Net Station Viewer and Waveform Tools
Tutorial

Net Station Viewer
and Waveform Tools

Tutorial

EGI

dense-array EEG

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Net Station Viewer and Waveform Tools Tutorial | S-MAN-200-TVWR-001 • December 21, 2006

PREFACE

N et Station from Electrical Geodesics, Inc. (EGI) is a complete software package for working with electroencephalography (EEG) and event-related potential (ERP) data. With Net Station, you can:

- acquire EEG, in conjunction with EGI's Net Amps and Neurotravel amplifiers, and dense-array Geodesic Sensor Nets

- perform various operations on your data, primarily for basic ERP derivation and analysis

- view and navigate EEG and ERP data

Note: Net Station does not support Unicode string.

This publication, the *Net Station Viewer and Waveform Tools Tutorial*, instructs you in the use of Net Station Viewer and Waveform Tools by guiding you through the analysis of a sample data set. It is not intended to be a comprehensive guide to these components, but it is a good place to start when learning about the software.

The Net Station Acquisition is the component of Net Station for acquiring EEG, in conjunction with the dense-array Geodesic Sensor Nets. The *Net Station Acquisition Technical Manual* describes Acquisition features and functions.

The Net Station Viewer is the component of Net Station for viewing and navigating EEG and ERP data. The *Net Station Viewer Technical Manual* describes Viewer features and functions.

The Net Station Waveform Tools is the component of Net Station for performing various operations on EEG data, primarily for basic ERP derivation and analysis. The *Net Station Waveform Tools Technical Manual* describes Waveform Tools features and functions.

The *Net Station File Formats Technical Manual* documents the objects contained in a native Net Station file, the formats of the export files, and other files associated with Net Station.

The Geodesic Sensor Net is EGI's patented device for acquiring electrical signals from the human scalp. The *Geodesic Sensor Net Technical Manual* describes all GSN features and functions.

GES hardware is all the system hardware except for the GSN. GES hardware supports the acquisition and processing of EEG data and includes an amplifier, a data-acquisition computer, a monitor, and, in most cases, a cart or travel case. The *GES Hardware Technical Manual* provides comprehensive descriptions of all GES hardware components and features.

(PDF versions of these publications and other EGI documentation are at www.egi.com/documentation.html.)

These publications contain a good deal of background information on the EEG and ERP field. However, they are not intended to represent a complete primer in this field. To get the most out of these books, you should have some background in EEG and ERP methods.

These manuals assume you are familiar with the Macintosh computer, the platform for Net Station software.

About This Tutorial

The purpose of this tutorial is to instruct you in the use of Net Station Viewer and Waveform Tools. These are the components of Net Station for working with existing EEG and ERP data, as opposed to those components for acquiring EEG data.

Net Station Viewer consists of the feature set you use for viewing and navigating EEG and ERP data. Net Station Waveform Tools consists of the tools you use for performing operations on your data, primarily for ERP derivation.

Note: This tutorial does not cover some of the advanced Waveform Tools and Viewer options, such as Markup from File, Ocular Artifact Removal, Short Epoch Filtering, t-test, Wavelet, Spectral Display, and video EEG. These tools represent operations that are not part of the core data-analysis path used to derive ERPs.

This tutorial is not intended to be a comprehensive guide to these components. Instead, the aim is to familiarize you with them by guiding you through the analysis of a sample data set.

Features

This manual is supplied as a PDF file and in printed form. The hard-copy version has been printed from the PDF so the content of both will match. The printed manual contains mostly grayscale images; the PDF contains color and grayscale images.

Tutorial Organization

This tutorial features a table of contents, list of figures, list of tables, and index, which in the PDF are all hyperlinked to the topics they reference in the publication.

The tutorial consists of four sections:

- Introduction
- Exploring Unprocessed Continuous Data
- Deriving ERPs
- Exploring ERPs

Each section contains chapters that elaborate on the section topic.

- Section I, "Introduction," describes the tutorial, introduces the tutorial data set, and discusses some important terms and concepts.

- Section II, "Exploring Unprocessed Continuous Data," describes how to use Net Station Viewer for exploring your data before the ERP derivation process.

- Section III, "Deriving ERPs," describes how to use Net Station Waveform Tools for the operations involved in deriving ERPs. It also shows you how to use Net Station Viewer to examine the results of each operation.

- Section IV, "Exploring ERPs," describes how to use Net Station Viewer and Waveform Tools for exploring ERPs once they have been derived.

Conventions and Typography

In this tutorial:

- A minimal amount of special fonts are used—*italics* for definitions or newly introduced terms, ***boldface italics*** for important concepts, and **boldface** for command paths (e.g., **File > Save**).

Additional Information

Two different methods are used to convey additional information: notes and cautions.

Note: This indicates information that is helpful in understanding Net Station operations.

Caution!: This denotes important information that, if unheeded, could hinder use of Net Station.

Troubleshooting, Support, and Repair

- For online updates to this book, check EGI's Documentation page at www.egi.com/documentation.html.

- For Net Station EEG software support, see Appendix A, "Software Technical Support."

- To update your Net Station license, see Appendix B, "Updating EGI Licenses."
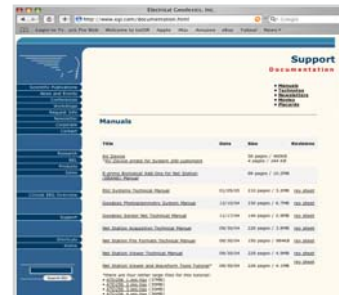
The EGI Documentation page at www.egi.com/documentation.html

Starting Net Station

How to start Net Station is discussed as part of the tutorial, as Step 1 of "Opening Net Station Data Files" on page 34.

SECTION 1:
INTRODUCTION

THE TUTORIAL DATA

The data that you will be analyzing as you go through this tutorial are from an *auditory target detection (ATD)* experiment (also known as *auditory oddball* or *auditory P300*).

This is a classic paradigm that produces some of the best-studied ERP components, including the *auditory N100*, a late auditory-cortex component, and the *P300*, typically elicited by task-relevant oddball stimuli of any sensory modality.

In this paradigm, the subject is presented with a series of frequent low-pitch tones (*standards*) occurring 80% of the time and infrequent higher-pitch tones (*targets*, sometimes referred to as *oddballs* or *deviants*) occurring 20% of the time. The subject is instructed to press a button immediately after each target tone.

The order of the tones is random, with the constraint that targets be separated by no fewer than two and no more than six standards. The duration between the tones varies randomly between 600 and 900 milliseconds.

The experiment begins with 10 practice trials. The trials contain an equal number of standard and target tones.

The Net Station recording files contain the EEG voltage samples as well as other information, most importantly the event markers for all the standard and target tones and subject responses.

The EEG data were recorded using a 256-channel Geodesic EEG System 200. The sampling rate was 250 samples per second.

Psychology Software Tool's E-Prime was used as the experiment control program.

In other words, E-Prime was used for:

- coding the experiment
- running the experiment, presenting the stimuli to the subject, and collecting the responses
- sending the stimulus event and response event information to Net Station

In this tutorial, you will:

- analyze ATD data from four subjects
- learn how to use Net Station to explore continuous recordings
- derive and explore ERPs, including the auditory N100 and the P300

IMPORTANT TERMS AND CONCEPTS

T he ATD experiment, and virtually all ERP experiments, consists of a sequence of *trials*. Each trial is a short sequence of stimulus events and/or response events. Trials generally have durations lasting from about a half-second to several seconds. Experiments are typically designed such that the trials share many similarities while also having strategic differences. The collection of trials is divided into different cells, based on one or more of the differences.

For example, in the ATD experiment, the trials are similar to each other in that:

- They all contain a tone stimulus that occurs between 600 and 900 milliseconds from the tone stimulus of the previous trial.

- The tone stimulus is followed by a period where a response (or nonresponse) from the user is collected.

Table 2-1 displays the way the trials differ from each other.

Table 2-1. ATD trial differences

	Tone stimulus	Correct behavior	Frequency
Standard	Low pitch	Do nothing	80%
Target	High pitch	Push button	20%

The trials in the ATD experiment are divided into two different cells: standard and target. When you create your experiment in E-Prime, for example, you determine how the trials are divided into cells.

Net Station recordings contain an event marker for each event in the experiment. The event markers indicate when each event occurs. Each event marker uses a four-character event code to indicate which event it represents. When you create your experiment, you determine which event codes are used for which events.

In the ATD experiment:

- Standard tone events have the event code *ast_* (**a**uditory **st**andard).

- Target tone events have the event code *atg_* (**a**uditory **targ**et).

- Standard tone events in the practice trials have the event code *astp* (**a**uditory **st**andard **p**ractice).

- Target tone events in the practice trials have the event code *atgp* (**a**uditory **targ**et **p**ractice).

- All responses have the event code *resp*.

Event markers contain additional information as well (e.g., which cell the trial is in).

For each trial in the experiment, Net Station recordings also contain **trial specifications** or **trial-specific** information (TRSPs). TRSPs contain the following information about the trial:

- *rsp#*: which key was pressed (if any)
- *rtim*: the reaction time (if applicable)
- *eval*: an evaluation of the response (correct or incorrect)

When you code your experiment, you can add additional information to the trial specification (e.g., what stimulus was presented or percent-of-trials-correct so far).

When you prepare to analyze your data, you conceptually divide your trials into different conditions based on criteria. The cell of a trial is usually included in the criteria, but not necessarily. For example, in the ATD experiment, you might have the conditions listed in Table 2-2.

Table 2-2. Sample conditions

Condition description	Criteria
Trials in which the subject made a correct response	TRSP eval = correct
Trials in which the subject made an incorrect response	TRSP eval = incorrect
Standard trials	cell = standard
Target trials	cell = target
Standard trials in which the subject made a correct response	TRSP eval = correct AND cell = standard
Standard trials in which the subject made an incorrect response	TRSP eval = incorrect AND cell = standard
Target trials in which the subject made a correct response	TRSP eval = correct AND cell = target
Target trials in which the subject made an incorrect response	TRSP eval = incorrect AND cell = target

When you analyze your data, your objective is to derive ERPs, which are patterns of electrical activity on the scalp. Generated by the brain, ERPs occur in response to, or in preparation for, a discrete sensory, cognitive, or motor event that takes place during a specific experimental condition.

Other than the optional technique of filtering, the first step in deriving ERPs from a data set is *segmentation*. In segmentation, you reduce your data to *segments* (short epochs) that fall into different *categories*. A category is defined by both the condition of the trial and the specific event to which the segment is temporally referenced.

For example, you may be interested in the trials whose condition is target trials in which the subject made a correct response. You can make two different categories of segments from trials of this condition. One category would be temporally referenced to the tone stimulus (the atg_ event), and the other would be temporally referenced to the response (the resp event).

The preceding discussion describes the recommended experiment structure, which is used in the vast majority of cases. If necessary, you can create an experiment with a different structure.

You will learn more about how event markers and TRSPs are stored in a Net Station recording in Chapter 6, "Inspecting Event Data." You will learn more about segmentation in Chapter 9, "Segmentation."

Before proceeding to the next chapter, it is important that you understand the following terms that were introduced in this chapter:

- trial
- cell
- event marker
- event code
- trial specification
- condition
- criteria
- ERP
- segmentation
- segment
- category

SECTION II:

EXPLORING
UNPROCESSED
CONTINUOUS DATA

INTRODUCING THE NET STATION VIEWER

N et Station Viewer consists of the feature set you use for viewing, and navigating through, EEG and ERP data. The Viewer window is the main window of the Net Station Viewer. It is very similar to the Dense Waveform Display, the window you use when acquiring data with Net Station.

In this section, you will learn to use Net Station Viewer to:

- inspect EEG (voltage) data
- recognize several types of noise
- inspect event data

By doing this, you will learn the basics of using Net Station Viewer and be prepared to understand Section III, "Deriving ERPs."

The remainder of this chapter teaches you how to open data files in Net Station.

Before You Begin

Obtaining the Tutorial Data Files

This tutorial uses Net Station recording files named:

- ATD256_1.ses
- ATD256_2.ses
- ATD256_3.ses
- ATD256_4.ses

These files are available in the ERP Analysis Tutorial folder, which you can copy to your desktop from the Net Station installation CD.

These files are also accessible from EGI's Documentation webpage (www.egi.com/documentation.html) or from EGI Support (see Appendix A, "Contacting EGI," on page 203).

Resetting Net Station to Its Default State

This tutorial assumes that you are starting with Net Station in its default state, otherwise, you may get results that appear different from those described. Net Station stores window states, settings, sizes, and locations from the most recent launch of Net Station in the following file:

- *Users:<user folder>:Library:Preferences:Net Station XX Preferences*

Where *XX* is the Net Station version number (e.g., Net Station 4.2 Preferences).

To reset Net Station to its default state, simply move the Net Station XX Preferences file from the System:preferences folder to another location. *(Make sure Net Station is not running when you do this.)* The next time you start Net Station, it will create a new Net Station XX Preferences file containing the default settings. You can then start the tutorial. To restore the original settings, move the original Net Station XX Preferences file back to the System:preferences folder (when Net Station is *not* running).

Opening Net Station Data Files

1 Start Net Station by double-clicking on the Net Station icon on the Finder Desktop. If the Net Station icon is in the Dock in Macintosh OS X, only a single click is needed (Figure 3-1).

Net Station icon on the Desktop

Net Station icon in the Dock
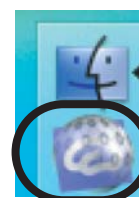
Figure 3-1. Starting Net Station

When Net Station is running with no files open, a start-up window is displayed with sections containing convenient shortcuts to the menu items for the different Net Station functions (Figure 3-2):
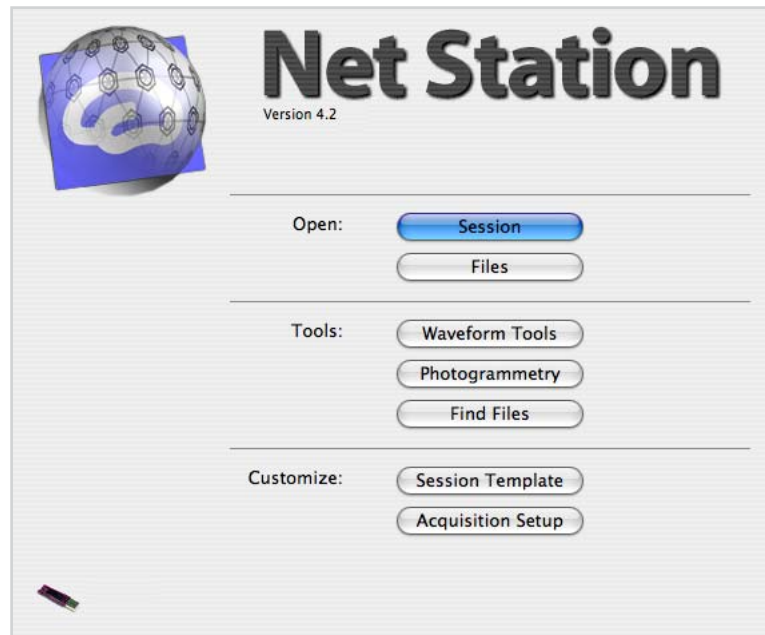
Figure 3-2. The Net Station start-up window

- *Open*: for acquiring data with a new Session file or opening a data file with Net Station Viewer
- *Tools*: for using Net Station Waveform Tools or Photogrammetry
- *Customize*: for editing Session Templates or Acquisition Setups

There are a number of ways to open Net Station files in Net Station. You can use the standard Macintosh-application methods:

- By using the file-selection dialog available when choosing **File > Open** or pressing Command-O (you can also access this dialog by clicking the Files button in the Net Station start-up window, shown in Figure 3-2).

- By double-clicking on the Net Station file in the Finder.

- By dragging the file from the Finder to the Net Station icon in the Finder.

If you are unsure of your file location, or if you simply want to browse from possible files, you choose **File > Find File**. This feature is also available by clicking the Find Files button in the Net Station start-up window.

2 Click the Find Files button in the Net Station start-up window.

3 From the Find File pop-up menu, choose "on local disks, except CD-ROMS".

4 Set the three pop-up menus of the middle panel to "kind is Net Station session" (Figure 3-3).
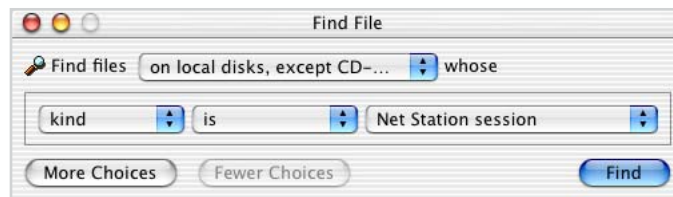
Figure 3-3. Find File window

5 Click the Find button.

6 When the Find File Results window appears, select ATD256_1.ses by either double-clicking on it or clicking on it once and then clicking the Open button.

Note: If a dialog appears, stating that "this file is stored in an older format. . . .," click the Convert button.

The Viewer window appears, displaying the data (Figure 3-4).
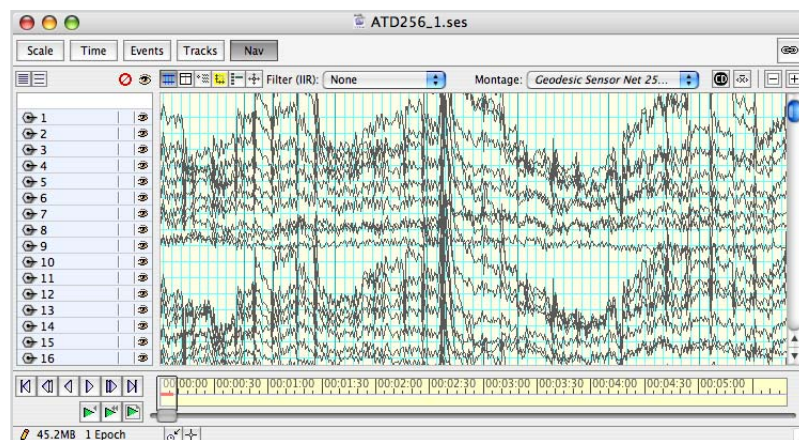
Figure 3-4. Viewer window in Chart view

Net Station allows you to view the data in a variety of ways. You can see the selection of views by clicking on the View menu. Chart view, shown in Figure 3-4, is the view most similar to the one you have during acquisition.

7 If you are not already in Chart view, choose **View > as Chart**.

8 The Scale, Time, Events, Tracks, and Nav buttons below the title bar are control-strip disclosure toggles. These buttons hide and display the associated control strips. Select all five control-strip disclosure toggles to display the associated control strips (see Figure 3-5 and the descriptions of the controls).

9 When finished viewing the control strips, select all five control-strip disclosure toggles to hide the associated control strips.

10 Close the file.
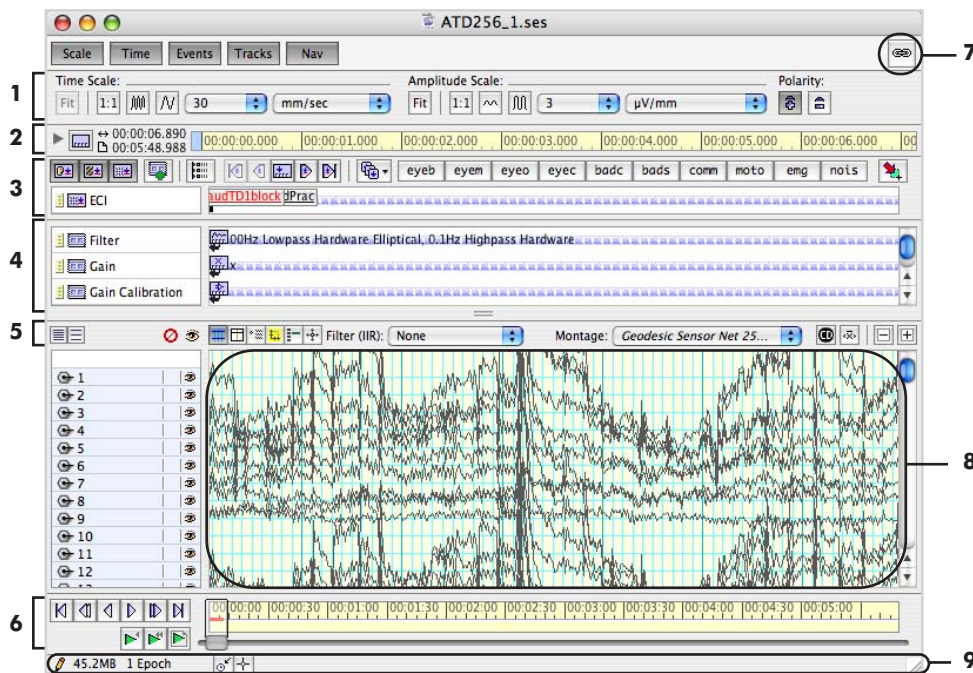
Figure 3-5. Viewer window with all five disclosure toggles selected

The following are brief descriptions of the numbered items from Figure 3-5.

1. Scale control strip. Allows you to adjust the time scale, amplitude scale, and polarity of the view. The Scale disclosure toggle hides and displays this control strip.

2. Time control strip. Allows you to control the time mode of the view. It also contains a timeline that gives feedback about where you are in the data. The Time disclosure toggle hides and displays this control strip.

3. Events control strip. Allows you to see event markers that indicate the temporal location of events in the data. The Events disclosure toggle hides and displays this control strip.

4. Tracks control strip. Allows you to see non-event information stored in the tracks of the data. (This information is also available in the File Info dialog opened by choosing **Edit > File Info**.) The Tracks disclosure toggle hides and displays this control strip.

5. Data-display control strip. Contains controls that control various aspects of the appearance of the data display.

6. Navigation control strip. Contains controls to navigate temporally through the data. The Nav disclosure toggle hides and displays this control strip.

7. Link button. Allows you to synchronize multiple windows containing different views of the same data.

8. Data display. Contents of the data-display area vary greatly, depending on the view used.

9. Status bar. Displays information about the data being viewed.

INSPECTING EEG

I n this chapter, you will learn how to use the Net Station Viewer to view, and
navigate in, continuous EEG in Chart view mode.

1 If necessary, start Net Station, and open the file ATD256_1.ses.

2 If you are not already in Chart view, choose **View > as Chart**.

Viewing the Data

1 Select the Scale control-strip disclosure toggle to display the Scale control strip
beneath the control-strip disclosure toggles.

2 In the Amplitude Scale panel, use the two pop-up menus to choose $10\,\mu V/mm$
and notice how this affects the waveform display.

3 In the Polarity panel, if necessary, choose the positive-up button. Your choice in
this panel affects the display only. The data file remains unchanged.

4 Select the Nav control-strip disclosure toggle to display the Navigation control
strip at the bottom of the display.

red line

In the Navigation control strip, directly under the data-display area, are the time ruler
and slider. (To the left are the navigation controls.) The time ruler represents the
timeline of the entire recording. The red horizontal line above the slider spans the
window of time currently displayed in the Viewer.

5 In the Time Scale panel of the Scale control strip, use the two pop-up menus to
choose 60 mm/sec and notice how this affects the waveform display and the
Navigation control strip's time ruler.

Note: Screen aliasing occurs with any setting more than 1 sample/pixel.

6 Select the Time control-strip disclosure toggle to display the Time control strip.

On the right side of the Time control strip is a timeline that contains labels and tick marks indicating the times within the recording of the underlying EEG samples.

Net Station can display the labels in four different time modes:

Absolute Time: time of and date according to the recording computer's internal clock, formatted as follows: yymmdd/hour:minute:second.ms. For example, 020311/18:30:30.500 represents 30,500 milliseconds after 6:30 p.m. on March 11, 2002.

Relative Time: the amount of time since the first sample in the file, formatted as follows: hour:minute:second.ms. For example, if in the previous example, the recording started at exactly 5:00 p.m., the Relative Time would be 01:30:30.500.

Epoch Time: epoch number, in brackets, followed by the amount of time since the first sample in the epoch, formatted as above. For example, [2]01:30:30.500 represents a sample that is recorded 1:30:30.500 into the beginning of the second epoch.

Segment Time: for viewing segmented data. For nonsegmented data, this time mode is the same as Epoch Time. You will learn about this time mode in Chapter 9, "Segmentation."

You set the time mode using the Time menu. You can also change time modes with the time-mode button, the leftmost component of the Time control strip. Clicking this button cycles through the four time modes.

The time mode affects the labels on the Time control strip and the status bar. The time ruler of the Navigation control strip is always in Relative Time mode. For inspecting continuous data, Relative Time mode is the most useful because the labels are in the same timeframe as the time ruler in the Navigation control strip.

7 If necessary, choose **Time > Relative Time**.

The leftmost time on the Time control-strip timeline corresponds to the left of the red horizontal line above the Navigation control-strip slider. Likewise, the rightmost time on the Time control-strip timeline corresponds to the right of the red horizontal line above the Navigation control-strip slider.
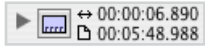
To the right of the time-mode button on the Time control strip are two time numbers:

- The top number represents the duration of the portion of the recording being displayed. This duration can be revised by changing the current time scale (as selected on the Scale control strip).

- The bottom number represents the total duration of the recorded file.

The disclosure triangle at the far left of the Time control strip allows you to choose between displaying one or two timelines. If you choose the two-timeline option, the top line simply indicates the point in recording time associated with the blue vertical line just beneath it on the lower timeline.

Navigating through the Data

You can scroll to any time window by dragging the Navigation control-strip slider until the red line spans the time window you desire.

As you are dragging the slider, the status bar under the slider updates to provide you with additional precise feedback about the time window to which you are scrolling. From left to right, the times displayed in the status bar are the time of the leftmost EEG sample, the time of the EEG sample at the center of the window, and the time of the rightmost EEG sample (Figure 4-1).
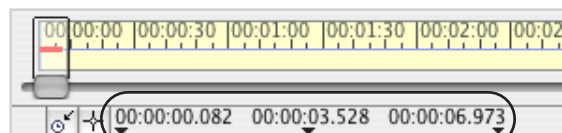
leftmost sample, center sample, rightmost sample

Figure 4-1. Status bar during navigation

You can also use the navigation controls (Figure 4-2) to the left of the ruler to scroll through your data.

Figure 4-2. Navigation buttons

The following are brief descriptions of the numbered items from Figure 4-2.

1. Go To Beginning button. Rewinds to the beginning of the recording.

2. Page Back button. Rewinds a whole page length.

3. Half-Page Back button. Rewinds a half-page length.

4. Half-Page Forward button. Advances a half-page length.

5. Page Forward button. Advances a whole page length.

6. Go To End button. Advances to the end of the recording.

7. Play Slow toggle. Toggles slow, smooth playback on and off. When on, the appearance is similar to the appearance of the Dense Waveform Display during acquisition.

8. Play Fast toggle. Toggles fast, smooth playback on and off. When on, the appearance is similar to the appearance of the Dense Waveform Display during acquisition.

9. Play Page toggle. Toggles paging (automatic, repeated full-page advance) on and off.

There is one additional way to scroll through the data. If you press the Control key while the cursor is over the data-display area, then the cursor takes the shape of a hand. You can then scroll through the data vertically and horizontally by dragging. Note that the Navigation control strip does not need to be displayed.

Experiment with different methods of navigating through the data.

EEG Selection

Net Station uses a vertical line as a selection cursor to indicate the sample or samples that are selected. When you first open a recording for viewing, the first sample is selected.

1   Click anywhere in the data-display area.

Note that the vertical selection cursor appears where you clicked.

Net Station allows you to make an extended selection of a contiguous epoch of data.

2   Drag across an area of the data display.

Note: Or you can use Shift-click to make an extended selection. Click anywhere in the data-display area. Then, while pressing the Shift key, click somewhere else.

As you scroll through the data, Net Station does not move the selection cursor. In other words, it is possible for the selection cursor to be outside the window. You can select an epoch of data that is bigger than a full page by using the Shift-click method of creating an extended selection.

Some of the things you can do with a selection are:

- save the selected data to a separate file by choosing **File > Save Selection**
- fill the EEG display (changing the time scale and the position of the slider in the Navigation control strip) with the selected data by choosing **Time > Zoom Selection To Window**
- operate on the data using Waveform Tools (discussed in Section III, "Deriving ERPs")

3   Click anywhere in the data-display area to deselect the selection.

4   Close the file.

RECOGNIZING NOISE

In this chapter, you will learn how to recognize different types of noise, while becoming familiar with more features of the Net Station Viewer.

Noise is broadly defined as those portions of the data that are not of interest to the researcher or those that do not originate in the system of interest. With respect to EEG, this means extracerebral contributions to the data. With respect to ERP waveforms, this additionally includes contributions to the EEG data unrelated to the event of interest.

We define an *artifact* as a special type of noise (specifically, large, isolated noise activity) often with specific, easily recognizable signatures, such as the contribution of a blink to the EEG data. (Note that some authors use the term *artifact* interchangeably with *noise*.)

Noise and artifacts can be generated by either biologic or nonbiologic sources.

In this chapter, you will learn how to recognize

- 50 Hz or 60 Hz line noise
- bad channels
- eye-blink artifacts

In the ERP derivation process, you eliminate these and other sources of noise, and greatly increase the signal-to-noise ratio, through a series of automatic processes. You will learn about this in Section III, "Deriving ERPs." However, it is useful to be able to recognize noise in the unprocessed, continuous recording. (The ability to recognize noise can also help you prevent noise when acquiring data.) Please keep in mind that this chapter covers some of the most important types of noise, but it is not a comprehensive guide.

If necessary, do the following:

1 Start Net Station.

2 Open the file ATD256_1.ses.

3 In the Scale control strip, use the Amplitude Scale panel to scale the data to 10 µV/mm and use the Time Scale panel to scale the data to 60 mm/sec.

Recognizing Line Noise

In today's world, surrounded by electrical equipment, the environment is filled with a narrowband electrical field generated by electrical lines. The activity of this field is 50 Hz in most countries and 60 Hz in the United States and several other countries. This field is a source of noise in the EEG. The noise is easily filtered out.

In this section, you will learn to recognize this line noise and, in the process, learn about Net Station's filters, linked-window feature, and channel highlighting.

Net Station allows you to view data in several different ways simultaneously. You do this by bringing up several windows with the same data. Then, you can change the settings, such as view, scale, filter, and montage, of each window individually. If you want the windows to stay in synch with each other as you navigate through the data, you can link them together.

Linking Windows

1 Create a new window with the data by choosing **View > Open New Window**.

2 Stack the two windows, with one window above the other.

You now have two independent views of the same data. Next, link them together.

3 Select the Link button (which features the chain icon) in the upper-right corner of both windows.

4 To save space on the screen, hide all the control strips in both windows. In the bottom window, click the Nav control-strip disclosure toggle, to display the Navigation control strip.

Now, if you navigate through the data in either window, the other window will stay in synch.

Comparing Windows

You can filter the data in one view, while leaving the other view unfiltered. Because these data were recorded in the United States, use the 60 Hz notch filter.

1   In the bottom window, choose **Filter > 60Hz Notch**.

2   Scroll both windows vertically until channel 25 is visible.

Note the difference between the data in the two windows, especially in channel 25, which is near the common ground.

You can use channel highlighting in both windows to make it easier to compare the filtered and unfiltered channel 25. To the left of the data display is a column of gray channel tiles that include a column of label tiles to the left. You can highlight any channel by clicking on the label tile. This turns the channel data red.

3   In both windows, highlight channel 25 by clicking on its label tile.

Figure 5-1 shows what your two windows should now look like.
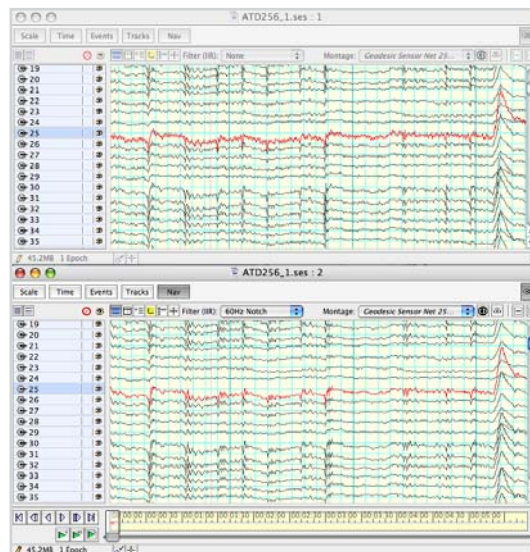
Figure 5-1. Linked filter window

Note: A 60 Hz filter actually filters more than that single frequency. In this case, the 60 Hz notch filters 59–61 Hz and attenuates down to 57 Hz and up to 63 Hz.

4 Close the top Viewer window.

5 In the remaining window, turn off the 60 Hz notch filter by choosing None from the Filter pop-up menu above the data-display area(Figure 5-2) and click on the label tile of channel 25 to remove the highlighting.
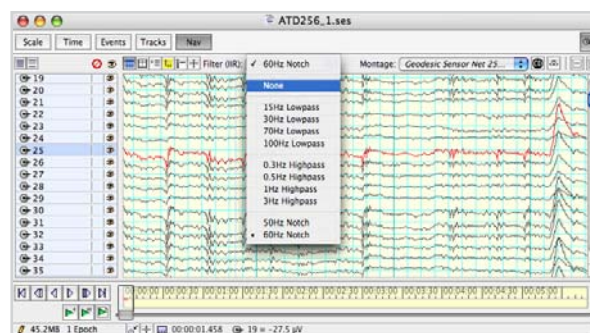
Figure 5-2. Remove the notch filter

This filter affects the display only. It does not change your data. Net Station allows you to save your data with the filter applied. If you want to do this, choose **File > Save A Copy As** to open the Save File As dialog, and select the Apply Viewer Transformations checkbox before clicking the Save As button.

However, there is no need to save the filtered data at this stage. When deriving ERPs, you eliminate the line noise with the Filtering tool by using either a notch filter at 50 or 60 Hz or a lowpass filter at a setting below 50 or 60 Hz.

Net Station uses an infinite impulse response (IIR) filter for viewing. IIR filters are suitable for real-time use because of their excellent computational speed. This allows you to rapidly change filter settings and see the results. IIR filters have the disadvantage, however, of distorting the data because they lack a linear phase response.

When you save your data with your filter settings applied, Net Station uses a finite impulse response (FIR) filter. FIR filters are generally too slow for use in real-time applications, but their phase response is linear, making them superior for permanently filtering a file with the greatest possible accuracy.

Note: You can use the Filter pop-up menu (see Figure 5-2) in the data-display control strip to choose from a variety of filter settings. If you require more detailed control of the filtering, you can use the various items in the Filter menu, including Show Filter Controls and Filter Options.

Recognizing Bad Channels

Bad channels contain data consisting entirely, or almost entirely, of noise. A typical recording contains some bad channels, perhaps because the sensors are defective (from normal wear and tear, for example) or because the sensors are dry or improperly placed on the subject's scalp.

The main symptoms of bad channels are:

- lots of line noise (50 or 60 Hz)
- amplitudes much bigger than the other channels
- amplitude shifts much bigger than the other channels

In this section of the chapter, you will learn to recognize bad channels and, in the process, learn about features of the channel tiles.

1   Use the vertical scroll bar to scroll so that channels 51, 75, and 76 are all visible.

Channel 51 is very bad. In fact, the amplitudes are so large and variable that it is difficult to tell which channel is the bad one. If you see a bad channel and have difficulty determining which channel it is, you can use the channel tile to highlight channels until you locate the bad one.

2   Highlight channels 51, 75, and 76 by clicking on their label tiles.

Figure 5-3 shows these channels highlighted.
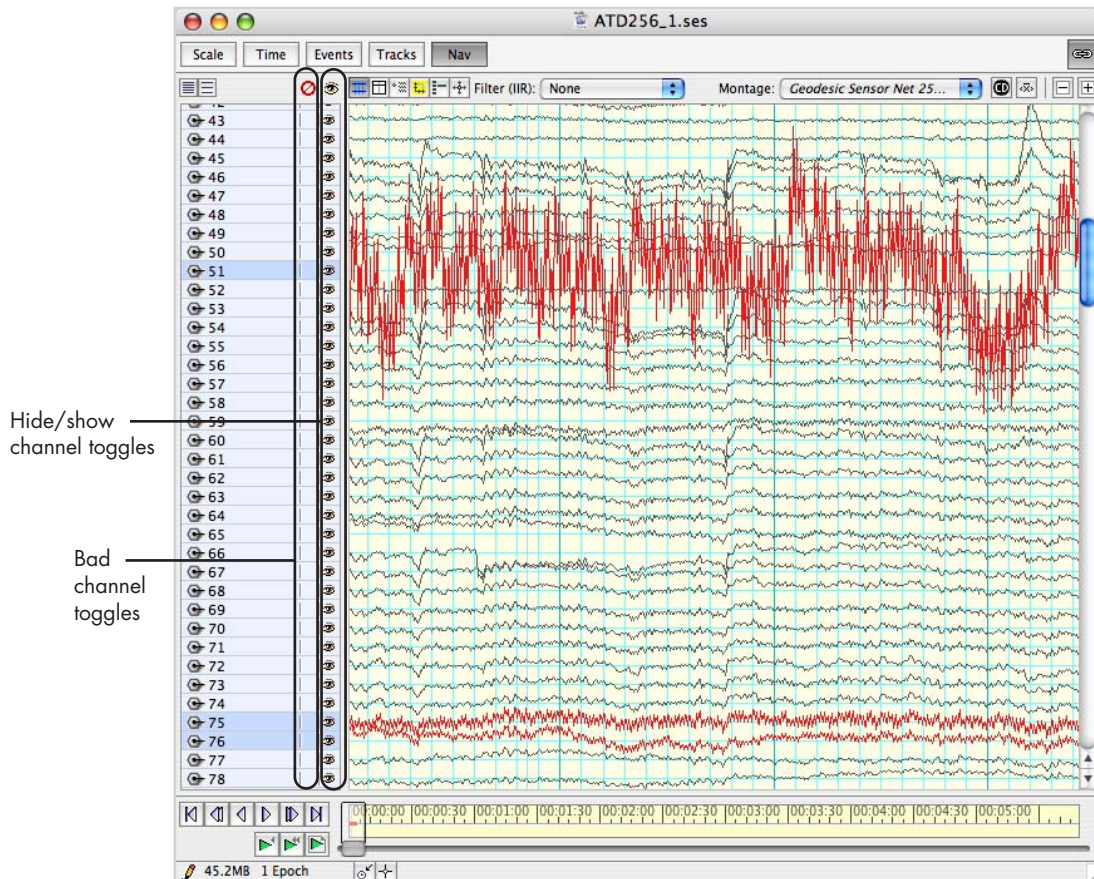
Figure 5-3. Channels 51, 75, and 76 highlighted

Channel 51 is so bad that it disrupts your view of nearby channels. The rightmost column of channel tiles contains the hide/show channel toggles. They allow you to hide and display channels. An eye icon in that column indicates that the channel is displayed. Clicking the tile toggles between hidden and displayed. This affects the view only. Hiding a channel does not delete the associated channel data.

3 Hide channel 51 by clicking on its hide/show toggle.

Now look at channels 75 and 76. These channels look bad because there is a particularly large amount of 60 Hz line noise.

4 Turn the 60 Hz notch filter back on by choosing it from the Filter pop-up menu in the data-display control strip.

Notice that with the notch filter on, channels 75 and 76 resemble their neighbors. These channels should not be marked bad because with the 60 Hz noise filtered out, they contain good data.

5 Display channel 51 by clicking on its hide/show toggle.

Channel 51 still looks bad even with the 60 Hz noise removed (Figure 5-4).

Channels 75 and 76 look good after applying the notch filter.
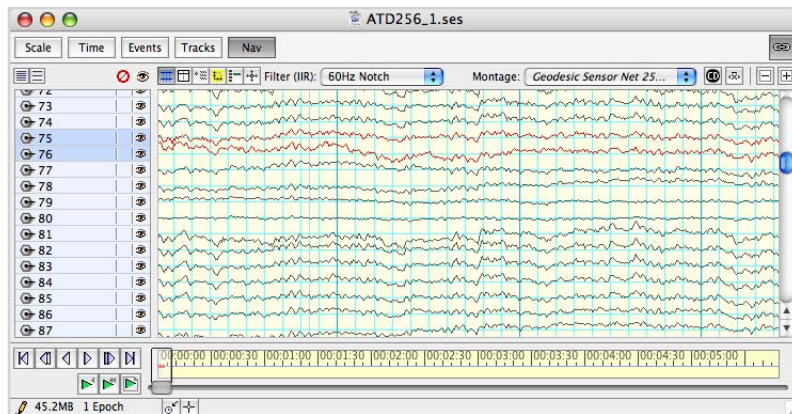
Channel 51 still looks bad after applying the notch filter.
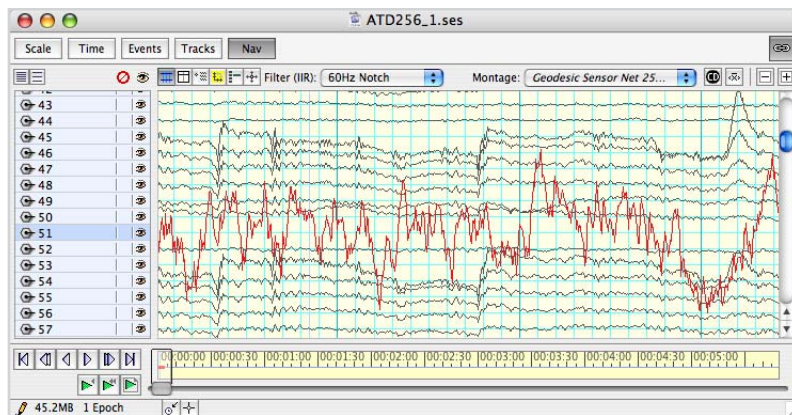
Figure 5-4. Channels 51, 75, and 76, with notch filter applied

The middle column of channel tiles contains the bad channel toggles (see Figure 5-3). They allow you to manually mark a channel as bad. A red slash-circle icon in that column indicates that the channel is marked bad. Clicking the tile toggles the bad channel marker on and off.

When deriving ERPs, you automatically eliminate bad channels by using the Artifact Detection tool to detect them, followed by the Bad Channel Replacement tool to replace them with data interpolated from the remaining channels. You will learn to do this in Chapter 10, "Artifact Detection," and Chapter 11, "Bad Channel Replacement." You will also learn other ways to recognize bad channels in those chapters.

Because you will be automatically detecting bad channels later, leave channel 51 unmarked for now.

6 Click on the label tiles of channel 51, 75, and 76 to remove the highlighting.

Recognizing Eye-blink Artifacts

Voltage potentials of the eyeball add a high-amplitude artifact during an eye blink or eye movement. These eye artifacts affect all channels, but they are greatest in the channels near the eyes.

In this section of the chapter, you will learn to recognize eye-blink artifacts and, in the process, learn about montages and user events.

Applying the Eyes Montage

1 Use the Navigation control strip to scroll to time 40.8 in the data.

Net Station's Montage feature allows you to create and edit montages and to select from existing montages. Individual channels can be selected, their display order reorganized, and each rereferenced to either a single common electrode or any bipolar combination of electrodes. To simplify the finding of ocular artifacts, use the existing Eyes montage.

2 From the Montage pop-up menu above the data-display area, choose Eyes.

If necessary, you can give each channel more space by dragging the bottom edge of any channel tile.

3 Make the channels wider to avoid overlapping of channel data.

Inserting an Eye-blink Event

You will now add an eye-blink event to the recording for the blink epoch.

1 Drag the cursor across the blink epoch to create an extended selection as shown in Figure 5-7.

2 Select the Events control-strip disclosure toggle to display the Events control strip.

Notice the series of labeled buttons in the Events control strip, above the Experimental Computer Interface (ECI) track (Figure 5-5). These buttons are for creating user-inserted events.
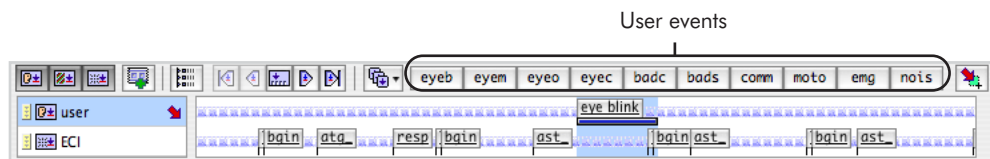
Figure 5-5. User event buttons in the Events control strip

3 Click the button labeled *eyeb*.

Net Station cautions you that the file has no user event tracks and asks you if you want to create one.

4 Click OK to create the track.

An input box appears, allowing you to name the new user event track.

5 Type "user" and click the New button.

The new user track appears with the epoch that you selected marked as a blink (Figure 5-6).
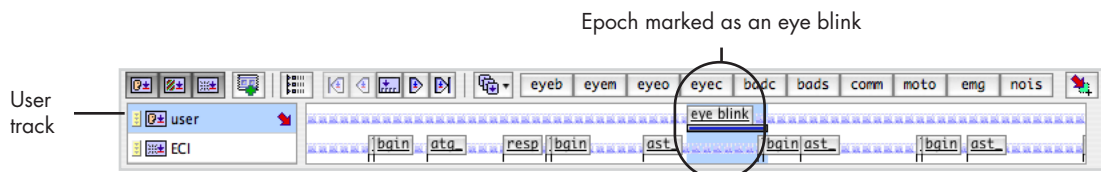
Figure 5-6. An eye blink in the User track

Your Viewer window should now look similar to Figure 5-7. Note that there is a positivity in channels 36 and 18, which are above the eyes, and a negativity in channels 242 and 241, which are below the eyes.
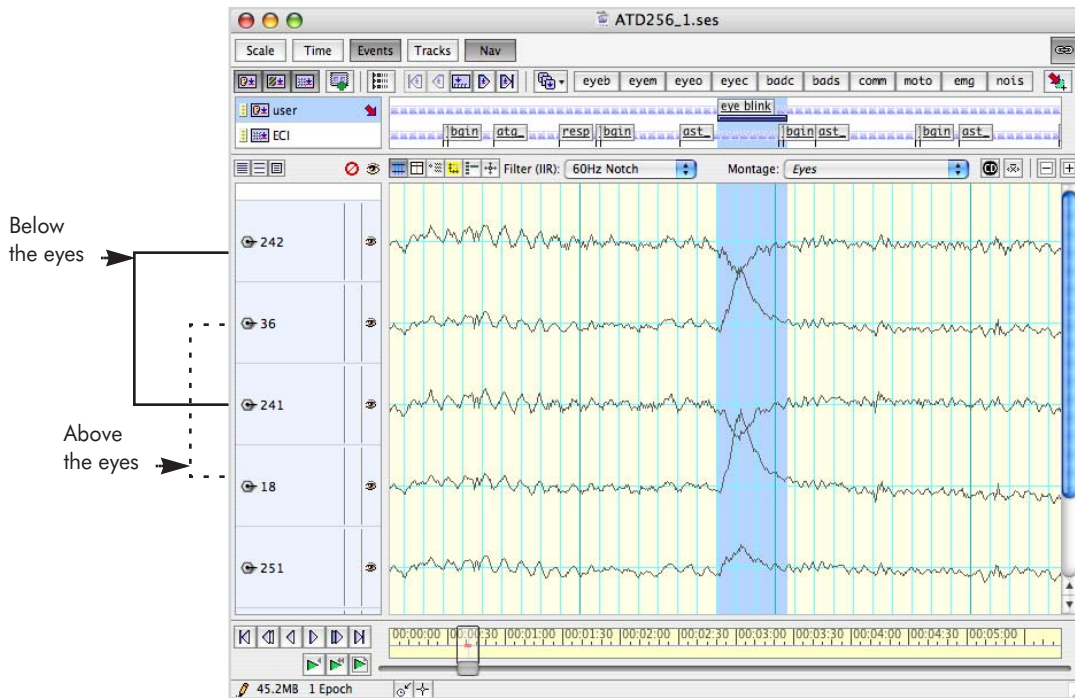
Figure 5-7. A blink event in the Viewer window

6 Return to the default montage Geodesic Sensor Net 256 2.0, and drag the channel tiles to their normal width. Click anywhere in the data-display area to deselect the selection.

7 Close the file.

Normally, when deriving an ERP, you do not have to manually find and mark blink artifacts. When deriving ERPs, you eliminate eye artifacts through the automatic detection and rejection of segments that are contaminated by them.

INSPECTING EVENT DATA

In this chapter, you will learn how the event information discussed in Chapter 5, "Recognizing Noise," is stored in a Net Station recording.

Opening the Event List Window

1 Open the file ATD256_1.ses.

2 If necessary, select the Events control-strip disclosure toggle to display the Events control strip.

At the bottom of the Events control strip is the ECI track. This track contains markers for all of the events transmitted by the experimental control computer. The purpose of the events is to indicate the timepoints/samples where specific stimulus and response events took place during the recording, as well as information about those events. Net Station lets you view event information in a variety of ways.
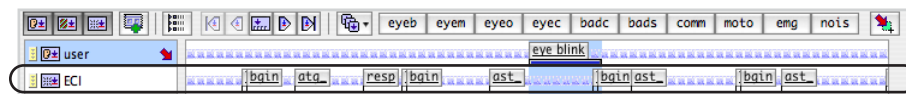
Figure 6-1. ECI track of the Events control strip

3 Choose **Events > Event List**.

The Event List window, depicted in Figure 6-2, appears.

codes and labels

Code	Description	Type	Track	Onset	Duration
▶ SESS	audTD1block	Stimulus Event	ECI	00:00:00.025	00:00:00.001
▶ CELL	ART	Stimulus Event	ECI	00:00:00.047	00:00:00.001
▶ CELL	ATDTarget	Stimulus Event	ECI	00:00:00.059	00:00:00.001
▶ CELL	ATDStandard	Stimulus Event	ECI	00:00:00.071	00:00:00.001
▶ CELL	ARTPrac	Stimulus Event	ECI	00:00:00.084	00:00:00.001
▶ CELL	ATDTargetPrac	Stimulus Event	ECI	00:00:00.095	00:00:00.001
▶ CELL	ATDStandardPrac	Stimulus Event	ECI	00:00:00.109	00:00:00.001
▼ bgin		Stimulus Event	ECI	00:00:10.906	00:00:00.001
cel#	6	Event Key			
obs#	1	Event Key			
pos#	1	Event Key			
argu	0	Event Key			
▼ astp		Stimulus Event	ECI	00:00:11.199	00:00:00.001
cel#	6	Event Key			
obs#	1	Event Key			
pos#	2	Event Key			
argu	0	Event Key			
▼ resp		Stimulus Event	ECI	00:00:11.682	00:00:00.001
cel#	6	Event Key			
obs#	1	Event Key			
pos#	1	Event Key			
rsp+	1	Event Key			
▼ TRSP		Stimulus Event	ECI	00:00:11.722	00:00:00.001
cel#	6	Event Key			
obs#	1	Event Key			
rsp#	2	Event Key			
eval	2	Event Key			
rtim	483	Event Key			
trl#	1	Event Key			
▶ bgin		Stimulus Event	ECI	00:00:11.749	00:00:00.001
▶ atgp		Stimulus Event	ECI	00:00:12.060	00:00:00.001
▶ TRSP		Stimulus Event	ECI	00:00:12.570	00:00:00.001

Figure 6-2. Event List window

The following are brief descriptions of the numbered items from Figure 6-2.

1. *Header events.* Contain information that is general to the entire recording.

2. *Events from first (practice) trial*, with disclosure triangles toggled to reveal metadata, such as the cell number of the trial, response key pressed, response time, and whether the response was correct or incorrect.
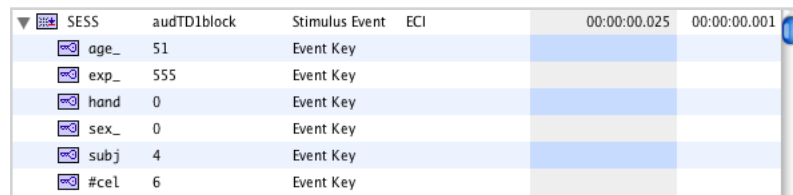
The Event List window gives you another view of the events in the ECI track. Note that the first two columns in the Event List are Codes and Label. Codes are limited to being exactly four characters long. In the ECI track, for events with labels, the labels appear on the event markers. Otherwise, the codes appear on the event markers.

The header events in Figure 6-2 are the 1 SESS event and 6 CELL events and appear at the top of the list. These events contain information that is general to the entire recording.

Exploring the Event List

1   Click on the disclosure triangle to the left of the first SESS event.

In this expanded view, you can see the key list that is included within the event. The key list contains metadata about the event. In this case, the metadata consist of subject information and the number of cells (Figure 6-3).

Figure 6-3. SESS key list

2   Click on the disclosure triangle again to collapse the event.

3   Click on the disclosure triangles next to the CELL events whose labels are ATDTarget, ATDStandard, ATDTargetPrac, and ATDStandardPrac (Figure 6-4). (The ART and ARTPrac CELL events refer to cells that are absent in these recordings.)

▶	CELL	ART	Stimulus Event	ECI		00:00:00.047	00:00:00.001
▼	CELL	ATDTarget	Stimulus Event	ECI		00:00:00.059	00:00:00.001
	cel#	2	Event Key				
	#obs	999	Event Key				
	#spc	12	Event Key				
▼	CELL	ATDStandard	Stimulus Event	ECI		00:00:00.071	00:00:00.001
	cel#	3	Event Key				
	#obs	999	Event Key				
	#spc	12	Event Key				
▶	CELL	ARTPrac	Stimulus Event	ECI		00:00:00.084	00:00:00.001
▼	CELL	ATDTargetPrac	Stimulus Event	ECI		00:00:00.095	00:00:00.001
	cel#	5	Event Key				
	#obs	999	Event Key				
	#spc	12	Event Key				
▼	CELL	ATDStandardPrac	Stimulus Event	ECI		00:00:00.109	00:00:00.001
	cel#	6	Event Key				
	#obs	999	Event Key				
	#spc	12	Event Key				

Figure 6-4. CELL key lists

The purpose of these CELL events is to associate a cell number with each cell. Notice that the metadata for these CELL events contain a cel# (cell number) key. Notice that the cell numbers for these cells are as follows:

- ATDTarget (target): 2
- ATDStandard (standard): 3
- ATDTargetPrac (target practice): 5
- ATDStandardPrac (standard practice): 6

Next, look at the events that follow the header events. These are repeating sequences of events that start with *bgin* (begin) events and end with *TRSP* (trial specification) events (Figure 6-5). Each of these sequences represents a single trial. Between the bgin and TRSP events are the stimulus and response events for the trial.

▶ bgin	Stimulus Event	ECI	00:00:10.906	00:00:00.001
▶ astp	Stimulus Event	ECI	00:00:11.199	00:00:00.001
▶ resp	Stimulus Event	ECI	00:00:11.682	00:00:00.001
▶ TRSP	Stimulus Event	ECI	00:00:11.722	00:00:00.001
▶ bgin	Stimulus Event	ECI	00:00:11.749	00:00:00.001
▶ atgp	Stimulus Event	ECI	00:00:12.060	00:00:00.001
▶ TRSP	Stimulus Event	ECI	00:00:12.570	00:00:00.001
▶ bgin	Stimulus Event	ECI	00:00:12.593	00:00:00.001
▶ atgp	Stimulus Event	ECI	00:00:12.746	00:00:00.001
▶ TRSP	Stimulus Event	ECI	00:00:13.256	00:00:00.001
▶ bgin	Stimulus Event	ECI	00:00:13.280	00:00:00.001
▶ atgp	Stimulus Event	ECI	00:00:13.620	00:00:00.001
▶ resp	Stimulus Event	ECI	00:00:13.912	00:00:00.001
▶ TRSP	Stimulus Event	ECI	00:00:14.143	00:00:00.001

Start of trial — bgin
Stimulus — astp
Response — resp
Trial data (such as whether the response is correct) — TRSP

Figure 6-5. Events of one trial

Recall from Section I, "Introduction," that every trial contains a stimulus event, which is either a standard tone or a target tone. Standard-tone events have the code *ast_* (auditory standard) or, for the practice trials, *astp* (auditory standard practice). Target-tone events have the code *atg_* (auditory target) or, for the practice trials, *atgp* (auditory target practice).

The response events have the code *resp*. Because the subjects were instructed to make a response after the target tones, the correct trials either

- contain an atg_ event (or atgp) and a resp event, or
- contain an ast_ event (or astp) and no resp event

Similarly, incorrect trials either

- contain an atg_ event (or atgp) and no resp event, or
- contain an ast_ event (or astp) and a resp event

4 Scroll down through the Event List and click on the disclosure triangle of any event.

By looking at the cel# metadata, you immediately know into which cell that event, and all the events from the trial, falls. The obs# metadata tell you how many trials from that cell have occurred. For example, if the cel# is 6 and the obs# is 1, then it is the 1st trial from the ATD standard practice cell (Figure 6-6).

Figure 6-6. Cel# and obs# metadata

5 Click on the disclosure triangle of all events from a trial. In other words, start with a bgin event and continue until you get to a TRSP event (see Figure 6-2).

Notice that all the events in the trial have the same cel# and obs# metadata. Also note that the metadata from the TRSP event include the following keys:

- *rsp#*: which key was pressed (if any)
- *eval*: an evaluation of the response (correct or incorrect)
- *rtim*: the reaction time (if applicable)

In this experiment, an eval value of 1 means correct, and 2 means incorrect.

6 Click on the disclosure triangles again to close all open events.

Opening the Filter Events Window
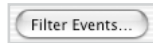
Filter Events...

1 Click the Filter Events button near the top of the Event List.

The Filter Events window, shown in Figure 6-7, appears.
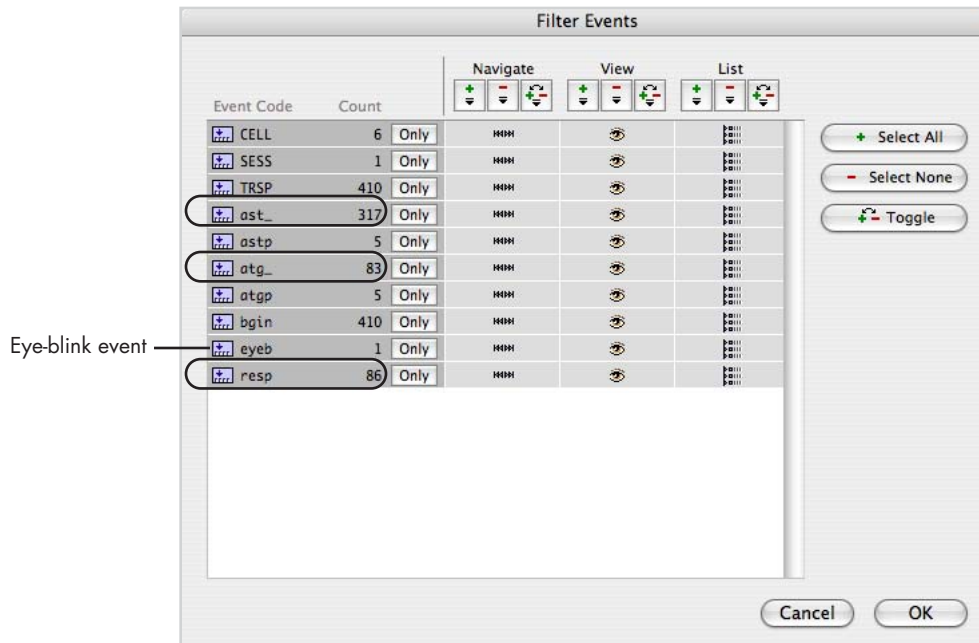
Figure 6-7. Filter Events window

In this window, you can see a summary of how many different events are in this file and how often they occur. Notice that the eyeb event that you added in the previous chapter is there. Also notice that there are 317 ast_ events and 83 atg_ events, as you would expect. Note that there are 86 resp events, which is approximately equal to the number of atg_ and atgp events. This indicates that the subject was probably doing what he or she was supposed to do.

You can verify this further by checking that the resp events generally follow the target (atg_ and atgp) events. The Filter Events window allows you to do this easily. First, you want to hide all the events except ast_, astp, atg_, atgp, and resp.

2 At the top of the right column, labeled List, click the button with the minus sign, to clear all the entries in the column.

3 In the List column, click the cells for these events: ast_, astp, atg_, atgp, and resp.

4 Click the OK button, which dismisses the Filter Events window, to display an Event List containing only the ast_, atg_, atgp, and resp events (Figure 6-8).

Figure 6-8. An Event List with only events of interest

By scrolling through the Event List, populated by only the events of interest, you can easily see that the subject's behavior was correct in the vast majority of cases.

Opening the Event Editor Window

Another way to view information about events is through the Event editor. You can access this window through the Event List or the ECI track.

1   Double-click on any event in the Event List.

The Event editor, shown in Figure 6-9, appears, providing a different view of the event.
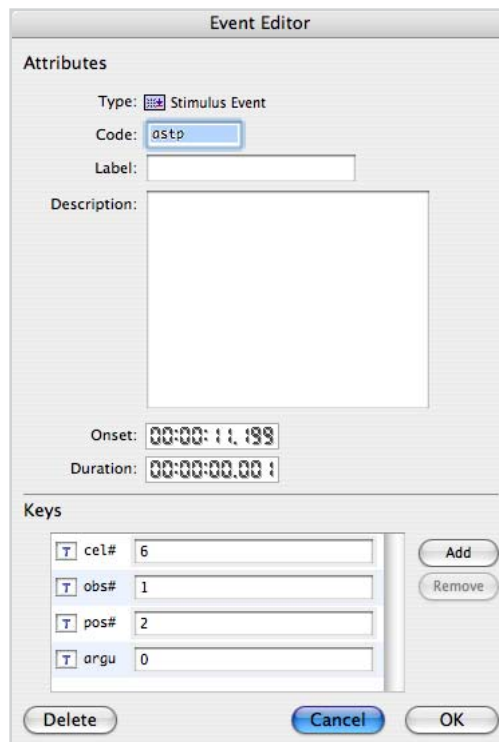
Figure 6-9. Event editor

2   Click Cancel to dismiss the Event editor and return to the Event List.

3   Click on any event in the Event List and click the Go To Event button in the upper-left corner of the window.

The EEG display becomes active and scrolls to the sample of the event (Figure 6-10).
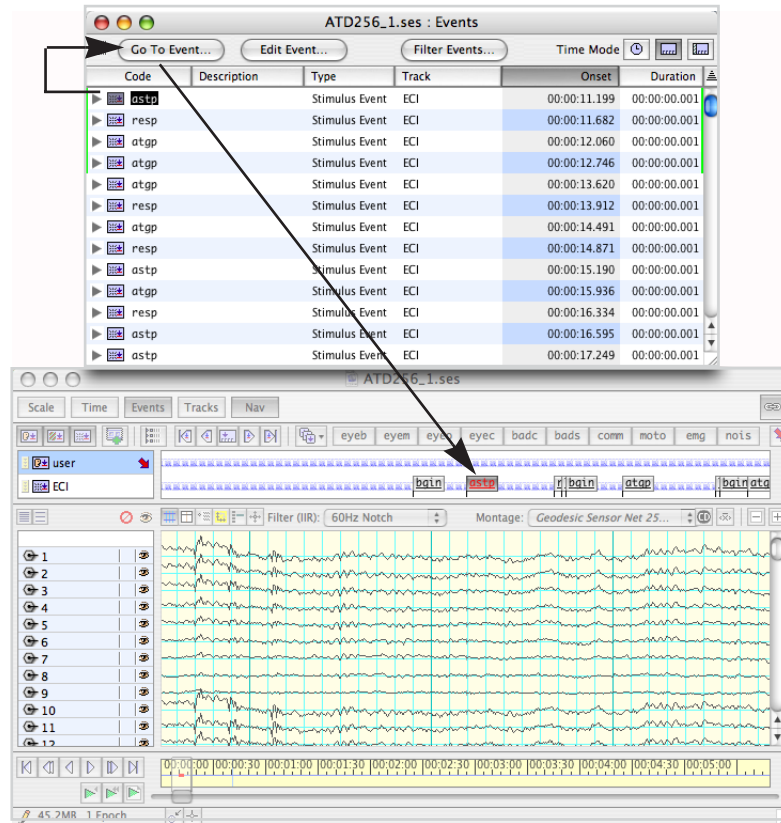
Figure 6-10. Go To Event button takes the user to the selected event in the Viewer

   4   Double-click on the event in the ECI track.

Again, the Event editor appears. You can use this to get information about an event when the Event List window is closed.

   5   Dismiss the Event editor and close the file.

You will revisit these events again in Chapter 9, "Segmentation."

SECTION III:

DERIVING ERPS

ERP DERIVATION AND WAVEFORM TOOLS

ERP Derivation Overview

An *event-related potential* (or *ERP*) is a pattern of electrical activity on the scalp, generated by the brain, that occurs in response to, or in preparation for, a discrete sensory, cognitive, or motor event that occurs during a specific experimental condition.

In the EEG from a single event from a single experimental trial, the ERP signal generated by the brain is swamped by many types of noise, including:

- background brain activity unrelated to the event or experimental condition

- artifacts, such as those generated by eye blinks, heart activity, muscle activity, eye movement, and head movement

- line noise

- data from bad channels

(See Chapter 5, "Recognizing Noise," for definitions of noise and artifacts.)

That is why an EEG recording for an ERP experiment consists of tens, hundreds, or thousands of repetitions of the events of interest. From this recording, you can derive ERPs by averaging all the trials of a given condition, time-locking to the event of interest. This increases the signal-to-noise ratio because activity not related to the event averages to zero. The result from this is a *single-subject average*, or ERP, for each event of interest in the experiment.

Once you have ERPs from more than one subject, you can create grand-average ERPs by averaging together the averages for the individual subjects. *Grand averaging* emphasizes the ERP patterns shared by all the subjects and deemphasizes individual differences.

ERP Derivation Operations

To derive a single-subject ERP from your continuous recording, you normally perform the following operations: filtering, segmentation, artifact detection, bad channel replacement, averaging, average referencing, and baseline correction.

Note: This tutorial does not cover some of the advanced Waveform Tools and Viewer options, such as Markup from File, Ocular Artifact Removal, Short Epoch Filtering, t-test, Wavelet, Spectral Display, and video EEG. These tools represent operations that are not part of the core data-analysis path used to derive ERPs.

⚠️ **Caution!:** *Before averaging, make sure that you have assigned a subject to the file to ensure that the subject information remains available for subsequent Waveform Tools operations, such as Averaging. Assigning a subject after averaging is **not** recommended. The "Assigning Subjects" section in Chapter 1, "The Waveform Tools Window," of the* Net Station Waveform Tools Technical Manual *discusses this topic in more detail.*

Each operation serves a specific signal-processing purpose, mostly related to increasing the signal-to-noise ratio. Each operation also outputs a version of the data that is used as the input to the operation that follows it.

- *Filtering*: In this operation, you filter out activity in frequencies that are not of interest. Traditional ERP research, for example, has focused on brain activity in frequencies below 30 or 40 Hz. Note that if you do a lowpass filter in this range, then the 50 Hz or 60 Hz line noise will be filtered out, so there is no need to do a notch filter. You will learn how to do this in Chapter 8, "Filtering and Using Waveform Tools."

- *Segmentation*: In this operation, you reduce your data to segments (short epochs) that fall into different categories. You define the criteria for the categories. Each category is temporally referenced to an event of interest, for a specific experimental condition of interest. You specify the duration, before and after the event, to include in the segment. You will learn how to do this in Chapter 9, "Segmentation."

- *Artifact detection*: In this operation, you automatically detect and mark bad channels and bad segments (segments that are contaminated by artifacts). You will learn how to do this in Chapter 10, "Artifact Detection."

- *Bad channel replacement*: In this operation, you replace the data in bad channels with data interpolated from the remaining channels. Bad channel replacement is based on the idea that, because of electrical volume conduction, channels in proximity to each other have similar data. This approximation increases in

validity as channel count increases. For 128 or 256 channels, the results of bad channel replacement are quite good, but for channel counts less than 64, considerable and serious errors exist in the reconstructed data. You will learn how to replace bad channel data in Chapter 11, "Bad Channel Replacement."

- *Averaging*: In this operation, you calculate a single, average segment from all the segments that were not rejected, for each category that you created during segmentation. You will learn how to do this in Chapter 12, "Averaging."

- *Average referencing*: In this operation, you rereference the data to an average of all the channels. The purpose of average referencing is to minimize the influence of the arbitrary recording reference channel on the data set. Also, because of the dipolar nature of brain sources, the average voltage over the entire surface of the head is zero. As channel counts increase, the average of all the channels approaches this ideal zero reference. You will learn how to do this in Chapter 13, "Average Referencing."

- *Baseline correction*: In this operation, you establish a baseline interval within your segment. You select the interval to use as the baseline. For stimulus events, the baseline interval normally precedes the stimulus. For each channel, the average of all the samples within the baseline interval is subtracted from every sample in the segment. This baseline value establishes a new zero-voltage value. You will learn how to do this in Chapter 14, "Baseline Correction."

Most of the operations require you to specify parameters. For example, filtering requires you to specify the frequencies to filter out.

Data-Analysis Path Issues

We define *data-analysis path* as the order in which you perform the operations, and the parameters. In this tutorial, you will perform the operations in the order listed in the preceding "ERP Derivation Operations" section.

For example, rereferencing and baseline correction are done *after* averaging. Although this is the same as performing rereferencing and baseline correction *before* averaging, it requires fewer computer resources. However, if you are interested in exploring individual trials, then you might prefer to do rereferencing and baseline correction before averaging. This tutorial assumes you are *not* interested in exploring individual trials.

It is best to design your data-analysis path so that the processed data that you are interested exploring are available in both the baseline-corrected and non-baseline-corrected form. That way, you can understand the effects of the baseline correction. *Note that you cannot undo the baseline-correction operation.* Therefore, baseline correction should be done as the last step before exploring the processed data.

For example, if you are interested in exploring both individual subject averages, and grand averages, the grand averages should be derived from the non-baseline-corrected, individual-subject averages. The baseline correction can be performed separately on both the individual-subject averages and grand averages. That way, you will have both baseline-corrected and non-baseline-corrected versions of both the individual-subject averages and the grand averages. If you derive your grand average from baseline-corrected, individual-subject averages, you will not have a non-baseline-corrected grand average. This approach is taken in the tutorial.

When you start analyzing data from an experiment, it usually takes some trial and error to find the order of operations and parameters that is best for you. To determine your optimal data-analysis path, it is advisable to first carefully process the data from a single subject to

- verify that you can do what you want to do (you may learn that you need to modify your experimental control script) and

- learn the effects of the various operations and their parameters

Once you have processed the data from one subject, you can process the data from the remaining subjects in a more automated fashion. This is the approach taken in this tutorial. In Chapters 8 through 14, you will learn to analyze the data from a single subject. Then, in Chapter 15, "Scripting," you will learn how to automate the processing of the remaining subjects.

Once you have ERPs from several subjects, you can create grand-average ERPs. You will learn how to do this in Chapter 16, "Combine and Grand Averaging."

Waveform Tools Overview

In Net Station, you perform all of these operations using Net Station Waveform Tools. Each Waveform Tool, except Script, represents a specific operation or a set of closely related operations.

Before you can use a tool, you must create a tool specification using the specification editor for the tool. In the specification editor, you edit fields to specify the operation parameters. For tools that create new files, as most tools do, you also specify the output options and the name and location of the output files in the specification editor.

To perform an operation on your data, you first select the input data and tool specification and then run the tool.

You use the Waveform Tools window to run the tool operations and to open tool specification editors for creating and editing tool specifications. In Chapter 8, "Filtering and Using Waveform Tools," you will learn the basics of using Waveform Tools. The remaining chapters assume you know the basics taught in Chapter 8.

Script is a special tool for automating your ERP derivation by chaining tool operations together. Script is similar to the other tools in that you use the Waveform Tools window to launch a scripting specification editor and to run the script. You will learn how to use the Script tool in Chapter 15, "Scripting."

Chapter Review

Before proceeding to the next chapter, it is important that you understand these terms, which were introduced in this chapter:

- average ERP (single subject)
- filtering
- artifact detection
- averaging
- baseline correction
- operations
- data-analysis path
- tool specification
- output options
- grand-average ERP
- segmentation
- bad channel replacement
- average referencing
- grand averaging
- parameters
- Waveform Tools

- tool specification editor
- scripting

FILTERING AND USING WAVEFORM TOOLS

In filtering, you filter out activity in frequencies that are not of interest. Traditional ERP research, for example, has focused on brain activity in frequencies below 30 or 40 Hz. Note that if you do a lowpass filter in this range, then the 50 Hz or 60 Hz line noise will be filtered out, so there is no need to apply a notch filter.

Create a Filtering Specification

Before you can filter your recordings, you must create a Filtering specification.

1 If necessary, start Net Station.

To create a tool specification, you will open the Waveform Tools window (Figure 8-1), open a specification editor for the tool, name the specification, edit the output options (if applicable), edit the tool-specific parameter fields, and close the editor, saving the specification.

Editing the Specification

1 Open the Waveform Tools window. You can do this by choosing **Tools > Waveform Tools**. If the Net Station start-up window is present, you can also do this by clicking the Waveform Tools button.

2 Open a Filtering specification editor by clicking the Create button and choosing Filtering from the pop-up menu (see Figure 8-1).
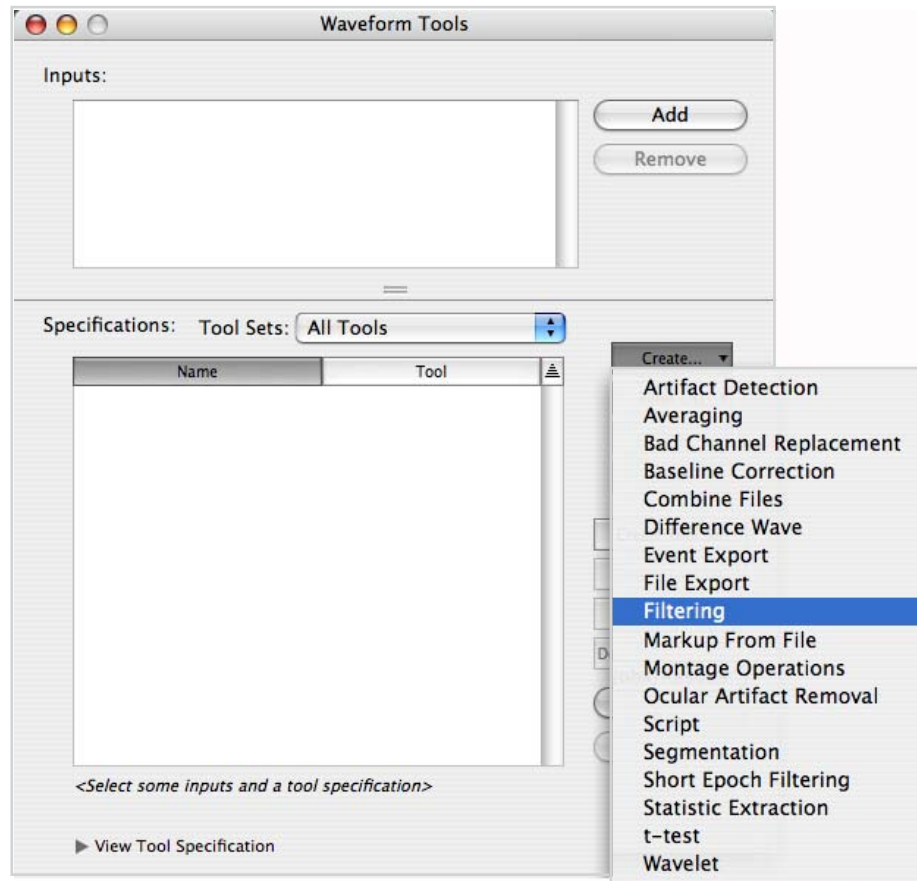
Figure 8-1. Create a Filtering tool in the Waveform Tools window

3 Name the Filtering specification "Lowpass 40 Hz" by editing the Filtering Specification Name text box. Deselect the Auto Set Name checkbox so the name you have chosen will not be overridden when you set the filter slider.

Edit the output options using the Output Options panel:

4 Set the name to Append ".40" as follows: Click the Name pop-up menu and choose Append Extension. When the input box appears, type ".40" and click OK.

5 Set the destination to Same As Source by using the Destination pop-up menu.

Setting the Tool-specific Parameters

Edit the Filter Settings panel in the middle of the specification editor:

1 Select the Lowpass checkbox to activate the slider.

2 Drag the Lowpass slider until the display to the right of the slider says 040.0.

Notice that you can also specify highpass and notch filters with this tool. To edit the Filtering specification further, click the Options button to open the Filter Options window (Figure 8-2).
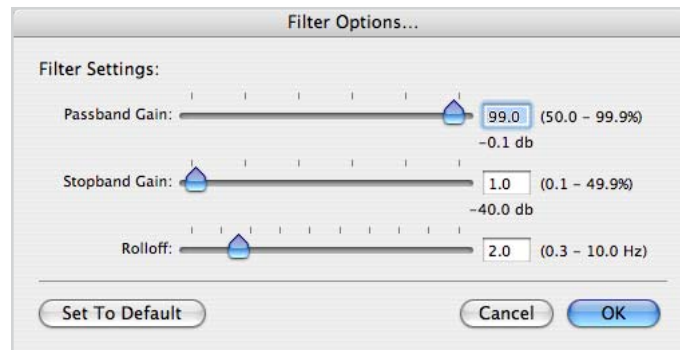
Figure 8-2. Filter Options window

Figure 8-2 displays the default values for passband gain, stopband gain, and rolloff. This tutorial uses the default values so click OK to close the window and to return to the specification editor window.

3 The Cycle Channels checkbox is selected by default. Leave it selected. The Unfiltered and Filtered windows will automatically display one channel after another in numerical sequence if you use the Preview Filtering feature.

Your Filtering specification is now fully defined. Figure 8-3 shows the finished Filtering specification.
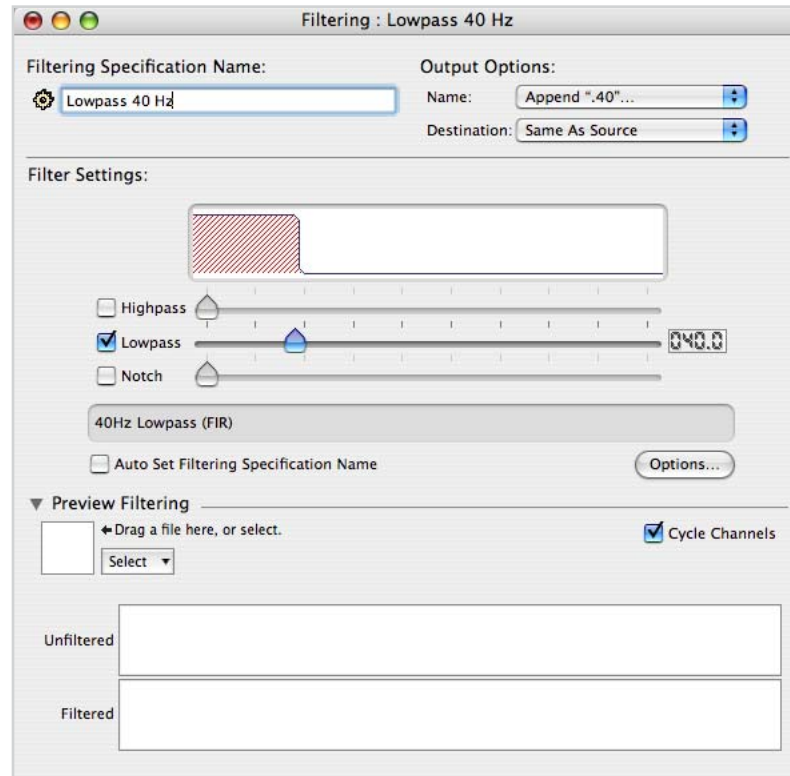
Figure 8-3. Filtering specification editor

4 Close the Filtering specification editor by clicking its close button (the red button in the upper-left corner of the window). When a dialog appears, asking if you want to save the changes, click Save.

Your new specification appears in the Specifications panel of the Waveform Tools window. You can edit the parameters of a tool specification by double-clicking on the tool name, which opens the specification editor.

Run the Filtering Tool

To perform an operation on your data, you first select the input data and tool specification and then run the tool.

1 Click the Add button in the Inputs panel of the Waveform Tools window. When the file-selection dialog appears, navigate to the file ATD256_1.ses and select it.

2 Click Add. (Another way to add files to the Inputs list is to drag them there from the Finder.)

The file-selection dialog disappears, and the file you selected appears in the Inputs list (Figure 8-4).
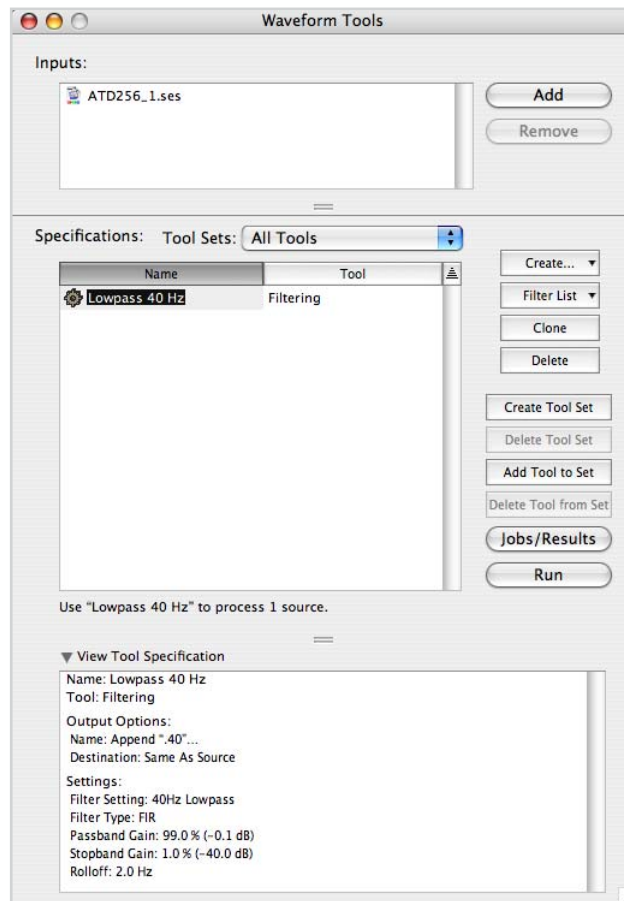
Figure 8-4. Choosing a tool and adding an input file in the Waveform Tools window

3 In the Specifications panel of the Waveform Tools window, highlight the Lowpass 40 Hz specification by clicking on it.

4 Click the Run button to begin filtering the file. (If you had wanted to run the filtering tool on multiple files, you would have added them to the Inputs pane, highlighted the Lowpass 40 Hz specification in the Specification pane, and then clicked Run.)

5 The Jobs and Results window automatically appears, allowing you to track the progress while the tool is running (Figure 8-5).
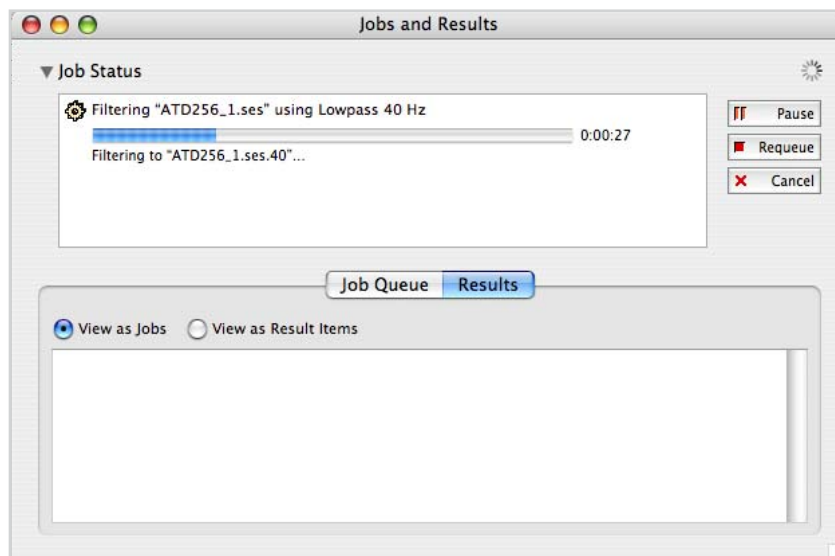
Figure 8-5. Jobs and Results window

The Jobs and Results window contains two tabbed panes.

The Job Queue pane shows you the queue of jobs, the progress of the current job, and the results of all jobs run during the current Net Station session. If an error occurs, more information about the error is provided in the Results panel. This is particularly helpful if you are running multiple jobs.

The Results pane allows you to view results in two ways: as Jobs, and as Result Items. For now, click the View as Jobs radio button. When your filtering job is completed, you should get a Results item with a green rectangle to the left, indicating success. (Errors are indicated by red rectangles.)

View the Results

In this section of the chapter, you will view the results of filtering on your data by comparing the filtered file with the original file.

1 Open the original file ATD256_1.ses in the Net Station Viewer.

You can use the Jobs and Results window as a shortcut for opening files that are the results of operations performed in the current Net Station session.

2 Open the result file ATD256_1.ses.40 by double-clicking on the entry in the Results pane of the Jobs and Results window.

Arrange the two Viewer windows horizontally as you did in "Recognizing Line Noise" in Chapter 5. You can now compare the original data with the filtered data and see the results of the filtering. For the best comparison, apply the 60 Hz IIR notch filter to the original data, as you learned in Chapter 5 (Figure 8-6).
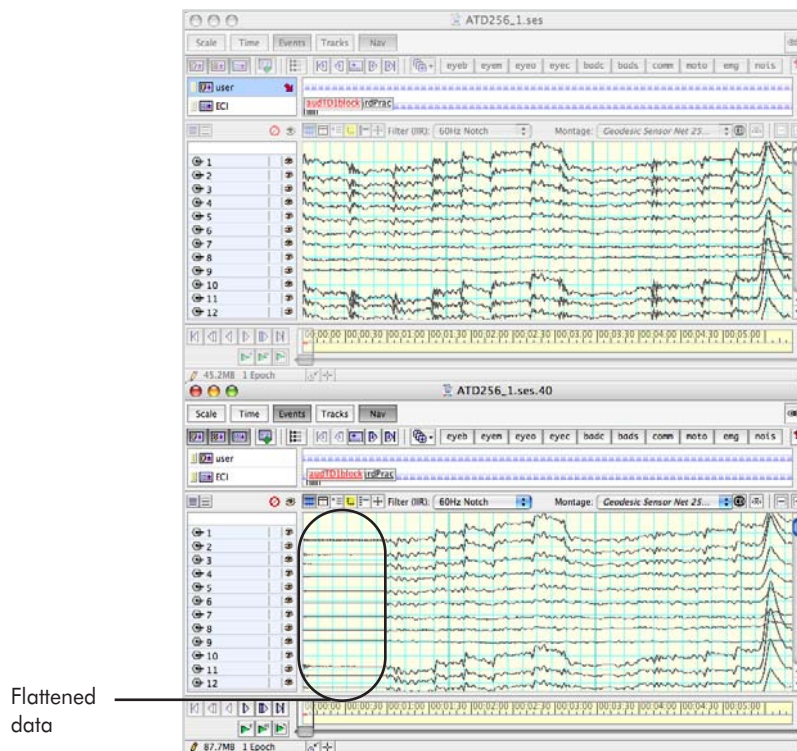
Figure 8-6. Comparing the filtered (bottom) and unfiltered (top) data

Note that the first and last 560 ms of the filtered data are flattened. The Filtering tool does this because at the beginning and end of the file, there is not enough data to do filtering without distortion in the form of ringing. The number of samples that get flattened at the beginning and ending of the file depends on the filter's rolloff.

3 Close both files.

SEGMENTATION

In segmentation, you reduce your data to segments (short epochs) that fall into different categories. You define the criteria for the categories. Each category is temporally referenced to an event of interest, for a specific experimental condition of interest. You specify the duration, before and after the reference event, to include in the segment.

This chapter takes you through a simple segmentation example. Segmentation can become complicated, depending on the event or event duration on which you wish to segment. For more information, see the "Segmentation" chapter in the *Net Station Waveform Tools Technical Manual*.
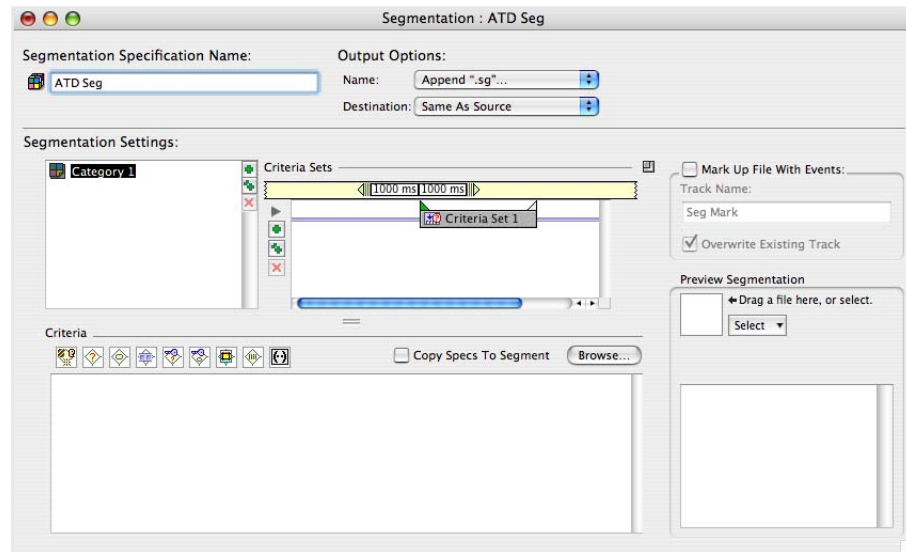
Create a Segmentation Specification

Before you can segment your recordings, you must create a Segmentation specification.

Editing the Specification

1 If necessary, start Net Station and open the Waveform Tools window.

2 Open a Segmentation specification editor and name the Segmentation specification "ATD Seg" (for auditory target detection segmentation).

3 In the Output Options panel, set the name to Append ".sg" (for segmentation) and the destination to Same As Source (Figure 9-1).

Figure 9-1. Setting up the Segmentation specification editor

Note: To prevent overly long filenames, this tutorial uses extensions that are shorter than the default extensions (e.g., ".sg" instead of ".seg").

Setting the Tool-specific Parameters

Next, you will define your segmentation rules. Your goal is to create two categories, each referenced to the stimulus-tone event: one for standards correct trials, and the other for targets correct trials.

Because your desired categories are similar, you can save time by defining one category in full before proceeding to the other. Then, you can use the duplication feature to create the other category.

1 In the Category list just below the Segmentation Settings label, click on Category 1. The name background will turn a different color, indicating that you can change the name. Type in "Standard Correct".

Now, edit the event criteria for this category, using the Criteria pane.

2 Click the Browse button.

Figure 9-3. Event condition panes

6 Click the Codes tab, and in the Codes pane look for 'ast_', the code that refers to the ATD standard condition.

7 Click on the line that says Code is 'ast_' and drag it to the edit portion of the Criteria pane of the Segmentation specification editor.

8 In the Browse Event Criteria window, click the Specs tab. You are now looking for the trial specification that refers to a correct trial. Based on the coding of the E-Prime experiment, Trial Spec 'Response Evaluation' is 1 is the correct trial specification. Drag this line to the edit portion of the Criteria pane (Figure 9-4).
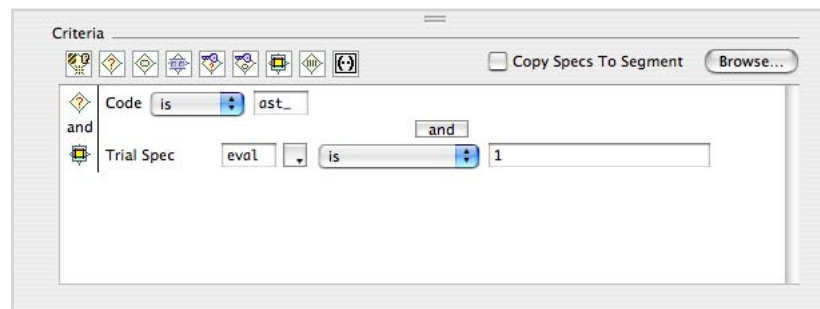
Figure 9-4. Populating the Criteria pane

9 Close the Browse Event Criteria window by clicking its close button.

If you know the event structure of the recording, you can do the equivalent of the preceding steps by dragging criteria icons from the top of the Criteria pane into the edit portion of the Criteria pane, and then filling in the input boxes.

10 Select the Copy Specs To Segment checkbox to the left of the Browse button in the Segmentation specification editor. This causes each resulting segment to contain a copy of the trial-specification data associated with that segment.

Now, specify how many milliseconds to keep before and after the stimulus onset.

11 Click on 1000 ms in the yellow time bar, to view the "segment length" pane.

12 Set the Segment Length Before box to 100 Milliseconds.

13 Set the Segment Length After box to 500 Milliseconds (Figure 9-5).
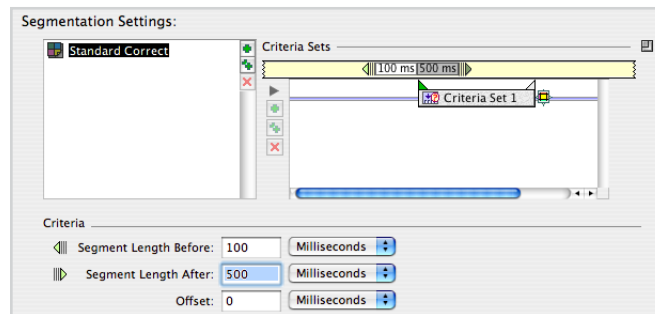
Figure 9-5. Specifying the segment length

The Standard Correct category is now fully defined.

Duplicating and Defining

Next, define the Target Correct category by duplicating and editing the first category.

1 Duplicate the Standard Correct category by clicking the ++ button ( ). You will see a new category named Standard Correct Copy.

2 Click on this new category. The name background will change color, indicating that you can change the name. Type "Target Correct."

3 The category is already defined in terms of criteria and segment length. All that remains to be done is to change the condition to correspond to the target stimulus rather than the standard stimulus. In the Criteria pane, change "ast_" to "atg_" to finish defining the Target Correct category.

Previewing the Specification

Before you close your specification, it is a good idea to preview segmentation. This gives you an opportunity to verify that your categories are defined correctly.

1 In the Preview Segmentation pane in the lower right of the Segmentation specification editor, click the Select button and select Other.

2 Navigate to ATD256_1.ses.40. Either double-click on the file name or highlight the name and click the Open button.

3 Net Station will scan the file for the categories that you have defined. Verify that you see the following results (Figure 9-6):

- *Standard Correct 317 segments*
- *Target Correct 82 segments*
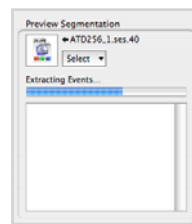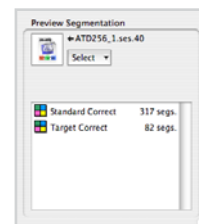
Figure 9-6. Previewing the Segmentation specification

Your Segmentation specification is now fully defined. Figure 9-7 shows the finished Segmentation specification.
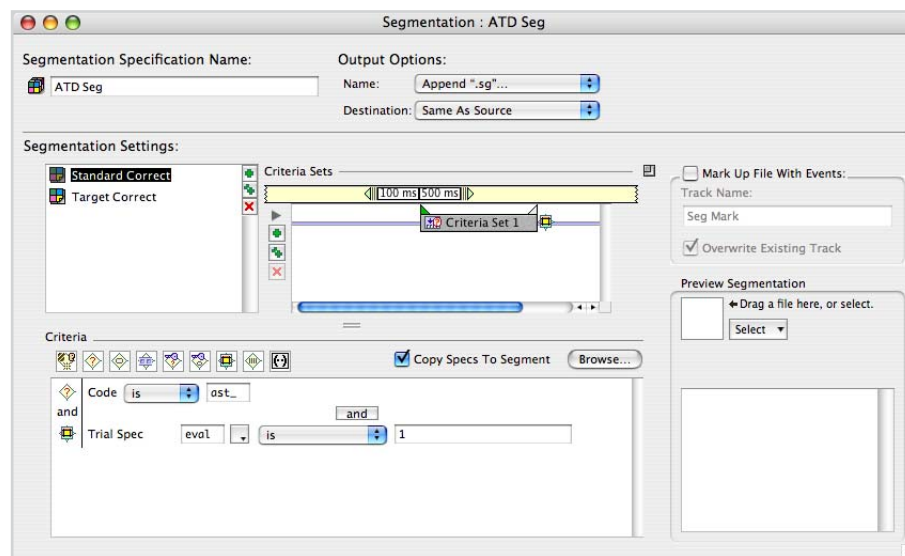
Figure 9-7. A defined Segmentation specification

4 Close the Segmentation specification editor, saving the changes.

Note: In this experimental design, you can distinguish standard trials from target trials by the code for the stimulus event. Many experiments are designed with the following, different strategy: All stimulus events have the same code (e.g., 'stim') and the cell is used to distinguish standards from targets. In that case, the event criteria would be different. Standard trials would be those whose

- *code is 'stim' and*
- *cell is 'Standard'*

Target trials would be those whose

- *code is 'stim' and*
- *cell is 'Target'*

Note that the above criteria does not include the constraint that the trials are correct.

Run the Segmentation Tool

In this section, you will run the Segmentation tool.

1 In the Waveform Tools window, add the ATD256_1.ses.40 file to the Inputs pane. There are several ways to do this:

  ° Click the Add button in the Waveform Tools window and navigate to the file.

  ° If the file is still in the Results pane of the Jobs and Results window, drag it from there to the Inputs pane of the Waveform Tools window.

  ° Drag it from the Finder into the Inputs pane of the Waveform Tools window.

2 Highlight the ATD Seg specification in the Specifications pane of the Waveform Tools window, and click the Run button.

View the Results

In this section of the chapter, you will learn to use Net Station Viewer features to view segmented files, and learn how to mark artifacts manually.

1 Open the result file ATD256_1.ses.40.sg.

2 If necessary, select the Navigation control-strip disclosure toggle to display the Navigation control strip (Figure 9-8).

Figure 9-8. Viewing segmented data

Notice that the data display contains equally spaced vertical lines. These lines separate the segments that you have created.

A useful way of viewing segments is as categories. This viewing option is available only for files that have been segmented.

3 Choose **View > as Categories**.

With this viewing option, you see one segment at a time (Figure 9-9). Also, a new set of controls appears in the Navigation control strip.
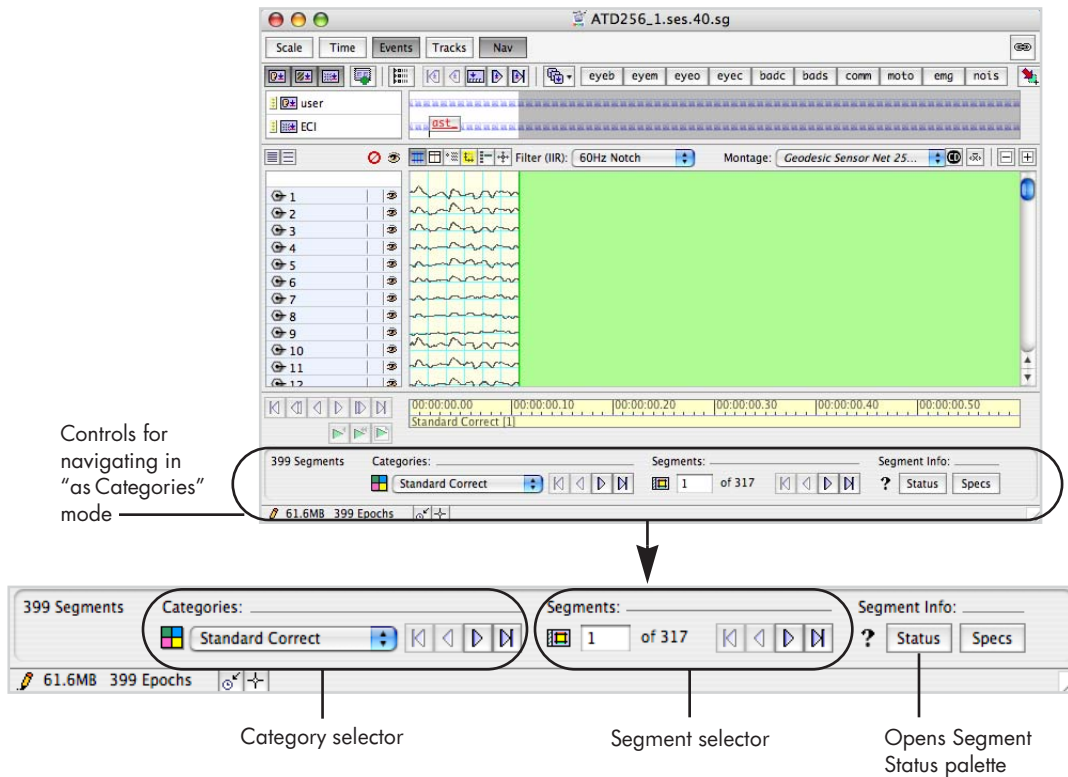
Figure 9-9. Viewing segmented data in "as Categories" mode

The category selector contains controls for traversing through the categories. The segment selector contains controls for traversing through the segments within the selected category. The controls to the left of the category selector step through all the segments sequentially, sorted by category.

Note that the category selector contains the two categories that you created in your Segmentation specification: Standard Correct and Target Correct.

4   Select each category and notice how many segments appear in the segment selector. These are the same numbers (317 Standard Correct and 82 Target Correct) you saw earlier when you previewed the segmentation.

5   Experiment with the different ways of navigating through the segments by clicking the various navigation buttons.

The best time mode in which to view segmented data is Segment Time. In this mode, time zero for each segment is the sample containing the event to which the segment is temporally referenced. Samples before time zero have negative time values.

6 Set the time mode to Segment Time by using either the Time menu or the Time control strip.

When viewing "as Categories," you can manually mark artifacts, such as:
- marking segments bad
- marking channels bad in individual segments
- marking channels bad in all segments

This information is used in operations that you will perform later (for example, artifact detection and bad channel replacement).

To mark segments bad, use the Segment Status palette.

7 Open the Segment Status palette by clicking the Status button located in the lower right of the Navigation control strip (see Figure 9-9).

Note that the question mark button of the Segment Status palette is selected (Figure 9-10). This indicates that Net Station does not yet know the status of the segment (that is, if the segment is good or bad). Observe that the Segment Status icon to the left of the Status button in the Navigation control strip is also displaying a question mark.

Figure 9-10.
Segment Status palette

You can change the segment status with the Segment Status palette. To mark the segment good, click the green light icon. To mark the segment bad, click the red slash-circle icon. To return the segment to the unknown status, click the question mark icon. The Segment Status icon to the left of the Status button in the Navigation control strip changes to reflect the setting.

8 Click the disclosure triangle of the Segment Status palette.

You now have a selection of status specifiers you can use to specify why segments are bad (Figure 9-11). These are dimmed (disabled) unless the channel is marked bad. You have the following choices:

- *badc*: bad channel
- *bads*: bad segment
- *comm*: comment
- *emg*: electromyograph (muscle artifact)
- *eye*: eye-blink artifact
- *eyem*: eye-movement artifact
- *moto*: motion artifact
- *nois*: noisy segment

In this way you can mark by hand which segments you want in the rest of your analysis. However, in this tutorial, you will use the Artifact Detection tool to detect the bad segments for you.
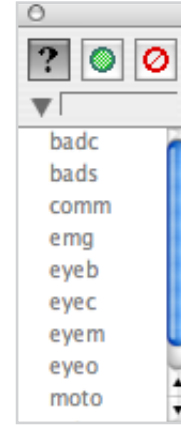
Figure 9-11. Segment Status palette expanded

9 If necessary, return the segment status to the unknown status and close the Segment Status palette.

Artifact Detection can set the following specifiers: badc, eyeb, and eyem. The other specifiers are available for manual use.

To mark a channel bad manually in the segment current displayed in the Viewer, click the bad channel tile for the channel (Figure 9-12).

Select toggle to mark or unmark channel as bad in segment
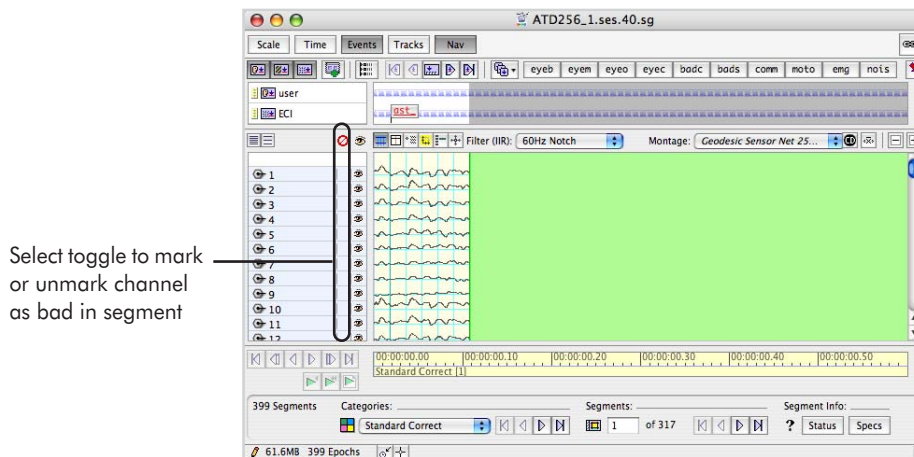
Figure 9-12. Marking channels bad manually

To mark a channel bad for the entire file, press the Option key while clicking the bad channel tile for that channel. When the cursor is hovering over a bad channel tile, it takes the form of the slash-circle icon. When you press the Option key while the cursor is hovering over a bad channel tile, the cursor's slash-circle icon sprouts arrows pointing to the left and right, indicating that you are poised to mark the channel bad for the entire file.

Once again, instead of marking any channels bad right now, you will use the Artifact Detection tool.

10 Close the file.

ARTIFACT DETECTION

In artifact detection, you automatically detect and mark *bad channels* and *bad segments* (which are segments that are contaminated by artifacts).

The Artifact Detection specification editor consists of two main sections (see Figure 10-1 on page 99).

- The first is the Threshold Artifact Detection Settings section, where you specify the parameters for detecting bad channels, eye movements, and/or eye blinks.

- The second is the Perform Inferences section, where you specify what inferences to make of the results produced by the Threshold Artifact Detection Settings section (e.g., whether to mark segments "bad" if they contain an eye movement or eye blink).

During operation, the Artifact Detection tool excludes:

- bad eye channels when detecting eye blinks and eye movements
- eye-blink segments when marking channels bad for the entire recording
- channels marked bad for the entire recording when marking bad segments

Threshold Artifact Detection Settings

In the Threshold Artifact Detection Settings section, the tool *detects and marks* bad channels and only *detects* eye blinks and eye movements.

To detect bad channels, eye blinks, or eye movement, the tool uses the data from each channel, eye-blink pair, or eye-movement pair, respectively. The tool can use either thresholds or moving averages (combined with thresholds) to detect artifacts.

If you choose the threshold option, the tool:

- runs through the channels,
- takes the data from the user-specified window,
- subtracts the minimum microvolt value from the maximum value, and
- compares the difference against the user-specified threshold in the Threshold Artifact Detection Settings section.

The moving-average option "smooths" the data to prevent any noisy sample from having too much influence in the algorithm. If you select this option, the tool performs the same steps as the threshold option, *except it performs a moving average on the data before subtracting the minimum microvolt value from the maximum value.*

Log File

After applying the Threshold Artifact Detection Settings to your data, you can view the artifact-detection results in a text-based log file output by the tool.

The log file contains failure records listing the channel number, segment number (if applicable), settings to the parameters in the threshold specification, and offset into the segment (if applicable) in which the failure occurred.

Perform Inferences

The Perform Inferences section allows you to specify criteria for either segmented or continuous data.

For segmented data, you can specify the criteria that will mark a segment bad because of bad channels, eye blinks, and eye movements. For continuous data, you can specify the criteria that will mark eye blinks and eye movements.

Eye Blinks or Eye Movements in Segmented or Continuous Data

To prevent bad eye channels from incorrectly influencing the marking of eye blinks or eye movements, the Perform Inferences section runs an algorithm that detects and discards segments or samples with bad eye channels and then runs through the remaining data, marking any threshold-violations as eye blinks or eye movements.

Bad Segments from Bad Channels

To prevent channels that are bad for the entire recording from being incorrectly marked as bad in a segment, the Perform Inferences section runs an algorithm that detects and discards these channels from the data. It sums up the number of bad channels per segment in the remaining data, and marks the segment or sample bad if it exceeds the threshold.

There is an important relationship between the number of bad channels marked and the number of bad segments derived. Specifically, the *more* bad channels allowed in the "Mark channel bad in recording if bad for greater than X percent" option in the Perform Inferences section, the *fewer* bad segments you will have.

The reason is that if a channel is borderline bad, and it is not marked bad for the entire recording, then the channel will be marked bad in many segments. Consequently, in those segments, there is an additional bad channel that could trigger the maximum-number-of-bad-channels criterion.

The default values for the Artifact Detection specification are typically sufficient. You will use them in this tutorial. (For more information about the artifact-detection algorithm, see Chapter 4, "Artifact Detection," in the *Net Station Waveform Tools Technical Manual*.)

Create an Artifact Detection Specification

Editing the Specification

Before you can perform artifact detection on your recordings, you must create an Artifact Detection specification.

1 If necessary, start Net Station and open the Waveform Tools window.

2 Open an Artifact Detection specification editor and name the Artifact Detection specification "Artifact Detection".

3 In the Output Options panel, set the name field to Append ".log" and the destination field to Same As Source. The Output Options panel applies *only to the Threshold Artifact Detection log file* (see "Log File" on page 96).

Note: The Artifact Detection tool does not create a new result file containing modified EEG data. It adds markings to an existing file.

Setting the Tool-specific Parameters

In this tutorial, you will use the ***default settings*** for the tool-specific parameters.

1 The Threshold Artifact Detection Settings section is blank. Click the "Add" button (the green "Plus" button to the right of the section) three times to populate the section with three panes. From the Operation pop-up menu in the panes, choose Bad Channels, Eye Blink, and Eye Movement (see Figure 10-1).

The default values in the Threshold Artifact Detection Settings and Perform Inferences sections are sufficient for this tutorial.

2 The Threshold Artifact Detection Settings and Perform Inferences sections contain checkboxes labeled "Overwrite all. . . ." If all these checkboxes are selected, then all prior threshold records, bad channel markers, and bad segment markers from previous artifact detection (whether created manually or with this tool) are cleared. This is useful if you ran the tool before and now want to run it with a different specification.

By default, the "Overwrite" checkbox is selected in the Threshold Artifact Detection Settings section and unselected in the Perform Inferences section.

3 If the "Output log file" checkbox at the bottom of the Threshold Artifact Detection Settings section is selected, a Threshold Artifact Detection log file is automatically generated after the tool is run (see "Log File" on page 96). By default, this checkbox is selected.

4 The Restrict Search pane allows you to limit the amount of the segment that is checked for artifacts (which can be useful for long segments that may contain artifacts outside the range of interest). By default, the artifact search region is unrestricted.

Your Artifact Detection specification is now fully defined. Figure 10-1 shows the finished Artifact Detection specification.
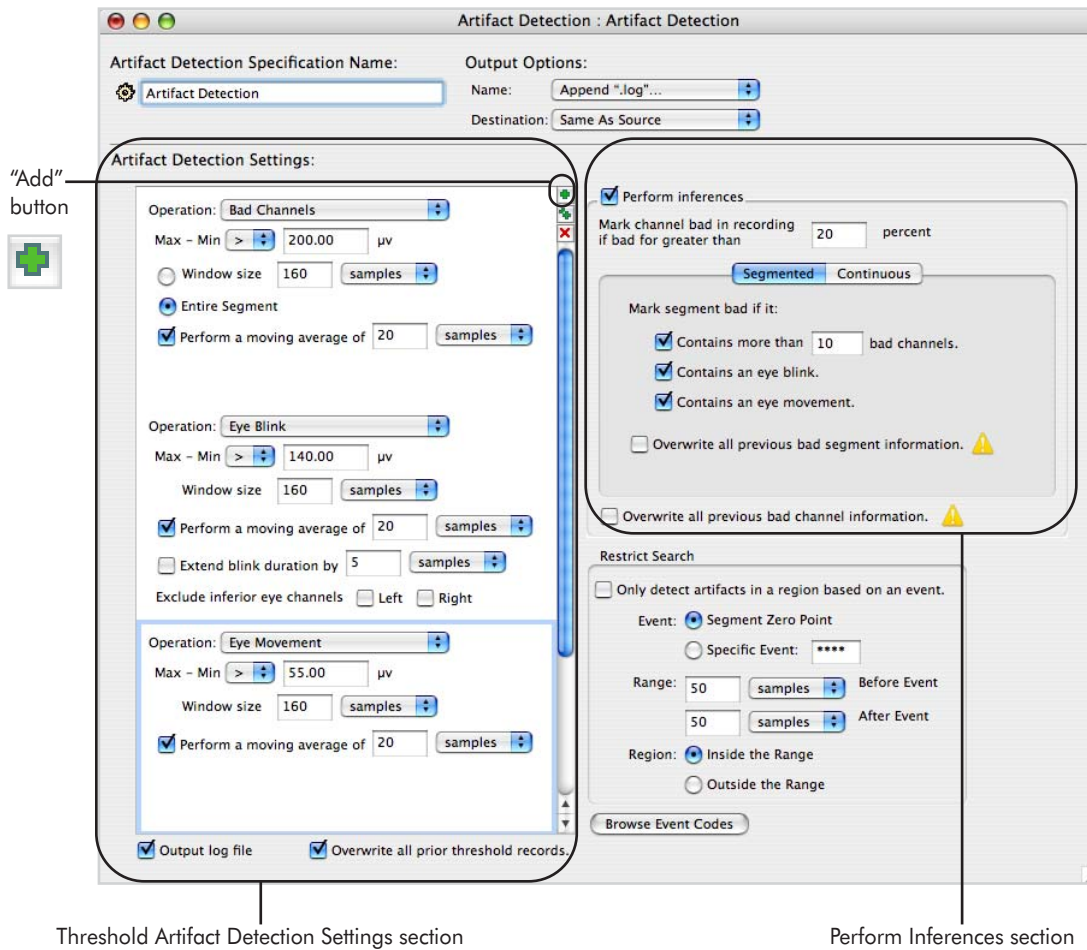
Figure 10-1. A defined Artifact Detection specification

5   Close the Artifact Detection specification editor, saving the changes.

Run the Artifact Detection Tool

In this section, you will run the Artifact Detection tool.

1 In the Waveform Tools window, add the ATD256_1.ses.40.sg file to the Inputs pane. There are several ways to add a file to the pane; see "Run the Segmentation Tool" on page 88 for a description of each method.

2 Highlight the Artifact Detection specification in the Specifications pane of the Waveform Tools window, and click the Run button.

Remember that this operation does not output a new result file, but instead modifies the input file by adding markings.
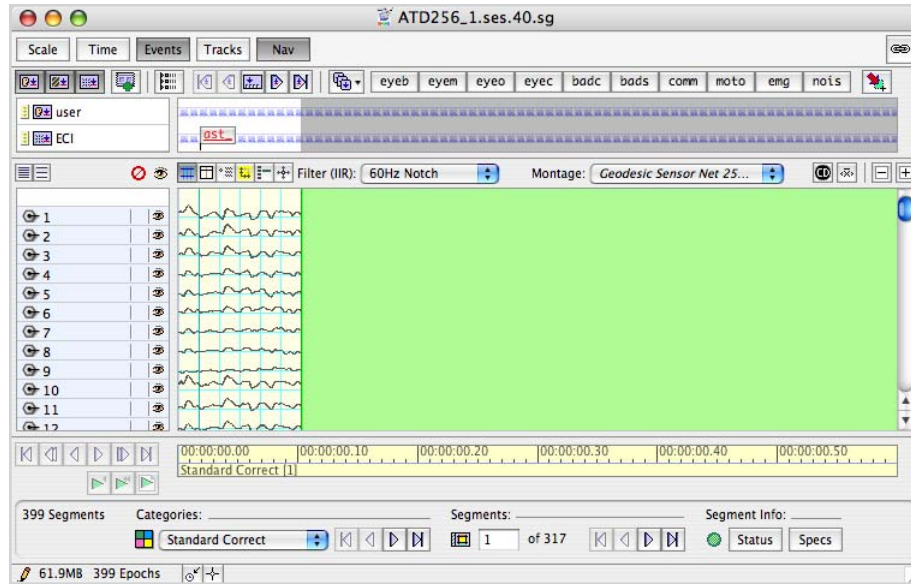
View the Results

In this section of the chapter, you will learn about Grid view and how to use Net Station Viewer and the File Info dialog to explore the results of your artifact detection.

Introducing Grid View

1 Open the result file ATD256_1.ses.40.sg.

2 If necessary, choose **View > as Categories**, display the Navigation control strip, and set the time mode to Segment Time (Figure 10-2).
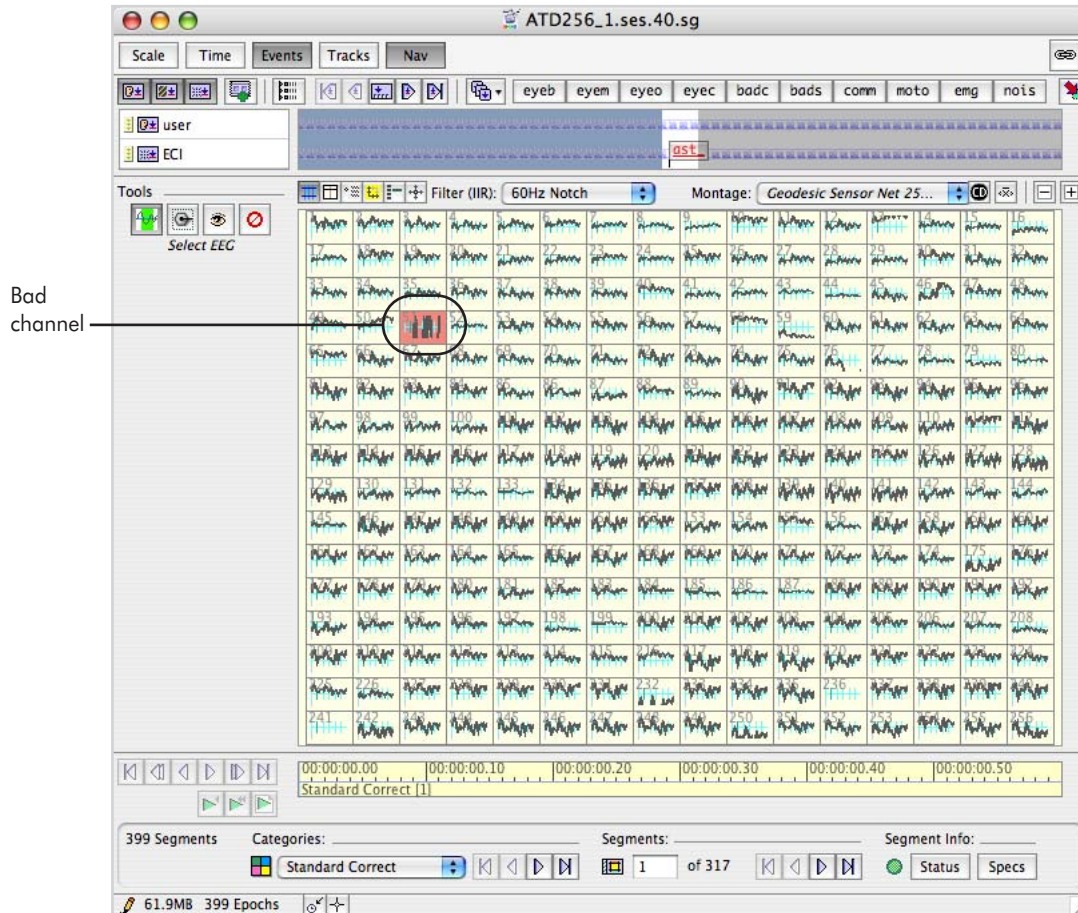
Figure 10-2. The result file displayed in Chart view

So far, you have used only Chart view of Net Station Viewer. Chart view is most similar to the view you have during acquisition. However, Net Station Viewer has four other views, each with different advantages.

Grid view offers a useful way to look at bad channels because you can see all the channels at once, sorted by channel number. The bad channels stand out because their data look very different from the data in all the other channels. Channels marked bad (either manually or by the Artifact Detection tool) for the segment you are looking at are indicated in pink.

3 Choose **View > as Grid**.

4 Choose **Time > Fit Segment To Window**, to allow you to see the entire segment without scrolling (Figure 10-3).

**Figure 10-3.** The result file displayed in Grid view

5 Randomly inspect some segments, noticing how the bad channels are colored to stand out in this view.

6 Turn off the Fit Segment To Window setting.

7 Return to Chart view by choosing **View > as Chart**, and return the time scaling to 60 mm/sec.

Using the File Info Dialog

The File Info dialog has some useful features for inspecting bad channels and bad segments.

1 Choose **Edit > File Info**, to open the File Info dialog.

2 Click the Categories tab.

3 In the View pop-up menu, choose Bad Channels.

4 In the Mode pop-up menu, choose Count Segments for Which Channel is Bad.

In the list that appears, you can see how many segments each channel is bad in. Notice that most channels are bad in *none* of the segments. A handful of channels are bad in 1–3% of the segments. Channel 51, which you saw was bad in Chapter 5, "Recognizing Noise," is bad in 100% of the segments. It, therefore, is marked bad for the entire recording (Figure 10-4).
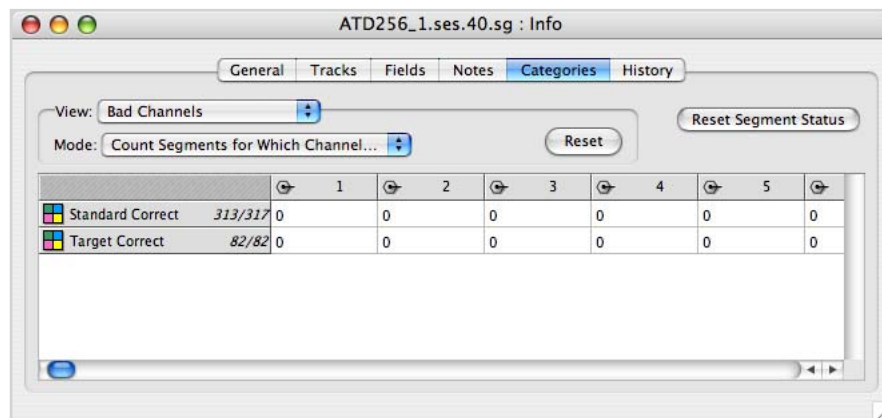
Figure 10-4. Channel 51 is marked bad in the Categories pane of the File Info window

5 In the Mode pop-up menu, choose List Bad Channels Per Segment.

You now see a list, rather than a count, of the bad channels.

Arrange your EEG display and File Info dialog horizontally as illustrated in
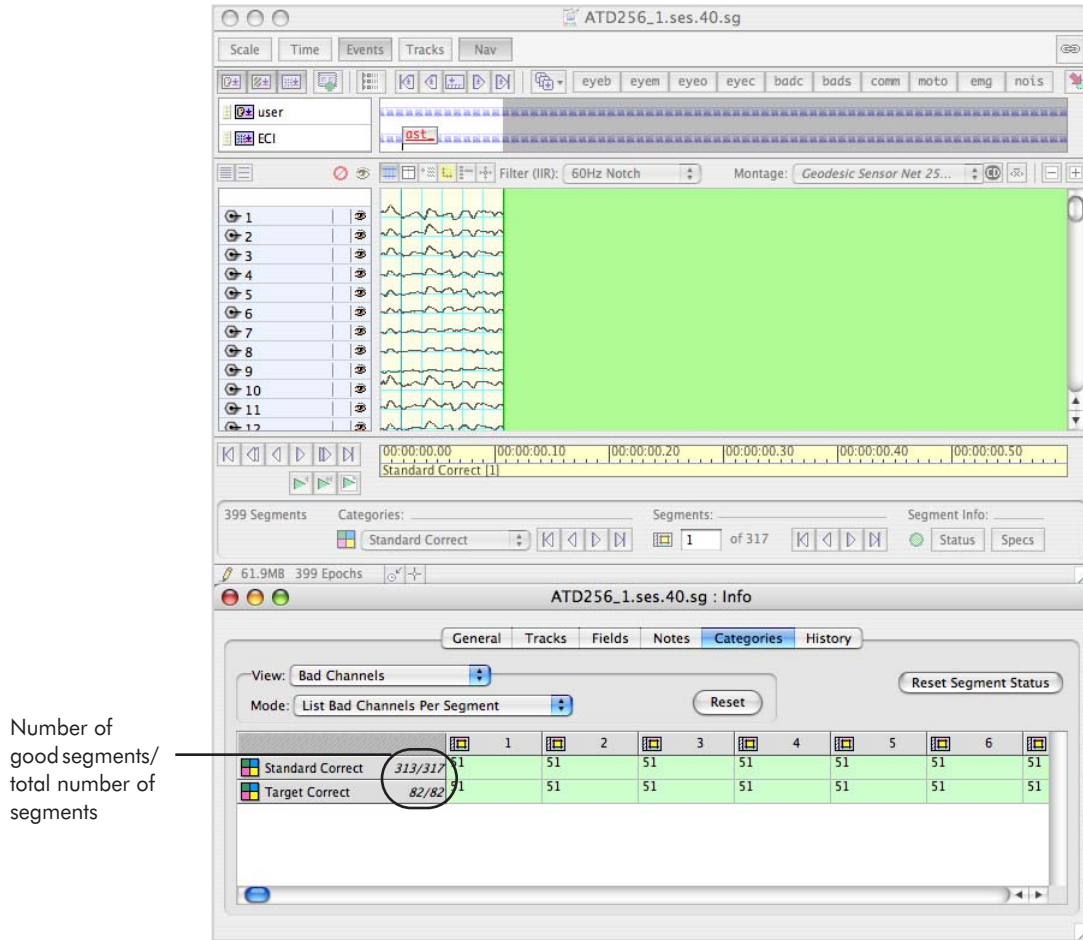Figure 10-5.

Figure 10-5. The EEG display (top) and File Info dialog (bottom)

The numbers (313/317) next to Standard Correct indicate that 313 out of 317 trials in
this category are good. In other words, this category contains four bad segments.
Similarly, you can see that the Target Correct category contains no bad segment. The
table of segments is color-coded, with green representing good segments and pink
representing bad segments.

In the File Info window, scroll to Segment 15, which is colored pink in the Standard Correct category, indicating that it is bad.

6 In the Viewer, use the Navigation control strip to navigate to segment 15 in the Standard Correct category (that is, choose Standard Correct in the Category selector and type 15 in the Segment selector). Notice the bad-segment icon (![icon]) to the left of the Status button.

7 Click the Status button to open the Segment Status palette.

You can see that this segment was marked bad because a blink artifact was detected.

8 If necessary, select the Events control-strip disclosure toggle to display the Events control strip.

The User event track reveals that this is the period that you marked as a blink in Chapter 5, "Recognizing Noise." (See Figure 10-6.)
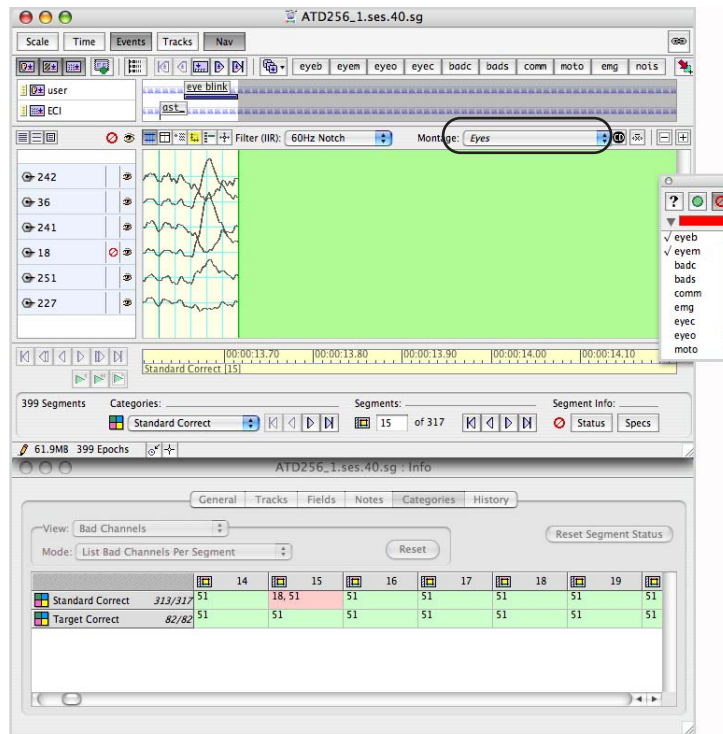
Stacking the windows allows you to find the bad segments in the Categories pane (bottom window) and to type in the segment number in the Segment selector in the Viewer (top window) so that you can go directly to that point in the data.
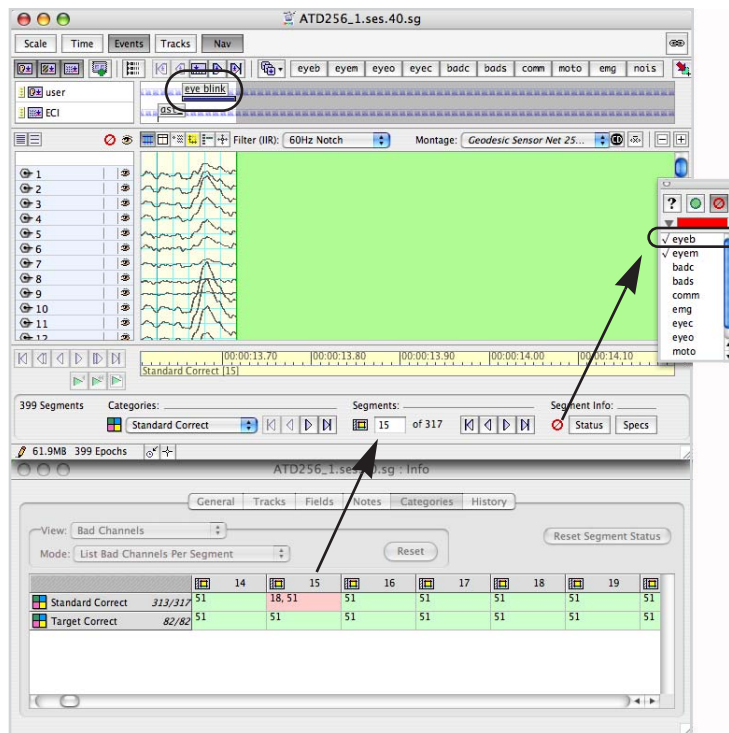
Figure 10-6. Segment 15 contains the eye blink marked earlier

Figure 10-7 shows this segment using the Eyes montage.

Figure 10-7. The Eyes montage in the Viewer allows an up-close view of the eye blink

9 Navigate to the next bad segment, segment 61 in the Standard Correct category.

This is also a blink artifact, as shown by the Segment Info panel and the data themselves.

If you want, you can inspect the remaining two bad segments, 122 and 223, in the Standard Correct category. They, too, are both blink artifacts.

Note: You need not go through this process every time. You can simply run the tools and review the final results. You are examining a few steps along the way to learn how to confirm that the program is performing correctly and to learn more about using Net Station Viewer.

10 Close the file.

Additional Artifact Correction Techniques

This section of the chapter discusses some additional artifact correction techniques you can try. Detailed descriptions of these techniques are beyond the scope of this tutorial, but they are described briefly here.

After averaging (discussed in Chapter 12), but before average referencing (discussed in Chapter 13), you can inspect the data for channels that do not look like their neighbors. The "View the Results" section in Chapter 11, "Bad Channel Replacement," describes how to do this. If you find channels that do not look like their neighbors, they might be bad channels that the artifact-detection algorithm missed.

If you find bad channels at this stage, you have several options:

- In the averaged file, mark the channels bad for the entire file, and then run Bad Channel Replacement. If you do this, you must do so before average referencing. Otherwise, the bad channels will influence the average reference.

- In the segmented file, mark the channels bad for the entire file, and then redo Artifact Detection, followed by the remainder of the ERP derivation process.

- With the segmented file, redo Artifact Detection with different parameters to see if you get better bad channel detection.

BAD CHANNEL REPLACEMENT

In bad channel replacement, you replace the data in bad channels with data interpolated from the remaining channels. Bad channel replacement is based on the idea that because of electrical volume conduction, channels in proximity to each other will have similar data. This *approximation* increases in validity as channel count increases. For 128 or 256 channels, the results of bad channel replacement are quite good, but for channel counts less than 64, considerable and serious errors exist in the reconstructed data.

The bad channel replacement algorithm operates on good segments only. For each good segment, it replaces every sample of every channel that is bad for that segment with data interpolated from the remaining channels. It uses spherical splines as the interpolation method.

Note: This implies that channels marked bad for the entire recording are replaced in every good segment, whereas channels marked bad for a subset of the segments are replaced only in the segments in which they are bad.
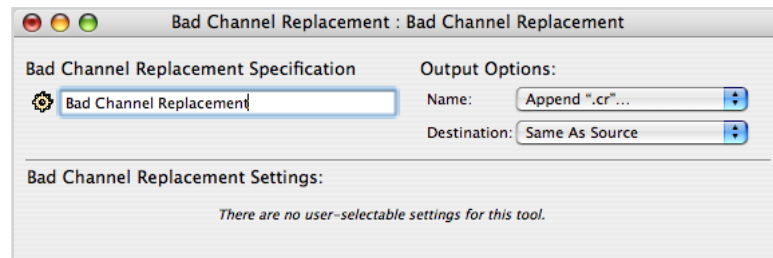
Create a Bad Channel Replacement Specification

Before you can perform bad channel replacement on your recordings, you must create a Bad Channel Replacement specification.

1 If necessary, start Net Station and open the Waveform Tools window.

2 Open a Bad Channel Replacement specification editor and name the Bad Channel Replacement specification "Bad Channel Replacement" (see Figure 11-1).

3 In the Output Options panel, set the name field to Append ".cr" (for channel replacement) and the destination field to Same As Source.

Note: To prevent overly long filenames, this tutorial uses extensions that are shorter than the default extensions (e.g., ".cr" instead of ".bcr").

Figure 11-1. Bad Channel Replacement specification editor

The Bad Channel Replacement tool does not take any tool-specific parameters, so you are now finished defining your specification.

4 Close the Bad Channel Replacement specification editor, saving the changes.

Run the Bad Channel Replacement Tool

In this section, you will run the Bad Channel Replacement tool.

1 In the Waveform Tools window, add the ATD256_1.ses.40.sg file to the Inputs pane. There are several ways to add a file to the pane; if necessary, see "Run the Segmentation Tool" on page 88 for a description of each method.

2 Highlight the Bad Channel Replacement specification in the Specifications pane of the Waveform Tools window, and click the Run button.

View the Results

In this section of the chapter, you will view the results of bad channel replacement on your data and learn about Topo Plot view.

Introducing Topo Plot View

1 Open the pre-bad-channel-replacement file ATD256_1.ses.40.sg.

2 If necessary, choose **View > as Categories**, display the Navigation control strip, set the time mode to Segment Time, and choose the default montage, Geodesic Sensor Net 256 2.0.

Topo Plot view offers a useful way to look at bad channels because you can see all the channels at once, organized in a two-dimensional representation by location. The bad channels stand out because they do not resemble their neighbors.

3 Choose **View > as Topo Plot**.

You now see a two-dimensional representation of the channel locations. You also have a new set of controls on the left side of the window. You will use those controls to optimize your view of the data (Figure 11-2).

4 In the Plot Size panel, click Fit To Window.

5 In the Layout panel, click Best Fit.

6 In the Channel Size panel, click No Overlap (Max).

7 In the Options panel, deselect every checkbox except Channel Numbers.

8 From the menubar, choose **Time > Fit Segment To Window**.
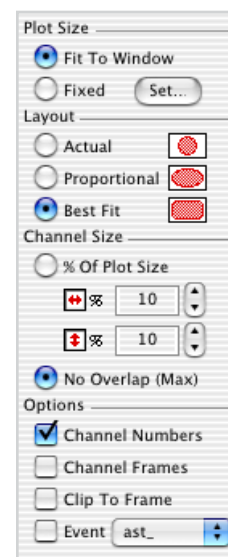
Figure 11-2. Topo Plot controls

The Viewer should now look like Figure 11-3. Because some of these settings are a matter of personal preference, you may want to experiment with them.
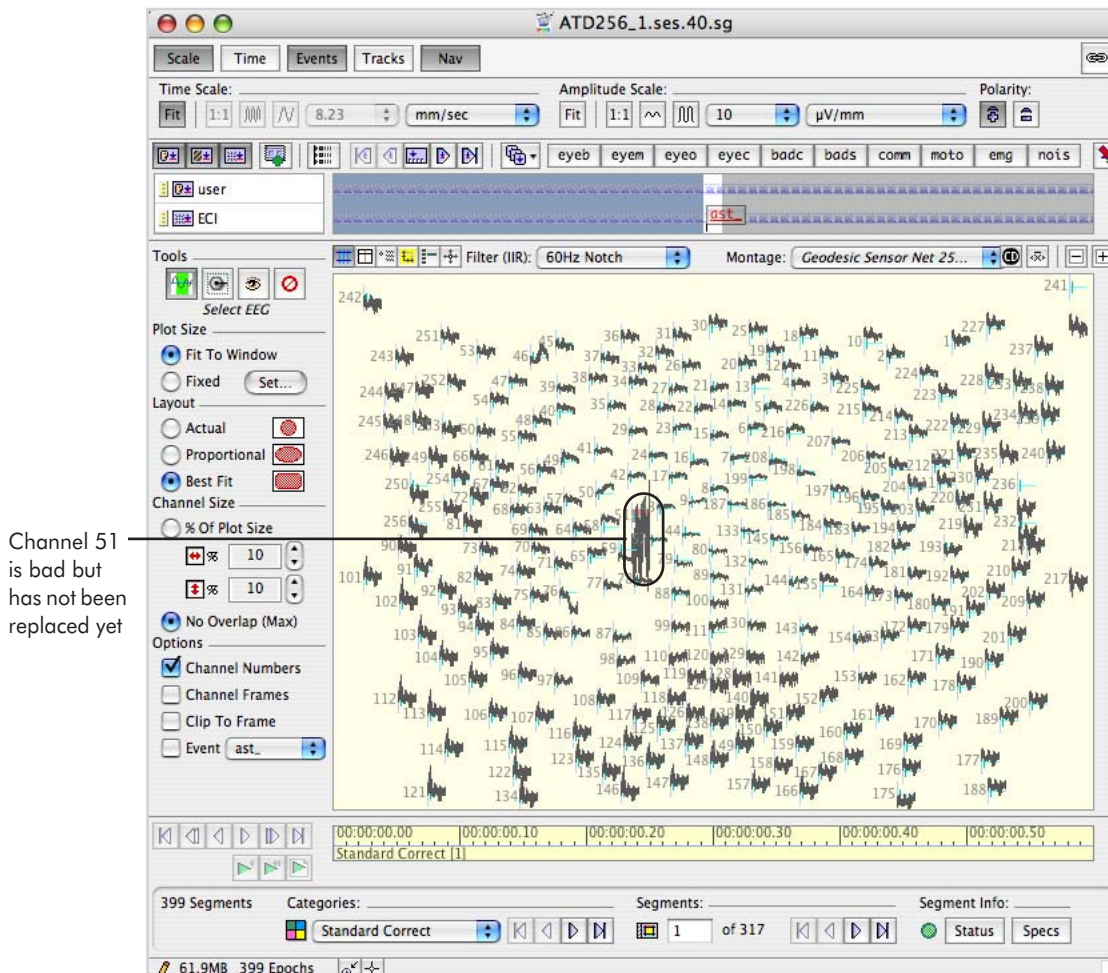

Figure 11-3. Data in Topo Plot view before bad channel correction
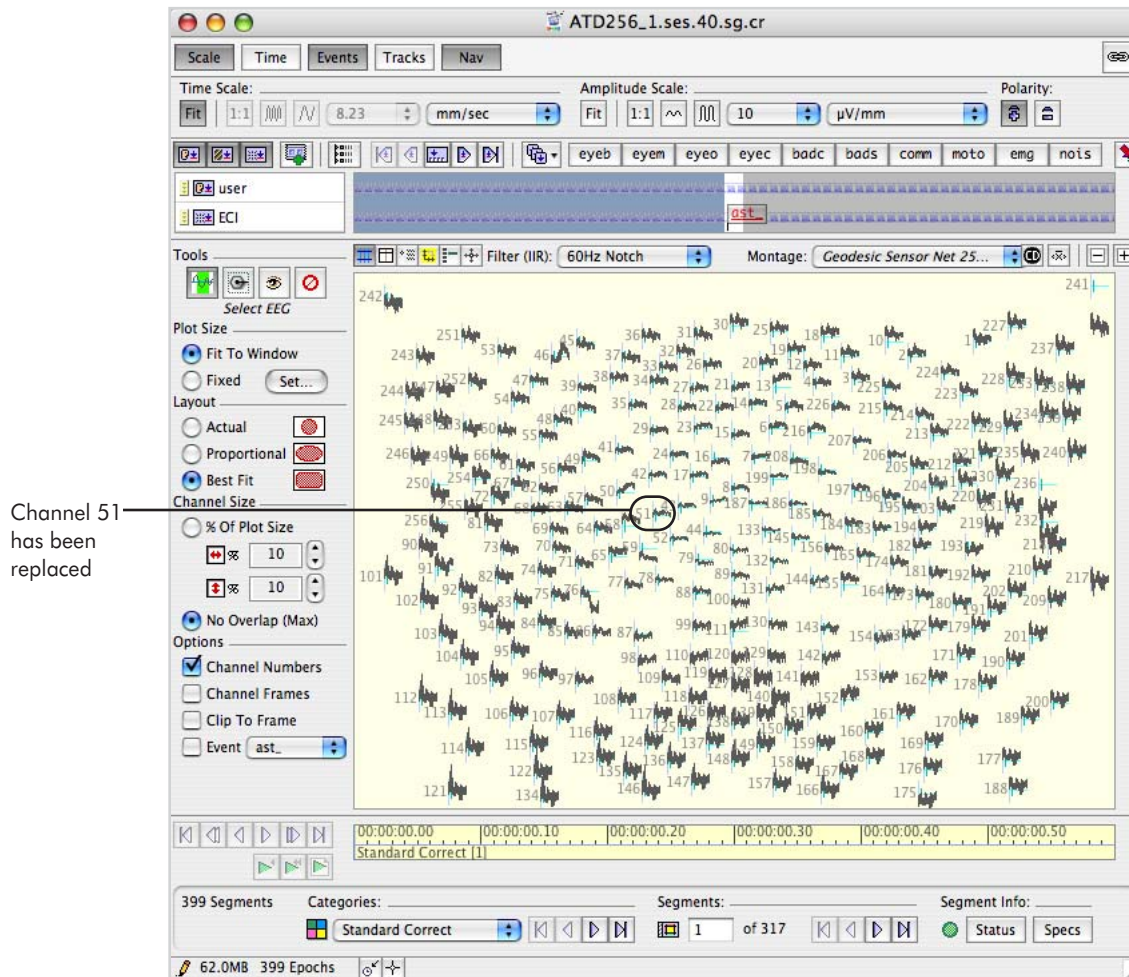
Inspecting Data in Topo Plot View

As you inspect the data by navigating to different segments and using different amplitude scales, you will notice the following: If you pick any handful of channels near each other, the waveforms in these channels tend to look very similar to each other. The one exception, as shown in Figure 11-3, is the bad channel, number 51.

1 Inspect the data, as described earlier, to your satisfaction.

Now compare this with the post-bad-channel-replacement file.

2   Open the result file ATD256_1.ses.40.sg.cr.

3   Set up the Viewer as you did for the previous file (as Categories, fit segment time to window, and so forth; Steps 2–8 on page 111).

Figure 11-4. Data in Topo Plot view after bad channel correction

4   Inspect the data, and notice that the waveforms of channel 51 now look like their neighbors.

5   Close both files.

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AVERAGING

In averaging, you calculate a single, average segment from all the segments that were not rejected, for each category you created during segmentation.

Create an Averaging Specification

Editing the Specification

Before you can perform averaging on your recordings, you must create an Averaging specification.

1 If necessary, start Net Station and open the Waveform Tools window.

2 Open an Averaging specification editor and name the Averaging specification "Average".

3 In the Output Options panel, set the name field to Append ".av" (for averaging) and the destination field to Same As Source.

Note: To prevent overly long filenames, this tutorial uses extensions that are shorter than the default extensions (e.g., ".av" instead of ".ave").

Setting the Tool-specific Parameters

Now, set the tool-specific parameters.

1 In the Handle Source Files panel, click the Separately button.

2 In the Handle Subjects panel, click the Separately button.

3 Click the Copy Events from First File (Slower) radio button.

Your Averaging specification is now fully defined. Figure 12-1 shows the finished Averaging specification.
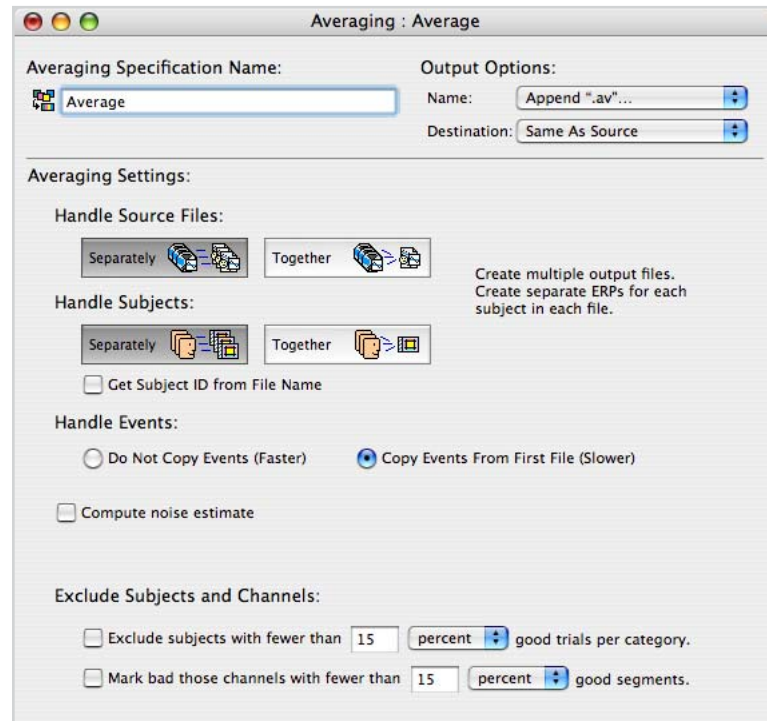
Figure 12-1. Averaging specification editor

4 Close the Averaging specification editor, saving the changes.

Run the Averaging Tool

In this section, you will run the Averaging tool.

1   In the Waveform Tools window, add the ATD256_1.ses.40.sg.cr file to the Inputs pane. There are several ways to add a file to the pane; if necessary, see "Run the Segmentation Tool" on page 88 for a description of each method.

2   Highlight the Average specification in the Specifications pane of the Waveform Tools window, and click the Run button.

View the Results

In this section of the chapter, you will learn how to navigate an averaged Net Station file and begin learning about the effects of referencing.

1   Open the result file ATD256_1.ses.40.sg.cr.av.

2   If necessary, choose **View > as Categories**, choose **View > as Topo Plot**, display the Navigation control strip, and set the time mode to Segment Time.

3   Select each category, and note that now there is only one segment in each category, named "Average: subj01" (Figure 12-2)
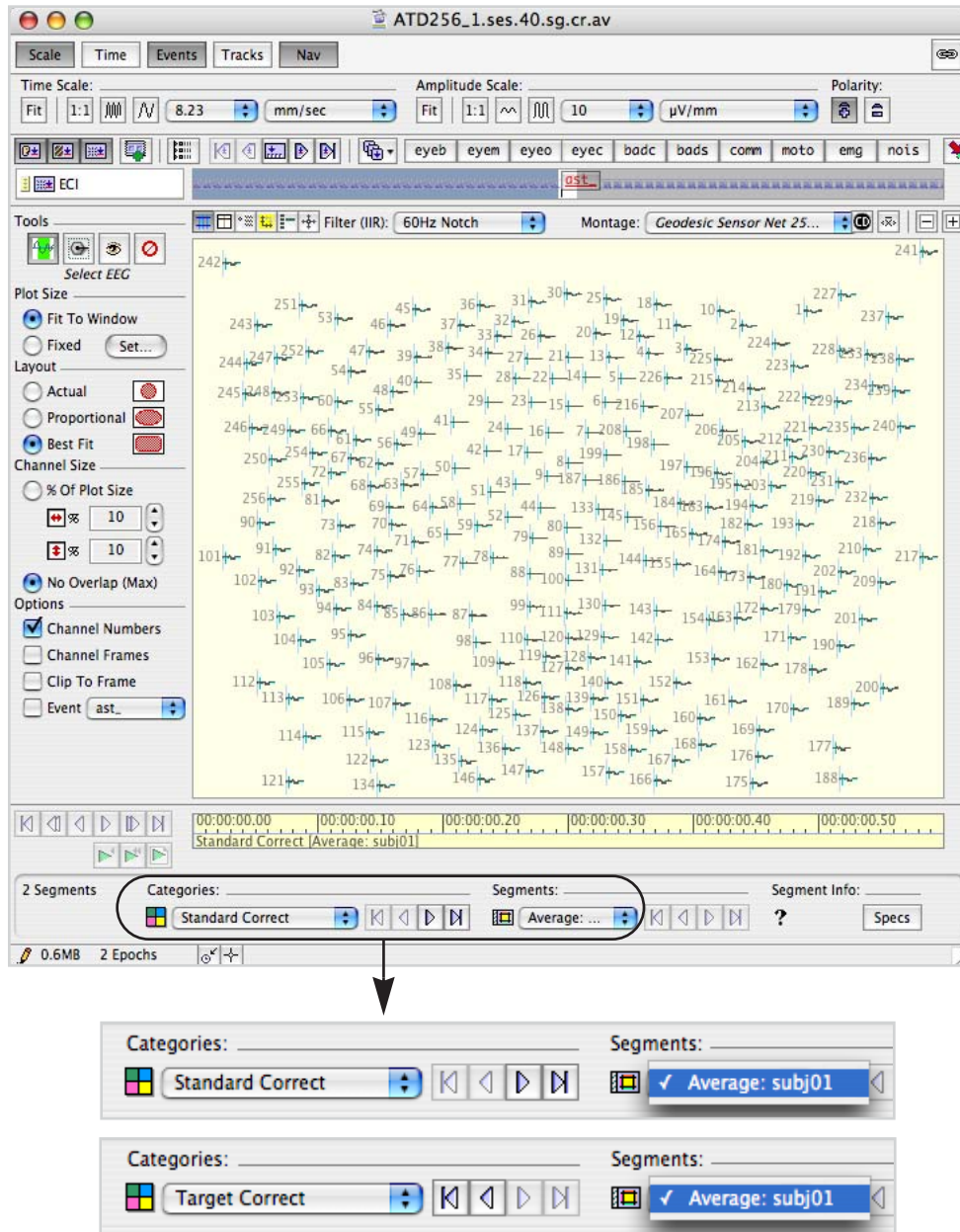
Figure 12-2. Averaged data with one segment per category

For each category, the one segment is the average of all the segments for that category.

If your amplitude scaling is set as it had been before averaging, your waveforms will seem very flat (see Figure 12-2). This is because the averaging operation reduces

amplitudes. Unprocessed, artifact-free EEG typically has ranges from –40 to 40 µV, whereas averaged EEG typically has ranges from –5 to 5 µV.

4 In the Amplitude Scale panel of the Scale control strip, set the scaling to 1 µV/mm (Figure 12-3).

before changing the amplitude

after changing the amplitude to 1 µV/mm
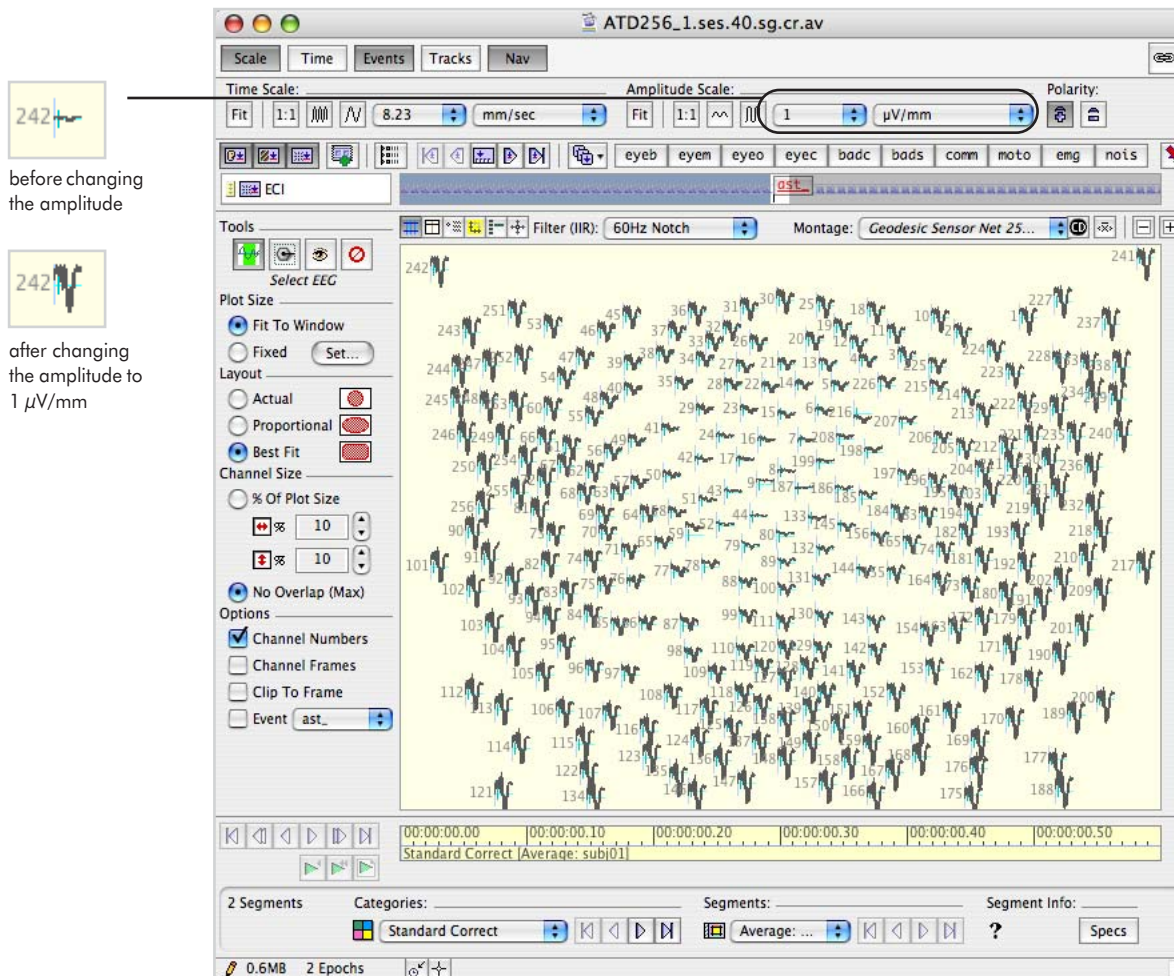
Figure 12-3. Averaged data with amplitude scale set at 1 µV/mm

The waveforms now show some shape. Notice that the amplitudes are greatest around the edges and are almost flat toward the center. This is because the data were recorded using the vertex as the reference. The reference channel, by definition, has values of zero. So, the closer the channels are to the reference channel, the flatter the waveforms.

In the next chapter, you will perform an average referencing operation on the data. In the Viewer, you can preview the results of average referencing by using the Average Reference montage.

5 Choose Average Reference from the Montage pop-up menu above the data-display area (Figure 12-4).

Apply the average reference montage
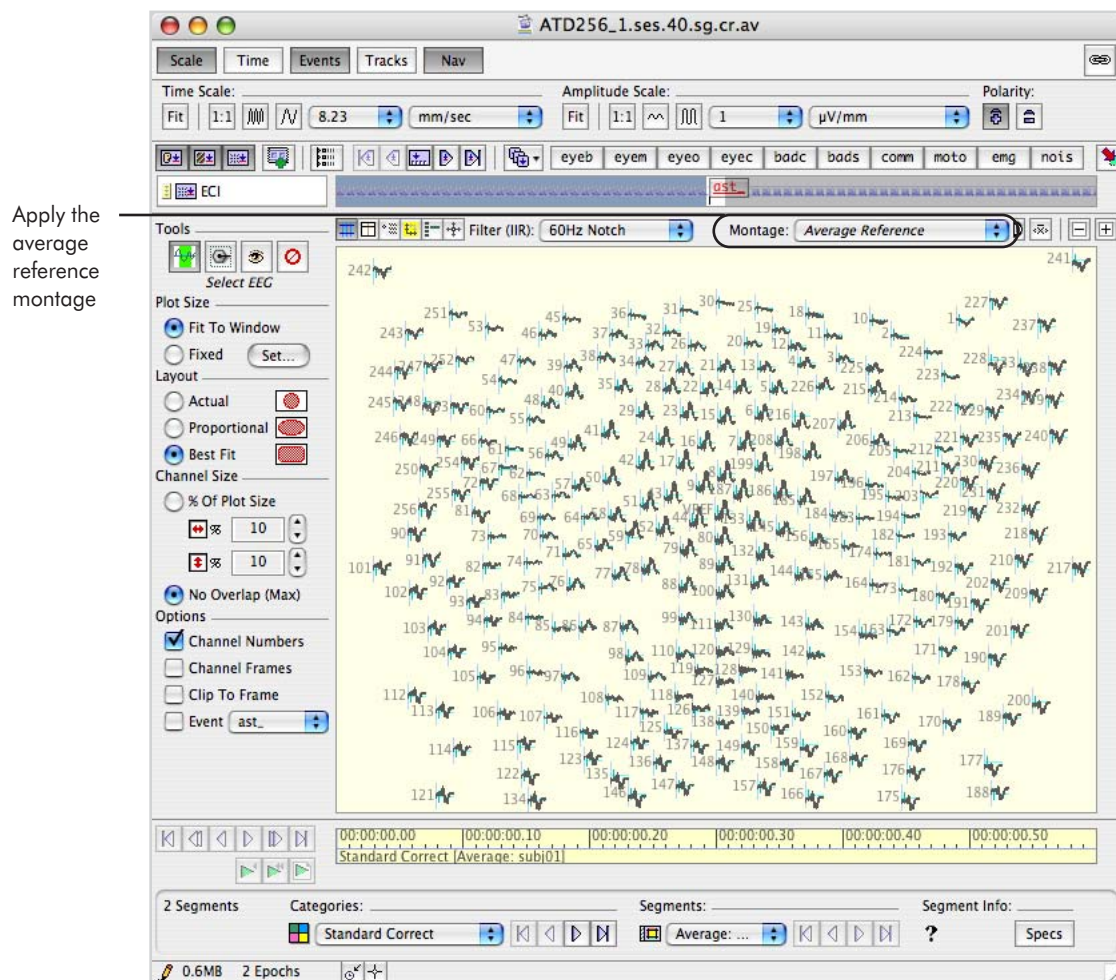
Figure 12-4. Averaged data with average reference montage applied

Notice the effect this has on the data display—the amplitudes are more evenly distributed among all the channels. This montage affects the display only. It does not change your data.

6 Close the file.

AVERAGE REFERENCING

In average referencing, you rereference the data to an average reference corrected for the polar average reference effect (PARE). What follows is a discussion of issues related to rereferencing and PARE-corrected average referencing.

EEG is a measure of voltage, and voltage measurements are inherently differential. In other words, any voltage measurement is really a measurement of the difference in potential between the site being measured and a reference site that is assumed to have a value of zero. In actuality, any choice of reference is arbitrary. There is no site that can be assumed to have a value of zero, and, to make matters worse, there is no site that can even be assumed to have an constant value from one timepoint to the next.

The objective of rereferencing EEG data is to estimate a true, nonarbitrary zero value to which to reference the voltage measurements. There are several reasons to believe that, at any given time, the average over every point on the surface of the body (i.e., the surface integral) would represent such an ideal reference value:

- If you assume, as many researchers do, that neural sources are dipolar (at practical distances from the sources), then positive and negative fields will sum to zero. Regardless of how many sources are active, if the entire surface of the volume is measured, assuming homogeneous conductivity, the surface integral will therefore be zero.

- Even if you do not make the preceding assumption, because of conservation of charge inside an electrically neutral body, the surface integral will be zero.

As channel counts increase, the average of all the channels better approximates the surface integral and, therefore, the ideal zero reference value. To eliminate the influence of the arbitrary recording reference channel and use instead a reference that approximates the ideal zero reference, many researchers prefer to rereference their data to the average reference.

However, if the head surface is unevenly sampled, then the average reference is biased toward the region that is sampled. This is known as the polar average reference effect

or PARE. For example, if the electrodes are concentrated on the top of the head, and inadequately sampled on the undersurface, then the average reference is biased toward the top of the head. Even with EGI's dense-array Geodesic Sensor Nets, the entire head surface cannot be adequately sampled (e.g., the underside is still not sampled). Therefore, there will always be a PARE when using the average reference.

One solution to this problem is to use a PARE-corrected average reference. The PARE-corrected average reference is computed from the entire surface of the head, including the surface not covered by electrodes. Spherical spline interpolation is used to estimate the voltages of the surface that is not covered. For more information on PARE, see the following:

- Junghoefer, M., Elbert, T., Tucker, D. M., & Braun, C. (1999). "The Polar Average Referenced Effect: A Bias in Estimating the Head Surface Integral in EEG Recording." *Electroencephalography and Clinical Neurophysiology*, 98, 422–434.

Create a Montage Operations Specification

Editing the Specification

Average referencing is performed with the Montage Operations tool. Before you can perform average referencing, you must create a Montage Operations specification.

1 If necessary, start Net Station and open the Waveform Tools window.

2 Open a Montage Operations specification editor and name the Montage Operations specification "PARE".

3 In the Output Options panel, set the name field to Append ".ar" (for average reference) and the destination field to Same As Source.

Note: To prevent overly long filenames, this tutorial uses extensions that are shorter than the default extensions (e.g., ".ar instead of ".sub").

Setting the Tool-specific Parameters

Setting the Montage Operations–specific parameters consists of selecting a montage, creating it first if necessary, and, for average referenced montages, indicating whether you want the reference PARE corrected (Figure 13-1).

1   From the Source Net pop-up menu, choose Geodesic Sensor Net 256 2.1.

A list of montages for this Net appears.
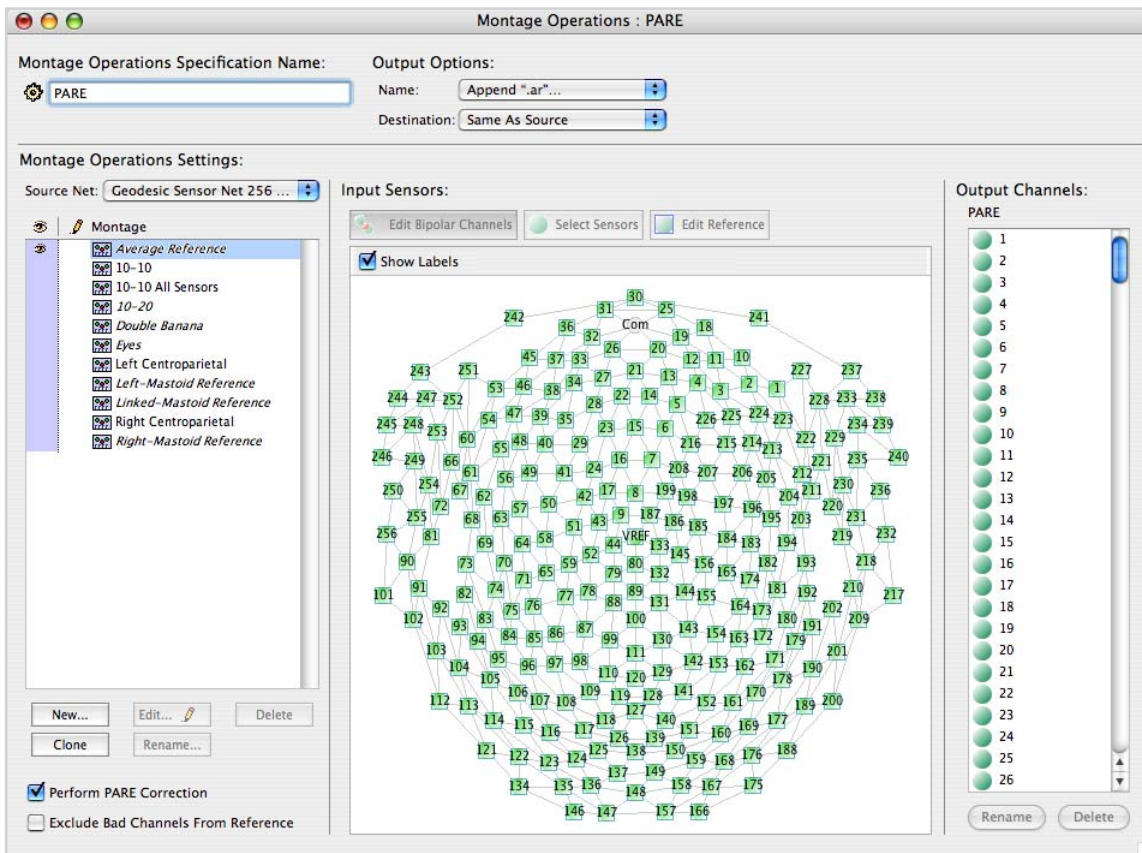
Figure 13-1. Montage Operations specification editor

2   Select the Average Reference montage.

3   Select the Perform PARE Correction checkbox at the lower left of the editor.

4 Below that checkbox, deselect the Exclude Bad Channels from Reference checkbox.

Your Montage Operations specification is now fully defined. Figure 13-1 shows the finished Montage Operations specification.

5 Close the Montage Operations specification editor, saving the changes.

Run the Montage Operations Tool

In this section, you will run the Montage Operations tool.

1 In the Waveform Tools window, add the ATD256_1.ses.40.sg.cr.av file to the Inputs pane. There are several ways to add a file to the pane; if necessary, see "Run the Segmentation Tool" on page 88 for a description of each method.

2 Highlight the PARE specification in the Specifications pane of the Waveform Tools window, and click the Run button.

View the Results

1 Open the result file ATD256_1.ses.40.sg.cr.av.ar.

2 If necessary, configure the Viewer as it had been in the previous chapter (as categories, as Topo Plot, in Segment Time).

Notice the effect of the referencing on the data (Figure 13-2).
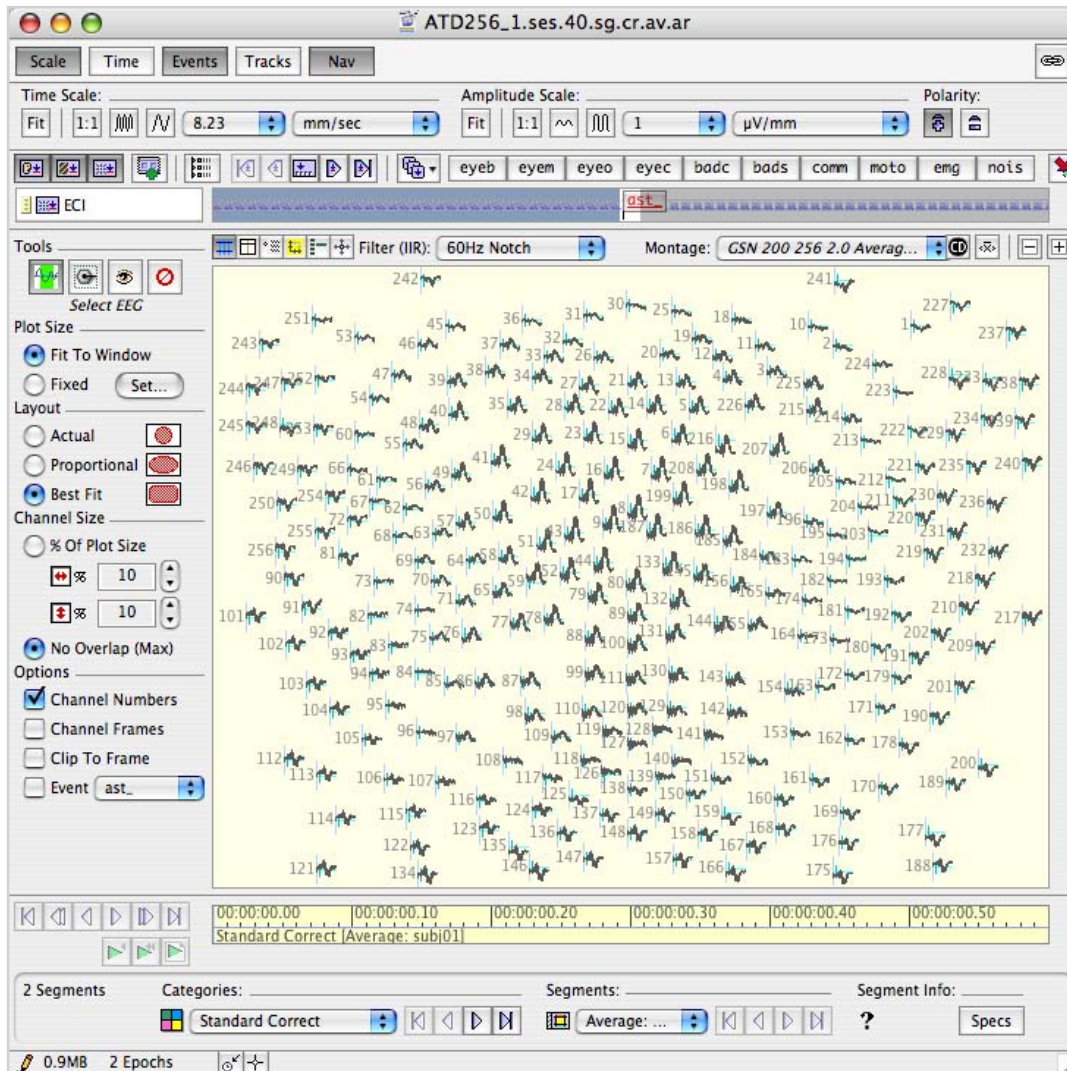
Figure 13-2. The PARE-corrected file ATD256_1.ses.40.sg.cr.av.ar

3 Close the file.

BASELINE CORRECTION

In baseline correction, you establish a baseline interval within your segment. You select the interval to use as the baseline. For stimulus events, the baseline interval normally precedes the stimulus. For each channel, the average of all the samples within the baseline interval is subtracted from every sample in the segment. This baseline value establishes a new zero-voltage value.

Create a Baseline Correction Specification

Editing the Specification

Before you can perform baseline correction on your recordings, you must create a Baseline Correction specification.

1   If necessary, start Net Station and open the Waveform Tools window.

2   Open a Baseline Correction specification editor and name the Baseline Correction specification "Baseline –100 to 0".

3   In the Output Options panel, set the name field to Append ".bc" (for baseline correction) and the destination field to Same As Source.

Note: To prevent overly long filenames, this tutorial uses extensions that are shorter than the default extensions (e.g., ".bc instead of ".blc").

Setting the Tool-specific Parameters

Now, set the tool-specific parameters.

1   From the Select Baseline From pop-up menu, choose Portion of Segment.

2   From the Select Baseline With Respect To pop-up menu, choose Segment Time= 0.

3   Use the input boxes to specify that the "baseline begins 100 ms before sample and is 100 ms long".

Your Baseline Correction specification is now fully defined. Figure 14-1 shows the finished Baseline Correction specification.
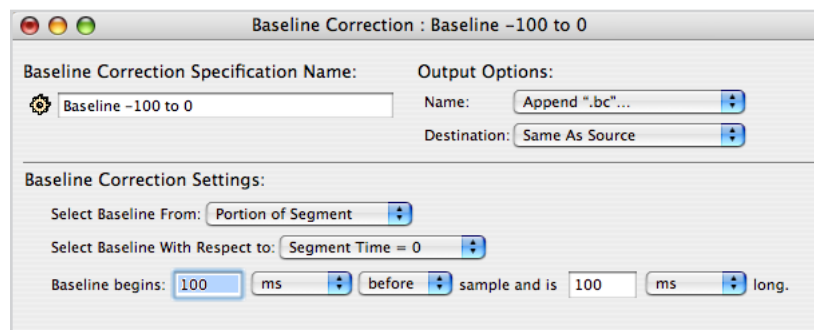
Figure 14-1. Baseline Correction specification editor

4   Close the Baseline Correction specification editor, saving the changes.

Run the Baseline Correction Tool

In this section, you will run the Baseline Correction tool.

1   In the Waveform Tools window, add the ATD256_1.ses.40.sg.cr.av.ar file to the Inputs pane. There are several ways to add a file to the pane; if necessary, see "Run the Segmentation Tool" on page 88 for a description of each method.

2   Highlight the Baseline -100 to 0 specification in the Specifications pane of the Waveform Tools window, and click the Run button.

View the Results

In this section of the chapter, you will view the results of baseline correction on your data and learn about the Butterfly montage.

Introducing the Butterfly Montage

1   Open the pre-baseline-correction file ATD256_1.ses.40.sg.cr.av.ar.

2   If necessary, choose **View > as Categories**, display the Scale and Navigation control strips, and set the time mode to Segment Time.

3   Switch to Chart View by choosing **View > as Chart**.

The Butterfly montage shows all the channels overlaid on each other. It is a good view for checking baseline correction, looking for bad channels, and finding peaks of activity.

4   Choose Butterfly from the Montage pop-up menu above the data-display area.

Immediately above the channel tiles, to the left, is a series of three buttons (see Figure 14-2).

These buttons control the height of each channel tile. The rightmost of these three buttons expands the channel tile to fill the available vertical space.

Figure 14-2. Channel-height buttons

5   Click the rightmost of these three buttons.

Expands channel to fit vertically

6   In the Scale control strip, click the Time-Scale Fit button, which expands the waveforms horizontally to fill the available space.

7   In the Scale control strip, set the amplitude scale to 0.4 μV/mm.

Comparing Files

1   From the Navigation control strip, click the category selector and choose Standard Correct.

2   Open the result file ATD256_1.ses.40.sg.cr.av.ar.bc.

3 Set up the Viewer as you did for the previous file (see Steps 2–7 on page 129).

Figure 14-3 shows the Standard Correct category, both before and after baseline correction.
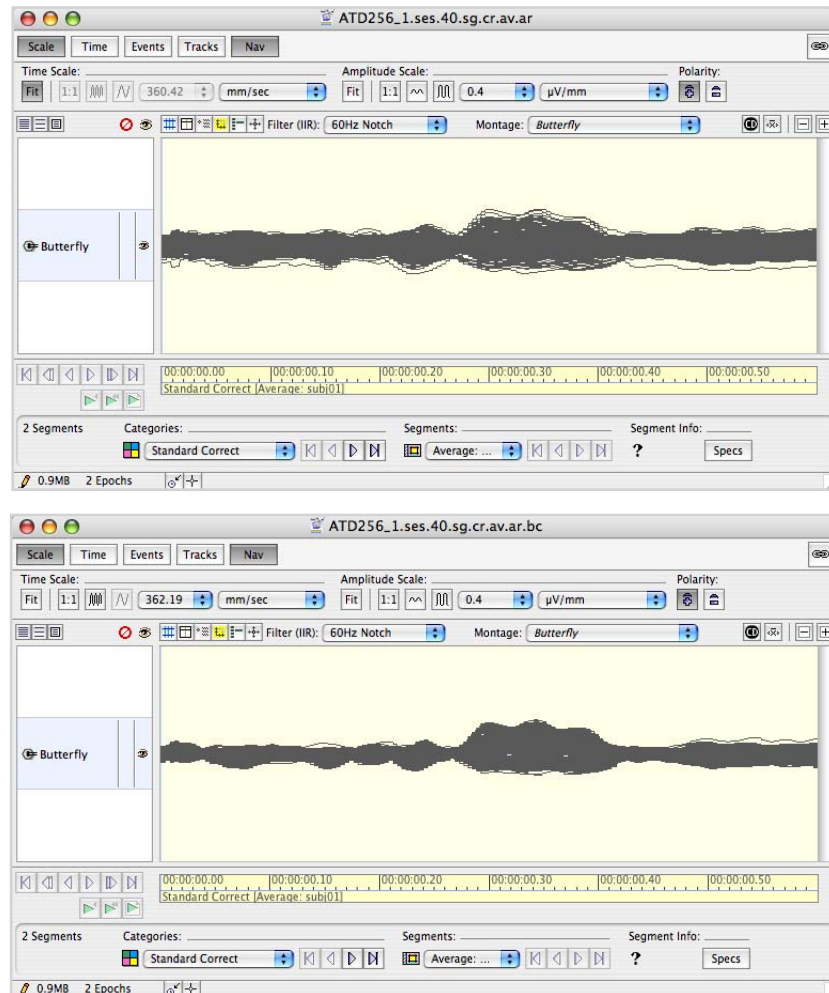
Figure 14-3. The Standard Correct category before baseline correction (top) and after (bottom)

Compare the baseline-corrected data with the pre-baseline-corrected data. Notice that in the baseline epoch (–100 to 0), the baseline-corrected data are smaller in amplitude. Compare the two files in the Target Correct category as well.

4 Close both files.

SCRIPTING

Once you are satisfied with your data-analysis path (i.e., which tools to use, in which order, with which parameters), you can automate your data analysis with scripting. Scripting is done with the Script tool, a special device for automating your ERP derivation by chaining tool operations together. Script is similar to the other tools in that you use the Waveform Tools window to launch a Script specification editor and to run the script.

Create a Script Specification

Before you can process your data with a script, you must create a Script specification.

1   If necessary, start Net Station and open the Waveform Tools window.

2   Open a Script specification editor and name the Script specification "ATD Script".

The Script specification editor has no Output Options panel. This is because, as you will see, the output options are set separately for each tool in the script.

3   Place the ATD Script specification editor next to the Waveform Tools window, and simply drag the following tool specifications (created in the previous chapters) from the Waveform Tools window to the Script Settings panel (see Figure 15-1) of the Script specification editor in this order:

- Lowpass 40 Hz
- ATD Seg
- Artifact Detection

- Bad Channel Replacement
- Average
- PARE
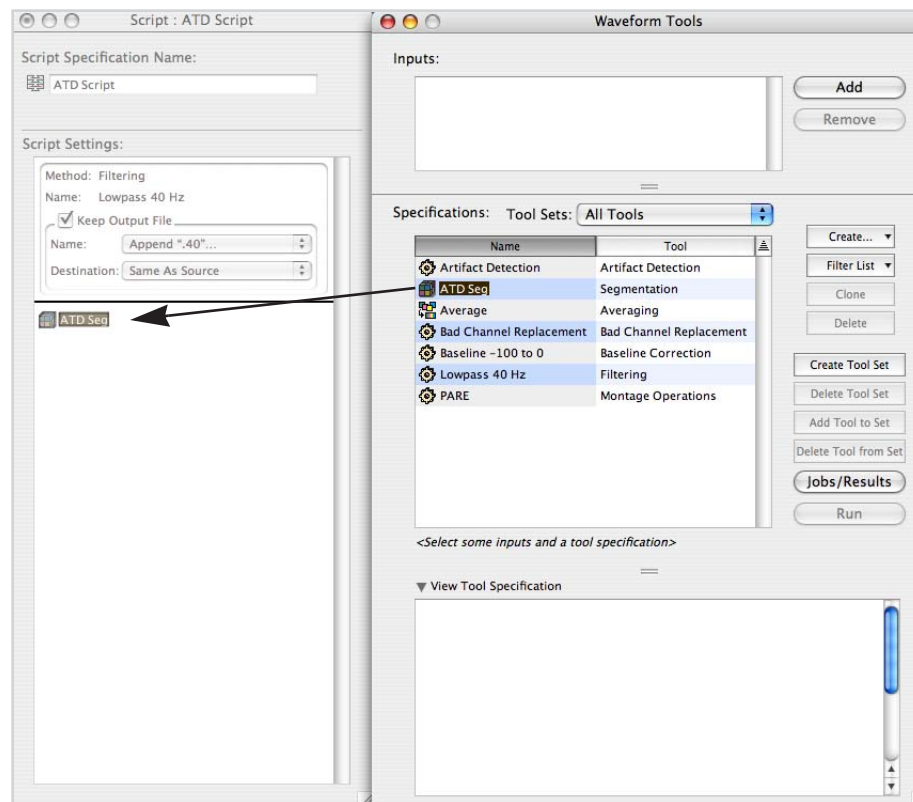
Figure 15-1. Drag tools to the Script Settings pane to create a script

Note: This list does not include the Baseline –100 to 0 specification. You will perform this operation in the next chapter.

Each item in the script has a Keep Output File option. You can save disk space by saving only the data files of interest. For now, the only file you need is the output of the final average referencing operation.

4 Deselect the Keep Output File checkboxes so that only the output of the final average referencing operation is kept. Figure 15-2 shows the completed specification.

Filtering specification from Chapter 8

Segmentation specification from Chapter 9

Artifact Detection specification from Chapter 10

Bad Channel Replacement specification from Chapter 11

Averaging specification from Chapter 12

Rereferencing specification from Chapter 13
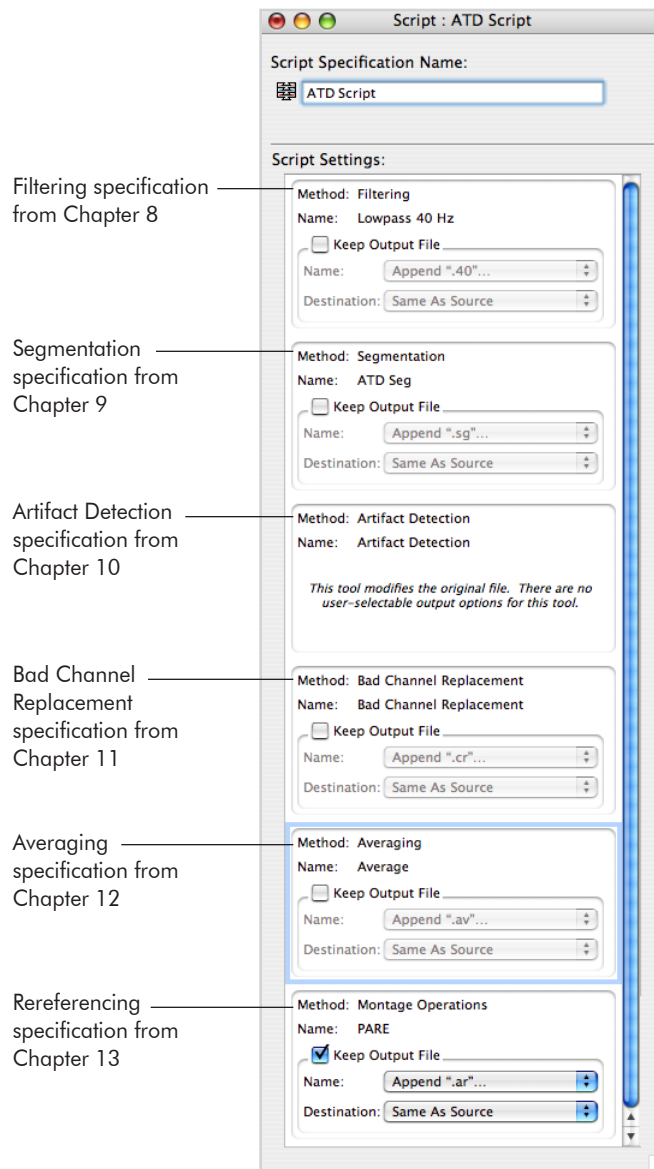
Figure 15-2. Script specification editor

5 Close the Script specification editor, saving the changes.

Run the ATD Script

1 There are three files you have not processed yet:

- ATD256_2.ses
- ATD256_3.ses
- ATD256_4.ses

Place all three files in the Inputs list of the Waveform Tools window using one of two methods:

° Click the Add button in the Waveform Tools window, navigate to the files, and select them by Shift-clicking.

° Shift-click on the file icons to select them all and drag them from the Finder into the Inputs pane of the Waveform Tools window.

2 Highlight the ATD Script specification in the Specifications pane, and click the Run button.

Note: Depending on your computer resources, running the script on these three files may require as much as two hours.

View the Results

In this section of the chapter, you will learn how to view the history of your data-analysis path, which is stored in a Net Station recording.

Note that there is now an average-referenced averaged file for each subject:

- ATD256_2.ses.40.sg.cr.av.ar
- ATD256_3.ses.40.sg.cr.av.ar
- ATD256_4.ses.40.sg.cr.av.ar

1 Open the result file ATD256_2.ses.40.sg.cr.av.ar.

2 Choose **Edit > File Info**.

The File Info dialog appears, displaying its six tabs.

3 Click the History tab.

4 Click the Collapse All button.

The History pane contains an item for each operation performed on the data through the creation of this file. Each item has a disclosure triangle for displaying more information about the corresponding operation.
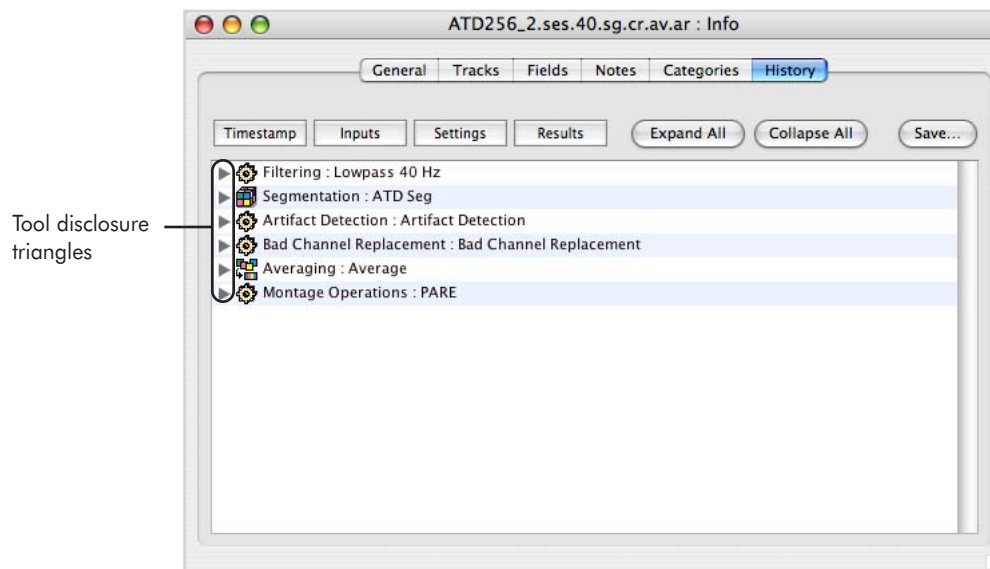
Figure 15-3. History pane

5 Click on the disclosure triangle for the Segmentation item. If the Timestamp, Inputs, Settings, and Results sections for the Segmentation item are not displayed, then click the correspondingly named toggles at the top left of the window to reveal this information (Figure 15-4). To hide any of these sections, click on their corresponding toggles.
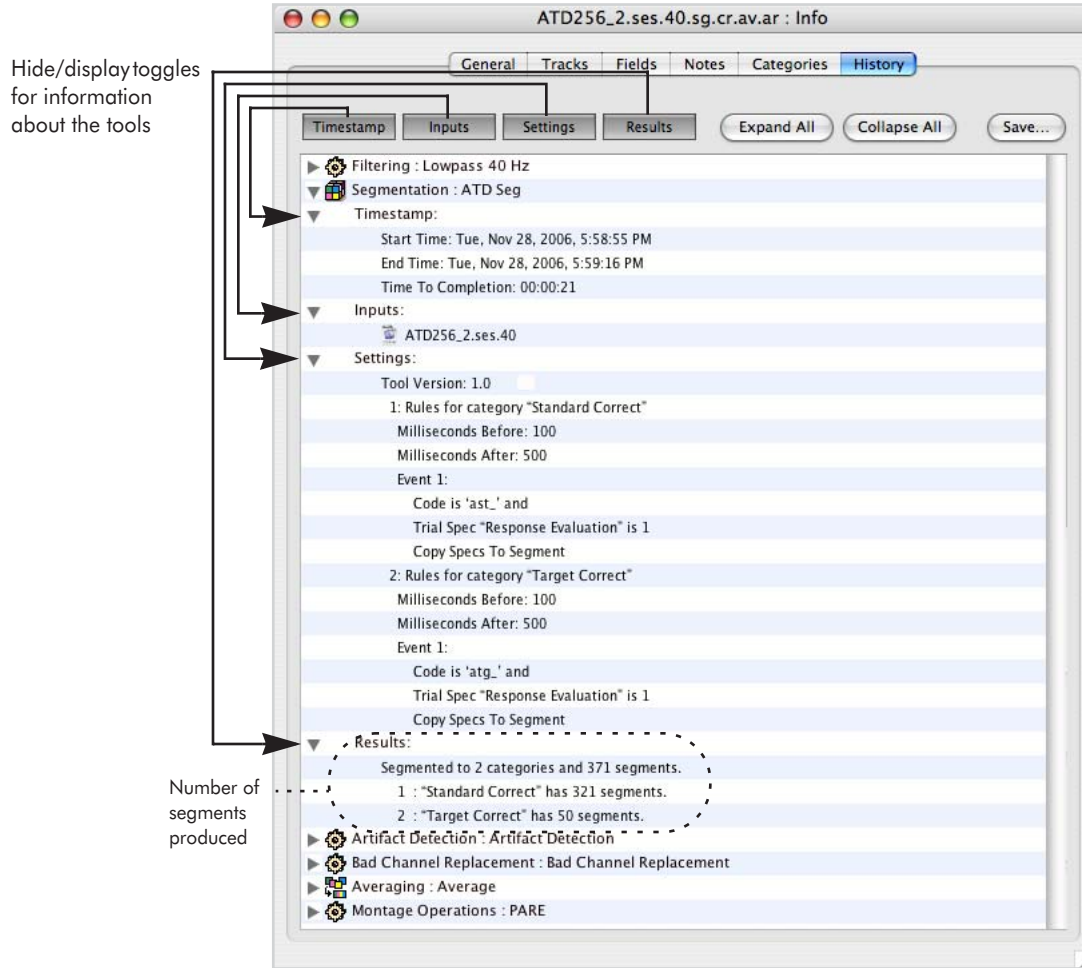
Figure 15-4. History pane: Segmentation

Notice that in the Results section of the History pane you can see how many segments there are in the Standard Correct and Target Correct categories.

6 Click the Segmentation disclosure triangle to close that section, and click on the Artifact Detection disclosure triangle to view its Results section.

Figure 15-5. History pane: Artifact Detection

Notice that you can see how many segments were marked bad.

If you want, you can view the history of the other operations. You can view the history of the other result files as well.

7 Close the file(s).

COMBINE AND GRAND AVERAGING

In grand averaging, you average all the individual-subject ERPs to create a cross-subject ERP. Grand averaging emphasizes the ERP patterns shared by all the subjects and deemphasizes individual differences. You should use non-baseline-corrected data for grand averaging so that you can understand the effects of baseline correction on your grand-average ERPs.

Grand averaging is done with the Averaging tool (the same tool you used for single-subject averaging). Before you can perform grand averaging on your data, you must create an Averaging specification.

In this chapter, you will actually do a little more than grand averaging. You will create and run a script that performs the following three tasks:

- combines all the individual-subject average files into a single file that has the average ERPs for all subjects
- creates a file with a grand-average ERP
- creates a file with a baseline-corrected grand-average ERP

Note: Combining files before grand averaging allows you to view individual subject EEG data in one grand-average file for direct comparison between subjects. The resulting file is also useful for checking which subjects contributed to the grand-average ERP, if some subjects had to be omitted from the grand averaging.

You will also run the baseline correction operation on the file that contains the average ERPs for all subjects.

Before you can do this, you will need to:

- create a Combine Files specification
- create an Averaging specification for grand averaging
- create a Script specification that includes the preceding two items as well as a Baseline Correction specification

Create a Combine Files Specification

Editing the Specification

1 Start Net Station and open the Waveform Tools window, if necessary.

2 Open a Combine Files specification editor and name the Combine Files specification "Combine".

3 In the Output Options panel, set the name field to "ATD256.av", using the Fixed command from the Name menu. Set the destination field to Same As Source.

Setting the Tool-specific Parameters

Now, set the tool-specific parameters.

1 From the Combine Files By pop-up menu, choose Merging Files.

Leave all checkboxes unselected. Your Combine Files specification is now fully defined (Figure 16-1).
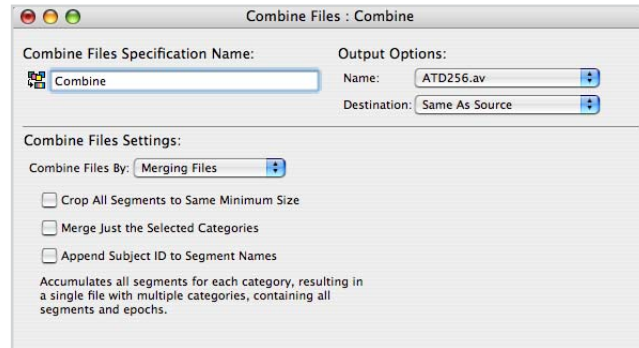
Figure 16-1. Combine Files specification editor

2   Close the Combine Files specification editor, saving the changes.

Create an Averaging Specification

Edit the Specification

1   Open an Averaging specification editor and name the Averaging specification "Grand Average" (see Figure 16-2).

2   In the Output Options panel, set the name field to Append ".ga" (for grand averaging) and the destination field to Same As Source.

Set the Tool-specific Parameters

Now, set the tool-specific parameters.

1   In the Handle Source Files panel, click the Together button.

2   In the Handle Subjects panel, click the Together button.

3   Click the Copy Events From First File (Slower) radio button (Figure 16-2).
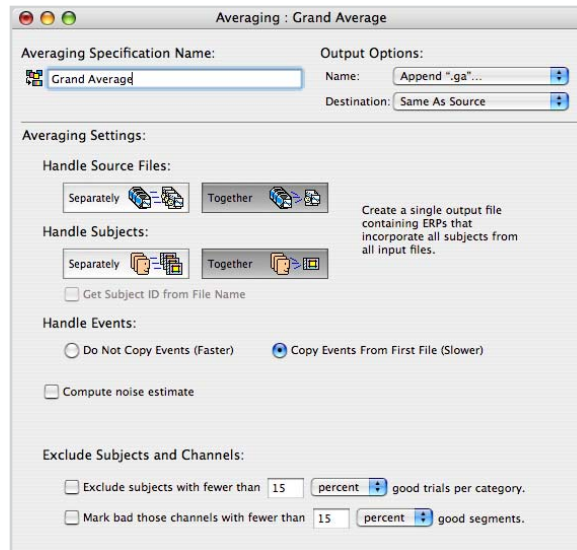
Figure 16-2. Grand Averaging editor

Your Averaging specification is now fully defined.

4   Close the Averaging specification editor, saving the changes.

Create a Script Specification

1   Open a Script specification editor and name the Script specification "ATD II Script".

2   Drag the following tool specifications from the Waveform Tools window to the Script Settings panel of the Script specification editor in this order:

• Combine
• Grand Average
• Baseline –100 to 0

3 Make sure that all three items have their Keep Output File checkboxes selected (Figure 16-3).
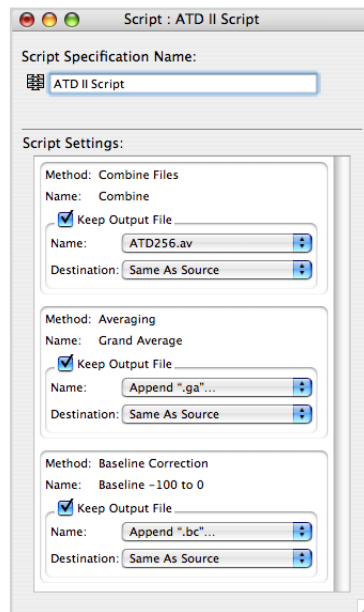
Figure 16-3. ATD II Script specification

4 Close the Script specification editor, saving the changes.

Run the ATD II Script

1 Place the following files in the Inputs pane of the Waveform Tools window by clicking the Add button and navigating to each file in numerical order, or by dragging each file into the pane in numerical order *(for the purposes of this tutorial, the files* **MUST** *be individually added to the Input pane in the following numerical order; do* **NOT** *select them using Option-click)*:

- ATD256_1.ses.40.sg.cr.av.ar
- ATD256_2.ses.40.sg.cr.av.ar
- ATD256_3.ses.40.sg.cr.av.ar
- ATD256_4.ses.40.sg.cr.av.ar

Note: In this example, we are using all of the subjects. You might choose to omit a subject for various reasons, such as noisy data or poor behavioral results (e.g., too many incorrects).

2   Highlight the ATD II Script specification in the Specifications pane, and click the Run button.

Run Baseline Correction on a Result File

To have a baseline-corrected copy of the combined file, run the Baseline Correction tool on ATD256.av, one of the files produced with the ATD II Script in the preceding section.

1   In the Waveform Tools window, add the ATD256.av file to the Inputs pane. There are several ways to add a file to the pane; see "Run the Segmentation Tool" on page 88 for a description of each method.

2   Highlight the Baseline -100 to 0 specification in the Specifications pane of the Waveform Tools window, and click the Run button.

View the Results

Section IV, "Exploring ERPs," is devoted to the lengthy topic of viewing and analyzing your grand-average ERPs. For now, you will learn how to navigate a multisubject average file.

1   Open the baseline-corrected multisubject averaged file ATD256.av.bc.

2   If necessary, choose **View > as Categories**, **View > As Topo Plot,** and **Montage > GSN 200 256 2.0 Average Reference 1.0**.

3 Select each category and note that there is one segment in each category for each subject, and that all the subjects who contributed to the grand average are listed (Figure 16-4).
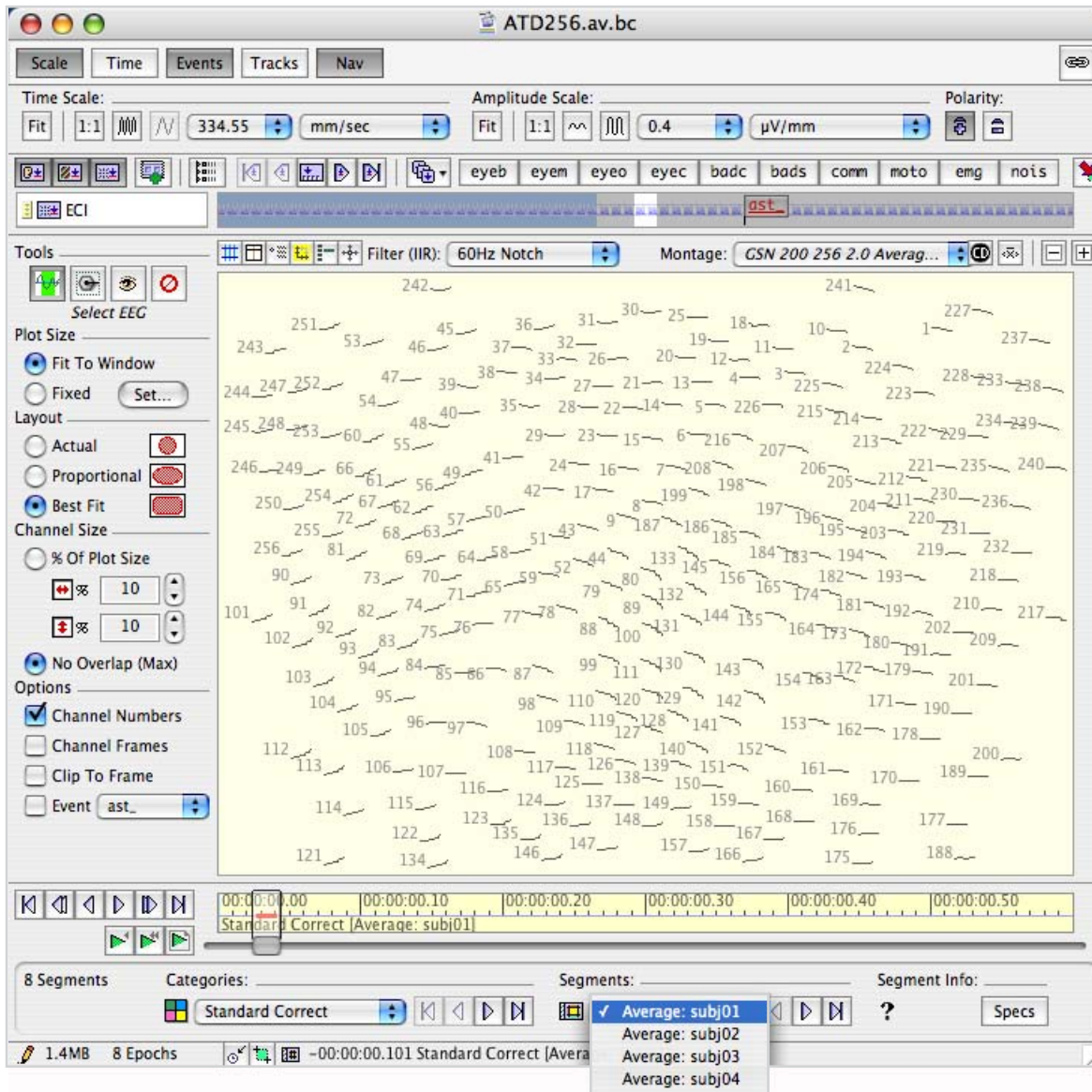
Figure 16-4. A multisubject average file, in "as Categories" mode

4 Close the file.

SECTION IV:

EXPLORING ERPs

VISUALIZING ERPs

In this section, you will learn how to explore and compare the ERPs of the two conditions using Topo Plot view, which you have already learned about, and the interpolated Topo Map view, which is introduced in this chapter.

1 Open the baseline-corrected grand-average file ATD256.av.ga.bc.

2 If necessary, set up a Topo Plot view as you did in "Introducing Topo Plot View" on page 111.

3 Set the amplitude scaling to 1 μV/mm.

Overlaid Segments in Topo Plot View

The "as Overlaid Segments" viewing option is useful for comparing different conditions.

1 Choose **View > as Overlaid Segments**.

Each channel now shows the waveforms for both conditions superimposed (Figure 17-1). The waveforms are color-coded.
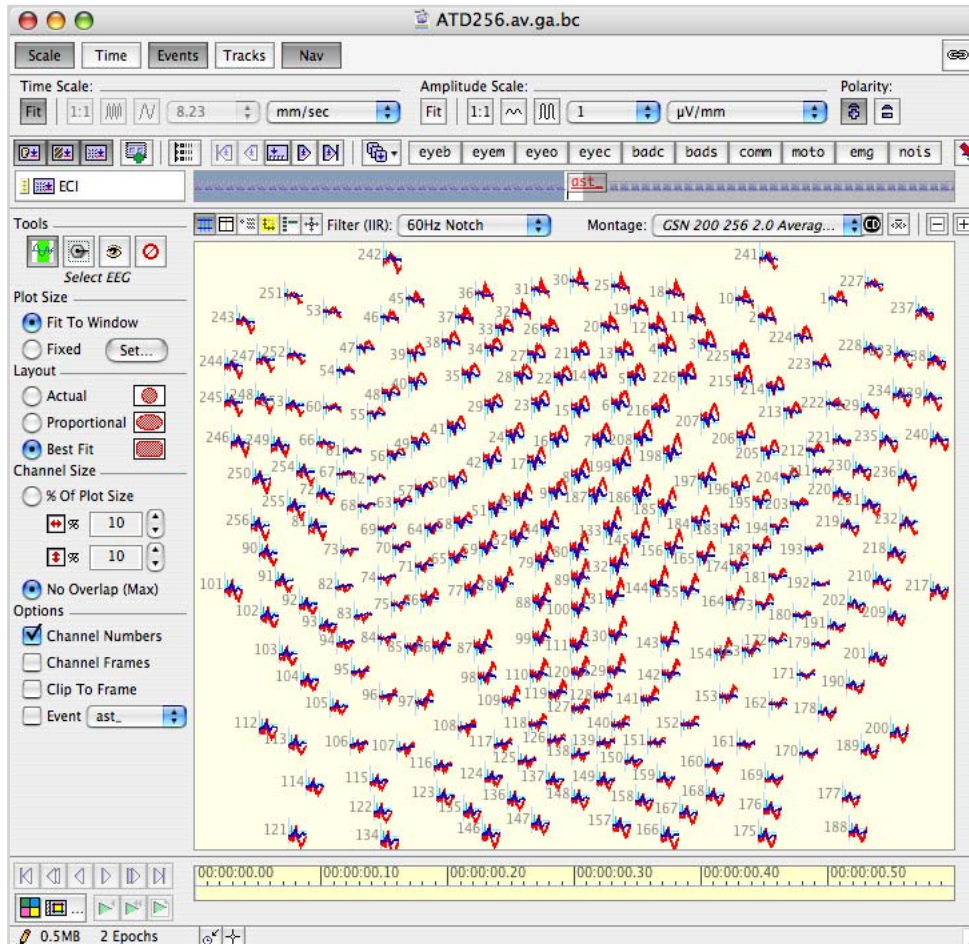
Figure 17-1. View "as Overlaid Segments"

Also, the Overlaid Segments palette appears (Figure 17-2).

This palette allows you to control how the overlaid segments are displayed. If you have more than two conditions, you can use this window to choose which conditions to include in the overlay. By clicking on the color control (the blue or red rectangle) for a given condition, you can use a variety of sophisticated methods for selecting the color for that condition.
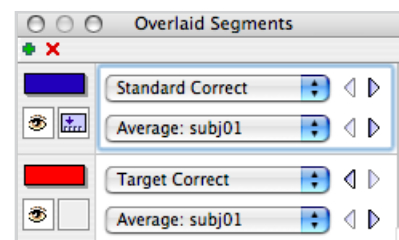
Figure 17-2. Overlaid Segments palette

Note: The order of the segments in the Overlaid Segments palette dictates the order in which the segments are drawn in the Viewer. In general, the segments are drawn from bottom to top, with the bottom segment serving as the grid (thus, in Figure 17-2, Target Correct would form the first layer). The next segment to be drawn in the Viewer is the one above the bottom segment in the Overlaid Segments palette and so on. Chapter 3, "Common Viewer Window Elements," in the Net Station Viewer Technical Manual *discusses this in more detail.*

2 Experiment with changing the colors of the waveforms.
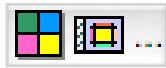
Overlay button

If you dismiss the Overlaid Segments palette, you can display it again by clicking on the button in the lower left of the Navigation control strip.

You can select a specific channel and zoom-in on it. To do this, double-click on the channel, which activates the Channel Zoom mode.

3 Double-click on channel 8 in the Topo Plot displayed in the Viewer.

Channel 8 appears by itself and displayed with triple the amplitude, for easier viewing. You can scale it to meet your needs. In Channel Zoom mode, the 1:1 time scaling is good because it eliminates aliasing. This is because with this scaling, there is one pixel for each sample.

4 From the Time menu, choose Actual Size (1:1).

With channel 8 zoomed (Figure 17-3), you can easily see the increased positivity in the Target Correct, compared with the Standard Correct condition, at around 350 ms. This increased positivity in the target is what is known as the *P300*. You can also see the negativity in both conditions at around 120 ms. This is the *auditory N100*.
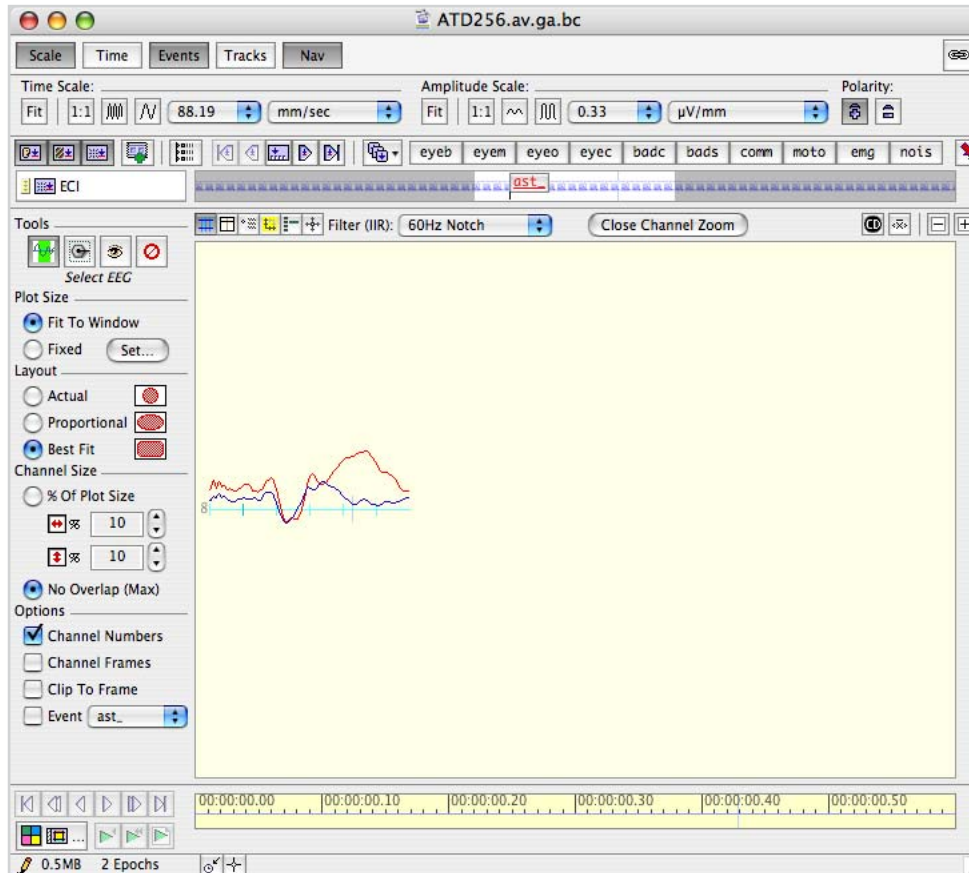
Figure 17-3. Zooming in on a channel

Interpolated Topo Map View

Topo Map view displays samples as disks that represent, in two dimensions, the topography of the entire head. Amplitudes are represented using color over the entire surface of the head, with interpolation used to calculate the amplitudes between the sensors. This view is useful for creating animations of ERP data.

Topo maps are accompanied by amplitude scales that allow you to tell, based on the color, the approximate voltage value of different points on the map. An amplitude scale is defined by a color spectrum and the amplitude range it represents. The maximum voltage value of the amplitude-scale range is associated with the high end of the spectrum, and the minimum value is associated with the low end.

Topo Map view offers features for very fine control over many aspects of the appearance of your topo maps. This tutorial covers several of the most basic and important of these features. You will view the data "as Topo Map" in a new window. Later you will use the current window, in Channel Zoom mode, in conjunction with the Topo Map window and the linked-window feature you learned about in Chapter 5, "Recognizing Noise."

1 Choose **View > Open New Window**.

A second window appears in Topo Plot view. The new window is exactly like the original, except that Channel Zoom is closed and all channels are displayed. Keep the first window in the background for use later in this chapter.

2 With the new window in the foreground, choose **View > as Topo Map**.

Topo Map view appears. Because you are still viewing "as Overlaid Segments," there are two topo maps, one for each condition (Figure 17-4).
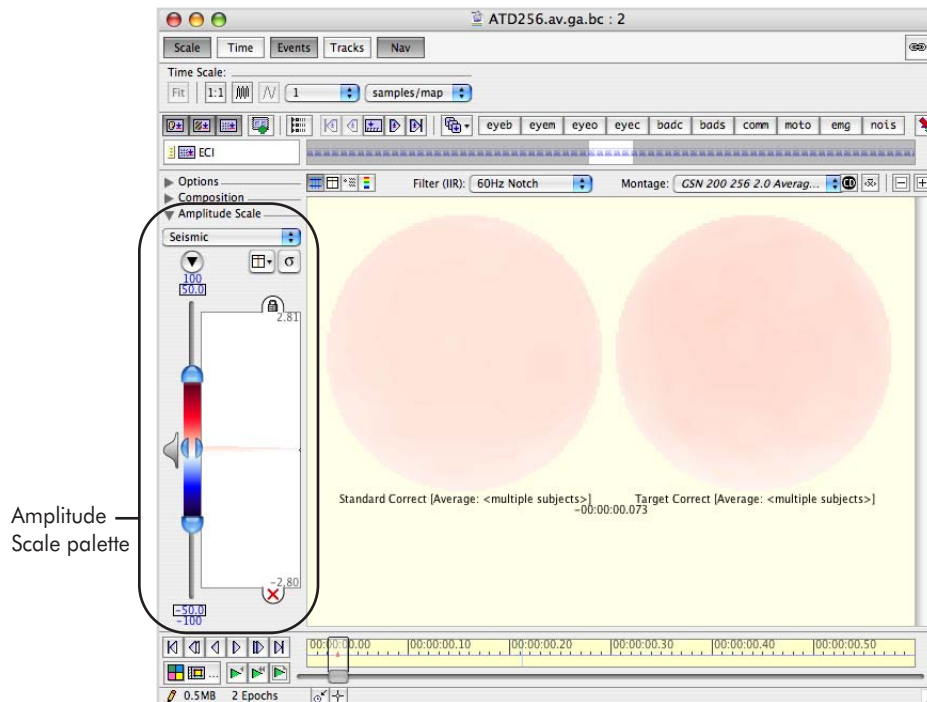
Figure 17-4. Topo Map view

Note: Your screen may appear slightly different, depending on your system's settings and history.

Next, you will set up the amplitude scale using the Amplitude Scale palette (Figure 17-5), which is on the left side of the Viewer window.

The Amplitude Scale palette offers many tools. The following are brief descriptions of the numbered items from Figure 17-5.

1. Spectrum pop-up menu. Allows selection of the color spectrum.

2. Palette-maximum label. Indicates the current palette maximum.

3. Palette-maximum slider. When dragged, this changes the palette maximum.

4. Histogram. Displays the distribution of voltage values in the sub-epoch chosen using the sub-epoch pop-up menu (12). Rolling the cursor over the histogram causes a popup to appear containing the range of voltage values for the histogram bin under the cursor, and the number of samples in the bin.

5. Palette-minimum slider. When dragged, this changes the palette minimum.

6. Palette-minimum label. Indicates the current palette minimum.

7. Histogram minimum label. Indicates the minimum value in the histogram (the smallest data value in the sub-epoch on which the histogram is based).
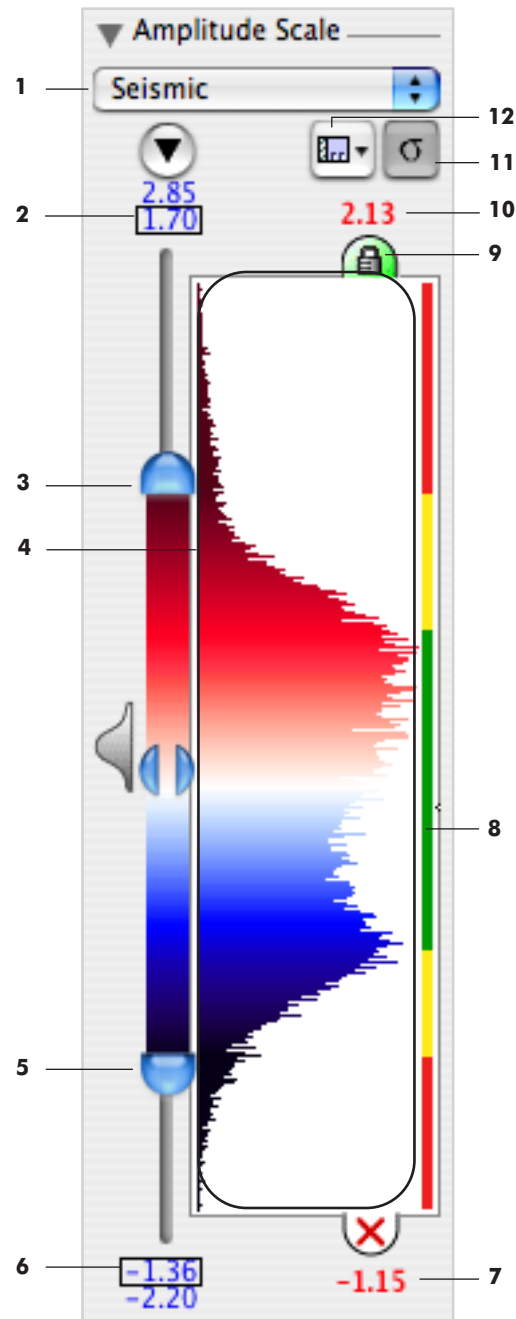
Figure 17-5. Amplitude Scale palette

8. Statistics bar. Contains different colored sections. The top and bottom red portions represent the maximum and minimum 2.3% of the voltage values, respectively. The top and bottom yellow portions represent the next maximum and minimum 13.7% of the voltage values, respectively.

9. Lock toggle. When depressed, this forces the histogram (3) to fill the histogram area.

10. Histogram maximum label. Indicates the maximum value in the histogram (i.e., the largest data value in the sub-epoch on which the histogram is based).

11. Statistics-bar toggle. Toggles the display of the statistics bar (8).

12. Sub-epoch pop-up menu (one for each histogram displayed). Allows you to select the sub-epoch on which the underlying histogram (3) is based.

Now, you can continue setting up the amplitude scale.

3   Choose Seismic from the Spectrum pop-up menu.

Use the amplitude-range tools to select an optimal amplitude-scale range.

4   Choose the Segment icon from the sub-epoch pop-up menu to use the entire segment as the sample range for the histogram (Figure 17-6).

Figure 17-6.
Segment icon

The histogram now references the entire segment.

5   Select the Lock toggle to force the histogram to fill the histogram area.

6   Select the statistics-bar toggle to display the statistics bar.

You now have a good statistical description of the data in the sample range. You know the maximum and minimum voltage values (that is, histogram minimum and maximum) and have a graphic representation of the distribution and standard deviation information.

You can use this information to select an optimal amplitude-scale range. You could do this by using the palette maximum and minimum sliders. However, there is an easier way.

7   Click in the yellow area of the statistics bar.

This forces the amplitude-scale range to exactly span 95% of the data (or all values within two standard deviations from the mean, assuming the values have a normal distribution). This is preferable to having the amplitude-scale range span 100% of the data because in that case, the outliers have too much influence on the amplitude scale.

8 Navigate to 371 ms.

You now have a different way of looking at the increased positivity in the Target Condition, known as the *P300* (Figure 17-7).
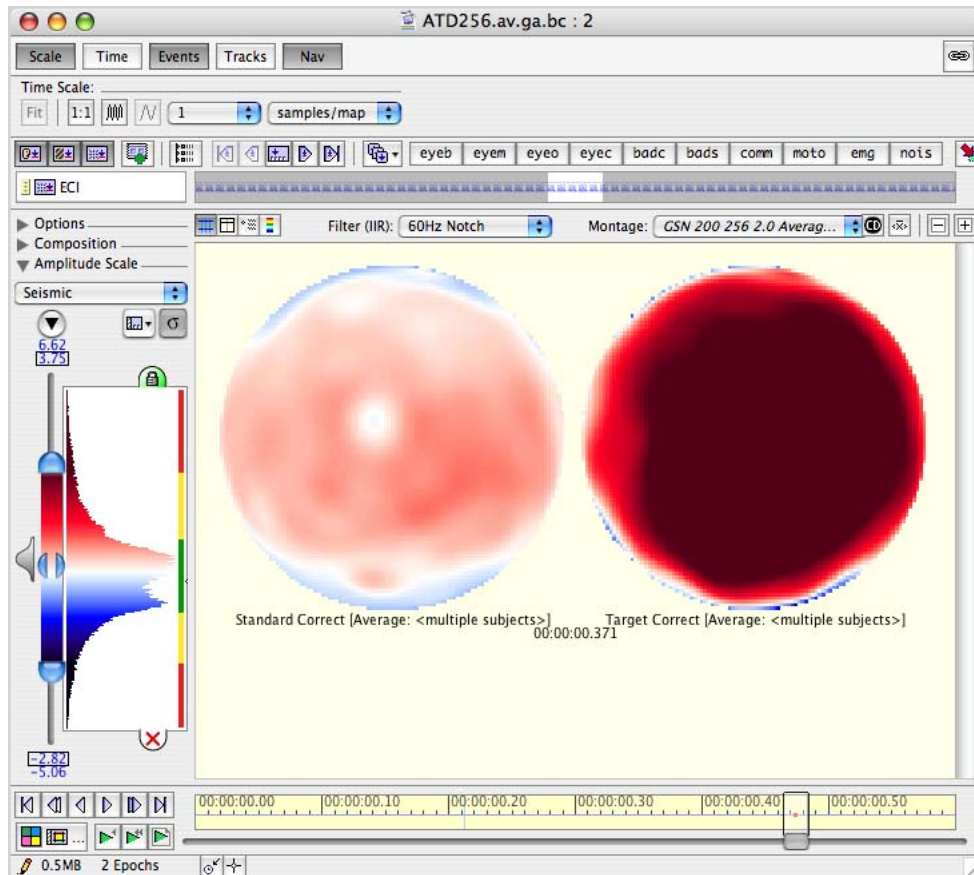
Figure 17-7. Topo Map P300

The remainder of this chapter describe three different ways to use Topo Map view to see how ERP evolves over time.

Watching ERPs Evolve over Time with Animation

One way to see how an ERP evolves over time is to use the animated scrolling buttons of the Navigation control strip (Figure 17-8).

Figure 17-8.
Animated
scrolling buttons

1 Navigate to the beginning of the segment, using the Navigation control-strip slider.

2 Click one of the animated scrolling buttons.

Watching ERPs Evolve over Time with Layout

Another way to see how an ERP evolves over time is to change the layout to show multiple samples simultaneously.

1 Navigate to the beginning of the segment, using the Navigation control-strip slider.

2 If necessary, click the disclosure triangle by the Options label to display the Options panel.

3 Click the Layout button of the Options panel.

The Layout dialog appears (Figure 17-9).
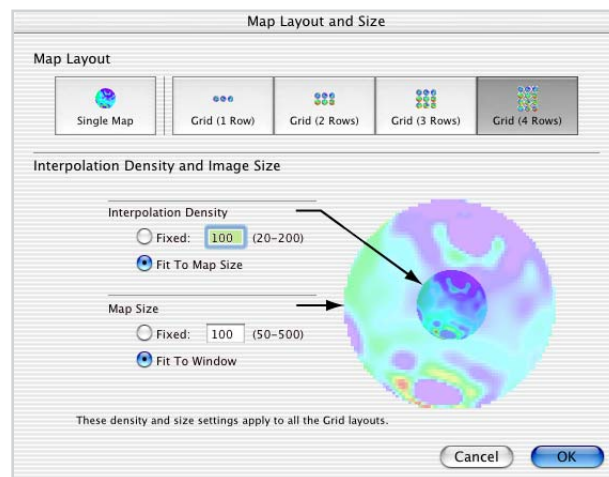
Figure 17-9. Map Layout and Size window

4   Set Map Layout to Grid (4 Rows).

5   Set Interpolation Density to Fit To Map Size.

6   Set Map Size to Fit To Window.

7   Click OK.

You now see 12 samples simultaneously (Figure 17-10).
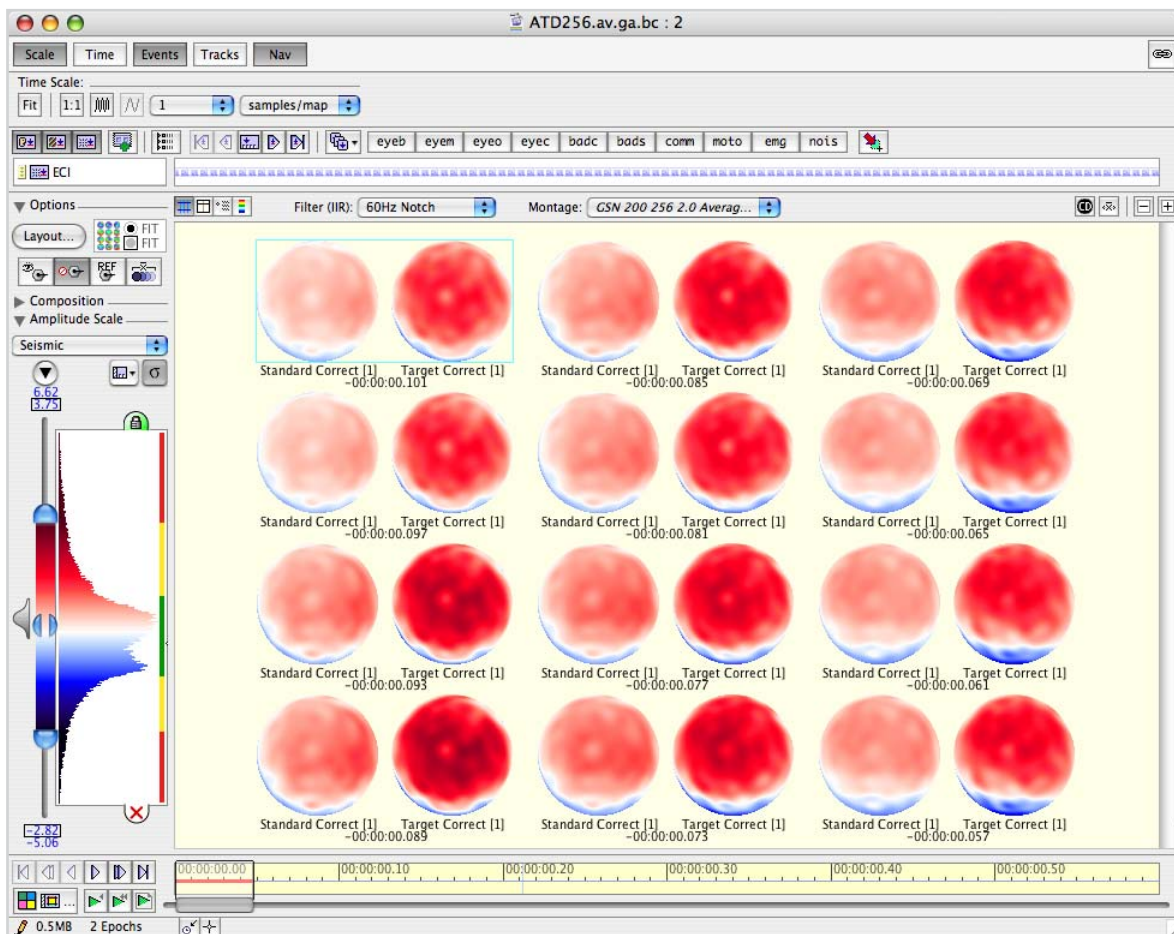
Figure 17-10. Multisample view

Note that time progresses from top to bottom, and then from left to right. In other words, the first sample is in the upper left; the second sample is the one immediately underneath the first; the fifth sample is in the upper center; and so on.

You now see an epoch spanning –101 ms to –57 ms. To see a bigger epoch at one time, you can choose to skip samples between maps. Note that the Time Scale panel of the Scale control strip is different in Topo Map View. In this view, you choose samples / map.

8 Use the Time Scale panel to select 10 samples / map.

9 Drag the slider of the Navigation control strip to the far right.

You now see an epoch spanning 19 ms to 459 ms (Figure 17-11).
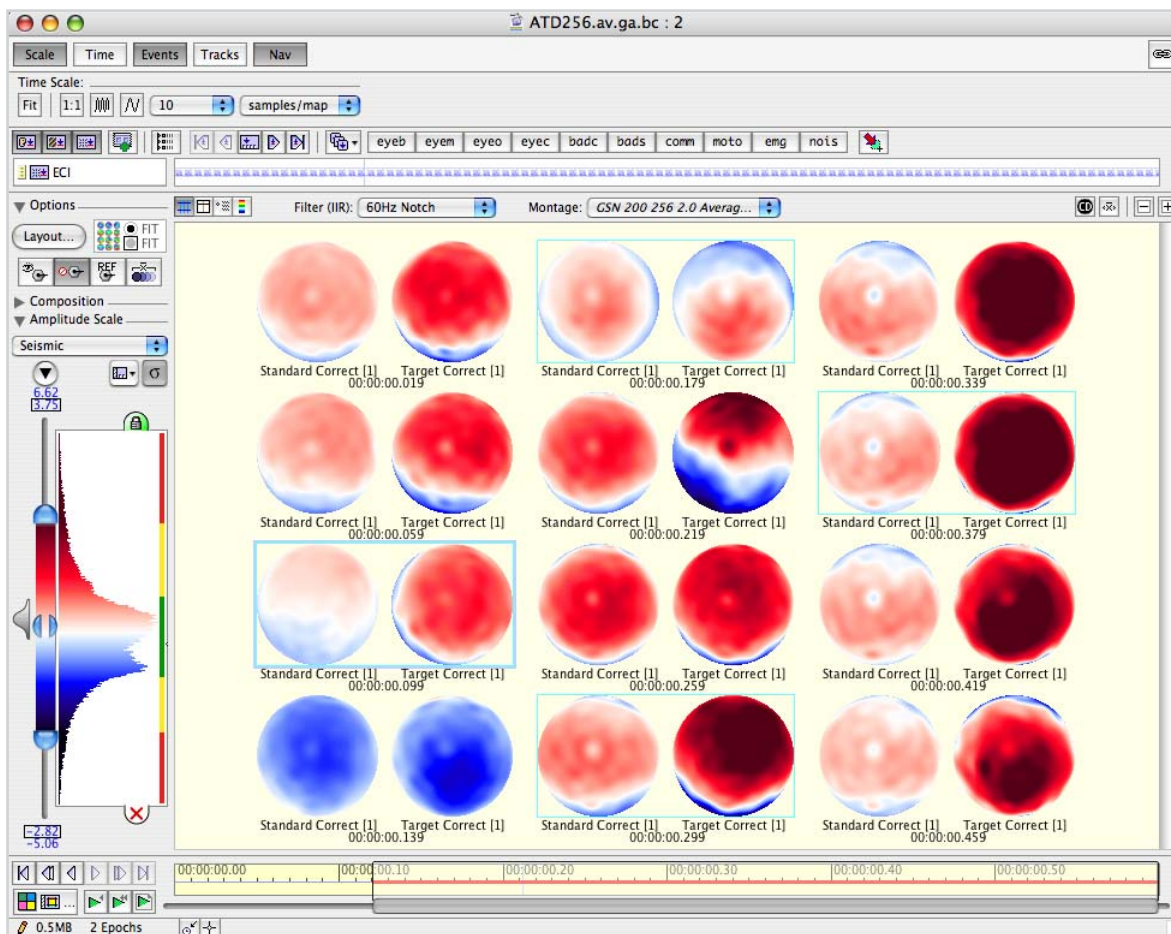
Figure 17-11. Multisample view with 10 samples/map

Watching ERPs Evolve over Time with Time Synch

Another way to see how an ERP evolves over time is to use the Time Synch and the Link feature you learned about in Chapter 5, "Recognizing Noise." This method is useful for locating an area of interest in a single channel and then viewing the topography of that timepoint over the entire head. You will use the current Topo Map view window and the Topo Plot view window that you set aside at the beginning of this chapter.

1   Return the Topo Map view time scale to 1 sample/map with the Time Scale panel, and return the layout to Single Map with the Layout dialog.

Link button

2   Select the Link button (located in the top-right corner of the Viewer window) in both the Topo Map view and Topo Plot view windows.

Time Synch toggle

3   Select the Time Synch toggle (located on the data-display control strip) in both windows.

You have now linked the two windows in time, so that the data sample underlying the Time Synch in Topo Plot view is the same as that which is displayed in Topo Map view.

In Topo Plot view, the Time Synch is a line, brown by default. You can change the color using the Viewer Preferences dialog. In Topo Map view, the Time Synch is a frame around the appropriate map.

As you navigate temporally through the Topo Plot window by dragging the Time Synch or by using the navigation controls in the Topo Map window, all other linked windows are automatically updated.

In the following steps, you will drag the Time Synch to a specific timepoint. To assist in navigating to a precise timepoint, you can use tools on the status bar. The status bar contains a timepoint indicator. The contents of the timepoint indicator depends on the state of the two toggle buttons to the left of the status bar (Figure 17-12).

millisecond   Time Synch

🖉 0.5MB   2 Epochs   ⊙ ⊞ ▦ –00:00:00.097 Standard Correct [Average: <multi...

Status bar in millisecond and Time Synch mode

millisecond   roll-over

🖉 0.5MB   2 Epochs   ⊙ ✛ ▦ –00:00:00.089 Standard Correct [Average: <multiple subjects>]

Status bar in millisecond and roll-over mode

sample   selection

🖉 0.5MB   2 Epochs   ∿ ▦ ▦ –26 Standard Correct [Average: <multiple subjects>]

Status bar in sample and selection mode
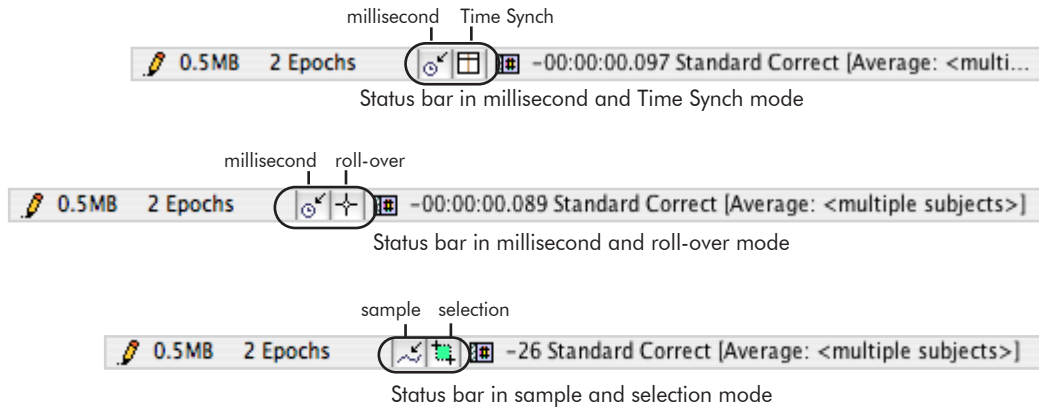
Figure 17-12. Status bar

The button on the left is the sample/millisecond toggle. Depending on the state of this toggle, information in the timepoint indicator will be expressed in either samples or milliseconds. The ∿ icon indicates samples mode, and the ⊙ icon indicates milliseconds mode. The default mode is milliseconds mode, the mode you will use in this chapter.

The button on the right is the selection/roll-over/Time Synch toggle. Depending on the state of this toggle, information in the timepoint indicator will be about either the current selection, the sample under the cursor, or the sample under the Time Synch marker. The ▦ icon indicates selection mode, the ✛ icon indicates roll-over mode, and the ⊞ icon indicates Time Synch mode. The default mode is roll-over mode. You will use the Time Synch mode in this chapter.

4   In the Topo Plot view window, set the sample/millisecond toggle to milliseconds mode, and the selection/roll-over/Time Synch toggle to Time Synch mode.

5   In the Topo Plot view window, drag the Time Synch to 371 ms, which you earlier determined was the location of the P300. The Topo Map view window will update to display the map for the same sample.

6   For easier side-by-side comparison, click the Minimize button (located on the far-right of the data-display control strip) in both windows.

Minimize button
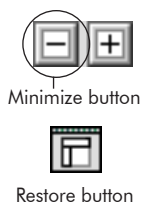
Restore button

The Minimize mode hides all Viewer controls and displays only the graph, chart, or map of interest. Only the title bar and a Restore button (on the right

side of the status bar) are displayed with the graphic. Click the Restore button to return the window to its normal state, with the Viewer controls displayed.

Figure 17-13 shows both windows in Minimize mode with the Time Synch at 371 ms. Note the different appearance of the Time Synch in the two views.
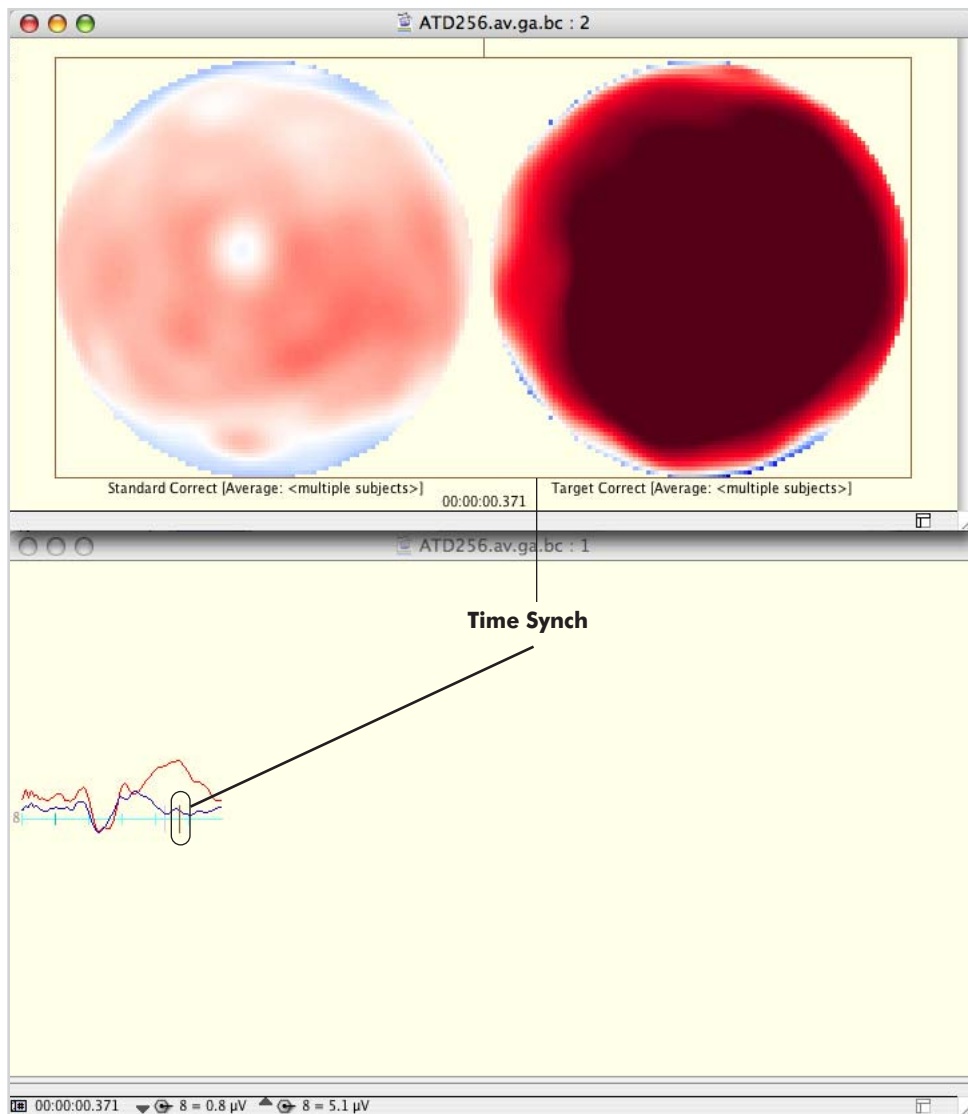
Figure 17-13. The P300 viewed using the Time Synch feature

7 In the Topo Plot view window, drag the Time Synch to 123 ms to view the topography of the N100 in the Topo Map view window.

8 Close both files.

EXTRACTING DATA FOR STATISTICAL ANALYSIS

This tutorial has taken you through the processing steps required to derive the ERP. In Chapter 17, "Visualizing ERPs," you were able to view the results of these steps, identify several ERP components (the N100 and P300), and visually inspect the ERP components for differences as a function of the experimental conditions. The next step is to determine whether a particular component is statistically different between experimental conditions.

In this chapter, you will create a text file suitable for importing into a statistical software package (such as SPSS or JMP) to show statistically that the P300 component is larger in amplitude for the target condition than it is for the standard. The text file is generated by the Statistic Extraction tool, which is a Waveform Tool that generates a text file, rather than a Net Station data file. Before you can use the Statistic Extraction tool, you must create events and a montage that specifies the time window and channel group for the statistics.

To extract data for statistical analysis, you will perform the following tasks:

- select time windows for the extraction of statistics
- create a user event track
- create a user event set and user events
- insert user events that span the selected time windows
- create a montage to verify the time windows for the individual subjects
- verify the time windows for the individual subjects
- create a Statistic Extraction specification
- run the Statistic Extraction tool
- view the results

Select Time Windows for the Extraction of Statistics

Before defining the window for statistic extraction, you must have a general idea of where you should place each ERP window. To do this, it is best to inspect the grand-average file.

1   Open the baseline-corrected, grand-average file ATD256.av.ga.bc.

2   View the data in Topo Plot view, in overlaid segment mode, and in Segment Time (by choosing **View > as Topo Plot**, **View > as Overlaid Segments**, and **Time > Segment Time**).

3   Choose **Time > Fit Segment To Window** (see Figure 17-1 in Chapter 17, "Visualizing ERPs").

Notice that the P300 can be seen clearly at the *centroparietal sites* (the channels near the vertex) for the target condition. The P300 peaks approximately 370 ms after the onset of the auditory signal. Also note that at approximately 135 ms after the target, there is a negative deflection over the same sites. This is the N100.

4   Switch to Chart view by choosing **View > as Chart**.

5   Choose **Time > Actual Size (1:1)**.

6   In the Viewer, scroll down to channels 80 and 89, which are near the vertex.

Next, you will drag the cursor to create a selection from 311 ms to 463 ms. To assist in making a precise selection, you can use tools on the status bar (see page 161 for an illustration of the status bar and a description of the tools).

7   Set the sample/millisecond toggle to milliseconds mode, and the selection/roll-over/Time Synch toggle to roll-over mode.

8 Using channel 89 to aid your selection, roll the cursor over the status bar until the timepoint indicator displays 311 ms (Figure 18-1).

Figure 18-1. Timepoint indicator of the status bar in milliseconds mode

9 Drag the selection until the timepoint indicator shows that your selection spans from 311 ms to 463 ms.

After you have made your selection, you can verify that it is correct by changing the selection/roll-over toggle to selection mode. That status bar should resemble the bar in Figure 18-2.

Figure 18-2. Status bar in selection mode

10 Switch back to Topo Plot view (**View > as Topo Plot**), and choose **Time > Fit Segment To Window**.

You can now see your selection in all channels. The selection covers the time period in which the P300 is maximally different between the two conditions. Note this time window so that you can use it later to define the P300 for the individual subjects.

11 Repeat Steps 4–6 on page 166.

12 Using channel 89 to aid your selection, drag the cursor to create a selection from 99 ms to 203 ms.

13 Switch back to Topo Plot view (**View > as Topo Plot**), and choose **Time > Fit Segment To Window**.

You can see your selection in all channels. The selection covers the time period in which the N100 is maximal for both conditions. Note this time window so that you can use it later to define the N100 for the individual subjects.

14 Close the file.

Create a User Event Track

After selecting the ERP windows from the grand-average file, the next step is to use this information to define the ERP windows for individual subjects. You will use the baseline-corrected, multisubject-average file ATD256.av.bc. The first step is to create an event track for user events that span the selected time windows.

1 Open the file ATD256.av.bc.

2 If necessary, select the Events control-strip disclosure toggle to display the Events control strip.

3 Click the Insert Event Track button (Figure 18-3).

4 Name the track "Windows" and click New.

Insert Event Track button   Select Event Sets pop-up menu
                                   (referred to in Step 3 on page 170)
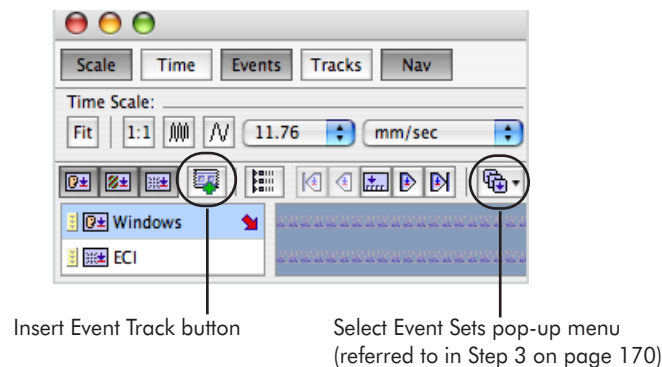
Figure 18-3. Event control strip details

Create a User Event Set and User Events

You will now create user events for defining ERP windows for statistic extraction.

1 Choose **Events > Define User Events/Sets**.

The Define User Events and Event Sets dialog appears.

First, create an event set.

2 Click the Add button of the User Event Sets panel and name the new set "ERP Events".
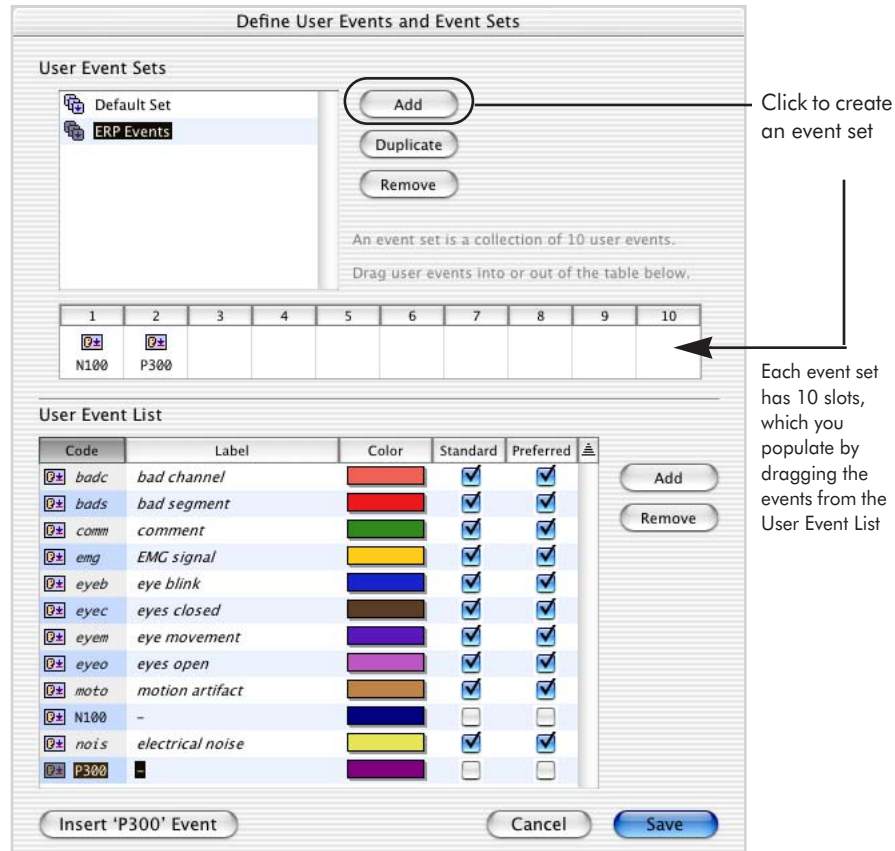
Figure 18-4. The Define User Events and Event Sets dialog

There are 10 slots for every event set that you create. Now, define the events.

3 Click the Add button of the User Event List panel and name the new event "N100".

4 Click the color bar next to the N100 event and define a new color.

5 Repeat Steps 3 and 4 to create a "P300" event.

6 Drag the N100 and P300 events (one at a time) into the numbered slots above the User Event List panel (Figure 18-4).

7 Click the Save button of the Define User Events and Event Sets dialog, saving your events and closing the dialog.

Insert User Events that Span the Selected Time Windows

You are ready to define ERP windows for statistics extraction using the user track and user events from the previous sections in this chapter.

1 Set up the Viewer by choosing the following:

   ° **View > as Chart**
   ° **View > as Continuous Data**
   ° **Time > Actual Size (1:1)**

2 If necessary, click the Windows event tile to select that track; the tile should change color and display a red arrow pointing at the track (Figure 18-5).
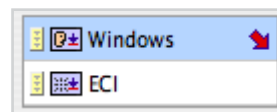
Figure 18-5. Select the Windows event track

3 Select ERP Events from the Select Event Sets pop-up menu (refer back to Figure 18-3).
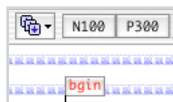
The Insert Event buttons above the event tracks now contain the N100 and P300 user events that you created.

4 In the first segment, drag the cursor to create a selection from 99 ms to 203 ms, using the technique you learned earlier in this chapter.

Note: You can actually do this in any segment because this time window will be applied to all segments in the next step.

5 Option-click on the N100 Insert Event button.

The Event Placement dialog appears (Figure 18-6). This dialog offers you the choice of placing the event in other segments (in this case, subjects) and categories. Note that the temporal location of the event is specified by the selection.

6 Click "all Segments in all Categories" and click Apply.
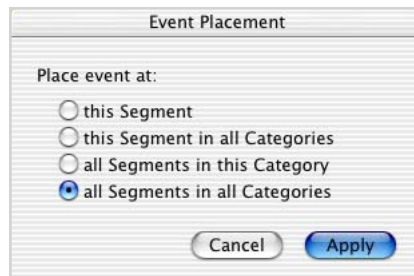
Figure 18-6. Event Placement dialog

After a brief period, N100 events appear at the specified time in all segments. Now, insert an event for the P300.

7 Repeat Steps 4–6 for the P300 event, using the 311–463 ms time window and the P300 Insert Event button.

Your event track should now resemble Figure 18-7.
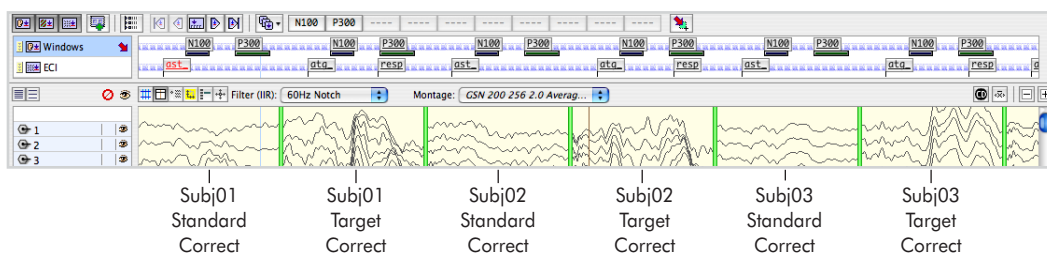
Figure 18-7. Event track with N100 and P300 time-window events

Create a Montage to Verify the Time Windows for the Individual Subjects

It is known that the N100 and P300 have centroparietal distributions. Therefore, you will want to inspect the accuracy of the defined window by looking at the channels over these sites. Create a montage for this purpose.

1   Choose **Montage > New Montage**.

2   Name the new montage "Centroparietal" and click New.
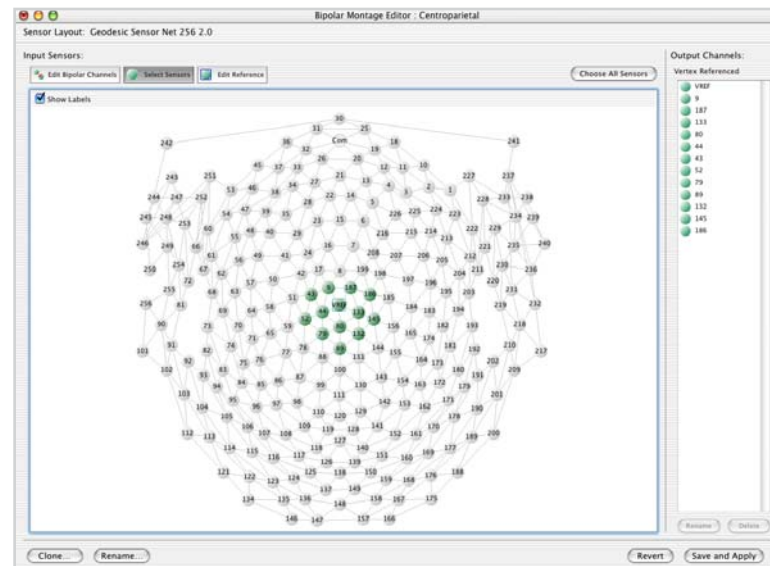
Figure 18-8. Montage editor with Centroparietal channel group

3   In the Sensor Layout area of the Montage editor, select channels VREF, 9, 187, 133, 80, 44, 43, 52, 79, 89, 132, 145, and 186. See Figure 18-8.

4   Close the window, saving the montage.

Verify the Time Windows for the Individual Subjects

Recall that you selected the windows from the grand-average file and applied the selections to the individual subjects. You will find that when you inspect individual subject data, they will often look substantially different from the grand-average data. Because of this, you will have to verify that the defined N100 and P300 windows for all subjects and categories are accurate.

Standard Correct Category

1 Choose View > **as Overlaid Segments**.

2 From the Montage pop-up menu above the data-display area, choose Centroparietal.
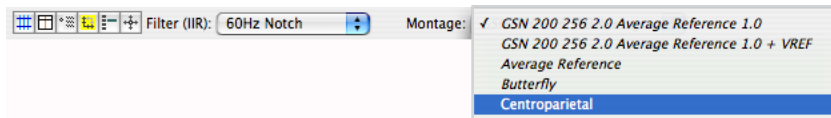
Figure 18-9. Montage pop-up menu in the data-display control strip

3 Option-click on the N100 event in the Windows event track.

This action selects N100 events for all categories and subjects (that is, segments). The duration of the event in the waveforms is highlighted with the color you defined for the N100 event.

4 Inspect the N100 window for all subjects. Use the Segment pop-up menu of the Overlaid Segments palette to change subjects (Figure 18-10). When changing to a new subject, do not forget to change to the new subject in both conditions.
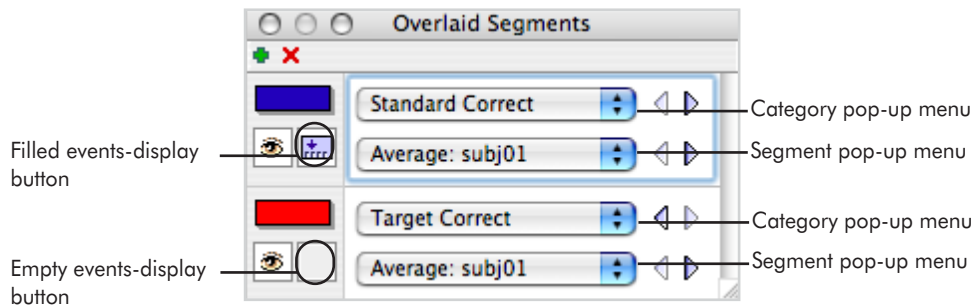
Figure 18-10. Overlaid Segments palette

Notice that this event accurately describes the N100 window for all subjects.

Verify the P300 event definition.

5 Option-click on the P300 event in the Windows event track.

6 Inspect the P300 window for all subjects. When changing to a new subject, do not forget to change to the new subject in both conditions.

Notice that the P300 event accurately describes the P300 window for all subjects except subj03. For this subject, the P300 appears 50 ms earlier. Change the definition of the P300 for this subject to take into account the latency difference. You must do this for each category.

7 The events-display button for the Standard Correct category should be filled. If the button is empty, click on it so it is now filled (see Figure 18-10).

8 Select Average: subj03 from the Segment pop-up menus for both the Standard Correct and the Target Correct categories.

In Overlaid Segments mode (as in all category-viewing modes), you can view the events for only one segment at a time. You will use the Events-display button to select the segment.

9 Click anywhere in the Windows event track to deselect the P300 event.

10 Double-click on the P300 event.

An Event editor for that event appears, showing the onset time as 2.812 (Figure 18-11). Note that the Event editor always shows onset times in Relative Time mode.
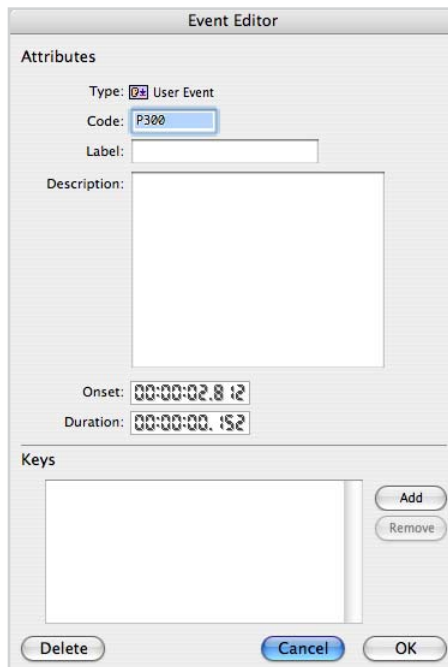
Figure 18-11. Event editor for P300 event

11 Change the value in the Onset box to 2.762 and click OK.

Target Correct Category

Repeat for the Target Correct category.

1 Click the empty events-display button for the Target Correct category so that it is now filled (see Figure 18-10).

2 Double-click on the P300 event.

3 Change the value in the Onset box from 3.412 to 3.362 and click OK.

4 Verify that you have moved the P300 events only for subj03 by Option-clicking on the P300 event and scrolling through the subjects.

5 Close the file.

Create a Statistic Extraction Specification

Now that you have specified the time windows and channel group, you will use them to extract the relevant statistic. You will first need to create a Statistic Extraction specification.

A single Statistic Extraction specification can contain the specifications for one or more statistical analysis. For each input file, the Statistic Extraction tool outputs a tab-delimited text file containing the number of statistical analyses created in the Statistic Extraction specification. In this case, you will create a Statistic Extraction specification with two analyses: one for the N100, and one for the P300.

For each analysis, you need to specify the following parameters:

- a time window
- a statistical measure (one of mean amplitude, adaptive mean, minimum amplitude, maximum amplitude, and latency)
- how the measure is to be reported for each channel group
- one or more categories
- one or more channel groups

In this case, you will choose *adaptive mean* as the statistical measure. This algorithm first finds a peak within the time window. Then, a new time window is defined around this peak. The mean voltage value is calculated from the new time window. The measure will be reported as the average of the channels in the channel group.

Editing the Specification

1 Open the Waveform Tools window.

2 Open a Statistic Extraction specification editor and name the Statistic Extraction specification "N100/P300 SE".

3 In the Output Options panel, set the name field to Append ".txt" (for text) and the destination field to Same As Source (Figure 18-12).

Editing the specification

Specifying the analysis

Finding categories and events in selected file

Creating channel groups for extraction
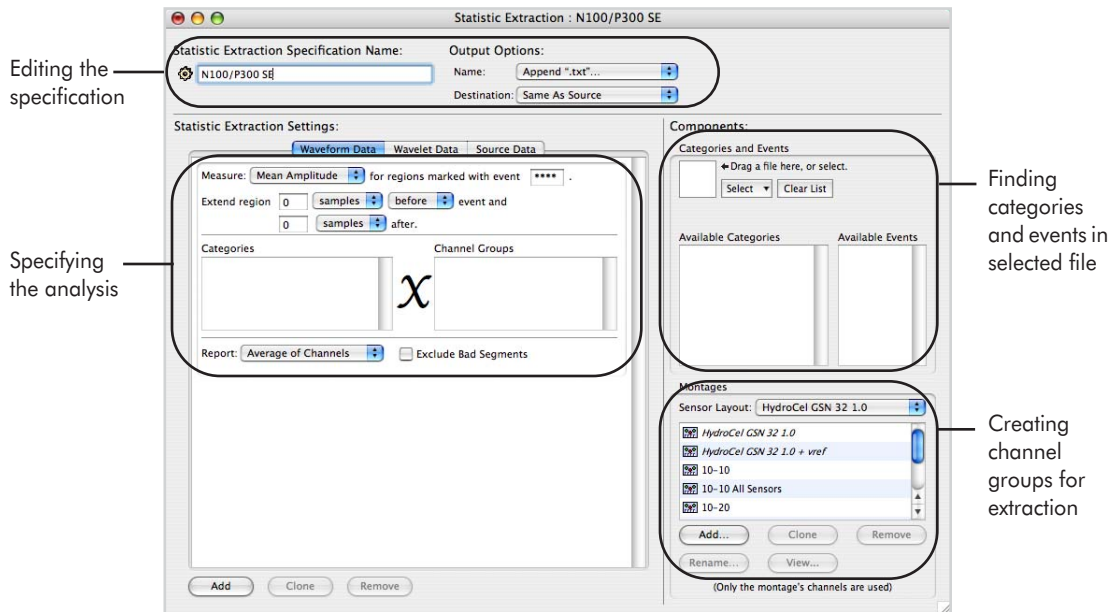
Figure 18-12. Statistic Extraction specification editor

Setting the Tool-specific Parameters

Now, set the tool-specific parameters. First, make the events and categories from the data file available to the specification editor.

1 Above the Available Categories and Available Events panes, click Clear List.

2 Above the Available Categories and Available Events panes, click the Select button, choose Other from the pop-up menu, navigate to and select the ATD256.av.bc file, and click Open.

You should now see the Standard Correct and Target Correct conditions in the Available Categories pane and the N100, P300, ast_, atg_, and resp events in the

Available Events pane. The N100 and P300 events are those that you have defined (Figure 18-13).
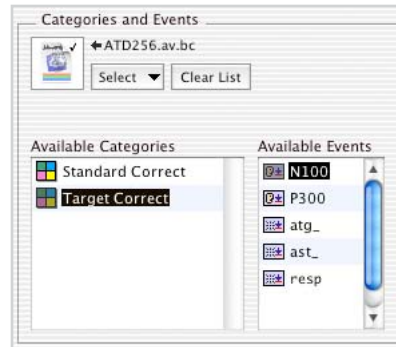
Figure 18-13. Available categories and events

Creating Montages

The next step is to create montages that represent the channel groups to be used to extract the measure.

1 In the Montage pane, choose Geodesic Sensor Net 256 2.1 from the Sensor Layout pop-up menu.
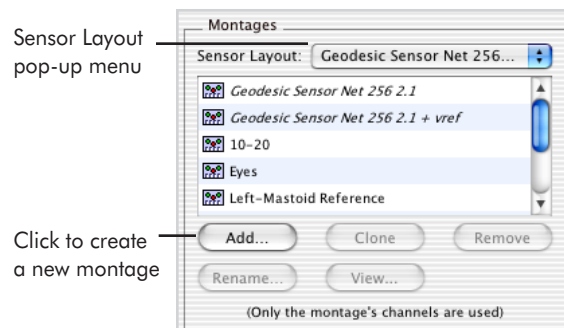
Figure 18-14. Montage pop-up menu and display

2 Click the Add button to open the New Montage dialog, name the montage "Left Centroparietal," and click the New button to close the dialog and view the Montage editor.

3 In the Sensor Layout area of the Montage editor, select channels 9, 43, 44, 52, and 79 (Figure 18-15).
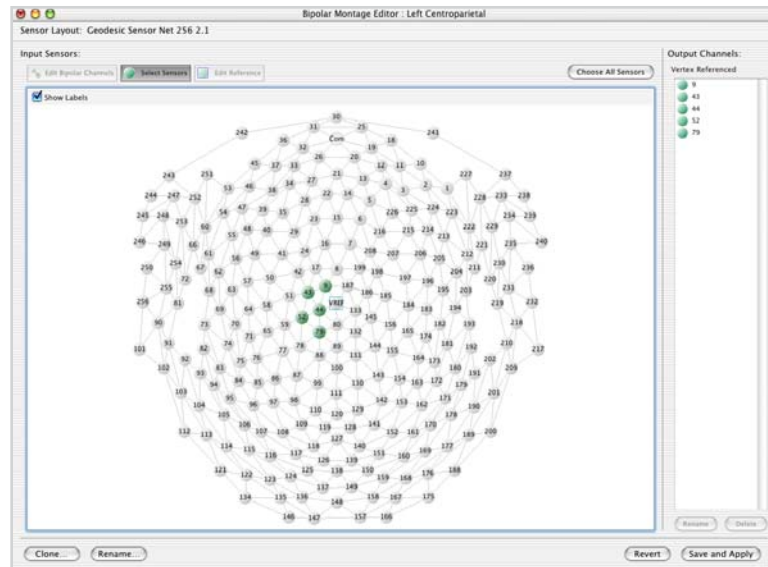
Figure 18-15. Creating the Left Centroparietal montage in the Montage editor

4 Close the Montage editor, saving the changes.

5 Repeat steps 2–4, but name the new montage "Right Centroparietal" and select channels 132, 133, 145, 186, and 187.

Specifying the N100 Analysis

The Statistic Extraction specification editor has three panes for three different kinds of data: waveform, wavelet, and source. Click the Waveform Data tab to view that pane. In the Waveform Data pane, specify the analysis for the N100, working in the Statistic Extraction Settings pane, from the top to the bottom.

1 Choose Adaptive Mean from the Measure pop-up menu (Figure 18-16).
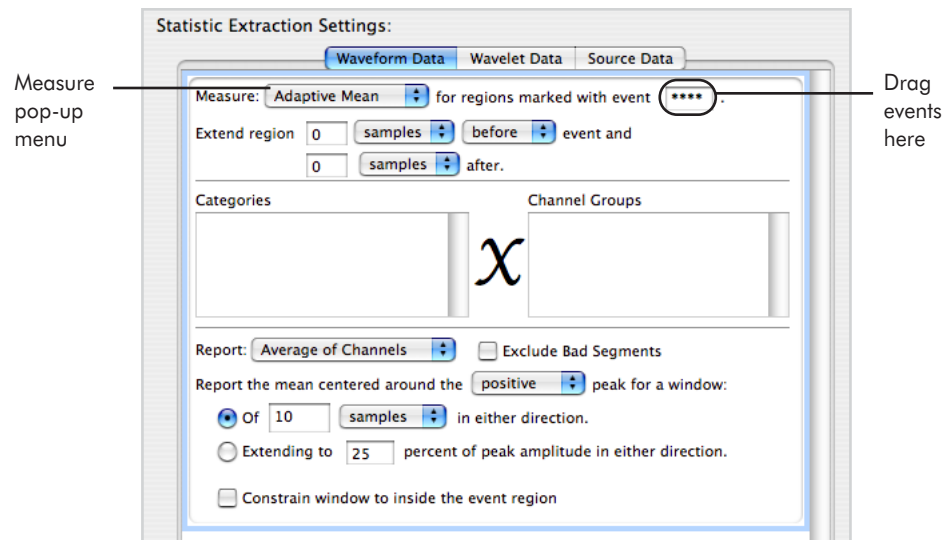
Figure 18-16. Statistic Extraction Settings pane

2 Drag the N100 event from the Available Events pane to the "Measure for regions marked with event" box (see Figure 18-16). (Leave the extending region parameters at zero because you have already specified fully the window width with the N100 event.)

3 Select Average of Channels from the Report pop-up menu

4 From the "Report the mean centered around the ___ peak" pop-up menu, choose "negative".

5 Click the "of ___ samples in either direction" button and type "5" into the box.

6 Make sure the "Constrain window to inside the event region" checkbox is unselected.

7 Drag the Standard Correct and Target Correct conditions from the Available Categories pane to the Categories pane.

8 Drag the Left Centroparietal and Right Centroparietal montages from the Montage pane to the Channel Groups pane (Figure 18-17).
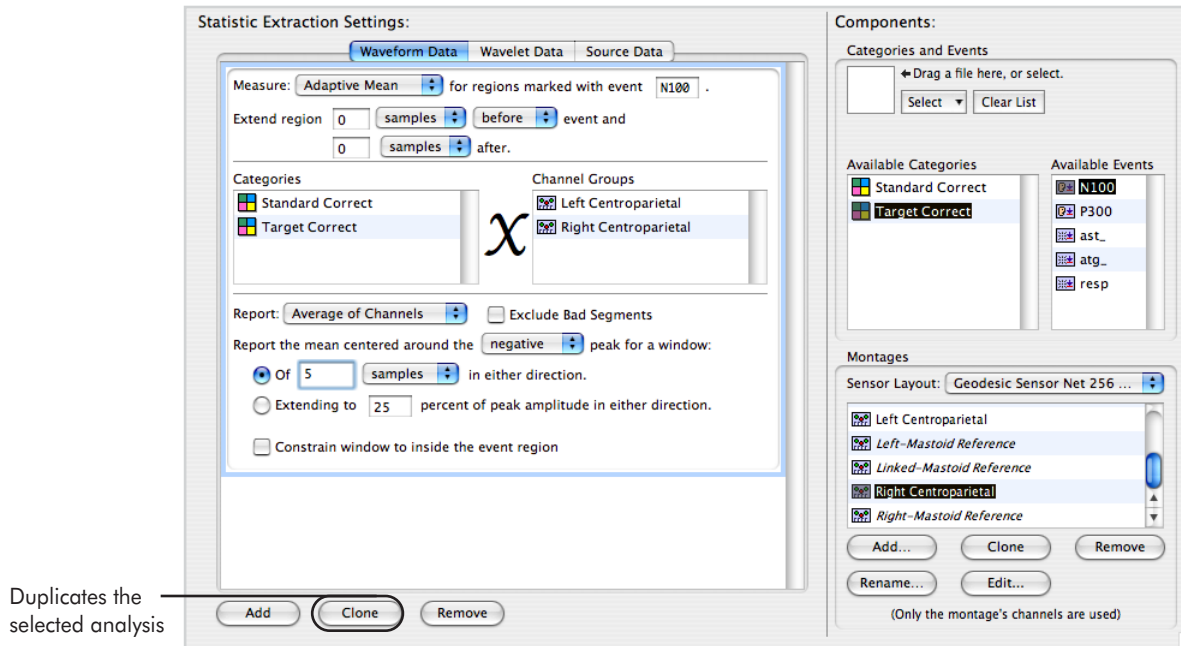
Figure 18-17. Statistic Extraction Settings pane with the N100 window defined

With this specification, the algorithm will first find the negative peak within the N100 window and then define a new window 11 samples wide (that is, 44 ms wide, with five samples on each side of the peak plus the peak sample). The average voltage value will be calculated for this new window. Note the "Constrain window to inside the event region" checkbox. If this box is checked, the new window will never go beyond the window specified by the N100 event.

Specifying the P300 Analysis

You have completely specified the analysis for the N100 (Figure 18-17). Next, specify the analysis for the P300.

1 Click the Clone button at the lower left of the editor to add another Analysis specification (see Figure 18-17).

A new Analysis specification appears below the one for the N100, a copy. In the new Analysis specification:

2 Drag the P300 event from the Available Events panel to the "Measure for regions marked with event" box.

3 From the "Report the mean centered around the ___ peak" pop-up menu, choose "positive".

The final Statistic Extraction specification should resemble Figure 18-18.
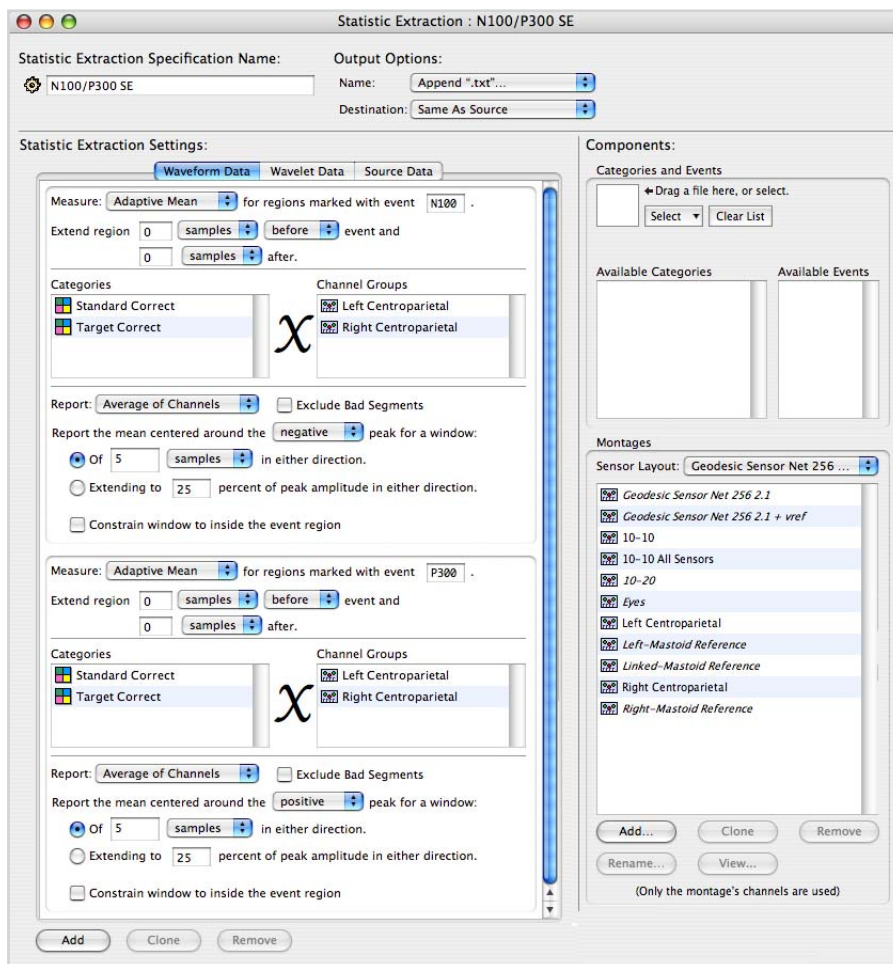
Figure 18-18. A completed Statistic Extraction specification

4 Close the Statistic Extraction specification editor, saving the changes.
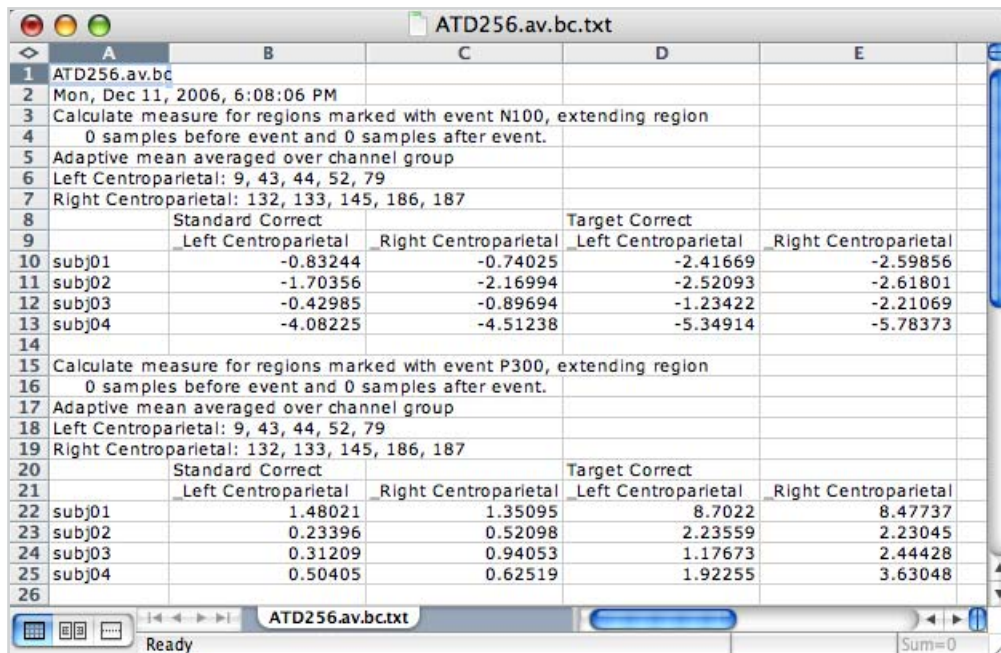
Run the Statistic Extraction Tool

In this section, you will run the Statistic Extraction tool.

1 In the Waveform Tools window, add the ATD256.av.bc file to the Inputs pane. There are several ways to add a file to the pane; if necessary, see "Run the Segmentation Tool" on page 88 for a description of each method.

2 Highlight the N100/P300 SE specification in the Specifications pane of the Waveform Tools window, and click the Run button.

View the Results

You now have a text file with the name ATD256.ave.bc.txt. This file opens with any text editor. Microsoft Excel is recommended. Figure 18-19 shows the results.

	A	B	C	D	E
1	ATD256.av.bc				
2	Mon, Dec 11, 2006, 6:08:06 PM				
3	Calculate measure for regions marked with event N100, extending region				
4	0 samples before event and 0 samples after event.				
5	Adaptive mean averaged over channel group				
6	Left Centroparietal: 9, 43, 44, 52, 79				
7	Right Centroparietal: 132, 133, 145, 186, 187				
8		Standard Correct		Target Correct	
9		_Left Centroparietal	_Right Centroparietal	_Left Centroparietal	_Right Centroparietal
10	subj01	-0.83244	-0.74025	-2.41669	-2.59856
11	subj02	-1.70356	-2.16994	-2.52093	-2.61801
12	subj03	-0.42985	-0.89694	-1.23422	-2.21069
13	subj04	-4.08225	-4.51238	-5.34914	-5.78373
14					
15	Calculate measure for regions marked with event P300, extending region				
16	0 samples before event and 0 samples after event.				
17	Adaptive mean averaged over channel group				
18	Left Centroparietal: 9, 43, 44, 52, 79				
19	Right Centroparietal: 132, 133, 145, 186, 187				
20		Standard Correct		Target Correct	
21		_Left Centroparietal	_Right Centroparietal	_Left Centroparietal	_Right Centroparietal
22	subj01	1.48021	1.35095	8.7022	8.47737
23	subj02	0.23396	0.52098	2.23559	2.23045
24	subj03	0.31209	0.94053	1.17673	2.44428
25	subj04	0.50405	0.62519	1.92255	3.63048
26					

Figure 18-19. Results of the Statistic Extraction operation

The first row contains the name of the data file upon which the specification operated, and the second row displays the date and time the text file was created. These rows are followed by the two analyses. For each analysis, the first two rows display the event (N100 or P300) and a description, and the following row provides information about the measure. The remaining rows contain information about the categories and channel groups.

Note that the actual data are formatted such that categories are indexed first (changing slowest), and channels are indexed second (changing the fastest). This is always true for the Statistic Extraction outputs.

Exported in this way, the data are ready to be imported, with only the removal of the rows containing the header information (rows 1–9 for the N100), into a statistic program in a within-subjects (that is, repeated measures) format. In this example, the analysis model would be a 2 (target and standard) X 2 (left and right) Analysis of Variance model with both factors being within-subjects factors.

After examining the results, close the text file.

. . . .

chapter 19

CREATING
DIFFERENCE WAVES

A common technique in psychological research is the subtractive method. The basic assumption is as follows:

If two experimental conditions differ in only one psychological process and the difference between these two conditions is taken, then common processes will be eliminated and the unique process will be preserved.

Neuroimaging researchers use the subtractive method to reveal the brain area(s) involved in an isolated psychological process. However, designing experimental conditions that differ in only one process is not always easy.

You should invariably inspect the original waveforms to understand the difference waveform. The experimental conditions can differ in just one psychological process, and this difference may be associated with a unique ERP component(s). However, this psychological difference may also lead to latency differences in shared ERP components. The latency differences will distort the difference waves and may lead to spurious ERP components.

In this chapter, you will learn how to create a file that contains the difference wave using the baseline-corrected, grand-average file ATD256.av.ga.bc.

Create a Difference Wave Specification

Editing the Specification

1   If necessary, start Net Station and open the Waveform Tools window.

2   Open a Difference Wave specification editor and name the Difference Wave specification "ATD Dif".

3   In the Output Options panel, set the name field to Append ".dif" (for difference) and the destination field to Same As Source.

Setting the Tool-specific Parameters

Now, set the tool-specific parameters.

1   From the Available Category pane, use the controls at the bottom of the pane (**Select > Other**) to select the file ATD256.av.ga.bc to view its categories.
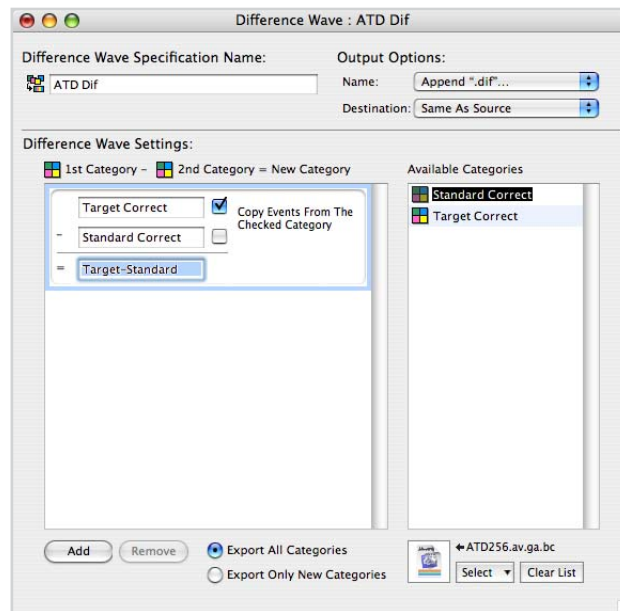
Figure 19-1. Difference Wave specification editor

In the Available Category pane, you will see the Standard Correct and Target Correct categories.

   2   Drag the Target Correct category to the first empty cell of the Difference Wave Settings pane.

   3   Drag the Standard Correct category to the second empty cell of the Difference Wave Settings pane.

   4   Name the new category "Target–Standard" (Figure 19-1).

Notice the checkboxes beside the Target Correct and Standard Correct cells in the Difference Wave Settings pane. These boxes allow you to specify which event track to carry over into the new difference wave category. In this chapter, you will want to know the process that is unique to the Target Correct condition.

   5   Select the checkbox by the Target Correct cell.

This will take all the events in the event track of the Target Correct category and copy them over to the new Target–Standard category.

To examine the difference waveforms along with the original waveforms, you will want to include the original categories in the new file.

   6   Click the Export All Categories radio button at the bottom of the pane.

Notice the Add and Remove buttons at the bottom of the pane. If the file ATD256.av.ga.bc had more categories, you would click the Add button to create additional difference wave settings. The Remove button deletes selected difference wave settings.

   7   Close the Difference Wave specification, saving the changes.

Run the Difference Wave Tool

In this section, you will run the Difference Wave tool.

1 In the Waveform Tools window, add the ATD256.av.ga.bc file to the Inputs pane. There are several ways to add a file to the pane; if necessary, see "Run the Segmentation Tool" on page 88 for a description of each method.

2 Highlight the ATD Dif specification in the Specifications pane of the Waveform Tools window, and click the Run button.

View the Results

1 After the process is complete, view the result file ATD256.av.ga.bc.dif in "as Overlaid Segments" mode.

This mode allows you to examine the difference wave and determine the source of the difference.

2 Close the file.

GENERATING 2D AND 3D ANIMATIONS

In this chapter, you will learn how to create two- and three-dimensional animations of the interpolated voltage data. These animations will allow you to view the spatiotemporal information inherent in EEG data. You will then learn how to make QuickTime movies for presentations and preparation of manuscripts.

It is assumed that you have completed the exercises in Chapter 17, "Visualizing ERPs," which introduced the functions of the interpolated Topo Map view that are required to generate 2D animations and the texture maps used for 3D animations. If terms or functions associated with Topo Map view in this chapter are unfamiliar, you may want to refer back to Chapter 17.

You can generate 2D animations entirely within Net Station. Creating 3D animations, however, is a two-part process: first, you generate texture maps in Net Station, and second, you model the texture maps on realistic head models and animate the results using Cinema 4D. This chapter is structured accordingly, with the following sections:

- common steps in creating 2D and 3D animations
- generating a 2D animation
- creating texture maps for 3D animations
- generating 3D animations

Common Steps in Creating 2D and 3D Animations

This section teaches you how to set the basic parameters for the 2D animations and 3D texture maps. Changing the parameters in Steps 6–10 allows you to alter the color spectrum and scaling of the 2D animations and 3D texture maps. To change the size of the resulting 2D animated maps, simply change the size of the Viewer window.

1 Open the baseline-corrected, grand-average file ATD256.av.ga.bc.

2 Choose **View > as Chart** and **View > as Overlaid Segments** (Figure 20-1).
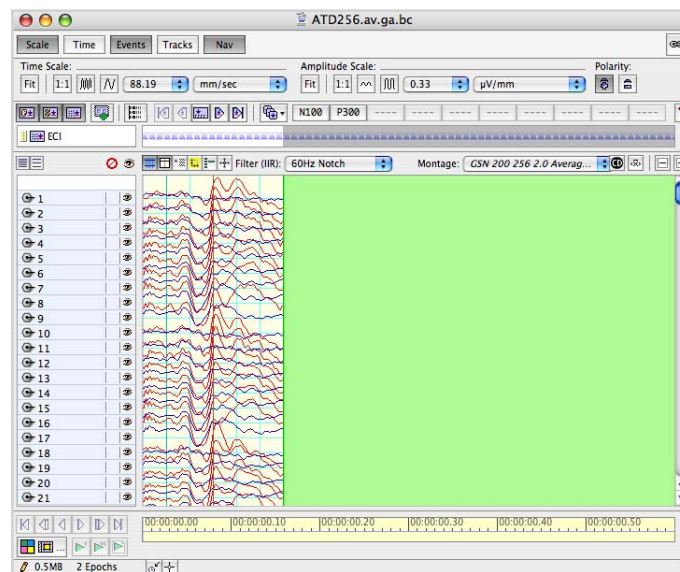
Figure 20-1. Choose to view as Chart and "as overlaid segments"

3 Choose **Time > Segment Time**.

4 In the data-display area, create a selection by dragging from –1 ms to 399 ms.

5 Choose **View > as Topo Map** (Figure 20-2).
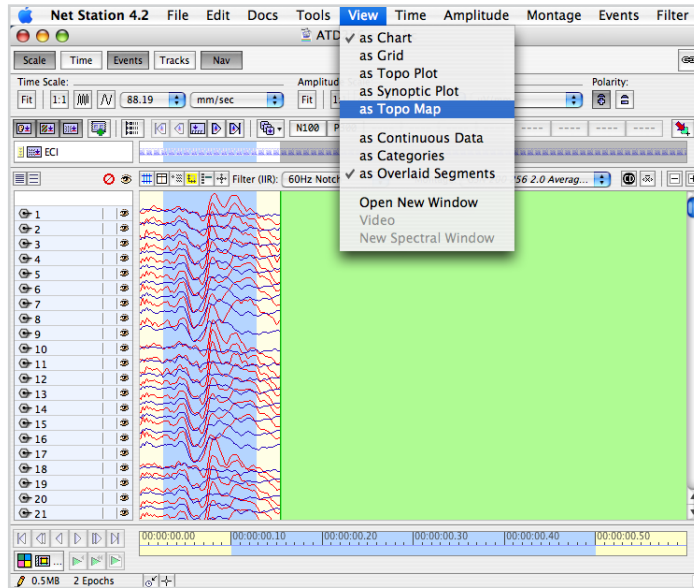
Figure 20-2. Make a selection and choose to view as Topo Map

6 In the Amplitude Scale palette to the left of the window, choose Seismic from the Spectrum pop-up menu (Figure 20-3).
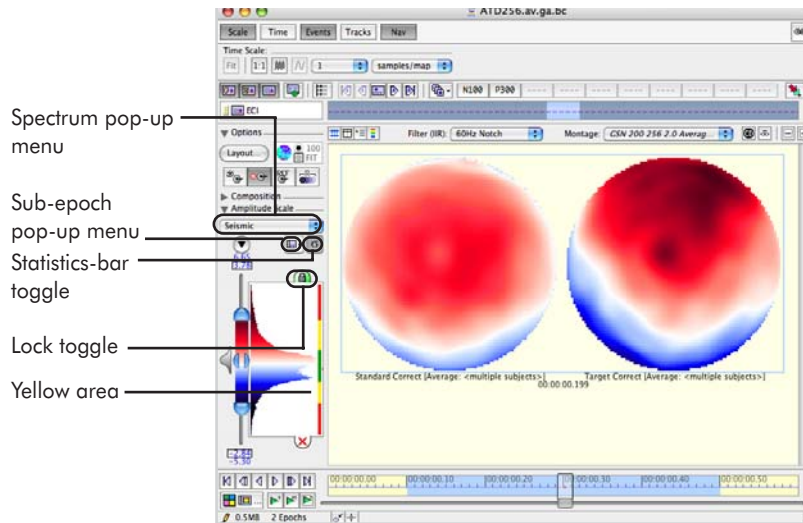
Figure 20-3. Set up the Amplitude Scale palette

7 In the Amplitude Scale palette, choose the segment icon from the sub-epoch pop-up menu to base the histogram on the segment.

8 In the Amplitude Scale palette, select the Lock toggle, which makes the histogram expand to fill the area.

9 In the Amplitude Scale palette, select the statistics-bar toggle to display the statistics bar.

10 In the Amplitude Scale palette, click in the yellow area of the statistics bar, which restricts the display of microvolts to within 2 standard deviations.

Generating a 2D Animation

Generating a 2D animation is straightforward, involving a simple file export to the 2D QuickTime Movie format.

1 Choose **File > Export**.

2 In the Export dialog, choose 2D QuickTime Movie from the Format pop-up menu and choose the tutorial file folder as the destination.

3 In the Export dialog, name the file "ATD256.av.ga.bc.mov".

4 In the Export dialog, click the Save button (Figure 20-4).
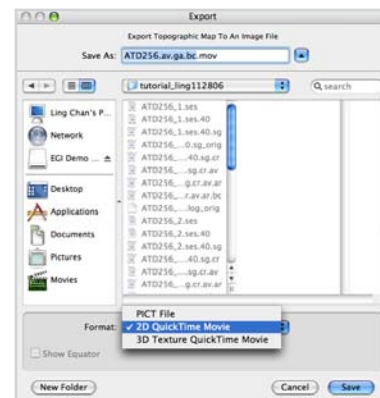
Figure 20-4. Export dialog

Viewing the 2D Animation

Net Station will generate a QuickTime movie of the time interval between 0 ms and 400 ms.

1 Double-click on the file ATD256.av.ga.bc.mov.

The file will automatically open using QuickTime, allowing you to view the movie (Figure 20-5).
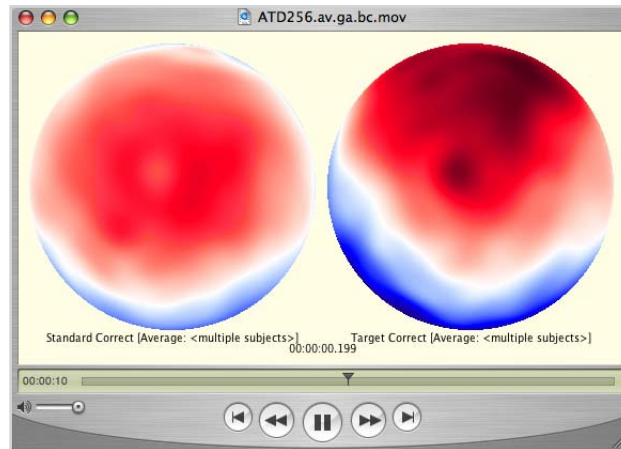
Figure 20-5. View the movie in QuickTime

Creating Texture Maps for 3D Animation

This section teaches you how to create a 3D texture map for wrapping onto a head model in Cinema 4D and converting to a QuickTime movie. In this section, you change the view from "as overlaid segments" to categories. Only one map is needed for wrapping on the head model.

1 If necessary, open the file ATD256.av.ga.bc.

2 Choose **View > as Chart**, and **View > as Categories**.

3 Select the Standard Correct category.

4 Follow Steps 3–10, starting on page 190 from the "Common Steps in Creating 2D and 3D Animations" section.

5 Choose **File > Export, to open the** Export dialog (see Figure 20-4).

6 Choose 3D Texture QuickTime Movie from the Format pop-up menu of the Export dialog.

7 Name the file "ATD256_STDCOR.mov" and choose the tutorial file folder as the destination.

8 Click the Save button.

If you wish to generate a QuickTime texture map for the Target Correct condition, repeat Steps 3–8, but instead of choosing the Standard Correct category, choose the Target Correct category.

9 Close the file.

Generating 3D Animations

For 3D head visualization, EGI recommends the Cinema 4D (version 10) product, available in both consumer grade and professional grade. The Cinema 4D programs are optimized for AltiVec and for multiple G4 processors, and can be run with rendering tasks distributed across multiple networked CPUs for maximum speed. The commercial Cinema 4D applications are available from EGI or directly from the publisher's website at *http://www.maxon.net*. Cinema 4D head models are available from EGI.

The head model and movie file used in this chapter reside on the Net Station installation disk. They are saved in the ERP Analysis Tutorial folder, in a folder called Cinema 4D Head Models (Figure 20-6). Make sure a copy of the Cinema 4D Head Models folder is on your desktop before proceeding.
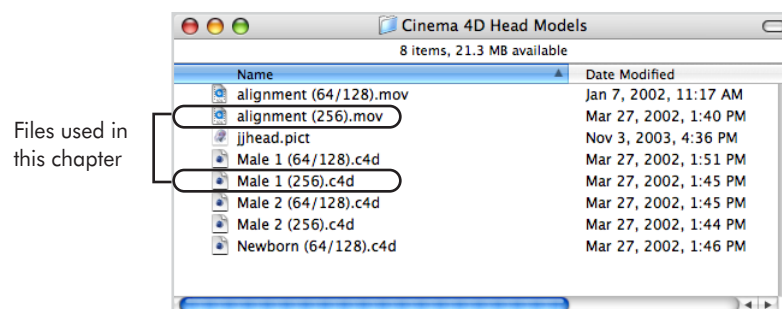
Figure 20-6. Files for creating a 3D head animation

In this part of the tutorial, you will determine the length of your 3D texture map and use that information to create a movie of your 3D head model.

1 In the Cinema 4D Head Models folder, make sure that the file "alignment (256).mov" is in the same location as the head model Male 1 (256).c4d.

2 Double-click on the head model Male 1 (256).c4d to launch Cinema 4D and to open the Male 1 (256).c4d file.

3 Double-click on the Texture button at the bottom left of the Male 1 (256).c4d window, to open the Material Editor window (Figure 20-7). The Material Editor window displays the attributes of the preloaded movie named alignment (256).mov; the movie's file name is displayed in the current-file button.

In the Male 1 (256).c4d window, double-click on the Texture button . . .

. . . to open the Material Editor window.

The current-file button displays the filename of the preloaded alignment movie
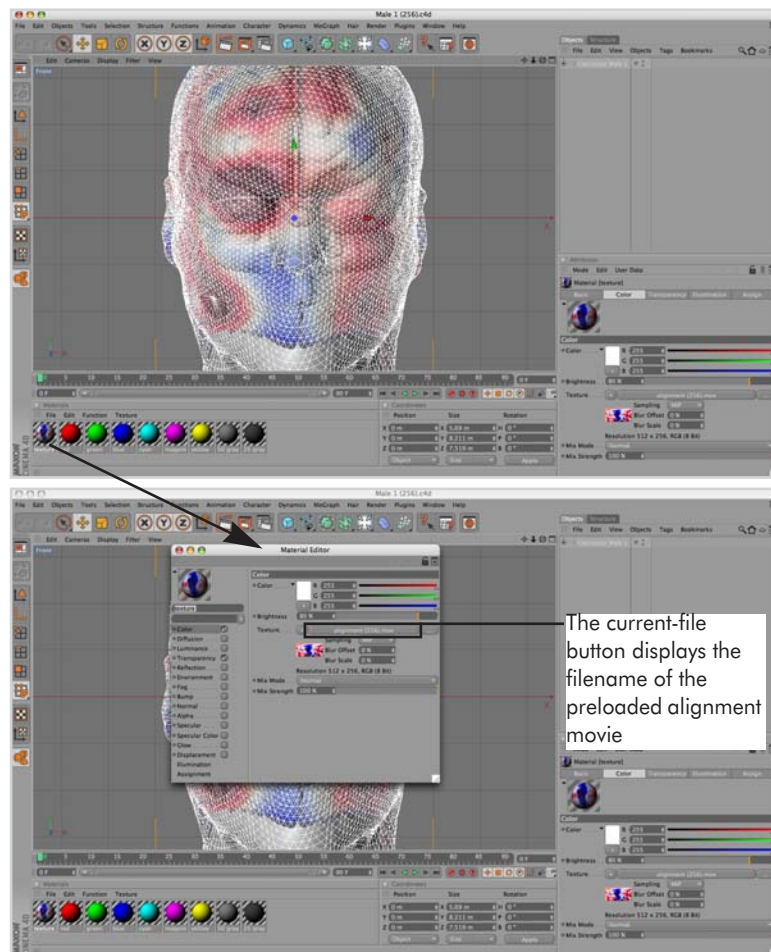
Figure 20-7. Open the Material Editor window

4 In the Material Editor window, click the file-navigation button (the ". . ." button; see Figure 20-8) to open a file-navigation window.

Current-file button   File-navigation button
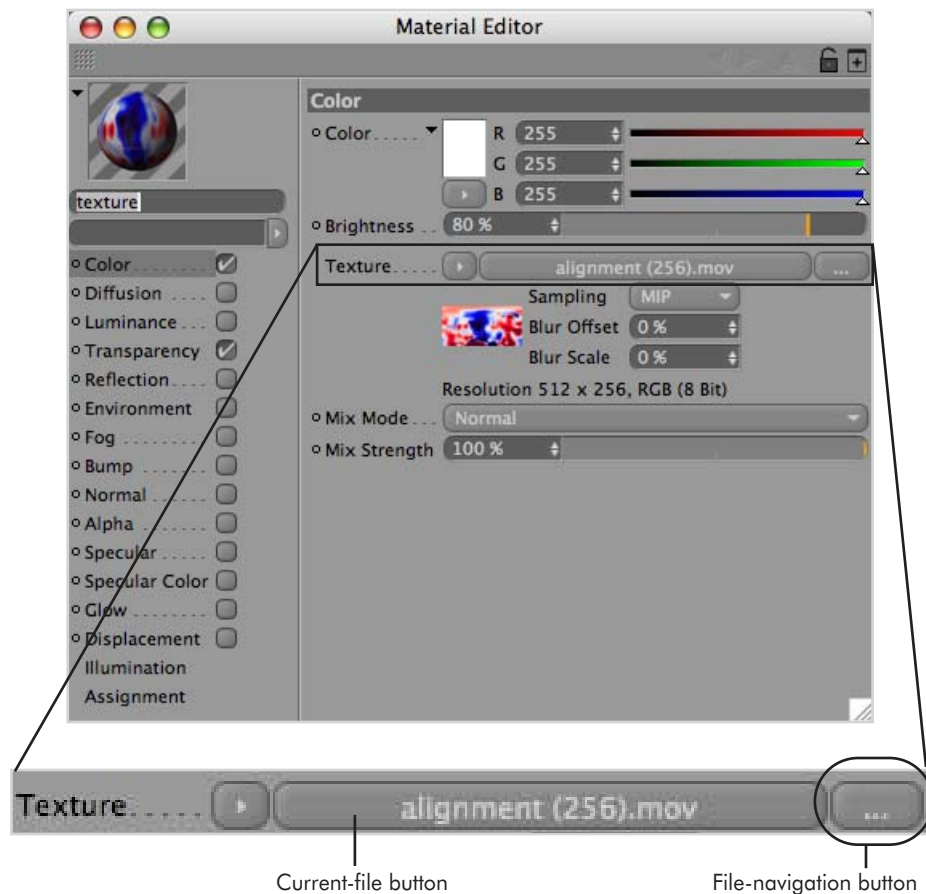
Figure 20-8. Click the file-navigation button

5 In the file-navigation window, navigate to and select the file named ATD256_STDCOR.mov, and click Open. If a dialog appears, stating that "this image is not in the document search path. . . .," click the Yes button. Notice that

the ATD256_STDCOR.mov file name is now displayed in the current-file button (Figure 20-9).

Current-file button displays the name of ATD256_STDCOR.mov
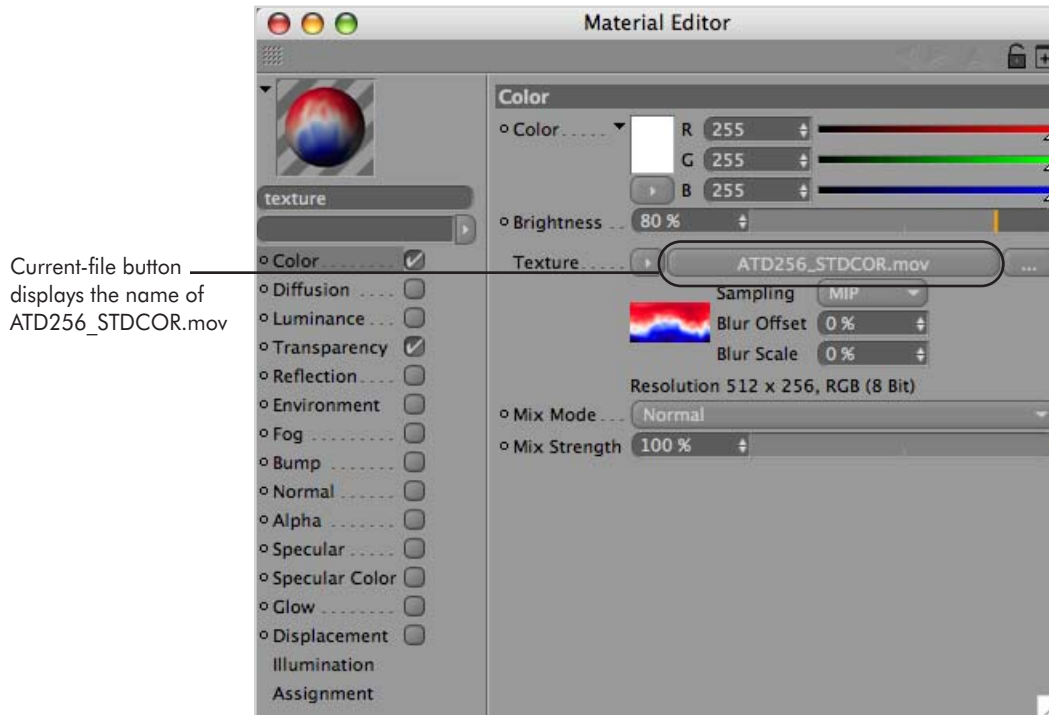
Figure 20-9. Replace the alignment movie with the 3D texture movie

6 Click the current-file button to display the Shader pane for the file ATD256_STDCOR.mov (Figure 20-10a).

7 Click the Animation button at the top of the Shader pane, to display the Animation pane (Figure 20-10b).

8 In the Animation pane, click the Calculate button (at the bottom) to view the animation parameters of the ATD256_STDCOR.mov (Figure 20-10c).
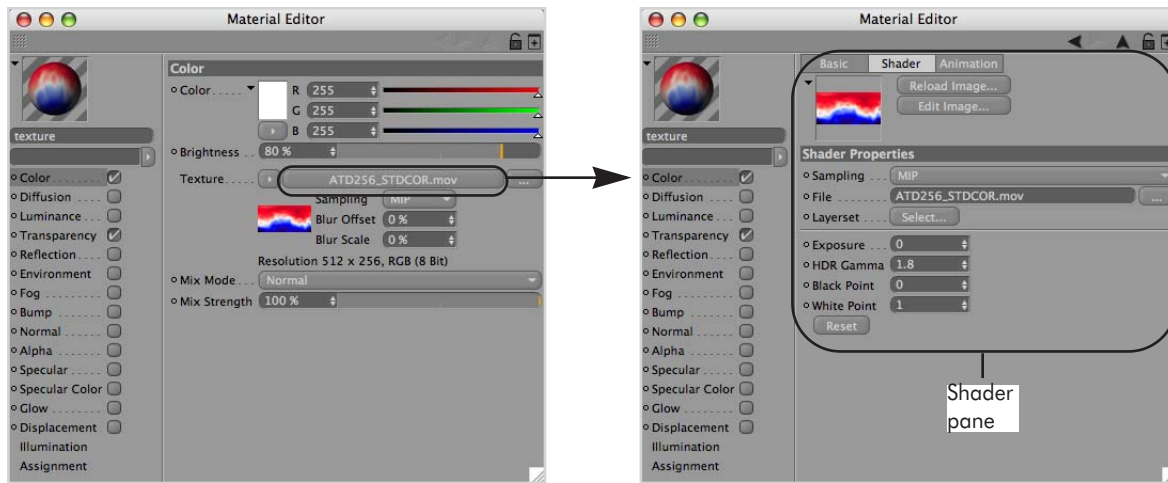
(a) Click the current-file button to open the Shader pane for the movie file ATD256_STDCOR.mov.
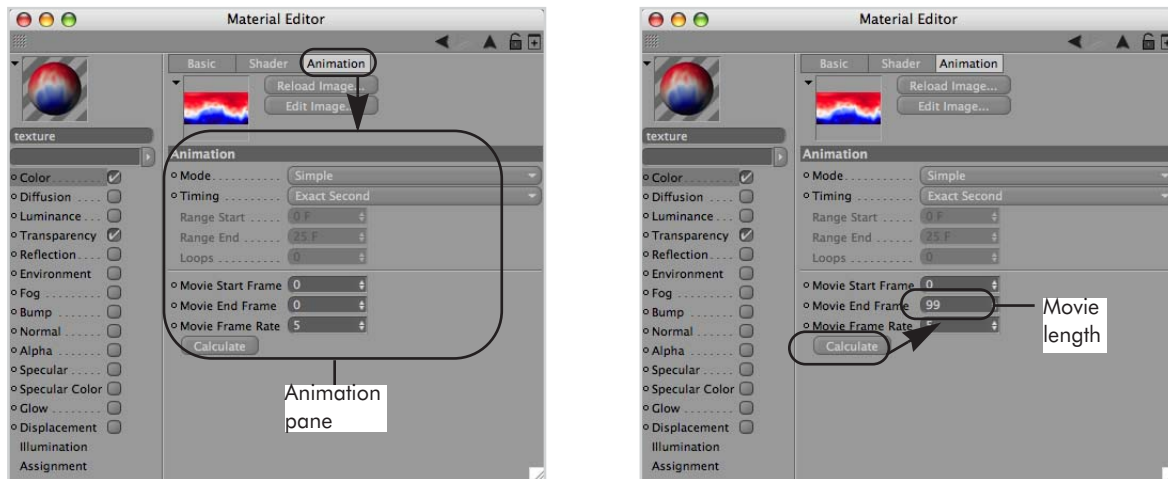
(b) Click the Animation button at the top to view the Animation pane.

(c) Click the Calculate button at the bottom to view the length of the movie.

Figure 20-10. Material Editor window, with its animation controls

9 Remember the value in the Movie End Frame box. This is the length of your movie, in frames (which is 99 for this example).

10 Close the Material Editor window.

11 In the Male 1 (256).c4d window, choose **Edit > Project Settings** (Figure 20-11) to open the Project Settings window.

12 Enter the length of your movie in the Maximum box of the Project Settings and close the window.

Type in the maximum
frame length
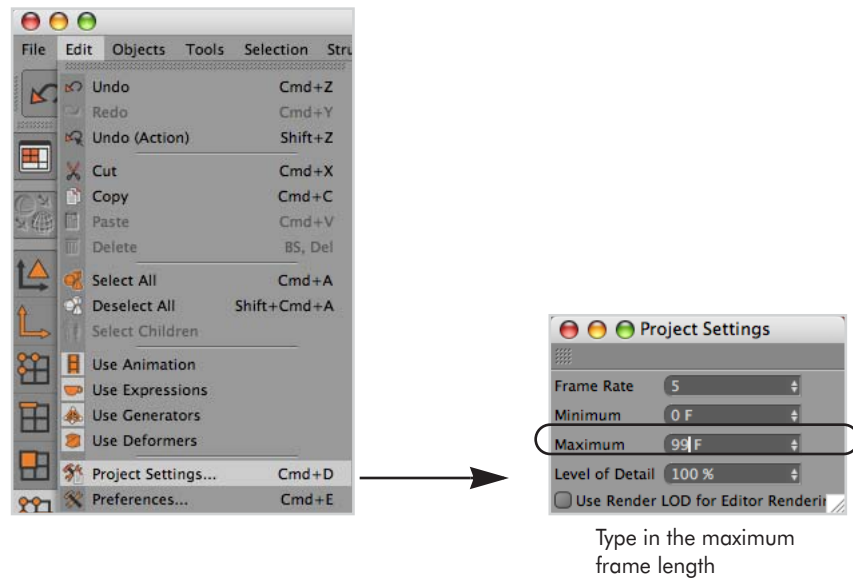
Figure 20-11. Enter length of movie in the Maximum box of the Project Settings window

13 In the Male 1 (256).c4d window, choose **Render > Render to Picture Viewer** (Figure 20-12).
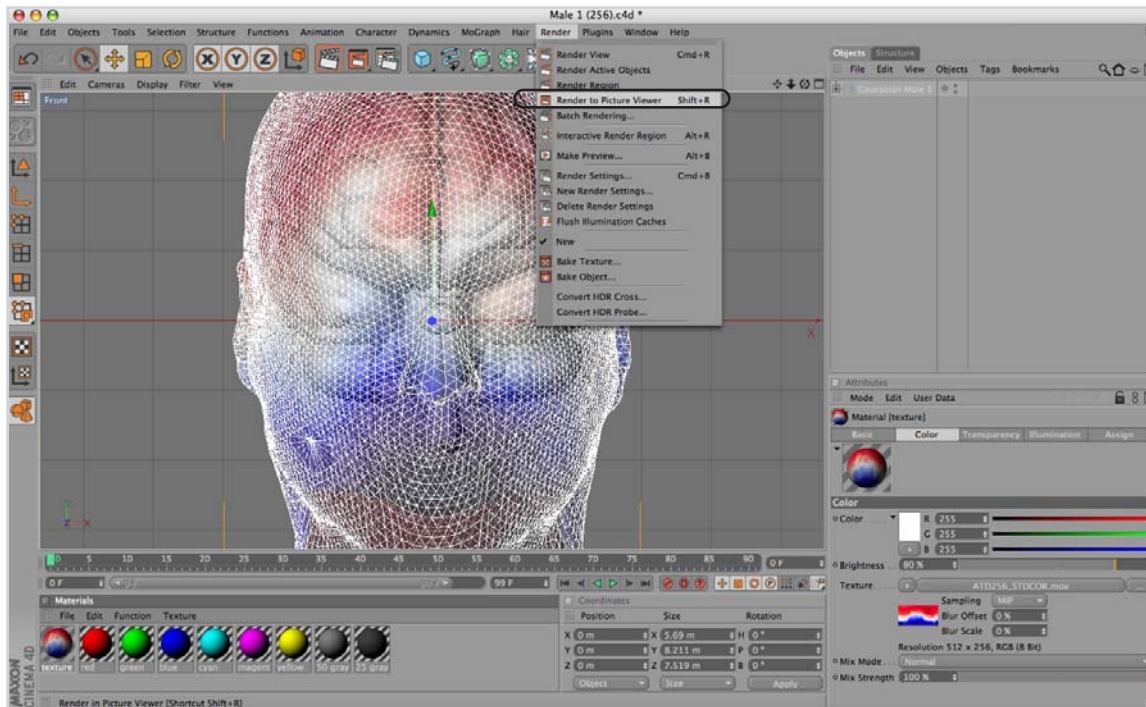
Figure 20-12. Choose Render to Picture Viewer from the Render menu

Your animation will begin rendering, frame by frame (Figure 20-13). The resulting movie will be named "head animation.mov" and will be located in the same folder as the head model. Double-click on the movie to play it.
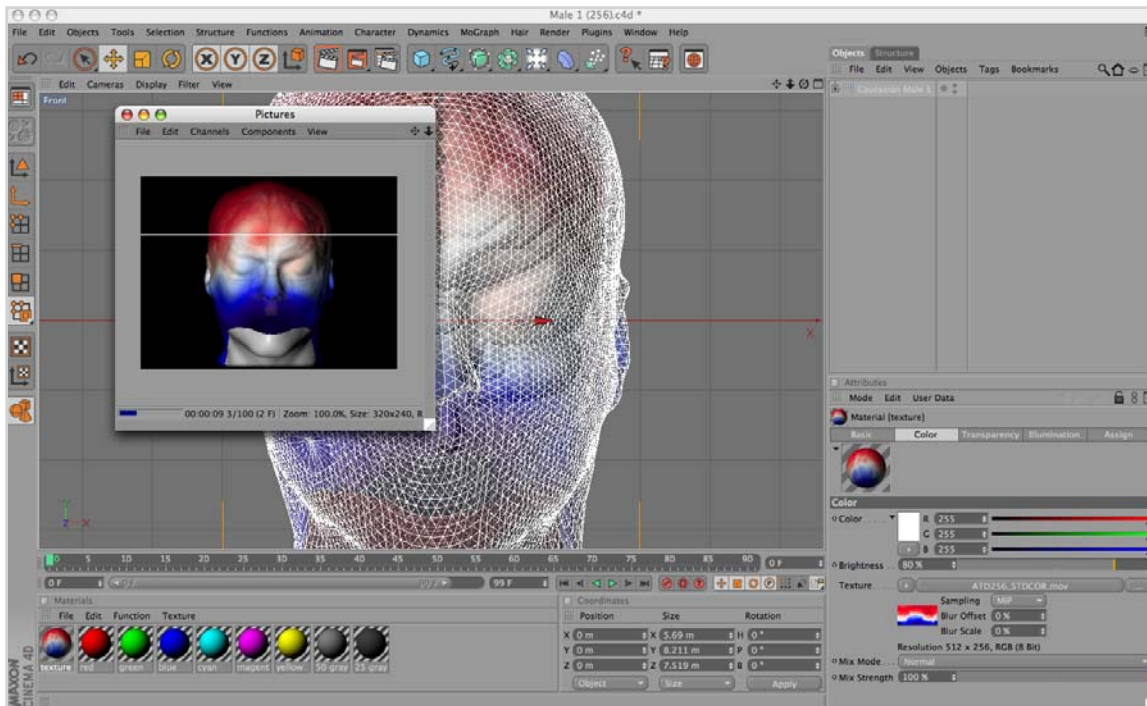
Figure 20-13. Head animation movie being rendered in Cinema 4D

SOFTWARE TECHNICAL SUPPORT

Before Contacting EGI

Please check the Contents on page v and the Index on page 229 for coverage of your issue or question. You can also perform an electronic search using Find or Search in the PDF version of this manual posted on the Documents page of the EGI website (www.egi.com/documentation.html).

In addition, the Support page of the EGI website (www.egi.com/support.html) may have the information you need.

If you need more help, EGI recommends the following:

• *Try to isolate the problem*. Is your problem well defined and repeatable?

• *Document the problem.* Carefully record and organize the details gleaned from the above step and report the problem to EGI.

Contacting EGI

EGI Support web page	www.egi.com/support.html
Email support	support@egi.com
Sales information	info@egi.com
Telephone	+541-687-7962
Fax	+541-687-7963
Address	Electrical Geodesics, Inc. 1600 Millrace Drive Suite 307 Eugene, OR 97403 USA

appendix B

UPDATING
EGI LICENSES

HASP key

EGI protects its software from unauthorized use by encoding licensing data in HASP keys. If you have purchased a complete EGI Geodesic EEG System, the HASP key is attached to the system cart handle. If you have purchased only the Net Station software, the key is included in the software installation package.

A HASP key is a small hardware device (sometimes called a *dongle*) that you plug into a computer's USB port. The information in the HASP key tells Net Station whether you are allowed to use the software.

All authorized Net Station users have a HASP key. To update your EGI license, *do not send EGI the actual hardware key*. Instead, you will need to generate a computer file from the HASP key and email the file to EGI, which will update the licensing information in the file and email it back to you. Use the edited HASP file to update your software. (See Figure B-1.)

Figure B-2 lists some points to keep in mind before you begin the HASP key–updating process. Step-by-step instructions for updating EGI licenses follow the tips.

2
Compress the file and email it to EGI.

1
Generate an Update file from your HASP key.

3
EGI will update the file and email it to you.

4
Uncompress the Updated file and use it to update your HASP key.

Success!
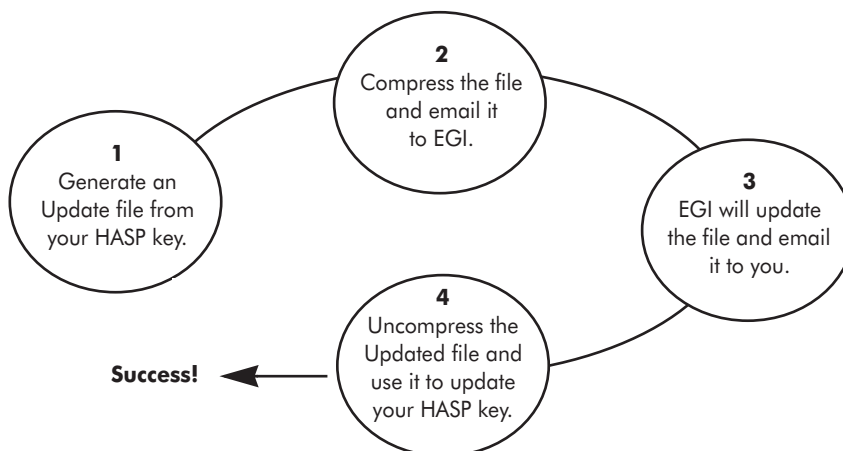
Figure B-1. Overview of the license-updating process

Tips on Updating EGI Licenses

File compression. Before emailing your Update file to EGI, compress the file (by Control-clicking on the file and choosing "Create Archive of <filename>" from the pop-up menu) to safeguard against file corruption during the email process.
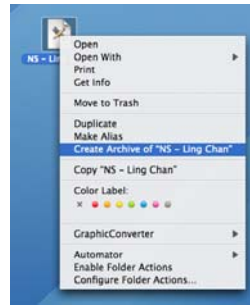
Unique HASPs. Updated HASP files are unique to their individual HASP keys. The HASP key that created the Update file must be plugged in when the Updated file from EGI is applied to update the license. *Note: You may have multiple HASP keys with the same name, followed by a number. The number of the HASP key **must** match the number of the Update file when updating.*
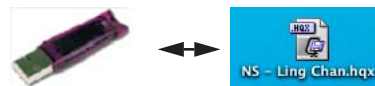
HASP names. To determine which HASP key is which, launch Net Station. The name of the HASP key is in the bottom-left of the Net Station start-up screen. Quit Net Station, launch the Updater application, and apply the **corresponding** HASP file.

File organization. Avoid duplicate Update files. After emailing your Update file to EGI, delete it from your computer. Likewise, after applying the Updated file from EGI to your HASP key, delete the file.
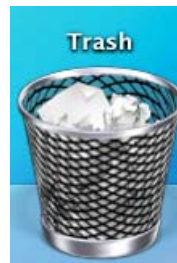
Figure B-2. HASP-updating tips

Opening the Updater Application

1 Quit Net Station, if necessary.

2 Insert the HASP key into the USB port at the side of your keyboard or at the back of your computer. A light should illuminate within the key.

3 On your hard drive, open the Applications folder.

4 Open the Net Station install folder in the Applications folder.

5 Open the Extras folder and double-click on the NS Remote HASP Updater icon to launch the application and open the Updater dialog.
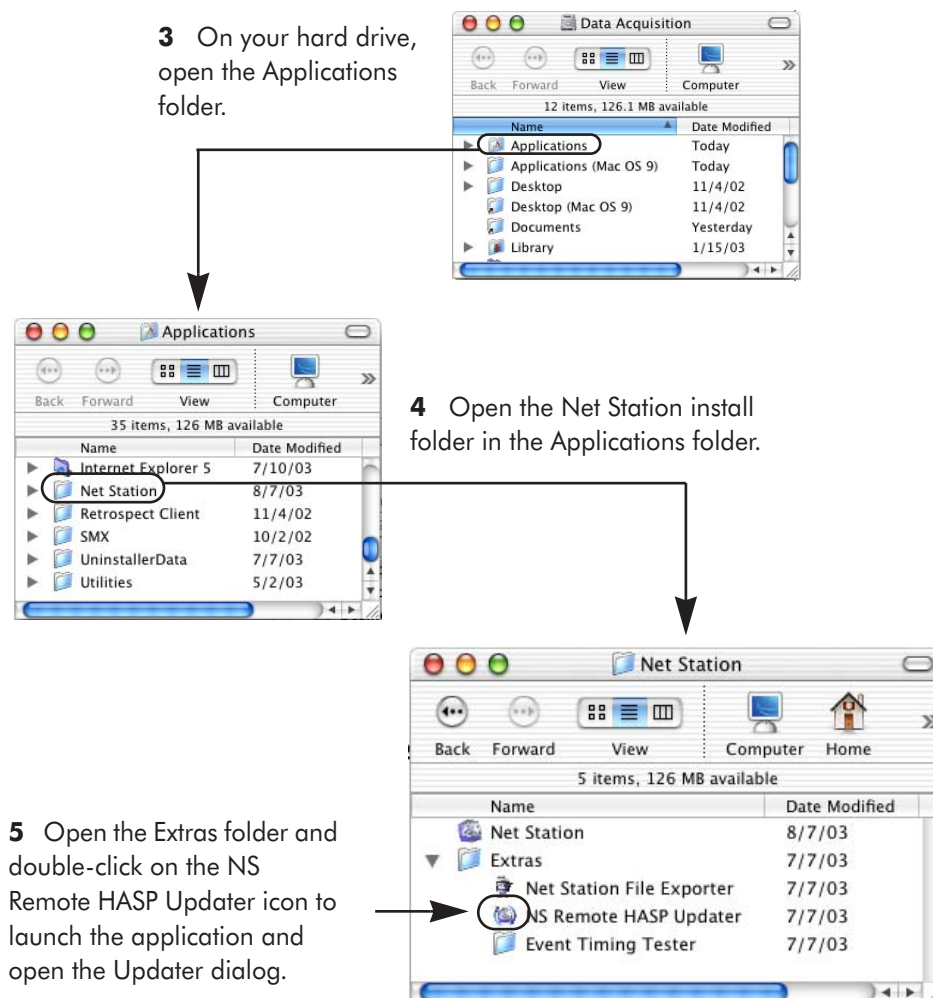
Figure B-3. Open the HASP Updater application

Generating the Update File

1 Make sure that the Create Update File tab is frontmost in the Updater dialog.

2 Click the HASP file button.

3 The Update dialog will automatically close, and an Update file will appear on your Desktop with the filename "NS – xxxx," where xxxx is the license holder's name. If you have more than one HASP, the number of the HASP will be appended (e.g., NS - Ling Chan, NS - Ling Chan 1).

4 Compress the file by Control-clicking on the file and choosing Create Archive of "<filename>" from the pop-up menu. This will ensure that your file is not corrupted in transit. Note that this operation **must** be performed on a Macintosh computer, not a PC.

5 Email the compressed file to support@egi.com and include in the email message your name, the license holder's name (if you are not the licensee), your organization, and a *description of what must be updated*. For best results, email the file from the Macintosh computer that generated it. Or, you can copy the file to a Mac HFS-formatted removable drive, transfer it to another Mac, and email it. Do not email it from a PC.
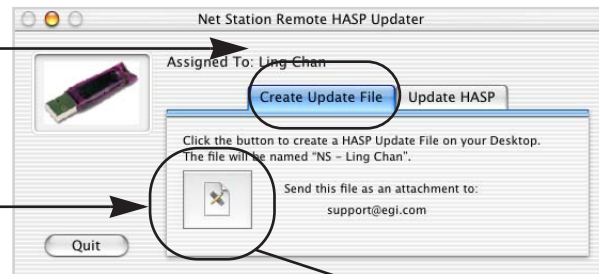
6 Delete the HASP Update file and any previous compressed copies from your Desktop.

7 EGI will modify the file, updating your license, and email it back to you, typically within two to three days.

Figure B-4. Create the HASP Update file, compress it, and email it to EGI

Applying an Updated File

1 Save to the Desktop the Updated file from EGI, uncompressing it if needed.

2 Quit Net Station, if necessary.

3 Insert the *corresponding* HASP key into the USB port at the side of your keyboard or at the back of your computer. A light should illuminate within the key.

4 Open the Net Station install folder in the Applications folder on your hard drive.

5 Double-click on the NS Remote HASP Updater icon, which will open the Updater dialog.

6 Make sure that the Update HASP tab is frontmost in the Updater dialog.

7 Drag the Updated file into the Update box.

Net Station Remote HASP Updater

Assigned To: Ling Chan

Create Update File | Update HASP

Locate your Net Station Update file from EGI.
Drag it into the box at the left.

Quit
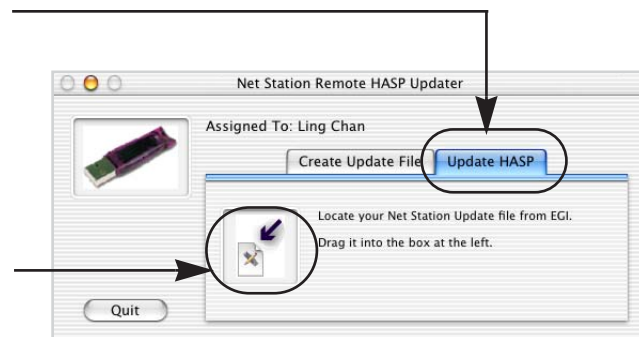
8 A dialog will appear, with a message indicating a successful update.

Net Station Remote HASP Updater

Assigned To: Ling Chan

Create Update File | Update HASP

Updated

Your HASP has been updated.
You may now run Net Station.

Quit
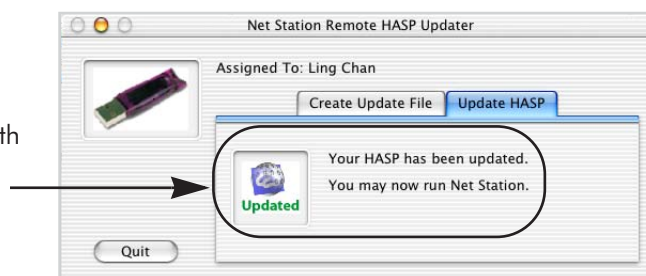
9 Delete the Updated file and any compressed copies from your Desktop.

Figure B-5. Apply the Updated file from EGI to the corresponding HASP

Questions

Contact EGI at support@egi.com with any questions regarding this document and the issues discussed.

HOW TO EXPORT FILES FOR GRAPHICS

This appendix provides a brief set of instructions on how to generate publication-quality graphics for ERP (EEG) waveforms. The appendix assumes that you are familiar with vector-based graphics program such as Adobe Illustrator or Deneba Canvas. We recommend that you use a vector-based graphics program rather than a raster-based (i.e., bitmap) program such as Adobe Photoshop because you can resize vector-based graphics without diminishing the resolution or creating "jaggies."

Two operations are covered: exporting ERP (EEG) waveforms and exporting topographic maps. The first process applies to EEG data viewed in Chart or Topo Plot mode, and the second relates to data in Topo Map View mode. Of the five views offered by Net Station, printing is enabled for only these three modes because the other two—Grid View and Synoptic Plot View—are designed to allow onscreen identification of bad channels, and spatial and temporal patterns, respectively.

You must have a PostScript-compatible printer to print Chart and Topo Plot Views; however, the printer driver cannot tell if a chart or plot is in grayscale or color, so it prints them only in grayscale. You can change them to color after exporting to a graphics program. Topo Map View, on the other hand, can print to a non-PostScript printer and can print in color.

Note: The graphics output is WYSIWYG (What You See Is What You Get), so you must ensure that the view (either in Chart or Topo Plot) is exactly as you would like it to appear.

*Note: Adobe Illustrator has difficulty properly orienting channel labels when it opens a Topo Plot PostScript file. Because Adobe Distiller does not have this problem, we recommend the following workaround: (1) Choose **Print > Set to Print Size > Page Setup** and choose Landscape orientation. (2) In the Print window, choose File in the Destination pop-up menu. (3) Run the PostScript file through Adobe Distiller, open the resulting PDF in Illustrator, and save in the appropriate graphics format.*

For additional information about the concepts discussed, see Chapter 10, "Topo Map View"; Chapter 14, "Amplitude-Scale Palette"; Chapter 16, "Printing"; and Chapter 19, "Montages," in the *Net Station Viewer Technical Manual*.

ERP (EEG) Waveforms

1   Select the relevant experimental conditions.

2   In either Chart or Topo Plot View, select the channel(s) desired for illustrating the waveform. Do this by using the Montage Controls window to create a montage with just those channels. (See "Montage Controls Window" in Chapter 15, "Montages," in the *Net Station Viewer Technical Manual*.)
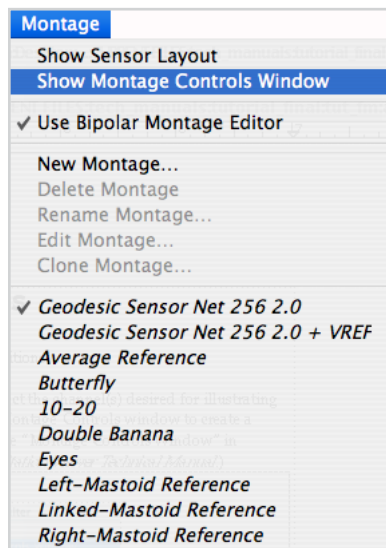
Choose Montage > Show Montage Controls Window
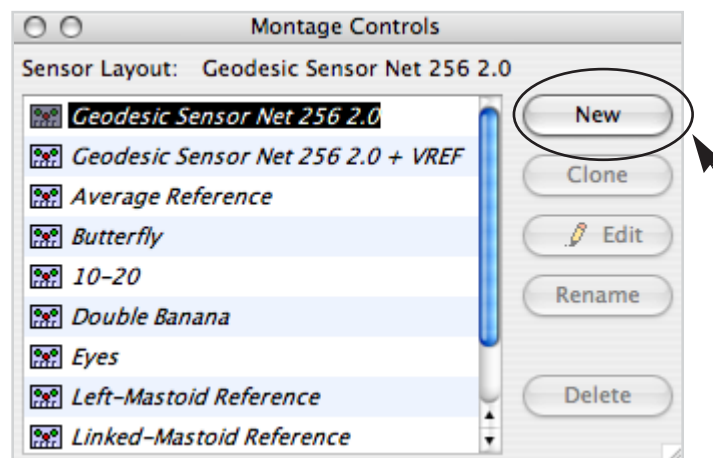
Click New to create a new montage with only the desired channels
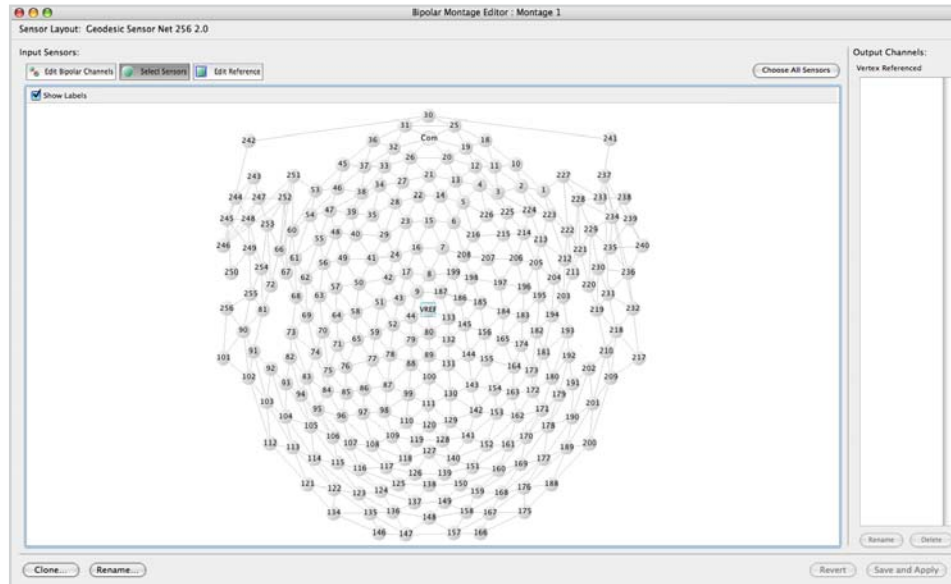
A blank montage template appears
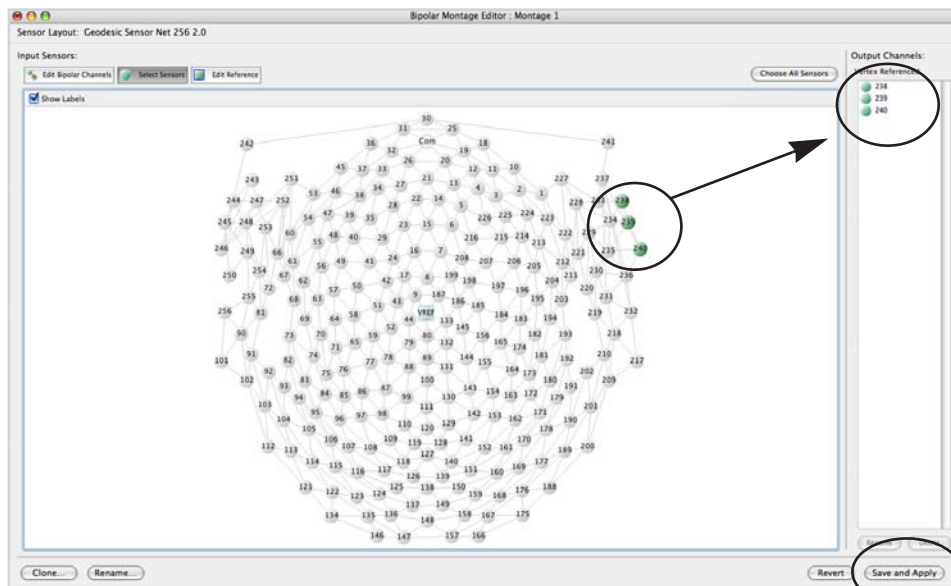
Click on the desired sensors to add them to the new montage (see list of output channels at right). To deselect a sensor, click it again. When finished, click Save and Apply.

3 Set Time and Amplitude Scales to best illustrate the data.
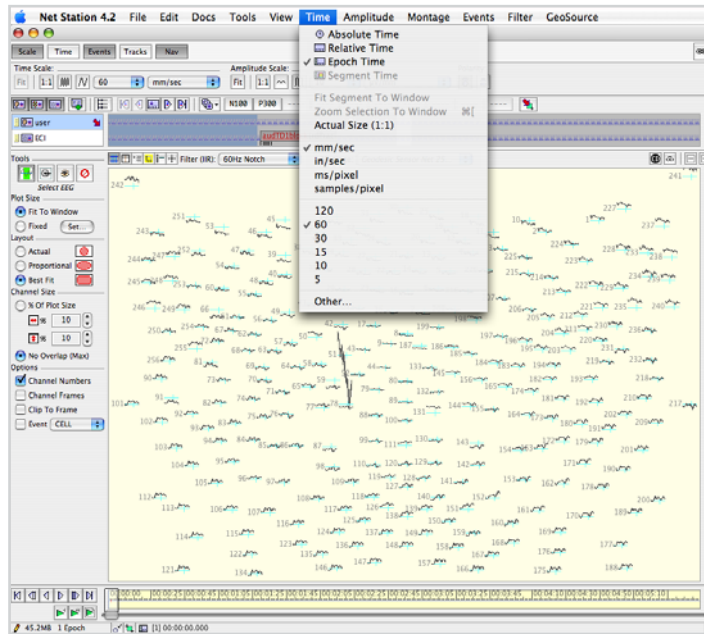
The Time menu
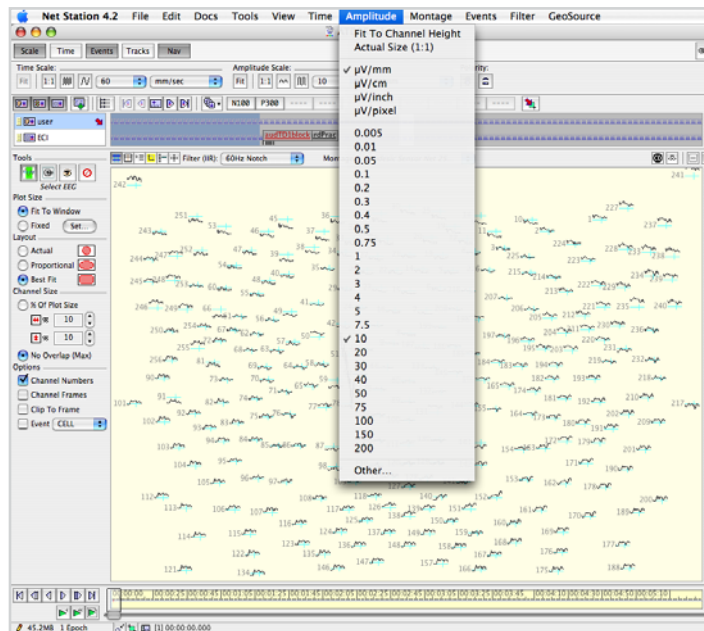
The Amplitude menu

Optional step: To include a scale ruler in your figures, click on the scale-ruler toggle to make the scale ruler appear. Adjust the amplitude and time scale of the scale ruler to the desired settings, and drag it next to a waveform channel.
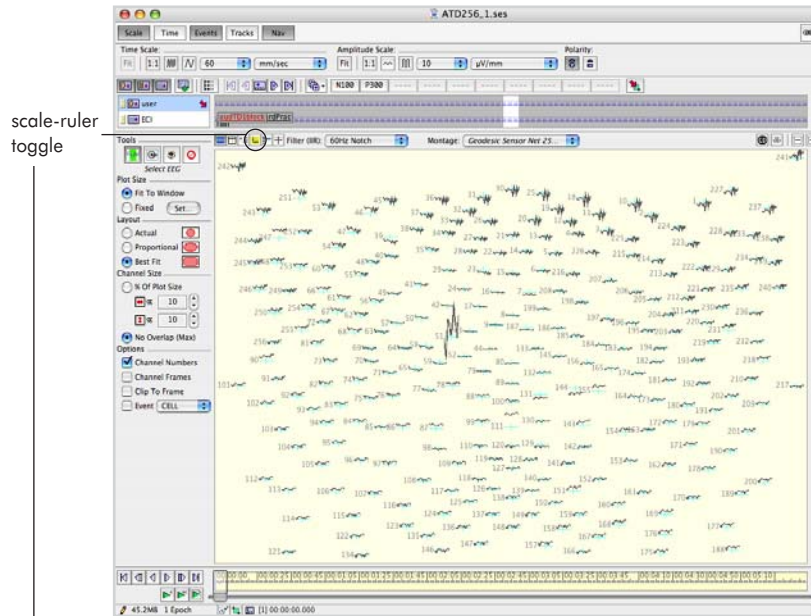
scale-ruler
toggle

Click on the scale-ruler toggle to make the scale ruler appear
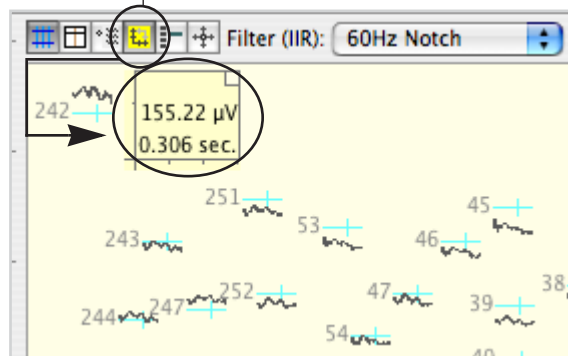
A close-up view of the scale ruler, a draggable display of the amplitude and time scales

4 Set Background Color (in Viewer Preferences) to white.
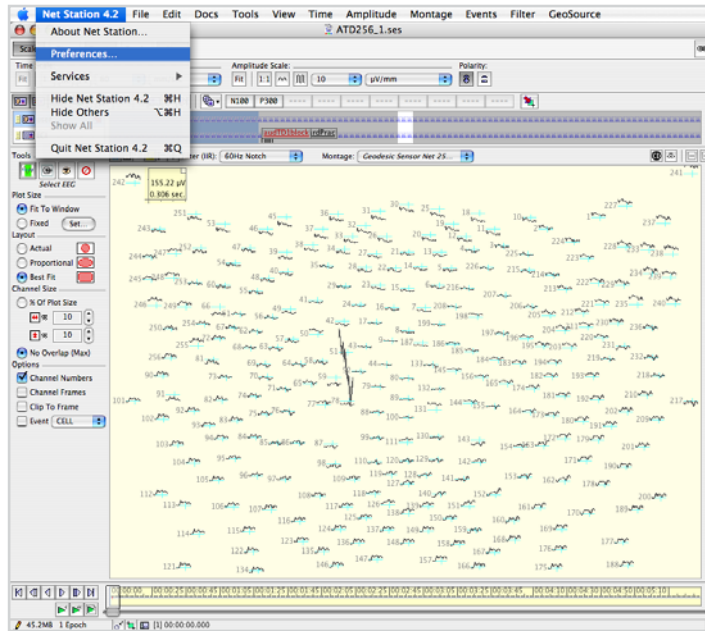
Choose Edit > Viewer Preferences
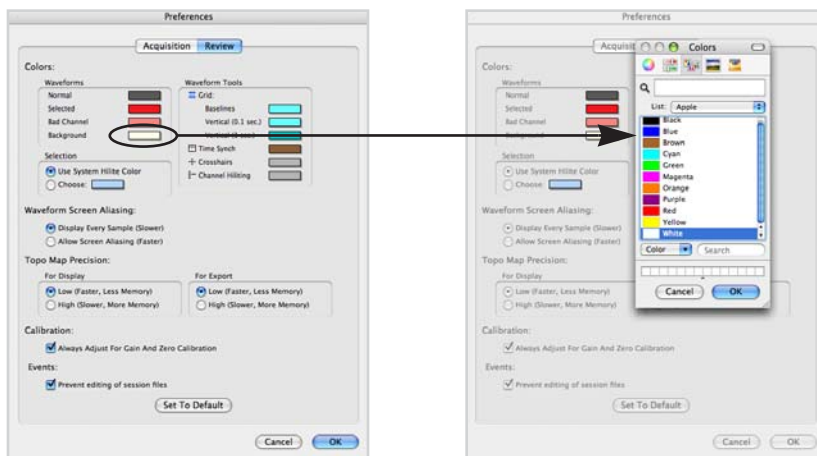
In the Viewer Preferences dialog, clicking on the color box next to the label
"Background" opens the Colors window, which allows you to change the color

5 Under the File menu, choose Print Window (for Chart View) or Print Topo Plot (for Topo Plot View).
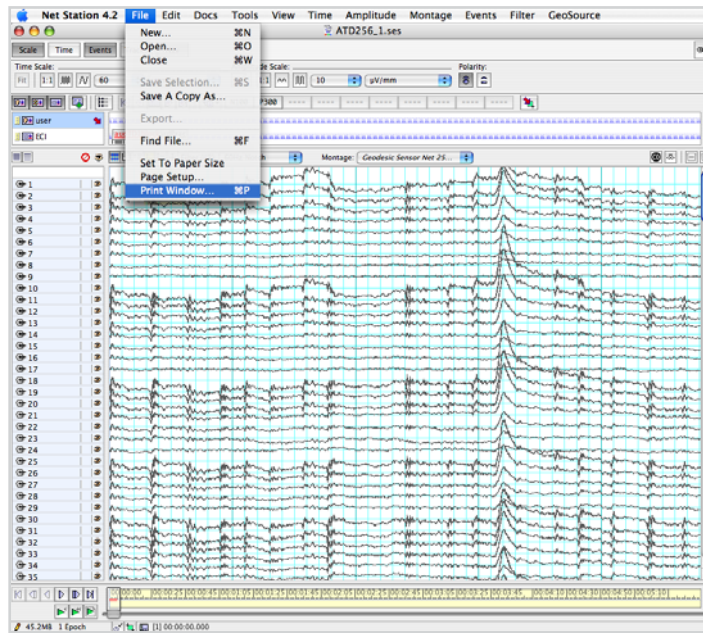
File > Print Window (in Chart View)
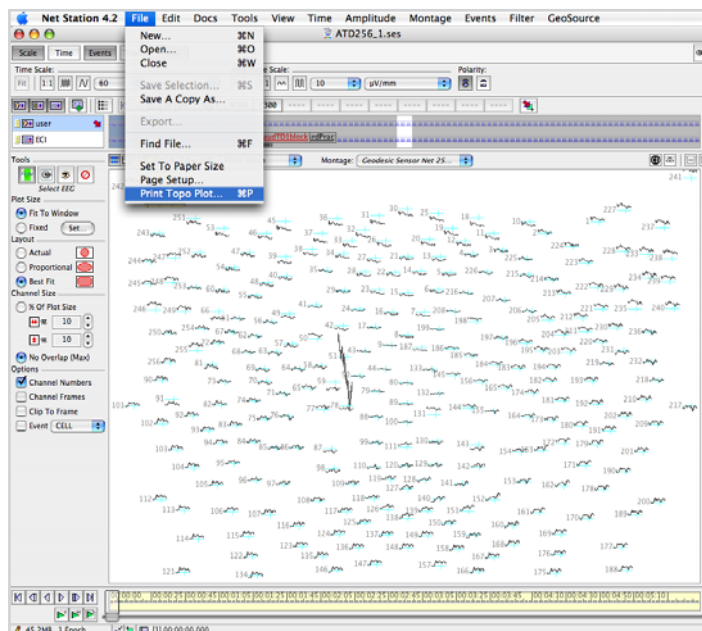
File > Print Topo Plot (in Topo Plot View)

6 In the Print dialog that appears, (a) choose Save PDF as PostScript in the PDF pop-up menu, which opens the Save to File dialog. (See Chapter 11, "Printing," in the *Net Station Viewer Technical Manual* for more information.)
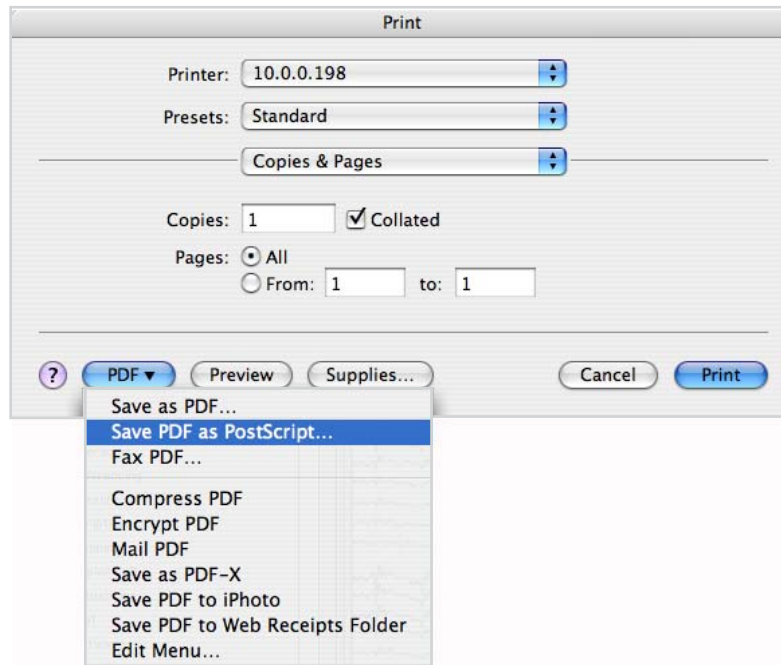
7 In the Save to File dialog, name the output file and select the output destination.
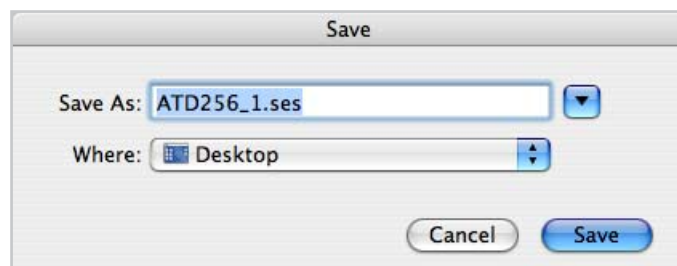
8 Click Save.

Topo Maps

1 In Topo Map View, select your desired timepoint(s).
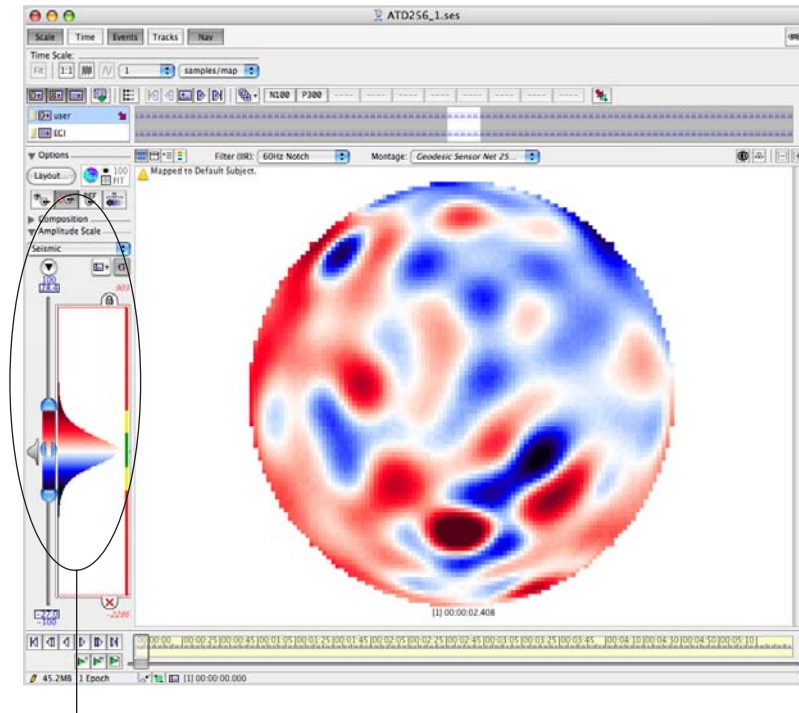
The controls for setting layout,
color, and range

Topo Map View

2 Set desired Layout.

3 Select desired color palette.

4 Set palette range.

(For more information about the Layout dialog, and the amplitude-scale palette
and the Set Ranges dialog, see Chapter 10, "Topo Map View" and Chapter 14,
"Amplitude-Scale Palette," respectively, in the *Net Station Viewer
Technical Manual*.)
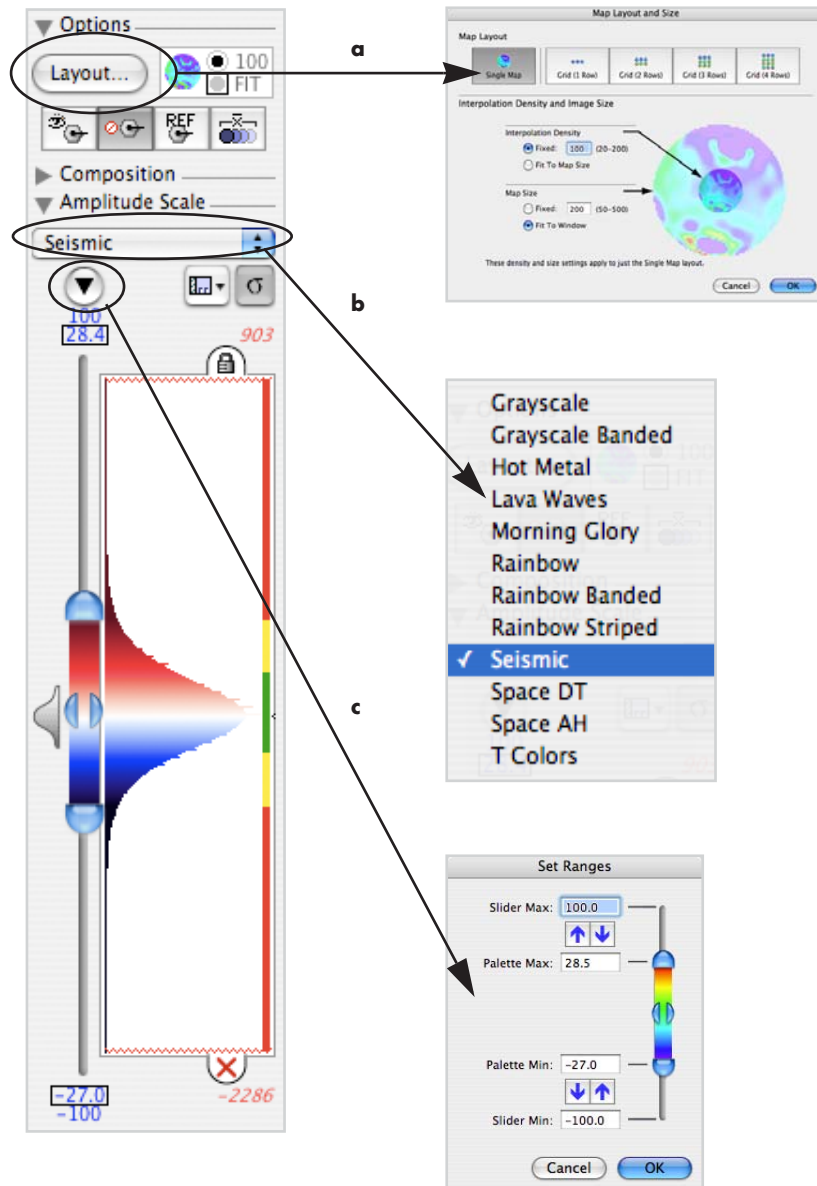
(a) Click Layout to open the Map Layout and Size dialog, (b) choose a color from the spectrum pop-up menu, and (c) click the Set Ranges button to open the Set Ranges dialog

Optional step: To include an amplitude scale in your figures, click on the amplitude-scale palette toggle to make the amplitude scale appear.

amplitude-
scale palette
toggle
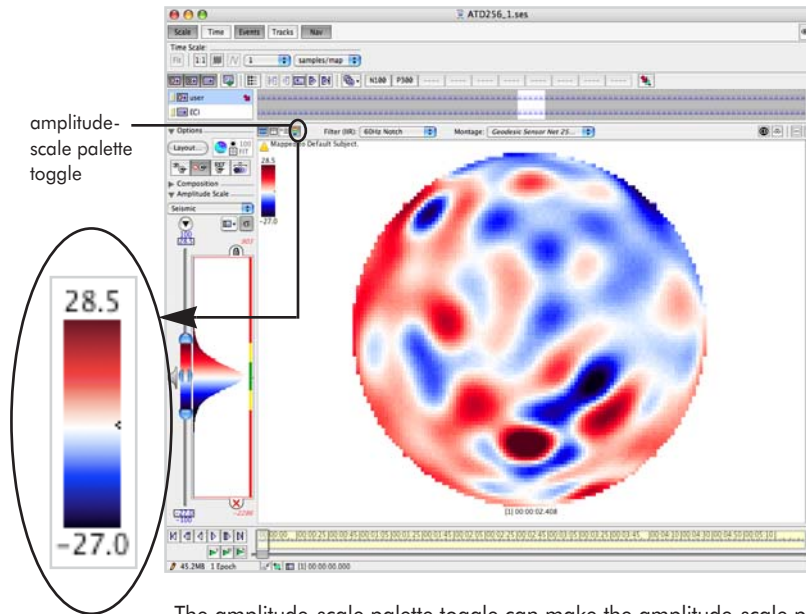
The amplitude-scale palette toggle can make the amplitude-scale palette appear
(enlarged view of palette at left), which you can capture in an image

5 Under the File menu, choose Print Window.
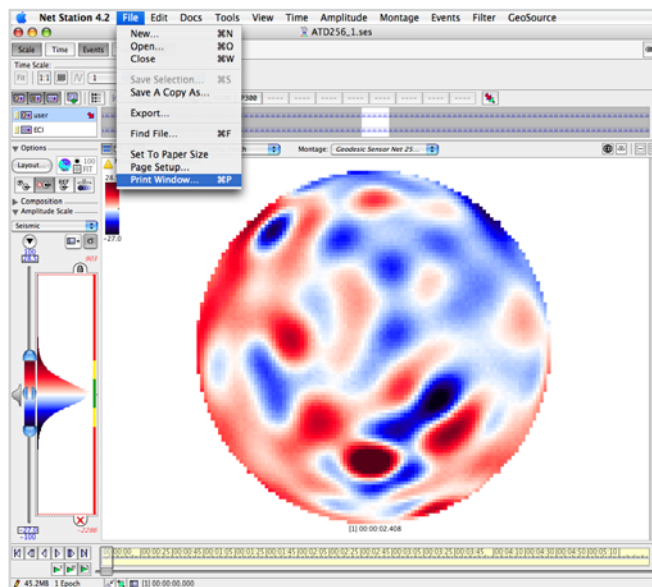
Choose File > Print Window

6 In the Print dialog that appears, (a) choose Save PDF as PostScript in the PDF pop-up menu, which opens the Save to File dialog. (See Chapter 11, "Printing," in the *Net Station Viewer Technical Manual* for more information.)
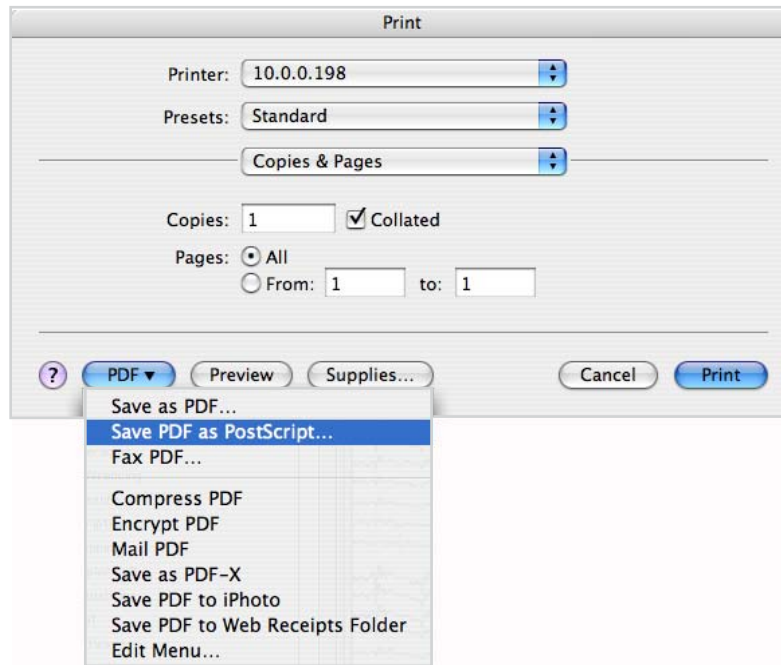
7 In the Save to File dialog, name the output file and select the output destination.
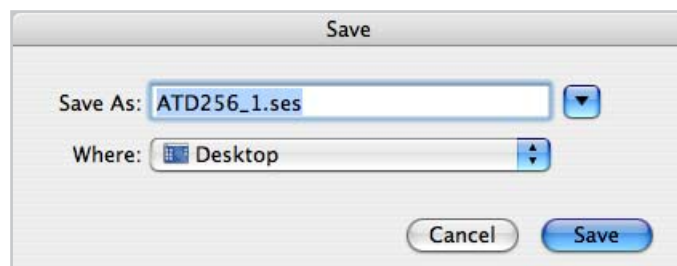
8 Click Save.

After the Export

You are now ready to open your file in either Illustrator or Canvas (or any other graphics program). Once you are in the graphics program, you may have to "ungroup" the object to edit individual components. You will then have the capability to arrange your data to meet your publication needs. (See "Exporting Texture Maps for 2D & 3D Animations" in Chapter 10 , "Topo Map View," in the *Net Station Viewer Technical Manual*.)

Graphics Resources

This section introduces you to some common computer graphics resources and terms. It is by no means complete or authoritative. The companies and products in the following list were discovered through various web searches; EGI is neither responsible for nor does it endorse them.

Graphics Websites and Books

Some developers of vector graphics software:

- Adobe (*products*—Illustrator and Free Hand): www.adobe.com
- CambridgeSoft (*product*—ChemDraw): www.cambridgesoft.com
- Computer Systems Odessa (*product*—ConceptDraw): www.conceptdraw.com
- Corel (*product*—CorelDraw): www.corel.com
- Microsoft (*product*—Expression): www.microsoft.com
- Deneba (*product*—Canvas): www.deneba.com

Some graphic design resources:

- *Computer Graphics—Principles and Practice*, by J.D. Foley et. al, published by Addison-Wesley: www.aw-bc.com

- *Displaying Your Findings—A Practical Guide for Creating Figures, Posters, and Presentations*, by A.A.M Nicol and P.M. Pexman, published by the American Psychological Association: www.apa.org

- Grantastic Designs: www.grantasticdesigns.com

- Pantone: www.pantone.com

- *The Dictionary of Computer Graphics and Virtual Reality*, by R. Latham, published by Springer-Verlag: www.springer-ny.com

Graphics Glossary

Sources: Grantastic Designs (www.grantasticdesigns.com), Edinburgh Online (www.dai.ed.ac.uk), and Hokum (http://hokum.freehomepage.com)

A

adaptive sampling A method of reducing aliasing artifacts when rendering by adapting the sampling rate in response to the local characteristic of the object being rendered. This technique is often used to reduce the jagged edges of objects.

aliasing In graphic design, aliasing occurs when a computer monitor, printer, or graphics file does not have a high enough resolution to represent a graphic image or text. An aliased image is often said to have the "jaggies."

animation Animation is the creating of a timed sequence or series of graphic images or frames together to give the appearance of continuous movement.

antialiasing Antialiasing is the smoothing or blending of the transition of pixels in an image. Antialiasing the edges on a graphic image makes the edges appear smooth, not jagged.

B, C

bitmap Strictly a one-bit-per-pixel representation for a defined area of a display.

bitmap image (bmp) A graphic image stored as a specific arrangement of screen dots or pixels. Web graphics are bitmap images. Also known as *raster* graphics, common bitmap formats include GIF, JPEG, Photoshop, PCX, TIFF, Macintosh Paint, Microsoft Paint, PNG, FAX, and TGA.

CMYK Stands for the colors cyan-magenta-yellow-black. In print design, colors are defined as a percentage of each of these four colors (e.g., the CMYK for black is 0-0-0-100). In contrast, display devices (i.e., computer monitors) typically define colors using *RGB*.

compression A method of packing data to save disk storage space or download time. JPEGS are generally compressed graphics files. Compression makes a file or data stream smaller.

D, E

dithered/dithering   To display a full-color graphic image on a 256-color monitor, computers must simulate the colors they cannot display. They do this by dithering, which is combining pixels from a 256-color palette into patterns that approximate other colors. At a distance, the human eye merges the pixels into a single color. Up close, the graphic image will appear pixelated and speckled.

dpi   Stands for dots per inch and specifies the resolution of an output device, such as a printer or printing press machine. Print resolution usually runs from 300 to 1,200 dpi on a laser printer, 125–255 dpi for photographic images on a print brochure, and 72 dpi for web publishing. (For information about input device measurement, see *ppi*.)

export   To save a file in a different program (e.g., many Adobe Photoshop files are exported to become GIF or JPEG files).

F, G, H

font   A font is a complete set of characters in a particular size and style of type. This includes the letter set, the number set, and all of the special character and diacritical marks obtained by pressing the Shift, Option, or Command keys (e.g., Times NewRoman Bold is one font, Times NewRoman Italic is another font, and Times NewRoman is a single typeface).

frame   In animation, a frame is a single graphic image in a sequence of graphic images.

GIF   Stands for Graphics Interchange Format. GIF images are the most widely used graphic format on the web. GIF images display up to 256 colors.

grayscale   An application of black ink (for print) or the color black (for the screen) that simulates a range of tones. Grayscale images have no hue (color). In print design, a grayscale graphic image appears to be black, white, and shades of gray, but it only uses a single color ink.

HSB   Stands for hue-saturation-brightness. HSB is based on three fundamental characteristics of color: *hue* is the color reflected from or transmitted through an object; *saturation* is the strength or purity of a color; and *brightness* is the relative lightness or darkness of the color.

hue   The actual color of an object. Hue is measured as a location on a color wheel, expressed in degrees. Hue is also understood as the names of specific colors, such as blue, red, and yellow.

I, J, L

interlace   Storing partial data from a single graphic image in multiple sequences. The purpose of interlacing is to have a partial image initially appear onscreen, rather than having to wait for the image to appear in its entirety. With interlacing, equally spaced sets of lines from the original image are stored together, and these sets appear one on top of the other in sequence.

JPEG   Abbreviation for Joint Photographic Experts Group. File format for full-color and black-and-white graphic images. JPEG images allow for more colors than GIF images and are usually smaller in size.

lossless compression   In graphic design, lossless compression refers to a data-compression technique where the file quality is preserved and no data are lost. Lossless compression is commonly used on GIF images, but it can only reduce the file size to about half its original size. *Lossy compression*, on the other hand, eliminates data to further decrease the file size.

lossy compression   A term coined by graphics programmers to refer to a technique of shrinking file sizes by giving away some precision of detail. JPEG is an example of a file that is compressed this way.

lpi   Stands for lines per inch.

LZW   Stands for Lemple-Zif-Welch. LZW is a *lossless compression* technique supported by TIFF, PDF, GIF, and Postscript file formats. It is most useful in compressing images that contain large areas of single color, such as screenshots or simple paint images.

M, O

moiré   A shimmering "interference" pattern produced when two geometrically regular patterns are superimposed.

opaque   Impervious to light. An opaque surface will reflect light to some degree dependent on surface attributes.

overlay   An image compositing method where an image is displayed over a background image.

P

pixel   Stands for picture element. A pixel is the smallest element that can be independently assigned color.

PNG   Stands for Portable Network Graphics format and is generally pronounced "ping." PNG is used for lossless compression and for displaying images on the web. The advantages of PNG is that it supports images with millions of colors and produces background transparency without jagged edges. The disadvantages are that PNG images will not show up on older browsers and still can be larger in file size than GIFs.

ppi   Stands for pixels per inch and specifies the resolution of the input device, such as a scanner, digital camera, or monitor. Web page resolution ranges from 72 to 96 ppi. (For information about output device measurements, see *dpi*.)

R

raster graphic   See *bitmap image (bmp)*.

rasterize   The process of converting a projected point, line, polygon, or the pixels of an image to fragments, each corresponding to a pixel in the framebuffer.

rendering   The process of creating an image from a description of a scene, its objects and light sources, and the viewer.

resolution   Indicates the number of pixels per image (see *ppi*). It is often represented as N x M, where N and M are the number of pixels per column and per row, respectively.

RGB   Stands for the colors red-green-blue. In web design and computer monitors, colors are defined in terms of a combination of these three colors (e.g., the RGB for blue is 0-0-255). In contrast, print designers typically define colors using *CMYK*.

S

saturation   The color intensity of an image. An image high in saturation will appear to be very bright. An image low in saturation will appear to be duller and more neutral. An image without any saturation is also referred to as a *grayscale* image.

subtractive colors   Cyan (C), magenta (M), and yellow (Y). These colors combine to absorb all color and to produce a muddy brown color. Black (K) is added to produce pure black. Also known as *CMYK*.

T, V

texture map   A bitmap used to texture a 3D polygon model, including adjustments for perspective correction, where vertices of the object model are mapped onto the 2D texture bitmap.

transparency   The ratio of the amount of light passing through a material to the amount of light incident on the material.

true color system   A 24-plane graphics subsystem that produces the complete range of 16.7 million available colors.

vector graphic   A graphic image drawn in shapes and lines, called *paths*. This allows them to be resized without any loss of resolution. Images created in Illustrator or FreeHand are vector graphics.

video   A series of framed images put together, one after another, to simulate motion and interactivity. A video can be transmitted by number of frames per second and/or the amount of time between switching frames. The difference between video and animation is that video is broken down into individual frames.

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