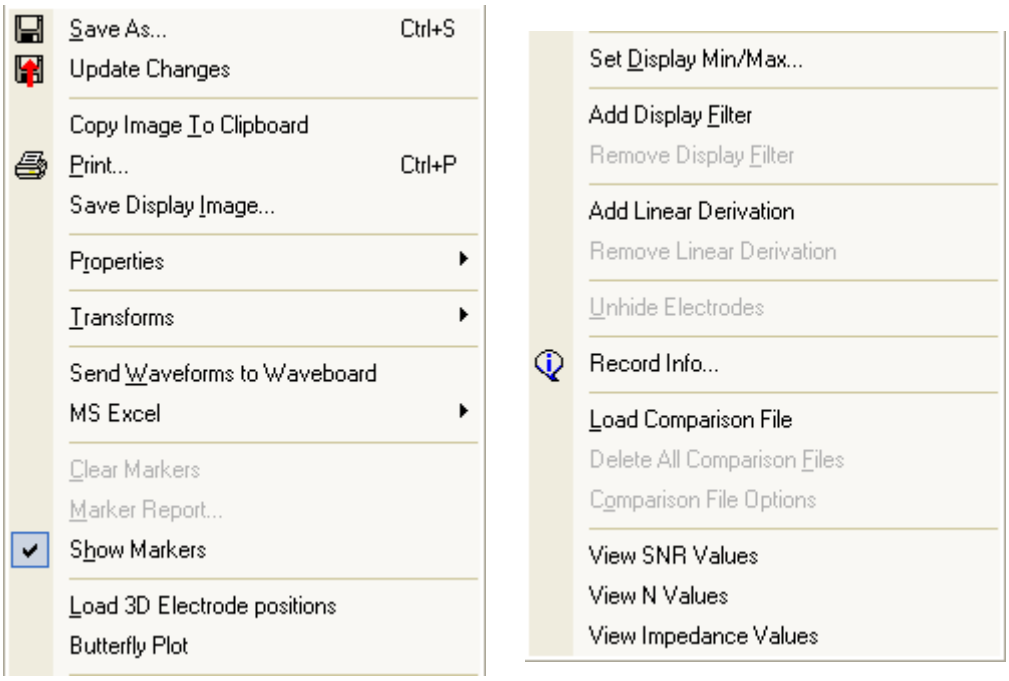
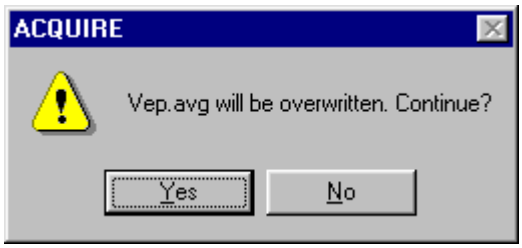


Save As... - Selecting this option allows you to save the file as a new data file. A Save As... display will appear in which you may enter the new file name and path designation.

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. 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 Windows 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, Triggers 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 (see the more complete description under List Open Files above).
>
> *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 and AVG files to Excel. It assumes you have Excel installed and that you have a licence for Toolbox 2003. 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.

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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.

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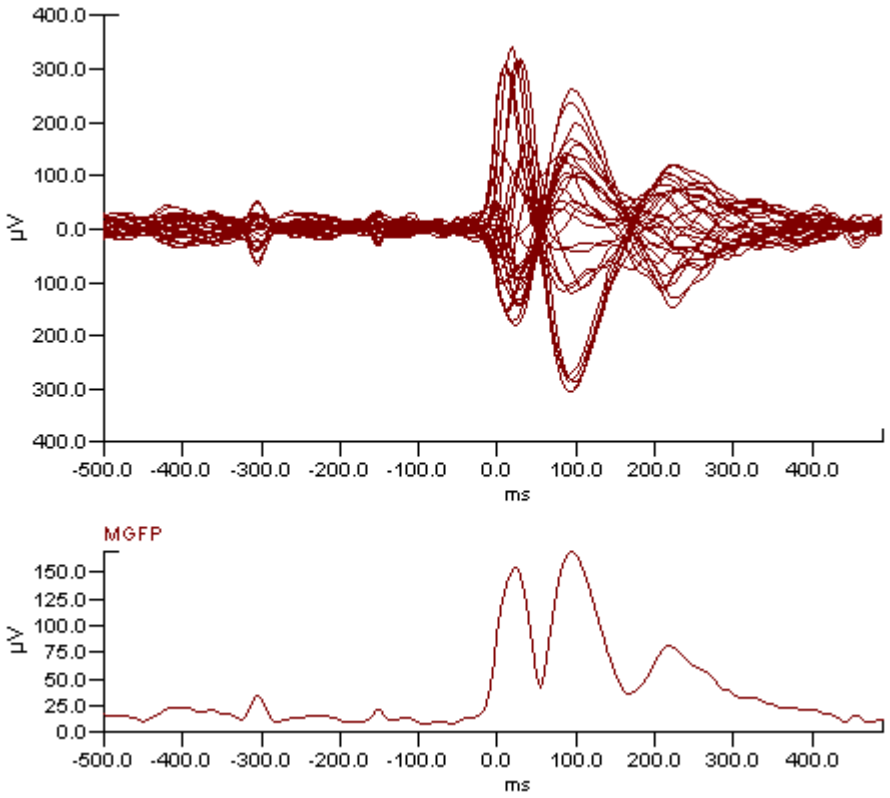
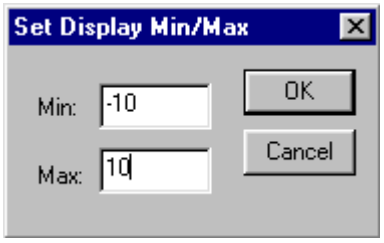


Deselect the option (or just close the window) to return to the original display.

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.

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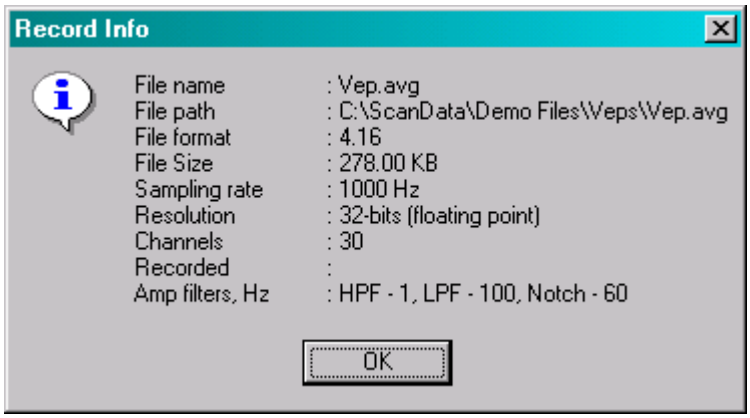
Add Linear Derivation / Remove Linear Derivation - The Add Linear Derivation option lets you select and apply an LDR file to the displayed data. Click the Remove Linear Derivation option to remove the derived changes.

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, COH) - 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.

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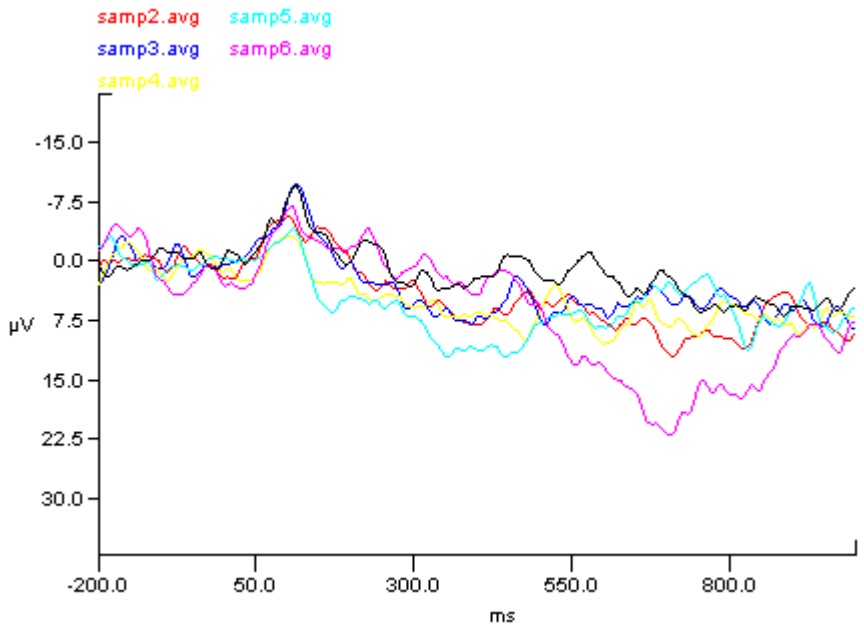
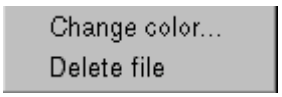


Right mouse button options - If you click on one of the electrode labels at the top with the right mouse button, you will see the following list of options.



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, COH) - 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.

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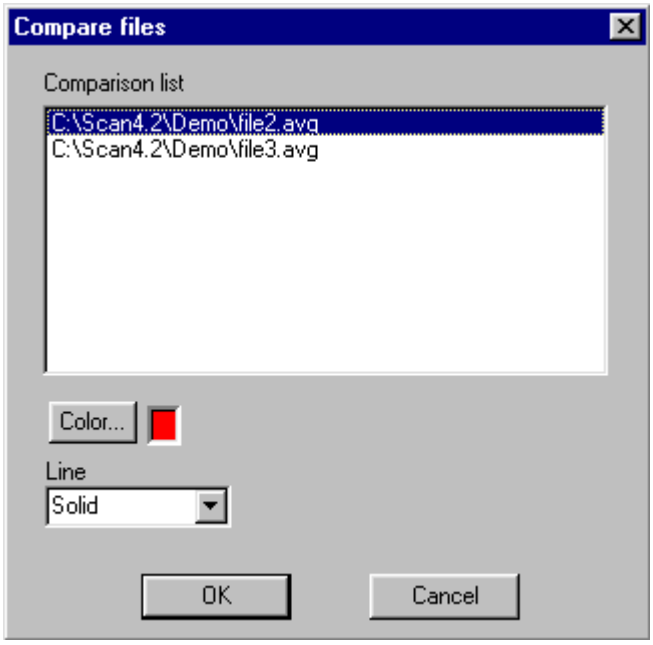


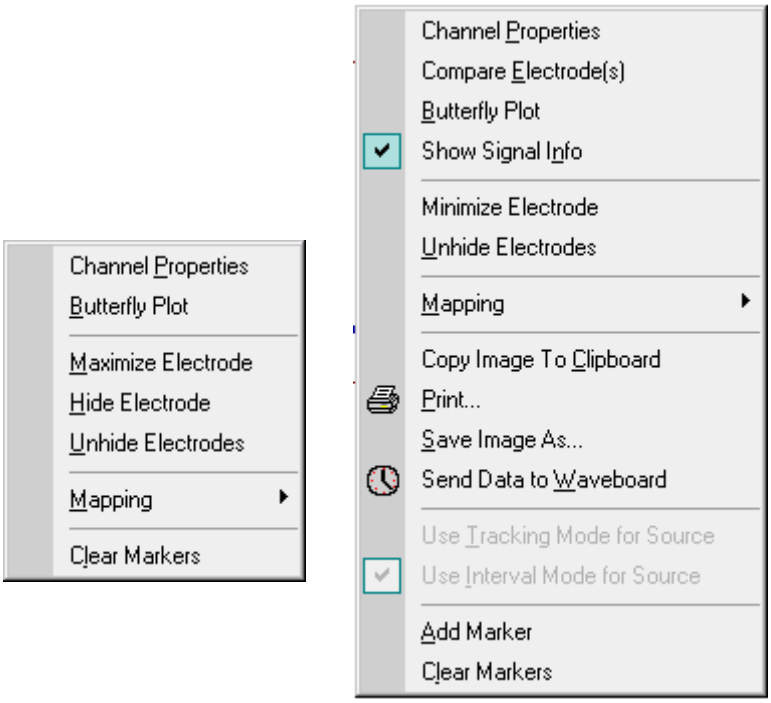
The Comparison list will show all the comparison files you have selected. Highlight one, then select the Color and Line style for that file. Then highlight the next file and make any modifications, and so on. The new styles will be seen when you enlarge one of the electrode displays.

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.

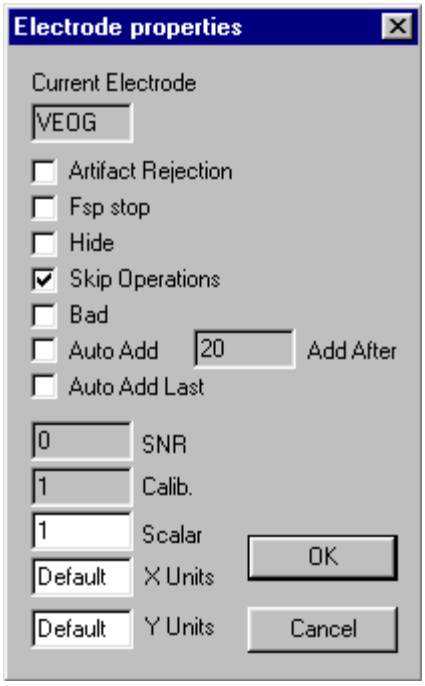
View Impedance Values - The last impedance values that are present when you are running the impedance routine are saved with the data file. Right click between electrode displays and select the View Impedance Values option to see the saved values. You then have the option to save the values to an ASCII file, if desired.

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.



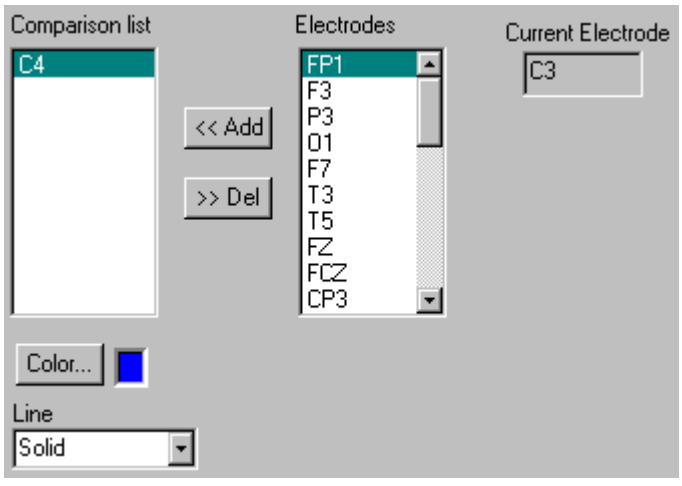
The first list of options above appears when click inside a *minimized* electrode display. All of these are also present when you click inside a maximized display, except for the Hide Electrode and Maximize Electrode options. Additional options are possible after the display is *maximized* (the second list above). 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



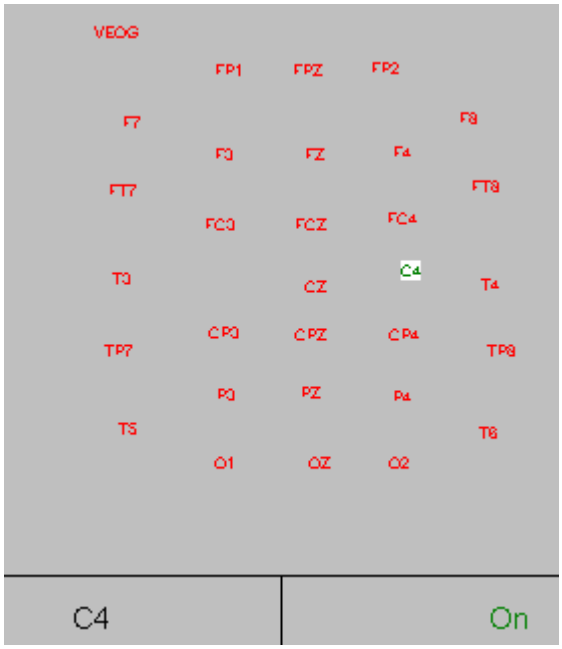
seen in ACQUIRE (under *Edit*). With CNT files, the Electrode Properties display is accessed by clicking on the desired electrode name (from the column of labels on the left side of the display). You may modify the settings as desired.

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).

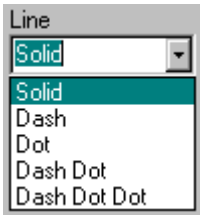


The Current Electrode is displayed in the top left field. The additional electrodes are list in the Electrodes column, and shown in the montage on the right side of the display. Highlight the C4 electrode from the list and click the 

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 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 superimposed on the original one.

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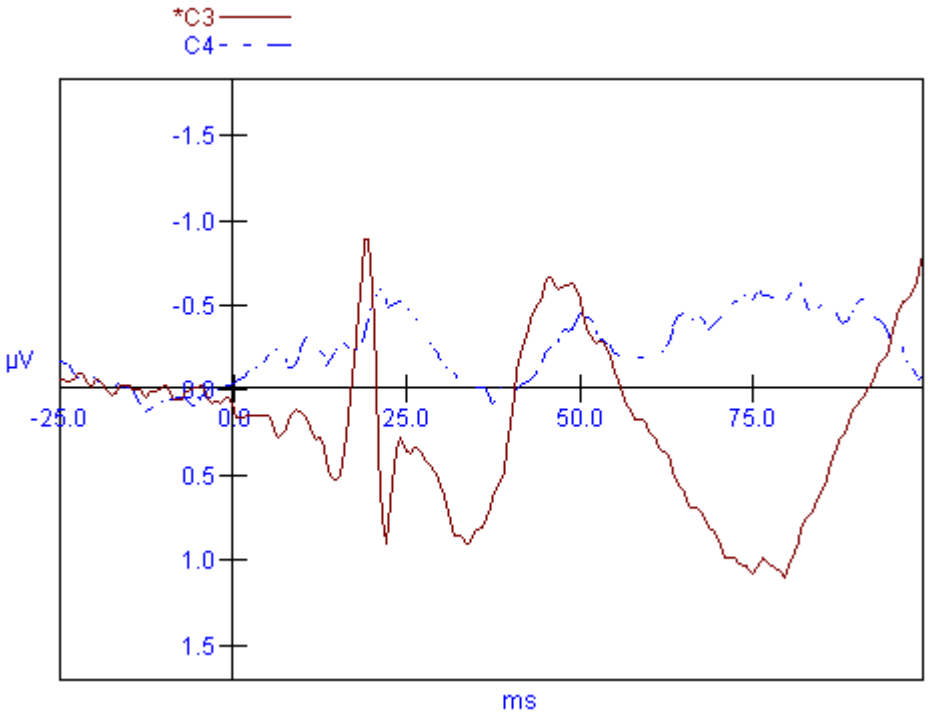
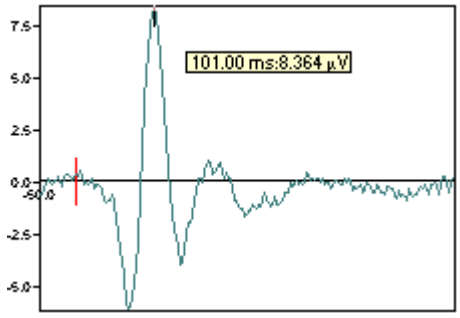


You can removed selected electrodes from the Comparison list by highlighting them and clicking the >> Del button.

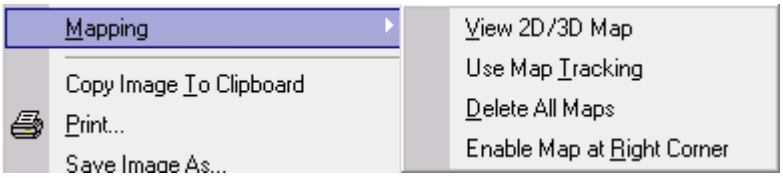
Butterfly Plot (AVG, EEG) - This is the same option as described above under *Right mouse button clicking between the electrode displays*.

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.

Mapping - This option displays a secondary menu that has the various mapping options.



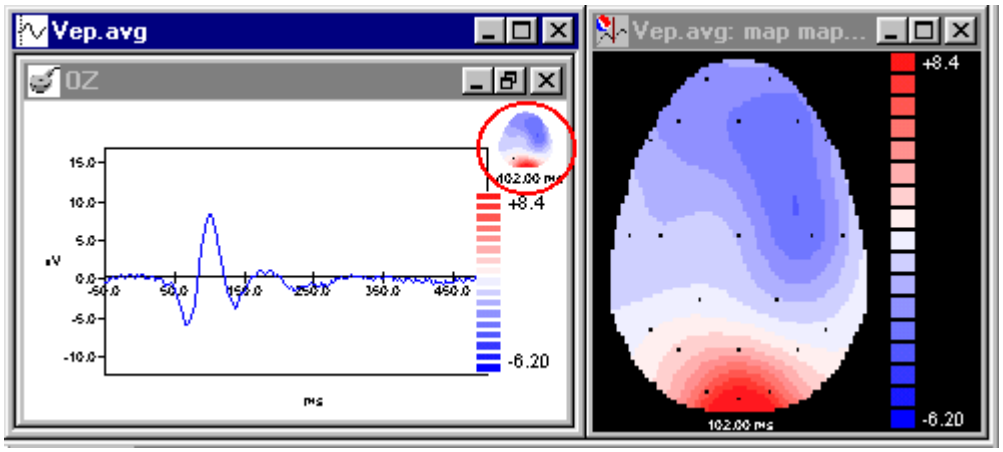
View 2D/3D Map (EEG, AVG) - This option will be active when you enlarge an electrode display to mid- or full-size. You may enable or disable 2D Mapping from this line. It may be accessed more easily from the Toolbar icon  . Refer to the 2D Mapping section above for mapping details.

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.



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The display is redundant, since you get the same map in the larger 2D mapping display (on the right), and the smaller 2D map can create confusion when printing a waveform display with multiple maps in it. Uncheck the option to remove the smaller 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 (97) 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.

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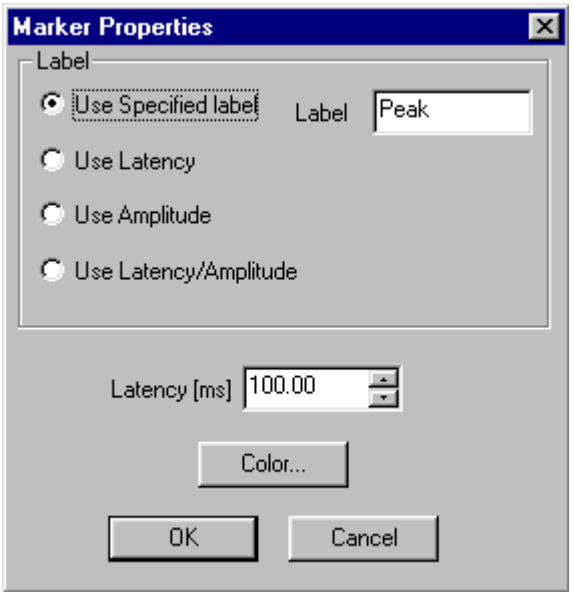

The Mark will appear in the display. Using the left mouse button, grab the cross hair that appears at the beginning of the Mark, and drag it to the desired location.

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.

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.

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.

Add Derivation - Add Derivation allows you to apply an LDR transform to the

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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 

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.

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 

button on the Channel Layout display). Clicking it displays the following screen.

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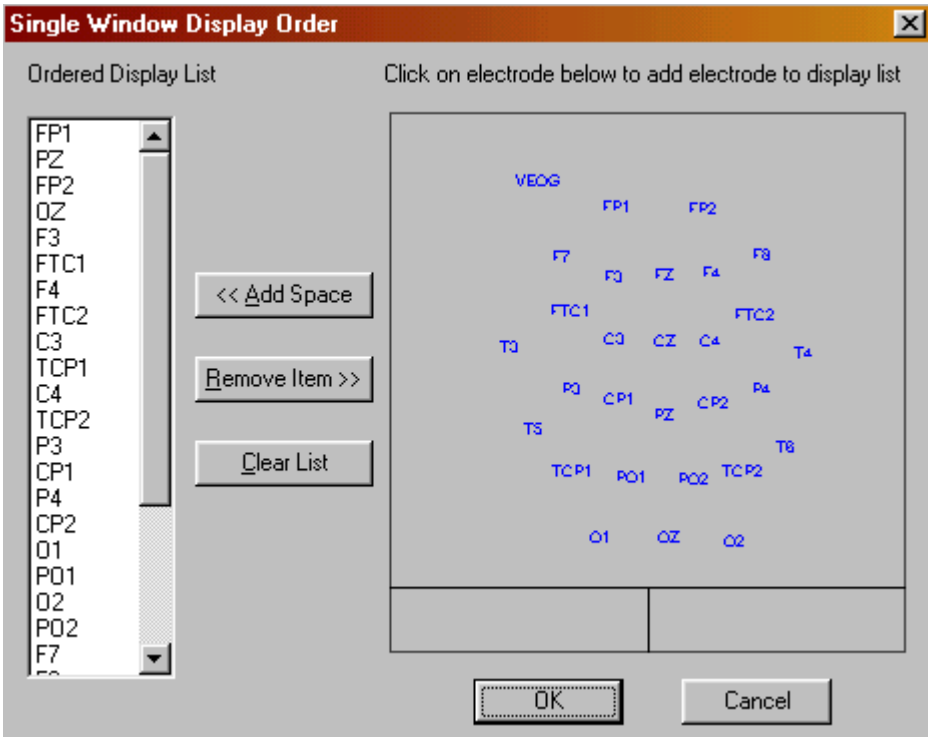

The current order of channels is in the left side column. To remove a channel from the list, just highlight it and click the Remove Item >> button. *Note: this removes the channel from the list, not from the display. There will always be the same number of channels displayed; this option will only alter 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 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.

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

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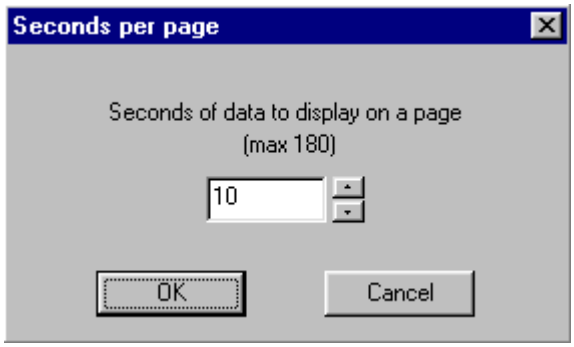
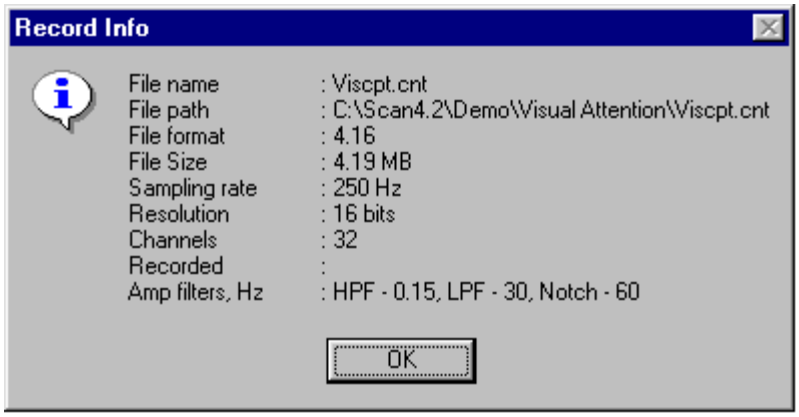
icons on the Toolbar to change the number of seconds displayed per page. Click it to see the "Seconds per page" dialog box, in which you may enter the number of seconds you want to be displayed (up to 180 seconds).



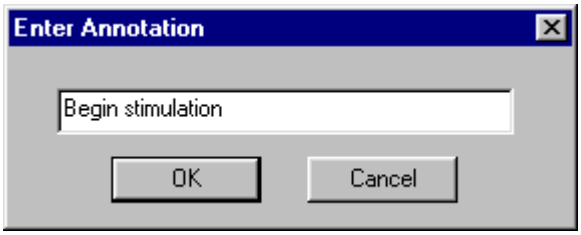
Record Info - Clicking this option displays information about the CNT data file.



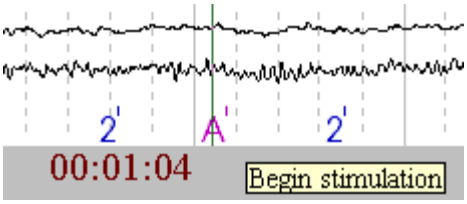
Click-dragging with the right mouse button in a Single Window Display - If you click the right mouse button on a CNT file, hold it, then drag and release it, you will see the following option list.

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.



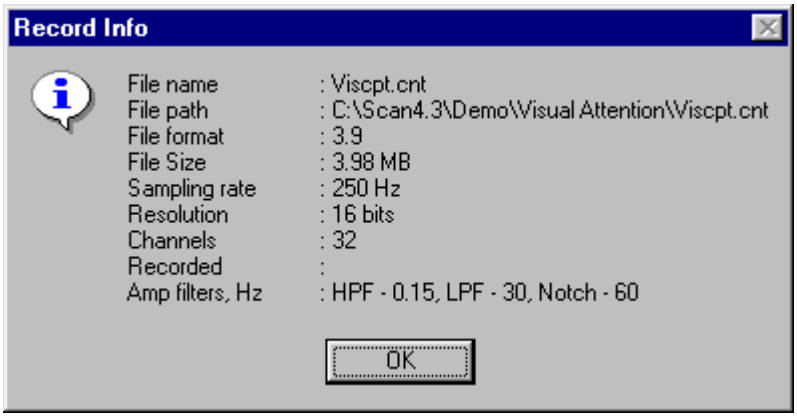
Accept Block / Reject Block. You can use this method to mark or unmark blocks of data in the CNT file. The other method is to use the Mark Block icon from the Toolbar. Marked blocks will be omitted during epoching (unless you deselect the Reject Epochs that Overlap rejected Blocks option in the Epoching 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.

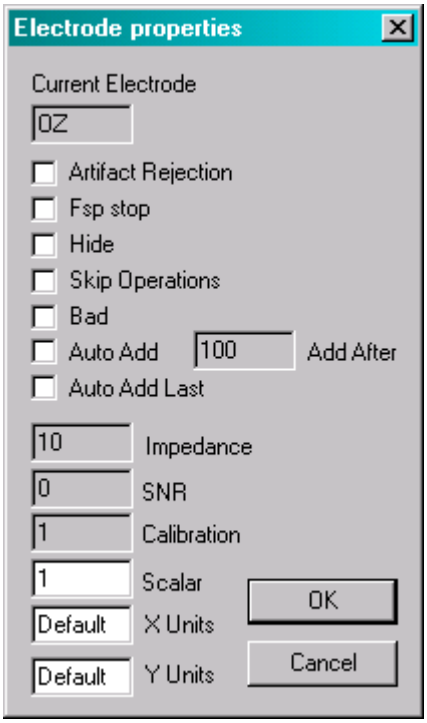
Map as 2D Cartoon. Delineate a block of data, select this option, and you will see that block of data mapped with a 2D cartoon (see the 2D cartooning description for details).

Record Info.... Clicking this option will display information about the CNT file.

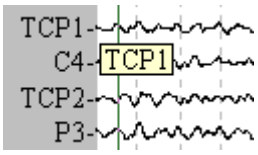


The remaining options - Copy, Print, Save, etc. - have been described elsewhere, and are largely self-explanatory.

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.



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This concludes the EDIT manual. Please see the following Appendices for descriptions of the Waveboard , the Montage Editor, and new Header information.