Net Station Waveform Tools

Technical Manual

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Technical Manual

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PREFACE

Net 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 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.

The following publications, and other technical documentation, are available as PDF files at www.egi.com/documentation.html:

- The Net Station Waveform Tools is the component of Net Station for performing various operations on EEG data, primarily for basic ERP derivation. This document, the ***Net Station Waveform Tools Technical Manual,*** describes all Waveform Tools features and functions.
- The Net Station Acquisition is the component of Net Station for acquiring EEG, in conjunction with EGI's Net Amps and Neurotravel amplifiers, and Geodesic Sensor Nets. The ***Net Station Acquisition Technical Manual*** describes all 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 all Viewer features and functions.

- 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 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.

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

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

About This Manual

Net Station's Waveform Tools is the component of Net Station for performing various operations on EEG data, primarily for basic ERP derivation and analysis. This manual provides comprehensive descriptions of all Waveform Tools features and functions.

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.

Manual Organization

This manual 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 publication is organized as follows:

- Chapter 1, "The Waveform Tools Window," describes the Waveform Tools window, which provides the main controls for processing data.
- Chapter 2, "Jobs and Results Window," describes the Jobs and Results window, which displays data-processing job status and results.
- Chapter 3, "Common Controls," describes controls that are common to all of the tools.
- Each of the remaining chapters describes one of the tools. These chapters are organized alphabetically by tool name.

For Net Station EEG and ERP software technical support, see Appendix A, "Software Technical Support," on page 201.

For EGI hardware-related information, see the *GES Hardware Technical Manual* or the *Geodesic Sensor Net Technical Manual*.

Conventions and Typography

In this manual:

- 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 (such as, **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

To start Net Station, double-click on its icon on the Finder desktop. If the Net Station icon is in the Dock in Macintosh OS X, only a single click is needed. A triangle pointing to the icon will appear, indicating the application's active status.

The Net Station icon

desktop

Dock

chapter 1

The Waveform Tools Window

Concepts

Waveform Tools is the component of Net Station for performing various operations on EEG data, primarily for basic ERP derivation and analysis. Each operation serves a specific signal-processing purpose, mostly related to increasing the signal-to-noise ratio.

Each Waveform Tool, except Script, represents a specific operation or a set of closely related operations. Each Waveform Tool outputs a version of the data that is used as the input to the operation that follows it. Most of the Waveform Tools require you to specify parameters. For example, filtering requires you to specify the frequencies to filter. Net Station provides the following Waveform Tools:

- Artifact Detection (Chapter 4)
- Averaging (Chapter 5)
- Bad Channel Replacement (Chapter 6)
- Baseline Correction (Chapter 7)
- Combine Files (Chapter 8)
- Difference Wave (Chapter 9)
- Event Export (Chapter 10)
- File Export (Chapter 11)
- Filtering (Chapter 12)
- Markup from File (Chapter 13)
- Montage Operations (Chapter 14)
- Ocular Artifact Removal (Chapter 15)
- Scripting (Chapter 16)
- Segmentation (Chapter 17)
- Short Epoch Filtering (Chapter 18)
- Statistic Extraction (Chapter 19)
- t-test (Chapter 20)
- Wavelets (Chapter 21)

Table 1-1 lists the input and output file options of all the Waveform Tools, in alphabetical order.

Table 1-1. Input and output file options

Tool	Input	Output
Artifact Detection	Net Station Native files	input file
Averaging	Net Station, EGIS, or simple-binary segmented or Combination files	Net Station Combination file
Bad Channel Replacement	Net Station Native files that have been operated on by the Artifact Detection tool	same format as input file
Baseline Correction	Net Station, EGIS, or simple-binary segmented or Combination files	Net Station segmented or Combination file
Combine Files	Most settings can accept all file types and selections; one exception is the "Merging Categories" setting, which cannot accept continuous files	Depends on settings: Flattening Files = continuous file Stacking Files = segmented file Merging Files = same format as input file Merging Categories = same format as input file
Difference Wave	Net Station segmented or Combination files	same format as input file
Event Export	Net Station Native files and data selections	ASCII file
File Export	any file type	file type chosen in the export options
Filtering	Net Station continuous, segmented, or Combination files and data selections	same format as input file
Markup from File	Net Station Native files	input file
Montage Operations	Net Station Native, EGIS, or simple-binary continuous, segmented, or Combination files and data selections	Net Station continuous, segmented, or Combination file or data selection
Ocular Artifact Removal	Net Station, EGIS, or simple-binary segmented files	Net Station segmented file
Script	does not operate directly on a file; it chains tool operations together	N/A
Segmentation	Net Station continuous, segmented, or Combination files	Net Station segmented file (or if using Segmentation Markup, the output is the input file)
Short Epoch Filtering	Net Station, EGIS, or simple-binary segmented files	Net Station segmented file
Statistic Extraction	Net Station averaged or segmented files	tab-delimited text file
t-test	Net Station, EGIS, or simple-binary Combination files	t-file
Wavelet	Net Station segmented or Combination files	Wavelet file

System Requirements

Net Station is designed for Mac OS X 10.3 or later (10.4 is recommended), and to run on Mac G4 or later (G5 is recommended) PowerPC units, either portable or desktop. Minimum hardware requirements are a 1.25 GHz processor and 1 GB of RAM.

Using Waveform Tools

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, then you run the tool. You can use an entire file or a selection of data from the Viewer window.

You use the Waveform Tools window to run the tool operations and to open tool specification editors for creating and editing tool specifications.

The Script tool automates 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.

Displaying the Waveform Tools Window

You can display the Waveform Tools window two ways:

- choose **Tools > Waveform Tools**
- click the Waveform Tools button in the Net Station start-up window

Creating a Tool Specification

1. From the Create pop-up menu, choose a tool specification editor.
2. In the editor, name the specification, and, where applicable, edit the output options and tool-specific parameter fields.
3. Close the editor, saving the specification.

Waveform Tools Window Components

Figure 1-1 shows the Waveform Tools window with one data file in the Inputs panel, one Tool Set in the Specifications panel, and one tool in the View Tool Specifications panel.

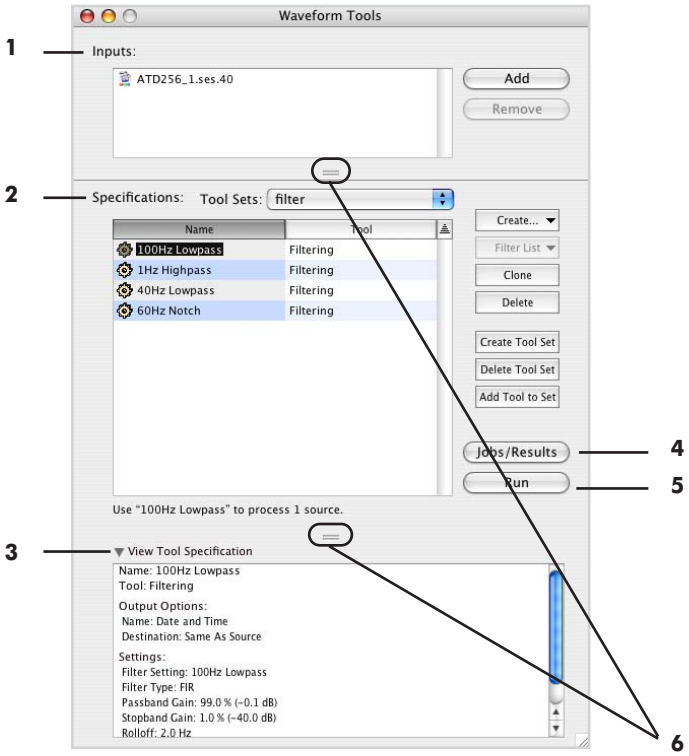


Figure 1-1. Waveform Tools window

Note: When a specification is selected, files in the Inputs panel that are unusable by that specification are shown in red. Possible errors may occur when Run is clicked and will be indicated by the message "None of the sources could be used by this tool."

The following are brief descriptions of the numbered items from Figure 1-1.

1. Inputs pane. Lists the files or selected epochs that will be processed when you run the tool using the specifications listed in the Specifications pane (2).

After processing, the list is cleared. There are many ways to add files to the list:

- Drag files from the Finder to the list.
- Drag folders from the Finder to the list. All valid files in the folder or subfolder at any level are added to the list.
- Drag files from Net Station's Find File Results window to the list.
- Drag items from the Results panel of the Jobs and Results window to the list.
- Click the Add button, which displays a file-selection dialog. Select the desired file and click the Add button. In the file-selection dialog, you can use the Shift key to select multiple files to add to the list.
- In Net Station Viewer, select a portion of the displayed data, then drag the selection to the list.

To remove list items, select the items and click the Remove button.

2. Specifications pane. Lists the tool specifications available to process the files. The list shows the name of each specification and the tool used to create it. The following buttons control the contents of the list.

- *Create pop-up menu*: displays a list of available tools. Choose a tool to launch the corresponding tool specification editor and create a specification. See "Launching a Tool Specification Editor" on page 27.
- *Filter List pop-up menu*: displays a list of available Waveform Tools. Choose a tool to list only the specifications for that tool. Choose All Tools to list all of the available specifications.
- *Clone button*: makes a copy of the selected specifications.
- *Delete button*: deletes the selected specifications.

- *Tool Set pop-up menu*: displays all the user-created Tool Sets. A Tool Set is a way to organize your tools into groups (for example, all the filters may be placed in a "Filters" Tool Set). A Tool Set does not remove specific tools from the All Tools set; it copies the tools to the new Tool Set.

  When an item is chosen from this menu, only the tools in that set are displayed in the Specifications pane (Figure 1-1 shows the tools in the Filters Tool Set).

- *Create Tool Set*: opens a dialog for naming a Tool Set. If any tools are selected in the Specifications panel when you click the Create Tool Set button, those tools are automatically part of the new Tool Set. Otherwise, the new Tool Set is empty and must be populated using the Add Tool to Set button (described later in this section).
- *Delete Tool Set*: deletes the Tool Set currently chosen from the Tool Set pop-up menu. The specific tools in that set are not deleted from the All Tools set.
- *Add Tool to Set*: adds selected tools to a user-chosen Tool Set. Select the tools in the Specifications pane, click the Add Tool to Set button, and choose a Tool Set from the Available Sets pop-up menu that appears.

3. View Tool Specifications pane. Lists the settings for the selected specification. These are the settings that were selected when the specification was created in the tool specification editor. The disclosure triangle in the upper-left corner toggles the display of this pane.

4. Run button. Begins processing the input data using the selected specification.

5. Jobs/Results button. Displays the Jobs and Results window, which shows the status of past and current processing jobs. For more information on the Jobs and Results window, see Chapter 2, "Jobs and Results Window."

6. Resize handles. Resize the Specifications panel (2). Drag a handle to resize.

Note that there are two ways to select multiple items in the Inputs pane and the Specifications pane.

- To select two items and everything between them: select an item, hold down the Shift key, then select another item.
- To select any combination of items: select an item, hold down the Command key, then select one or more other items.

When multiple specifications are selected in the Specifications pane, you may Clone or Delete them, but you cannot Run them.

Launching a Tool Specification Editor

In the Waveform Tools window, click the Create button and select the desired tool specification editor from the pop-up menu.

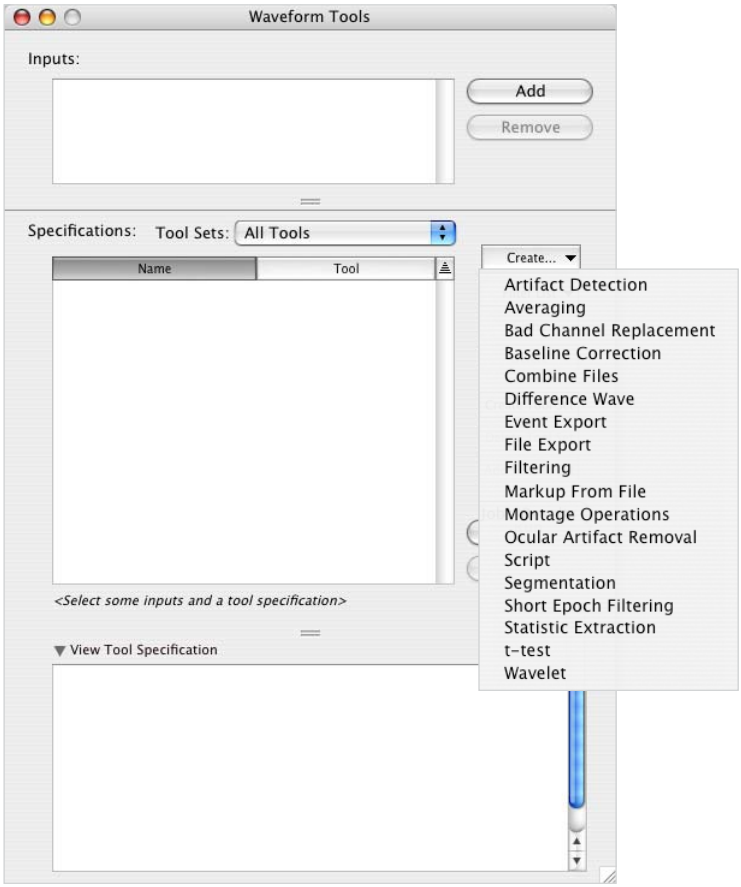


Figure 1-2. Launching a tool specification editor

Tips on Using Waveform Tools

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 first to process the data from a single subject carefully to:

- verify that you can do what you want to do (you may learn that you need to modify your experimental control script)
- learn the effects of the various operations and their parameters

As described in Chapter 7, "ERP Derivation and Waveform Tools," of the *Net Station Viewer and Waveform Tools Tutorial*, the normal order of the performing Waveform Tools operations to derive a single-subject ERP is:

- Filtering,
- Segmentation,
- Artifact Detection,
- Bad Channel Replacement,
- Averaging,
- Average Referencing, and
- Baseline Correction.

We strongly recommend filtering your data before segmenting them. Although we offer a Waveform Tool for filtering short epochs, it is not as accurate as the Filtering tool (described in Chapter 12, "Filtering").

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, Combine Files, and Statistic Extraction. Assigning a subject after averaging is* ***not*** *recommended. The following section, "Assigning Subjects," discusses this topic in more detail.*

Once you have processed the data from one subject, you can process the data from the remaining subjects in a more automated fashion by using the Script tool.

Once you have ERPs from several subjects, you can create grand-average ERPs. 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.

If you wish to add the Ocular Artifact Removal (OAR) tool to your data-analysis path, then the recommended order is:

- Filtering,
- Segmentation,
- Artifact Detection,
- Bad Channel Replacement,
- OAR,
- Artifact Detection with "overwrite" all previous bad channel/segment information checkboxes selected,
- Bad Channel Replacement,
- Averaging,
- Average Referencing, and
- Baseline Correction.

Artifact Detection (with "overwrite" all previous bad channel/segment information checkboxes selected) should be run after OAR for two reasons:

- To change the status of trials that Artifact Detection marked "bad" the first time because of eye blinks. With the removal of eye blinks by OAR, the second application of Artifact Detection will mark these trials as "good."
- To mark eye channels as "bad." (This occurs only if you selected the "Flatten Eye Channels" checkbox in the Ocular Artifact Removal specification editor; see page 123.) This ensures that eye-channel data are not used in future operations.

Assigning Subjects

Ideally, you should assign a subject when you use a Session Template to create a Net Station file (see the *Net Station Acquisition Technical Manual*). Failing that, you can still provide subject information after the data-acquisition session by opening the Net Station file, choosing **Edit > File Info**, and clicking the Assign Subject button in the General pane.

Either method *globally* assigns the subject information to the file in Net Station, which ensures that the subject ID is accessible to all Waveform Tools. After operations such as averaging, Net Station changes how it accesses the subject information internally. This change is reflected in the File Info window, where the subject ID is displayed in the Categories pane, rather than the General pane. To view the subject information in the Categories pane, choose Segment Spec Value from the View pop-up menu and Subject ID from the Spec pop-up menu (Figure 1-3).

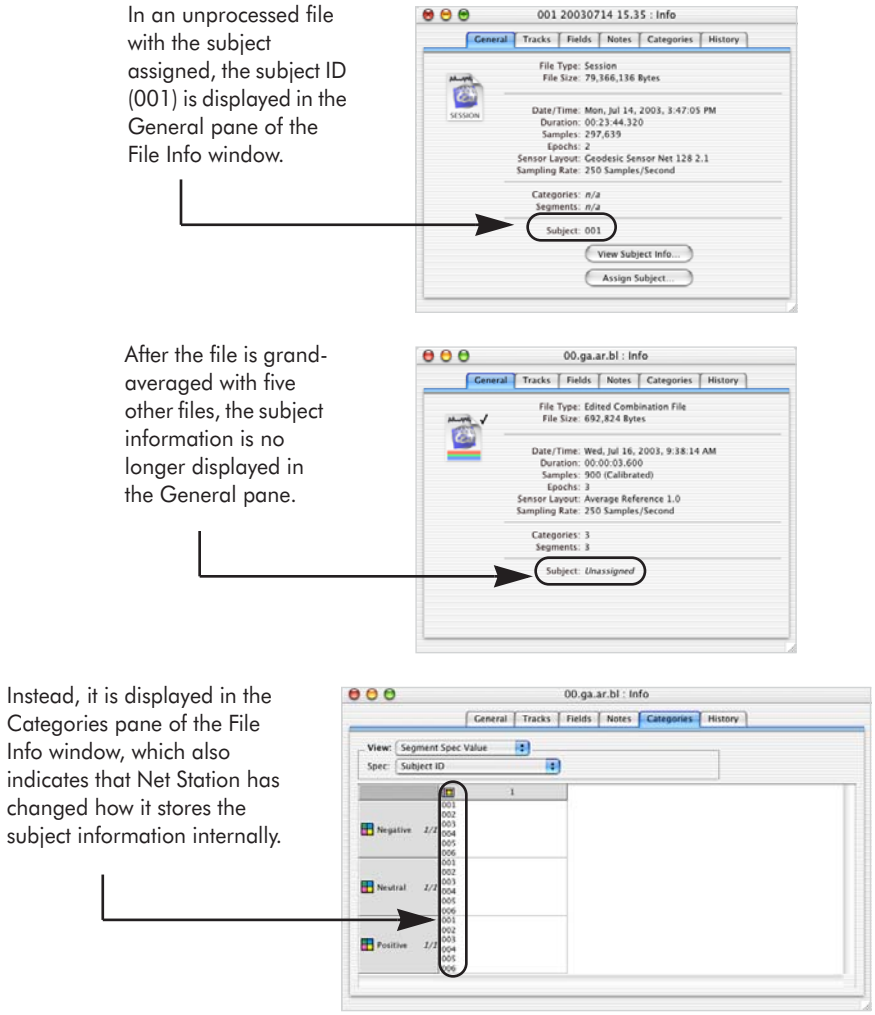


Figure 1-3. Subject ID before and after averaging

If you discover that a subject has ***not*** been assigned after applying Waveform Tools to the file, EGI recommends returning to the source file, assigning the subject ID using the Assign Subject button in the General pane of the File Info window, and reprocessing the file using the Waveform Tools.

Waveform Tools Database

The tool specifications that you create reside in a file called the *Tool Database*. The Tool Database is located in *Users:<user name>:Documents:Net Station User Data:Support*. You can copy tool specifications for the purpose of backing them up or sharing them with others (for example, colleagues or EGI technical support for troubleshooting). You can do this by either copying the Tool Database file or copying individual specifications.

To copy one or more individual tool specifications:

1. In the Waveform Tools window, select the specifications you want to share.
2. Drag the selected specifications to the Desktop. The selected specifications become a Macintosh OS clipping.
3. To access the specifications, other users can drag the clipping to the Specifications panel of their Waveform Tools windows.

Thus, Net Station is really a system built around a growing collection of resources designed to be accessed by other applications as well as from within Net Station itself. A dynamically linked library enables translation of Net Station functions to other environments.

The only Waveform Tool with specifications that cannot be shared is the Markup from File tool. It derives its tool-specific parameters from a file that is selected in the tool specification editor by the user. Copying the tool clipping from one computer to another breaks the file path.

Waveform Tools Menus

Most of the menus work the same way in all of the Net Station modules and throughout the Waveform Tools interface. In Waveform Tools, the following menus have unique functions:

- The File menu has different commands available, depending on whether the Jobs and Results window, the Waveform Tools window, or a specification editor is displayed.
- The Edit menu is the only menu that works on Waveform Tools; the other menus launch other Net Station modules.

File Menu

Figure 1-4 shows the Waveform Tools File menu.

Figure 1-4. Waveform Tools File menu

- *New*: displays a window that allows you to create a new Acquisition Setup, Session Template, or Session.
- *Open*: displays the Finder Open window, which allows you to locate and open files.
- *Close*: closes the active window or specification editor.
- *Save*: saves a tool specification. Save is disabled in the Waveform Tools window and in the Jobs and Results window.
- *Save As*: is disabled in the Waveform Tools window and in the Jobs and Results window.
- *Export*: is disabled in the Waveform Tools window and in the Jobs and Results window.
- *Find File*: displays the Finder Find File window, which allows you to search for files using keywords and other search criteria.
- *Set To Print Size*: is disabled in the Waveform Tools window and in the Jobs and Results window.

- *Page Setup*: displays the Page Setup window, which allows you to set printing options. Page Setup is disabled in the Waveform Tools window and in the Jobs and Results window.
- *Print*: displays the Finder Print window, which allows you to make printer settings and to print. Print is disabled in the Waveform Tools window and in the Jobs and Results window.

Edit Menu

Figure 1-5 shows the Waveform Tools Edit menu.

Figure 1-5. Waveform Tools Edit menu

- *Undo*: reverses the last action. Undo is disabled in the Waveform Tools window and in the Jobs and Results window.
- *Cut*: deletes the selected item and places it onto the Clipboard. Cut is disabled in the Waveform Tools window and in the Jobs and Results window.
- *Copy*: copies the selected item to the Clipboard.
- *Paste*: inserts the item on the Clipboard into the selected field or list. Paste is disabled in the Waveform Tools window and in the Jobs and Results window.
- *Clear*: deletes the contents of a field or list.
- *Select All*: selects all the items in a list. Select All is disabled in the Waveform Tools window.
- *Unselect All*: cancels the selection of all the items in a list. Unselect All is disabled in the Waveform Tools window.

Docs Menu

Figure 1-6 shows the Waveform Tools Docs menu.

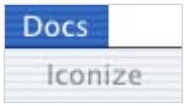


Figure 1-6. Waveform Tools Docs menu

- *Iconize*: is disabled in the Waveform Tools window and in the Jobs and Results window.

The Docs menu also contains a menu item for all files currently open in the Viewer window. Selecting one of these items brings the corresponding Viewer window to the foreground.

Tools Menu

Figure 1-7 shows the Waveform Tools Tools menu.

Figure 1-7. Waveform Tools Tools menu

- *Waveform Tools*: launches the Waveform Tools window.
- *Photogrammetry*: launches the Photogrammetry dialog.
- *Jobs and Results*: displays the Jobs and Results window (see Chapter 2, "Jobs and Results Window").
- *Browse Event Criteria*: displays the Browse Event Criteria window, which allows you to select event criteria for segmentation specifications. Note that if you alter a file displayed in the Browse Event Criteria window, you must drop

the newest version into the file selector to update the event criteria list. (For more information on the Browse Event Criteria window, see the *Net Station Viewer Technical Manual*.)

- *Browse Files*: displays the Browse Files window. (For more information on the Browse Files window, see the *Net Station Viewer Technical Manual*.)
- *Browse Subjects*: displays the Browse Subjects window. (For more information on the Browse Subjects window, see the *Net Station Viewer Technical Manual*.)

Disk Full Message

When you use the Waveform Tools, Net Station defines "disk full" at 300 Mb because OS X, on which version 4.2 is based, does not allow you to use up the hard drive. It reserves about 250 Mb on disk.

chapter 2

Jobs and Results Window

Concepts

The Jobs and Results window displays the following information about processing jobs:

- a queue of jobs to be processed
- the status of the current job
- the results of completed jobs for the current Net Station session
- errors that occurred during processing

Displaying the Jobs and Results Window

You can display the Jobs and Results window two ways:

- choose **Tools > Jobs and Results**
- click the Jobs/Results button in the Waveform Tools window

Jobs and Results Window Components

Figure 2-1 shows the Jobs and Results window.

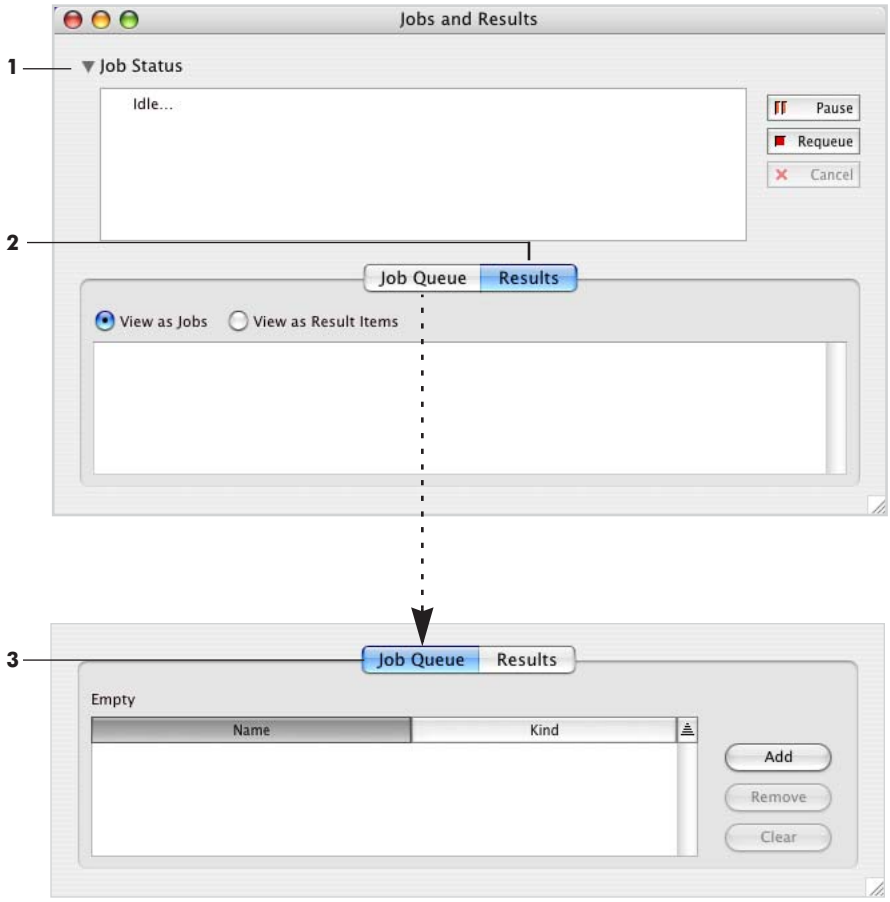


Figure 2-1. Jobs and Results window

The following are brief descriptions of the numbered items from Figure 2-1.

1. Job Status pane. Displays information about the progress of the current job. Idle indicates that no job is currently running.

Three buttons allow you to control the current job.

- *Pause button*: stops the job; clicking it again allows you to resume processing.
- *Requeue button*: stops the job and puts it back into the queue.
- *Cancel button*: stops the job.

The disclosure triangle in the upper-left corner toggles the display of this pane.

2. Results pane. Displays the results of the job, including error messages if any errors occurred. Two radio buttons allow you to display the results in different ways.

- *View as Jobs button*: displays a complete list of output files for all jobs (successful, failed, and canceled). Lists all messages and temporary files. See Figure 2-2 for details.
- *View as Result Items button*: displays a summary listing of output files for successful jobs, without messages and temporary files. See Figure 2-3 for details.

The disclosure triangle in the upper-left corner toggles the display of this pane. You can choose **Edit > Clear** to clear selected results items. You can choose **Edit > Select All** or **Edit > Unselect All**, or click on the items themselves, to select and deselect items in the Results pane.

3. Job Queue pane. Lists the data files that have been submitted for processing from the Waveform Tools window. Clicking the Add button displays the Waveform Tools window, where you can run the tools.

Two buttons allow you to remove files from the list.

- *Remove button*: removes the selected files.
- *Clear button*: removes all of the files.

The disclosure triangle in the upper-left corner toggles the display of this panel.

Results Pane with View as Jobs

Figure 2-2 shows the Results pane, with View as Jobs selected.

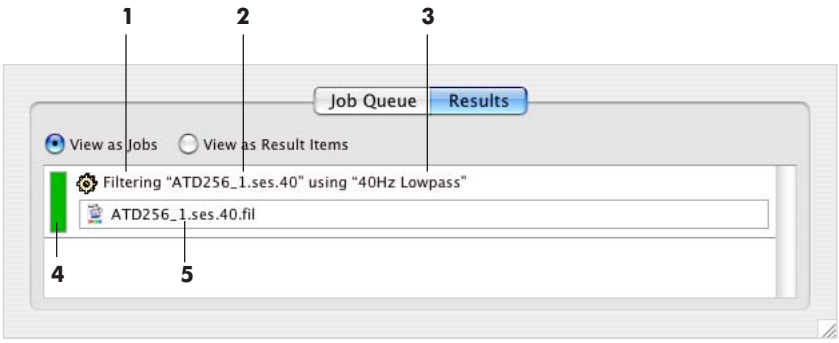


Figure 2-2. Results pane, with View as Jobs selected

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

1. Tool. Indicates the Waveform Tool that was used to run the job.

2. Input file. Lists the name of the input file that was processed by the job.

3. Specification. Lists the name of the tool specification that was used in processing the job.

4. Success/failure bar. Indicates success or failure through use of color. Green indicates success; red indicates failure.

5. Output file. On successful jobs, shows the output file name. Double-click to open the file in Net Station Viewer. You can drag this item to the Inputs panel of the Waveform Tools window. On unsuccessful jobs, contains an error message describing the error. Messages can result from successful jobs as well, but they are advisory in nature and do not interfere with the execution of the operation.

Results Pane with View as Result Items

Figure 2-3 shows the Results pane, with View as Result Items selected.

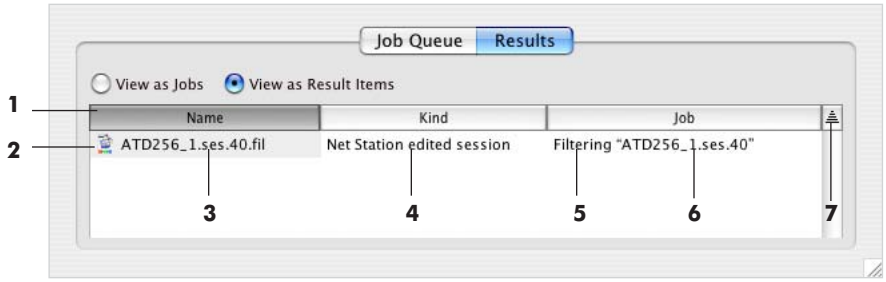


Figure 2-3. Results pane, with View as Result Items selected

The following are brief descriptions of the numbered items from Figure 2-3.

1. ***Column heading***. When clicked, sorts by Name, Kind, or Job.

2. ***Result item***. When clicked, selects that row. Double-clicking opens the selected file.

3. ***Output file***. When double-clicked, the file opens in Net Station Viewer. You can drag this item to the Inputs panel of the Waveform Tools window.

4. ***Kind***. Indicates the type of file (for example, Net Station Session file).

5. ***Tool***. Indicates the Waveform Tool that was used to run the job.

6. ***Input file***. Lists the name of the input file that was processed by the job.

7. ***Sort order toggle***. Toggles between ascending and descending sorting when clicked.

Note that there are two ways to select multiple items in the Queue pane and the Results pane.

- To select two items and everything between them: select an item, hold down the Shift key, then select another item.
- To select any combination of items: select an item, hold down the Command key, then select one or more other items.

chapter 3

Common Controls

Concepts

Some controls are shared by the tool specification editors. With these common controls, you can:

- name tool specifications
- specify output destinations and output names for the files created by running the tool specifications
- select files for various purposes using a flexible file selector

Specification Name and Output Options

Figure 3-1 shows the Specification Name text box and the Output Options panel, the common elements that appear at the top of all the tool specification editors.

The following are brief descriptions of the numbered items from Figure 3-1.

1. Specification Name text box. Appears in the top-left corner of every tool specification editor. You can enter a name to identify the tool specification.

2. *Output Options section.* Appears in the top-right corner of tool specification editors that create a new file when they are run.

- *Name*: allows you to select a file naming setting for all files processed by this specification. See Table 3-1 for a description of the naming options.

  Note: Do not use colons when naming your file. A file name with a colon will result in an error message and no output file.

- *Destination*: specifies the destination for the files created by running the tool specification. See Table 3-2 for a description of the destination options.

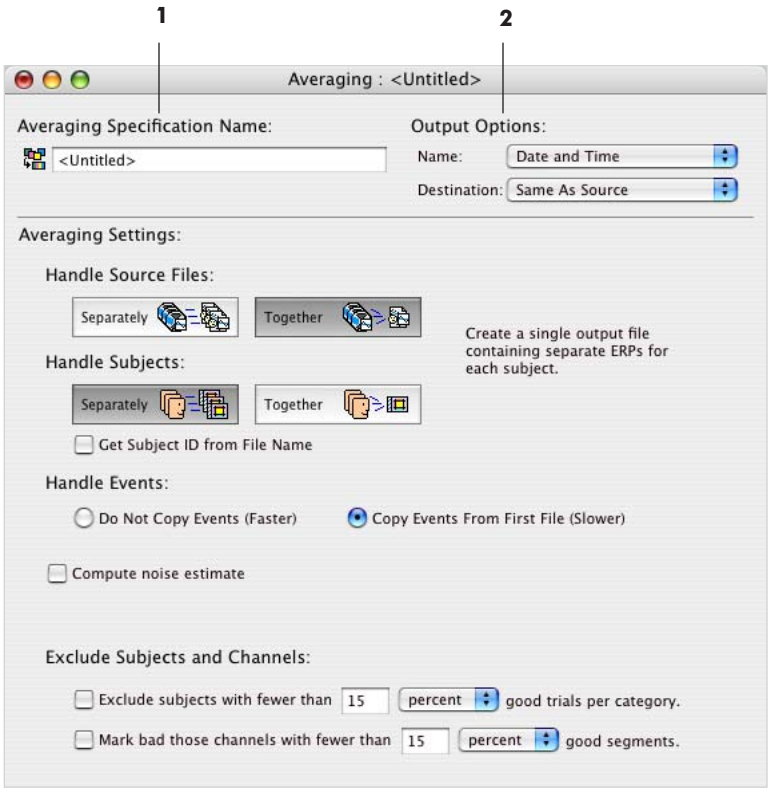


Figure 3-1. Specification Name text box and Output Options panel

Table 3-1. Output File naming options

Option	Description
Date and Time	The output file is named in the following format: *<tool-name> <date> <time>* *<date>* and *<time>* are formatted as follows: *yyyymmdd hh.mm* Example file name in Date and Time format: Filtered 20020925 11.56
Append Extension	Type in an extension to be appended to the input file name. Note that colons are prohibited in file names. Waveform Tools assign the default extension: .ave = Averaging .bcr = Bad Channel Replacement .blc = Baseline Correction .dif = Difference Wave .evt = Event Export .nsf = File Export .fil = Filtering .sub = Montage Operations .oar = Ocular Artifact Removal .seg = Segmentation .fil = Short Epoch Filtering .ttest = t-test Artifact Detection, Combine Files, Statistic Extraction, and Wavelet do not have default extensions.
Replace Extension	Type in a new extension to replace the previous one. Note that colons are prohibited in file names.
Fixed	Type in a file name. Note that colons are prohibited in file names.
Ask	Waveform Tools prompt for a file name whenever you run the tool. Note that colons are prohibited in file names.

Table 3-2. Output File destination options

Option	Description
Same as Source	Output files are saved to the folder that contains the input files.
Net Station Results Folder	Output files are saved to the Net Station Results folder (Documents:Net Station User Data:Results).
Temporary File Cache	Output files are saved to a temporary cache in the Net Station package. Net Station deletes the files in this cache at startup. This option is useful for tool specifications that are to be run as part of a script, where the interim results are not needed. Output files that have been saved to the temporary cache are accessible from the Jobs and Results window for viewing (double-click) or dragging to the Inputs panel of the Waveform Tools window.
Select	Displays a folder-selection panel, where you can select a destination folder.
Ask	Waveform Tools prompt for a destination whenever you run the tool.

The File Selector and Associated Display Panes

Many of the tool specification editors provide a file selector. Use the file selector to select files that you need to edit the specification. The file selector functions differently depending on the editor.

- In the Filtering, Segmentation, and Short Epoch Filtering editors, you use the file selector to see the effect of the current specification on the selected file.
- In the Artifact Detection, Baseline Correction, Event Export, Markup from File, and Wavelet editors, you use the file selector to get a list of event types in the selected file. Then you can select the event types of interest for the specification you are defining.
- In the Combine Files, Difference Wave, and t-test editors, you use the file selector to get a list of categories in the selected file. Then you can select the categories of interest for the specification you are defining.
- In the Statistic Extraction editor, you use the file selector to get both a list of categories and a list of events in the selected file.

Figure 3-2 shows the file selector and an associated display pane.

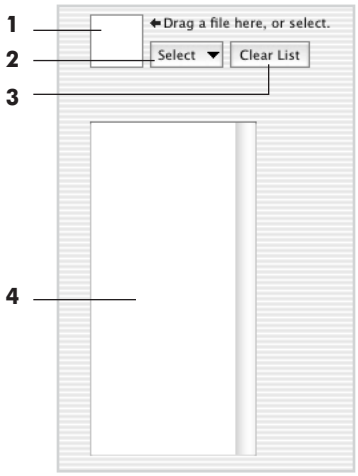


Figure 3-2. File selector and display pane

The following are brief descriptions of the numbered items from Figure 3-2.

1. File box. Represents one way to put files into the file selector. You can drag files from the Finder to this box.

2. Select button. Represents one way to put files into the file selector. You can click this button and select from a pop-up menu of the files currently open in Net Station Viewer. You can also select Other from the list, which opens a file-selection dialog that allows you to locate the file.

3. Clear List button. Deletes all items from the list in the display pane (4). Note that this button deletes the ***category lists from other specifications*** as well as from the displayed specification. This button does not appear in the file selectors for the Filtering, Segmentation, and Short Epoch Filtering editors because those file selectors do not populate a list.

4. Display pane. Displays information related to the file in the file selector. There are three types of display panes associated with the file selectors in the Waveform Tools editors.

- *Event list*: displays all the unique event identifiers in the file. This type of pane appears in the Artifact Detection, Baseline Correction, Event Export, Markup from File, and Wavelet editors. It also appears next to a category list in the Statistic Extraction editor.

- *Category list*: displays all the categories in the file. This type of pane appears in the Combine Files, Difference Wave, and t-test editors. It also appears next to an event list in the Statistic Extraction editor.
- *Effects*: displays the effect of the specification on the data in the file. This type of pane appears in the Segmentation editor. In the Filtering and Short Epoch Filtering editors, it shows the effect of the current filter; another pane shows the unfiltered data.

chapter 4

Artifact Detection

Concepts

The Artifact Detection tool is designed to operate on any Net Station Native file.

The Artifact Detection tool does not produce an output file; it automatically detects and marks *bad channels* and *bad segments* in the input file. Bad channels in good segments are replaced when you run the Bad Channel Replacement tool (see Chapter 6, "Bad Channel Replacement"). Bad channels in bad segments are not replaced, and bad channels and bad segments are automatically excluded when you run the Averaging tool (see Chapter 5, "Averaging").

Modular Interface for Flexible Operation

The Artifact Detection specification editor provides a *modular* and *flexible* way to detect and mark bad channels or eye-blink or eye-movement artifacts.

The specification editor consists of two main modules (see Figure 4-1 on page 50).

- The first module is the Threshold Artifact Detection Settings section, where you specify the parameters for detecting bad channels, eye movements, and/or eye blinks.
- The second module is the Perform Inferences section, where you specify what inferences to make of the results produced by the Threshold Artifact Detection Settings section (for example, whether to mark segments "bad" if they contain an eye movement or eye blink).

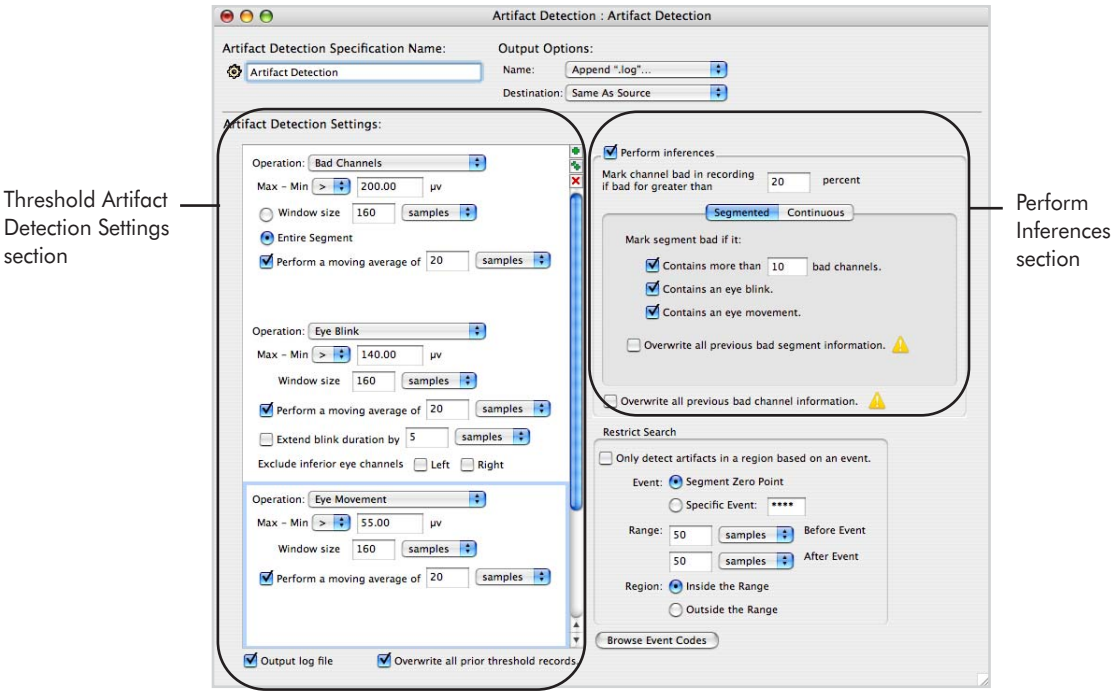


Figure 4-1. Artifact Detection main modules

The Artifact Detection tool is flexible because you can create Artifact Detection tools that consist of:

- a Threshold Artifact Detection Settings section only,
- a Perform Inferences section only, or
- both sections.

Note: Creating tools containing only one of the two sections allows you to combine threshold-only and inference-only tools for maximum flexibility. For example, you can compare artifact-detection thresholds by running the same inference-only tool on copies of a file that have been processed by different threshold-only tools.

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

The Threshold and Inferences Sections

To create an Artifact Detection tool, fill in the Threshold Artifact Detection Settings section only, the Perform Inferences section only, or both sections.

Threshold Artifact Detection Settings

In the Threshold Artifact Detection Settings section, the tool both *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. Table 4-1 lists the eye-blink pairs and the one eye-movement pair for each GSN model.

Note: All models except the 32- and 64-channel HCGSNs have four eye-blink pairs; those two models feature only two eye-blink pairs.

Table 4-1. Eye-blink and eye-movement pairs for each GSN model

GSN model	Eye-blink pairs		Eye-movement pairs
	Left	Right	
32-channel HCGSN	2 & 30	1 & 29	31 & 32
64-channel HCGSN	10 & 63	5 & 62	61 & 64
128-channel HCGSN	25 & 127 and 21 & 127	8 & 126 and 14 & 126	125 & 128
256-channel HCGSN	37 & 241 and 32 & 241	18 & 238 and 25 & 238	226 & 252
64-channel GSN 200 v.1	14 & 64 and 11 & 64	1 & 63 and 6 & 63	18 & 60
64-channel GSN 200 v.2	14 & 64 and 11 & 64	1 & 63 and 6 & 63	19 & 60
128-channel GSN 200	26 & 127 and 33 & 127	8 & 126 and 1 & 126	125 & 128
256-channel GSN 200	36 & 242 and 45 and 242	18 & 241 and 10 & 241	227 & 251

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 "smooths" the data to prevent any noisy sample from having too much influence in the algorithm. If you select the moving-average option, the tool:

- runs through the channels,
- takes the data from the user-specified window,
- performs a moving average on the data,
- 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 Threshold Artifact Detection Settings section also allows you to:

- Specify as many or as few artifact-detection thresholds as desired in the Threshold Artifact Detection Settings section.
- Specify artifact-detection thresholds with different window sizes.
- Specify a low- or a high-activity threshold by choosing the "less than" or "greater than" button.
- Evaluate the results in a text-based log file output by the tool (described in the next paragraph), change the tool parameters, select the "overwrite" checkboxes, and run Artifact Detection again.

Log File

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

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

In the Perform Inferences section, you can specify what conclusions to make from the bad-channel, eye-blink, and eye-movement information produced by the Threshold Artifact Detection Settings section. 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.

The resulting information is stored in a threshold record, which is inaccessible to the user.

Eye Blinks in Segmented or Continuous Data

To prevent bad eye channels from incorrectly influencing the marking of eye blinks, 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.

If the Perform Inferences section cannot run because all the eye channels are bad, a warning will appear.

If the Perform Inferences section cannot run because of bad inferior eye channels, a dialog will appear, suggesting that you select the “Exclude inferior eye channels” checkbox and run the tool again.

Eye Movements in Segmented or Continuous Data

To prevent bad eye channels from incorrectly influencing the marking of 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 movements.

If the Perform Inferences section cannot run because all the eye channels are bad, a warning will appear.

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.

Artifact Detection Specification Editor

Figure 4-2 shows the Artifact Detection specification editor.

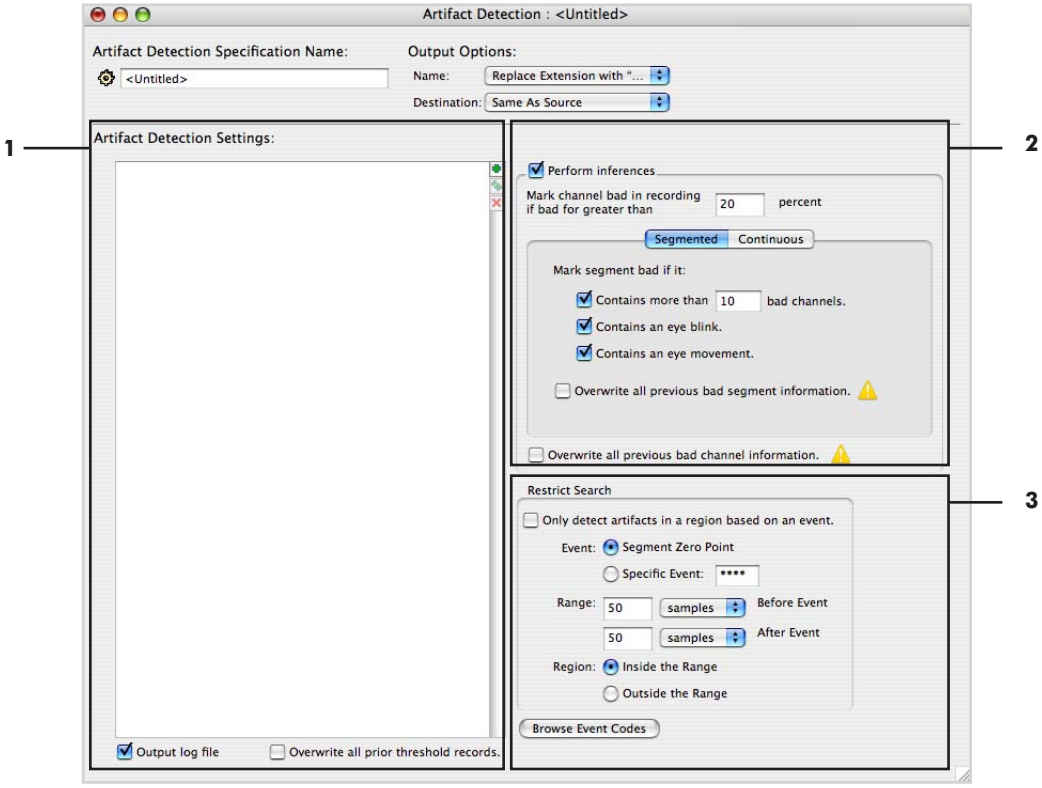


Figure 4-2. Artifact Detection specification editor

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

1. Threshold Artifact Detection Settings section. Adds the Threshold Artifact Detection function to the specification. This section is described in detail on page 57.

Note: If no thresholds are specified but the "Perform Inferences" checkbox (2) is selected, the specification will perform only inferences.

2. "Perform Inferences" section. Adds the Perform Inferences function to the specification. This section is described in detail on page 61.

Note: If the "Perform Inferences" checkbox is unselected but the Artifact Detection Threshold Settings (1) are specified, the specification will perform only artifact detection.

3. Restrict Search checkbox and pane. You can use the Restrict Search pane of the specification editor to limit the amount of the data that is checked for artifacts. This can be useful for long segments or files that may contain artifacts outside the range of interest.

After the "Only detect artifacts in a region based on an event" checkbox is selected, refine the search space using the following "Restrict Search" controls:

- *Segment Zero Point*: detects artifacts inside regions specified with respect to the segment's zero point (Segment Time = 0; see page 131 for more information). You can specify the size of the region before or after the event in samples or milliseconds. Figure 4-2 shows the Restrict Search pane set to Segment Zero Point.
- *Specific Event*: restricts artifact detection to regions specified with respect to a specific event. You specify whether to restrict to regions inside or outside the region defined by the event. You can specify the size of the region before or after the event in samples or milliseconds. To specify events, either type in the 4-character event code or click the Browse Event Codes button to extract a list of event codes.
- *Browse Event Codes button*. When clicked, this button opens the Browse Event Criteria window for extracting events from files that you select. (For more information about this window, see the *Net Station Viewer Technical Manual*.) Select an event code in the window and drag it to the Specific Event text box.

Threshold Artifact Detection Settings Section

Figure 4-3 shows the Threshold Artifact Detection Settings section.

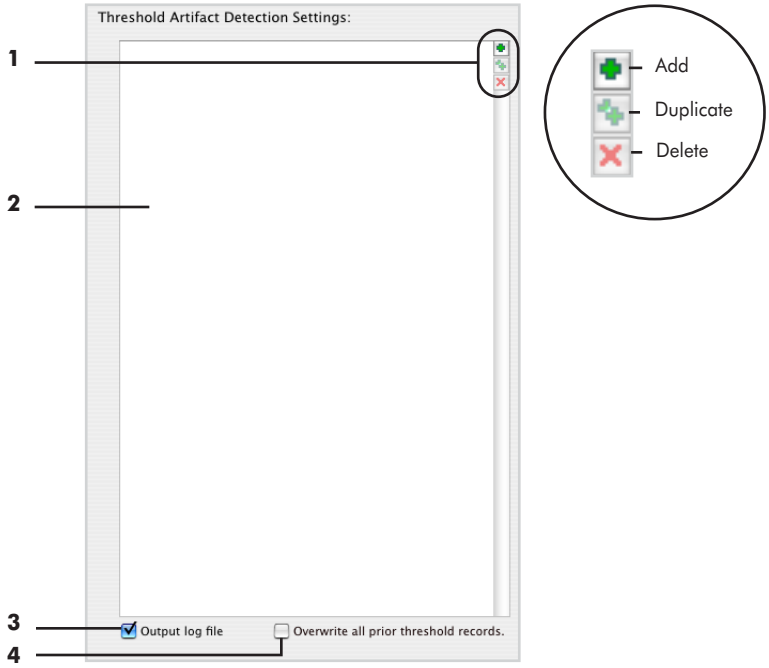


Figure 4-3. Threshold Artifact Detection Settings section

The following are brief descriptions of the numbered items from Figure 4-3.

1. ***Setting control buttons***. The setting control buttons enable you to:
   - add an artifact-detection threshold pane to the threshold specification area (2);
   - duplicate an artifact-detection threshold pane selected in the threshold specification area; or
   - delete an artifact-detection threshold pane selected in the threshold specification area.

Artifact-detection threshold panes contain settings that can be created for bad channels, eye blinks, or eye movements. Descriptions of these panes begin on page 58.

2. ***Threshold specification area.*** Displays the current artifact-detection threshold specifications. Populate this area by clicking the "add" setting control button (1), which will insert an artifact-detection threshold pane into the section.

3. "Output log file" checkbox. When selected, this generates a text file of 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.

4. "Overwrite all prior threshold records" checkbox. When selected, this replaces any previous threshold information stored in the file with the currently generated threshold information. If unselected, previous threshold information is retained and added to. This information, which is inaccessible to the user, is used by the "Perform Inferences" section.

Threshold Panes

Clicking the "add" setting control button inserts an artifact-detection threshold pane into the threshold specification area. You can specify thresholds for detecting eye movements, bad channels, and eye blinks.

Eye-Movement Threshold Pane

Note: The controls in the eye-movement pane are also common to the bad-channel and eye-blink panes. This section describes these controls, and the following sections describe controls specific to the bad-channel and eye-blink panes, respectively.

The eye-movement pane allows you to set the parameters for detecting eye movements. Figure 4-4 shows this pane.

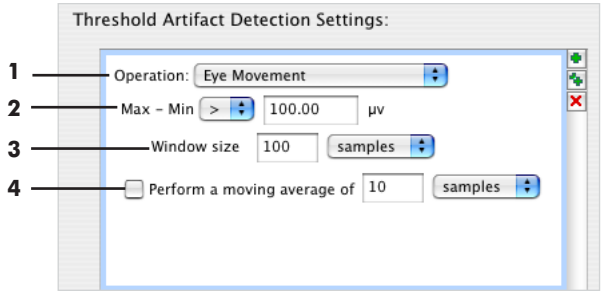


Figure 4-4. Eye-movement threshold pane

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

1. Operation pop-up menu. Allows you to select an artifact type to detect bad channels, eye blinks, or eye movements. The controls in the pane vary, depending on the item selected from this menu.

2. Max-Min controls. Click the Max-Min pop-up menu to select whether the threshold should be greater than (>) or less than (<) the microvolt value that you type in the text box.

3. Window size controls. Click the button to specify the size of the search space for the threshold defined in the Max-Min controls (2). The window can be expressed either in milliseconds or samples.

4. "Perform a moving average" controls. Select the checkbox to use a moving average to "smooth" the data before applying the threshold to detect artifacts. Type in a number and choose samples or milliseconds from the pop-up menu.

Bad-Channel Threshold Pane

The bad-channel threshold pane enables you to set the parameters for detecting bad channels. Figure 4-5 shows this pane.

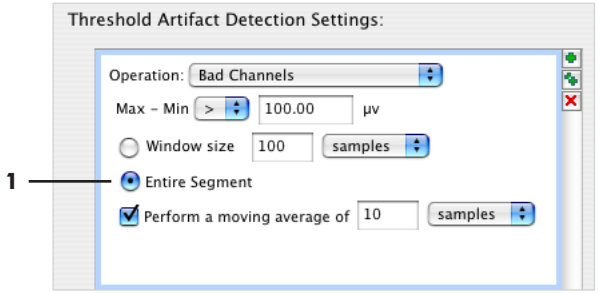


Figure 4-5. Bad-channel threshold pane

The following is a brief description of the numbered item from Figure 4-5.

1. Entire Segment button. Click the button to specify the entire segment as the search space for the threshold defined in the Max-Min controls.

Note: For descriptions of the other controls, see "Eye-Movement Threshold Pane" on page 58.

Eye-Blink Threshold Pane

The eye-blink threshold pane allows you to set the parameters for detecting eye blinks. Figure 4-6 shows this pane.

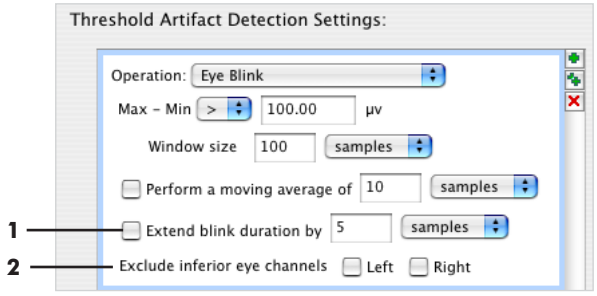


Figure 4-6. Eye-blink threshold pane

The following are brief descriptions of the numbered items from Figure 4-6.

1. "Extend blink duration" controls. Select to extend the amount of data considered as part of an eye blink, to reject data from the blink-recovery period.

2. "Exclude inferior eye channels" checkboxes. When selected, this omits the left, right, or both inferior eye channel data from the artifact-detection operation, and copies and inverts a second superior eye channel (listed in Table 4-2) to create an eye-channel pair. This feature is useful if the inferior eye channels are bad or if the Geodesic Sensor Net has no inferior eye channels (for example, children's Nets).

Table 4-2. Supplemental eye-blink channels for each GSN model

GSN model	Left eye-blink channel	Right eye-blink channel
32-channel HCGSN	N/A	N/A
64-channel HCGSN	N/A	N/A
128-channel HCGSN	25	8
256-channel HCGSN	32	25
64-channel GSN 200 v.1	11	6
64-channel GSN 200 v.2	11	6
128-channel GSN 200	33	1
256-channel GSN 200	45	10

Note: For descriptions of the other controls, see "Eye-Movement Threshold Pane" on page 58.

Perform Inferences Section

The Perform Inferences section enables you to specify what conclusions to make from the information produced by the Threshold Artifact Detection Settings section.

For example, you can set a channel "bad" for the entire recording if it is bad for more than a certain percentage of samples or segments. Or, for segmented data, you can specify how "bad" segments are detected and marked.

Figure 4-7 shows the Perform Inferences section.

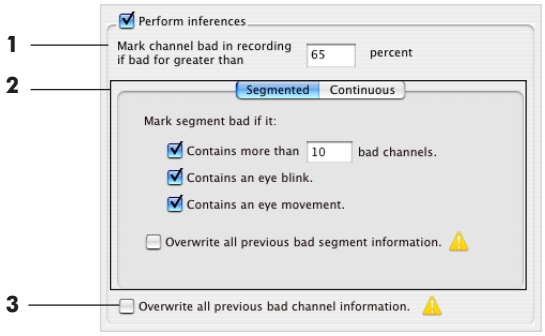


Figure 4-7. Perform Inferences section

The following are brief descriptions of the numbered items from Figure 4-7.

1. "Mark channel bad in recording if bad for greater than x percent" text box. Allows you to input a percentage value for marking a channel bad for the entire file.

2. Data pane. Allows you to specify the parameters for segmented or continuous data; see "Data Pane: Segmented" on page 62 and "Data Pane: Continuous" on page 63, respectively.

3. "Overwrite all previous bad channels "checkbox. When selected, this clears all bad channel markers from previous artifact-detection operations. This is useful if you ran this tool before and want to run it again with a different specification.

Data Pane: Segmented

Figure 4-8 shows the Segmented pane of the Perform Inferences section.

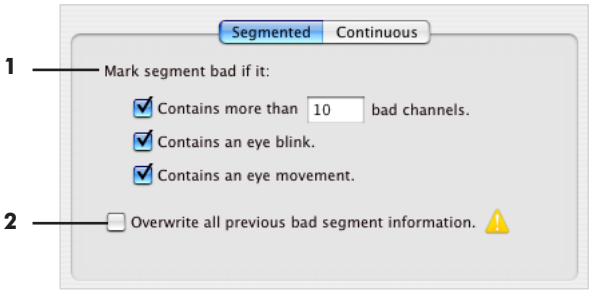


Figure 4-8. Segmented pane

The following are brief descriptions of the numbered items from Figure 4-8.

1. Mark segment bad checkboxes. Contains the following controls for inferring which segments are bad:

- *Contains more than*: When checked, this criterion assumes that if channels are marked "bad" in a given *segment* (not for the *entire recording*; see note that follows), this is evidence of an artifact. If the number of these channels exceeds the user-set criterion, then the segment is marked "bad," with the *badc* status specifier.

*Note: Channels marked "bad" for the **entire recording** are excluded from being used for this criterion.*

- *Contains an eye blink*: When checked, this criterion assumes that if the Threshold Artifact Detection Settings section has detected an eye blink in a given segment, then that segment is "bad" and will mark it with the *eyeb* status specifier.
- *Contains an eye movement*: When checked, this criterion assumes that if the Threshold Artifact Detection Settings section has detected eye movements in a given segment, then that segment is "bad" and will mark it with the *eyem* status specifier.

2. Overwrite all previous bad segment information checkbox. When checked, clears all bad segment markers from previous artifact detection. This is useful if you ran this tool before and want to run it again with a different specification.

Data Pane: Continuous

Figure 4-9 shows the Continuous pane of the Perform Inferences section.

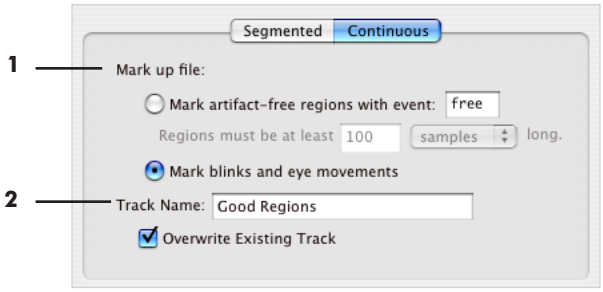


Figure 4-9. Continuous pane

The following are brief descriptions of the numbered items from Figure 4-9.

1. Mark up file section. Contains controls that allow you to mark up the file to indicate artifact-free regions or eye blinks and eye movements:

- *"Mark artifact-free regions with event" control*s: Click to mark up artifact-free regions in the data. You select artifact-free regions for markup based on length (in samples or milliseconds) and specify the name to use for the markup event tag. You cannot select both this button and the "Mark blinks and eye movements" button.
- *"Mark blinks and eye movements" button*: Click to mark eye blinks and eye movements in the data. You cannot select both this button and the "mark artifact-free regions with event" button.

2. Track Name text box. Allows you to specify a name for the events marked up in the file.

- *Overwrite Existing Track checkbox*: Allows you to replace the markup event tags from a previous operation.

chapter 5

AVERAGING

Concepts

Do not confuse the Averaging tool with the Combine Files tool. The Averaging tool collapses all the segments in a category to a single, averaged segment. The Combine Files tool reorganizes segments without collapsing them.

The Averaging tool is designed to operate on Net Station, EGIS, or simple-binary segmented or Combination files. The results are output to a Net Station Combination file.

In averaging, you calculate a single, average segment from all the segments that were not "marked bad," for each category that you created during segmentation. (For more information about the term "marked bad," see page 61 and page 62 of Chapter 4, "Artifact Detection.") The Averaging tool copies events from the first segment in the first file in the source list, which is reordered alphabetically each time a new file is added. Before averaging a file, make sure that a subject has been assigned (see "Assigning Subjects" on page 29).

In grand averaging, you average all the individual-subject ERPs to create a cross-subject ERP. All the individual-subject files must have the same sampling rate.

Grand averaging emphasizes the ERP patterns shared by all of 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.

Averaging and grand averaging are done with the Averaging tool.

Note: If you have a grand-average data file, and you want to add one more subject, it is necessary to regenerate the grand average from ***all*** *the subjects. If you simply average the grand-average data with the data from the new subject, you will end up with an erroneous grand average where the new subject has as much contribution to the new grand average as all the other subjects combined.*

Averaging Specification Editor

Figure 5-1 shows the Averaging specification editor.

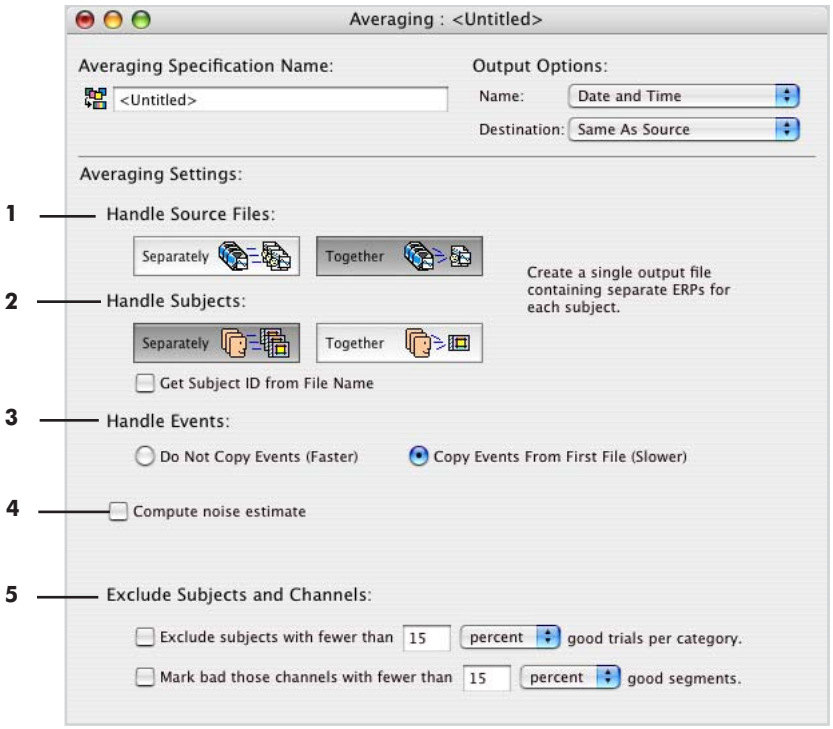


Figure 5-1. Averaging specification editor

The following are brief descriptions of the numbered items from Figure 5-1.

1. Handle Source Files. Specifies whether to combine source files into a single output file.

- *Separately*: creates multiple output files (the same number of output files as input files).
- *Together*: creates a single output file.

Handle Source Files interacts with Handle Subjects (see Table 5-1 for a summary of the interactions).

Table 5-1. Interactions between Handle Source Files and Handle Subjects

		Source Files	
		Separately	**Together**
Subjects	**Separately**	Create multiple output files. Create separate ERPs for each subject in each file.	Create a single output file containing separate ERPs for each subject.
	Together	Create multiple output files. For each output file, create separate ERPs that incorporate all subjects from only the corresponding input file.	Create a single output file containing ERPs that incorporate all subjects from all input files.

2. ***Handle Subjects***. Specifies whether to combine subjects into a multisubject grand average.

- *Separately*: for each category, creates a separate ERP for each subject (an average for each subject).
- *Together*: for each category, creates a single ERP for all subjects (a multisubject grand average).
- *Get Subject ID from File Name*: uses the file name to rename the subject ID. An example of when this is useful is if a file has no subject ID assigned.

Handle Subjects interacts with Handle Source Files (see Table 5-1 for a summary of the interactions).

3. ***Handle Events buttons***. Specifies whether to copy events from the first segment to the average segment.

- *Do Not Copy Events (Faster)*: does not copy events to the average segment.
- *Copy Events From First File (Slower)*: for each category, copies all events from the first segment in that category to the average segment.

4. Compute Noise Estimate checkbox: when checked, this calculates the amount of noise on the waveform. The Averaging tool does this by multiplying every other segment by –1, to subtract the ERP data from the noise. You can view the result by opening the resulting averaged file, choosing **View > as Categories**, displaying the Navigation control strip, and choosing "Noise Est_" from the segment selector in the control strip. (The new categories are labeled "Noise Est_" plus the original category name.)

5. Exclude Subjects and Channels. Allows you to select thresholds for excluding subjects and channels.

- *Exclude subjects with fewer than*: allows you to set the threshold for excluding subjects as a percent or a total number of good trials per category.
- *Mark bad those channels with fewer than*: allows you to set the threshold for marking bad channels as a percent or a total number of good segments.

chapter 6

Bad Channel Replacement

Concepts

The Bad Channel Replacement tool is designed to operate on any Net Station Native file that has been operated on by the Artifact Detection tool. The results are output to a file that has the same format as the input file.

The Bad Channel Replacement tool replaces the bad channels detected by the Artifact Detection tool with data interpolated from the remaining channels and inactivates the "bad channel" status. For more information about detecting artifacts, see Chapter 4, "Artifact Detection."

Caution!: *If Bad Channel Replacement is run on a file that has undergone Montage Operations with a bipolar montage, the file may crash.*

Theory

Because of electrical volume conduction, scalp locations in proximity to each other have similar voltage values. It has been shown that by using spherical splines, you can accurately interpolate the voltage at a given scalp location from the voltage values at many other locations. Assuming that the locations that you are interpolating from are evenly distributed across the scalp, your ability to interpolate the voltage at any location accurately depends on

- the spatial frequency of voltages across the scalp (the rate at which voltages change as you move from one scalp location to another)
- the number of locations from which you are interpolating

In bad channel replacement, you replace the data in bad channels with data interpolated from the remaining channels, using spherical splines. This approximation increases in validity as channel count increases.

For more information on the interpolation of scalp voltages, see the following sources:

- Fletcher, E.M., Kussmaul, C.L., & Mangun, G.R. (1996). Estimation of interpolation errors in scalp topographic mapping. *Electroencephalography and Clinical Neurophysiology*, 98, 422–434.
- Luu, P., Tucker, D.M., Englander, R., Lockfeld, A., Lutsep, H., & Oken, B. (2001). Localizing acute stroke-related EEG changes: Assessing the effects of spatial undersampling. *Journal of Clinical Neurophysiology*, 18, 302–317.
- Perrin, F., Pernier, J., Bertrand, O., Giard, M., & Echallier, J.F. (1987). Mapping of scalp potentials by surface spline interpolation. *Electroencephalography and Clinical Neurophysiology*, 66, 75–81.
- Soong, A.C.K., Lind, J.C., Shaw, G.R., & Koles, Z.J. (1993). Systematic comparisons of interpolation techniques in topographic brain mapping. *Electroencephalography and Clinical Neurophysiology*, 87, 185–195.
- Srinivasan, R., Tucker, D.M., & Murias, M. (1998). Estimating the spatial Nyquist of the human EEG. *Behavior Research Methods, Instruments, and Computers*, 30, 8–19.

Practice

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.

This implies that channels that are marked bad for the entire recording get replaced in every good segment, whereas channels that are marked bad for a subset of the segments get replaced only in the segments in which they are bad.

The Bad Channel Replacement tool never perfectly re-creates a channel. The resulting waveform is only an ***approximation*** of the signal that was present at that location on the scalp during recording. Because reconstructing a bad channel is an approximation of the actual missing data, it is limited by the spatial frequency of your electrode system and the spatial frequency of the actual underlying signal. A channel reconstructed from 64-channel data will be less accurate than one reconstructed from 128-channel data, if sufficiently high spatial frequencies are present.

Bad Channel Replacement Specification Editor

Figure 6-1 shows the Bad Channel Replacement specification editor. There are no user-settable controls for this tool, except the common controls for Specification Name and Output Options (see "Specification Name and Output Options" on page 43).

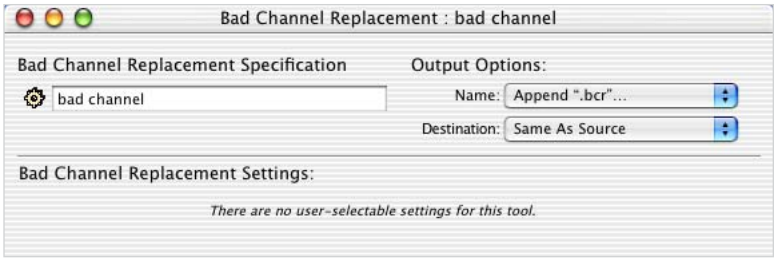


Figure 6-1. Bad Channel Replacement specification editor

chapter 7

BASELINE CORRECTION

Concepts

The Baseline Correction tool is designed to operate on Net Station, EGIS, or simple-binary segmented or Combination files. The results are output to a Net Station segmented or Combination file.

In baseline correction, you establish a new zero-voltage value based on a *baseline interval* that you select within your segment. The baseline interval could be a portion of the segment or the entire segment. 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.

Baseline Correction Specification Editor

Figure 7-1 shows the Baseline Correction specification editor.

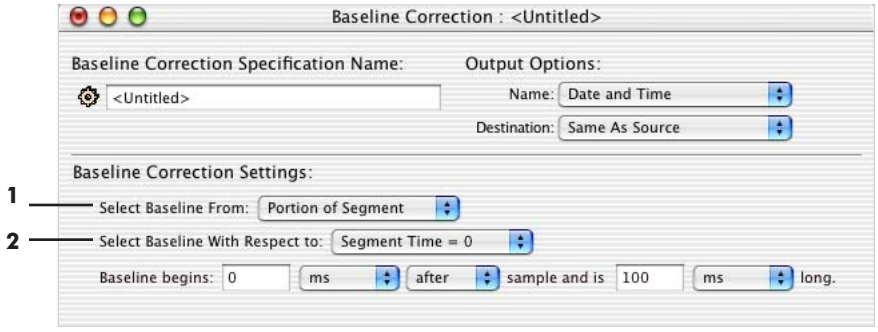


Figure 7-1. Baseline Correction specification editor

The following are brief descriptions of the numbered items from Figure 7-1.

1. Select Baseline From pop-up menu. Specifies the source for the baseline interval. Depending on the option that you select, different controls appear in the Baseline Correction specification editor.

- *Portion of Segment*: uses a portion of the segment as the baseline interval. Figure 7-1 shows the Baseline Correction specification editor, with Portion of Segment selected. With this option, the Select Baseline With Respect To pop-up menu (2) appears, which allows you to select the baseline with respect to either Segment Time = 0 (the segment's zero point; see page 131 for more information) or Start of Segment. You specify the beginning of the baseline interval and its length, in samples or milliseconds.
- *Entire Segment*: defines the baseline interval as the length of the entire segment. With this choice, there is no need for other controls (see Figure 7-2).

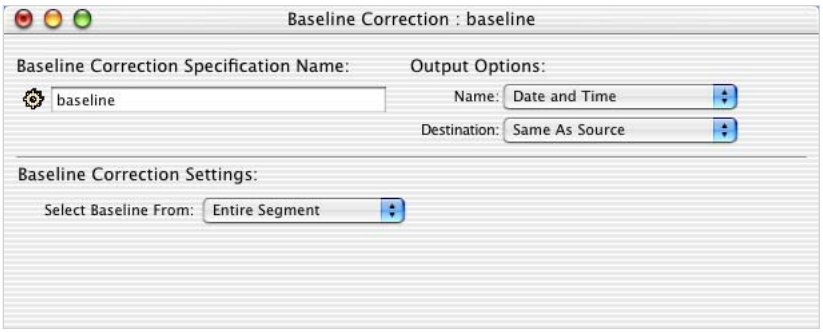


Figure 7-2. Baseline Correction specification editor, with Entire Segment selected

- *Event*: uses an event as the point of reference for the baseline interval. When you select this option, additional controls appear. This option is discussed in the "Select Baseline From Event" section on page 75.

2. Select Baseline with Respect to. Specifies the start and duration of the baseline interval. The pop-up menu offers two items:

- *Start of Segment*: the baseline interval begins a specified time or sample count after the segment start.
- *Segment Time = 0*: the baseline interval begins a specified time or sample count before or after the first sample that occurs after the event on which segmentation is based + the offset.

Select Baseline From Event

Figure 7-3 shows the Baseline Correction specification editor with Select Baseline From Event selected. With this option, you specify an event as the point of reference for the baseline interval. For more information about events, see Chapter 18, "Event Sets and User Events," in the *Net Station Viewer Technical Manual*.

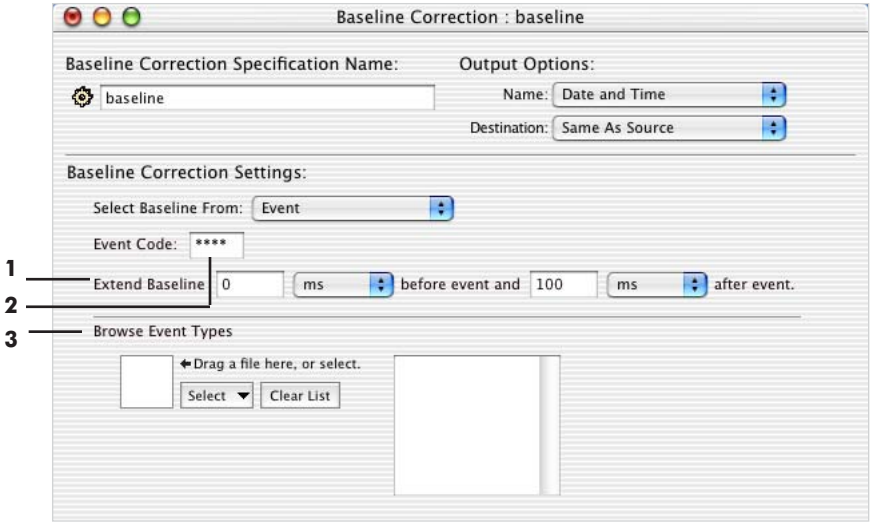


Figure 7-3. Baseline Correction specification editor, with Select Baseline From Event selected

The following are brief descriptions of the numbered items from Figure 7-3.

1. Extend Baseline. Specifies the size of the baseline interval around the reference point. You can make the baseline interval greater than the duration of the event by extending it before the beginning, and/or after the ending, in samples or in milliseconds.

2. Event Code. Allows you to specify events by typing in the event. You can also use the Browse Event Types pane (3) to select an event.

3. Browse Event Types pane (with file selector). Displays a list of events. You populate this list by using the file selector to select one or more Net Station files. The events are extracted from the file(s) you select. For more information, see "The File Selector and Associated Display Panes" on page 46. Select an event in the list on the right side of the panel and drag it to the Event Code field (2).

chapter 8

COMBINE FILES

Concepts

Do not confuse the Averaging tool with the Combine Files tool. The Combine Files tool reorganizes segments without collapsing them. The Averaging tool collapses all the segments in a category to a single, averaged segment.

The files on which the Combine Files tool is designed to operate depend on the tool's settings. Most settings can accept all file types and selections; one exception is the "Merging Categories" setting (see page 83), which cannot accept continuous files. The output results depend on the settings chosen:

- *Flattening Files*: continuous file
- *Stacking Files*: segmented file
- *Merging Files*: same format as input file
- *Merging Categories*: same format as input file

The Combine Files tool has two functions:

- It reorganizes the category information of the input file in a variety of ways.
- It consolidates multiple data files into a single output data file.

Caution!: *An empty subject field may cause problems during the Combine Files process. Make sure that a subject has been assigned before applying Waveform Tools such as Averaging, Combine Files, and Statistic Extraction (see "Assigning Subjects" on page 29).*

Note: The Combine Files tool always outputs a single file, regardless of the number of input files. To reorganize the category information of your input files without consolidating them into a single output file, run Combine Files on each file individually.

Combine Files Specification Editor

The Combine Files tool offers four methods for reorganizing the category information of the input files.

- *Flattening Files*: removes all category information, resulting in a single file containing all segments and epochs sequentially in time. See "Flattening Files" on page 79 for more information.
- *Stacking Files*: collapses all segments into a single new category, resulting in a single file with one category containing all segments and epochs. See "Stacking Files" on page 80 for more information.
- *Merging Files*: accumulates segments for all or selected categories, resulting in a single file with multiple categories, containing all segments and epochs. For each segment in the resulting file, category information is preserved. See "Merging Files" on page 81 for more information.
- *Merging Categories*: accumulates all segments for the selected categories into a new category, resulting in a file with one category containing the selected segments. The effect is to collapse several categories into a single category. You can optionally carry the selected and/or unselected categories to the new file. See "Merging Categories" on page 83 for more information.

You select the method using the Combine Files By pop-up menu. The editor changes appearance, depending on the method you choose.

Flattening Files

Flattening Files removes all category information, resulting in a single file containing all segments and epochs sequentially in time. Figure 8-1 shows the Combine Files editor for Flattening Files.

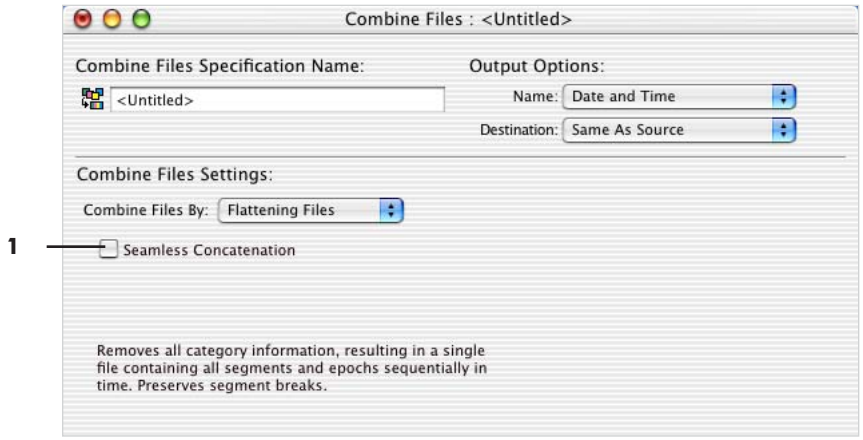


Figure 8-1. Combine Files specification editor for Flattening Files

The following is a brief description of the numbered item from Figure 8-1.

1. Seamless Concatenation checkbox. When this checkbox is selected, segment breaks are removed in the output file. When this checkbox is not selected, segment breaks are preserved in the output file.

Stacking Files

Stacking Files collapses all segments into a single new category, resulting in a single file with one category containing all segments and epochs. Figure 8-2 shows the Combine Files editor for Stacking Files.

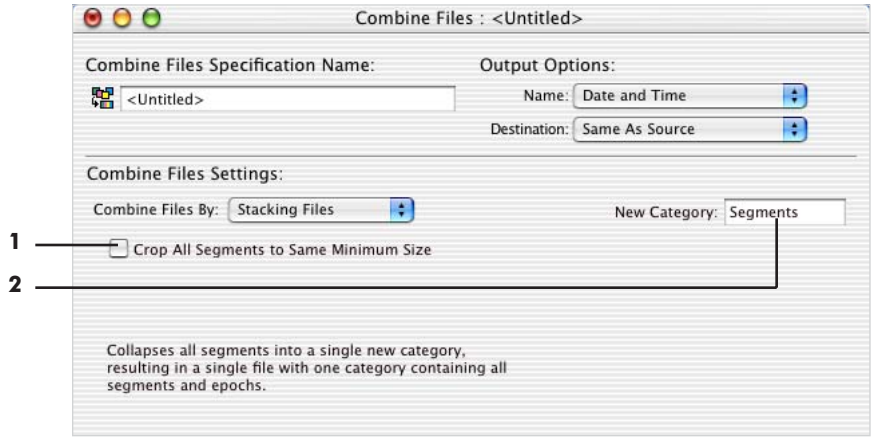


Figure 8-2. Combine Files editor for Stacking Files

The following are brief descriptions of the numbered items from Figure 8-2.

*1. **Crop All Segments to Same Minimum Size checkbox**.* When this checkbox is selected, all segments and epochs are cropped from the end until they are the same length as the shortest segment or epoch.

*2. **New Category text box**.* Allows you to enter a name for the new category.

Merging Files

Merging Files accumulates segments for all or selected categories, resulting in a single file with multiple categories, containing all segments and epochs. For each segment in the resulting file, category information is preserved. Figure 8-3 shows the Combine Files editor for Merging Files.

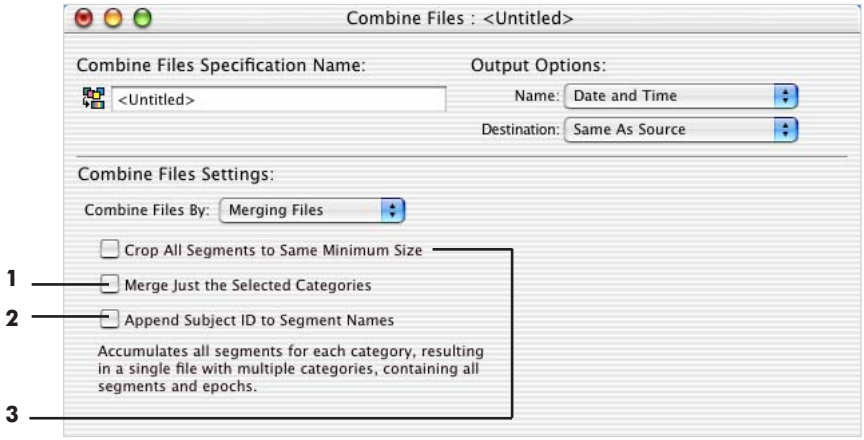


Figure 8-3. Combine Files editor for Merging Files

The following are brief descriptions of the numbered items from Figure 8-3.

1. Merge Just the Selected Categories checkbox. When this checkbox is selected, the new file contains only the categories that you select, reducing the number of categories. Unless this checkbox is selected, the main result is to consolidate multiple files into a single file. Selecting this checkbox displays new controls for selecting categories (see "Merge Just the Selected Categories" on page 82).

2. Append Subject ID to Segment Names checkbox. When merging multiple files, selecting the Append Subject ID to Segment Names checkbox results in output files that identify which segments came from which subjects.

3. Crop All Segments to Same Minimum Size checkbox. When this checkbox is selected, all segments and epochs are cropped from the end until they are the same length as the shortest segment or epoch.

Note: If all three checkboxes are unselected, and if there is only one input file, then the output file is identical to the input file.

Merge Just the Selected Categories

If the Merge Just the Selected Categories checkbox is selected, then the new file contains only the categories that you select, reducing the number of categories. Selecting this checkbox results in new controls appearing for selecting categories. Figure 8-4 shows these new controls.

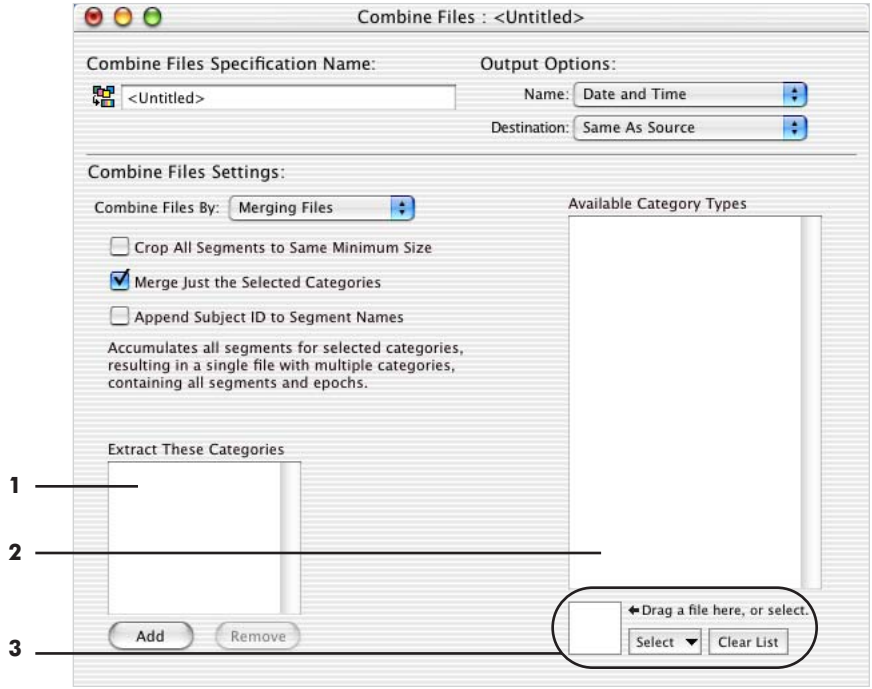


Figure 8-4. Combine Files editor for Merging Files, with Merge Just the Selected Categories selected

The following are brief descriptions of the numbered items from Figure 8-4.

*1. **Extract These Categories pane**.* Specifies the list of categories to extract. You populate this list by dragging categories from the Available Category Types pane (2) or by clicking the Add button and typing a category name.

*2. **Available Category Types pane**.* Displays a list of categories. You populate this list by using the file selector (3) to select one or more Net Station files. The categories are extracted from the file(s) you select. To specify the categories to be extracted, drag categories from this list to the Extract These Categories pane (1).

*3. **File selector**.* Lets you select files for the purpose of populating the Available Category Types pane (2). For more information, see "The File Selector and Associated Display Panes" on page 46.

Merging Categories

Merging Categories accumulates all segments for the selected categories into a new category, resulting in a file with one category containing the selected segments. The effect is to collapse several categories into a single category. You can optionally carry the selected and/or unselected categories to the new file. Figure 8-5 shows the Combine Files editor for Merging Categories.

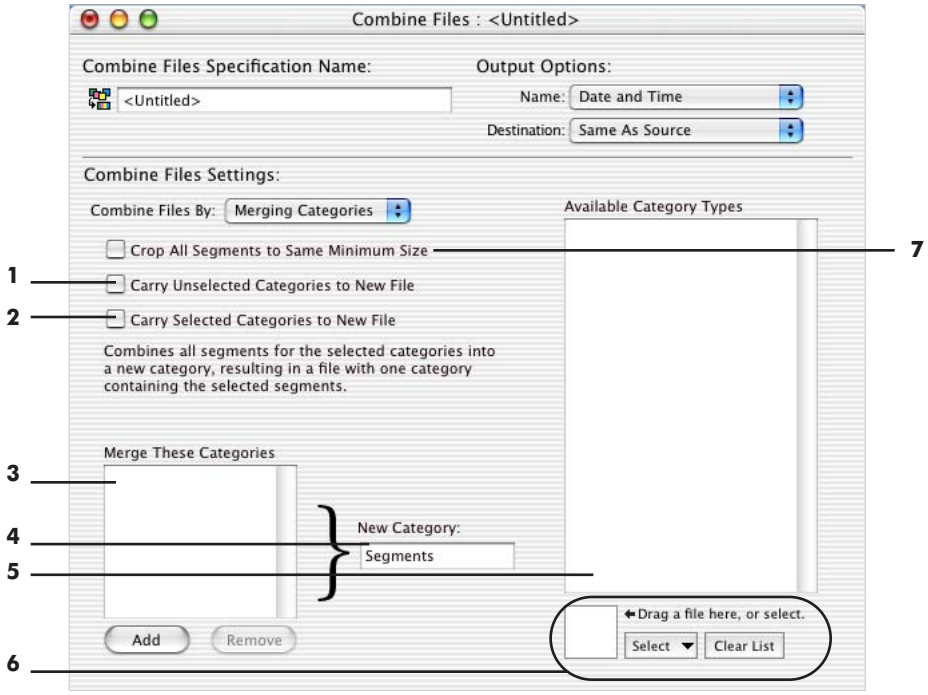


Figure 8-5. Combine Files editor for Merging Categories

The following are brief descriptions of the numbered items from Figure 8-5.

*1. **Carry Unselected Categories to New File**.* Allows you to specify whether to carry the unselected categories [those *not* in the Merge These Categories pane (3)] to the new file in addition to the new category.

2. Carry Selected Categories to New File. Allows you to specify whether to carry the selected categories [those in the Merge These Categories pane (3)] to the new file in addition to the new category.

3. Merge These Categories panel. Allows you to specify the list of categories to merge. You populate this list by dragging categories from the Available Category Types pane (5).

4. New Category text box. Allows you to specify the name of the new category.

5. Available Category Types pane. Displays a list of categories. You populate this list by using the file selector (6) to select one or more Net Station files. The categories are extracted from the file(s) you select. To specify the categories to be extracted, drag categories from this list to the Merge These Categories pane (3).

6. File selector. Lets you select files for the purpose of populating the Available Category Types pane (5). For more information, see "The File Selector and Associated Display Panes" on page 46.

7. Crop All Segments to Same Minimum Size checkbox. When this checkbox is selected, all segments and epochs are cropped from the end until they are the same length as the shortest segment or epoch.

chapter 9

DIFFERENCE WAVE

Concepts

The Difference Wave tool is designed to operate on Net Station segmented or Combination file. The results are output to a file that has the same format as the input file.

The tool is based on the subtractive method, which is a common technique in psychological research. 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 entirely easy. *You should always 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 one or more unique ERP components. 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.

The Difference Wave tool creates new output categories that are the difference between input categories that you specify. If there is more than one segment in each category, then each segment is subtracted. If categories are of different lengths (for example, segment number and size), then the tool skips that category and issues a warning that a problem has occurred. Both segmented and unsegmented files are processed similarly.

You can choose from two options for the output file. The output file may consist of only the output categories, or it may consist of all the categories from the input file *and* the output categories.

Difference Wave Specification Editor

Figure 9-1 shows the Difference Wave specification editor.

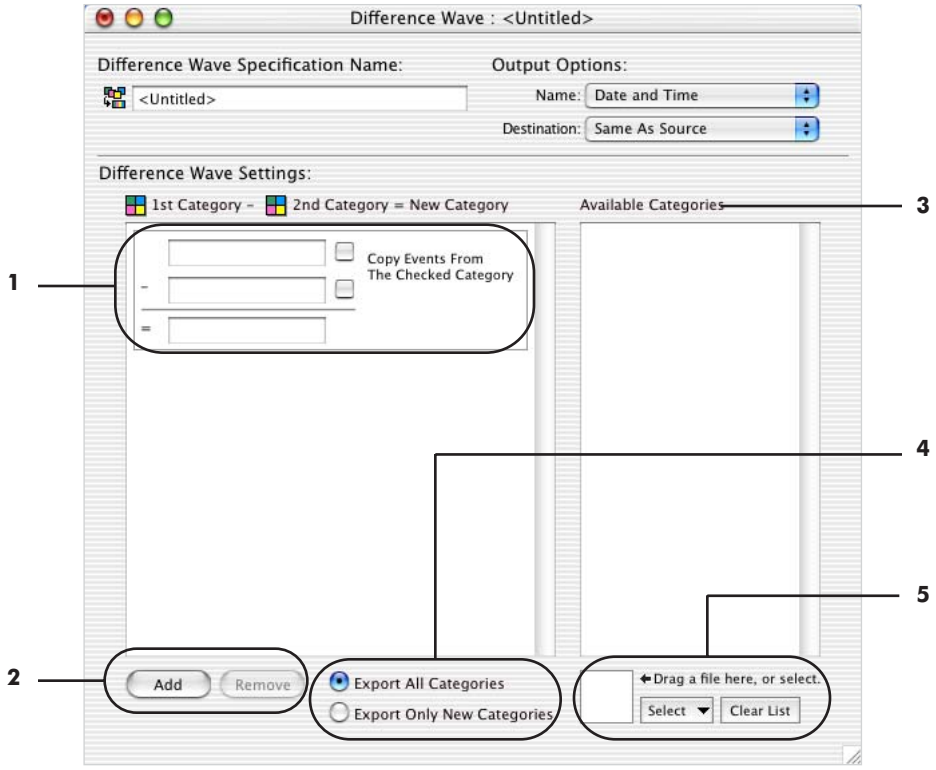


Figure 9-1. Difference Wave specification editor

The following are brief descriptions of the numbered items from Figure 9-1.

1. Subtraction specification. Allows you to specify the parameters for a single subtraction. You specify the two input categories (minuend and subtrahend) by either typing their names into the text fields or dragging them from the Available Categories pane (3). You specify the output category by typing its name into the output category

text field (to the right of the "="). The checkboxes by the input category text fields give you the option of copying the events from an input category to the output category.

2. Add/Remove buttons. Allow you to add and remove Subtraction specifications. Note that, if necessary, the scroll bar to the right of the Subtraction specification becomes active.

3. Available Categories pane. Contains a list of categories. You populate this list by using the file selector (5) to select one or more Net Station files. The categories are extracted from the file(s) you select. To specify the input categories for the subtraction, drag categories from this list to the input category text fields of a Subtraction specification.

4. Output file buttons. Let you choose to create an output file that consists of either the new output categories only or all the categories from the input file *and* the output categories.

5. File selector. Lets you select files for the purpose of populating the Available Categories pane (3). For more information on the file selector, see "The File Selector and Associated Display Panes" on page 46.

chapter 10

EVENT EXPORT

Concepts

The Event Export tool is designed to operate on any Net Station Native file and data selections.

The Event Export tool creates an ASCII file of all the events from the source data. You can use this event file with custom programs or other applications. You also can review the export file as a Microsoft Excel spreadsheet. Event information is displayed in the spreadsheet much as it is in the Net Station Event List. Figure 10-1 shows the Event List for file ATD256.av.ga.bc and the Event Export in Excel for the same file.

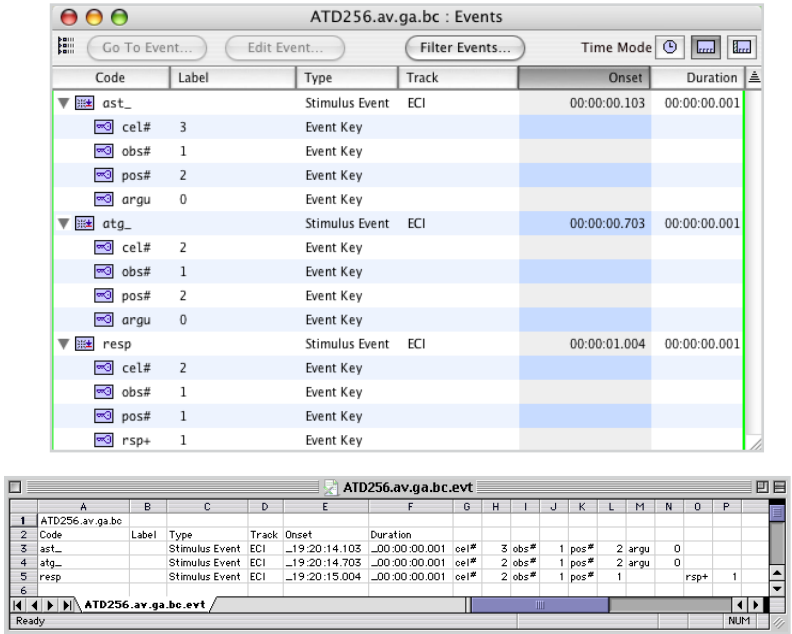


Figure 10-1. Event List of a file in Net Station (top) and an Event Export of that file in Excel (bottom)

The spreadsheet contains the file name in line 1, followed by headers on line 2 for Code, Label, Type, Track, Onset, and Duration. Lines 3, 4, and 5 contain the corresponding event information under each header. The last columns contain Key List information for each event, with the Key Name followed by the Key Value.

Event Export Specification Editor

Figure 10-2 shows the Event Export specification editor.

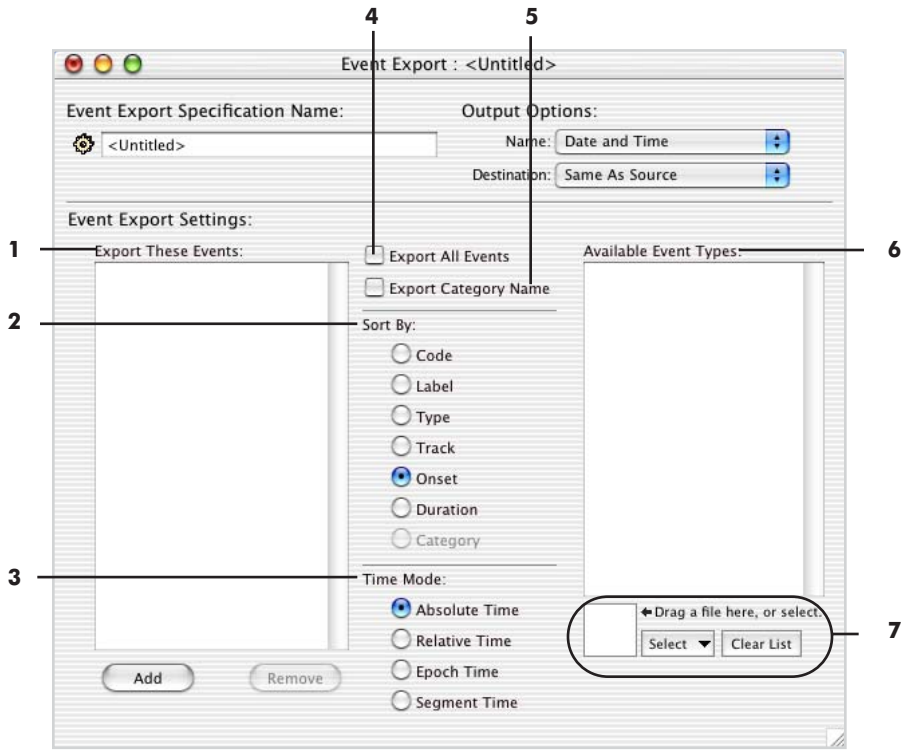


Figure 10-2. Event Export specification editor

The following are brief descriptions of the numbered items from Figure 10-2.

1. Export These Events pane. Exports only the events of the types in the list. To add events to the list:

- Click the Add button and enter the event type.
- Drag one or more event types from the Available Event Types pane (6).

2. *Sort By radio buttons*. Determine the order of the events in the output file. You can sort events by the following event fields:

- Code
- Label
- Type
- Track
- Onset
- Duration
- Category [becomes available only when the Export Category Name checkbox (5) is selected]

For more information about the Net Station event data format, see the *Net Station File Formats Technical Manual*.

3. *Time Mode radio buttons*. Determine the type of timestamp for events in the output file.

- *Absolute Time*: system date and time
- *Relative Time*: time relative to the first sample of the recording
- *Epoch Time*: time relative to the first sample of the epoch
- *Segment Time*: time relative to the segment's zero point (Segment Time = 0; see page 131 for more information)

4. *Export All Events checkbox*. Exports all events, not just those listed in the Export These Events pane (1).

5. *Export Category Name checkbox*. Includes category names in the exported data file.

6. *Available Event Types pane*. Displays a list of events. You populate this list by using the file selector (7) to select one or more Net Station files. The events are extracted from the file(s) you select. To specify events for export, drag one or more event types to the Export These Events pane (1).

7. *File selector*. Lets you select files for the purpose of populating the Available Event Types pane (6). For more information, see "The File Selector and Associated Display Panes" on page 46.

chapter 11

FILE EXPORT

Concepts

The File Export tool is designed to operate on any file type.

The File Export tool converts Net Station output files to other file formats for use with custom programs or other applications. For more information on the Net Station output file formats, see the *Net Station File Formats Technical Manual*.

Caution!: *When exporting data to text files, Net Station truncates file names longer than 22 characters; if truncated file names are identical, they may overwrite each other.*

File Export Specification Editor

Figure 11-1 shows the File Export specification editor.

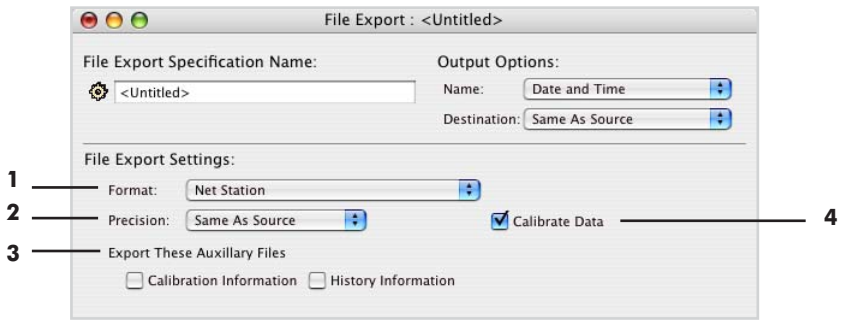


Figure 11-1. File Export specification editor

The File Export specification editor has only one panel, File Export Settings. The following are brief descriptions of the numbered items from Figure 11-1, which are from the File Export Settings panel:

1. Format pop-up menu. Allows you to specify an output format. Table 11-1 describes the supported formats and their associated precision options and checkboxes.

2. Precision pop-up menu. Specifies a precision setting for the exported data. Availability of menu depends on what is chosen in the Format pop-up menu (1).

- *Same As Source*: the precision of the exported data is the same as that of the input data.
- *Integer*: rounds values to the nearest integer; in some cases, scaling is also applied. Files with integer precision are approximately half the size of files with floating-point precision.
- *Floating Point*: does not round values. Files with floating-point precision are approximately twice the size of files with integer precision.

3. Export These Auxiliary Files. If either checkbox is chosen, a text file containing gains and zeros or file history is exported with the output file. Availability of menus depends on what is chosen in the Format pop-up menu (1).

4. Checkboxes. These are different for each selected format. See Table 11-1 for descriptions.

Table 11-1. Formats, precision, and checkboxes

Format	Precision	Checkboxes
Net Station Recording	Available	Calibrate Data
EGIS Session File	Not available	None
Simple Binary File	Available	Export Reference Channel
Simple Binary File (Ignore Events)	Available	Export Reference Channel
Simple Binary File, Epoch Marked	Available	Export Reference Channel
Tab Delimited Text	Not available	Export Only Good Segments
MATLAB MAT-File	Not available but you can choose export array type: Individual Arrays, Cell Array, or 3D Array	Export Only Good Segments Export Events
Persyst File	Not available	Write Event File
EDF+	Not available	None

Formats, Precision, and Checkboxes

Each format selection has a different set of checkboxes available to define further the type of output data to be produced on export. The three precision choices are available for some formats, but not for others. Table 11-1 summarizes the available checkboxes and precision choices for each format.

The following list describes the effects of the various checkboxes on the exported data.

- *Calibrate Data*: converts data from A/D units to microvolts. See the "Gains and Zeros" section in the *Net Station Acquisition Technical Manual*.
- *Export Reference Channel*: For data that have not been rereferenced, this includes the vertex reference channel (containing values of zeros) along with the data channels. (Each Net—except the 32-channel model—has a certain number of data channels, plus one vertex reference channel. For example, the 128-channel Net has 128 data channels, plus one channel for the vertex reference. The 32-channel Net uses the average signal from channels 1 and 2 as the reference.) For data that have been rereferenced, this checkbox is ignored.
- *Export Only Good Segments*: excludes those segments that have been marked bad. (Segments can be marked bad manually or by the Artifact Detection tool.)
- *Export Events*: includes events in the MATLAB .MAT output files.
- *Write Event Files*: creates a Persyst style event file as well as a data file.

For more information on the Net Station output file format, see the *Net Station File Formats Technical Manual*.

chapter 12

FILTERING

Concepts

The Filtering tool is designed to operate on Net Station continuous, segmented, or Combination files and data selections. The results are output to a file that has the same format as the input file.

The Filtering tool enables you to filter out activity in frequencies that are not of interest, using one of three filter types. Each type allows you to filter out frequencies with respect to a specified frequency:

- *Highpass*: attenuates frequencies below the specified frequency, while passing frequencies above the specified frequency.
- *Lowpass*: attenuates frequencies above the specified frequency, while passing frequencies below the specified frequency.
- *Notch*: attenuates frequencies in a narrow band around the specified frequency, while passing frequencies outside the band. The notch filter is primarily used to filter out 50 or 60 Hz line noise. (Typically, line noise is 60 Hz in the United States, and 50 Hz in most other countries; Japan uses either frequency, depending on the region.)

You can further define filtering characteristics with three filter options that apply to all the filters. The following filter options are available (see Figure 12-1).

- *Passband gain*: controls the amount of the signal that the filter retains in the passband (the frequency range in which the signal is to be retained). For example, a passband gain of 0.1 dB results in approximately 98.86% of the signal being retained; a passband gain of 1.0 dB results in approximately 89.13% of the signal being retained.

- *Stopband gain*: controls the amount of the signal that the filter attenuates in the stopband (the frequency range in which the signal is to be attenuated). For example, a stopband gain of 40 dB results in 99% of the signal being attenuated; a stopband gain of 20 dB results in 90% of the signal being attenuated.
- *Rolloff*: controls the frequency range of the transition band (the frequency range in which the filter transitions from retaining the signal to attenuating it). Rolloff is typically measured in Hertz (for example, from 10 to 11 Hz).

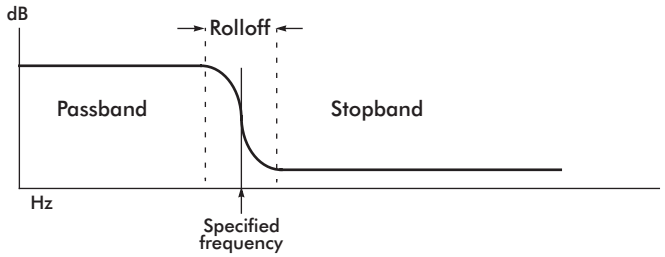


Figure 12-1. Filtering options

FIR versus IIR Filtering

Net Station Viewer 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 near the filter frequency because they lack a linear phase response (they shift the data).

When you save your data with your filter settings applied, Net Station Viewer 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. The Waveform Tools Filtering tool uses an FIR filter.

The IIR filter used by Net Station Viewer is of the *elliptic* type. The FIR filter used by Net Station Viewer and the Filtering Waveform Tool is of the *Kaiser* type. Consult the following references for more information on filter types:

- Embree, P.M, & Danieli, D. (1999). *C++ algorithms for digital signal processing*. Upper Saddle River, New Jersey: Prentice Hall.
- Oppenheim, A.V., & Schafer, R.W. (1975). *Digital signal processing*. Upper Saddle River, New Jersey: Prentice Hall.
- Rabiner, R., & Gold, B. (1975). *Theory and application of digital signal processing*. Upper Saddle River, New Jersey: Prentice Hall.
- Thede, L. (1996). *Analog and digital filter design using C*. Upper Saddle River, New Jersey: Prentice Hall.

Flattening

FIR filters flatten the first section of data, so filtering should usually be performed on continuous files before segmentation. The flattening can be seen in the preview window. The amount of flattening is a function of the sampling rate; in general, it tends to be about 600 ms at each end.

Filtering Specification Editor

Figure 12-2 shows the Filtering specification editor.

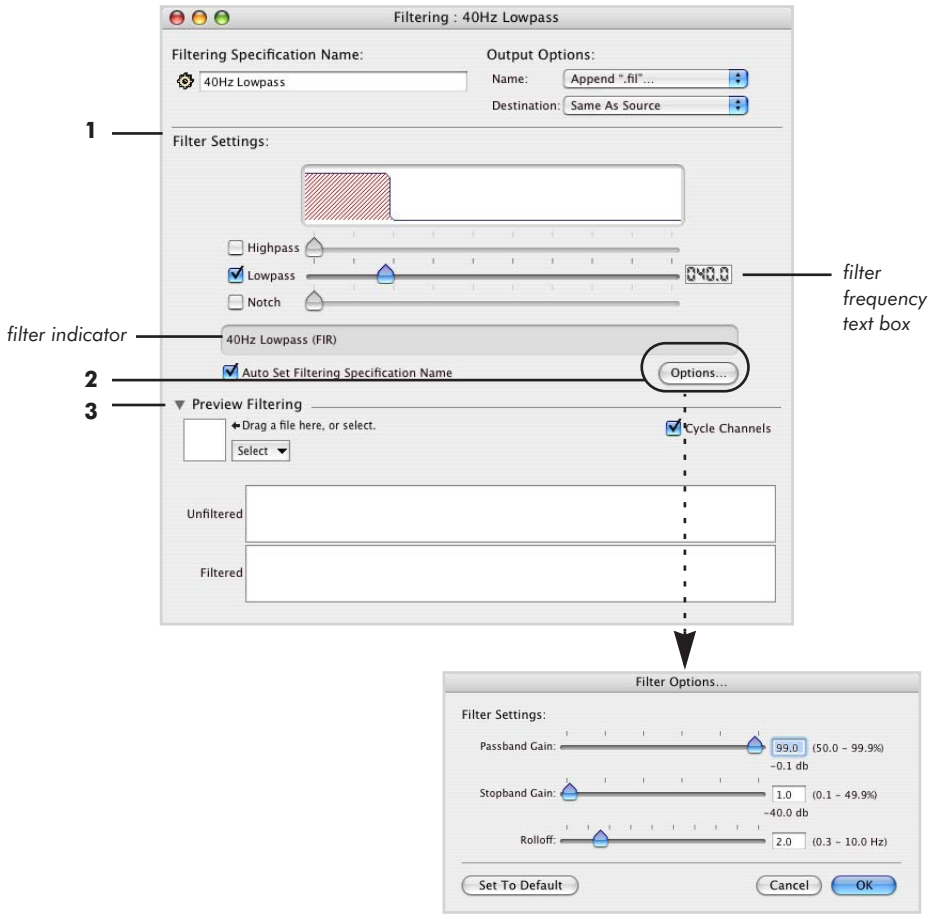


Figure 12-2. Filtering specification editor

The following are brief descriptions of the numbered items from Figure 12-2.

1. Filter Settings pane. Controls the type and specified frequency of the filter. You can select one or more of three filter types: highpass, lowpass, and notch.

Some notes:

- Each filter has a *filter type checkbox* and a *slider bar*: select the checkbox to activate the slider bar for the desired filter. Move the slider bar to specify the desired frequency. When the checkbox is selected, the *filter frequency text box*—a numerical input box—appears to the right of the slider bars and displays the specified frequency. You can also specify a frequency by typing a value directly into the filter frequency text box. The graphical display above the slider bars shows the contour of the filter band. The space below the sliders is the *filter indicator*, which displays the type of filter chosen.
- *Auto Set Name checkbox*: when this checkbox is selected, the specification name is automatically set to match the current filter setting. For example, Figure 12-2 shows a 40 Hz lowpass filter, so the name is *40Hz Lowpass*.
- If you set a notch filter with a specified frequency that falls within the stopband of another filter type, the panel displays a warning icon (see Figure 12-3 on page 102).

2. Options button. Opens the Filter Options window, which controls the shape of the filter band. You can select Passband Gain, Stopband Gain, or Rolloff. The Set To Default button returns the settings in this panel to their default values.

3. Preview Filtering pane (with file selector). Displays the effect the filter will have on a selected file. Two windows display the Unfiltered and Filtered versions of the file. You can select the file using the file selector in the lower-left corner of the pane. For more information about the file selector, see "The File Selector and Associated Display Panes" on page 46.

- *Cycle Channels checkbox*: Select this to automatically display one channel after another in numerical sequence, in the Unfiltered and Filtered windows.

Filter Settings Pane with Warning Icon

Figure 12-3 shows the Filter Settings pane displaying a warning icon. A notch filter has been set up with a specified frequency that falls within the stopband of another filter type. The warning icon indicates the presence of redundant filtering. Click the icon to see an informational message.

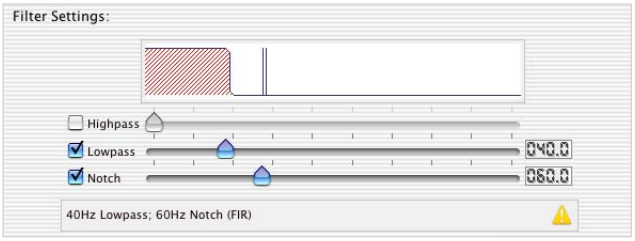


Figure 12-3. Filtering Settings pane, with warning icon displayed

chapter 13

MARKUP FROM FILE

Concepts

The Markup from File tool is designed to operate on any Net Station Native file.

The Markup from File tool does not produce an output file; it modifies the current input file. Specifically, the tool enables you to:

- separate the EEG data from the mark-up events in a Net Station file;
- modify either the data or the mark-up events or both outside of Net Station; and then
- recombine them into the Net Station file.

Markup from File also permits you to create an ASCII text file that adds mark-up events to a Net Station file or that marks good or bad channels or segments.

Caution!: *Because the Markup from File tool* ***modifies*** *the file it is run on, run the tool only on the file associated with those specific mark-up events or on a copy of the file.*

Note: A tool clipping of the Markup from File specification cannot be successfully made and shared. Markup from File derives its tool-specific parameters from a file that is selected in the tool specification editor by the user. Copying the tool clipping from one computer to another breaks the file path.

Event File Formats

To add mark-up events to a Net Station EEG file using the Markup from File tool, the mark-up events must be in one of three file formats:

- Event Export
- Persyst CSV
- Markup from File format

*Note: When you apply a Markup from File tool to a Net Station file, the **time formats of the data and mark-up events must be the same**. If the time formats are different, you may receive the following error message in the tool's Results pane: "There were events that were not on sample boundaries."*

Event Export

An Event Export file is an ASCII text file of all the mark-up events from your data; it is created by using the Event Export tool, which is described in Chapter 10.

For Markup from File, the events must be exported in either **Relative or Epoch Time**.

Persyst CSV

A Persyst CSV file is a comma-separated value format. The general CSV file format is used to exchange data between disparate applications. Each record is a line, and each field is separated by a comma. Please consult Persyst's documentation for information about the manufacturer's version of this format.

For Markup from File, the time format for the mark-up events must be in milliseconds since the beginning of the recording (for example, `61000` is 1 minute and 1 second from the start of the recording or 0:01:01.000).

Markup from File Format

The Markup from File format is tab-delimited and requires that you create an ASCII text file and write your own code to perform any or all of the following three functions:

- Add mark-up events to a Net Station file based on the results of a separate event-generating program, such as an eye-tracker.
- Add mark-up events to a Net Station file that indicate good or bad channels.
- Add mark-up events to a Net Station file that indicate good or bad segments.

For Markup from File, the time format for the mark-up events must be in milliseconds since the beginning of the recording (for example, `61000` is 1 minute and 1 second from the start of the recording or 0:01:01.000).

The following sections describe the required coding conventions for this format:

- Angle brackets `<xxx>` are employed to indicate user-entered information.
- The angle brackets themselves should **not** be included in the code.
- If an item in the following sections is not enclosed by angle brackets, then it is mandatory.

Adding Events

To add a mark-up event, your code should contain a line that includes:

- the time of the event (in milliseconds since the beginning of the recording),
- a tab space, and
- the four-character code of the event.

Table 13-1. Codes for adding events in the Markup from File format

Task	Code	Example
Add a mark-up event at a specific timepoint, in milliseconds since the start of the recording.	`<time>  <4-character code>`	`6000  eyeb` marks an eye blink 1 minute from the start of the recording

Marking Channels Good or Bad

The commands in Table 13-2 are presented in order of increasing specificity: from marking a channel (or all channels) good or bad *throughout an entire recording*, to marking a channel (or all channels) good or bad for *a particular category and segment*.

Table 13-2. Codes for marking channels in the Markup from File format

Task	Code	Example
Mark a channel good or bad in all categories and segments.	`channel <good or bad> <channel number or all>`	`channel bad 59` marks channel 59 bad in all categories and segments; `channel bad all` marks all channels bad in all categories and segments
Mark a channel good or bad in a particular category and in all segments in that category.	`channel <good or bad> <channel number or all> {<CategoryName>}`	`channel bad 59 {Target}` marks channel 59 bad in the Target category for all segments
Mark a channel good or bad in a particular category and segment.	`channel <good or bad> <channel number or all> {<CategoryName>} <segment number or all>`	`channel bad 59 {Target} 5` marks channel 59 bad in the Target category for segment 5

Marking Segments Good or Bad

The commands in Table 13-3 enable you to mark segments good or bad. Notice that the format is designed to be more amenable to marking segments good, rather than bad, to minimize the effects of an incorrectly coded command.

Table 13-3. Codes for marking segments in the Markup from File format

Description	Code	Example
Mark all segments good —and only good—for an entire recording.	`segment good`	although `segment good` means that no segment is bad, note that `segment bad` will **not work** because a recording with all bad segments is unusable
Mark all segments good—and only good—for a particular category.	`segment good {<CategoryName>}`	segment `good {Target}` marks all segments good in the Target category
Mark a segment good or bad in a particular category and a particular segment.	`segment <good or bad> {<CategoryName>} <segment number or all>`	`segment good {Target} 5` marks segment 5 good in the Target category

Application Examples

Figures 13-1, 13-2, 13-3, 13-4, and 13-5 provide examples of using the Markup from File tool to combine modified or externally generated mark-up events with Net Station EEG data. The tool also permits you to replace the existing mark-up events in the Net Station file, if desired.

Note: To replace Net Station mark-up events with modified or externally generated mark-up events, select the "Overwrite" checkbox in the Markup from File tool (described on page 113) and type in the name of the mark-up event track to overwrite, in the Track Name text box. If the checkbox is unselected, the tool creates a new track entitled "Markup Track" in the Net Station file.

Figure 13-1 contains an example of:

- modifying Net Station mark-up events outside of Net Station and
- combining them with the original Net Station EEG data.

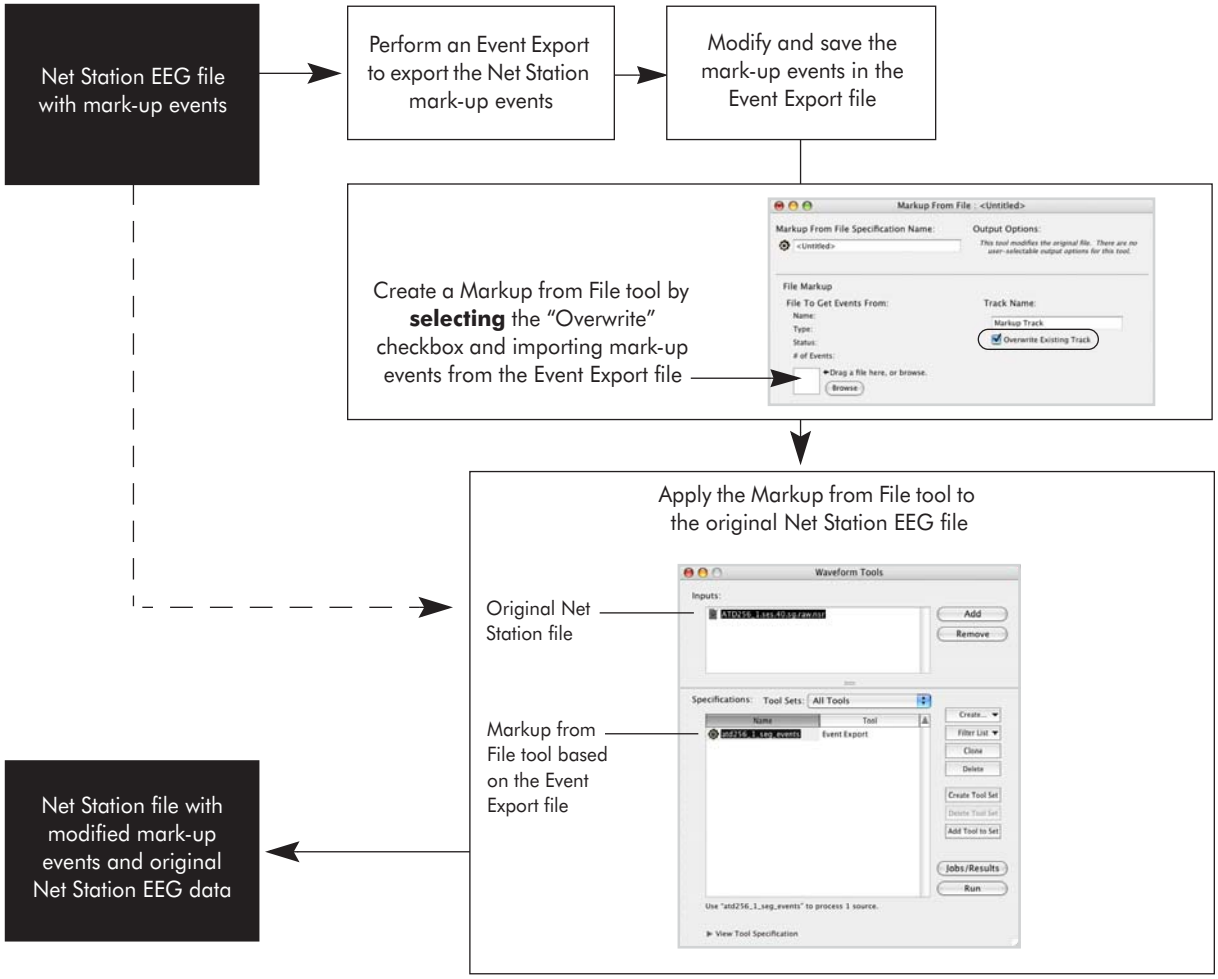


Figure 13-1. Diagram of combining modified mark-up events with Net Station EEG data

Figure 13-2 contains an example of:

- adding externally generated mark-up events to a Net Station file that contains EEG data and mark-up events.

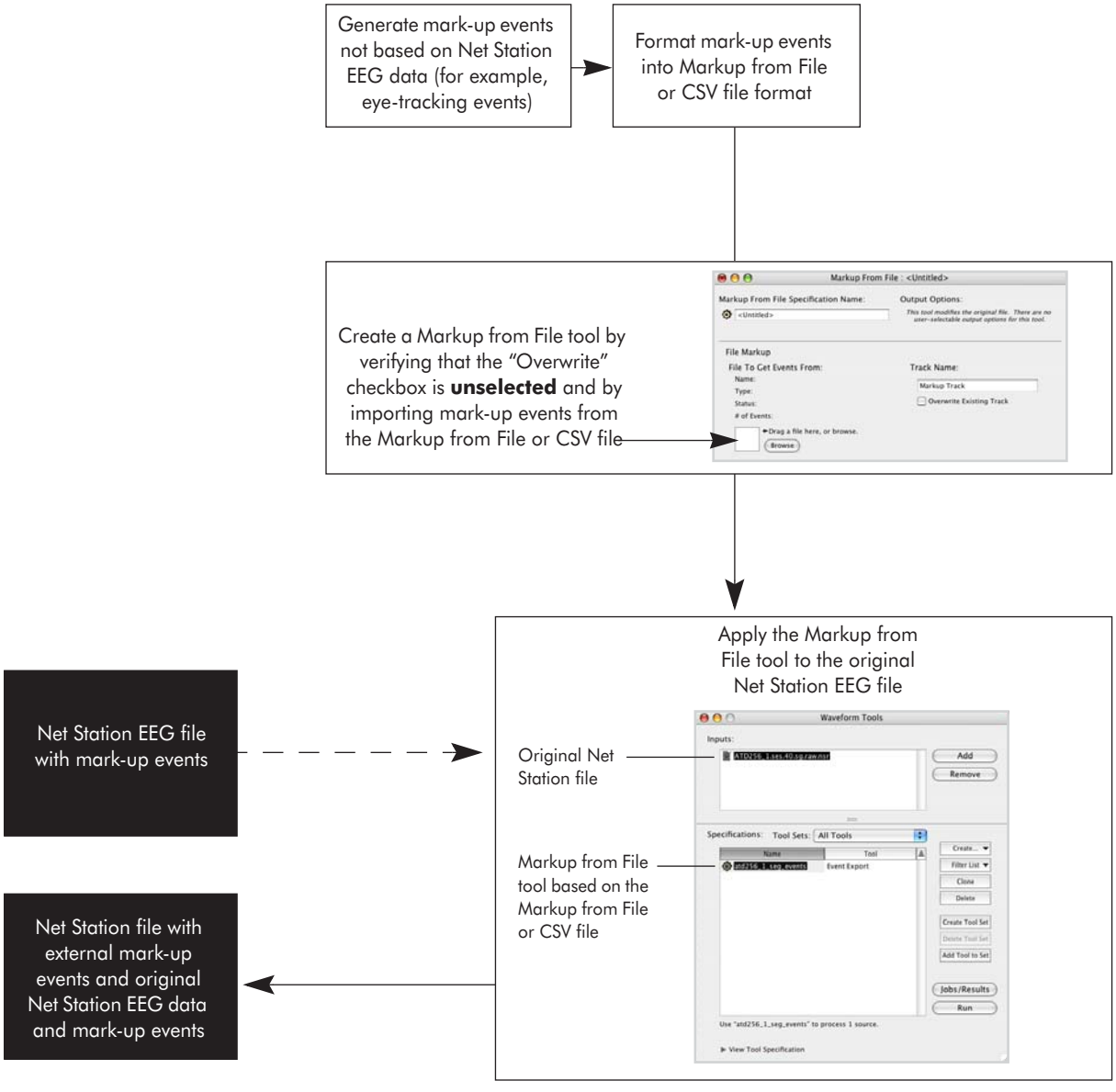


Figure 13-2. Diagram of combining external mark-up events with Net Station EEG data and events

Figure 13-3 contains an example of:

- modifying Net Station EEG data outside of Net Station and
- combining them with the original Net Station mark-up events.

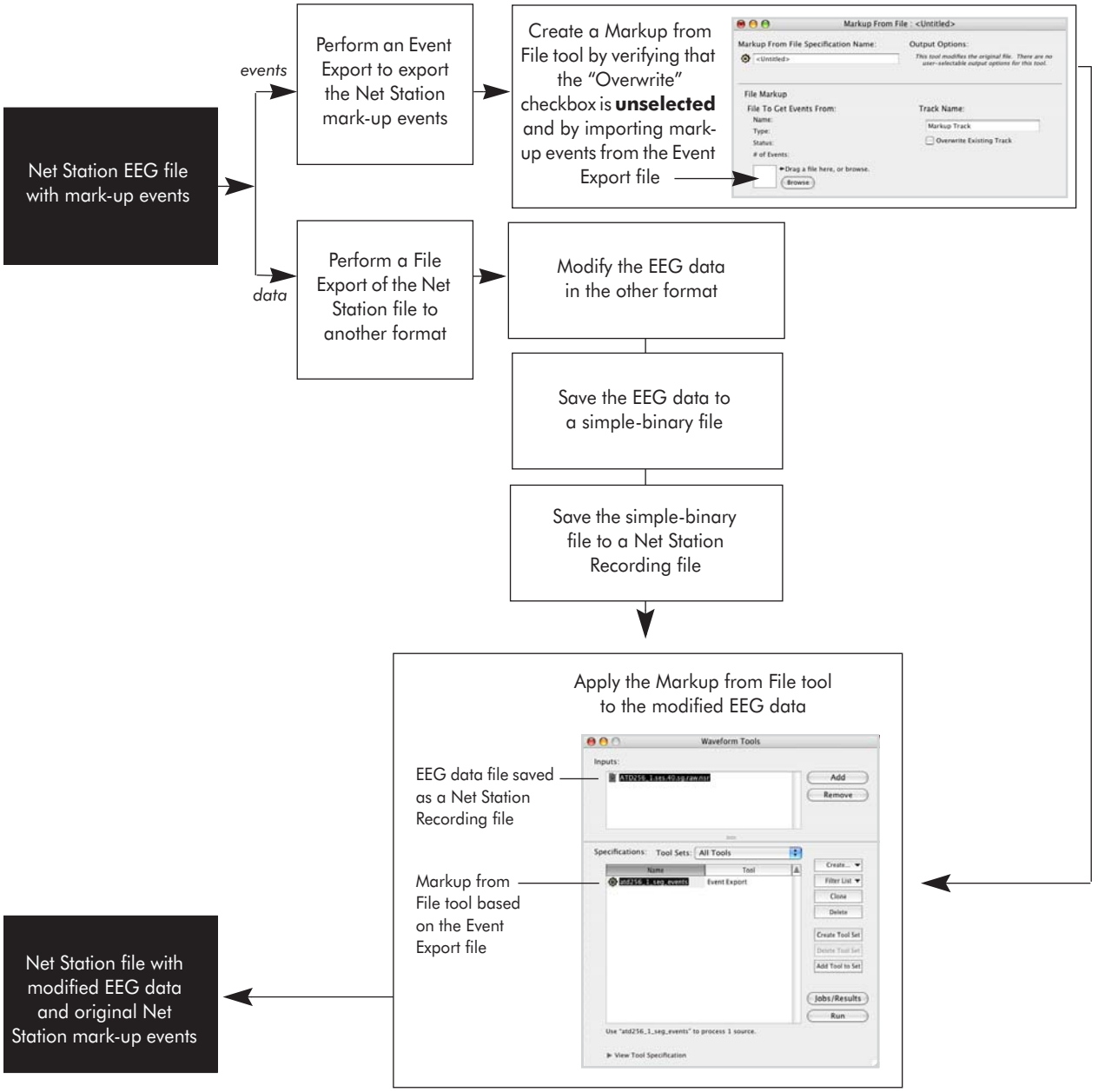


Figure 13-3. Diagram of combining modified EEG data with Net Station events

Figure 13-4 contains an example of:

- externally generating mark-up events based on the Net Station EEG data and
- combining them with the original Net Station EEG data.

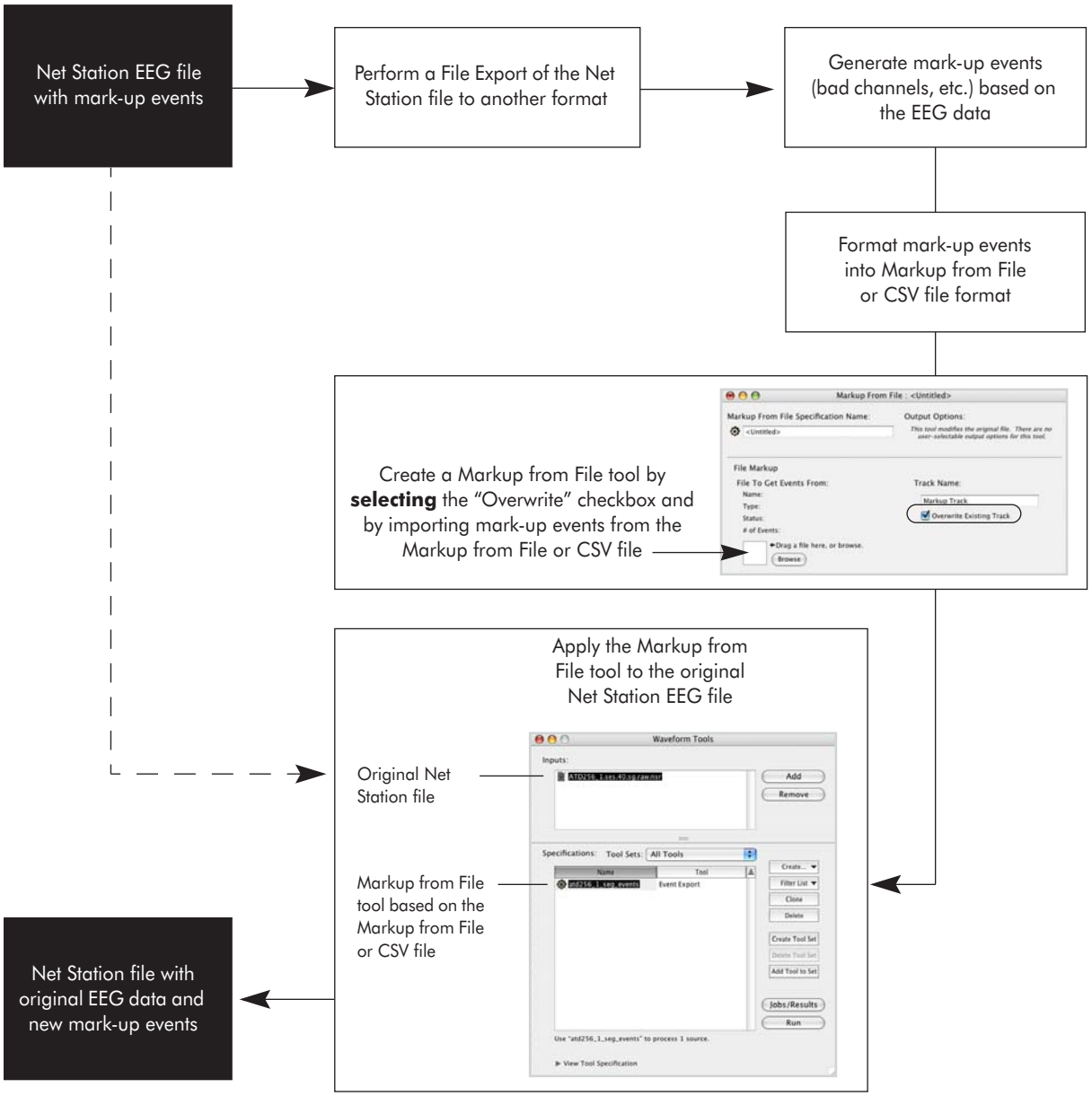


Figure 13-4. Diagram of combining new mark-up events with Net Station data

Figure 13-5 contains an example of:

- modifying Net Station EEG data,
- generating mark-up events based on the modified Net Station EEG data, and
- combining the modified data and mark-up events into a Net Station file.

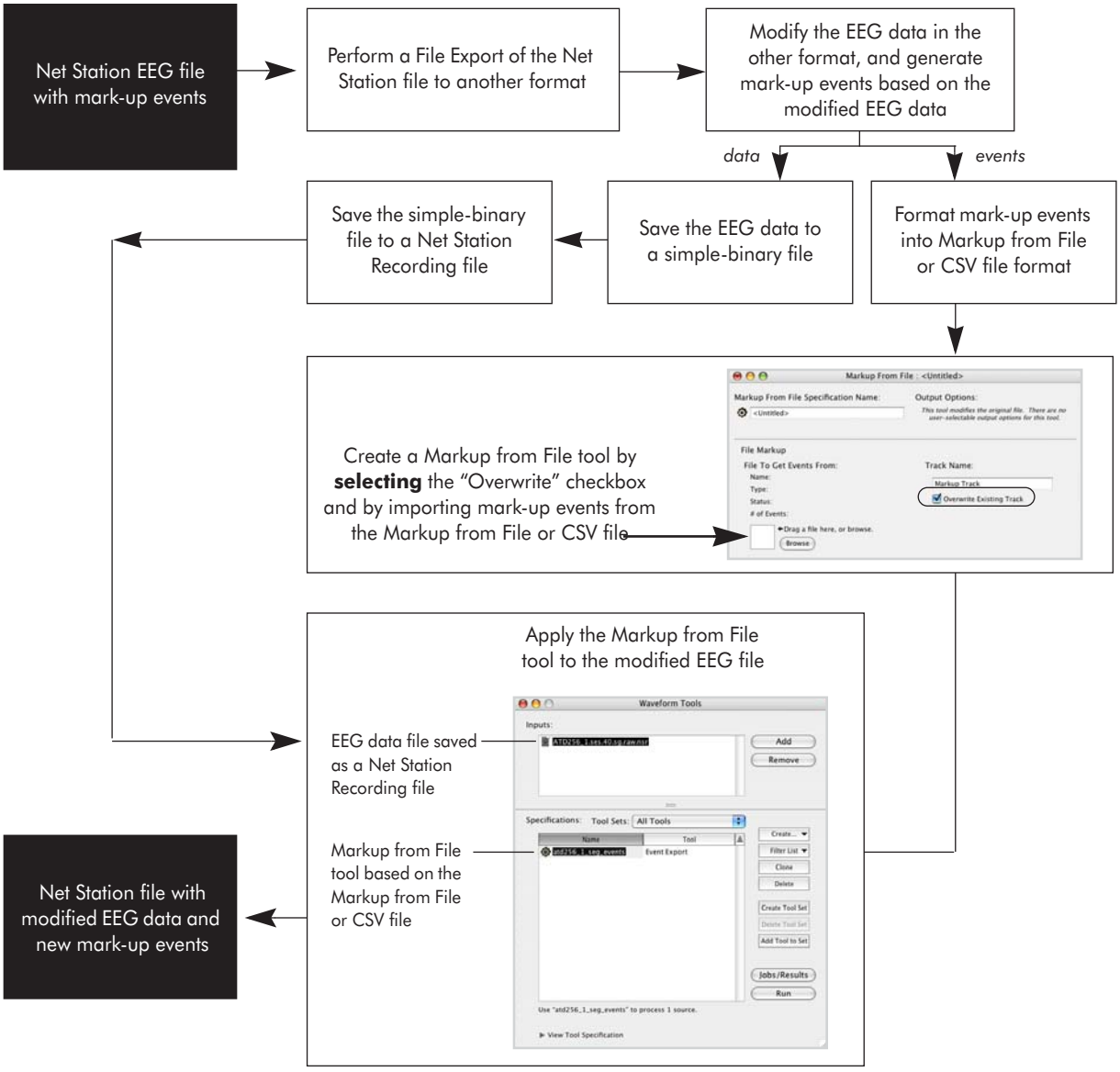


Figure 13-5. Diagram of combining new mark-up events with modified EEG data

Markup from File Specification Editor

Figure 13-6 shows the Markup from File specification editor.

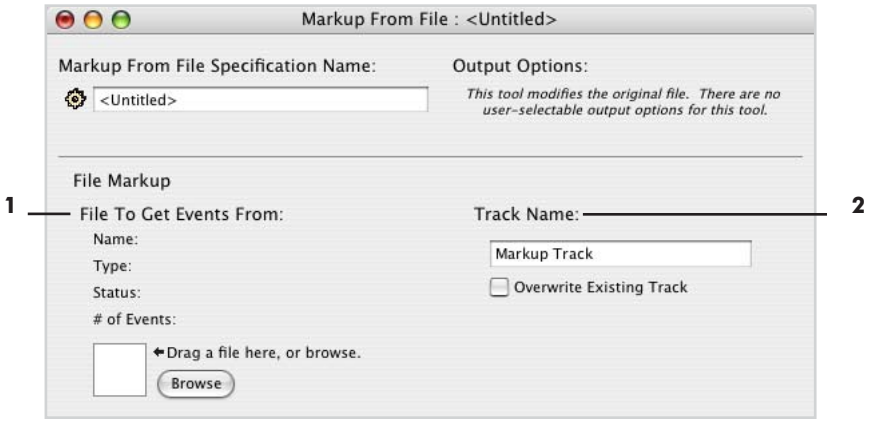


Figure 13-6. Markup from File specification editor

The following are brief descriptions of the numbered items from Figure 13-6. (Note that the Markup from File specification editor does not have an Output Options panel because the tool does not create an output file; it adds markings to the input file.)

1. File to Get Events From. This is the file with mark-up events that you wish to import into Net Station. The file must be in one of the three mark-up formats described on page 104: Event Export, Persyst CSV, or Markup from File. When you use the file selector to choose the file, the tool automatically extracts the following information:

- *Name*: file name
- *Type*: Event Export, Persyst CSV, or Markup from File format
- Status: "no errors" or an error message
- *# of Events*: the number of events in the file

2. ***Track Name***. In this text box, you can type in the name for the mark-up event track produced by the Markup from File tool. Under the Track Name text box is this checkbox:

- *Overwrite Existing Track checkbox*: If selected, the tool will replace an existing mark-up event track in the Net Station file with the event track imported by the Markup from File tool, *if the tracks have the same name*. If unselected, the tool will create a track entitled "Markup Track" for the mark-up events imported by the Markup from File tool.

chapter 14

MONTAGE OPERATIONS

Concepts

The Montage Operations tool is designed to operate on Net Station Native, EGIS, or simple-binary continuous, segmented, or Combination files and data selections.

A *montage* consists of a reference specification and subset of channels. When you run The Montage Operations tool, the resulting file is modified in the following ways:

- The data are rereferenced.
- If the specified set of channels is less than the set of channels in the input file, the data are downsampled. In other words, only data for the specified set of channels are included in the output file.
- The new montage is displayed in the Viewer montage track, as well as in the Tracks tab of the File Info dialog. The list of available montages in the Viewer Montage menu and the Montage pop-up menu in the data-display control strip will include only those choices that apply to the new montage.

What follows is a discussion of issues related to rereferencing.

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 (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 don't make the preceding assumption, the surface integral will be zero because of the conservation of charge inside an electrically neutral body.

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 (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 (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*, 110, 1149–1155.

In ERP derivation, you use Montage Operations to rereference your data. You can rereference your data to any channel or to the average of any set of channels. Average referencing means rereferencing your data to the average of all the channels. When you average reference your data using the Montage Operations tool, you have the option of using a PARE-corrected average reference.

In general, EGI recommends doing an average reference or a PARE-corrected average reference. However, if you intend to compare your data with the data of another researcher, then for the purpose of the comparison you should use the same reference as the other researcher.

Montage Operations Specification Editor

Figure 14-1 shows the Montage Operations specification editor.

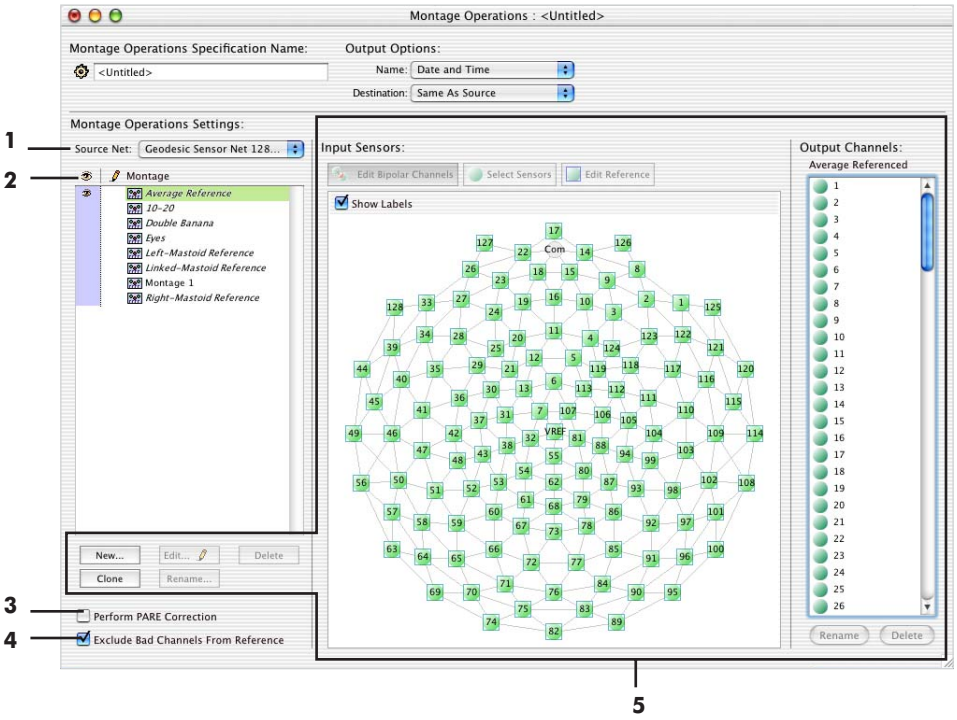


Figure 14-1. Montage Operations specification editor

The following are brief descriptions of the numbered items from Figure 14-1.

*1. **Source Net pop-up menu**.* Lists the EGI source Nets. Select the Net with which you recorded your data to view a list of its available montages in the Montage list (2).

2. Montage list. Lists the available montages for the Net selected in the Source Net pop-up menu (1).

3. Perform PARE Correction checkbox. Is available only if there is an average reference, in which case a PARE-corrected average reference is computed from the entire surface of the head.

4. Exclude Bad Channels From Reference checkbox. Excludes any bad channels that are specified as references in the montage, if you are performing average referencing. If this checkbox is unselected and bad channels are found, a warning is generated.

However, if this checkbox is unselected during multichannel rereferencing, bad channels are not automatically excluded; instead, an error message will notify you that "there were bad channels in the re-referencing group." If the checkbox is unselected and bad channels are found, a warning is generated.

5. Montage editor. This built-in montage editor allows you to edit the available montages or create new ones. The editor has the same features and functions as the Net Station Montage Editor in the Viewer, and the two are linked (for more information on the Net Station Montage Editor, see the *Net Station Viewer Technical Manual*).

Montages created in both the Viewer Montage Editor and the Waveform Tools Montage Operations specification editor are available for use in either interface, and changes made to montages in either are persistent.

Note: It is important to remember that the Montage Editor in the Viewer is for display purposes only and does not alter the file, while the Montage Operations tool in the Waveform Tools outputs a new file with the chosen montage, even if the file has only been rereferenced.

Note: Important—On acquisition, the data are referenced to the VREF (vertex) channel. The Montage Editor was originally designed for use with nonrereferenced data. Therefore, in the Montage Editor, "Vertex Referenced" means no rereferencing. One effect of this is that data that have been rereferenced with the Montage Operations Waveform Tool cannot be rereferenced to the vertex.

chapter 15

Ocular Artifact Removal

Concepts

Ocular Artifact Removal (OAR) is designed to operate on Net Station, EGIS, or simple-binary segmented files recorded with 64-, 128-, or 256-channel GSNs. The results are output to a Net Station segmented file.

OAR corrects your data by detecting and removing eye blinks and eye movements, allowing you to retain more of your recording.

For information about where to use OAR in the data-analysis process, see page 29, which recommends running Artifact Detection and Bad Channel Replacement both *before* and *after* running OAR on your data.

If you do not replace bad channels with values greater than 2,047.0375 µV *before* running OAR, OAR cannot operate on your data and you will receive an error message. Page 29 describes the reasons for running Artifact Detection and Bad Channel Replacement *after* OAR.

OAR Background

OAR is based on the eye movement correction procedure (EMCP) developed at the University of Illinois Cognitive Psychophysiology Laboratory and described in:

- Gratton, G., Coles, M.G.H., & Donchin, E. (1983). A new method for off-line removal of ocular artifacts. *Electroencephalography and Clinical Neurophysiology, 55*, 468–484.
- Miller, G.A., Gratton, G., & Yee, C.M. (1988). Generalized implementation of an eye movement correction procedure. *Psychophysiology, 25*, 241–243.

The OAR version of the EMCP algorithm is based on EMCPX, which was written by James Turner, in 1993. Subsequent modifications were made by Brian Foote, Kevin Spencer, and Bill Gehring.

For further information about the algorithm coding and parameters, please see the following documents, which are available from the University of Michigan's Human Brain Electrophysiology Laboratory website:

- Gehring, W.M. & Foote, B. (1996). EMCP.doc. In emcp2001.zip. Retrieved from http://www-personal.umich.edu/~wgehring/software.html.
- Miller, G.A. (1988). EMF11P.txt. (In emcp2001.zip; see preceding bulleted item for URL.)

OAR Overview

Studies have shown that eye blinks and eye movements affect EEG data differently. Therefore, the EMCP—and hence the OAR—algorithm separates eye blinks from eye movements so that it can compute and apply different correction factors.

The following procedure is used:

- *to detect and mark eye blinks*: the algorithm runs through the entire waveform of the eye-blink channel (see Table 15-1) to detect and mark as *eye blinks* instances in which the slope of the waveform exceeds the Blink Slope Threshold (described on page 122);
- *to differentiate between eye blinks and eye movements*: if a data sample is not part of an eye blink, the algorithm considers it to be an *eye movement* (thus, in regards to correction factors, every sample is considered either part of an eye blink or an eye movement);
- *to determine the correction factors for eye blinks*: the algorithm uses a time-domain regression technique that determines the correlation between the eye-blink data of the *eye-blink channel* and the data for the corresponding time intervals on each of the other EEG channels except eye channels;
- *to determine the correction factors for eye movements*: the algorithm uses a time-domain regression technique that determines the correlation between the eye-movement data of the *eye-movement channel* (see Table 15-1) and the data for the corresponding time intervals on each of the other EEG channels except eye channels; and

- *to remove ocular artifacts from the EEG data*: the algorithm applies the scaled and separate eye-blink and eye-movement correction factors to each EEG channel (notice that the correction factors decrease in size as the channels increase in distance from the eyes).

The ocular artifact detection and removal functions do not apply to the eye-blink or eye-movement channels. If the "Flatten Eye Channels" checkbox in the OAR specification editor (see page 123) is unchecked, the eye channels will remain unchanged, with no corrections applied. If the checkbox is selected, the eye channels will be flattened.

Eye Channels

The OAR algorithm uses the data from two separate eye channels: the eye-blink channel above the *right* eye, and the eye-movement channel to the outside of the *right* eye (see Table 15-1). If a right eye channel is good in some segments and bad in others, the algorithm will still use the data from the *right* eye channel.

Note: OAR cannot operate on 32-channel data.

Table 15-1. Right eye-blink and eye-movement channels for each GSN model

GSN model	Right eye-blink channel	Right eye-movement channel
64-channel HCGSN	5	61
128-channel HCGSN	8	125
256-channel HCGSN	18	226
64-channel GSN 200	1	60
128-channel GSN 200	8	125
256-channel GSN 200	18	227

However, if a right eye channel is bad for the entire recording or is missing (because of subsampling for a montage), the algorithm will use data from the corresponding *left* eye channel (see Table 15-2). If the left eye channel is bad or missing, OAR cannot operate on your data and you will receive an error message.

Table 15-2. Left eye-blink and eye-movement channels for each GSN model

GSN model	Left eye-blink channel	Left eye-movement channel
64-channel HCGSN	10	64
128-channel HCGSN	25	128
256-channel HCGSN	37	252
64-channel GSN 200	14	19
128-channel GSN 200	26	128
256-channel GSN 200	36	251

Blink Slope Threshold

The Blink Slope Threshold is the slope of the eye-blink channel, in microvolts per millisecond, at selected datapoints. The algorithm uses the slope to compute a criterion that determines whether the eye-blink channel's activity should be classified as an eye blink or an eye movement.

The default for the Blink Slope Threshold is 14 μV/ms and is based on a value used in EMCP.doc and EMF11P.txt (see page 120 for the citations). In those documents, slope is derived by multiplying 14 by the "EOG sensitivity," which is the sensitivity of the eye-blink channel in A/D units per microvolt. According to EMF11P.txt, the value of "14" was chosen because it is arithmetically equivalent to the original algorithm developers' formula for one dataset. The Ocular Artifact Removal specification editor (described in the next section) gives you the option of changing this value.

The value of "14" was specific to the conditions at the developers' lab. It is possible that you will need to use a Blink Slope Threshold value other than 14, so that it applies to your own environmental conditions. Although we cannot provide specific guidelines for setting this value, we do suggest that you find the optimal value through an iterative process of running the tool on your data, inspecting the results, and changing the value, if necessary.

Ocular Artifact Removal Specification Editor

Figure 15-1 shows the Ocular Artifact Removal specification editor.

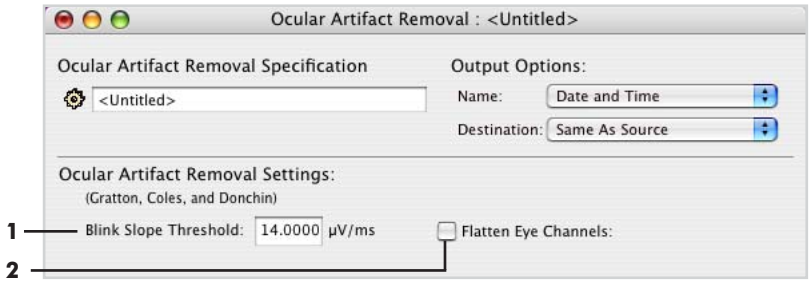


Figure 15-1. Ocular Artifact Removal specification editor

The following are brief descriptions of the numbered items from Figure 15-1.

1. Blink Slope Threshold text box. Allows you to type in a value for determining whether an eye blink has occurred on the eye-blink channel. For more information, see the "Blink Slope Threshold" section on page 122.

2. Flatten Eye Channels checkboxes. When this checkbox is selected, the algorithm flattens the eye channels after correcting for ocular artifacts. The flattened channels ensure that they will be marked "bad" if you run the Artifact Detection tool on the file after running OAR, as suggested on page 29. The data are unusable because the algorithm uses data from these channels to remove the ocular artifacts from all other channels. Therefore, the eye channels cannot be corrected.

Caution!: *If you leave the "Flatten Eye Channels" checkbox unselected, then you should manually mark the eye channels as "bad," to ensure that they are excluded from future operations.*

chapter 16

SCRIPT

Concepts

The Script tool is a special tool that chains tool operations together. It does not operate directly on a Net Station file and does not produce an output file.

The Script tool enables you to automate your data analysis, once you are satisfied with your data-analysis path (which tools to use, in which order, with which parameters). Script is similar to the other tools in that you use the Waveform Tools window to launch the Script specification editor and run the script.

A script runs each tool in the order you specify. For most tools, this results in the output of the first tool being processed by the second tool, then the output of the second tool being processed by the third tool, and so forth. Exceptions are the Averaging tool, when set to handle source files together, and the Combine Files tool. These tools can take multiple input files and generate a single output file. In a script, these tools accumulate all of the input files first and then generate the output file.

It is possible to specify tools in an incompatible order. For example, if you set up a script to export a file to a format that is not supported for import by Waveform Tools and then try to perform another operation on the file, the Script specification editor generates an error message during the scripting session.

Some tool combinations will be revealed as invalid only when the script is run. For instance, if Segmentation is followed by Averaging, and the Segmentation output happens to contain no segments at all, averaging cannot be done. In this case, Waveform Tools generate an error when you run the script.

Another example is the case where you run a script that runs the Filtering tool followed by the Averaging tool, and continuous data are supplied to the Filtering tool. The Averaging tool will fail because it requires segmented data. This type of error can

be detected only at run time because the Script specification editor cannot know ahead of time what type of data will be supplied.

Script Specification Editor

Figure 16-1 shows the Script specification editor. The Script Settings panel contains the specifications to be run by the script, in the order in which they are to be run.

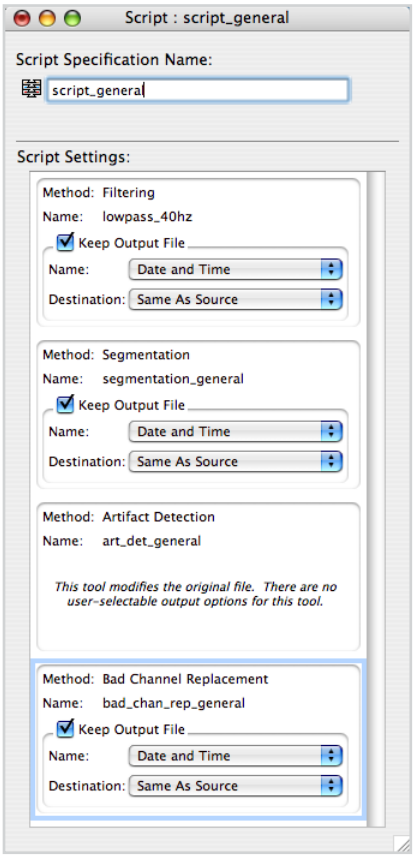


Figure 16-1. Script specification editor

To create scripts, drag the desired tool specifications, one at a time, from the Waveform Tools window to the Script Settings pane of the Script specification editor. You can drag a specification to any location in the Script specification editor,

controlling the order in which it is run. You can also change the order of the specifications in the script by dragging them.

You might be interested in only some of the output files generated by the script. Each specification contains a Keep Output File checkbox. This allows you to keep only the output files of interest. When this checkbox is selected, you can edit the output options of the specification directly from the Script specification editor.

Editing Specifications from within the Script Specification Editor

You can double-click on any specification in the Script Settings pane and launch the appropriate editor to edit the specification. When you close the editor, the Waveform Tools prompt you to specify how you want the changes applied (see Figure 16-2).

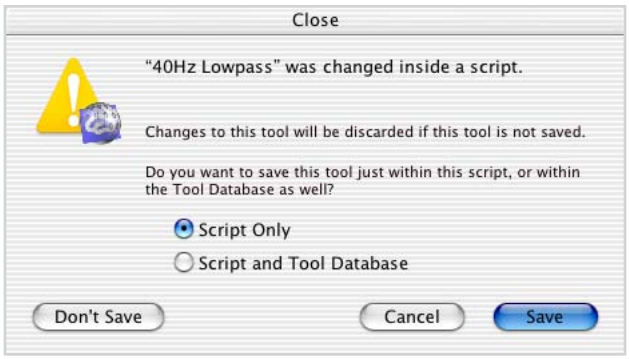


Figure 16-2. Close dialog

You can choose to save your changes two ways:

- *Script Only*: saves only the version of the specification that is part of the script.
- *Script and Tool Database*: saves both the original version of the specification (as it appears in the Waveform Tools window) and the version that is part of the script.

You can also drag changed specifications from a script to the Waveform Tools window. If a specification of the same name already exists, you will be asked if you want to replace the existing one or not.

chapter 17

SEGMENTATION

Concepts

The Segmentation tool is designed to operate on Net Station continuous, segmented, or Combination files. The Segmentation specification editor allows you to specify settings for segmentation or for segmentation markup. For segmentation, the output is a Net Station segmented file (for segmentation markup, the output is the marked-up input file).

In ***segmentation***, you break a continuous recording into event-locked epochs (called *segments*) based on a set of selection rules and user-defined criteria. The purpose of segmentation is to organize your data into categories so that you can average them or perform other operations on them.

In ***segmentation markup***, you place event markers into the source data to locate the segments, but unlike segmentation, you do *not* segment the data or generate an output file. Segmentation markup allows you to extract data from the Net Station key lists to a form suitable for export into other applications that do not support key lists. In most applications, events have only names; they contain no key lists. After segmentation markup, you can perform segmentation in these other applications.

Note: Segmentation markup is also useful for reviewing or diagnosing data without creating a new file.

Using a simple standard/target experiment as an example, in Net Station all the stimulus events might be named *stim*. The distinction between standard and target stimuli cannot be determined from the event name; it can be determined only from the key lists. Segmentation markup allows you to create new events at the appropriate locations, called *targ* and *stnd*. You can segment on these events in other applications.

With segmentation and segmentation markup, *you* define the criteria and the rules. To do this successfully, you must understand how the Segmentation tool works.

Segmentation Overview

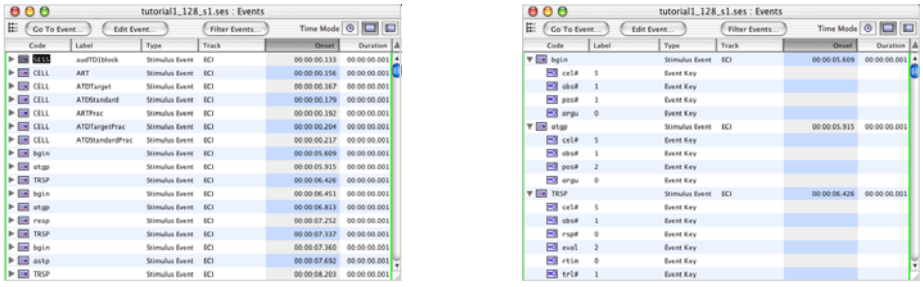
In Segmentation, the key is to define your specification precisely so that only the data of interest are produced. This entails knowing which conditions belong to which events and understanding the concept of *temporal relations*.

This section provides an overview of the segmentation process, with Figure 17-5 illustrating the discussion. (A discussion of the Segmentation specification editor's controls begins on page 139.)

Segmentation Terminology

Following are some fundamental Net Station segmentation terms:

- *Events*: the events in the data, viewable in the Event List (Figure 17-1).



Event List Event elements in one trial

Figure 17-1. Event List

- *Criteria set*: the set of criteria you create in the Segmentation editor's Criteria Sets pane that are based on the events in the data (Figure 17-2). These sets are rules for segmentation, defined by conditions and temporal relations.

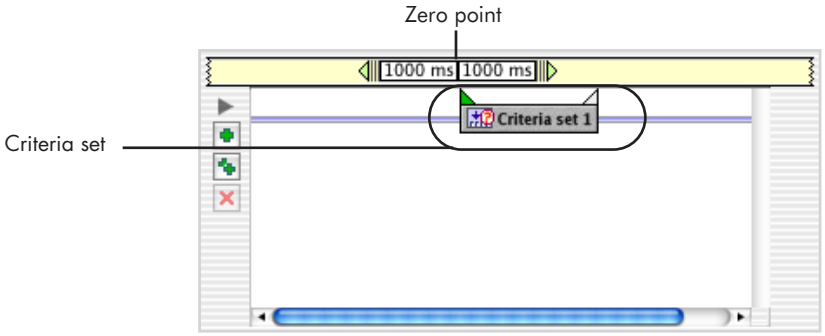


Figure 17-2. Criteria Sets pane

- *Zero point*: the vertical line between the Segment Length text boxes in the Criteria Sets pane's time bar (see Figure 17-2). This represents the segmentation event plus (+) the offset, and is sometimes referred to as t=0 or Segment Time=0.
- *Segmentation event*: the leftmost green event triangle in the Criteria Sets pane. This represents the segment's zero point minus (–) the offset (Figure 17-3). ***The goal of your work in the Segmentation specification editor is to define a segmentation event (or period; see next section) on which to base your segmentation.***

The segmentation event is the zero point minus (–) the offset. In this example, the Segment Length Before text box was selected, which reveals the segment length pane. An offset of 50 milliseconds automatically shifts the segmentation event to the left of the zero point.

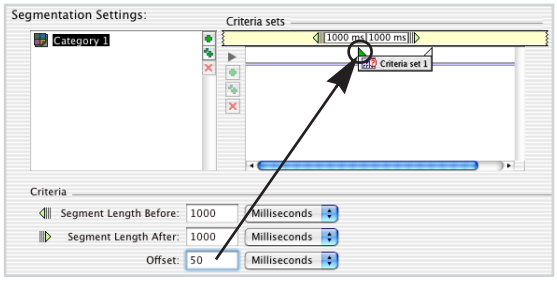


Figure 17-3. Segmentation event

- *Segmentation triangles*: the triangles that sit on top of each criteria set icon in the Criteria Sets pane. Net Station automatically selects the left triangle of the first criteria set (Criteria Set 1 in the pane) as the default segmentation event; you can change the segmentation event by clicking on (thus, selecting) a different segmentation triangle. Selected segmentation triangles are colored green. You can also select a second segmentation triangle, which defines a *period*, rather than a point in time, on which to segment. This is called a *segmentation duration* (Figure 17-4).

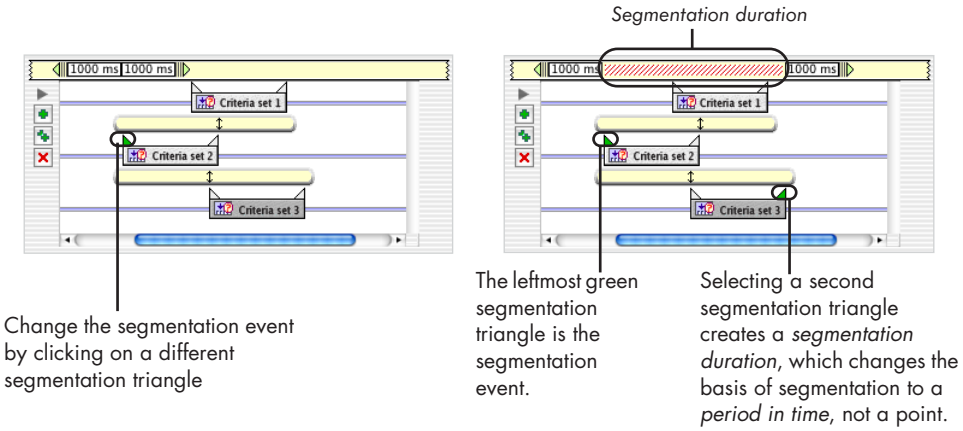


Figure 17-4. Segmentation triangles

Segmentation Process

Segmentation can be simple to understand: you choose an event in the continuous data as a reference and specify the amount of time before and after the event to include in the segment. This is the *segmentation event* and, if it requires only one criteria set for its definition, it can make up a segmentation category.

The process becomes more complicated when you define a category as having more than one criteria set. In this case, you must relate the second criteria set to the first in terms of position and time, called a *temporal relation*. Temporal relations can involve many variables and are discussed in detail on page 134.

In general, the process involves the following:

1. Your experiment should be well designed, isolating the phenomena of interest. This makes it easy to determine on which events you want to base segmentation. In the Category pane of the Segmentation Settings section of the Segmentation specification editor, name the category or categories of interest.

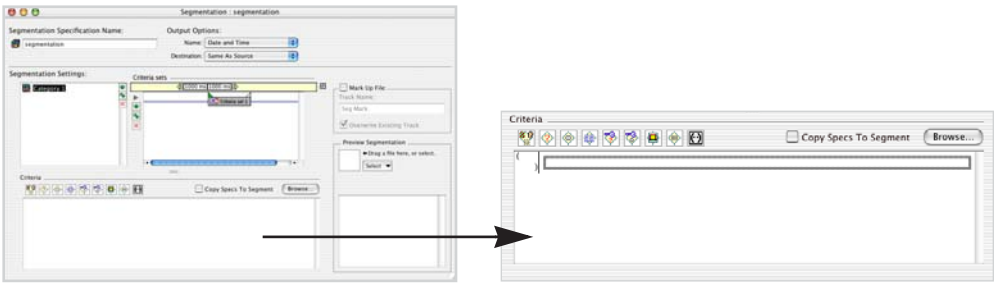
2. Define the categories by identifying the events on which you wish to segment. An event is made up of *conditions*., which include the event's type, code, label, track, key code, and value. You can produce a list of these events by choosing **Events > Event List** to view the experiment setup, which can help you determine the condition of the trial and the events.

3. Define a criteria set by creating a *criterion* from those conditions. A *criterion* can contain one condition or more; if it contains more than one, a criterion strings multiple conditions together to define the event precisely, using the Boolean expressions AND and OR. Click the Browse button to view the available event criteria (see "4. Browse button," on page 142). (Step 1 in Figure 17-5).

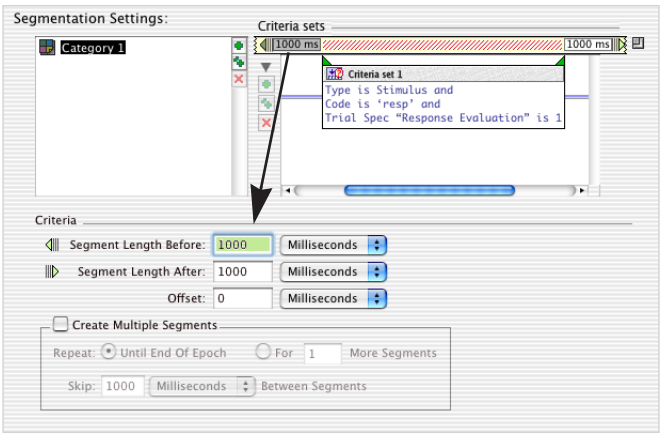
Note: For segmentation markup, stop after this step and name the markup event.

4. If you are continuing with segmentation, specify the length and offset of the segment by clicking the Segment Length text boxes (Step 2 in Figure 17-5).

Step 1: Name the category and, in the Criteria section, create its criterion from the event conditions.



Step 2: The criterion appears in the Criteria Sets pane. In the yellow time bar, click in either one of the two Segment Length text boxes to open the "segment length" section, which is where you specify the segment length and offset.



Step 3: If the category contains more than one criteria set, create and define the second criteria set and specify the sets' relative positions by clicking the temporal relationship bar between the sets to open the "temporal relationships" pane.

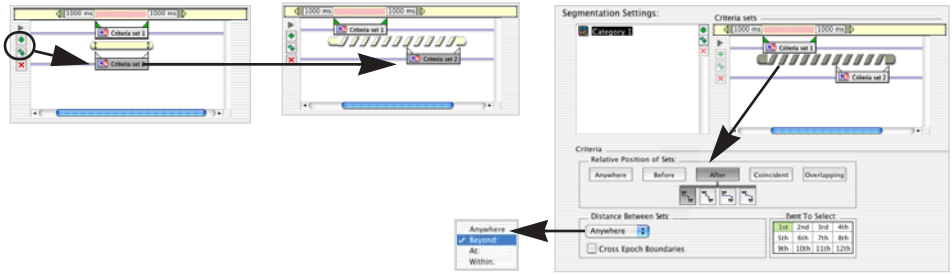


Figure 17-5. Segmentation basics

5 A category can consist of one criteria set. If it consists of more than one, you must define their relative positions using the "temporal relationships" pane (Step 3 in Figure 17-5).

Once this process is completed, you have finished defining your Segmentation specification.

The number of segments that you get as a result of segmentation might be fewer than the number of events that meet the criteria for the category. This is caused by an interaction with the durations that you specified, before and after the segmentation event, to include in the segment. Some events that meet the criteria for the category might overlap an epoch boundary.

Remember that segmentation and the optional technique of filtering are the first steps in deriving ERPs from a data set. ***If filtering is used, it should be done before segmentation***.

Temporal Relations

Figure 17-6 shows how Net Station works with temporal relations. After you specify the temporal relations, Net Station runs through the first criteria set (Criteria Set 1) and creates a list of events from the continuous file that match the event criteria. Net Station then does the same for the second criteria set (Criteria Set 2) and each subsequent criteria set. The result is two or more separate lists (Figure 17-6).

Next, Net Station looks at the temporal relationship that you specified between the criteria sets and matches the events from the file accordingly. Each event in list 1 is compared with each event in list 2. The matching is not always one-to-one; some events in one list may match up with multiple events in the others (for example, if you specify an event that is within 1,000 milliseconds of Criteria Set 1). The matching is one-to-one if the definition is very specific (for example, the first event after Criteria Set 1).

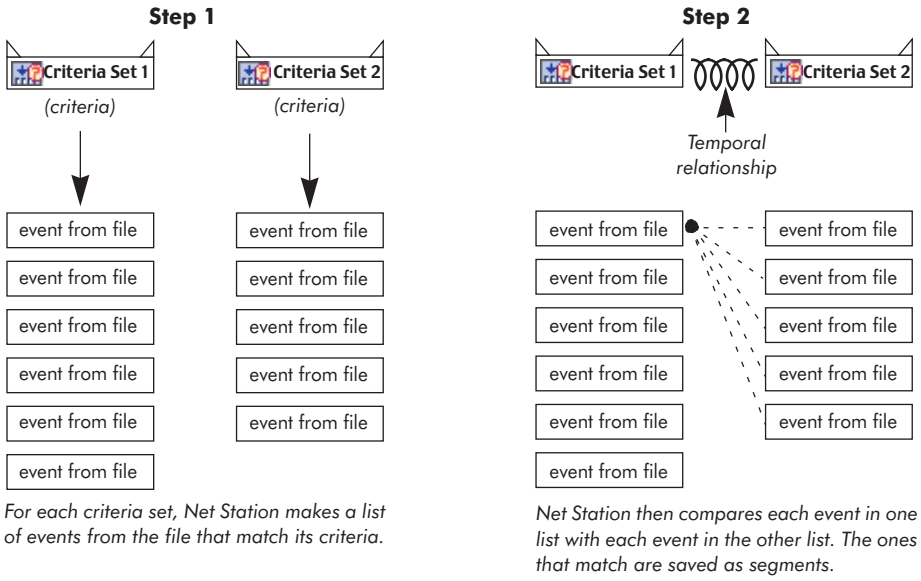


Figure 17-6. The Net Station segmentation process: (1) It compiles a list of events for each criteria set; and (2) it matches events based on how you defined the temporal relationship

General Example

A simple example will help. Figure 17-7 shows events in an experiment. The goal is to segment on **** events in which the next event is resp. From Figure 17-7, we can see that correct segmentation should be based on two event pairs (*** 3 and resp 4; **** 7 and resp 8).

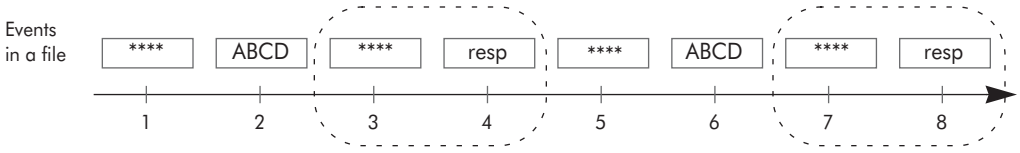


Figure 17-7. Experiment setup

Figure 17-8 shows an incorrect way to define this specification.

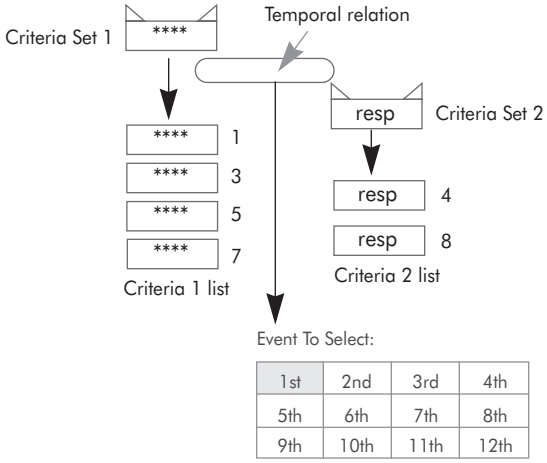


Figure 17-8. Incorrect segmentation specification

The specification in Figure 17-8 is incorrect because it provides oversimplified instructions to Net Station. It uses one criteria set to define both position and condition, and assumes that the software will understand that you want event pairs only where the resp occurs *immediately after* the **** event.

Instead, based on its segmentation logic (see Figure 17-6), Net Station interprets this as a request to find the *first* resp event that follows an **** event, even if other events separate them. Rather than the two correct event pairs, this specification produces four pairs (see Table 17-1).

Table 17-1. Incorrect specification definition

Criteria Set 1	Criteria Set 2	Temporal relation	Answer	Event pair
**** 1	resp 4	Is resp 4 the first resp event after *** 1?	yes	1 and 4
**** 3	resp 8	Is resp 8 the first resp event after *** 1?	no	
**** 5		Is resp 4 the first resp event after *** 3?	yes	3 and 4
**** 7		Is resp 8 the first resp event after *** 3?	no	
		Is resp 4 the first resp event after *** 5?	no	
		Is resp 8 the first resp event after *** 5?	yes	5 and 8
		Is resp 4 the first resp event after *** 7?	no	
		Is resp 8 the first resp event after *** 7?	yes	7 and 8

To approach this correctly, you must use two criteria sets to describe the second event, which comprises a specific position and a specific condition.

In Figure 17-9, Criteria Set 2 tells Net Station to stop at the next event following Criteria Set 1, regardless of its code—this establishes the *position* of the event. Then, Criteria Set 3 tells Net Station to keep only those events that have a resp code, thus establishing the *condition* of the event.

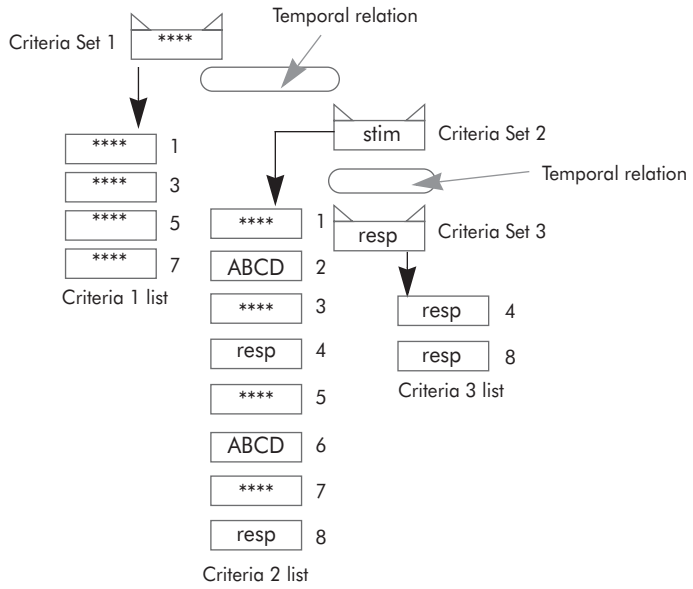


Figure 17-9. Correct segmentation specifications

As shown in Table 17-2, this specification yields the two correct event pairs.

Table 17-2. Correct specification

Criteria Set 1	Criteria Set 2 (determines position)	Criteria Set 3 (determines condition)	Answer	Event pair
**** 1	ABCD 2	Is ABCD 2 a resp?	no	
**** 3	resp 4	Is resp 4 a resp?	yes	3 and 4
**** 5	ABCD 6	Is ABCD 6 a resp?	no	
**** 7	resp 8	Is resp 8 a resp?	yes	7 and 8

Depending on your segmentation needs, this can become complex, with some categories including as many as 12 criteria sets! The detailed, real-world examples on page 156 should help illustrate these descriptions.

Double-Checking Your Specification

If you know beforehand the number of segments that should be produced (for example, total number of standards and targets), then you can tell immediately after running the segmentation tool if your specification is defined correctly.

If you do not know the number beforehand, you can find out by exporting the events from the continuous file into a Microsoft Excel spreadsheet, sorting the events in Excel, and counting the total. You can also create a category that will provide this information (for example, a category to segment on all response events), preview the segmentation, and afterward delete the extra category.

Segmentation Tips

Some tips to help you avoid common segmentation pitfalls:

- When programming experiments, make sure there is *enough time* before the first event in the file, otherwise the first trial will not be included in the segmentation output.
- One key to performing advanced segmentation is understanding *temporal relations*.
- *Do not combine conditions from different events* by carelessly using the ANDs, ORs, and parenthesis tools in the Criteria pane; view the Event List or the Browse Criteria Event window to determine which conditions belong to which events and then, if necessary, use multiple criteria sets to describe one event.
- The *segmentation triangles* can change the segmentation event or segmentation duration. The leftmost selected (green) segmentation triangle is the *segmentation event*, which is the zero point minus (–) the offset of the segment. Net Station selects the left segmentation triangle of Criteria Set 1 as the segmentation event by default.

  Selecting a different segmentation triangle than the default changes the segmentation event. Selecting a second segmentation triangle creates a *segmentation duration*, which increases the duration so that:

  duration = time before segment length + segmentation event + segmentation duration + time after segment length

- If you are creating multiple categories, once you have defined the first category, *duplicate it* and change it, as necessary, for the other categories, to save time.

Segmentation Specification Editor

Figure 17-10 shows the Segmentation specification editor.

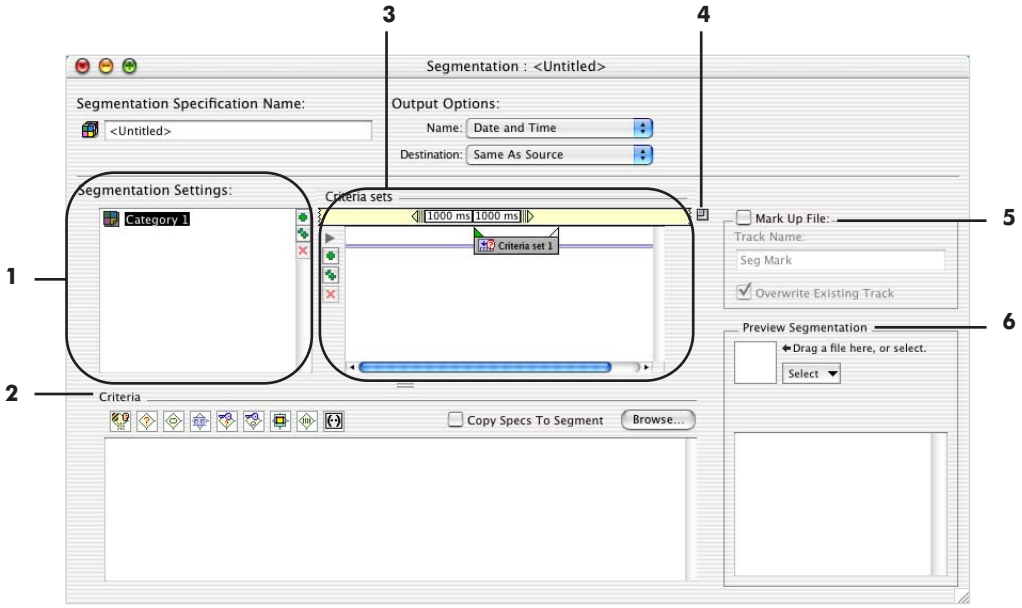


Figure 17-10. Segmentation specification editor

The following are brief descriptions of the numbered items from Figure 17-10.

*1. **Category list***. Lists segmentation categories. Use the Criteria pane (2) to specify segmentation rules for the selected category. The category-editing icons allow you to add a new category, duplicate a selected category, or delete a selected category. Table 17-3 summarizes the icons and their functions.

Table 17-3. Category-editing icons

Icon	Description
	Creates a new category.
	Duplicates a selected category.
	Deletes a selected category.

2. Criteria pane. Allows you to specify event criteria for the category selected in the Category list (1). For details, see "Criteria Pane" on page 141.

If the Mark Up File checkbox is unselected and you click the Segment Length text boxes, this pane changes appearance and becomes the "segment length" pane. For details, see "Segment Length Pane" on page 145.

3. Criteria Sets pane. Performs five functions related to criteria sets or mark-up code: (1) specifies the length of a segment as time before and after the segmentation event; (2) allows you to set offsets; (3) creates multiple criteria sets; (4) allows you to add, duplicate, and delete criteria sets from the pane; and (5) specifies the temporal relationships between criteria sets. For more details, see "Criteria Sets Pane" on page 144.

4. Expansion box. Expands the Category list (1), Criteria pane (2), and Criteria Sets pane (3) to the full width of the editor window, replacing the Mark Up File and Preview Segmentation panes (5, 6).

5. Mark Up File pane. Allows you to define a segmentation markup track. For details, see "Markup Panes (Segmentation Marking)" on page 154. Segmentation markup is useful because it allows you to extract data from the Net Station key lists to a form suitable for export into applications that don't support key lists. You can then perform segmentation in another application.

6. Preview Segmentation pane (with file selector). Shows the effect of the current segmentation specification on a data file. When you put a file in the file selector, the box in the lower-right corner of the panel displays the number of segments for each category that will be generated. Missing categories may indicate that no segments match the selected criteria. If you alter a file displayed in the Preview Segmentation panel, you must drop the newest version into the file selector to update the segmentation preview. For more information see "The File Selector and Associated Display Panes" on page 46. If you make changes to the specification, you can cause the preview to recalculate the results.

Criteria Pane

Figure 17-11 shows the Criteria pane. To display this pane, click on a criteria set icon in the Criteria Sets pane (see "Criteria Sets Pane" on page 144).

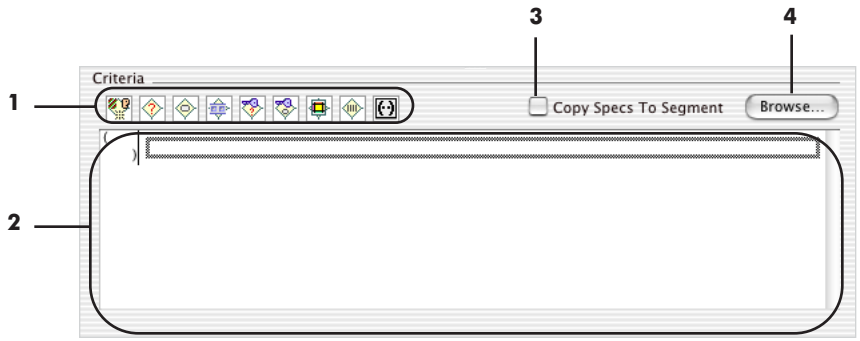


Figure 17-11. Criteria pane

The following are brief descriptions of the numbered items from Figure 17-11.

1. Criteria definition icons. Represent event conditions. To insert a condition code into the criteria, drag the icon to the Criteria definition pane (2). Table 17-4 shows the icons and their settings.

Table 17-4. Criteria definition icons

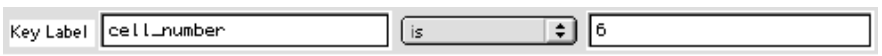
Icon	Criteria settings
	

Table 17-4. Criteria definition icons

Icon	Criteria settings
	Group (parenthesis); see "Using Group Icon to Define Operator Precedence" on page 143.

2. Criteria definition pane. Contains the criterion definition. Criteria statements are executed from the top of the list. AND conditions are evaluated before OR conditions, but you can use parenthesis to define the operator precedence (see "Using Group Icon to Define Operator Precedence" on page 143).

You can drag criteria from the Browse Event Criteria window, or you can construct criteria by dragging the Criteria definition icons. For more information on the Browse Event Criteria window, see the *Net Station Viewer Technical Manual*.

Use the Parenthesis icon to insert parenthesis into the criteria statements. First drag the Parenthesis icon to the Criteria definition pane. Then define the criteria inside the parenthesis by using the icons or dragging criteria from the Browse Event Criteria window.

3. Copy Specs to Segment checkbox. Causes each resulting segment to contain a copy of the trial specification data associated with the event. You can view and edit the trial specification in the Net Station Viewer Specs palette.

4. Browse button. Displays the Browse Event Criteria window, which allows you to extract event types and their criteria from a file. If you alter a file displayed in the Browse Event Criteria window, you must drop the newest version into the file selector to update the window. You can drag criteria from the Browse Event Criteria window to the Criteria definition pane (2) (the edit portion of the Criteria pane). For more information on the Browse Event Criteria window, see the *Net Station Viewer Technical Manual*.

Using Group Icon to Define Operator Precedence

You can use the Group icon to put combinations of criteria in parenthesis to define a specific precedence of operations. Figure 17-12 shows the Criteria area after dragging in the Group icon. A rectangle (1) is displayed.

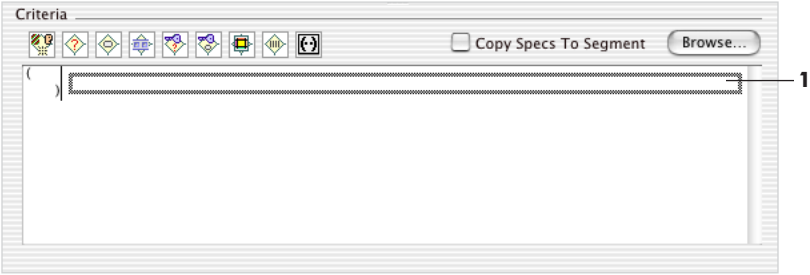


Figure 17-12. Parenthesis in the Criteria area

You can drag criteria into the rectangle to place them inside the parenthesis (see Figure 17-13).

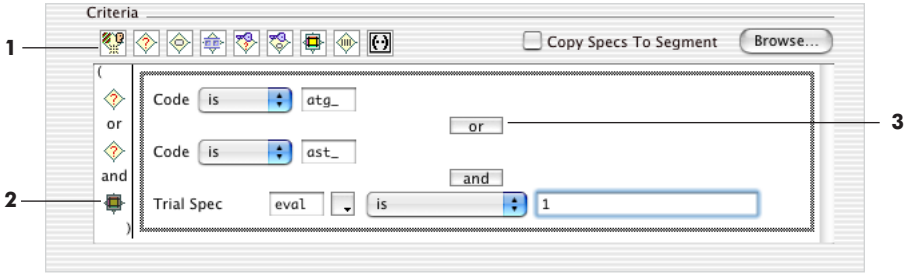


Figure 17-13. Using Parenthesis to define operator precedence

You can drag criteria in three ways:

- Use the Browse Event Criteria window to drag criteria that have been extracted from a file.
- Drag Criteria icons (1) and manually set up the values.
- Drag criteria that are already in the Criteria area (2) to another part of the Criteria area.

In addition, you can click the Boolean operator (3) to change it from AND to OR and back.

Criteria Sets Pane

Figure 17-14 shows the Criteria Sets pane.

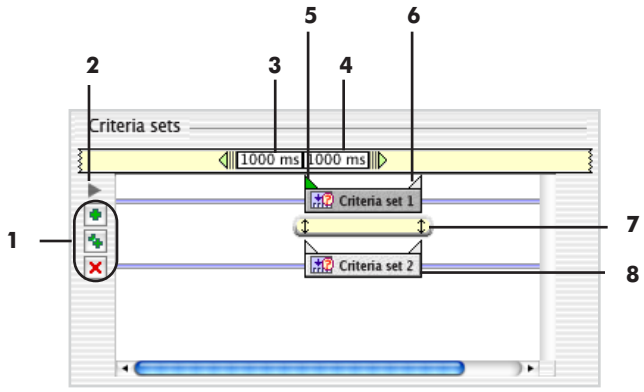


Figure 17-14. Criteria Sets pane

The following are brief descriptions of the numbered items in Figure 17-14.

1. Criteria set–editing icons. Allow you to add new criteria sets, duplicate a selected criteria set, or delete a selected criteria set. Table 17-5 summarizes the icons and their functions.

Table 17-5. Criteria set–editing icons

Icon	Description
	Creates a new criteria set.
	Duplicates a selected criteria set.
	Deletes a selected criteria set.

2. Criteria set disclosure toggle. Displays the criteria for the criteria sets in the pane, below the criteria set icons.

3. Segment Length Before text box. Displays the amount of time before the segmentation event to begin the segment. Clicking this text box displays the Segment Length pane, where you can enter a value for Segment Length Before. For details, see "Segment Length Pane" on page 145.

4. Segment Length After text box. Displays the amount of time after the segmentation event to end the segment. Clicking this text box displays the Segment Length pane, where you can enter a value for Segment Length After. For details, see "Segment Length Pane" on this page.

5. Event onset. Click to specify the event onset as the point of reference for segmentation. If only this segmentation triangle is selected, this becomes the *segmentation event*. Note that you can select both the onset and the offset (6) to include the duration of the event, which becomes the *segmentation duration*.

6. Event offset. Click to specify the event offset as the point of reference for segmentation. Note that you can select both the onset (5) and the offset to include the duration of the event, which becomes the *segmentation duration*.

7. Temporal relationship bar. Click to display the temporal relationship pane. This pane specifies a time relationship between two events. For details, see "Temporal Relationship Pane (Coincident Sets)" on page 147.

8. Criteria set icon. Click to display the Criteria pane, where you can view or edit the criteria for the set (see "Criteria Pane" on page 141).

Segment Length Pane

Figure 17-15 shows the "segment length" pane. To display this pane, click the Segment Length Before or Segment Length After text boxes in the Criteria Sets pane (see "Criteria Sets Pane" on page 144).

This pane is available only if the Mark Up File checkbox is unselected.

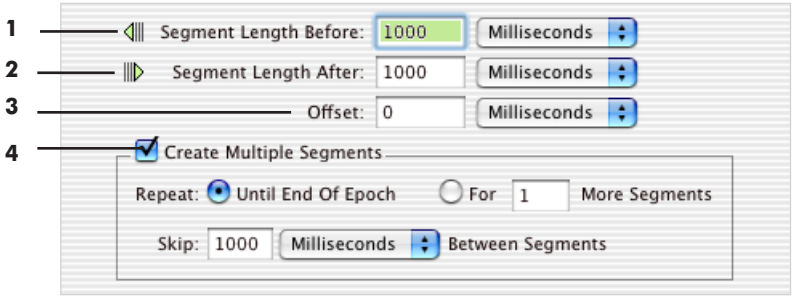


Figure 17-15. Segment length pane

The following are brief descriptions of the numbered items from Figure 17-15.

1. Segment Length Before text box. Specifies the amount of time before the segmentation event to begin the segment. You can set this value by entering a number into the text box. You can specify the value in milliseconds or in samples.

The Segment Length Before text box is also displayed in the Criteria Sets pane. For details, see "Criteria Sets Pane" on page 144.

2. Segment Length After text box. Specifies the amount of time after the segmentation event to end the segment. You can set this value by entering a number into the text box. You can specify the value in milliseconds or in samples.

The Segment Length After text box is also displayed in the Criteria Sets pane. For details, see "Criteria Sets Pane" on page 144.

3. Offset text box. Specifies a shift of the segmentation event to a point other than the zero point. You can specify the offset in milliseconds or in samples, and the offset can be positive or negative. You can use an offset to compensate for an electromechanical delay between the time reported by the experiment control module (the timestamp) and the time that the physical stimulus is presented to the subject.

4. Create Multiple Segments pane. When the Create Multiple Segments checkbox is selected and an event or series of events meets the criteria for segmentation, a segment is taken, and then segments of the same size are automatically taken at intervals. You can specify multiple segments until the end of the current epoch, or you can specify a specific number of segments. You can also specify an interval between segments in milliseconds or in samples.

Temporal Relationship Pane (Coincident Sets)

Figure 17-16 shows the temporal relationship bar (1) and the temporal relationship pane (2) with coincident criteria sets.

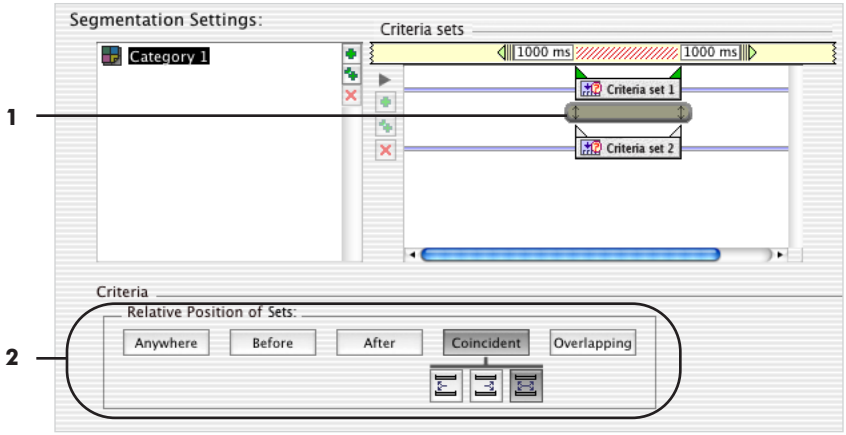


Figure 17-16. Temporal relationship pane (coincident sets)

The following are brief descriptions of the numbered items from Figure 17-16.

*1. **Temporal relationship bar.*** Clicking this bar displays the temporal relationship pane (2). The bar is solid with vertical dashed lines at each end to indicate the coincident relationship of the criteria sets.

*2. **Temporal relationship pane with Coincident button.*** This button displays icons for defining the coincident positions of Criteria Sets 1 and 2. Table 17-6 describes the icons.

Table 17-6. Criteria-set relationship icons (coincident)

Icon	Description
	Coincident onsets
	Coincident offsets
	Coincident onsets and offsets

Temporal Relationship Pane (Overlapping Sets)

Figure 17-17 shows the temporal relationship bar (1) and the temporal relationship pane (2) with overlapping criteria sets.

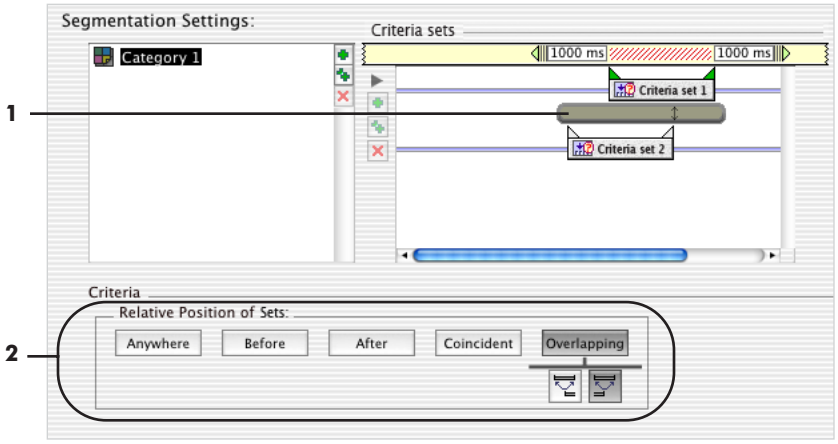


Figure 17-17. Temporal relationship pane (overlapping sets)

The following are brief descriptions of the numbered items in Figure 17-17.

*1. **Temporal relationship bar.*** Clicking this bar displays the temporal relationship pane (2). The bar is solid to indicate the overlapping relationship of the criteria sets.

*2. **Temporal relationship pane with Overlapping button.*** Clicking this button displays two icons for defining the overlapping positions of Criteria Sets 1 and 2. Table 17-7 describes the icons.

Table 17-7. Criteria-set relationship icons (overlapping)

Icon	Description
	Criteria Set 1 overlaps the onset of Criteria Set 2.
	Criteria Set 1 overlaps the offset of Criteria Set 2.

Temporal Relationship Pane (Before)

Figure 17-18 shows the temporal relationship bar (1) and the temporal relationship pane (2) with separated criteria sets (Criteria Set 2 before Criteria Set 1). When you select Before, After, or Anywhere relationships, the Distance Between Sets and Event To Select panes appear.

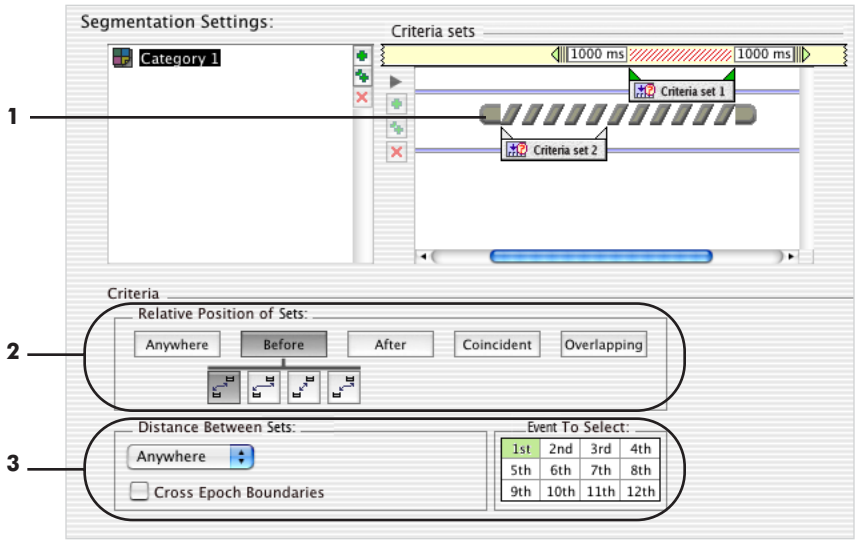


Figure 17-18. Temporal relationship pane (before)

The following are brief descriptions of the numbered items from Figure 17-18.

*1. **Temporal relationship bar.*** Clicking this bar displays the temporal relationship pane (2). The bar has diagonal stripes to indicate the that the criteria sets are separated.

*2. **Temporal relationship pane with Before button.*** Clicking this button displays four icons for defining the positions of Criteria Sets 1 and 2. Table 17-8 describes the icons.

Table 17-8. Criteria-set relationship icons (before)

Icon	Description
	Onset of Criteria Set 2 is before onset of Criteria Set 1.
	Onset of Criteria Set 2 is before offset of Criteria Set 1.
	Offset of Criteria Set 2 is before onset of Criteria Set 1.
	Offset of Criteria Set 2 is before offset of Criteria Set 1.

3. Distance Between Sets and Event To Select panels. Are described in "Subordinate Temporal Relationship Controls" on page 153.

Temporal Relationship Pane (After)

Figure 17-19 shows the temporal relationship bar (1) and the temporal relationship pane (2) with separated criteria sets (Criteria Set 2 after Criteria Set 1).

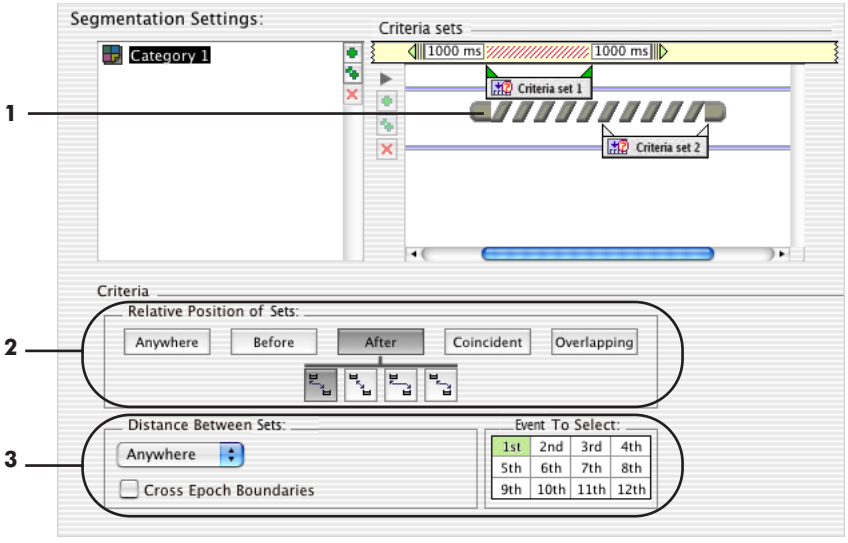


Figure 17-19. Temporal relationship pane (after)

When you select Before, After, or Anywhere, the Distance Between Sets and Event To Select panes appear.

The following are brief descriptions of the numbered items from Figure 17-19.

1. Temporal relationship bar. Clicking this bar displays the temporal relationship pane(2). The bar has diagonal stripes with rounded ends to indicate that the criteria sets are separated, but position is relevant.

2. Temporal relationship pane with After button. Clicking this button displays four icons for defining the positions of Criteria Sets 1 and 2. Table 17-9 describes the icons.

Table 17-9. Criteria-set relationship icons (Criteria Set 2 after Criteria Set 1)

Icon	Description
	Onset of Criteria Set 2 is after onset of Criteria Set 1.
	Offset of Criteria Set 2 is after onset of Criteria Set 1.
	Onset of Criteria Set 2 is after offset of Criteria Set 1.
	Offset of Criteria Set 2 is after offset of Criteria Set 1.

3. Subordinate Temporal Relationship controls. Are described in "Subordinate Temporal Relationship Controls" on page 153.

Temporal Relationship Pane (Anywhere)

Figure 17-20 shows the temporal relationship bar (1) and the temporal relationship pane (2) with two criteria sets in an Anywhere relationship. When you select Before, After, or Anywhere relationships, the Distance Between Sets and Event To Select panes appear.

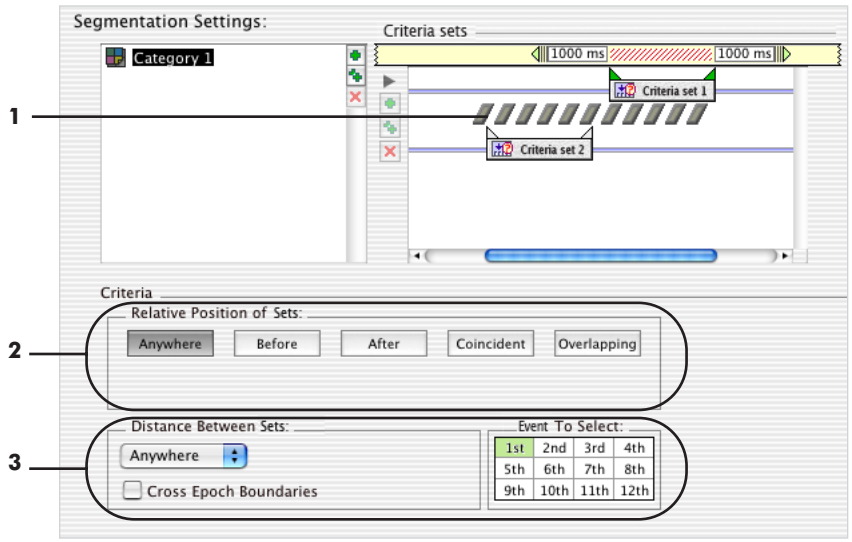


Figure 17-20. Temporal relationship pane (anywhere)

The following are brief descriptions of the numbered items from Figure 17-20.

*1. **Temporal relationship bar**.* Clicking this bar displays the temporal relationship pane (2). The bar has diagonal stripes without the rounded ends to indicate that the criteria sets are not in a fixed relationship.

*2. **Temporal relationship pane with Anywhere button**.* Clicking this button allows the two criteria sets to occur in any positional relationship.

*3. **Subordinate temporal relationship controls**.* Are described in ""Subordinate Temporal Relationship Controls" on page 153.

Subordinate Temporal Relationship Controls

With Before, After, or Anywhere relationships, you must further refine the timing specifications to avoid ambiguity. When you select Before, After, or Anywhere relationships, the Distance Between Sets and Event To Select panes appear. Figure 17-21 shows these panes and the corresponding appearance of the temporal relationship bar.

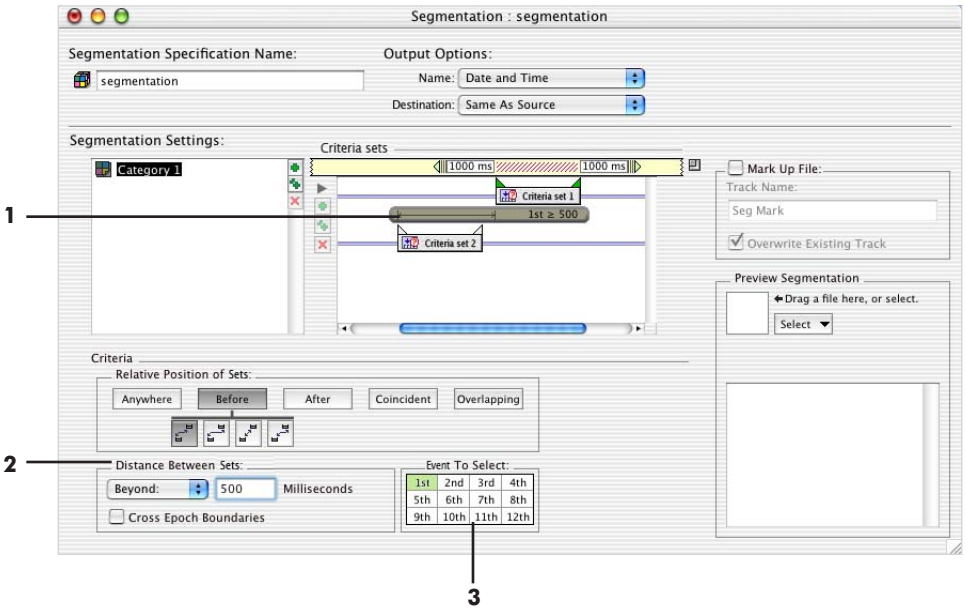


Figure 17-21. Distance Between Events and Event to Select panes

The following are brief descriptions of the numbered items from Figure 17-21.

*1. **Temporal relationship bar**.* For Before and After relationships, the bar is shaded and indicates the exact timing relationship specified in the Distance Between Sets pane (2).

*2. **Distance Between Sets pane**.* Specifies the exact timing relationships for criteria sets that are separated. The pop-up menu gives four choices for exact timing relationships:

- *Anywhere*: specifies that Criteria Set 2 can occur anytime before or after Criteria Set 1 (depending on whether you are specifying a Before or After relationship).

- *Beyond*: specifies that Criteria Set 2 must occur at least the specified number of milliseconds before or after Criteria Set 1 (depending on whether you are specifying a Before or After relationship).
- *At*: specifies that Criteria Set 2 must occur exactly the specified number of milliseconds before or after Criteria Set 1 (depending on whether you are specifying a Before or After relationship).
- *Within*: specifies that Criteria Set 2 must occur in a time period less than or equal to the specified number of milliseconds before or after Criteria Set 1 (depending on whether you are specifying a Before or After relationship).

The Cross Epoch Boundaries checkbox allows segmentation beyond the current epoch boundaries.

Note: Net Station, by default, does not cross epoch boundaries to retrieve event information. An example of when you would select this checkbox is when you want the first trial after an incorrect trial and do not care if there is a block break between them.

3. Event To Select pane. Restricts segmentation to a single event that meets the timing criteria specified in the Distance Between Sets pane (2). Clicking a cell in this matrix selects one of the events that meets the timing criteria specified in the Distance Between Sets pane (sorted by time). For example, if you wanted the second trial after an incorrect trial, you would select "2nd."

Markup Panes (Segmentation Marking)

Segmentation markup is useful because it allows you to extract data from the Net Station key lists into a form suitable for export into applications that do not support key lists. You can then perform segmentation in another application.

You can also use segmentation markup to review or diagnose data without creating a new file.

Figure 17-22 shows the Segmentation specification editor with the Mark Up File box (1) checked. Checking this box displays the Markup Event Code Specification pane (2).

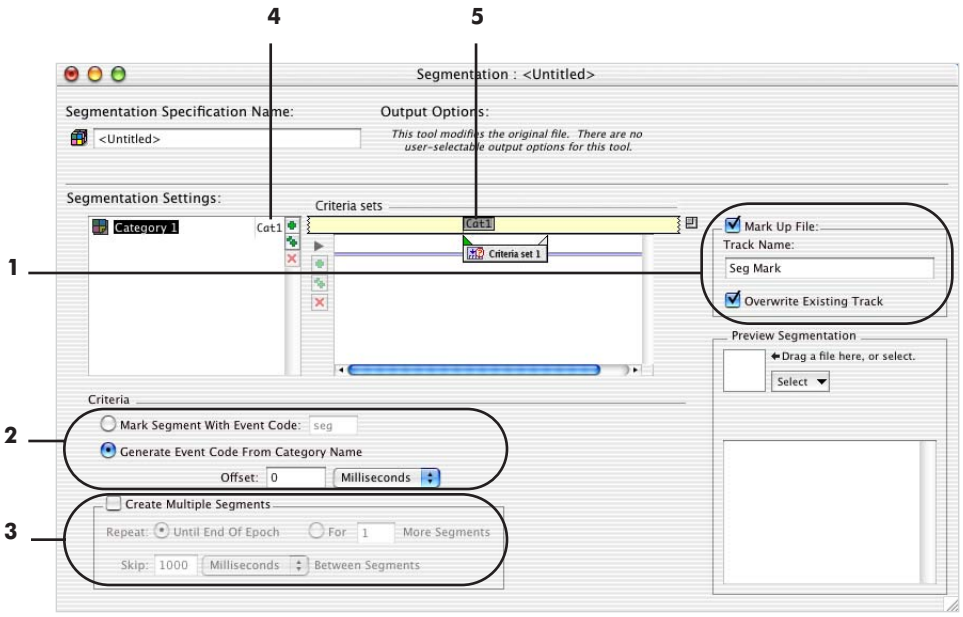


Figure 17-22. Segmentation specification editor, with Markup Event Code Specification pane

The following are brief descriptions of the numbered items from Figure 17-22.

1. Mark Up File pane. Specifies that segmentation markup will be applied to the source file.

- *Mark Up File checkbox*: checking this box tells the specification to markup to file.
- *Track Name*: allows you to enter a name for the new markup track.
- *Overwrite Existing Track*: when this checkbox is selected, the new markup track replaces any existing markup track of the same name. If this checkbox is not selected, the new markup track is added and any existing markup track is preserved.

2. Markup Event Code Specification pane. Allows you to specify how the markup events are to be labeled.

- *Markup Segment With Event Code radio button*: allows you to enter any four-character event code.

- *Generate Event Code From Category Name radio button:* event codes are generated by combining the first three characters and the last character of the category name. Note that this could result in different categories getting the same markup label. For example, the categories "Cat_ABC_1" and "Cat_XYZ_1" would both get the label "Cat1."

3. Offset text box and Create Multiple Segments pane

- *Offset text box*: allows you to specify a shift of the reference point of the segment to a point other than the zero point. You can specify the delay in milliseconds or in samples. You can also use an offset to compensate for an electromechanical delay between the time reported by the Experimental Control Module (the timestamp) and the time that the physical stimulus is presented to the subject.
- *Create Multiple Segments pane*: when the Create Multiple Segments checkbox is selected, the segmentation tool automatically creates multiple segments. You can specify multiple segments until the end of the current epoch or specify a specific number of segments. You can also specify an interval between segments in milliseconds or in samples.

4. Category name with markup event code. The markup event code is displayed in the category list.

5. Event icon with markup event label. Selecting this icon opens the Markup Event Code Specification pane (2).

Example Applications

Example 1: Simple

The "spec" criteria is a shortcut that allows you to use information from another event when segmenting without using temporal relations (Net Station is using temporal relations behind the scenes). Specifically, when using the spec shortcut, you are using the keys associated with the *trial-specific (TRSP)* event. We can mimic what the spec shortcut is doing as a simple demonstration of temporal relations.

Experiment setup: The sample experiment is a visual target detection task, with standard and target (novel) stimuli. This type of experiment is a classic paradigm and its design is well known.

In this paradigm, the subject is presented with a series of neutral images (standards) occurring 80% of the time and positive or negative images (targets) occurring 20% of the time. The subject is instructed to press a button immediately after each target image (Figure 17-23).

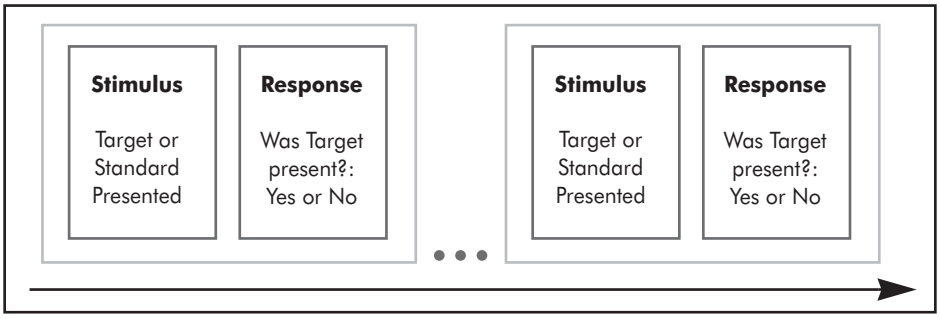


Figure 17-23. Trial containing a stimulus and response for a visual target detection experiment

Segmentation goal: To create segments based on whether the subject responded correctly or incorrectly to the standard and target stimuli.

This creates four categories:

- Correct + standard
- Incorrect + standard
- Correct + target
- Incorrect + target

Because we know the number of standards and targets presented in the experiment, after segmentation we can total the number of segments produced to double-check our Segmentation specification.

Challenge: As indicated in "Temporal Relations" on page 134, Net Station creates separate lists of events in the data that meet the event criteria and then compares the items in the lists, downward through the temporal relations. The challenge is not to think of the events linearly, which results in an incorrect specification.

Key to the specification: We need three, not two, criteria sets to define this specification. You cannot use one criteria set to describe the second event because, as described in the following paragraphs, you would be incorrectly matching events.

We base the segmentation on the stimulus event code stm+ and the key code cel#, which is part of the stimulus event. We then use the response evaluation to separate the correct and incorrect responses. The evaluation is contained in a key that is part of the TRSP event. There is a TRSP event at the end of every trial; thus, every trial has a unique stim+/TRSP pair.

The first criteria set is the stimulus and, from the Event List, we know we can define it by its cell number (key code "cel#" is 2).

We use the second criteria set to indicate the next event following the first criteria set, regardless of whether it is correct or incorrect (that is, regardless of its eval value). We want the first TRSP event that occurs anywhere after the first criteria set. The second criteria set is defined by its code, which is TRSP. We then create a third coincident criteria set to define the response as being correct (key code "eval" is 1). Figure 17-24 shows the definition for Standard Correct.

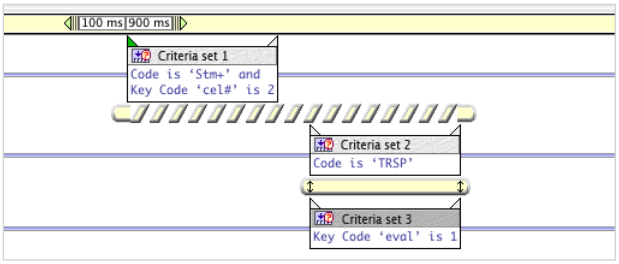


Figure 17-24. Criteria Sets pane for Standard Correct category

The key is not to group the two criteria into one criteria set. If we had defined the second criteria set as code is "TRSP" AND key code "eval" is 1, then Net Station would find *only events that met both conditions*, which would produce incorrect event pairs (Figure 17-25).

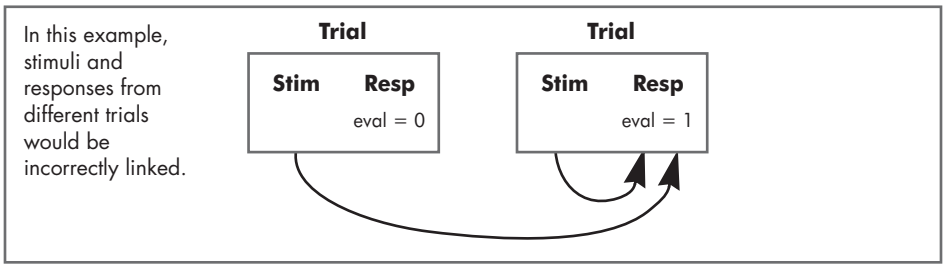


Figure 17-25. The result of an incorrect segmentation event definition

The second criteria set (defined as code is "TRSP") establishes the event's position, by telling Net Station to create a list of all TRSP events that follow a stimulus event. The third criteria set creates a third list of correct events. Net Station's temporal relations logic moves from left to right, comparing each event in list 1 to each event in list 2 until it finds a match; then it compares the matched event to each event in list 3 until it finds a match.

To define Standard Incorrect, duplicate the Standard Correct category but change the evaluation value in the third criteria set to 0. To define the Target categories, simply duplicate both Standard categories and change their cell numbers to the correct values (in this example, 1).

Specification rules: Table 17-10 shows the criteria sets for the categories in this example.

Table 17-10. Criteria sets for Example 1

Category	Criteria sets
Standard + correct	Criteria Set 1: code = stim+; key code cel# = 2
	Temporal relation between Criteria Sets 1 and 2: After, Anywhere, 1st
	Criteria Set 2: code = trsp
	Temporal relation between Criteria Sets 2 and 3: Coincident
	Criteria Set 3: trial spec response eval = 1
Standard + incorrect	Criteria Set 1: code = stim+; key code cel# = 2
	Temporal relation between Criteria Sets 1 and 2: After, Anywhere, 1st
	Criteria Set 2: code = trsp
	Temporal relation between Criteria Sets 2 and 3: Coincident
	Criteria Set 3: trial spec response eval = 0
Target + correct	Criteria Set 1: code = stim+; key code cel# = 1
	Temporal relation between Criteria Sets 1 and 2: After, Anywhere, 1st
	Criteria Set 2: code = trsp
	Temporal relation between Criteria Sets 2 and 3: Coincident
	Criteria Set 3: trial spec response eval = 1
Target + incorrect	Criteria Set 1: code = stim+; key code cel# = 1
	Temporal relation between Criteria Sets 1 and 2: After, Anywhere, 1st
	Criteria Set 2: code = trsp
	Temporal relation between Criteria Sets 2 and 3: Coincident
	Criteria Set 3: trial spec response eval = 0

Example 2: Advanced

Experiment setup: Two sets of words are presented, one of which contains a "solution word." The participant must find the word or guess which set contains the word. The participant is then asked if the word was known. He or she has three seconds to respond.

The design of each trial consists of five main stages, in this order:

- fixation
- stimulus presentation (word sets)—Stimulus 1
- 8-second delay for response (delay is terminated once response is made)—Response 1
- question (did the participant know the word?)—Stimulus 2
- 3-second delay for response to the question—Response 2

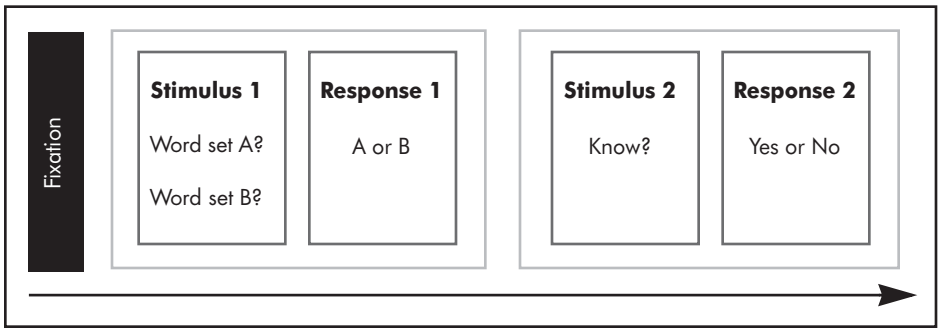


Figure 17-26. Trial containing two stimuli and two responses

Segmentation goal: To segment based on whether the response to Stimulus 1 was correct or incorrect; and whether or not the participant responded to the question in Stimulus 2.

This creates four categories:

- Correct + response
- Correct + no response
- Incorrect + response
- Incorrect + no response

We will create a fifth category to segment on Response 1, regardless of the presence of Response 2. This allows us to double-check the segmentation total.

Challenge: Segmenting on responses is challenging because, unlike stimuli, responses vary in *when* and *if* they occur. Also, this specification includes two categories based on the lack of a participant response.

Key to the specification: Because we are dealing with two events (the first and second responses of each trial), it would seem as though we need two criteria sets. However, we actually need *three* criteria sets to define the specification.

The first criteria set is easy to define: it is the first response. We define it by position number (key code pos# = 1) and response evaluation (0 = incorrect, for instance). The second is harder. We cannot merely define it by position number (key code pos# = 2) and event code (RESP) because if a subject did not respond, the second response (key code pos# = 2) that occurs in relation to the first criteria set is actually the first response in the next trial (see Figure 17-27).

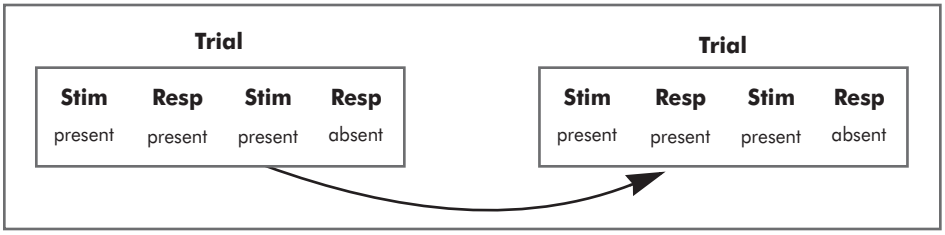
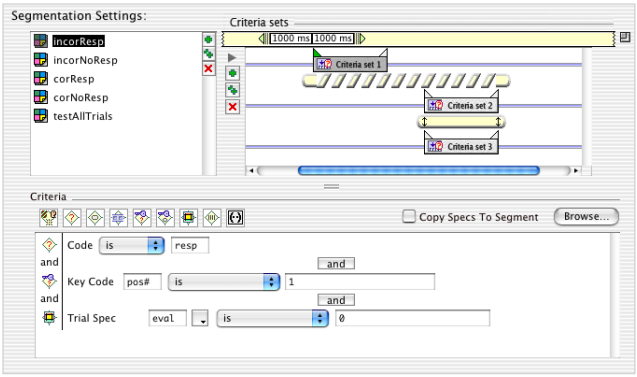


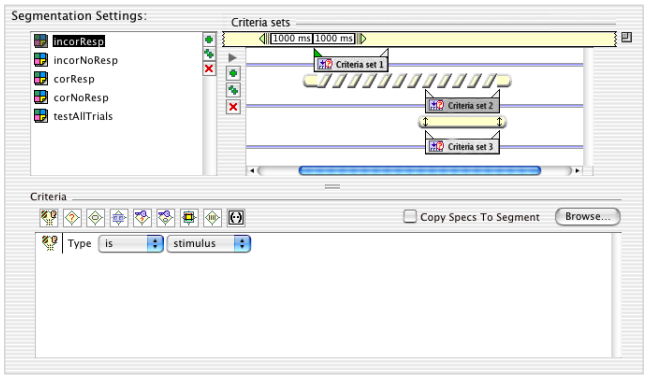
Figure 17-27. The second response

We must use two criteria sets to define the second response: the first defines the event's position in relation to Criteria Set 1; the second defines its characteristics (code = RESP, see Figure 17-28).

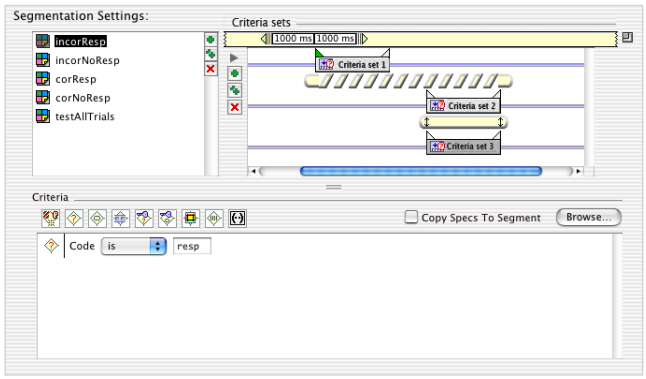
Because of the structure of this experiment, if a participant does not respond to Stimulus 2, we know that the event code in the position of the response is TRSP.



Criteria Set 1



Criteria Set 2



Criteria Set 3

Figure 17-28. Example criteria sets for one category

Specification rules: Table 17-11 shows the criteria sets for the categories in this example.

Table 17-11. Criteria sets for Example 2

Category	Segmentation events
Incorrect + response	Criteria Set 1: code = resp; key code pos# = 1; trial spec response eval = 0
	Temporal relation between Criteria Sets 1 and 2: Anywhere, After, 3rd
	Criteria Set 2: type = stimulus
	Temporal relation between Criteria Sets 2 and 3: Coincident
	Criteria Set 3: code = resp
Incorrect + no response	Criteria Set 1: code = resp; key code pos# = 1; trial spec response eval = 0
	Temporal relation between Criteria Sets 1 and 2: Anywhere, After, 3rd
	Criteria Set 2: type = stimulus
	Temporal relation between Criteria Sets 2 and 3: Coincident
	Criteria Set 3: code = trsp
Correct + response	Criteria Set 1: code = resp; key code pos# = 1; trial spec response eval = 1
	Temporal relation between Criteria Sets 1 and 2: Anywhere, After, 3rd
	Criteria Set 2: type = stimulus
	Temporal relation between Criteria Sets 2 and 3: Coincident
	Criteria Set 3: code = resp
Correct + no response	Criteria Set 1: code = resp; key code pos# = 1; trial spec response eval = 1
	Temporal relation between Criteria Sets 1 and 2: Anywhere, After, 3rd
	Criteria Set 2: type = stimulus
	Temporal relation between Criteria Sets 2 and 3: Coincident
	Criteria Set 3: code = trsp
Test (all segments)	Criteria Set 1: code = resp; key code pos# = 1

chapter 18

Short Epoch Filtering

Concepts

The Short Epoch Filtering tool is designed to operate on Net Station, EGIS, or simple-binary segmented files. The results are output to a Net Station segmented file.

The Short Epoch Filtering tool was created to produce minimal phase distortion on the ends of your data segments, allowing you to use it on short epochs. It uses a finite impulse response (FIR) filter, a Blackman window, discrete temporal convolution, and a truncated filter kernel to reduce the "end effect," a phenomenon where the ends of a data segment are only partially filtered.

With Short Epoch Filtering, you can filter out activity in frequencies that are not of interest, using one of two filter types:

- *Lowpass*: attenuates frequencies above the specified frequency, while passing frequencies below the specified frequency.
- *Notch*: attenuates frequencies in a narrow band around the specified frequency, while passing frequencies outside the band. The notch filter is primarily used to filter out 50 or 60 Hz line noise. Typically, line noise is 60 Hz in the United States, and 50 Hz in most other countries; Japan uses either frequency, depending on the region.

Short Epoch Filtering does not perform highpass filtering because that requires a longer filter kernel than feasible for short data segments.

FIR versus IIR Filtering

Net Station uses an infinite impulse response (IIR) filter for viewing real-time data, and FIR filters for saving data. IIR filters are suitable for real-time use because of their excellent computational speed, but they tend to distort the data near the filter frequency. FIR filters are too slow for real-time applications, but they permanently filter a file with much better accuracy. (For more information, see “Concepts” on page 97 of Chapter 12, "Filtering.”)

The Filtering and the Short Epoch Filtering Waveform Tools both use FIR filters. A disadvantage of FIR filters is that they tend to distort the first and last sections of data (with the Filtering tool, this is generally the first and last 600 ms of a file). With long epochs of data, this is generally not an issue.

With short epochs, however, discarding 1,200 ms of a file could mean discarding a significant portion (or all!) of the recording. Short Epoch Filtering uses a truncated filter kernel to greatly reduce the phase distortion on the ends of your data segments. The tradeoff with a truncated filter kernel, however, is that it slightly degrades the performance of the filter.

Therefore, we recommend using the Short Epoch Filtering tool *only* on short data segments not requiring highpass filtering, and the Filtering tool on all other segment lengths. If you filter your data before performing segmentation, *which we strongly recommend* (see page 28), then you should use the Filtering tool.

Short Epoch Filtering Design

This section briefly describes the design of the Short Epoch Filtering tool. It is not meant to be a primer on the topic; for that, we suggest the works cited on page 99 in Chapter 12, "Filtering.”

To reduce computation time, Short Epoch Filtering transforms the data segment and the filter kernel from the time domain to the frequency domain. The tool uses a fast Fourier transform (FFT) algorithm, which is restricted to sequences of exactly power-of-two length. Thus, the tool must “zero-pad” the data epoch and the filter kernel up to a power-of-two number of samples before transforming them to the frequency domain, where the data and the filter kernel are cross-multiplied.

In Fourier analysis, time and frequency waveforms are represented as infinite in length, so before the tool applies an inverse discrete Fourier transform to revert the data epoch and the filter kernel back to the time domain, it also truncates the “ideal” infinite filter kernel to a finite length.

Back in the time domain, the "real" filter kernel is also truncated, to reduce the "end effect." However, the actual frequency response will be a smeared version of the ideal one. To alleviate this smearing, Short Epoch Filtering uses a Blackman window, which tapers the filter kernel down to near zero at each end.

Because the filter kernel is now shorter than the data segment, the ends of the data segment contain additional samples. Short Epoch Filtering rectifies this by simply discarding them.

Short Epoch Filtering Specification Editor

Figure 18-1 shows the Short Epoch Filtering specification editor.

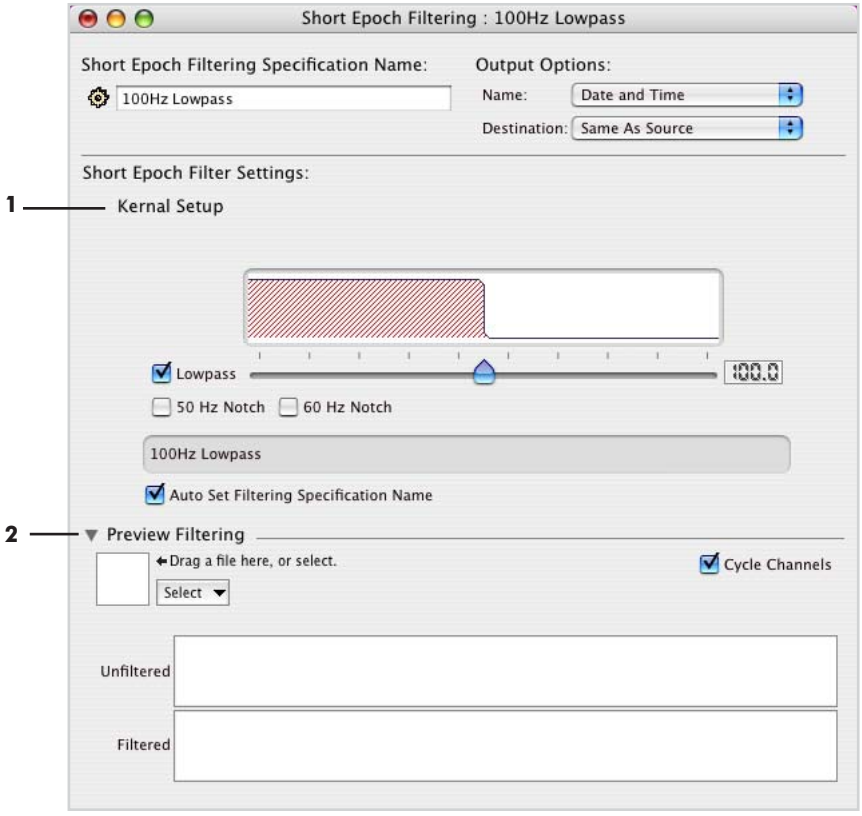


Figure 18-1. Short Epoch Filtering specification editor

The following are brief descriptions of the numbered items from Figure 18-1.

1. Filter Settings pane. Controls the type and specified frequency of the filter. You can select one or both of the two filter types—lowpass and/or notch—and the width of the notch filter. A graphic display above the controls shows the contour of the chosen filter band.

The controls in the pane include:

- *Lowpass*: Select the checkbox to activate the slider and the text box. Drag the slider to the desired frequency, or directly input the frequency into the text box.
- *Notch*: Select either 50 or 60 Hz for the notch filter. Typically, line noise is 60 Hz in the United States, and 50 Hz in most other countries; Japan uses either frequency, depending on the region.
- *Filter indicator*: displays the type of filter chosen.
- *Auto Set Filtering Specification Name*: when this checkbox is selected, the specification name is automatically set to match the current filter setting. For example, Figure 18-1 shows a 100 Hz lowpass filter, so the name is *100Hz Lowpass*.

2. Preview Filtering pane (with file selector). Displays the effect the filter will have on a selected file. Two windows display the Unfiltered and Filtered versions of the file. You can select the file using the file selector in the lower-left corner of the pane. For more information about the file selector, see "The File Selector and Associated Display Panes" on page 46.

- *Cycle Channels checkbox*: Select this to automatically display one channel after another in numerical sequence, in the Unfiltered and Filtered windows.

chapter 19

STATISTIC EXTRACTION

Concepts

The Statistic Extraction tool is designed to operate on Net Station averaged or segmented files. It outputs a tab-delimited text file of the statistical analysis.

The tool contains panes for waveform, source, and wavelet data. *Waveform data* refers to the scalp data (in microvolts) acquired with your Geodesic EEG System. *Source data* are the cortex data (in nano-amp meters) derived by using EGI's GeoSource software. *Wavelet data* are joint time-frequency information produced when you run the Wavelet tool on your data.

For each input file of waveform or source data, the Statistic Extraction tool outputs a tab-delimited text file containing one or more statistical analyses. For both single or multiple input files of wavelet data, the Statistic Extraction tool outputs a single tab-delimited text file.

You typically use the Statistic Extraction tool to help determine whether a particular component is statistically different between experimental conditions. To do this, you run the Statistic Extraction tool on a multisubject averaged file and import the output into a statistical software package (for example, SPSS or JMP) for analysis.

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

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

You specify time windows using events. Before using the Statistic Extraction tool, you may need to add events to your data file. For more information on events, see Chapter 18, "Event Sets and User Events," in the *Net Station Viewer Technical Manual*.

You specify channel groups with montages. In other words, you create a montage that contains the channels you are interested in, and then use that montage for your channel groups parameter.

Caution!: *An empty subject field may cause problems during the Statistic Extraction process. Make sure that a subject has been assigned before applying Waveform Tools such as Averaging, Combine Files, and Statistic Extraction (see "Assigning Subjects" on page 29).*

Note: When you run Statistic Extraction, the sensor layout of the input data must match the sensor layout of the montages used as channel groups. Otherwise, an error will occur.

Figure 19-1 shows the output of Statistic Extraction performed on waveform data, viewed in Microsoft Excel.

	A	B	C	D
1	ATD256.av.bc			
2	Thu, Sep 9, 2004, 7:13:48 PM			
3	Calculate measure for regions marked with event N100, extending region			
4	0 samples before event and 0 samples after.			
5	Mean amplitude averaged over channel group			
6	Eyes: 242, 36, 241, 18, 251, 227			
7		Standard Correct	Target Correct	
8		_Eyes	_Eyes	
9	subj01	-0.32292	0.07983	
10	subj02	-0.37461	0.46317	
11	subj03	0.37553	0.27764	
12	subj04	-0.23202	-0.59616	
13				
14	Calculate measure for regions marked with event P300, extending region			
15	0 samples before event and 0 samples after.			
16	Mean amplitude averaged over channel group			
17	Eyes: 242, 36, 241, 18, 251, 227			
18		Standard Correct	Target Correct	
19		_Eyes	_Eyes	
20	subj01	-0.36425	-1.22654	
21	subj02	-0.83758	1.11043	
22	subj03	0.41509	-0.90724	
23	subj04	-0.70422	-0.83659	
24				

Figure 19-1. Statistic Extraction output of waveform data

This output file contains two analyses: one in cells A3 through C12, and the other in cells A14 through C23. In each analysis, the upper-left cell indicates the time window.

In Figure 19-1, N100 is the time window for the upper analysis, and P300 is the time window for the lower analysis. In the figure, except for the time window, the two analysis are identical to each other. The row below the time-window row contains a

description of the measure (in this case, mean amplitude), and how the measure is reported (in this case, averaged over channel group).

The columns in Figure 19-1 are organized hierarchically, with channel groups within categories. In other words, the categories are indexed first (changing the slowest), and channel groups are indexed second (changing the fastest). There is one row for each subject.

Statistic Extraction Specification Editor

Figure 19-2 shows the Statistic Extraction specification editor.

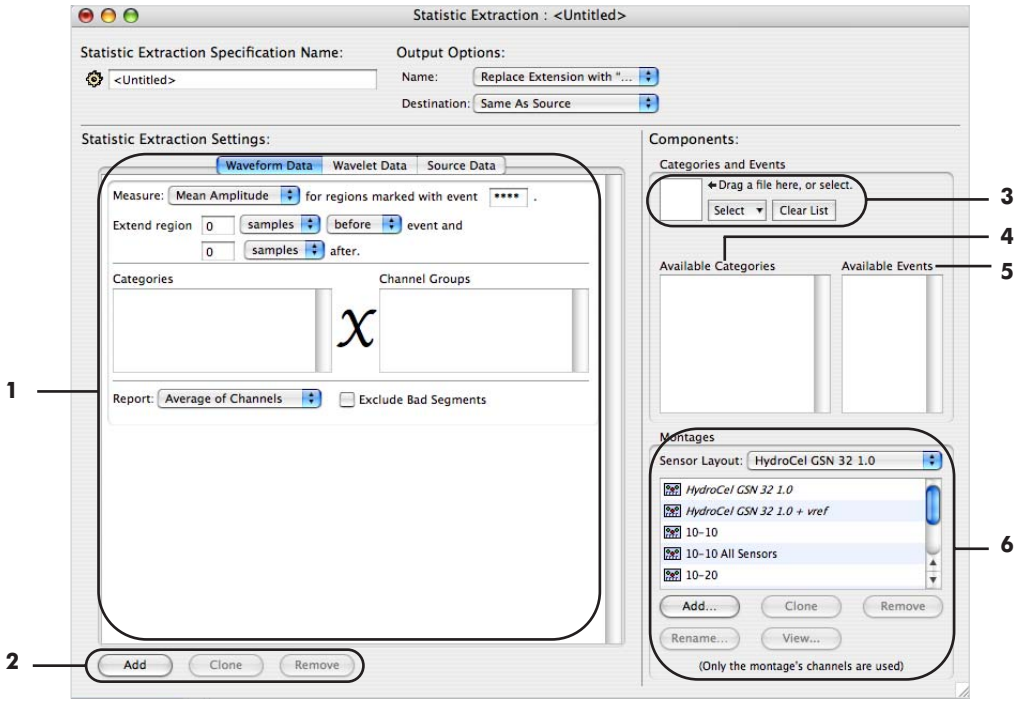


Figure 19-2. Statistic Extraction specification editor

The following are brief descriptions of the numbered items from Figure 19-2.

1. Analysis specification. Allows you to specify the parameters for a single analysis. For more information, see "Analysis Specification" on page 172.

2. Add/Clone/Remove buttons. Allow you to add, clone, and remove Analysis specifications (1). Note that, if necessary, the scroll bar to the right of the Analysis specification becomes active.

3. File selector. Lets you select files for the purpose of populating the Available Categories and Available Events panes (4, 5). For more information, see "The File Selector and Associated Display Panes" on page 46.

4. Available Categories pane. Displays a list of categories. You populate this list by using the file selector (3) to select one or more Net Station files. The categories are extracted from the file(s) you select. To specify the category parameter for an analysis, drag categories from this list to the Categories pane of an Analysis specification (1).

5. Available Events pane. Displays a list of events. You populate this list by using the file selector (3) to select one or more Net Station files. The events are extracted from the file(s) you select. To specify the time-window parameter for an analysis, drag events from this list to the event box of an Analysis specification (1).

6. Montage pane. Contains a montage list. The purpose of this pane is to enable you to specify the channel groups parameter for an analysis. You do this by dragging montages from the montage list to the Channel Groups pane of an Analysis specification (1). The Montage pane is discussed further in "Montage Pane" on page 181.

Analysis Specification

The Analysis specification allows you to specify the parameters for a single analysis of waveform data, source data, or wavelet data. The Statistic Extraction specification editor offers a pane for each data type.

Waveform Data Pane and Source Data Pane

Figure 19-3 shows an Analysis specification consisting of the Waveform Data pane.

Waveform data refers to the scalp data (in microvolts) acquired with your Geodesic EEG System, compared with *source data*, which are the cortex data (in nano-amp meters) derived by using EGI's GeoSource software. The two data types, however, are

similar, and thus the Waveform Data pane and the Source Data pane have the exact same controls. For conciseness, the following descriptions apply to both panes.

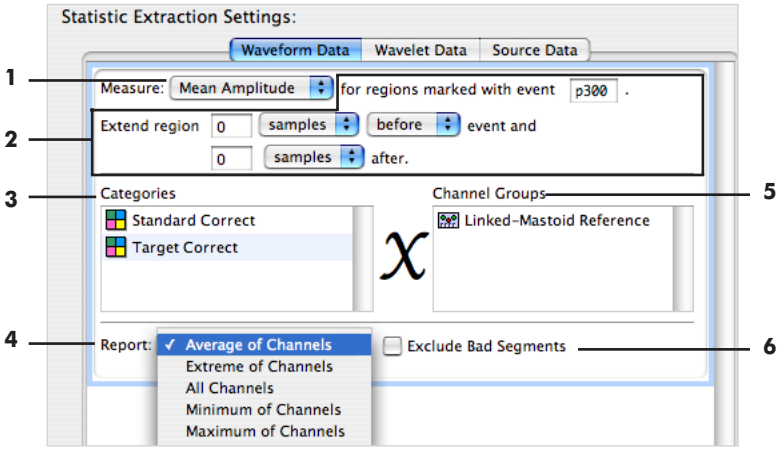


Figure 19-3. Analysis specification in the Waveform Data pane (same as the Source Data pane)

The following are brief descriptions of the numbered items from Figure 19-3.

1. ***Measure pop-up menu***. Allows you to choose one of the following measures:
   - *Mean Amplitude*: the mean voltage value is calculated from the time window.
   - *Adaptive Mean*: first, the algorithm finds a peak (maximum) within the time window. Then, a new time window is defined around this peak (maximum). The mean voltage value is calculated from the new time window. This measure requires additional parameters, specifying how to define the new time window. So, if you select this measure, additional controls appear. They are discussed in "Adaptive Mean Controls" on page 178.

Note: By "peak," we mean the maximum point in the window. In some cases, the maximum may occur on the edges of the time window, and technically not be a peak (that is, not have a rise and fall); see Figure 19-4.

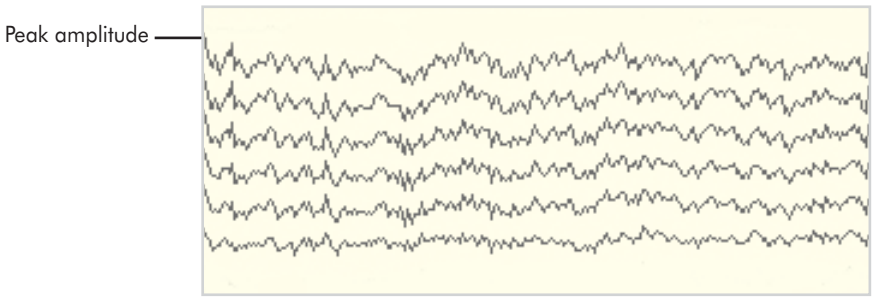


Figure 19-4. A "peak" value

- *Min Amplitude*: the minimum voltage value is calculated from the time window.
- *Max Amplitude*: the maximum voltage value is calculated from the time window.
- *Latency*: the latency of a point based on the peak (maximum; see Figure 19-4) amplitude is calculated. This measure requires additional parameters, specifying how to locate the point. So, if you select this measure, additional controls appear. They are discussed in "Latency Controls" on page 179. The returned value is reported in Segment Time (that is, the time with respect to the sample to which the segmentation was temporally referenced).

2. ***Time window specification***. Allows you to specify the time window for the analysis by using events. You can type an event code directly into the text box or drag an event code from the Available Events panel. You can extend the time window before and/or after the event in terms of samples or milliseconds.

3. ***Categories pane***. Allows you to specify the categories parameter for the analysis. You populate this pane by dragging one or more categories from the Available Categories pane.

4. Report pop-up menu. Allows you to specify how to report the statistics for each channel group. You have the following choices:

- *Average of channels*: the measure will be calculated for each channel within the channel group and then averaged across all channels. The reported value will be a single value representing the average of the voltage value for that channel group.
- *Maximum of channels*: the measure will be calculated for each channel within the channel group. The reported value will be a single maximum voltage value (that is, datum from the channel that has the largest positive voltage value) for that channel group. If there are no positive values, the smallest negative voltage value will be reported.
- *Minimum of channels*: the measure will be calculated for each channel within the channel group. The reported value will be a single minimum voltage value (that is, datum from the channel that has the largest negative voltage value) for that channel group. If there are no negative voltage values, the smallest positive voltage value will be reported.
- *Extreme of channels*: the measure will be calculated for each channel within the channel group. The reported value will be a single voltage value that represents the extreme value over the entire channel group.
- *All channels*: the measure will be calculated for each channel within the channel group. The value for every channel will be reported.

5. Channel Groups pane. Allows you to specify the channel groups parameter for the analysis. You populate this pane by dragging one or more channel groups from the Montage list.

6. Exclude Bad Segments checkbox. Allows you to exclude bad segments from the output file.

Wavelet Data Pane

Wavelet data are produced when you run the Wavelet tool on your data. Figure 19-5 shows an Analysis specification consisting of the Wavelet Data pane.

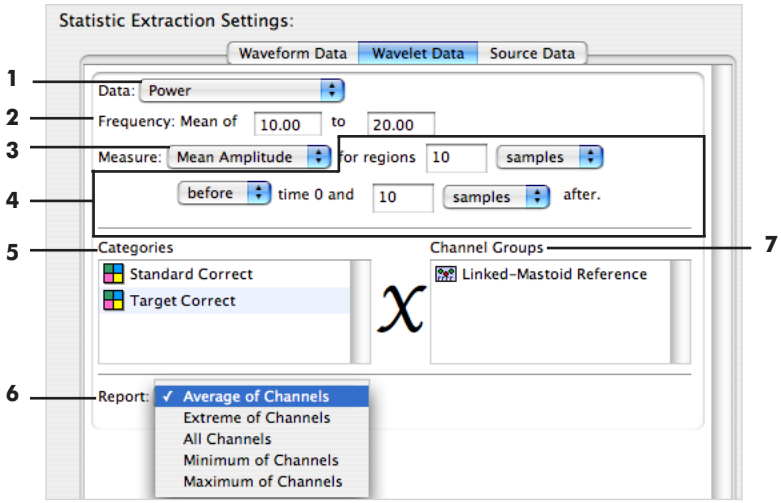


Figure 19-5. Analysis specification in the Wavelet Data pane

The following are brief descriptions of the numbered items from Figure 19-5.

1. ***Data pop-up menu***. Allows you to choose one of the following data types:

   - *Power*: represents the amplitude squared, which is a measure of the magnitude. May be used to judge the strength of the particular component being examined.
   - *Circular Variance*: represents a measure of the phase stability. If the value is close to 0, the phase is very stable; if the value is close to 1, the phase is much more random. Often used in single-trial analysis to show periods of correlated and uncorrelated activity across trials.

2. ***Frequency text boxes.*** Allows you to specify the frequency window for the analysis. The Statistic Extraction tool takes the mean of the frequencies in that window, reducing them into one time series.

3. ***Measure pop-up menu***. Allows you to choose one of the following measures:

   - *Mean Amplitude*: the mean voltage value is calculated from the time window.
   - *Adaptive Mean*: first, the algorithm finds a peak (maximum; see Figure 19-4 on page 174) within the time window. Then, a new time window is defined around this peak (maximum). The mean voltage value is calculated from the new time window. This measure requires additional parameters, specifying how to define the new time window. So, if you select this measure, additional controls appear. They are discussed in "Adaptive Mean Controls" on page 178.
   - *Min Amplitude*: the minimum voltage value is calculated from the time window.
   - *Max Amplitude*: the maximum voltage value is calculated from the time window.
   - *Latency*: the latency of a point based on the peak (maximum; see Figure 19-4 on page 174) amplitude is calculated. This measure requires additional parameters, specifying how to locate the point. So, if you select this measure, additional controls appear. They are discussed in "Latency Controls" on page 179. The returned value is reported in Segment Time (that is, the time with respect to the sample to which the segmentation was temporally referenced).

4. ***Time window specification***. Allows you to specify the time window for the analysis by using events. You can type an event code directly into the text box or drag an event code from the Available Events panel. You can extend the time window before and/or after the event in terms of samples or milliseconds.

5. ***Categories pane***. Allows you to specify the categories parameter for the analysis. You populate this pane by dragging one or more categories from the Available Categories pane.

6. ***Report pop-up menu***. Allows you to specify how to report the statistics for each channel group. You have the following choices:

   - *Average of channels*: the measure will be calculated for each channel within the channel group and then averaged across all channels. The reported value will be a single value representing the average of the voltage value for that channel group.

- *Maximum of channels*: the measure will be calculated for each channel within the channel group. The reported value will be a single maximum voltage value (that is, datum from the channel that has the largest positive voltage value) for that channel group. If there are no positive values, the smallest negative voltage value will be reported.
- *Minimum of channels*: the measure will be calculated for each channel within the channel group. The reported value will be a single minimum voltage value (that is, datum from the channel that has the largest negative voltage value) for that channel group. If there are no negative voltage values, the smallest positive voltage value will be reported.
- *Extreme of channels*: the measure will be calculated for each channel within the channel group. The reported value will be a single voltage value that represents the extreme value over the entire channel group.
- *All channels*: the measure will be calculated for each channel within the channel group. The value for every channel will be reported.

7. ***Channel Groups pane***. Allows you to specify the channel groups parameter for the analysis. You populate this pane by dragging one or more channel groups from the Montage list.

Adaptive Mean Controls

The Adaptive Mean algorithm first finds a peak (maximum; see Figure 19-4 on page 174) within the time window. Then, a new time window is defined around this peak (maximum). The mean voltage value is calculated from the new time window.

The Adaptive Mean measure requires additional parameters, specifying how to define the new time window. So, if you select Adaptive Mean as your measure, additional controls appear. Figure 19-6 shows an Analysis specification with the Adaptive Mean controls.

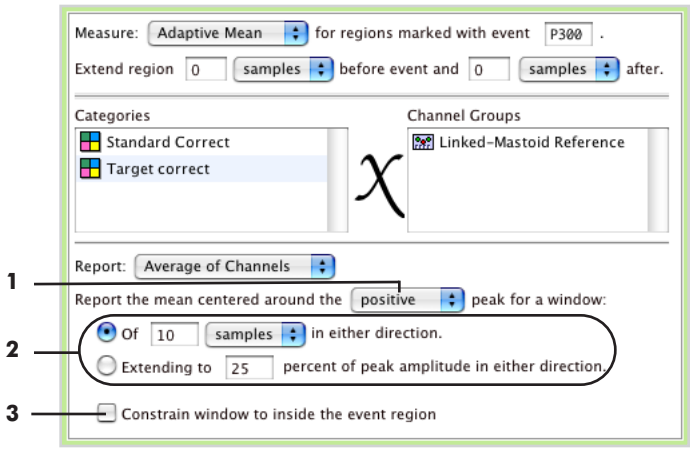


Figure 19-6. Adaptive Mean controls

The following are brief descriptions of the numbered items from Figure 19-6.

1. Peak-direction pop-up menu. Allows you to specify whether the adaptive mean is based on a positive or negative peak (that is, an upward-pointing maximum or a downward-pointing minimum).

2. Samples/percent-peak radio buttons. Allow you to specify whether the width of the new window is a fixed number of samples or a percent of the peak (maximum) amplitude. For each option, there is a text box for specifying the number of samples/percent-peak for the width of the new window.

3. "Constrain window to inside the event region" checkbox. When checked, this box causes the new window to be truncated to fit in the time window specified by the time-window specification, described in "Analysis Specification" on page 172.

Latency Controls

The latency of a point based on the peak (maximum; see Figure 19-4 on page 174) amplitude is calculated. Either the latency of the peak amplitude is calculated, or the latency of a point where the amplitude is a specific percent of the peak amplitude is calculated. In the latter case, you can specify the percentage of the peak amplitude to use and whether to use a point before or after the peak.

Note: If there are two peaks of the same value in the same time range, Net Station will report the latency of the first peak.

The Latency measure requires additional parameters, specifying how to locate the point. So, if you select Latency as your measure, additional controls appear. Figure 19-7 illustrates the Latency controls.

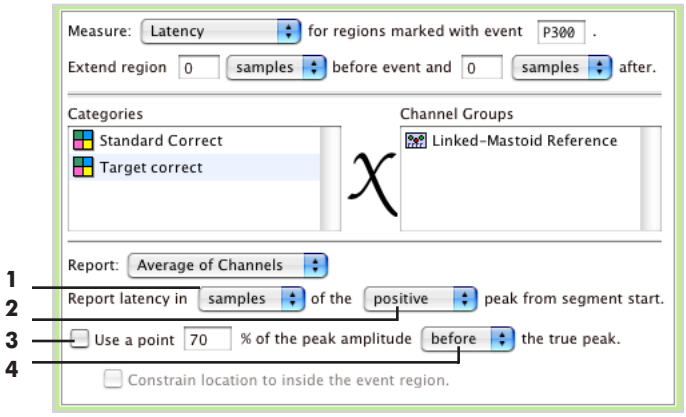


Figure 19-7. Latency controls

The following are brief descriptions of the numbered items from Figure 19-7.

1. Samples/milliseconds pop-up menu. Allows you to specify whether the latency is reported in terms of samples or milliseconds.

2. Peak-direction pop-up menu. Allows you to specify whether the latency is based on a positive or negative peak (that is, an upward-pointing maximum or a downward-pointing minimum).

3. Percent-peak amplitude checkbox. When this box is checked, the latency of a point where the amplitude is a specific percent of the peak (maximum) amplitude is used. There is a text box for specifying the percent of the peak amplitude, and a pop-up menu for specifying whether to use a point before or after the peak.

4. "Constrain location to inside the event region" checkbox. When this box is checked, the point is forced to fall inside the time window specified by the time-window specification, described in "Analysis Specification" on page 172. If the point falls before the time window, the first point of the time window is used. If the point falls after the window, the last point of the time window is used.

Montage Pane

The purpose of this pane is to allow you to specify the channel groups parameter for an analysis. You do this by dragging montages from the Montage list to the Channel Groups pane of an Analysis specification.

Note that only channel selection information from montages is used by Statistic Extraction. Information related to reference channels is ignored. If the reference channel information is required, you must rereference the data first using the Montage Operations tool.

Figure 19-8 shows the components of this pane.

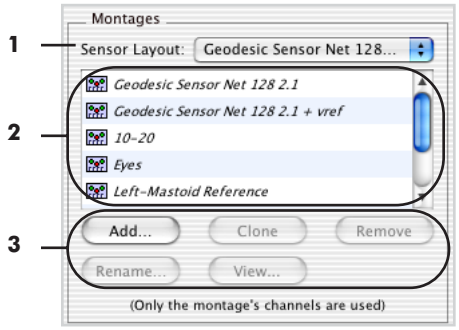


Figure 19-8. Montage pane

The following are brief descriptions of the numbered items from Figure 19-8.

1. Sensor Layout pop-up menu. Lists the EGI source Nets. You can select a Net to display its available montages in the Montage list (2).

2. Montage list. Displays the list of montages for the Net selected in the Sensor Layout pop-up menu (1). To specify the channel groups parameter for an analysis, you can drag montages from this list to the Channel Groups pane of an Analysis specification.

Note: For source data, the montages available are the same montages related to dipole sets (Figure 19-9).

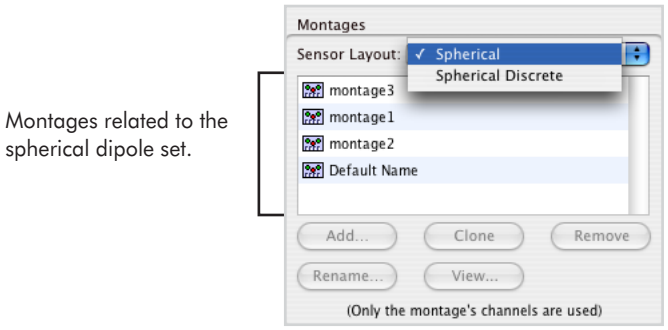


Figure 19-9. Montage pane for source data

3. Montage editor buttons. Let you create (New), View, Delete, copy (Clone), and Rename montages. The New and View buttons open the Net Station Montage editor. (For more information on the Net Station Montage editor, see the *Net Station Viewer Technical Manual*.) By having access to the Montage editor from here, it is convenient to create montages specifically for use as channel groups.

Note: Because Statistic Extraction ignores information related to reference channels, when you open the Net Station Montage editor from here, all the controls that are related to reference channels are disabled.

chapter 20

T-TEST

Concepts

The t-test tool is designed to operate on Net Station, EGIS, or simple-binary Combination files. The t-test tool compares categories between multiple subjects to determine if there is a statistical difference between categories.

The tool can operate on a single file containing multiple subjects or on multiple files, each containing a different subject but with the same sensor layout. The input files must be segmented and averaged. The t-test tool reports subjects who are missing one or more categories and omits such subjects from its calculations. Subjects who contribute to the results are listed in the file's History pane. T-test will fail to run if there is only one subject with all the data.

The results are output to a modified Net Station file called a *t-file*.

T-test Background

The t-test is a commonly used statistical technique that enables you to test a hypothesis regarding population means, when the population standard deviation is unknown.

A hypothesis test compares a sample mean with the sampling distribution of the mean. If the resulting number from that ratio is larger than the level of significance (determined by referring to a table of significance), then the outcome is not likely to have occurred by chance and is considered *statistically significant*.

The t-test comes in various versions, depending on the number of samples and the relationship between samples. Some tests are designed for a single sample, two independent samples, or two dependent samples.

T-test Waveform Tool

The t-test tool is designed for two dependent samples. The tool outputs a Net Station file that displays t-values and standard errors for each channel at each timepoint. The output file is described further beginning on page 185.

Overview of t-test Statistics

This section broadly outlines the statistics underlying the t-test Waveform Tool; it is not a primer on statistics. For that, please refer to a basic statistics textbook, such as:

- Witte, R.S. (1985). *Statistics* (2nd ed.). New York, NY: CBS College Publishing

The t-test Waveform Tool compares the *average difference* between two samples with the standard error of that *difference*. By taking the difference, we are essentially converting a two-sample test into a one-sample test.

Figure 20-1 and Figure 20-2 portray a simplified view of the t-test for two dependent samples. Here, we take the difference between the two samples, plot it as one line graph, determine the mean, and compare that mean with the mean of the normal distribution, which is called the *t distribution*.

Sample 1	Sample 2	Difference
5	9	–4
6	8	–2
6	9	–3
5	7	–2
...	...	...

Figure 20-1. Difference between two samples

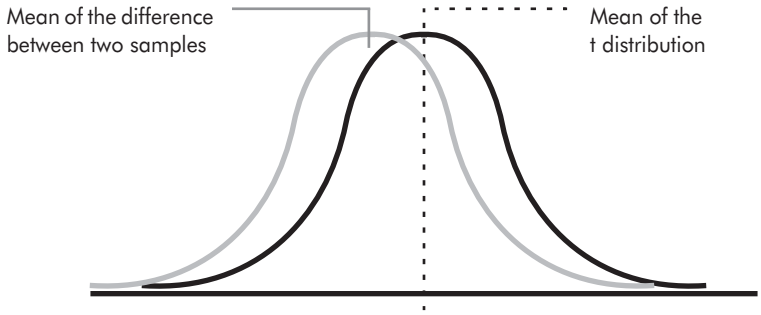


Figure 20-2. The mean of two samples compared with the mean of the t distribution

Mathematically, this relationship can be expressed by a simplified formula:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{SE(\bar{X}_1 - \bar{X}_2)}$$

where $\bar{X}_1$ and $\bar{X}_2$ are the means of the first and second samples, respectively; and *SE* is the standard error. The resulting *t-value* indicates how far the mean of the difference is from the mean of the t distribution.

Each t distribution is associated with a number that is the sample size minus one, called the *degrees of freedom*. After calculating the t-value, you can refer to a table of significance, look up your degrees of freedom and the level of significance you want (.05,.01, or .001, for example), and find the critical value of t. If the t-value is larger than the critical value, then the difference between your two samples is statistically significant.

Two- or Four-Cell Test

The t-test Waveform Tool contains four cells into which you may enter categories for comparison. The cells are arranged in a two-column by two-row format. You can enter categories into two cells or four cells.

Two Cells

With a two-cell t-test, you enter the categories into the *columns*, not the rows.

Caution!: *If you enter categories into the rows and try to save the t-test specification, an error message appears.*

The tool compares the relationship between the two columns. If you enter values such as:

a	b

the tool performs a t-test of the mean of **cell a** compared with the mean of **cell b**.

For example, you might have an experiment where subjects read a list of words and indicate for each word whether it has a positive (“good”) or negative (“bad”) connotation. You could enter “good” into cell a and “bad” into cell b.

good	bad

The two-cell t-test would compare the mean of the EEG data evoked by the "good" words with that of the "bad" words to determine whether subjects had a stronger response to either word type.

The results are output to a t-file. The t-file for a two-cell t-test includes two categories:

- Column t-test
- Column t-test Error

The Column t-test category contains the t-values for each channel at each timepoint, and the Column t-test Error category shows the standard error of the difference for each channel at each timepoint. You can view these data by rolling your cursor over the data; Figure 20-3 shows the t-test pop-up window for the Column t-test category, displaying information regarding the time, channel number, and t-value.

Figure 20-3. T-test pop-up window

The formula for a two-cell t-test with a and b categories is:

$$t_1 = \frac{\sum (a_i - b_i)/n}{S_{(a-b)}/(\sqrt{n})}$$

where *a* is the first sample, *b* is the second sample, *n* is the number of values, and *S* is the standard error.

Four Cells

To expand on the example given in "Two Cells" on page 185, let us have the subjects indicate not only if a word has a positive ("good") or a negative ("bad") connotation, but also whether it applies ("yes") or does not apply ("no") to themselves. This would result in four complex categories, each consisting of two traits.

With our word experiment, we would enter "good-no" and "good-yes" into column a-c, and "bad-no" and "bad-yes" into column b-d, so that the columns and rows are crossed ("good" and "bad" in each column, and "no" and "yes" in each row):

	(good)	(bad)
(no)	**a**	**b**
(yes)	**c**	**d**

The tool compares the relationships between the columns, the rows, and the *interaction* between the columns and rows (the interaction qualifies the main effects).

The resulting three t-tests are:

- a t-test of the mean of cells **a and c** compared with the mean of cells **b and d** (a *Column t-test*)
- a test of the mean of cells **a and b** compared with the mean of cells **c and d** (a *Row t-test*)
- a t-test of the *difference* between **cells a and b** compared with the *difference* between **cells c and d** (an *Interaction t-test*)

Because the cells contain compound categories (such as "bad-no," rather than simply "bad"), the interaction allows us to separate the traits in the categories. This allows us to show how a main effect (for example, bad words having a greater medial frontal negativity) is qualified by the interaction (a greater response of "yes" to bad words).

The results are output to a t-file that includes six categories:

- Column t-test
- Column t-test Error
- Row t-test
- Row t-test Error
- Interaction t-test
- Interaction t-test Error

The Column, Row, and Interaction t-test categories contain the t-values for each channel at each timepoint for each respective comparison; the Column, Row, and Interaction t-test Error categories show the standard error of the difference for each channel at each timepoint for each respective comparison. You can view these data by rolling your cursor over the data (for an example, see Figure 20-3 on page 186).

The formulas for the four-cell t-test are:

for columns

$$t_1 = \frac{\sum[(a_i + c_i) - (b_i + d_i)]/n}{S_{(a+c)-(b+d)}/(\sqrt{n})}$$

for rows

$$t_2 = \frac{\sum[(a_i + b_i) - (c_i + d_i)]/n}{S_{(a+b)-(c+d)}/(\sqrt{n})}$$

for interaction

$$t_{1\times 2} = \frac{\sum[(a_i - b_i) - (c_i - d_i)]/n}{S_{(a-b)-(c-d)}/(\sqrt{n})}$$

T-test Specification Editor

Figure 20-4 shows the t-test specification editor.

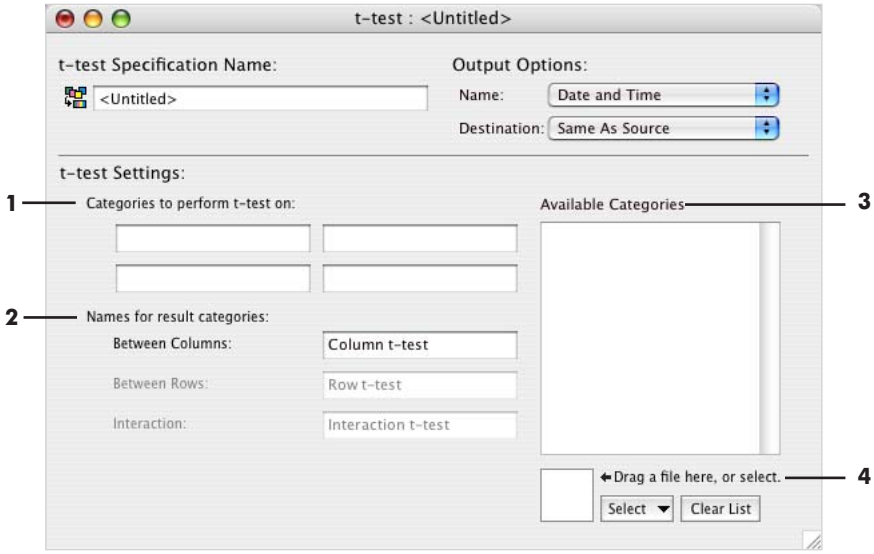


Figure 20-4. T-test specification editor

The following are brief descriptions of the numbered items from Figure 20-4.

1. "Categories to perform t-test on" text boxes. Categories that are used in the t-test. Populate these text boxes by typing in category names, or by dragging category names from the Available Categories pane (3) to these boxes.

2. "Names for result categories" text boxes. Names for the t-values produced by the Column, Row, or Interaction t-tests. You can replace the default names by swiping and typing.

3. Available Categories pane. Displays a list of categories. You populate this list by using the file selector (4) to select one or more Net Station files. The categories are extracted from the file(s) you select. To choose categories for a t-test, drag them from this list to the "Categories to perform t-test on" text boxes (1).

4. File selector. Lets you select files for the purpose of populating the Available Categories pane (3). For more information, see "The File Selector and Associated Display Panes" on page 46.

chapter 21

WAVELET

Concepts

The Wavelet tool is designed to operate on Net Station segmented or Combination files. It operates only on data from good channels.

The tool performs a wavelet transformation on Net Station data, decomposing the EEG signal into its temporal and frequency components and outputting this information in a Wavelet file.

Wavelet Analysis

Wavelet analysis can provide both temporal and frequency information because it uses a scale-varying basis function: the wavelet.

Net Station uses the Morlet wavelet, which is created by multiplying a sinusoidal wave (Figure 21-1; left) by a Gaussian envelope (middle). The result is a small wave that oscillates with varying amplitude within a finite period, concentrating its energy around a point in time (right).

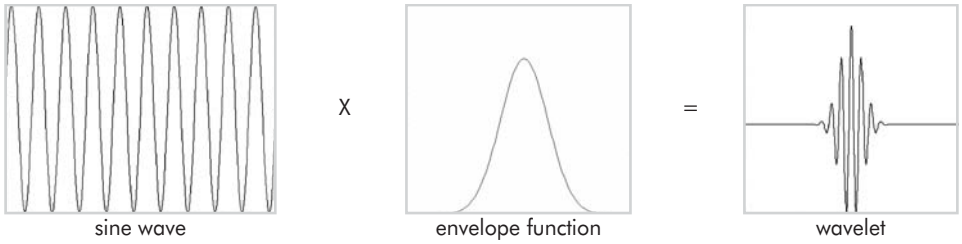


Figure 21-1. Sine wave (left) multiplied by an envelope function (middle) produces a wavelet (right)

In wavelet transformation, a wavelet can be considered similar to a frequency-selective "window" that is convolved (shifted) along a signal in the time domain to determine the degree to which the frequency content of the signal corresponds to that of the wavelet.

The convolution reveals the magnitude of the correspondence, which is represented by the *wavelet coefficient*. Magnitude is indicated by units of power (which is amplitude squared). A high wavelet coefficient indicates a high correspondence between the frequencies measured by the wavelet and the frequencies contained in a localized section of the signal. A low coefficient indicates a low correspondence.

(The wavelet coefficient also provides information about phase stability, which indicates whether activity is correlated across trials; this is described further in Chapter 12, "Wavelet Display," in the *Net Station Viewer Technical Manual*.)

Compressing or dilating the wavelet in time creates other members of the wavelet family, enabling you to adjust the frequency selectivity of the wavelet. Compressed wavelets measure higher frequencies; dilated wavelets measure lower frequencies. Each member of the wavelet family is convolved with the EEG signal in the time domain to determine the presence of other frequency ranges.

Note: In the frequency domain, a wavelet is in effect a bandpass filter, and a series of wavelets is similar to a filter bank.

In essence, we are filtering different frequency bands, cutting these bands into slices in time, and analyzing their energy content. The result is a signal whose frequency content is localized in time by the values of its wavelet coefficients; the wavelet coefficients for each position and frequency of the scaled wavelets can be plotted on a graph. Net Station displays this information in the Wavelet Display (see the *Net Station Viewer Technical Manual*).

Resources for newcomers to wavelets include:

- Graps, A. (1995–2004). Amara's wavelet page. Retrieved from http://www.amara.com/current/wavelet.html
- Herrmann, C.S., Grigutsch, M., & Busch, N.A. (2005). EEG oscillations and wavelet analysis. In T.C. Handy (Ed.), *Event-related potentials: A methods handbook* (pp.229–259). Cambridge: MIT Press.
- Valens, C. (1999). A really friendly guide to wavelets. Retrieved from http://perso.wanadoo.fr/polyvalens/clemens/wavelets/wavelets.html

Wavelets in Net Station

Wavelet transforms can occur in either the time domain or the frequency domain. For computational efficiency, Net Station uses the fast Fourier transform in the frequency domain, rather than convolution in the time domain.

The Morlet wavelet, used by Net Station, is a Gaussian-modulated sinusoid. Morlet wavelets are symmetrical and feature gentle, irregularly shaped curves that are suitable for analyzing biological signals such as EEG. Figure 21-2 shows the Morlet and other common wavelets.

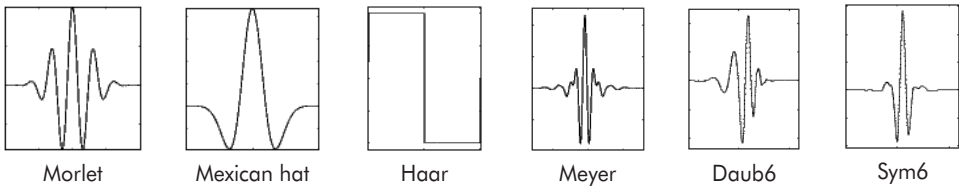


Figure 21-2. Common wavelet shapes

Frequency Scale Factor and Frequency Step

The Wavelet specification editor (Figure 21-5 on page 197) enables you to generate a wavelet family by specifying the following parameters:

- frequency scale factor (fsf)
- starting frequency
- ending frequency
- frequency step (or resolution)

The fsf determines the width of the wavelet by specifying the number of oscillations in time, thus stretching or compressing the wavelet. For a given center frequency, a smaller fsf produces a wider wavelet, and a larger fsf yields a narrower wavelet in the frequency domain (see Figure 21-3).

The frequency step determines the constant spacing between successive center frequencies (f_0) of the wavelets. A smaller frequency step produces more wavelets, and a larger frequency step results in fewer wavelets.

The fsf and each wavelet's center frequency (which is implicitly specified through the combination of starting frequency and frequency step) parameterize the wavelets such that:

$$fsf = f_0 / \sigma_f \Leftrightarrow \sigma_f = f_0 / fsf$$

Figure 21-3 shows that wider wavelets in the time domain result in more timepoints being considered in the wavelet analysis and produce higher resolution in the frequency domain. The inverse is true; narrower wavelets in the time domain result in fewer timepoints being considered in the wavelet analysis and produce lower resolution in the frequency domain.

The top images show a wavelet compressed at different scales in the time domain; directly beneath each image is the wavelet's resolution in the frequency domain. Notice the inverse nature of time–frequency resolution; for example, in the first image the temporal resolution is poor (spread over many timepoints) but the frequency resolution is good (narrowly centered about a frequency range). *(Images created in Matlab.)*

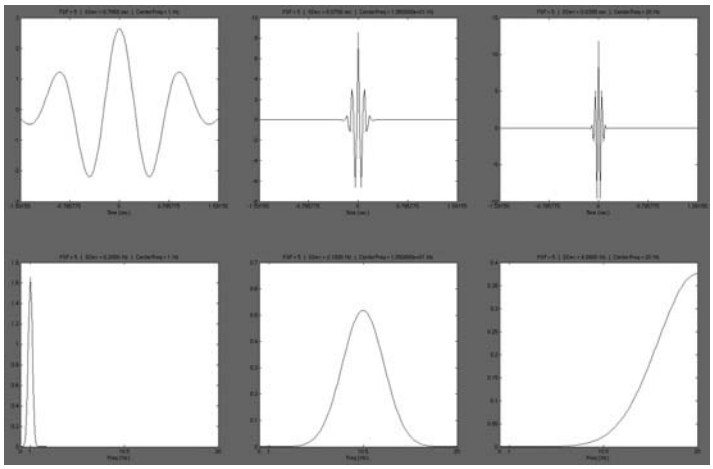


Figure 21-3. Compressed and dilated wavelets: in (top) time domain and (bottom) frequency domain

Striking a Balance between fsf and Frequency Step

The Wavelet specification editor contains a sum-of-power graph that plots frequency widths based on user-entered values for fsf, frequency step, and frequency range.

In the Wavelet specification editor, you should choose the fsf and the frequency step so that the frequency widths of the wavelets overlap *sufficiently*. If they overlap too much, the sum of the power over the wavelets will be erratic, resulting in a biasing toward specific frequencies. If they overlap too little, certain frequencies may not be measured at all.

Well-chosen settings will result in a sum of power that is *constant* (or flat) over the frequency range of interest. To achieve this balance, a smaller fsf may call for a larger frequency step and vice versa.

In Figure 21-4, the following numbers were entered into the specification editor:

- *fsf*: 7
- *frequency step*: 2 Hz
- *starting frequency*: 10 Hz
- *ending frequency*: 100 Hz

Note: Because of the relationship among fsf, frequency step, and frequency range, the Wavelet tool will not use the exact user-entered values; instead, it will find the nearest actual values that will allow the equations to work (see the following section entitled "Net Station's Values").

As Figure 21-4 suggests, these settings are suitable for the approximate frequency range of 30 –100 Hz.

Keep in mind that various combinations of fsfs and frequency steps may produce similar-looking sum-of-power graphs, but will not yield identical time-frequency analyses because of the differences in fsf values. The fsf values determine the widths of the wavelets in the frequency and time domains (and, hence, their interrelated resolutions); consequently, the user must choose an fsf that achieves an acceptable tradeoff between frequency resolution and temporal resolution.

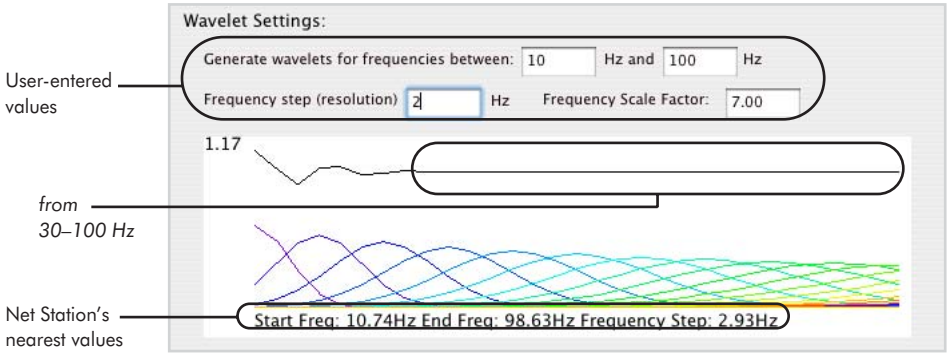


Figure 21-4. Sum-of-power plot in the Wavelet specification editor

Net Station's Values

The graph in the Wavelet specification editor is designed to guide your selection of settings. To calculate the values it displays, the graph assumes that the data segment is one second in length and has a sampling rate of 1,000 samples per second. Consequently, the user-entered values for the settings are often adjusted to fit these parameters (see the bottom of Figure 21-4).

When running the Wavelet tool on your file, the user-entered values are adjusted to fit the parameters of your actual data segment (the tool settings are displayed in the File History window, which is opened by choosing **Edit > File Info > History**). Because data transformations from the time domain to the frequency domain require sequences of exactly power-of-two length, the tool also "zero-pads" the data segment to the next power of two.

Viewing Wavelet Data

You can view the resulting wavelet data in the Net Station Viewer, as either power or circular variance values, and in either Grid or Topo Plot view. For more information, see the *Net Station Viewer Technical Manual*.

Note: If baseline correction is included in the Wavelet Waveform Tool, then negative power values are possible.

For information about running the Statistic Extraction tool on your wavelet data, see "Wavelet Data Pane" on page 176.

Wavelet Specification Editor

Figure 21-5 shows the Wavelet specification editor.

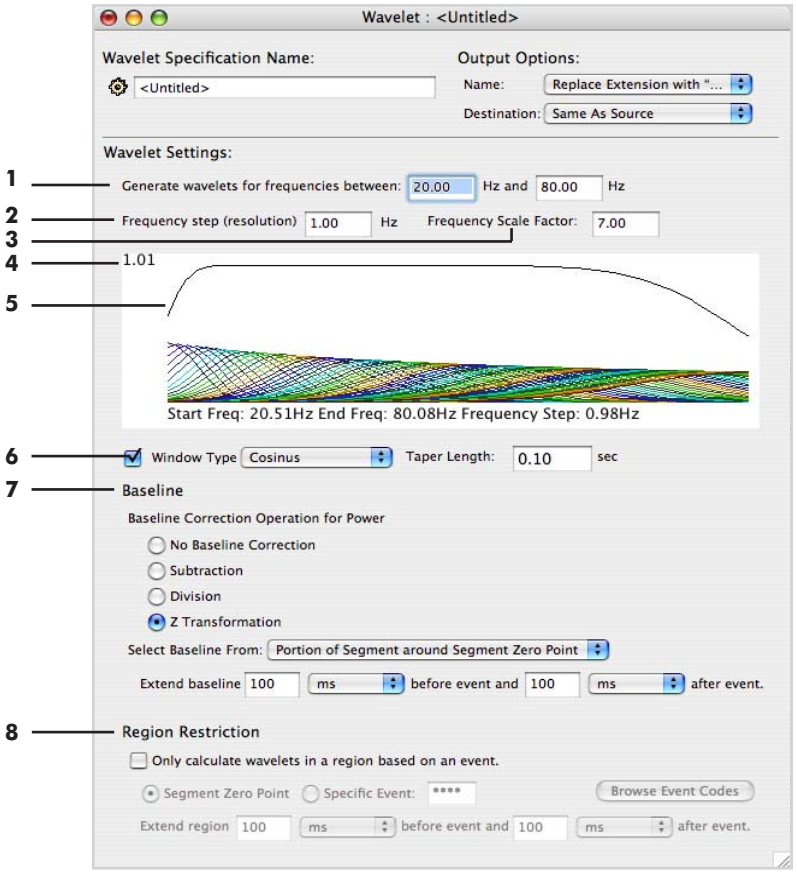


Figure 21-5. Wavelet specification editor

The following are brief descriptions of the numbered items from Figure 21-5.

1. "Generate wavelets for frequencies between" text boxes. Allows you to enter the nominal starting and ending frequencies for the wavelet family.

2. "Frequency step" text box. Allows you to determine the number of wavelets by specifying the constant spacing between the successive center frequencies of the wavelets. A smaller frequency step produces more wavelets; a larger frequency step yields fewer wavelets.

3. "Frequency scale factor" text box. Allows you to determine the width of the wavelets by specifying a fixed ratio between the center frequency [implicitly defined in the "frequency step" text box (2)] and the wavelet width. The user must make a tradeoff between frequency and temporal resolution when specifying the fsf value.

4. Sum of power. Displays the sum of power of the wavelets.

5. Sum-of-power graph. Plots the sum of power over the wavelets in the frequency domain, which enables you to determine if the fsf and frequency step are appropriately defined for the frequency range. The graph should be flat over the frequency range of interest.

6. Window Type checkbox and controls. These controls taper the data, smoothing the discontinuities at the ends of a segment before wavelet analysis is performed. Following are descriptions of the window types and the Taper Length text box:

- *Parzen*: a weighted moving-average transformation that smooths the power values for each frequency by assigning the greatest weight to the observation being smoothed in the center of the window, and increasingly smaller weights to values that are farther away from the center.
- *Cosinus*: sums individual terms to form the window, so that the low-frequency peaks in the frequency domain combine in such a way as to decrease sidelobe height. This has the side effect of increasing the mainlobe width.
- *Taper Length text box*: allows you to specify the amount of data to taper on the ends of the segment, in terms of seconds. The maximum tapering amount is one-half the total segment length. If the value entered into this text box is too large, the Wavelet tool automatically reduces the tapering amount to the maximum. Figure 21-6 shows how the taper length affects the window shape.

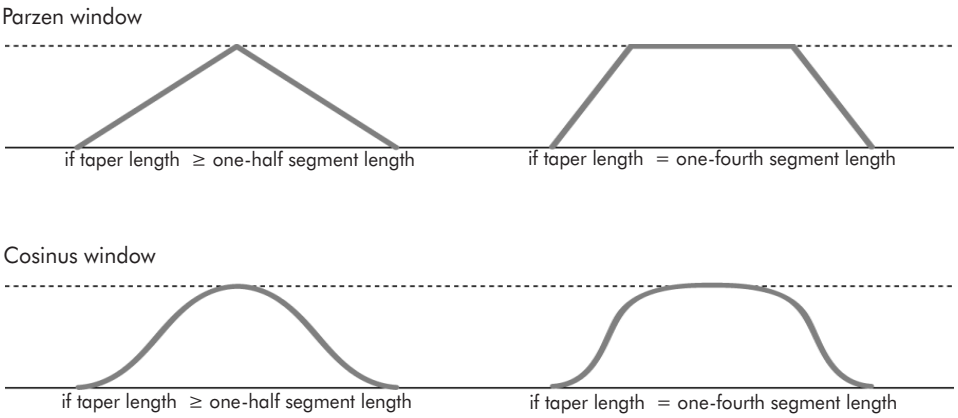


Figure 21-6. Effect of the taper length on the shape of the Parzen and Cosinus window

As Figure 21-6 shows, a taper length greater than or equal to one-half the segment length applies the window to the entire segment. Taper lengths of smaller values result in larger portions of the segment remaining unaffected.

7. Baseline controls. Compares the power of a particular timepoint relative to another timepoint (a reference point), to establish a new zero-power value based on a *baseline interval* that you select within your segment. The controls allow you to select the baseline method and baseline interval:

- *Baseline method*:
  - *No Baseline Correction:* applies no correction.
  - *Subtraction*: subtracts the mean from each datapoint (this is useful if you have oscillatory EEG activity that is present or not present depending on the cognitive event).
  - *Division*: divides each datapoint by the mean of the baseline (this is useful if you have oscillatory EEG activity that modulates its amplitude according to the cognitive event).
  - *Z Transformation*: determines each datapoint's standard deviation from the baseline mean (this is useful if you wish to obtain a measure of how many standard deviations you are above or below the baseline power).
- *"Select Baseline From" pop-up menu and text boxes*: These controls allow you to select one of the following on which to base the baseline interval:
  - *Segment Zero Point*: specifies the segment zero point (Segment Time = 0; see page 131 for more information) as the reference point for the baseline interval; additional controls allow you to specify the length of the interval, in samples or milliseconds.
  - *Entire Segment*: specifies the length of the entire segment as the baseline interval.

8. Region Restriction checkbox and pane. When the checkbox is selected, this pane enables you to identify a portion of a segment for which to calculate wavelets. The "Region Restriction" controls include:

- *Segment Zero Point*: calculates wavelets inside regions specified with respect to the segment's zero point (Segment Time = 0; see page 131 for more information). You can specify the size of the region before or after the event in samples or milliseconds.
- *Specific Event*: calculates wavelets in regions specified with respect to a specific event. You specify whether to restrict the wavelet calculation to regions inside or outside the region defined by the event. You can specify the size of the region

before or after the event in samples or milliseconds. To specify events, either type in the 4-character event code or click the Browse Event Codes button to extract a list of event codes.

- *Browse Event Codes button*. When clicked, this button opens the Browse Event Criteria window for extracting events from files that you select. (For more information about this window, see the *Net Station Viewer Technical Manual*.) Select an event code in the window and drag it to the Specific Event text box.

appendix A

SOFTWARE TECHNICAL SUPPORT

Before Contacting EGI

Please check the Contents on page v and the Index on page 209 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.

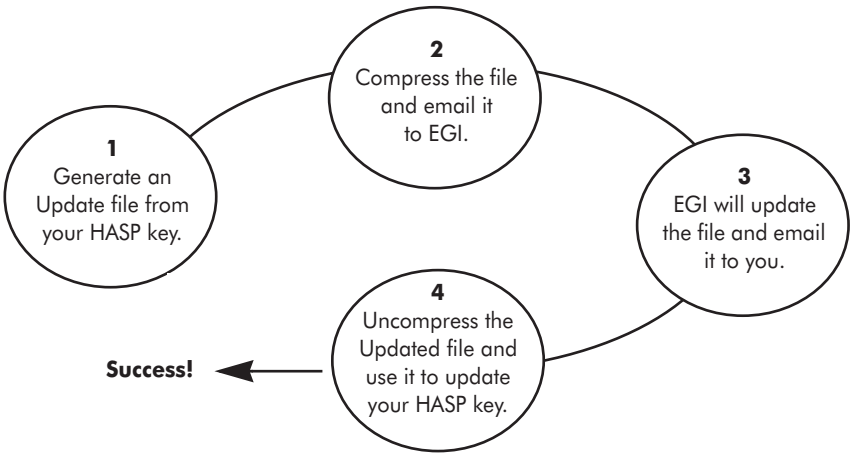


Figure B-1. Overview of the license-updating process

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.

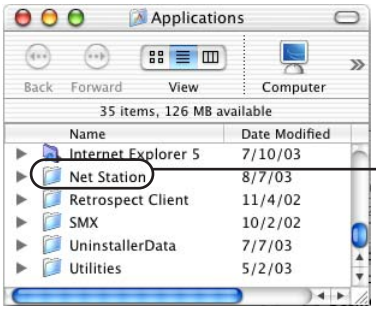
Figure B-2. HASP-updating tips

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.

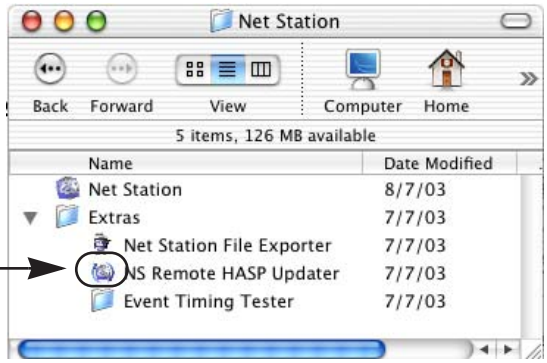
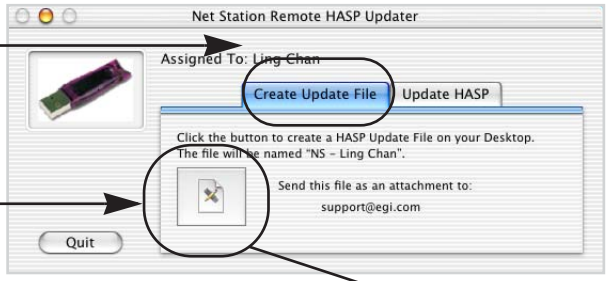


Figure B-3. Open the HASP Updater application

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.

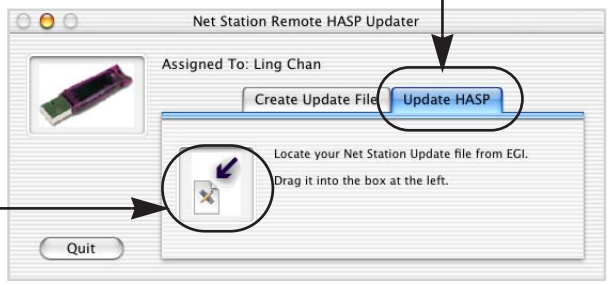
3 Insert the ***corresponding*** HASP key into the USB port at the side of your keyboard or at the back of your computer. A light should illuminate within the key.

4 Open the Net Station install folder in the Applications folder on your hard drive.

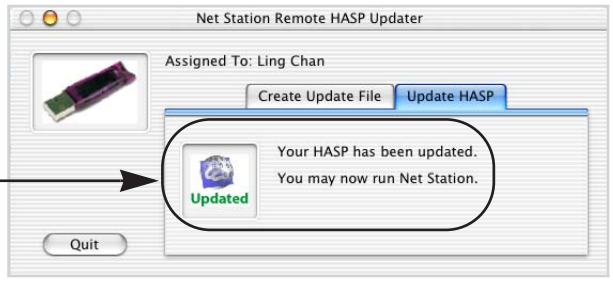
5 Double-click on the NS Remote HASP Updater icon, which will open the Updater dialog.

6 Make sure that the Update HASP tab is frontmost in the Updater dialog.

7 Drag the Updated file into the Update box.



8 A dialog will appear, with a message indicating a successful update.



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.

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