NeuroMap Software User Guide

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1. NeuroMap Software

1.1. Intended Use

NeuroMap software analyzes data from the Trigno Wireless Biofeedback System for biofeedback purposes and for research purposes. The Trigno system is a battery-powered biofeedback device that enables clinicians and researchers to acquire EMG and related biofeedback signals for relaxation training and muscle re-education. NeuroMap software provides the clinician and the researcher a mathematical analysis of the biofeedback data acquired with the Trigno System. Interpretation of the NeuroMap software output and supporting signals by a qualified individual is required.

Rx Only

Please refer to the Trigno Wireless Biofeedback System User Guide for important usage information relating to the biofeedback system.

1.2. System Requirements

- Windows 64-bit operating system (Windows 10 recommended)
- At least 2.0 GHz processor clock speed (3.0 GHz recommended)
- At least 2 processor cores (4 recommended)
- 2 GB of HDD space for NeuroMap Explorer and MATLAB RunTime installations (SSD recommended)
- At least 4 GB of RAM per processor core

1.3. Software Overview

Diagram here

1.4. List of Abbreviations and Definitions

sEMG	**Surface Electromyogram –** the electrical signal generated by a muscle contraction as detected from the skin surface
MU	**Motor Unit** – a group of muscle fibers innervated by a single motoneuron
MUAP	**Motor Unit Action Potential** – the electrical signal generated by a motor unit firing
MFR	**Mean Firing Rate** – time-varying motor unit firing rate, calculated as the convolution of the motor unit firing train with a Hann window
IPI	**Inter-Pulse Interval** – time between consecutive motor unit firings

2. Getting Started

NeuroMap software is a suite of programs for visualization & statistical analysis of biofeedback data.

Software:

- NeuroMap
- NeuroMap Reports
- NeuroMap Explorer

2.1. Installation

- Download and run the NeuroMap installer from the Delsys website to install all three NeuroMap software programs
    - Make sure you are logged in as an administrator
    - During installation, accept the prompt to install MATLAB RunTime v9.3 (even if it has previously been installed)
    - After installation, open NeuroMap and email the two codes generated to support@delsys.com. Two activation codes will be provided; input these codes to activate your NeuroMap software.

3. NeuroMap

3.1. Overview

NeuroMap software analyzes biofeedback signals and estimates motor unit behavior by a process called “EMG decomposition.”

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Inputs to Software:

Biofeedback data files (.hpf format)

Outputs of Software:

Enhanced biofeedback data files (.dhpf format)

3.2. Processing EMG Signals

3.2.1. Load files

Load files for processing by clicking the “Add Files” button. Select multiple files by holding SHIFT or CTRL.

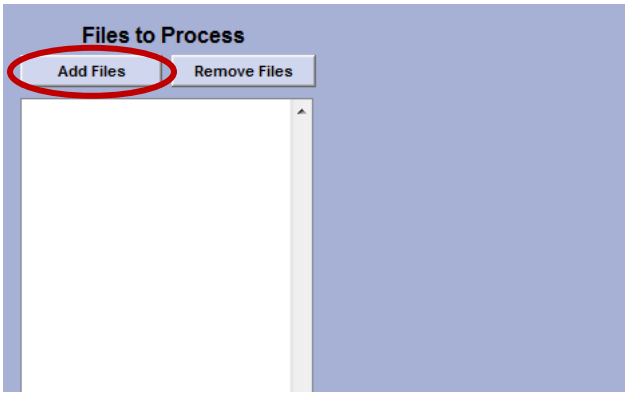


Figure 1: The “Add Files” dialog. Note: Only HPF files containing unaltered biofeedback data will be loaded for processing.

3.2.2. Remove files

Remove files you do not wish to process by selecting files within the “Files to Process” list and clicking the “Remove Files” button. Remove multiple files at a time by holding SHIFT or CTRL.

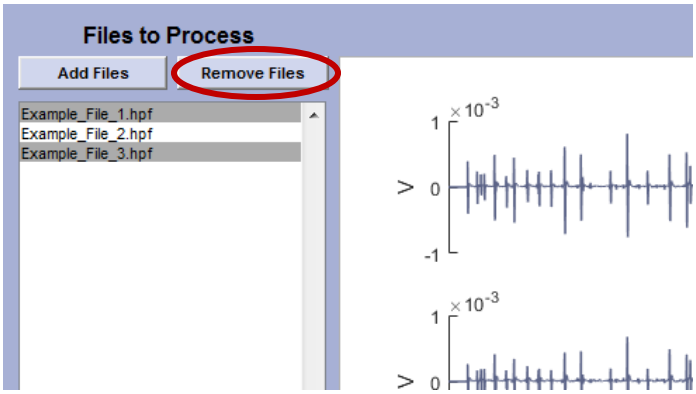


Figure 2: The "Remove File" dialog.

3.2.3. Preview files

Preview a single file by selecting it from the file list. Check additional data channels by using the scroll bar on the right.

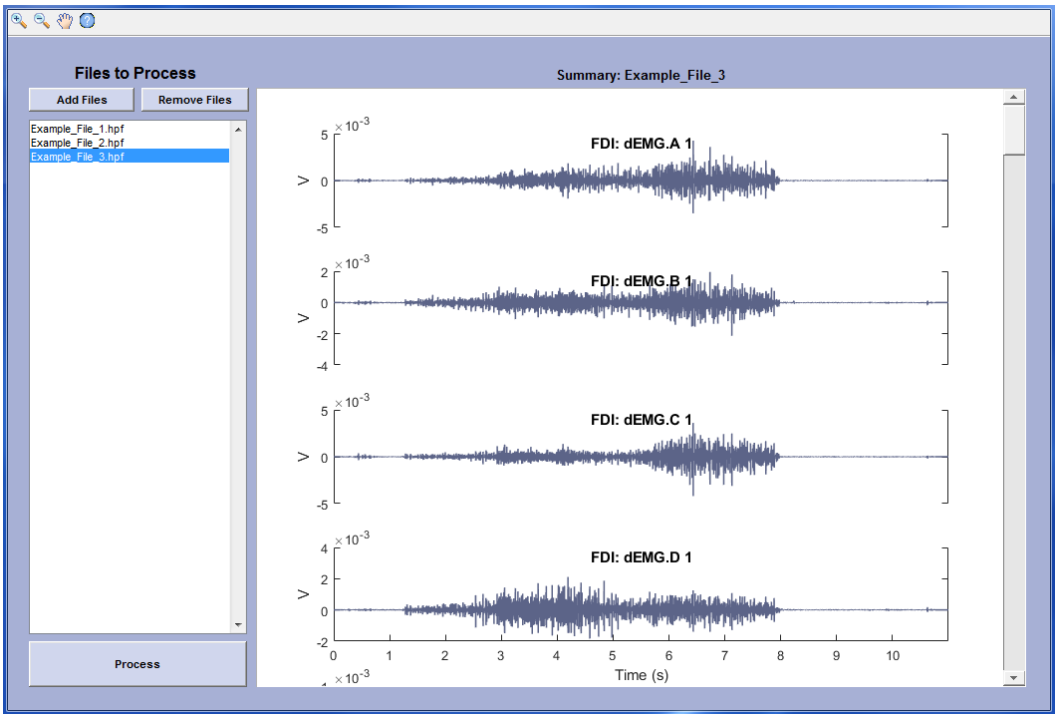


Figure 3: The Preview Files Window. Note: Long files can take up to 10 seconds before display.

3.2.4. Process files

Process the files in the file list by clicking the "Process" button and choosing a save location for the motor unit data files that will be created. Note that file processing is resource-intensive and can take up to 1 minute per second of data, so we recommend processing file batches on PCs that will not be used for the duration.

Important Notes:

- *Do not close progress windows or NeuroMap software while processing files*
- *Ensure your PC will not sleep, restart or update while processing files*
- *Close other programs to free up computer resources and improve processing speed*

Intermediate files will be saved to your chosen save location during processing. Do not move, open, or delete these files until processing has fully completed or the files may be corrupted.

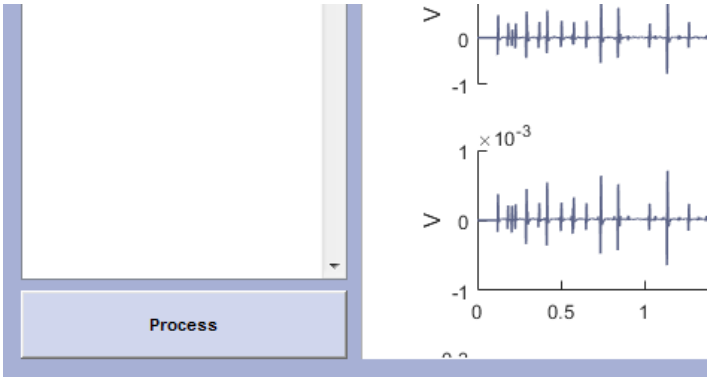


Figure 4: The process button is located on the bottom left of the window pane.

3.2.5. Processing progress

The progress window monitors processing progress for each sensor and segment of a file.

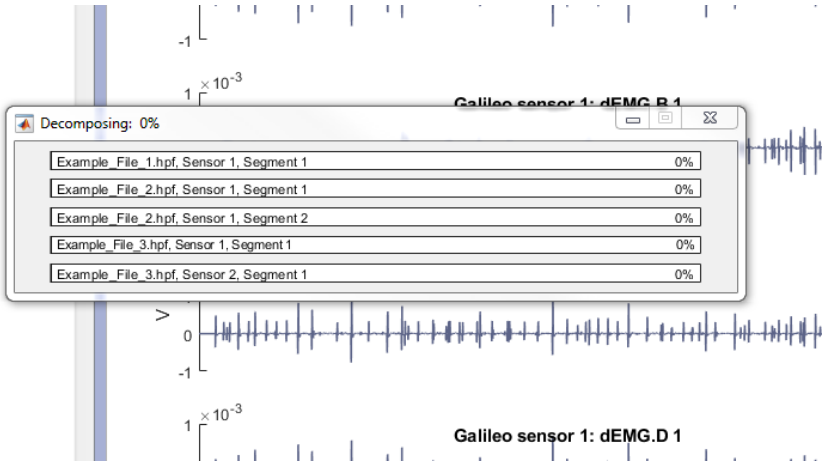


Figure 5: Progress bar during decomposition calculations. Note: Individual segments are created if clipping is present in the file. For more information, see the "Signal Clipping" section of the User Guide.

Each progress bar will update as each segment finishes processing:

- **Green:** Successfully found motor unit data
- **Red:** Failed to find reliable motor unit data

Segments & files may not finish processing in order due to the parallelized architecture of the software. If no reliable motor unit data were found from any segments within a single HPF file, no corresponding DHPF file is created.

3.3. Viewing Results

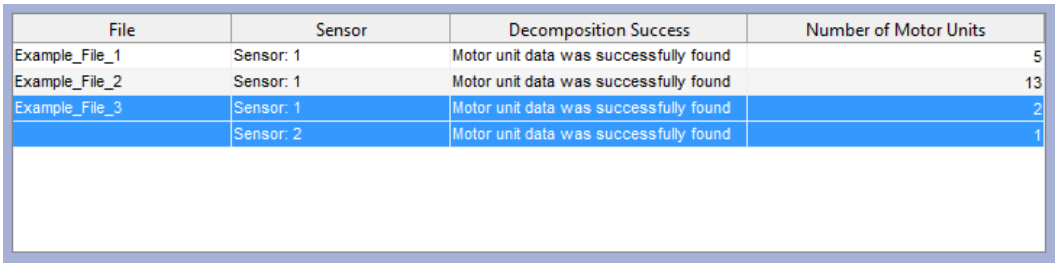
After processing, the progress window closes automatically and the results screen appears.

Important Notes:

- *Files are saved in the selected folder in DHPF format*
- *If the algorithms were unable to find reliable motor unit data in a file, an output file will not be saved*

3.3.1. View results from entire file

Click the desired file in the results table to display motor unit data from that file. If there are multiple sensors in the file, each sensor will display as a subplot.

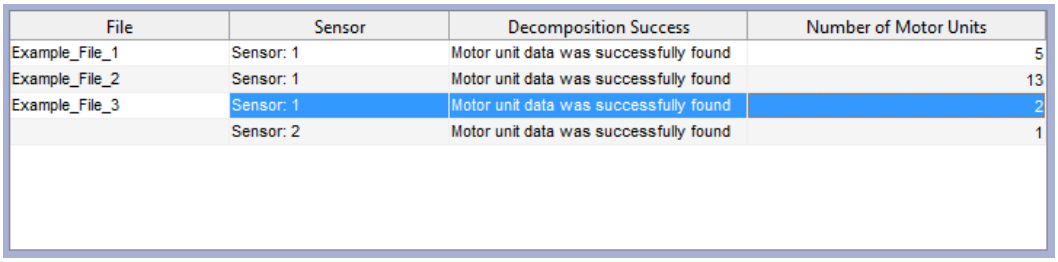


File	Sensor	Decomposition Success	Number of Motor Units
Example_File_1	Sensor: 1	Motor unit data was successfully found	5
Example_File_2	Sensor: 1	Motor unit data was successfully found	13
Example_File_3	Sensor: 1	Motor unit data was successfully found	2
	Sensor: 2	Motor unit data was successfully found	1

Figure 6: Calculation Results window; viewing data from an entire fileset.

3.3.2. View results from single sensor

Click the desired sensor in results table to display motor unit data from that particular sensor.



File	Sensor	Decomposition Success	Number of Motor Units
Example_File_1	Sensor: 1	Motor unit data was successfully found	5
Example_File_2	Sensor: 1	Motor unit data was successfully found	13
Example_File_3	Sensor: 1	Motor unit data was successfully found	2
	Sensor: 2	Motor unit data was successfully found	1

Figure 7: Calculation Results window; viewing data from a single sensor

3.4. Next steps

Process additional files by clicking the “Decompose Additional Files” button or move on to data analysis and launch NeuroMap Explorer or NeuroMap Reports by clicking their respective buttons.

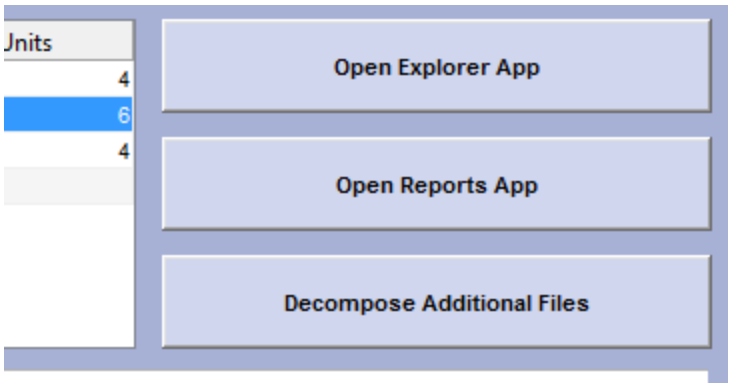


Figure 8: Launching the NeuroMap Explorer, the NeuroMap Reports App or process additional files.

3.5. Signal Clipping

Under certain conditions, movement artifacts or repositioning of the sensor may result in clipping across all four EMG channels. If this occurs, there is no guarantee that the sensor was replaced in the same position, and there may be multiple distinct subsets of motor units present in the same file.

In this case, NeuroMap software processes the EMG signal segments between each instance of clipping separately. After processing, the results for each segment will be saved in the same file.

3.5.1. Identifying signal clipping

A red patch highlights clipped areas of the EMG signal while previewing files. The EMG signals are segmented between the highlighted patches and processed separately.

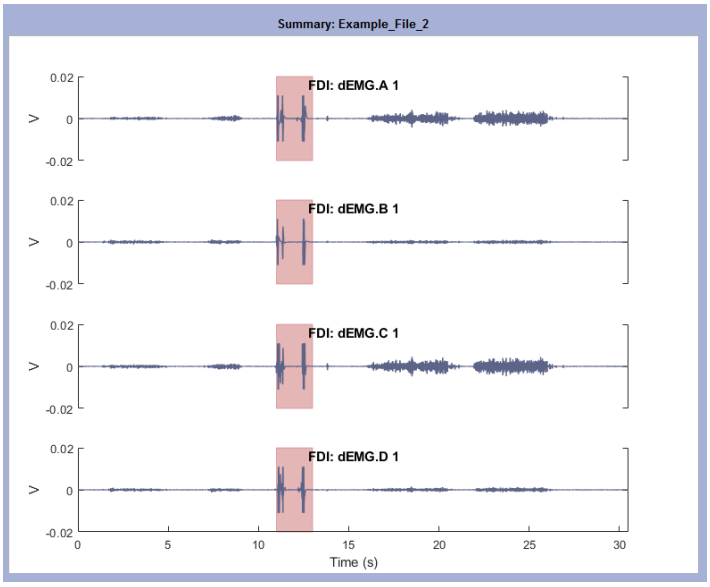


Figure 9: Identifying data sections with signal clipping

3.5.2. Motor unit data from clipped signals

Since each segment processes independently, motor units will not be compared across segments. Therefore, each segment will have a unique subset of motor units, with no overlap between segments.

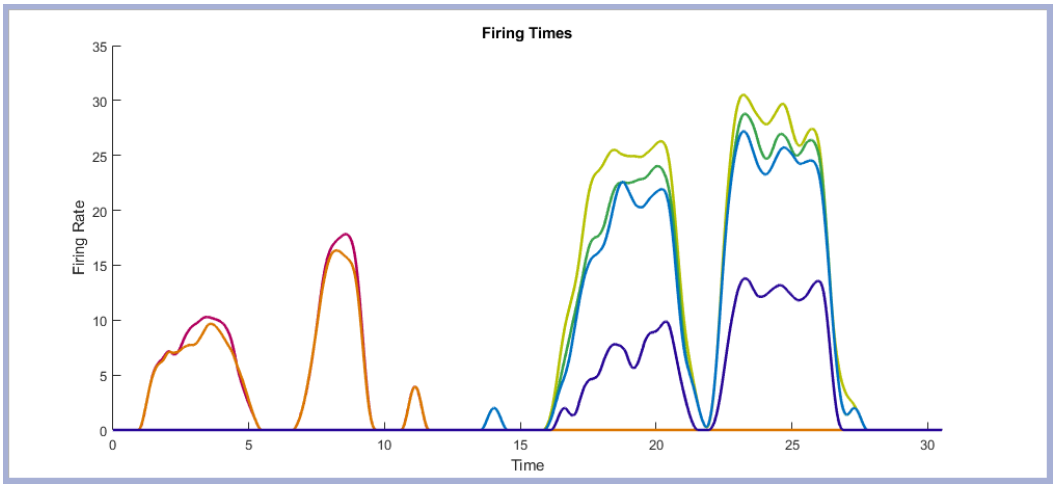


Figure 10: Motor unit data from clipped signals.

4. NeuroMap Reports

4.1. Overview

NeuroMap Reports automatically calculates metrics & generates easy-to-read reports from your DHPF data files. Click either of the buttons on the home screen to get started.

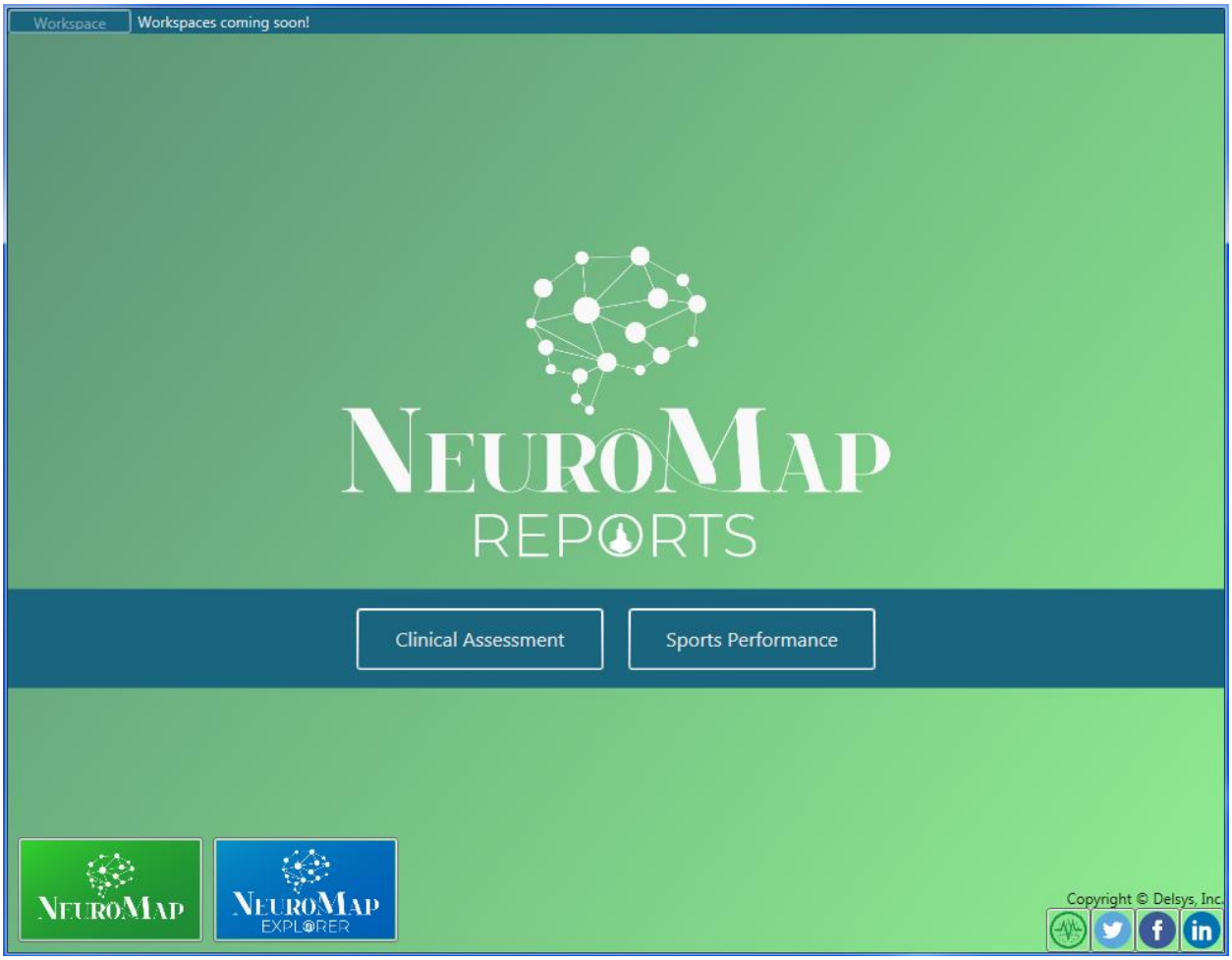


Figure 11: Launching the NeuroMap Reports App.

4.2. Load & Visualize MU Data

4.2.1. Load files

After clicking either report module for the first time, choose a DHPF data file to open.

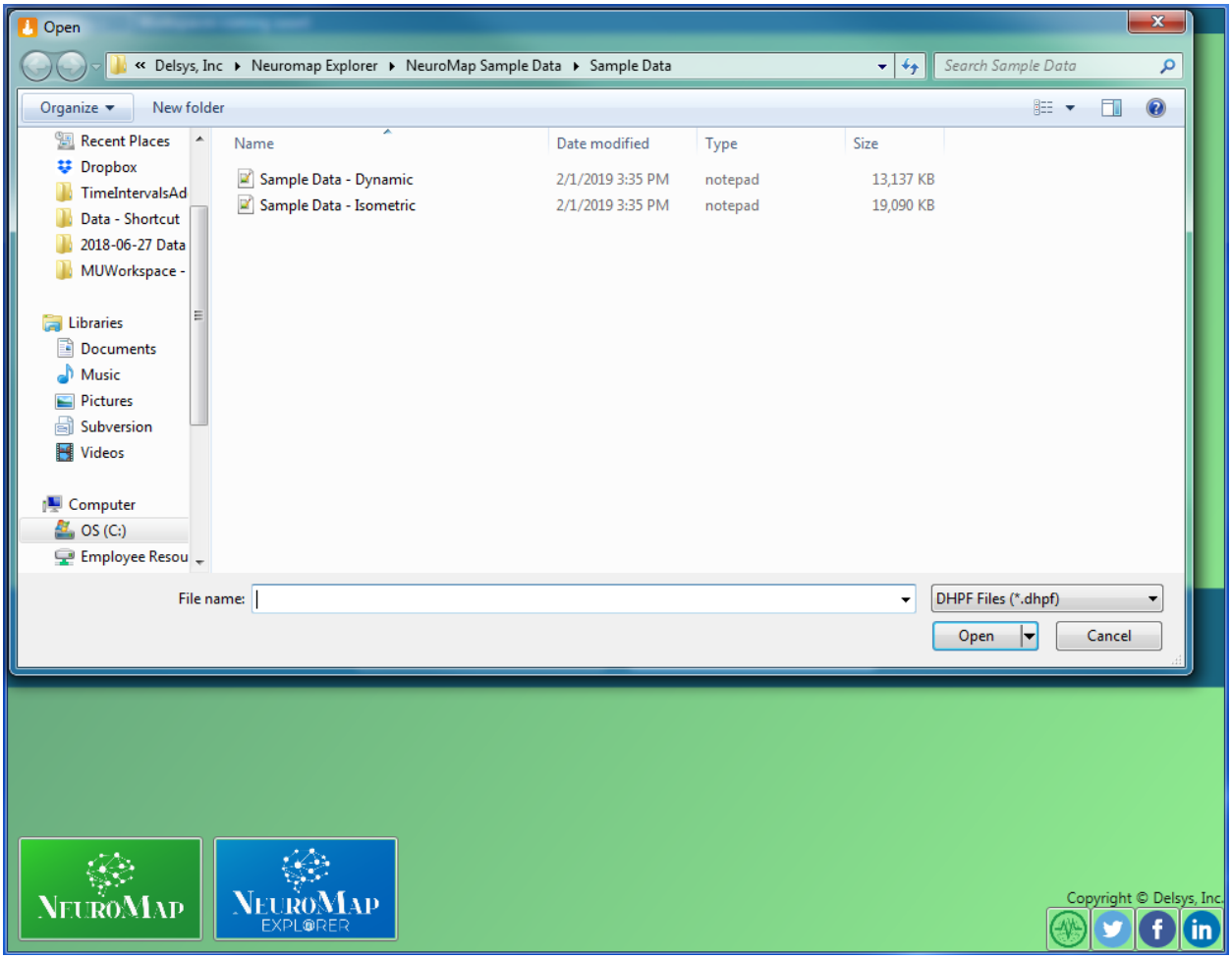


Figure 12: Loading previously decomposed data into NeuroMap Reports. Only one DHPF data file can be loaded at one time.

4.2.2. User interface

Once a data file is loaded, both report modules share a similar user interface:

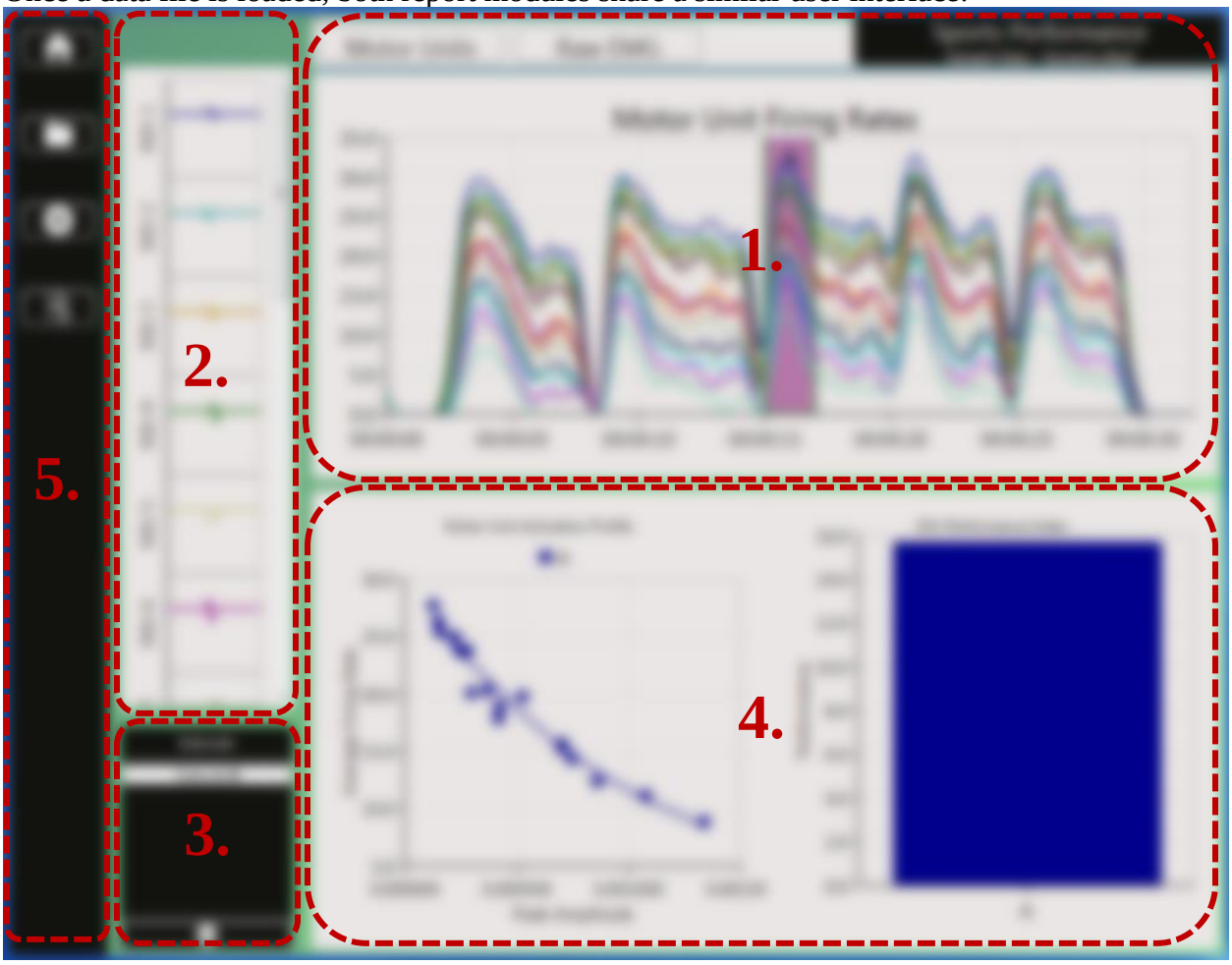


Figure 13: NeuroMap Reports User Interface layout.

1. **Plot Panel:** Visualize raw EMG data & MU firing rates
2. **MUAP Panel:** View MUAP waveforms
3. **Interval Panel:** See the list of analysis intervals, select active interval, and remove intervals
4. **Report Preview Panel:** Report-specific figures & charts corresponding to the active analysis interval
5. **Toolbar:** Return to home screen, load new MU data files, add analysis intervals and generate PDF reports

4.2.3. Select analysis intervals

Analysis intervals are user-selected time periods of interest. Both NeuroMap Report modules generate report outputs for each analysis interval created.

Analysis intervals appear as shaded regions on the MU Firing Rates plot:

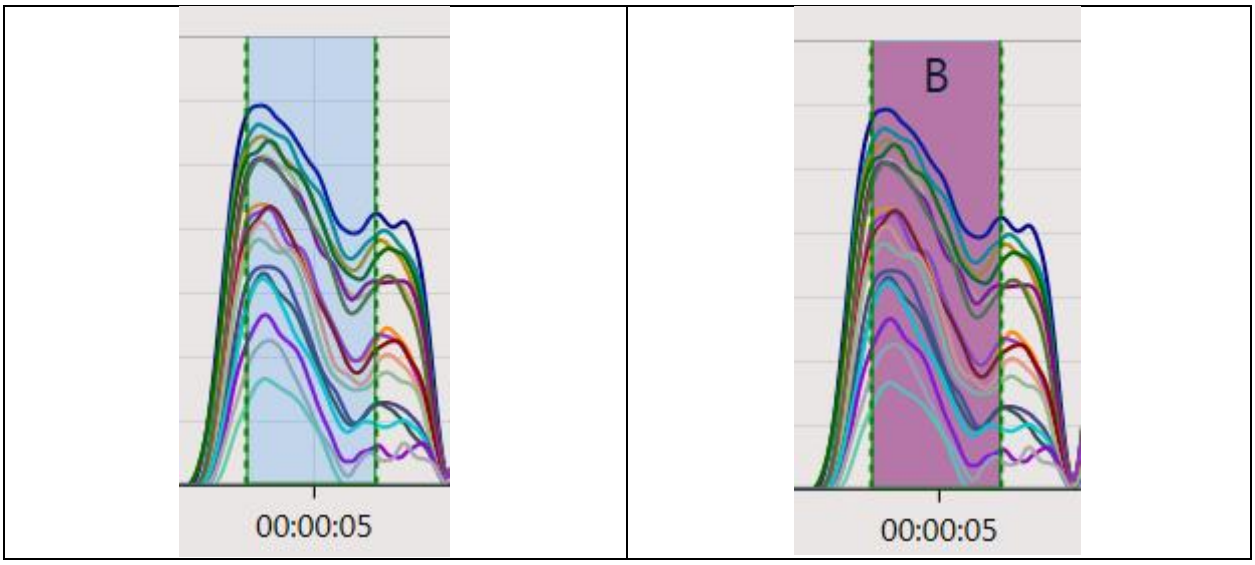


Figure 14: Define analysis interval widths by dragging the vertical bars individually, or move entire analysis intervals by dragging the shaded region (left). Lock analysis intervals by right-clicking the shaded region (right).

Drag the dotted vertical lines to adjust the width of the analysis interval, or drag the shaded region to move the analysis interval. Lock the analysis interval in place by right-clicking on the shaded region:

4.3. Generate MU Reports

4.3.1. Preview report

Locking an analysis interval generates a report preview for that time interval. The particular plots & metrics displayed depend on the chosen report module:

Sports Performance calculates a regression comparing Peak MUAP Amplitude (x-axis) vs. Average MU Firing Rate (y-axis), an approach used in the literature to characterize motor unit firing behavior (see *Applications* section of References).

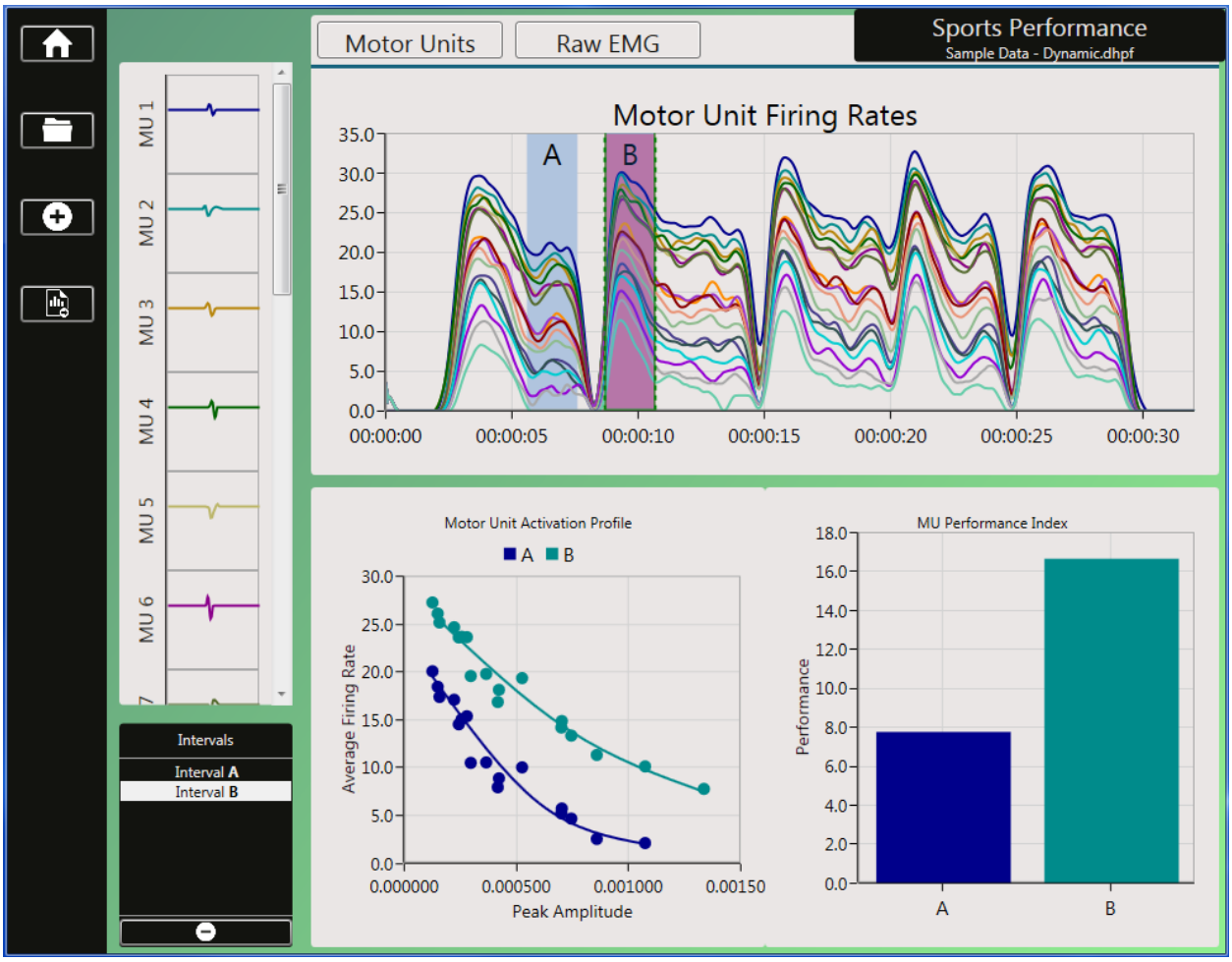


Figure 15: Sports Performance report.

It also computes the "MU Performance Index" for each analysis interval, which is the average firing rate of the MUs that fall within a common amplitude range. For instance, the common amplitude range between the two analysis intervals in the image above looks like this:

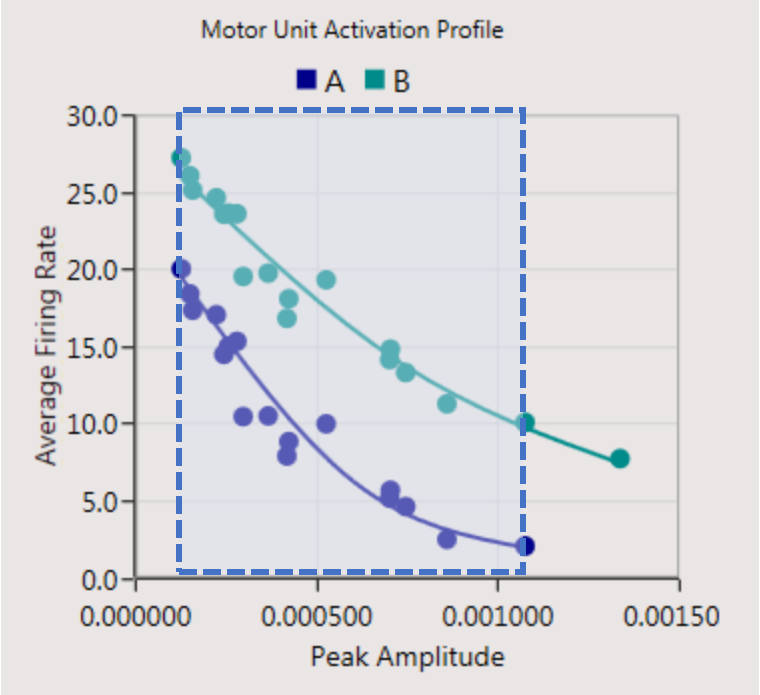


Figure 16: Common MUAP amplitude range between two analysis intervals.

Motor Unit Assessment offers a quick way to characterize the pool of active MUs. It calculates two histograms for each analysis interval which display 1) the distribution of peak MUAP amplitudes, and 2) the distribution of peak MU firing rates.

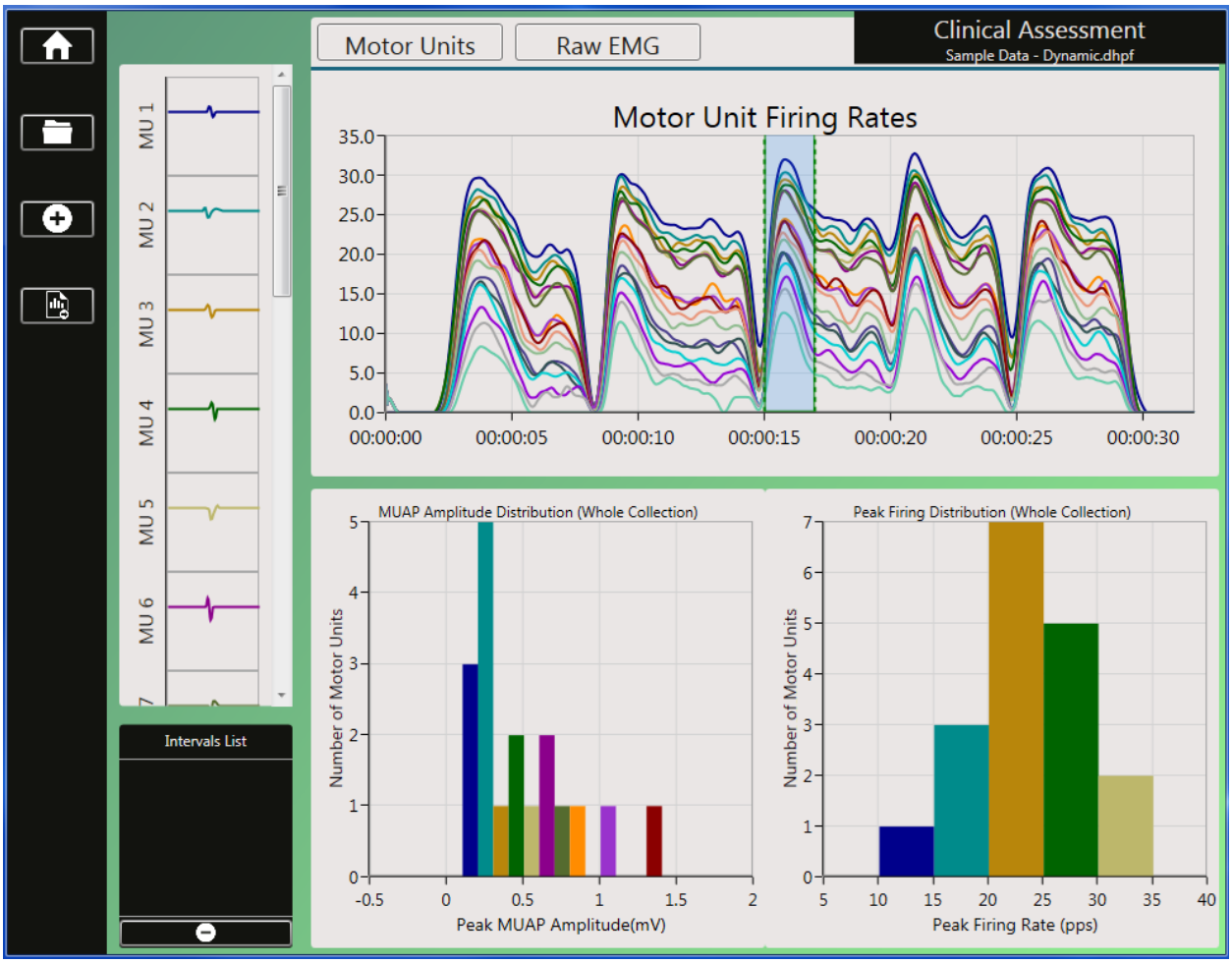


Figure 17: Motor Unit Assessment report.

4.3.2. Generate PDF report

After locking your desired analysis intervals, click the Generate Report button in the toolbar to create a full report in PDF format. Enter any file-specific information that you would like reported in the Report Information window and click “Save.”

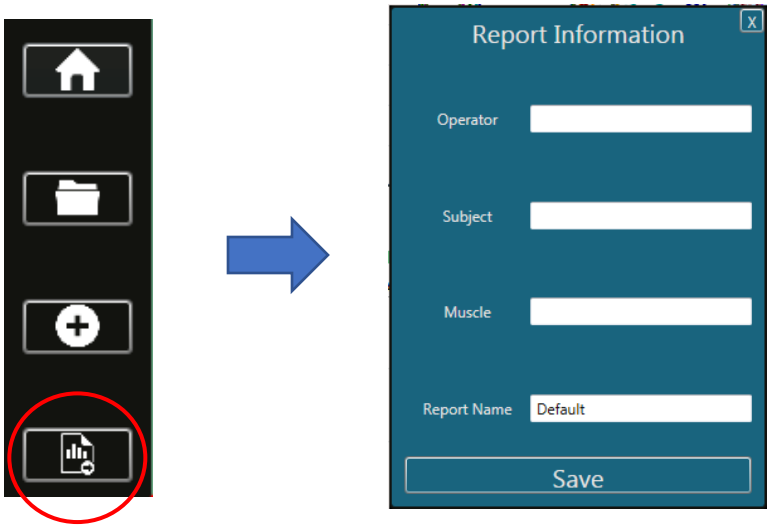


Figure 18: Generating a PDF report.

5. NeuroMap Explorer

5.1. Overview

NeuroMap Explorer is an application for viewing and analyzing motor unit data acquired using the NeuroMap system. The user interface is divided into 3 panels:

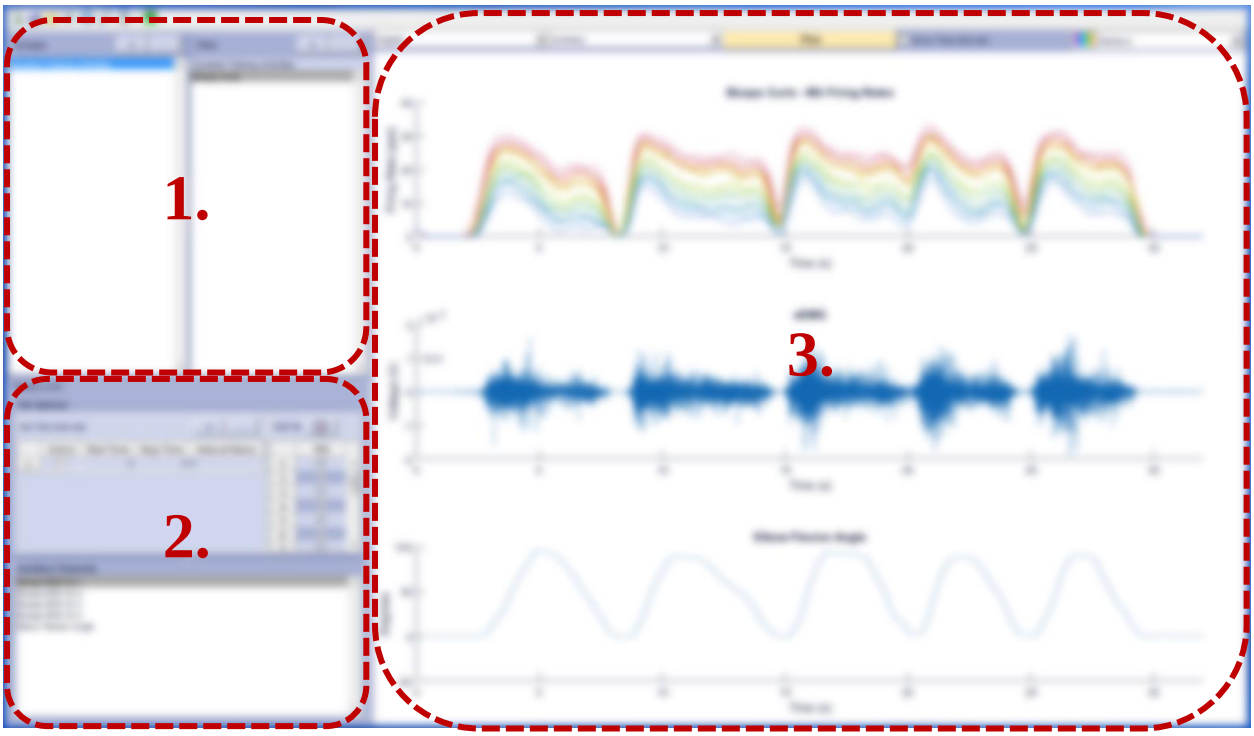


Figure 19: NeuroMap Explorer interface

1. **Groups and Files:** Here, you can load and group motor unit data files (DHPF files) into your workspace.

2. **File Information Panel:** Create and edit specific analysis criteria here. Choose which motor units to display, which time intervals to analyze, and more.

3. **Plot Panel:** Choose which plot type to display.

5.2. Data Management

NeuroMap Explorer uses a hierarchical approach for data organization. All data is referenced and organized without disrupting your local file structure.

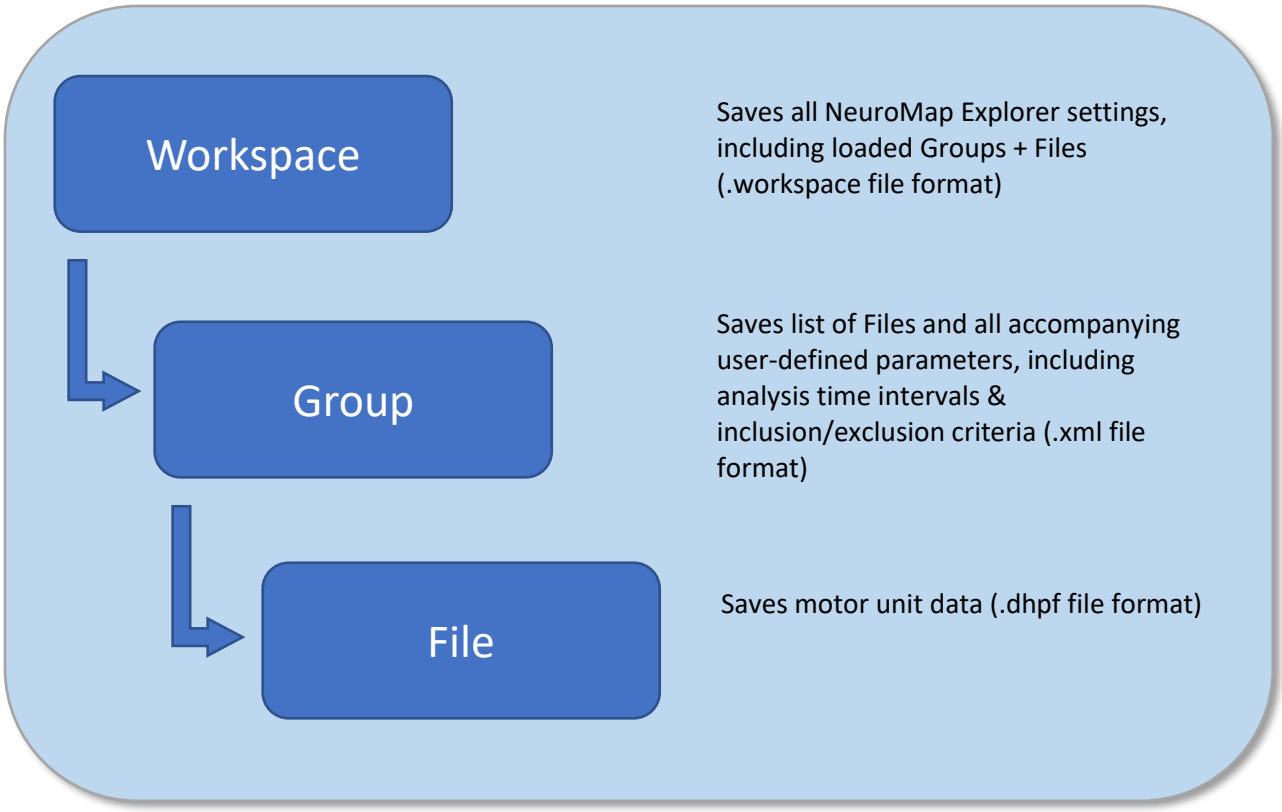


Figure 20: Hierarchical data types in NeuroMap Explorer.

5.2.1. Creating groups

Upon entering NeuroMap Explorer you will see the landing page:

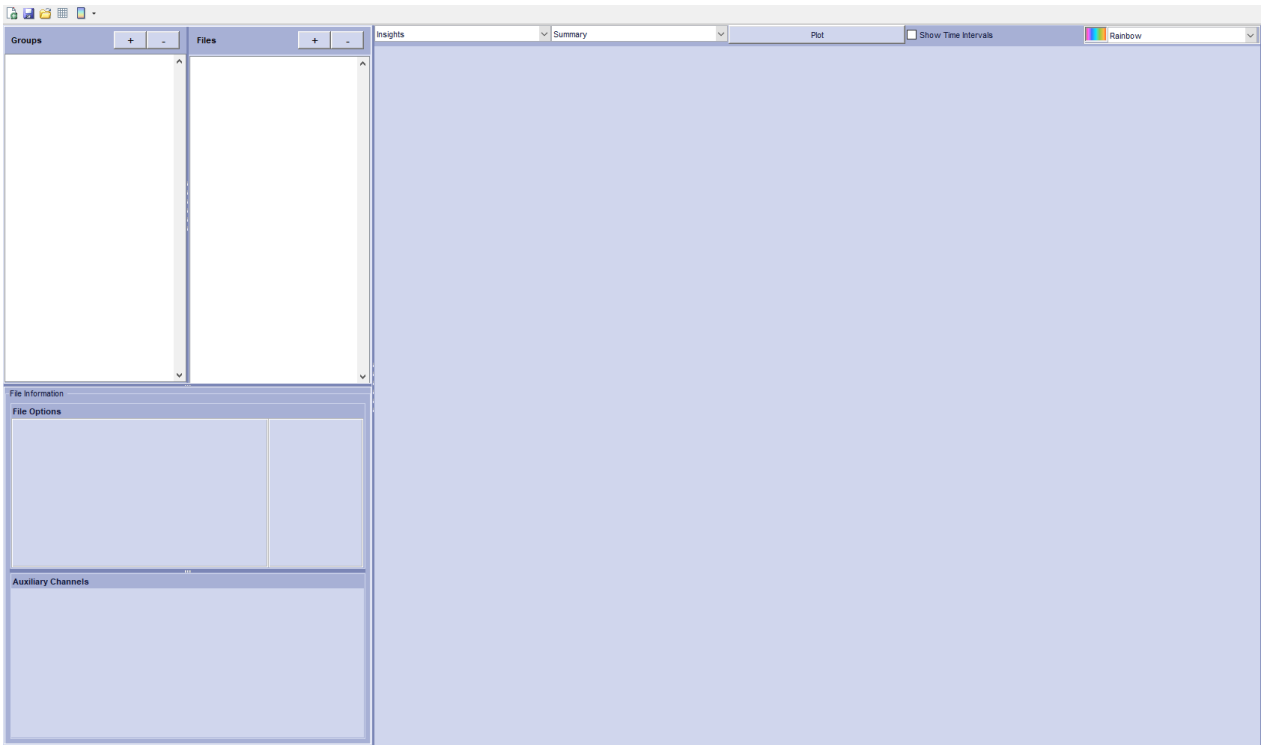


Figure 21: NeuroMap Explorer initial screen.

From here, create a new group either by clicking on the '+' button in the Groups panel, or by right clicking in the Groups panel and selecting "Add New Group:"

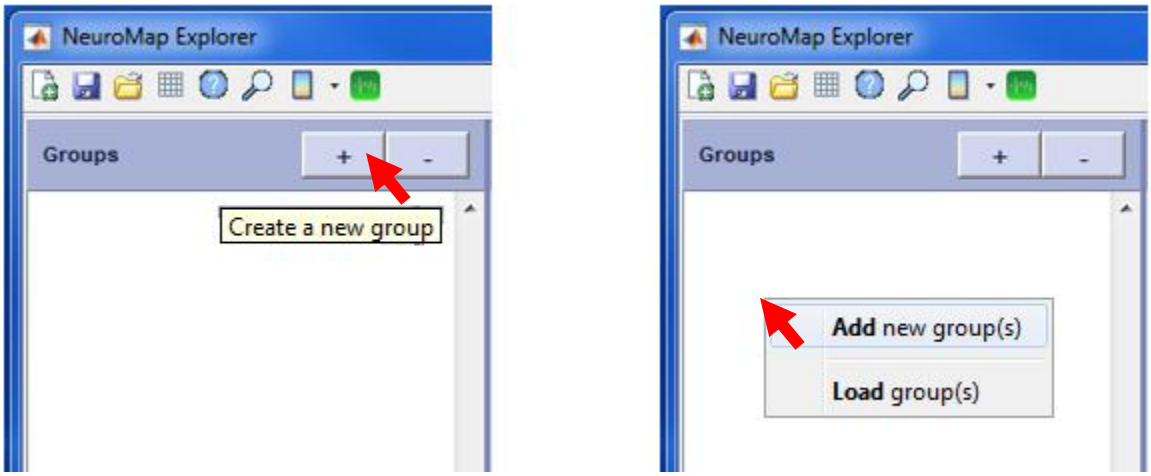


Figure 22: Adding and managing groups.

5.2.2. Adding files to groups

Once you have created a new group, you can then add files to your newly created group. Click the '+' button in the file panel, or right-click inside the file panel and select "Add New File(s)".

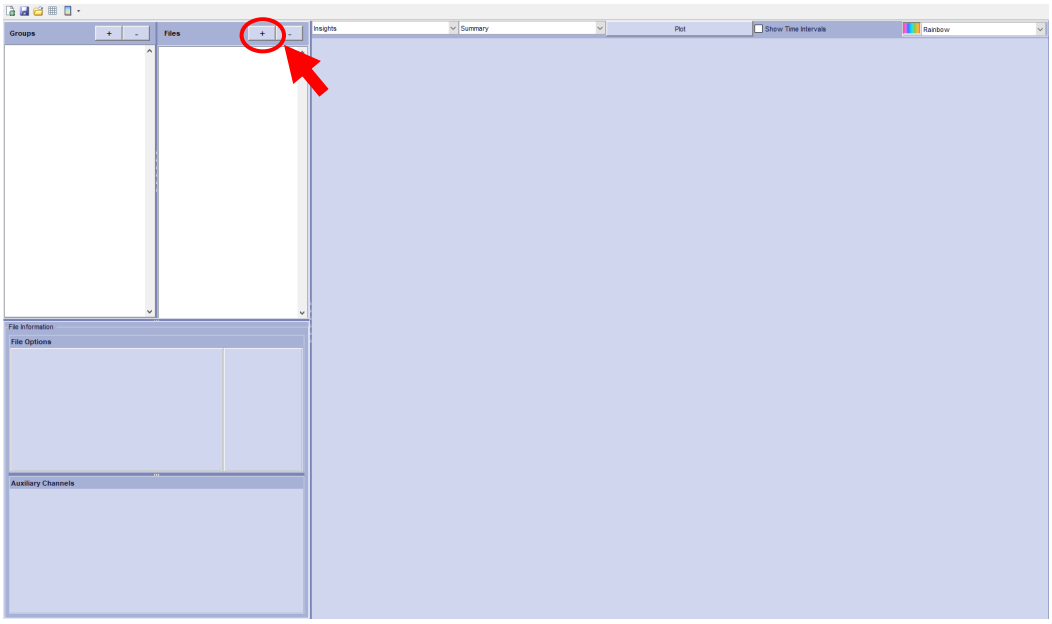


Figure 23: The "Add File" button. Note: NeuroMap Explorer only accepts DHPF files.

5.3. Data Visualization

In the NeuroMap Explorer software, there are many different analysis options for the user to visualize, calculate, and compare different representations of their collected EMG signals.

Once files have been loaded into the group to analyze, the plot button will change to a bright yellow color, indicating that plotting is now enabled.

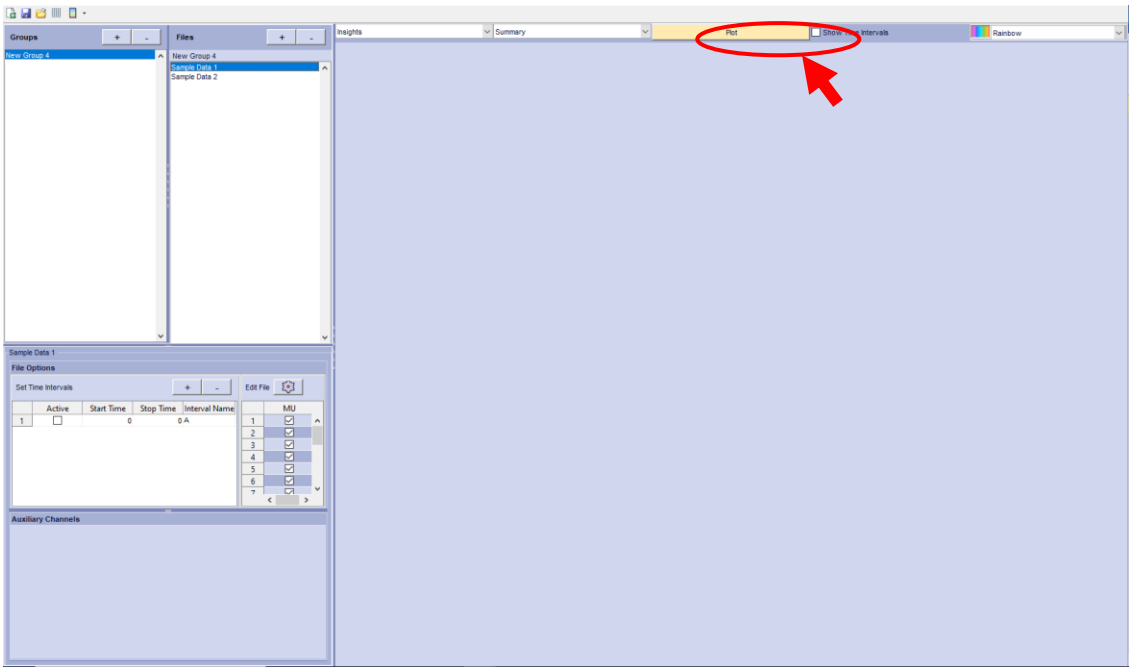


Figure 24: Uploaded files enabling the plot button.

After clicking on the plot button, the software plots the data from the selected file:

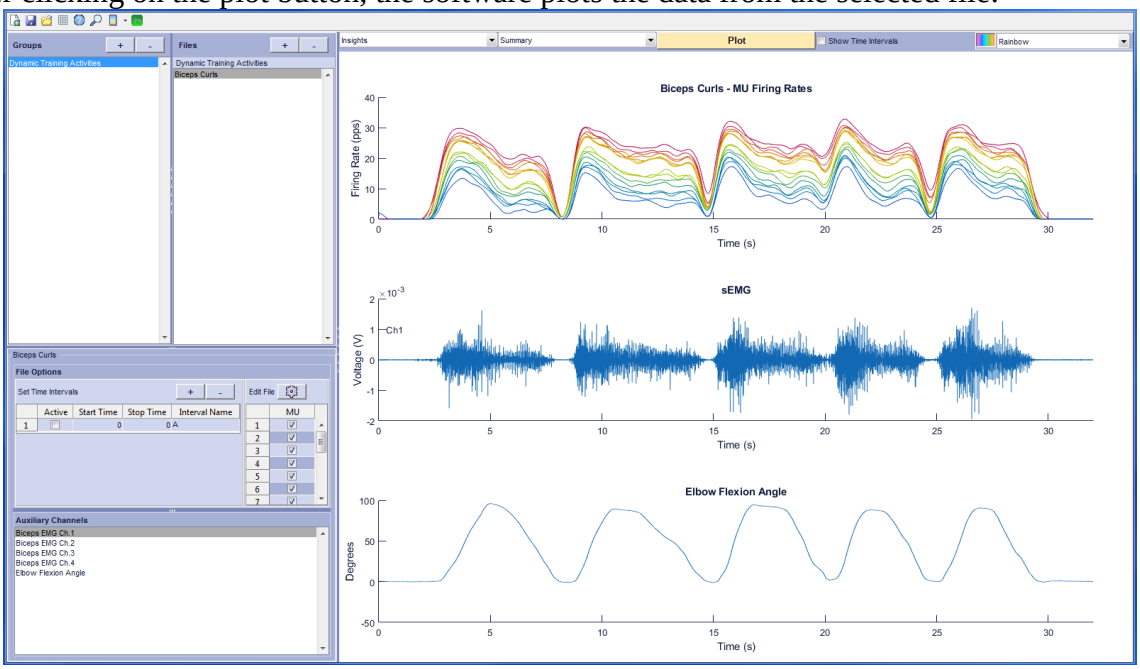


Figure 25: Plotting uploaded files.

5.4. Insights

5.4.1. Summary

The *Summary* plot provides an overview of the selected data file. It displays three plots:

1) Mean firing rates of active motor units
2) One channel of the raw EMG data
3) A selected auxiliary channel (if applicable)

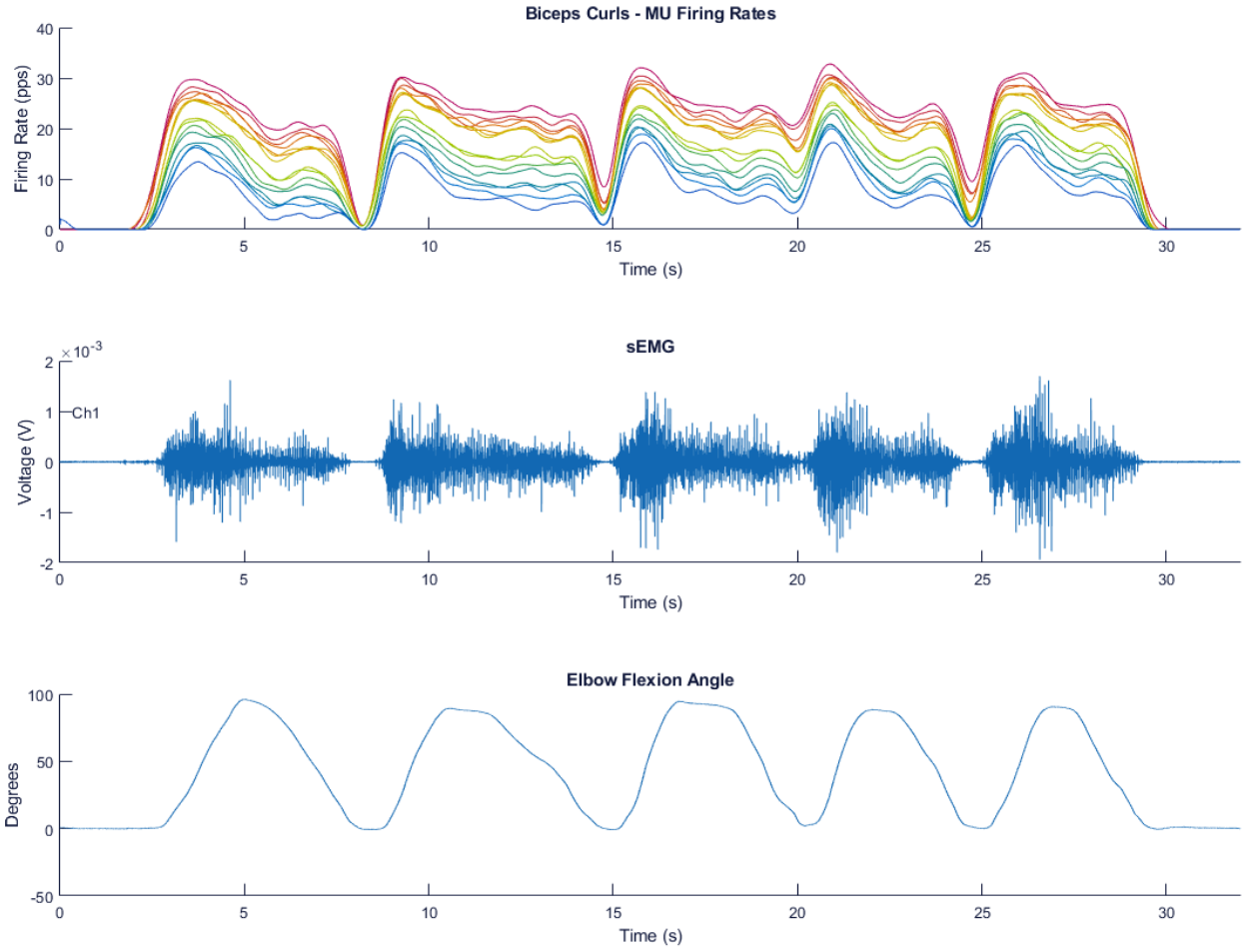


Figure 26: Mean MU firing rates (top), raw sEMG signal (middle), primary feedback signal (bottom).

5.5. Explore Data

5.5.1. MU Firings

The *MU Firings* plot shows the firing times for each identified motor unit. Each MU is presented on a separate row, and each firing is represented as a vertical bar:

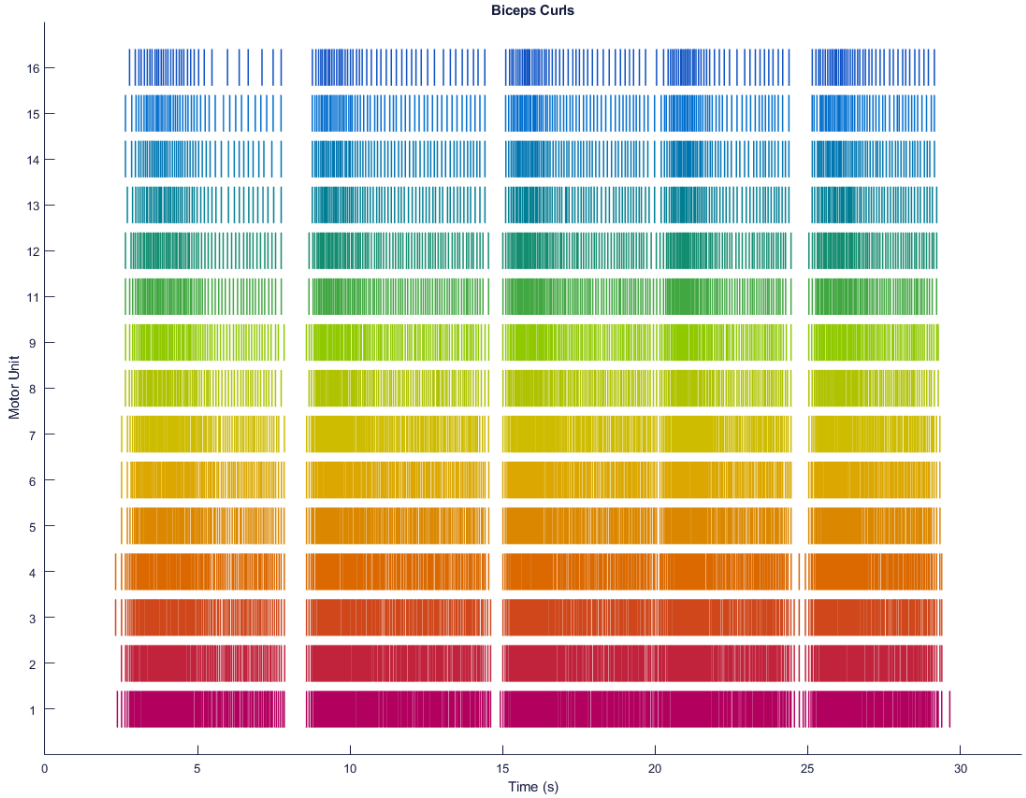


Figure 27 :Motor Unit Firing times represented by vertical bars.

5.5.2. MU Firing Rates

The *MU Firing Rates* plot shows the mean firing rates for each identified motor unit. The mean firing rate of a single MU is calculated by passing its firing instances through a Hann window; as firings occur more or less frequently, the mean firing rate rises or falls accordingly.

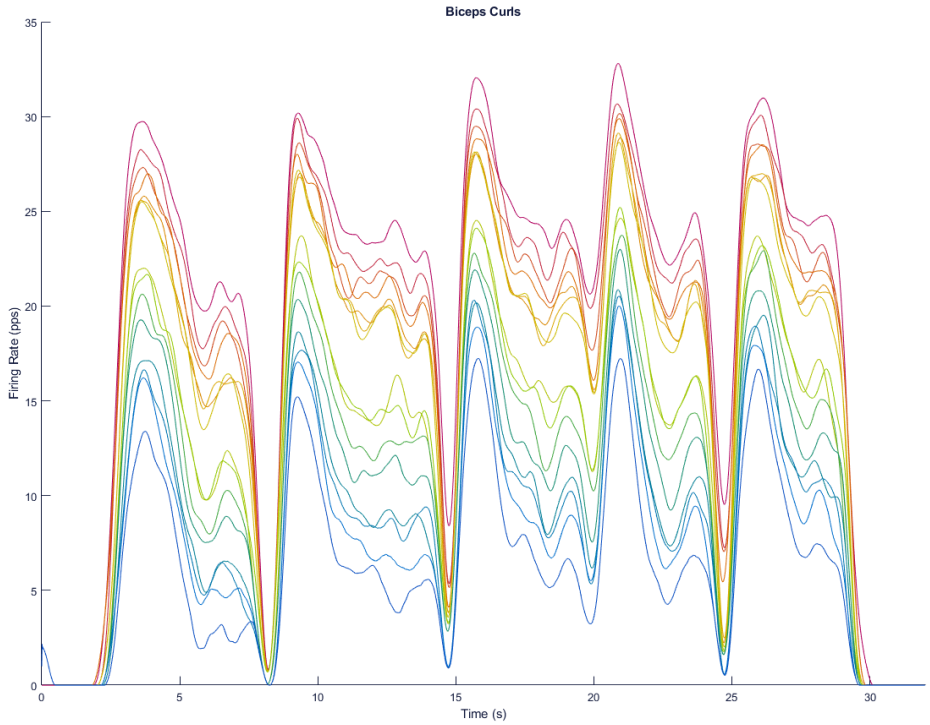


Figure 28: Motor Unit Firing Rates as a function of time.

5.5.3. sEMG

The *sEMG* plot presents the four raw EMG signals from the selected file.

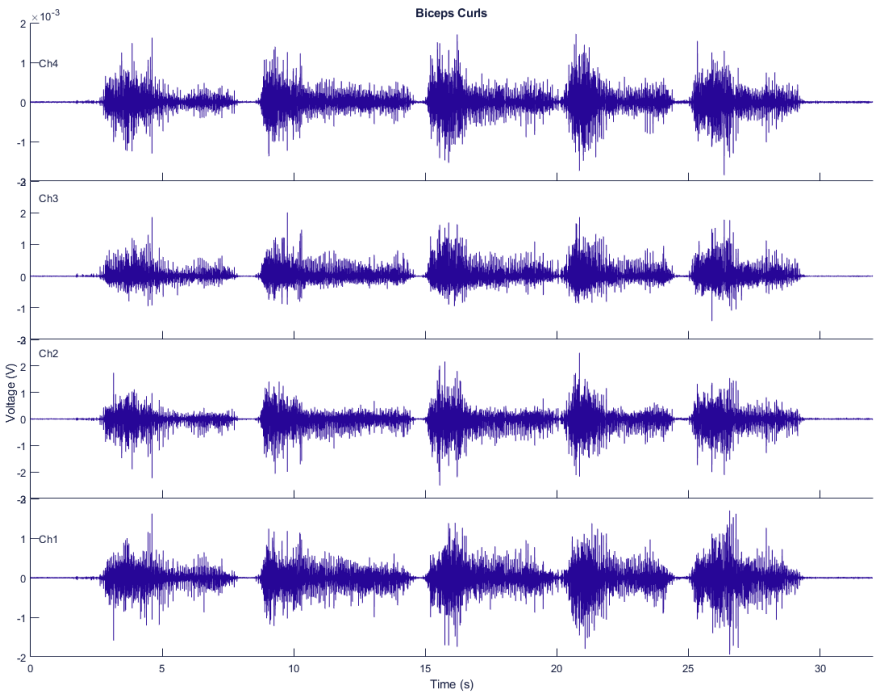


Figure 29: Raw sEMG data as a function of time.

5.5.4. MUAP

The *MUAP* plot shows the unique motor unit action potential shapes found throughout the signal during decomposition. Each identified motor unit has four MUAP waveforms, representing its action potential shape in each recorded EMG channel.

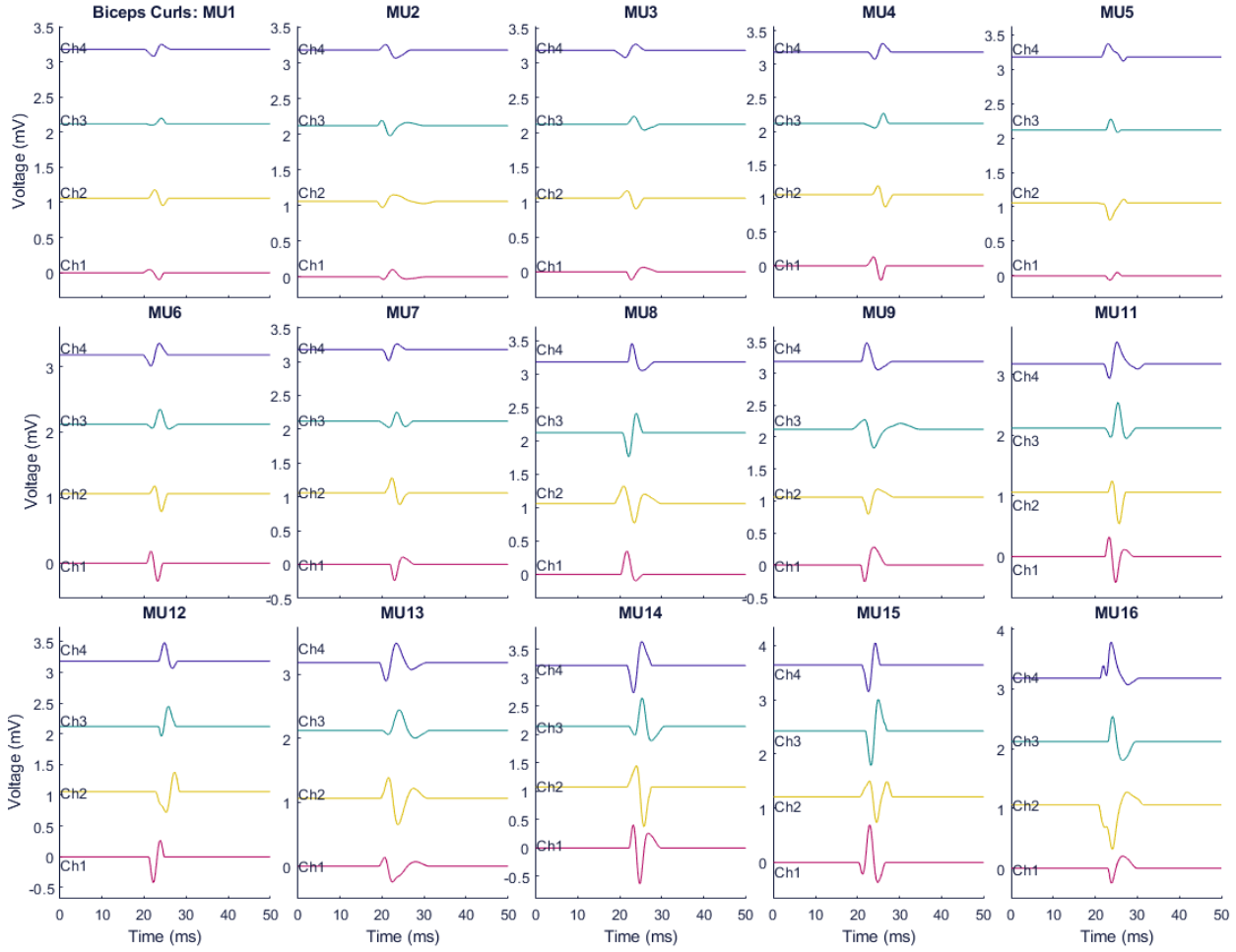


Figure 30: Motor Unit Action Potentials (MUAPs)

5.5.5. MU Firings – Accuracy

The *MU Firings - Accuracy* plot provides a summary of all MUs obtained from sEMG decomposition. The accuracy (Equation 1) is calculated as 1 minus the sum of false positives (FP, addition symbols), and false negatives (FN, circles), divided by the sum of true positives (TP) and true negatives (TN) for all firings of each MU.

$$(1)\ Accuracy\ (\%) = 1 - \frac{FP+FN}{TP+TN}$$

You may exclude MUs with lower accuracy by setting a threshold in the Analysis and Plot Options panel.

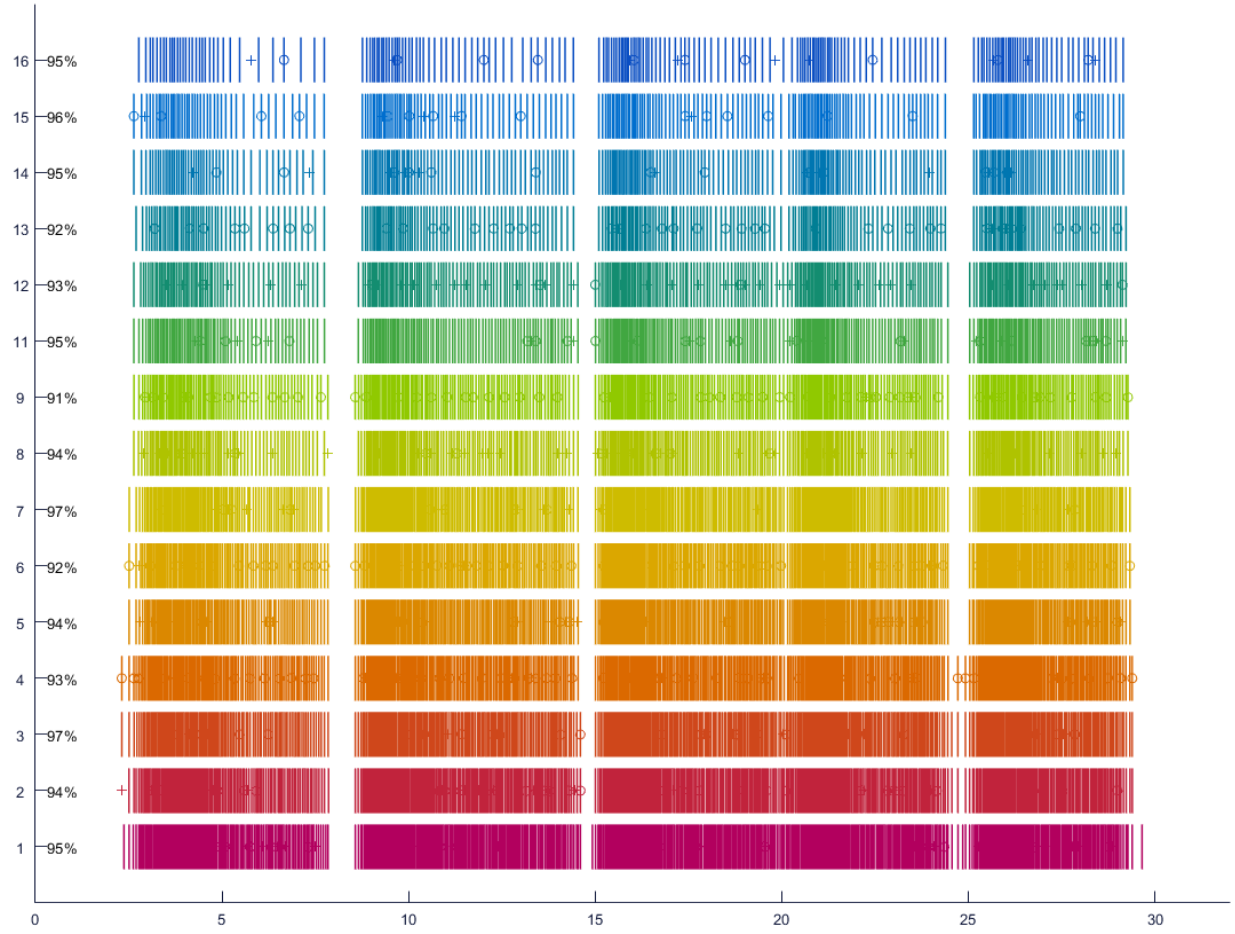


Figure 31: Motor Unit Firing accuracy assessment

5.6. Statistics

5.6.1. Analysis intervals

From the File Information panel, you add or modify time intervals that can be used any Statistical plot type to analyze time-dependent features in your MU data.

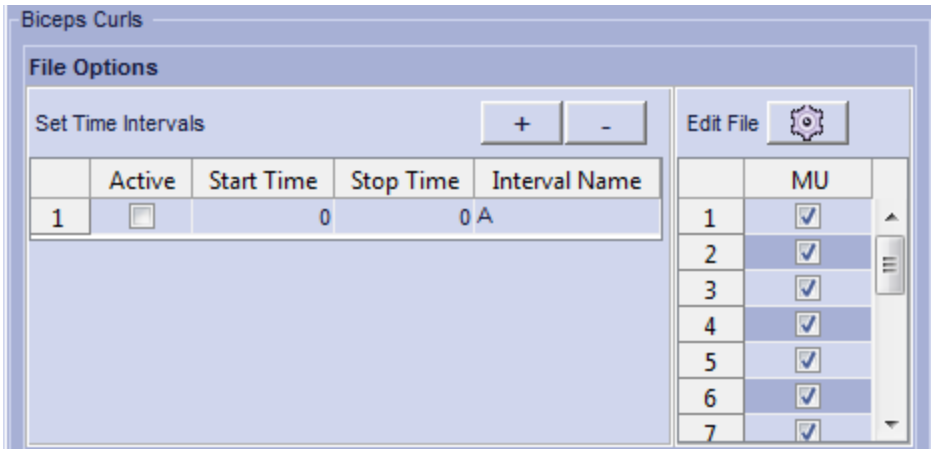


Figure 32: Initiating the Time Interval dialog window.

To change the analysis intervals of a specific file, you can edit the "Set Time Interval" table directly. To add or subtract rows from the table, click on the "+" and "-" buttons. Only active time intervals will be displayed.

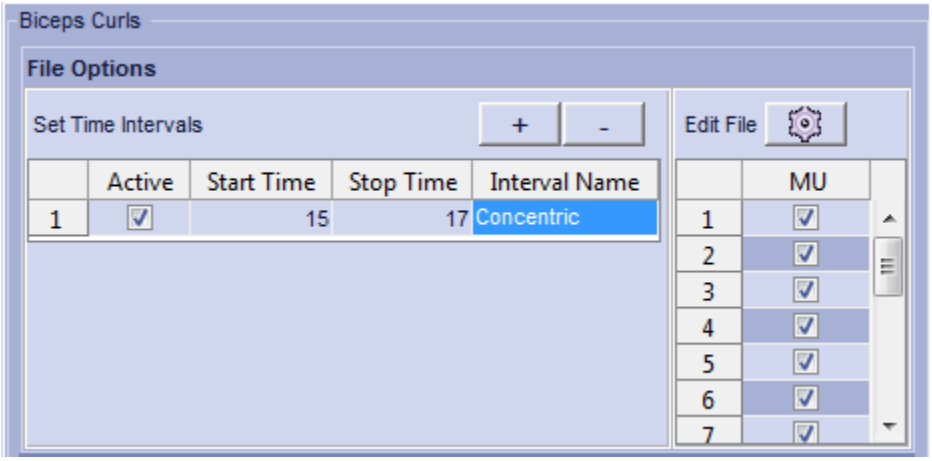


Figure 33: Specifying parameters in the Time Interval window.

Once you have created an analysis interval and set it to be active, you can display in on the plot by checking the "Show Time Intervals" checkbox on the plot bar and then clicking the "Plot" Button.

Figure 34: Showing the selected Time Intervals.

The new time interval displays on the chosen plot as a labeled translucent patch:

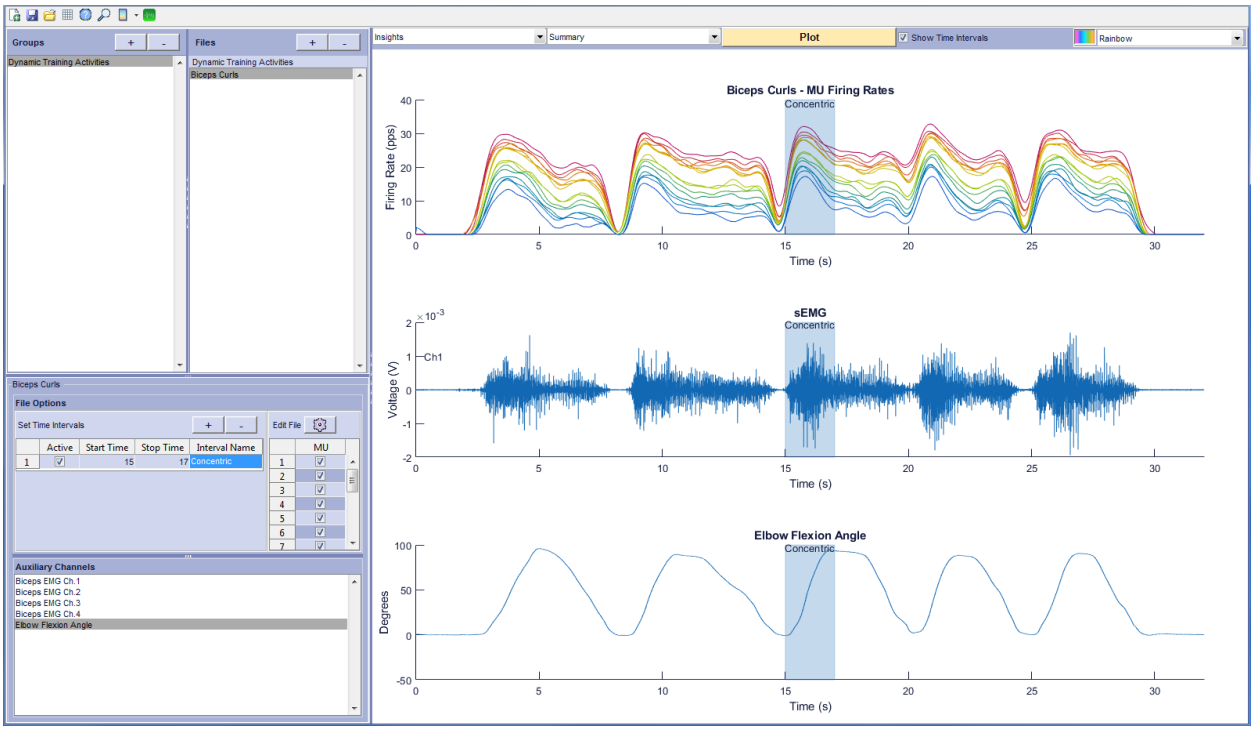


Figure 35: Plotting data with the selected Time Intervals.

5.6.2. Histogram

The *Histogram* plot displays the distribution of different statistical variables specified by the X-Data dropdown menu.

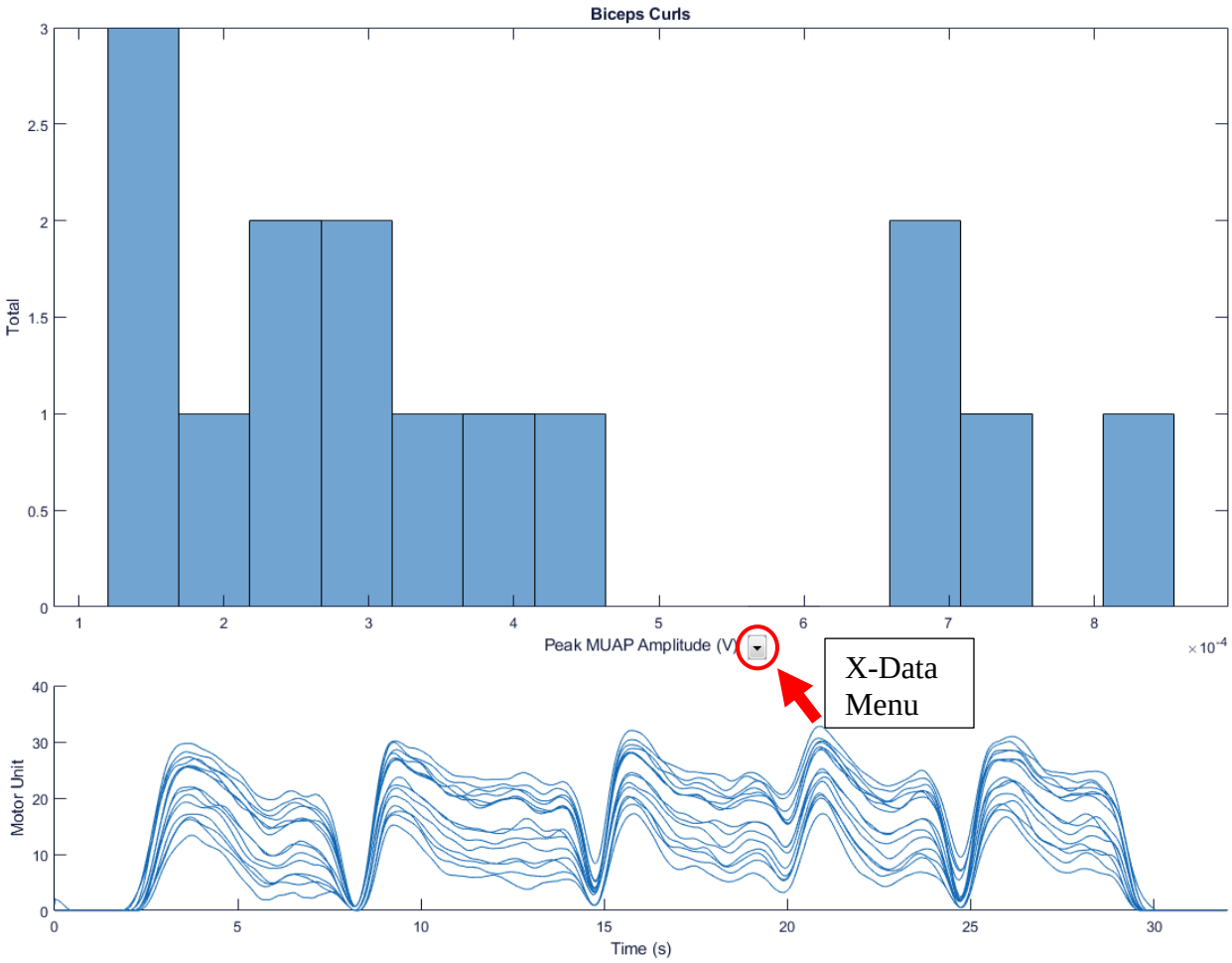


Figure 36: Histogram of the Motor Unit amplitude shapes.

5.6.3. Regression

The *Regression* plot displays the multi-variable regression specified by the X Data and Y Data dropdown menus:

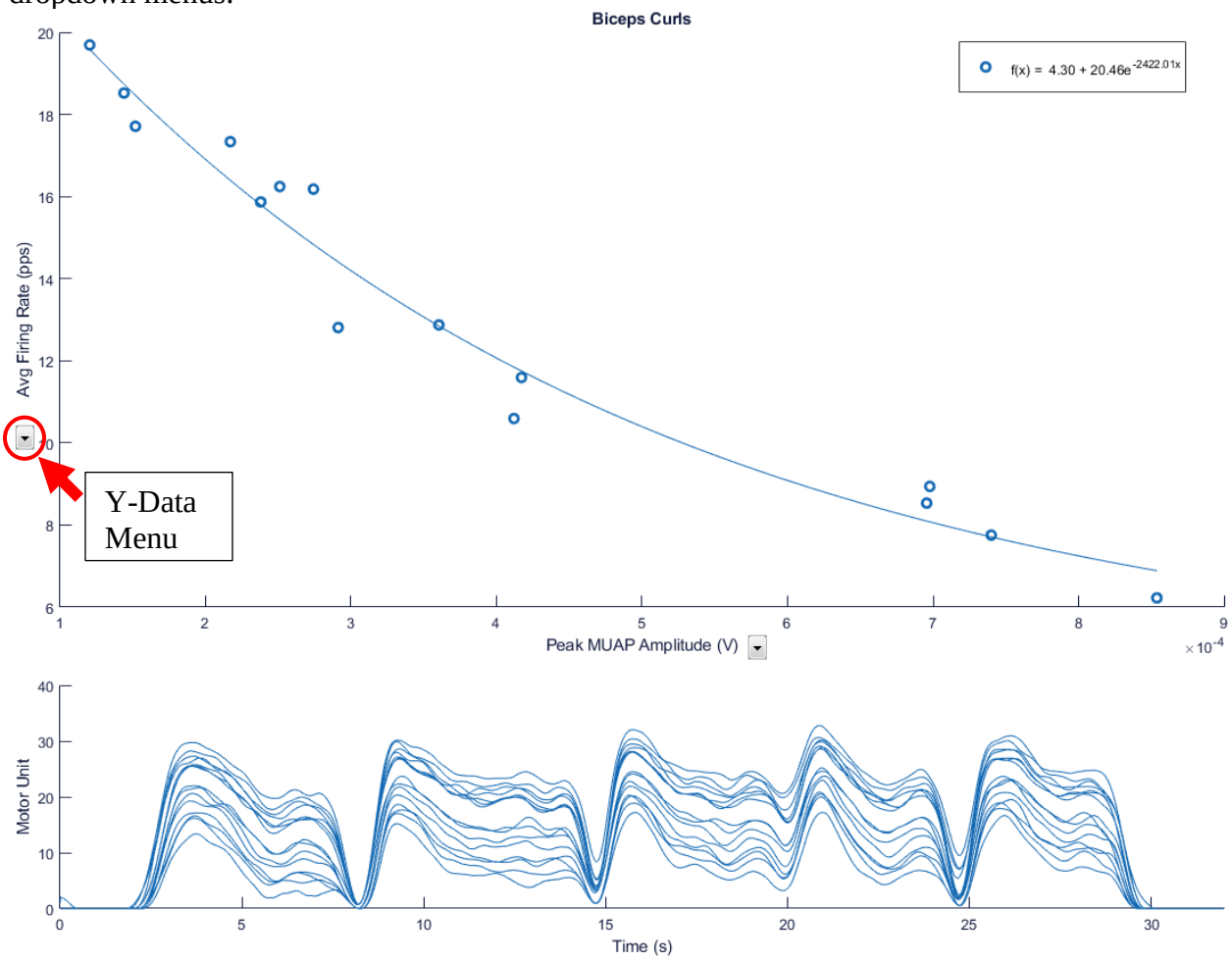


Figure 37: Regression analysis of the averabe motor unit firing rate. Note default regression is Peak MUAP Amplitude (X-Data) vs. Peak MU Firing Rate (Y-Data).

5.6.4. Statistics variables

Peak Firing Rate provides a histogram of the peak firing rate of the MU. It is calculated from the inverse of the max inter-pulse interval (IPI) of all MU firing instances within the specified time interval. Each IPI is a measure of the interval between adjacent MU firing instances.

Average Firing Rate provides a histogram of the average firing rate of the MU. It is calculated from the inverse of the average IPI of all MU firing instances within the specified time interval. Each IPI is a measure of the interval between adjacent MU firing instances.

Peak MUAP Amplitude provides a histogram of the peak MUAP amplitudes, calculated as the maximum across all channels of the maximum value of the rectified MUAP waveforms.

Average MUAP Amplitude provides a histogram of the average MUAP amplitudes, calculated as the mean across all channels of the maximum value of the rectified MUAP waveforms.

IPI Average provides a histogram of the average IPI of all MU firing instances within the specified time interval. Each IPI is a measure of the interval between adjacent MU firing instances.

IPI Standard Deviation provides a histogram of the standard deviation of the IPIs of all MU firing instances within the specified time interval. Each IPI is a measure of the interval between adjacent MU firing instances.

IPI Coefficient of Variation provides a histogram of the coefficient of variation of the IPIs of all MU firing instances within the specified time interval. Each IPI is a measure of the interval between adjacent MU firing instances.