

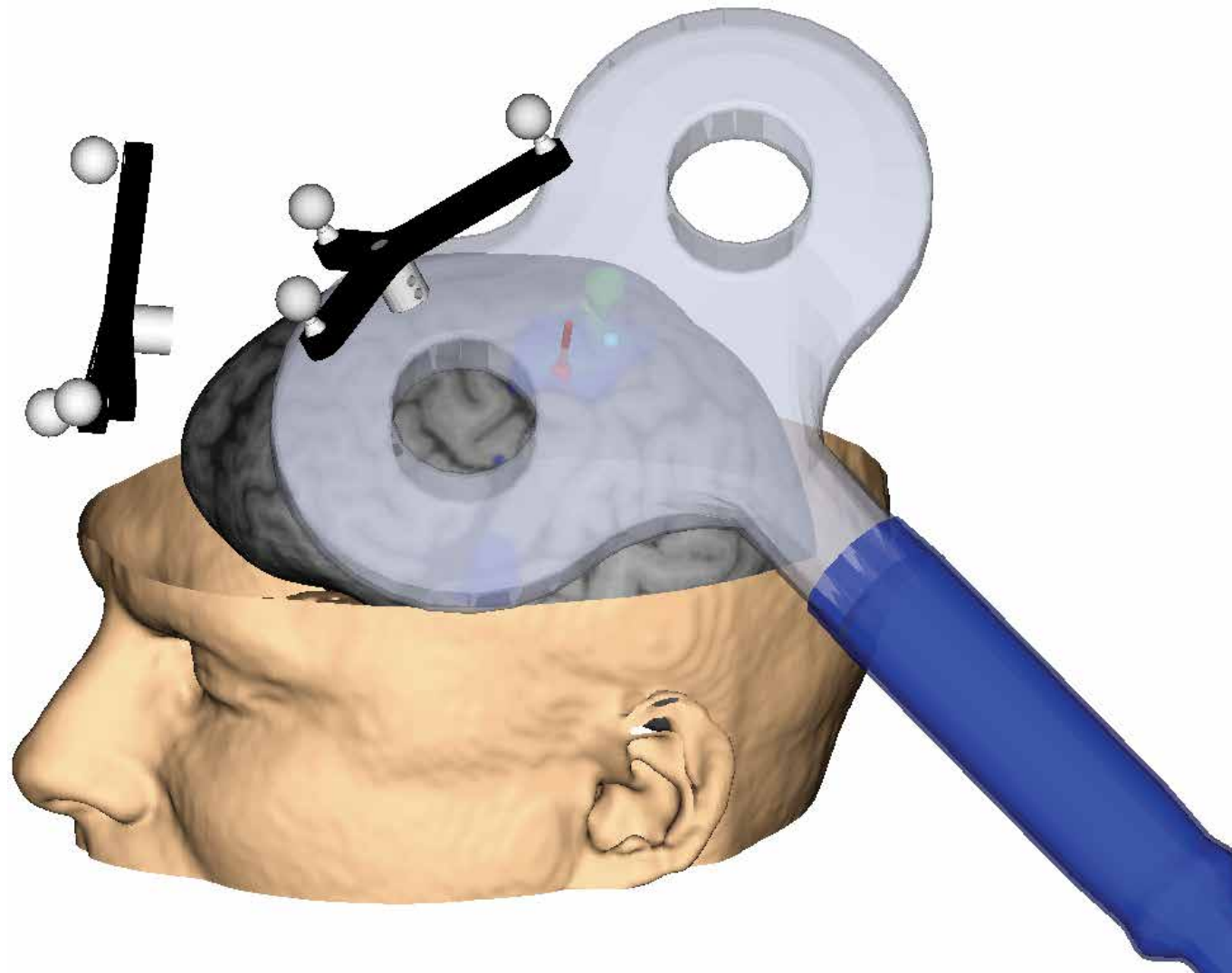
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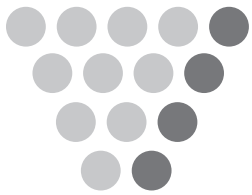
TMS

USER MANUAL

v2.3

For software version 2.3.5
(April 2017)





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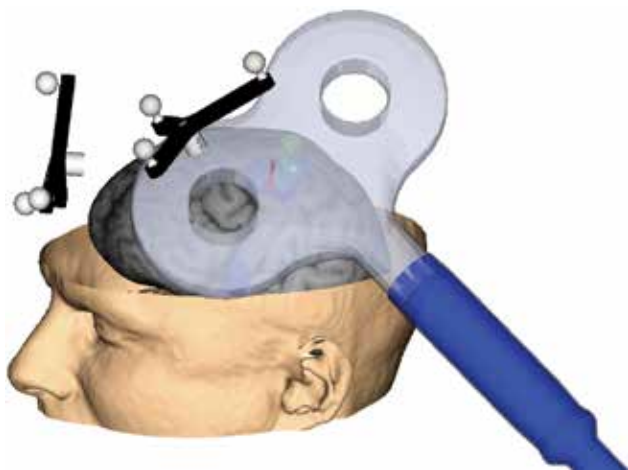
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Montréal, Canada



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libusb

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- d) If a facility in the modified Library refers to a function or a table of data to be supplied by an application program that uses the facility, other than as an argument passed when the facility is invoked, then you must make a good faith effort to ensure that, in the event an application does not supply such function or table, the facility still operates, and performs whatever part of its purpose remains meaningful.

(For example, a function in a library to compute square roots has a purpose that is entirely well-defined independent of the application. Therefore, Subsection 2d requires that any application-supplied function or table

used by this function must be optional: if the application does not supply it, the square root function must still compute square roots.)

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Thus, it is not the intent of this section to claim rights or contest your rights to work written entirely by you; rather, the intent is to exercise the right to control the distribution of derivative or collective works based on the Library.

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This option is useful when you wish to copy part of the code of the Library into a program that is not a library.

4. You may copy and distribute the Library (or a portion or derivative of it, under Section 2) in object code or executable form under the terms of Sections 1 and 2 above provided that you accompany it with the complete corresponding machine-readable source code, which must be distributed under the terms of Sections 1 and 2 above on a medium customarily used for software interchange.

If distribution of object code is made by offering access to copy from a designated place, then offering equivalent access to copy the source code from the same place satisfies the requirement to distribute the source code, even though third parties are not compelled to copy the source along with the object code.

5. A program that contains no derivative of any portion of the Library, but is designed to work with the Library by being compiled or linked with it, is called a "work that uses the Library". Such a work, in isolation, is not a

derivative work of the Library, and therefore falls outside the scope of this License.

However, linking a "work that uses the Library" with the Library creates an executable that is a derivative of the Library (because it contains portions of the Library), rather than a "work that uses the library". The executable is therefore covered by this License. Section 6 states terms for distribution of such executables.

When a "work that uses the Library" uses material from a header file that is part of the Library, the object code for the work may be a derivative work of the Library even though the source code is not. Whether this is true is especially significant if the work can be linked without the Library, or if the work is itself a library. The threshold for this to be true is not precisely defined by law.

If such an object file uses only numerical parameters, data structure layouts and accessors, and small macros and small inline functions (ten lines or less in length), then the use of the object file is unrestricted, regardless of whether it is legally a derivative work. (Executables containing this object code plus portions of the Library will still fall under Section 6.)

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Labjack exodriver

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GIMP Toolkit (GTK+) GLib

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If distribution of object code is made by offering access to copy from a designated place, then offering equivalent access to copy the source code from the same place satisfies the requirement to distribute the source code, even though third parties are not compelled to copy the

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If such an object file uses only numerical parameters, data structure layouts and accessors, and small macros and small inline functions (ten lines or less in length), then the use of the object file is unrestricted, regardless of whether it is legally a derivative work. (Executables containing this object code plus portions of the Library will still fall under Section 6.)

Otherwise, if the work is a derivative of the Library, you

may distribute the object code for the work under the terms of Section 6. Any executables containing that work also fall under Section 6, whether or not they are linked directly with the Library itself.

6. As an exception to the Sections above, you may also compile or link a “work that uses the Library” with the Library to produce a work containing portions of the Library, and distribute that work under terms of your choice, provided that the terms permit modification of the work for the customer’s own use and reverse engineering for debugging such modifications.

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b) Accompany the work with a written offer, valid for at least three years, to give the same user the materials specified in Subsection 6a, above, for a charge no more than the cost of performing this distribution.

c) If distribution of the work is made by offering access to copy from a designated place, offer equivalent access to copy the above specified materials from the same place.

d) Verify that the user has already received a copy of these materials or that you have already sent this user a copy. For an executable, the required form of the “work that uses the Library” must include any data and utility programs needed for reproducing the executable from it. However, as a special exception, the source code distributed need not include anything that is normally distributed (in either source or binary form) with the major components (compiler, kernel, and so on) of the operating system on which the executable runs, unless that component itself accompanies the executable.

It may happen that this requirement contradicts the license restrictions of other proprietary libraries that do not normally accompany the operating system. Such a contradiction means you cannot use both them and the Library together in an executable that you distribute.

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GNU Triangulated Surface Library (GTS)

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If distribution of object code is made by offering access to copy from a designated place, then offering equivalent access to copy the source code from the same place

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GNU gettext

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MNI 152 Average Brain (used in MNI-based projects)

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WARNINGS AND CAUTIONS

Always connect the power cable to the Polaris optical position sensor while its power switch is OFF (or in the case of the Vicra, with the power cable un-plugged). Failure to do so may cause serious damage to the Polaris camera.

CHANGE LOG

Changes in version 2.3.5 (since 2.3.4): (2017-04-03)

- Added initial support for our new Vet Robot product.
- Improved performance and responsiveness when dealing with large amounts of NIRS or EMG data. Previously, live NIRS and EMG views would always try to draw at 3 Hz, but now drawing speed is increased/decreased dynamically based on how busy the computer is. So, smaller workloads will now draw much faster and more smoothly, while larger workloads will draw more slowly and choppily, but with the benefit that the computer should not become unworkably slow.
- Opening a menu or popup menu no longer stops live drawing (of Polaris tool positions, EMG/NIRS waveforms, etc.)
- The Session > Electrodes step now allows using the bullseye view to help position optodes/electrodes in the desired location.

- The reconstruction+chamber clipping feature will now warn if either reconstruction or chamber mesh consists of more than one part, because the resulting output uses only the largest part of each.
- Fixed a crash trying to open very large medical image files (as anatomical or overlay). Also improved performance dealing with such large files.
- The sagittal view in the AC-PC-Box window now has the nose pointing left, like all the other sagittal views in other windows.
- Fixed a longstanding (but merely cosmetic) bug where the edge-most voxel in all 2D and 3D slice views was a half voxel instead of a full voxel.
- Fixed miscellaneous bugs.

Changes in version 2.3.4 (since 2.3.3): (2017-02-17)

- Numerous performance improvements in various places:
- Improved 2D & 3D drawing performance in various places, especially with overlays on curvilinear reconstructions.
- Better performance working with many landmarks or electrodes.
- Faster region painting.
- TTL triggers (ex: from our optional foot switch) can now be used during the coil/tool calibration procedure (useful for single operators).
- Sample colour can now be changed from the

Session Perform window.

- Fixed a crash that could occur in the region paint window when choosing certain “isolation colours”.
- Fixed various issues with the reconstruction+chamber clipping feature where it would previously sometimes hang, crash, or produce the wrong result.
- Fixed a bug where electrode names would still be visible in 3D views even if the view was rotated such that they were in the back.
- Fixed a bug where loading files with many electrodes would hang.
- Fixed a bug where changing chamber properties would fail to redraw 2D views.
- Connection tubes drawn between NIRS optodes in 3D views can now be clicked, which selects the two optodes at each end.
- Image views are now able to draw characters from many more languages than before (ex: Japanese).
- In addition to the CAD formats that can already be imported/exported (.stl, .ply, .dxf, .bscad), the .vtk polydata format is now also supported.
- All the various parts of the user interface that show or accept numbers now use the localization settings from macOS System Preferences (ex: comma vs period for the decimal point).
- Fixed miscellaneous bugs.

Changes in version 2.3.3 (since 2.3.2): (2016-09-29)

- Grids can now be snapped to a reconstruction surface. Additionally, for trajectory-type grids, the grid nodes can be oriented tangential to the same or another surface. In case the automatic snapping needs tweaking, individual grid nodes can now be moved/reoriented.
- Samples are now indicated in NIRS waveform views with vertical lines that show when each sample occurred.
- The ‘Save As...’ feature has been restored, but only in macOS 10.12 Sierra, where Apple has fixed a bug that affected Brainsight.
- Trying to enable Polaris tracking while a NIRS acquisition is in progress will now warn first.
- Fixed a crash that sometimes occurred when closing a session perform window.
- Fixed several compatibility issues with macOS 10.12 Sierra.
- Fixed miscellaneous bugs.

Changes in version 2.3.2 (since 2.3.1): (2016-08-19)

- Improved performance of views that show waveforms, especially for long acquisitions, or ones with many channels.
- Coil/tool calibrations can now use a custom CAD file for their 3D shape.
- Fixed a bug where the Polaris camera and/or

Magstim stimulator would sometimes not be detected.

- Fixed a bug in MNI Head-based projects where accessories were shown slightly skewed.
- Fixed a bug where a cloned session’s electrodes were never visible in the session review window.
- The Axilum Robotics TMS-Robot’s force sensor sensitivity can now be adjusted.
- The Axilum Robotics TMS-Robot’s custom ‘welcome’ positions are now shown with their specific names.
- Tables that show folders now use a folder icon to make it more clear what they are.
- Improved compatibility with macOS 10.12 Sierra Beta.
- Fixed miscellaneous bugs.

Changes in version 2.3.1 (since 2.3): (2016-06-17)

- Samples can now be exported into DICOM files, either as a new overlay or as a copy of the anatomical. Each sample is drawn as a sphere. The spheres’ voxel values can be either from the EMG peak-to-peak or specified explicitly.
- Improved the MNI152 model head subject registration algorithm.
- Improved performance when working with many hundreds of samples.
- Fixed a bug where cloning a session would result in

the clone showing the motor maps of the original session.

- Fixed a bug where Brainsight Vet would incorrectly warn at launch that the Support Files were not installed.
- Fixed a bug where exporting a .txt file from the Electrodes Recording window incorrectly stated the coordinate system as “Brainsight” when in fact the coordinates are relative to the subject tracker.
- Fixed a bug where grid targets would sometimes be unreachable by the Axilum Robotics TMS-Robot.
- You can now move the Axilum Robotics TMS-Robot’s arm and seat to their ‘welcome’ positions separately.
- The 3D annotation shapes (Cone, Arrow, Brainsight) have been tweaked to have a thin projection line, helping to show the inwards direction.
- The Targets, Perform, and Review windows now show overlays by default.
- The Session Registration window now allows changing the crosshairs shape.
- The Polaris Configuration window now shows the device serial number and date the camera was last re-characterized.
- Fixed miscellaneous bugs.

Changes in version 2.3.0 (since 2.2.15): (2016-01-27)

Important: Brainsight 2.3 now requires Mac OS X 10.9 Mavericks or newer. If your Mac is reasonably recent

(~2007 or newer), you only need to update the OS, see Apple’s website. If your Mac is older, it’s possible you might not be able to update your OS, in which case contact Rogue Research for other upgrade options.

Note: the project file format has changed. Brainsight 2.3 can open documents created by older versions of Brainsight, but older versions of Brainsight cannot open documents created by Brainsight 2.3.

Note: Brainsight is now installed directly in the Applications folder, no longer in a Brainsight subfolder.

- Note: the project file format has changed. Brainsight 2.3 can open documents created by older versions of Brainsight, but older versions of Brainsight cannot open documents created by Brainsight 2.3.
- Note: Brainsight is now installed directly in the Applications folder, no longer in a Brainsight subfolder. Added support for the Brainsight NIRS device.
- Added support for the Axilum Robotics TMS-Robot.
- Added support for using the MNI ICBM 152 average brain as the anatomical, for cases where you do not have a scan of the subject. In this case, the subject registration procedure is different, and includes a new ‘scaling’ step in online sessions.
- An optional refinement of subject registration can now be performed in the Session > Validation step. This is often useful to make corrections to small registration errors.
- TTL triggers (ex: from our optional foot switch)

can now be used during the subject registration procedure (useful for single operators).

- The ruler tool now works in 3D views, allowing measurement along any reconstruction surface.
- Added a new kind of bullseye view that is target-centric instead of coil-centric. Both kinds of bullseye views now also show a twist angle.
- The session window has been reorganized, with several new steps added or changed:
 - IOBox - this step allows for configuration and testing of the IOBox and EMG pod. You can choose which triggers to use, how long of a dead time, and which EMG channels to record. Note that the option to trigger from high to low has been removed; all triggers are now low to high only. These settings are now remembered as part of the session, and different sessions can now have different options. This step also displays a live view of the data coming from the EMG pod, to help you ensure that electrodes are well attached.
 - NIRS - this step allows for configuration and testing of the Brainsight NIRS device.
 - Neuro Prax - this step allows for configuration and testing of the neuroConn NEURO PRAX® device.
 - Axilum - this step allows for configuration and testing of the Axilum Robotics TMS-Robot.
 - Electrodes - this step is now also available in offline sessions. Electrode positions can now be

imported from more file formats. The file coordinates are converted to subject space by choosing either an atlas space or the anatomical's world coordinates. Additionally, you can now optionally project the location of electrodes sampled with the pointer to the skin to compensate for the thickness of the electrode itself.

- Improvements to waveform views:
 - You can now zoom in by holding the command key and dragging. A box will appear, and its contents will become the full extent of the view. To zoom out, you must still use the buttons in the HUD or option-scroll with the mouse.
 - Multiple waveforms can now be viewed at the same time, staggered along the y axis, in the same view. This replaces the 'EEG Vertically Stacked' view (now removed) and works not only for EEG but for EMG, ECG, EOG, and NIRS.
 - Waveform views can now be customized, specifically, you can show/hide channels and rearrange their order.
 - The 'Fit in Y' button was renamed to 'Fit All Y', and a new 'Fit Y' button fits by looking only at the currently visible time range.
 - From Preferences, you can now customize colours for the background, axes, and waveforms themselves.
 - Inverted the option-mouse-wheel zoom shortcut

to be consistent with 2D and 3D views.

- You can now pan by using the mouse wheel.
- You can now view the FFT (Fast Fourier Transform) and RMS (Root Mean Squared) of any waveform (EMG, EEG, NIRS)
- Improvements to the legend (at the top-right of waveform views):
 - Can now be expanded or collapsed and overlapping or not, as needed.
 - Can now be scrolled when there are a lot of channels.
 - Provides a checkbox for every channel that can be toggled to show/hide that channel.
 - Provides a contextual menu to show/hide waveforms and to centre a waveform in the view.
- EMG improvements:
 - There is now a live display of EMG data.
 - Added support for baseline subtraction in live EMG views. The Session > IOBox step now provides a button to compute a per-channel baseline (or you can specify them manually) and this value will be subtracted from all live EMG views. This doesn't impact data recording, only visualization.
 - Fixed a bug where motor map visualizations could not be created if all the peak-to-peak values were manually entered (not from our EMG Pod).

• EEG improvements:

- When exporting electrodes in Session > Electrodes, you can now choose the coordinate system to use (for file formats that allow it).
- Electrode orientation can now be exported/imported from text files (instead of only x, y, z).
- Electrodes are now displayed with orientation instead of only as a point.
- The Electrode Recording and Session > Electrode windows can now import electrode names and MNI positions from Brainsight .txt files.
- When creating a new session by importing a Brainsight .txt file, electrodes are now also created for any electrode information in the file.
- Electrodes are now listed in the session review window.
- When creating cortical targets, it is now easy to set their orientation to be optimal for placing a TMS coil on the scalp. Previously, clicking on a curvilinear reconstruction always set the orientation to be normal to the curvilinear reconstruction itself, now you can optionally specify a different reconstruction (usually the skin reconstruction) using the popup button under the lat/twist/AP sliders.
- The AP/Lat/Twist oblique crosshair angles can now be entered numerically in textfields, instead of only manipulated by sliders.

- During a session, Polaris tracking can now be disabled by toggling the 'enable tracking' checkbox. This is especially useful when working with NIRS, where the Polaris' infrared emissions may cause interference.
- Better support for communicating with Magstim 200² and BiStim² stimulators. If the device reports an error condition, the status text is now shown in red. The BiStim² is better supported with the pulse interval and second power now displayed and recorded as part of a sample.
- An atlas space's 4x4 matrix can now be exported as a MINC .xnm file. This is especially useful when using our manual AC-PC-box method, as you can now export and use the exact registration in other software.
- Curvilinear reconstructions can now be cropped using the '3D Crop Tool'.
- Curvilinear reconstructions can now be exported as a folder of CAD files, one file per peel (this only gives the shape, not the colours).
- You can now change the opacity of curvilinear reconstructions.
- Surface reconstructions (ex: a skin reconstruction) can now be made with even more smoothness than before.
- When importing/exporting reconstructions to CAD files, atlas space coordinates can no longer be used,

since they often involve a scaling component and would thus distort the shape/size of the reconstruction.

- In the session window, pressing left and right with the Apple Remote now changes steps.
- In the session perform and session review windows, a new optional table column is available that shows how a sample was created, ex: by TTL1, TTL2, etc.
- The file format of .txt files exported from the review window has changed slightly: EMG channels are now numbered starting at 1 instead of at 0 (to match how they are displayed visually).
- Cloning a session now preserves more details, such as the view layout, view orientations, crosshairs position, custom views, etc.
- To accommodate different accents, the preferences window now allows you to specify custom words for 'sample', 'next', and 'previous' when using speech recognition.
- In 2D and 3D views, holding the command key and scrolling the mouse wheel is a new shortcut for panning.
- Added new region painting shortcuts: as before, when using the various painting tools, holding the option key toggles between paint and fill; now, holding the shift key toggles between paint and erase. So by using option and shift, you can now, paint, erase, fill, and erase fill without having to

switch tools.

- Fixed a bug where the curvature of rectangular grids was not behaving as intended. The maximum curvature now results in 'tighter' grids.
- In Preferences, the highlight colour used when selecting targets/landmarks/samples can now be customized (the default is still red).
- Various performance improvements: much faster waveform views, better handling of large datasets, faster rotation of 3D views, faster computation of atlas spaces, faster computation of automatic curvilinear, faster ROI painting.
- The newest versions of the KeySpan (3.0) and FTDI (2.3) device drivers are now installed (these control communication with RS-232 serial devices like the Polaris camera and Magstim TMS stimulator).
- Fixed miscellaneous bugs.

Chapter 1: Introduction

Welcome to Brainsight! Brainsight 2 represents the fruition of many years of effort in design and development. Brainsight 2.3 represents the latest installment in feature additions to the Brainsight 2 core. We hope that you find this new generation of neuronavigation tool useful, and as always, we value your feedback.

HOW THIS DOCUMENT IS ORGANIZED

This document is intended to give you all the information you need to take advantage of all the features of Brainsight 2.3. The overall structure is designed to present the information in the same logical order as you would need it in the normal use of the system. There are occasions where some background information that will be useful throughout the document will be presented. These will be given in the first place where they will be needed, and usually highlighted by being in a grey box.

Document formatting

In numerous places, you will be instructed to select menu items, or click on buttons. Rather than describing these in a “long winded ” way (e.g. “select Open... from the File menu”, or “click on the OK button”), a more concise shorthand will be used. For example, “select **File->Open**” will be used for menu selection and “click **OK**” will be used for button clicks.

SYSTEM REQUIREMENTS

Brainsight 2.3 requires a recent Macintosh computer with the following minimum characteristics:

- Mac OS X 10.10. or greater
- Intel CPU
- 8 GB RAM (16+ recommended)

If you are contemplating a new computer purchase, we recommend a computer with at least 8GB RAM to ensure that the computer will be useful for a long time.

HOW TO GET HELP (or HOW YOU CAN HELP US MAKE BRAINSIGHT BETTER FOR YOU)

Brainsight 2 was designed and developed using high standards in product planning, software coding and testing. It is our expectation that on the whole, the software will work without major issues, however you may use Brainsight in ways that we did not foresee, and encounter new issues. You can provide us with valuable feedback in the following ways:

- **Automated crash reporting**

If Brainsight 2 crashes (“Quit unexpectedly”, or “Quit while unresponsive”), a message will appear after the crash to send info to Apple. Please use this, however only Apple gets that message and is useful if the crash was caused by the OS. When you restart Brainsight, a second crash reporter will appear that allows you to send the report directly to us. The second reporter will include a screen with an error message and a record of what the software was doing when it crashed. Please add a brief description of what you were doing, and any information that you think might be helpful to us to reproduce the event. Finally click on the **Send to Rogue Research**. Several team members will receive an e-mail alert and will act on it quickly. No personal information (other than the IP address of your computer) is included, so if you want us to follow-up with you regarding the crash, please include your name and e-mail in the comments, or send us an e-mail (so

we know who to contact).

While Brainsight is running, help can be obtained from the help menu. It contains a link to a PDF version of the user manual, which is always up to date, and shortcuts to the e-mail to our support address.

- **mail support@rogue-research.com.**

As with the crash reporter, several experienced people (the engineers that actually develop Brainsight) get the support e-mail so you should get a reply as soon as possible from someone who can help out in a meaningful way.

If you are a Brainsight 1 user, your current version 1.x software licence key (serial number) **will not be able** to enable the functionality of Brainsight 2. Rogue Research has adopted a new serial number scheme for Brainsight 2. For upgrade information, please contact us at info@rogue-research.com.

Note: If you are using a beta or a trial version, it will have an expiry date. After it expires, you will still be able to load projects and view your data and perform 3D reconstructions, but you will not be able to calibrate coils or perform TMS sessions. In the case of a beta version, a newer one will have already been released for you to download. If it was a trial version, contact us (info@rogue-research.com) for upgrade information.

Chapter 2: Installing Brainsight

Brainsight 2 uses a simple installer to install the software and various components with the exception of your tools files, which need only be installed once. If you are a Brainsight 1 user, the file format for your tools has changed. You will need a new serial number to download Brainsight 2 and the new tools files. Contact Rogue Research for more details.

GET THE SOFTWARE

If you have an up to date Brainsight CD or USB thumb-drive, insert it into the computer's CD drive or USB port. Otherwise, follow the instructions on the download page at www.rogue-research.com to download the disk image and if you have not done so yet, your tools archive and support files.

INSTALLING THE SOFTWARE

Brainsight uses an installer to install the software as well as the drivers and support files. Double-click on the disk

Fig. 2-1

Example of a Brainsight 2 disk image.



image to mount it on your desktop.

Double-click on the installer package to initiate the install process (Fig. 2-1).

Click on Continue to get to the terms of use page. If you agree to the terms, then click “Continue” a second time. In the next screen (Fig. 2-3), simply click “Install” and all

Fig. 2-2

First step in the installer.



Fig. 2-3

Final confirmation screen.



the required components will be installed.

Once you click the Install button, you will be requested to enter the name and password of a user with administrative privileges. Enter it to continue the install.

Note that some of the drivers are the same as used in Brainsight 1.7, namely the driver for your Polaris. The installer will install the latest version if it is not already there. Updating should not affect the usability of Brainsight 1.7.

Once the install is complete the final screen will appear confirming success. Click on the Close button to complete

the install.

INSTALLING SUPPORT FILES

(Perform this only once)

If you have not already done so, install the TMS support files. These include sample data (which will be installed on your desktop) as well as the files needed for MNI atlas support and the model head-based project template.

Double-click on the **Support Files-Human.mpkg** icon to launch the installer. Follow the same steps described in “Installing the Software” on page 3 to complete the installation.

QUICKLOOK PLUGIN

One of the software components installed is a Quicklook™ plugin. This adds the ability to display preview thumbnail images rather than a generic icon. The plugin supports many of the image data formats supported by Brainsight including (but not limited to) DICOM, MINC, NIFTI and Analyze. Note that if you use other software on your computer that installs its own QuickLook plugin for the same formats, either one may be called upon by the operating system.

INSTALLING YOUR TOOLS

(Perform this only once)

As mentioned earlier, Brainsight 2 uses a new file format to represent your tools (when compared to Brainsight 1). A new database entry was created with your specific tools and you should have downloaded them along with Brainsight, or if Brainsight 2 came on a CD, then a tools

folder will have been included on the CD. Brainsight 2 keeps your tools in a private folder (instead of setting the path to the tools folder in the preferences window as you did in Brainsight 1). You only need to open the tool file in Brainsight 2 and Brainsight will copy the tool file to the appropriate place.

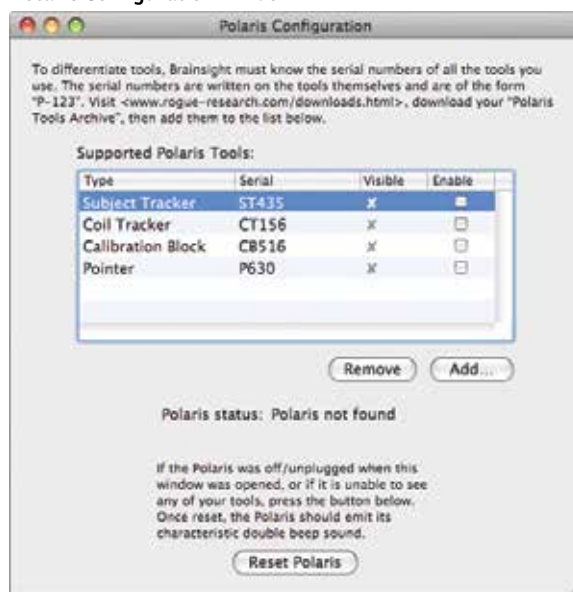
Note that if you have already installed your new tools for an earlier version of Brainsight 2 (including any beta versions), you can skip this step, otherwise:

Make sure your tools folder is accessible (i.e. decompress it if it is an archived folder by double-clicking on the archive).

1. Launch Brainsight, and click **I Agree** to dismiss the splash screen.
2. Select **Window->Polaris Configuration** to open the Polaris window (Fig. 2-4).
3. Click **Add...** and select all the tools in the subsequent file selection dialog box. Click Open to confirm the selected tools. Note that the tools should appear in the list of tools.
4. If they are not already enabled, Enable each tool by clicking on the check box next to each one. Note that you can only enable one tracker of a type (e.g. CT-xxx class of trackers) at any given time. If, for example, you wish to calibrate two separate coils, both with CT-type trackers, then you will have to enable one first, perform the calibration, then return to this screen again to switch the enabled tracker to the

Fig. 2-4

Polaris Configuration Window



Note:

If you are upgrading from Brainsight 1.5 or earlier and are using a P4 model Polaris (serial number P4-xxxxx), you need to run the Polaris firmware updater, or the camera will fail to track your tools. The updater can be found on any Brainsight 1.7 CD or downloaded disk image (you would have run this when upgrading to Brainsight 1.7).

other, then calibrate that second coil. When you are using the coils during a TMS session, Brainsight will automatically switch the active tracker if you switch the tracked tool.

Once all the tools have been added, you can delete the tools folder you downloaded since Brainsight has copied the tools into the private folder.

SETTING YOUR PREFERENCES

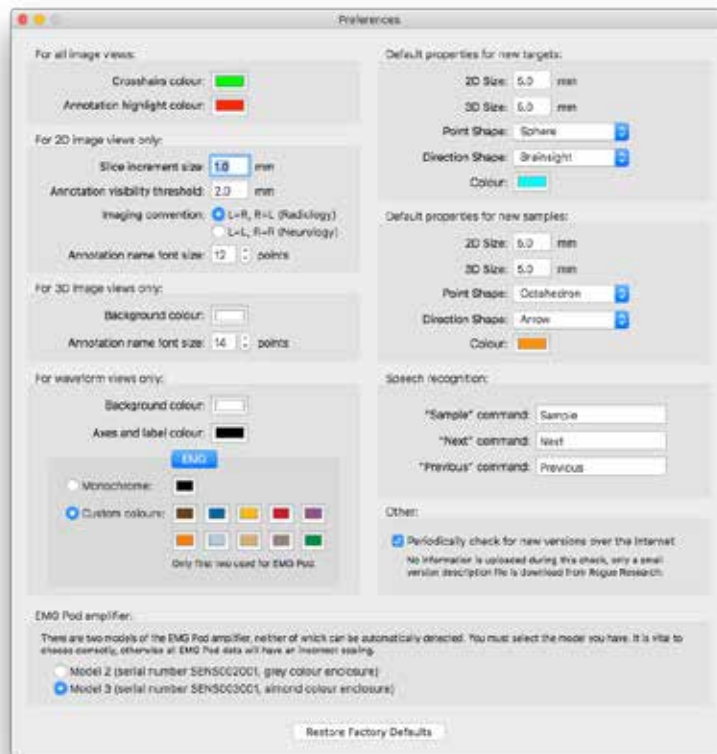
When you first install Brainsight, it should work “right out of the box”. There are many options that allow you to customize certain aspects of the software. This section will describe these options. Some of these options require an understanding of the software’s functionality that is described later in the manual. It is a good idea to read through this as a list first with the understanding that many of these options will become clearer once you have familiarized yourself with the different aspects of Brainsight.

Launch Brainsight, and select **Brainsight->Preferences** (see Fig. 2-5).

Crosshairs colour: Refers to the colour of the crosshairs that indicate the location of the cursor. To change the colour, click on the colour box to open the colour picker to pick a new one.

Annotation highlight colour: An annotation can be a landmark, target or sample. When any of them are selected in any list, the 2D and 3D representations in

Fig. 2-5
Preferences Pane



any window are highlighted by a box that surrounds the object. The colour of the box is set by this preference. To change the colour, click on the colour box to open the colour picker to pick a new one.

Slice increment size: When viewing a 2D plane it is possible to go from one slice to the other using the arrow keys or the mouse's scroll wheel. Each keypress of the

arrow or movement of the scroll wheel will move the cursor the distance set by this preference. Change it by typing a new number in the box.

2D View annotation visibility threshold: When a marker location intersects a 2D imaging plane, the annotation is drawn on the plane. The threshold value determines how close to the plane the marker needs to be to be

considered on the plane.

Imaging convention: When viewing 2D transverse and coronal slices, there is an ambiguity regarding which side of the image is the subject's left or right (this ambiguity dates back to when X-rays were viewed as translucent films placed on a light box). There are two conventions, often referred to as Radiology and Neurology for historical reasons. Radiology is the convention where the subject's right is displayed on the left of the screen and vice-versa. Neurology refers to the convention of the subject's right being on the right of the screen (think of it as looking at the subject's face, or the subject's back, or looking with the subject). Brainsight always displays an R symbol for the subject's right side (on the left when in Radiology convention, and on the right when in Neurology convention), so you will always know which convention you are using.

Annotation label font size (2D): This is the size of any labels associated with any annotation, when the relevant display option is active. Change the font size by entering a number, or clicking on the up/down arrows.

3D Background colour: When Brainsight renders a 3D scene, the surrounding space (background) requires a colour. To change the colour, click on the colour box to open the colour picker to pick a new one.

Annotation label font size (3D): This is the size of any labels associated with any annotation, when the relevant display option is active. Change the font size by entering a

number, or clicking on the up/down arrows.

Waveform View Preferences The waveforms can be viewed in any view either as a monochrome colour, or as colours with each channel having a different colour. Each colour can be individually set by clicking on them and selecting the desired colour from the colour picker. Note that in instances where there are more channels than colours, the colours will be repeated in the same order.

Default properties for new targets: In Chapter 12, you will define targets for stimulation, and how they are to appear on the screen. When a new target is created, some default values are needed, and they are defined here. The **2D size** represents the size of the glyph when drawn on 2D planes (e.g. transverse), while the **3D size** determines the size when drawn in a 3D view (they are different because the nature of the displays often require different values for effective display). The **point shape** describes the shape of the glyph that indicates the location of the target. The **Direction shape** determines the shape of the glyph that indicates orientation (when the target is a trajectory, rather than a simple marker). The **colour** is the colour to use when drawing the glyphs when the marker is not highlighted. Highlighted markers are always drawn in red to differentiate them from the others.

Targets are points that are set prior to a TMS session.

Samples are recordings of the location and orientation of the coil during a TMS session. The default values for their appearance can be set here. The attributes are the same as for targets, so refer to the target preferences for

a description of the individual attributes.

Speech recognition words: The default words for Brainsight to use during the subject registration step representing Sample, Next and Previous commands. Change the words by typing them in these fields.

Periodically check for new versions of Brainsight over the internet: Refers to a function that communicates with our server each time it is launched to see if there are any updates available. If your computer is connected to the internet, enable this feature to ensure you are informed when an update is available.

EMG Pod amplifier: Brainsight now has 2 models of EMG amplifier. Set the model you have here. The model# is printed on the label on each amplifier. You can also use the colour of the case. If the amplifier is in a grey case, then it is model 2. If it is an almond case, then it is model 3. **Failure to select the correct model will result in incorrect EMG amplitudes being recorded or displayed.**

SETTING UP THE POLARIS VICRA POSITION SENSOR

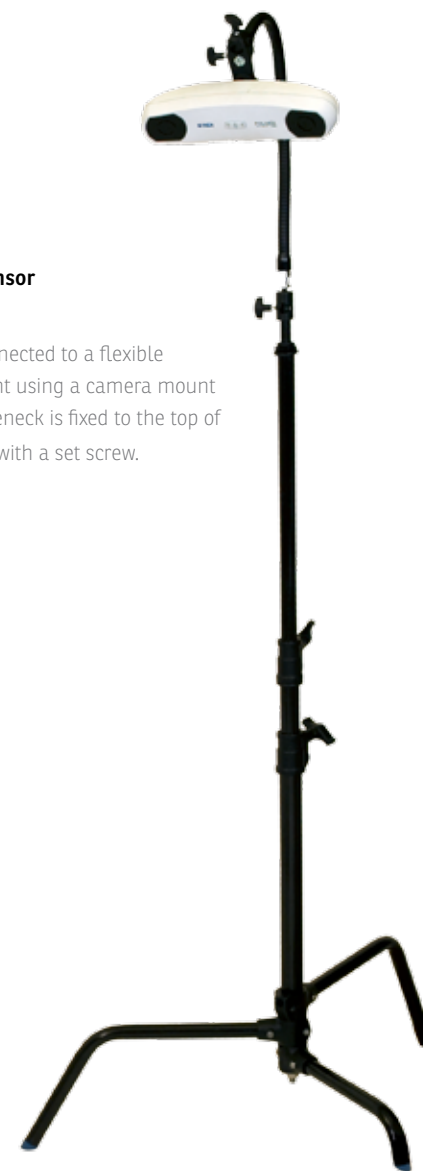
Your Brainsight system will have come with a Polaris Vicra position sensor system. If you are upgrading from a previous version of Brainsight with the traditional Polaris camera, refer to the Brainsight 1.7 user manual for connection instructions.

The Polaris Vicra position sensor system comprises the camera body, a cable with integrated USB-Serial adapter

Fig. 2-6

Vicra position sensor camera on stand

The camera is connected to a flexible gooseneck segment using a camera mount adapter. The gooseneck is fixed to the top of the camera stand with a set screw.



(dongle), a power supply and camera stand. If your Brainsight system included the mobile computer trolley, then refer to Chapter 19 for instructions on how to make the electrical and data connections to the Vicra from the trolley's I/O interface box as some of these components are in the I/O box.

Physical Setup

The camera sits on top of a lighting stand with a flexible "gooseneck" segment between the two (Fig. 2-6). To assemble these:

- Open the legs of the camera stand. As you open each of the three legs, they will snap into position at 120° increments of each other.
- The flexible "gooseneck" bar has two ends, one for the camera mount adapter, and the other with a receptacle that fits on the top of the camera stand. Insert the camera stand end into the camera stand top, and tighten the set screw.
- Fix the camera adapter to the other end of the gooseneck as in figure Fig. 2-7.
- Fix the camera body to the camera adapter, again referring to Fig. 2-7.
- The Vicra cable has a plug at one end (Lemo connector) that connects to the camera, and a dongle with power and USB jacks at the other end. String the Vicra connector through the hole in the camera mount adapter and then plug it into the Vicra. Stringing it through the hole acts as a strain

relief for the cable.

- If you are using your own Brainsight computer (or an early model Brainsight trolley without the I/O box):
 - Connect the power supply cable into the power jack of the dongle.
 - Connect the USB cable into the dongle, and the other end into the Brainsight computer. Take care not to use a USB port on the keyboard as it may not provide enough power for the USB-Serial adapter causing the Vicra to function intermit-



Fig. 2-7

Close-up of Vicra on the camera stand.

The bottom of the gooseneck connects to the top of the stand, while the Vicra is connected to the gooseneck via the mounting adapter.

Fig. 2-8

Wiring diagram for Vicra (without Brainsight computer I/O box)



tently, or cause USB-over current error messages. If you are lacking ports, use a USB 2.0 compliant powered hub.

- The Vicra power supply does not have a power switch. When using the Vicra, simply plug the power into a powered surge protector.
- If you are using the Brainsight trolley with an I/O box:
 - The power and USB cables should come out of the I/O box (are tied together). Connect the two into the power and USB jacks of the dongle.
 - The trolley will have a Vicra power button on the rear panel (see Chapter 19), so turn it on when you need to use the Vicra.

Testing the Vicra

The best way to verify proper functioning of the Vicra is to try to track tools with it. Make sure the Vicra is turned on, and connected to the computer via the USB cable. Select **Windows->Polaris Configuration** to open the window (see Fig. 2-4). You should hear the Polaris reset beeps (2). Make sure the tools are enabled in the list, and move one of them in front of the camera while observing the checkbox next to the tool in the list. If the check changes from a red "X" to a green "check", then it is tracking the tool. If instead of a red "X" or green check, you see a grey "X", then the tool is not enabled due to an error. Contact Rogue Research in this case. You can perform a more detailed check with the Polaris visualizer described in Fig.

2-7.

Troubleshooting Tracking Problems

The Polaris position sensor is a reliable and accurate device. When set set up correctly, it will be able to track your tools without problems. If you encounter a situation where one or more tools do not seem to be tracking correctly, verify the following:

- That there is no glass (e.g. window, mirror) in the camera's field of view.
- That there are no sources of infrared light (e.g. halogen lamp) in the camera's field of view.
- That the spheres of the tool are free of scratches, dirt and are seated properly on the posts.
- That the lenses of the Polaris are clean. If needed, GENTLY wipe off dust and dirt using photographic lens cleaning solution and cloth (or lens paper).
- Make sure that you only have one tool of any given type (e.g. coil tracker) in the camera's field of view at a time.

Note that the camera requires periodic maintenance at the factory to maintain proper performance. The manufacturer suggests that the camera be re-calibrated annually, however we have found that the interval can be considerably longer (a few years). If you find that the camera's field of view is slowly shrinking, it is a sign that re-calibration is needed. Contact Rogue Research to arrange for re-calibration.

Chapter 3: The Overall Steps of Image-guided TMS

INTRODUCTION

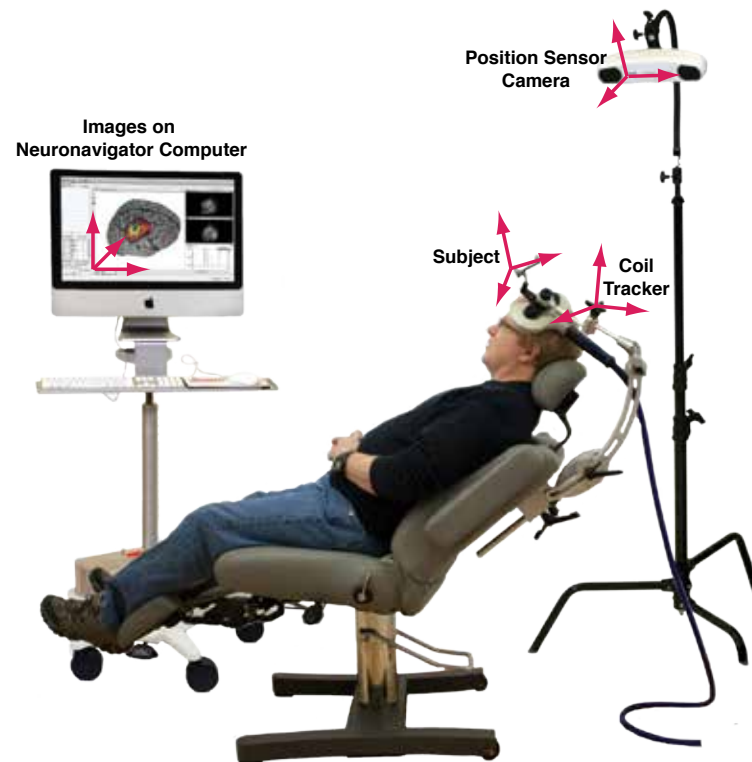
This chapter is intended for those that are new to neuronavigation. The general steps will be outlined and each step will be covered in more detail in subsequent chapters.

NEURONAVIGATION

Neuronavigation (often referred to as frameless stereotaxy or Image-guided TMS) can be described like a GPS system. A GPS system uses satellites to find the GPS unit on the earth. Software in the GPS unit translates the calculated position that are in latitude and longitude coordinates to coordinates on a map in the GPS' memory. The GPS uses this information to display a representation of the unit on the map. It is assumed that you are holding the GPS unit since we don't care where the GPS is unless it is attached to whatever we want to track (us, our car etc...).

A neuronavigator does the same thing. The satellite is replaced by a position sensor, usually an optical camera. The GPS antenna (that receives the satellite signals) is replaced by a tracker, in our case a small triangular shaped object with 3 or more reflective spheres on it. The map is replaced by anatomical images (usually MR images) of the subject. The navigation software communicates with the position sensor to obtain the location of the trackers (one on the TMS coil and one on the subject) and uses a registration matrix (obtained by identifying homologous anatomical landmarks on the images and the subject) to map the location of the TMS coil from the real world (as measured by the position sensor) to the image space. Once calculated, a representation of the coil can be displayed on the images. Stimulation targets can be identified in advance and the navigator can help you get the coil over the target.

Fig. 3-1
Overview of neuronavigation



The overall layout of Brainsight 2 is designed to follow the typical steps involved in preparing and ultimately performing a TMS study. With the exception of the coil calibration, each tab along the top of the window represents one step in the process of getting ready for or carrying out a TMS session. The results of these preparations are stored in a Brainsight Project file. This file will contain links to the image data used as well as all the information you've input into the system. It will also be the repository for all data acquired during the TMS session(s) you perform using the project file.

The remainder of this chapter will introduce each step and how they are related. Each step will be explained in detail in the chapters that follow.

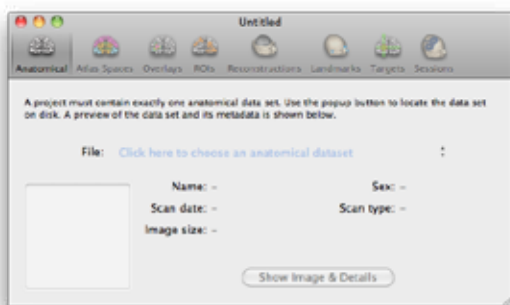


Fig. 3-2

Brainsight project window.

TYPICAL STEPS FOR IMAGE-GUIDED TMS

Calibrate your TMS Coil

The position sensor monitors the location and orientation of a tracker mounted on the coil. Additional information is needed to convert that position to the position of a point of reference for the coil (or the display of the coil's magnetic field). You will, under the software's direction, use a calibration tool to teach the computer where the reference point is on the coil.

Select the Anatomical Data Set

This is a short, simple step. You will select the anatomical image file(s). Currently, we support DICOM (and ACR-NEMA), MINC (both MINC1 & MINC2), Analyze 7.5, NIFTI-1, PAR/REC and BrainVoyager™ anatomical (.vmr).

Co-register to the MNI (and Talairach) Coordinate Space

This step is optional. If you wish to use MNI or Talairach coordinates as a source of target(s), then you need to co-register the individual subject's MR to the MNI coordinate space. You can do this by loading the matrix from MINC tools (e.g. using mritotal), typing in the matrix from SPM, or you can perform the registration manually in Brainsight.

Once the registration is performed, the images will not change (it is common in fMRI analysis to warp the individual's MR into MNI space for comparison) as we remain in "native" space. The transformation between the native MRI and MNI space (and by extension, Talairach

space) is kept in memory allowing the coordinates of the cursor to be expressed in native or MNI coordinates.

Select One or More Overlay Data Sets

This step is optional. If you are using functional data as a guide for targeting, you can load them in Brainsight and display them on both the 2D slices as well as the curvilinear reconstruction (described below).

Create a Region of Interest Using the Region Paint Tool

This step is optional. If you wish to highlight a particular region (e.g. motor cortex), use the region paint tool to paint the region in the anatomical (or any overlay) data. The region of interest will be visible in any of the 2D views, and can be used as the boundary to generate a 3D representation of it as well (see Perform 3D reconstruction).

Perform 3D reconstruction(s)

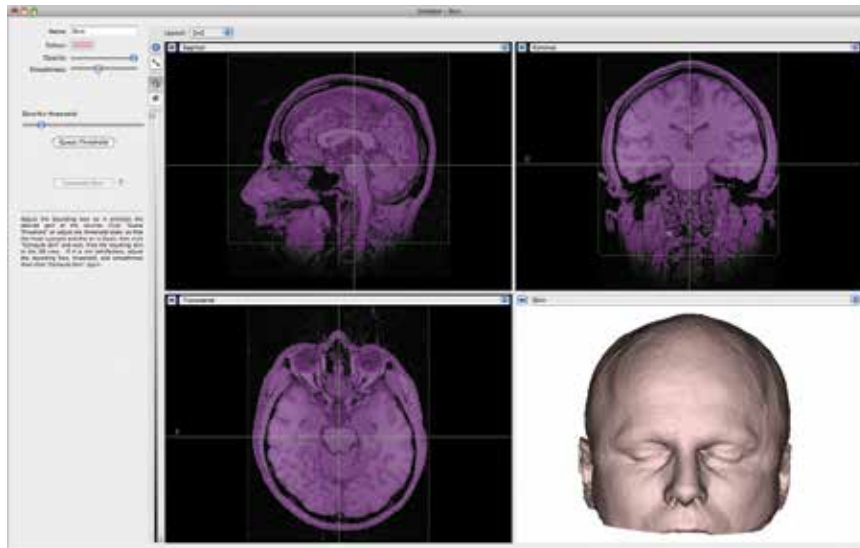
One of the most important features in modern image display software is the ability to display 3D representations of your data. This is especially useful in neuro-navigation where you are required to use the image display to position a tool in 3D over the subject's head. Brainsight currently supports two types of reconstruction: Surfaces based on voxel labelling (either automatically using intensity thresholding) or manual region painting, and curvilinear reconstruction.

The first is often referred to as a segmented surface mesh, or isosurface, where a surface (e.g. skin) is repre-

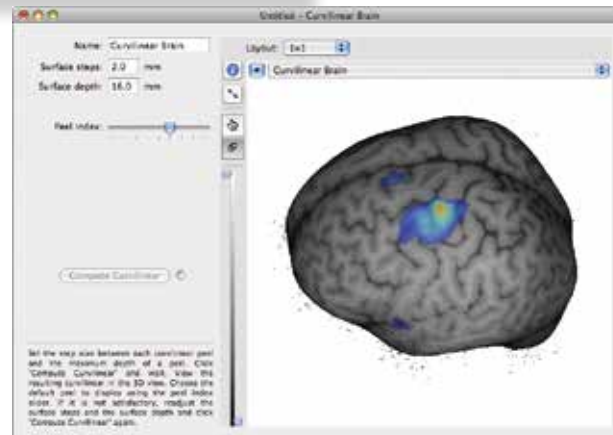
Fig. 3-3

A: Typical screenshot of the automatic skin segmentation.

Notice that the MR voxels of the head are highlighted in purple (as opposed to the “air” voxels as was the case in Brainsight 1), and the resulting skin surface.



B: Curvilinear surface generated by the automatic curvilinear surface tool.



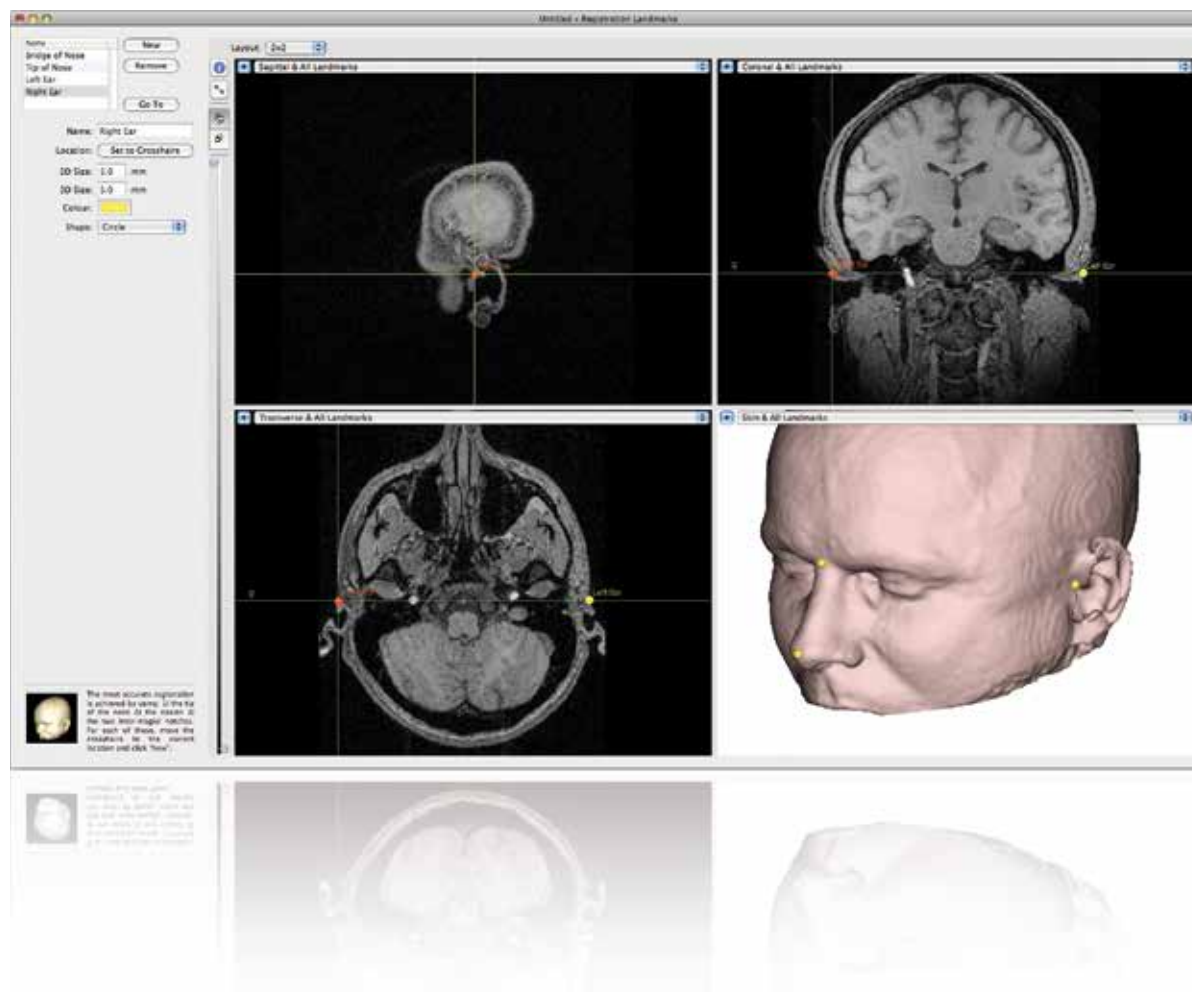
sented as a series of triangles generated by segmenting the raw MRI voxels (see Fig. 3-3a for an example of a segmented skin surface) based on a voxel intensity threshold.

The second reconstruction technique is called curvilinear reconstruction. This technique was originally developed for visualization of a class of lesions involved in Epilepsy called focal cortical dysplasia (see Bastos et. al, Annals of Neurology, July 1999). The technique also proves useful for TMS because it allows for detailed viewing of the brain anatomy within the region of the cortical ribbon that is thought to be reached by TMS.

In short, a smooth surface representing the outer shape of the brain is generated along with a series of concentric surfaces (like the layers of an onion), and those surfaces are painted with the intensity values of the voxels that intersect that surface. By interactively peeling these surfaces, an excellent appreciation of the anatomy within the cortical ribbon can be obtained (see Fig. 3-3b).

Fig. 3-4

Close-up of the 4 typical anatomical landmarks.



Select anatomical landmarks for registration

As mentioned earlier, co-registering the subject to the images is performed by identifying homologous points between the images and subject. The image version of the landmarks are identified in advance, typically by clicking on the landmark on the 3D skin and/or the 2D MRI slices, and recording the landmark.

Select your target(s)

Targets can be chosen using a variety of methods. The most straightforward is to visualize the target anatomically on the image display and record the location. If an MNI registration was performed, then MNI or Talairach coordinates can be used. Finally, if functional data is superimposed, then functional peaks can be used by clicking on the peaks and dropping a marker.

Targets can be recorded as a simple point (x, y, z), a trajectory (which is a point along with an orientation), or a grid of points for mapping exercises.

Perform a TMS session

Once all the "homework" has been done, a TMS session can be performed. The session itself is performed as a sequence of steps. As with the main window, the steps for a session are laid out as a sequence of buttons along the top of the window.

1. **Prepare the setup.** Before starting the session (usually before the subject arrives), you need to set up your equipment. Much of the setup is dependent on the protocol for the experiment. In the context of

the neuronavigation equipment, the setup involves making sure the position sensor camera is in a position to see the trackers on the subject, the coil (particularly when it is the intended position on the subject) and the pointer in the various positions required to identify the landmarks.

- 2. Connect the equipment.** Brainsight 2 offers new features when connected to a supported TMS device via a serial port. For example, you can connect your Brainsight to any stimulator that has a TTL trigger out signal using a BNC cable to automatically record the coil location when it is fired. If you add a serial cable to the Magstim 200² or bi-stim device, Brainsight can communicate with the device to record the coil intensity for each pulse. More devices may be supported in the future as well.
- 3. Sit the subject and fix the subject tracker.** Once the apparatus is set, you are ready to begin the experiment. Place a subject tracker on the subject's head using either the head strap or the glasses. Place the subject in the chair (if you are using a chair).
- 4. Perform the subject-image registration.** Under the direction of the software, touch the same landmarks on the subject's head that were identified on the images. After identifying all the points, verify the quality of the registration by touching the scalp at different locations about the head and observe where they are on the computer screen.

- 5. Position the coil and stimulate.** Now, using the 3D brain, oblique 2D slices and the bull's-eye display, steer the coil to the target and begin your stimulation. During the TMS session, the location and orientation of the coil can be recorded (and other information in some cases), either manually or using the TTL pulses from the stimulator to trigger the acquisition. These are referred to as coil samples.
- 6. Acquire physiological data** (optional). If you are using our EMG and/or supported EEG and/of NIRS device, then you can record data during the TMS session (e.g. EMG at each pulse).

Review the acquired data

After the TMS session, you may want to review the data acquired. For example, you may wish to look at the recorded TMS locations to see how they correlate with the stimulus results, verify that the intended targets were indeed stimulated for quality assurance purposes, or pick selected recorded TMS locations for use as targets in future TMS sessions. If you acquired EEG or NIRS physiological data during the acquisition, you can export the data in file formats common to that modality (e.g. EDF+ for EEG and ".nirs" for NIRS).



Chapter 4: Calibrating Your Coil

Brainsight tracks your TMS coil using a small triangular shaped (3 spoke) device called a tracker. A tracker has three or more reflective spheres in a distinct formation. The distinctness allows the position sensor to distinguish the coil tracker from the subject tracker (despite their similar appearance) and other tracked objects. Brainsight needs additional information in order to be able to display the coil's position given the position of the tracker attached to it. This information is the offset from the tracker to the coil's **reference point**, usually associated with the point thought to be at the coil's maximum output, often referred to as its **hot spot**. The procedure to obtain this information is called calibrating the coil.

PLACING THE TRACKER ON THE TMS COIL

The tracker is fixed to the coil using a short, hexagonal rod and a coil specific adapter that accepts the rod. The tracker is attached to the fixation adapter using a short hex rod. Receptacles for the hex rods are found under the tracker and on the fixation adapter. The receptacles have one or two set screws that are used to fix the hex rod in the receptacle. While attaching the tracker to the coil, take into consideration the orientation of the tracker while keeping in mind the expected location of the coil and the position sensor camera (see Fig. 4-1).

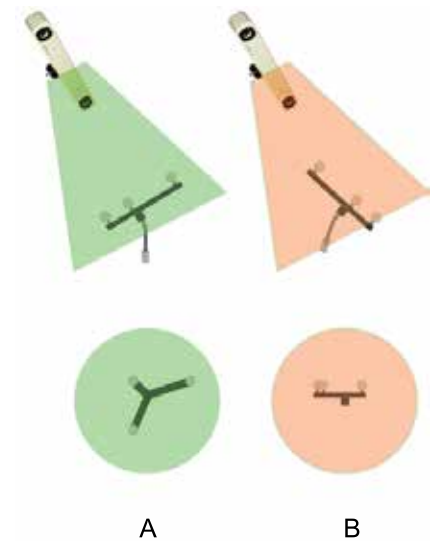


Fig. 4-1

Coil Calibration Manager.

Coil-specific Tracker Adapters

The coil tracker is attached to the coil using a coil specific adapter, taking into account the shape and design of each coil type. In addition, if you are using our Gen 4 subject chair, you may have a combination tracker mount/coil arm fixation mount adapter. In these cases, the adapter will have both the tracker mount and receptacle for the coil holder arm. In general, coil tracker adapters need to be rigidly attached to the coil in such a way as to enable the tracker to be well positioned for visibility, be rigid (not move accidentally), not impede normal use of the coil and not damage the coil.

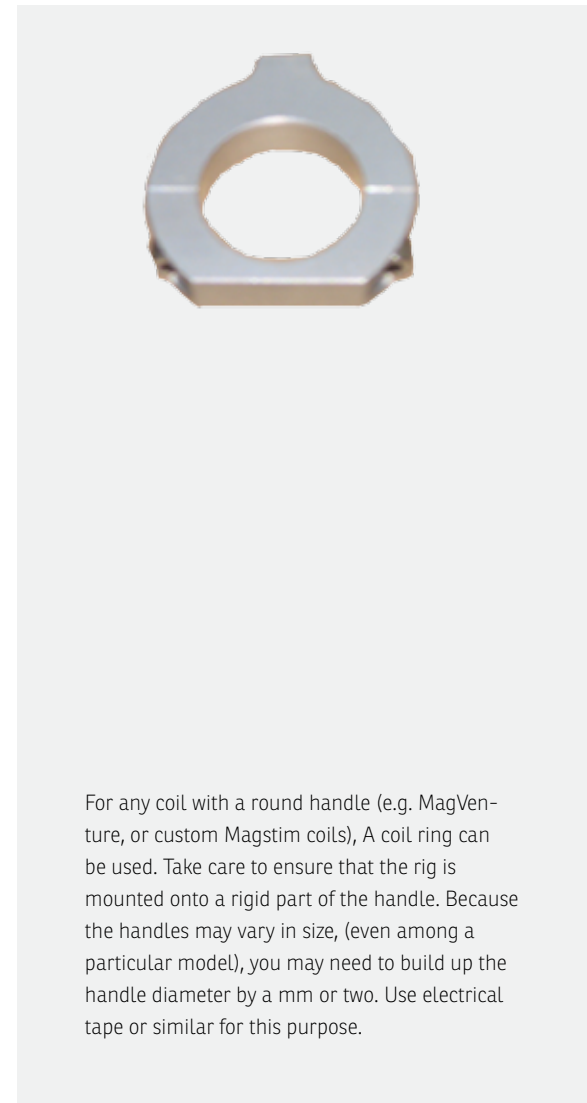
Coil winding hole: When the coil has holes in the winding, a plastic “plug” can be attached to the hole. This method has the advantages of placing the tracker over the top of the coil itself which is the optimum location.

Coil handle: When the coil does not have a hole, then the handle may be an appropriate place by using a ring style adapter. Coil rings for several coil models are available. The main drawback is that the coil handle may be made of a soft material, making it difficult to rigidly attach the ring. It is advisable to re-calibrate the coil often when coil rings are used in case the tracker ring slips without being noticed.

Fixed to another feature of the coil body: In some coils, there are no handles (or appropriate ones) nor are there holes. In these cases, another method is used. For example, the Magstim air-film coil has a specific adapter that uses the mounting points originally intended for the 2 handles.



For three generations of Magstim figure-8 coils (the beige 1st generation, model 9925, blue 2nd generation model 3190 “remote” coil, and 4102 D702 coils) have plastic inserts that fit into either hole. To install, place the upper half into the hole (either one is ok), then the lower half under the coil. Use the plastic bolt to fix both halves together. **Be careful not to overtighten the plastic bolt** (it is plastic, not metal!). When present, be sure to align the lower part of the adapter towards the middle of the coil to prevent the disk from touching the head.



For any coil with a round handle (e.g. MagVenture, or custom Magstim coils), a coil ring can be used. Take care to ensure that the ring is mounted onto a rigid part of the handle. Because the handles may vary in size, (even among a particular model), you may need to build up the handle diameter by a mm or two. Use electrical tape or similar for this purpose.

The adapter for the **Magstim air-film** coil uses the mounting points for the handles as a rigid hard-points. This requires that the coil be partially disassembled to remove the handles. Once the handles are removed, the adapter is placed in the holes for the handles, and using longer screws, the original handles are replaced into holes on the top of the adapter and the assembly is held together using the longer screws that go out of the coil, through the adapter and into the handles. Note that this procedure should be performed by authorized personnel. Contact Rogue Research or Magstim for details.



If you have the **Brainsight Gen4 subject chair** and coil arms, you will likely be using a different type of tracker adapter for your coil. The new chair uses a new method of fixing the coil to the arm, improving the ease in orienting the coil while being held by the arm. The new arm uses coil-specific adapters to attach the coil to the arm, and in many cases, the adapter includes an integrated coil tracker fixation sleeve.



The tracker is attached to the fixation adapter using a short hex rod. Receptacles for the hex rods are found under the tracker and on the fixation adapter. The receptacles have one or two set screws that are used to fix the hex rod in the receptacle. While attaching the tracker to the coil, take into consideration the orientation of the tracker while keeping in mind the expected location of the coil and the position sensor camera (see Fig. 4-1).

- Loosen the set screws on both the tracker and the adapter, taking care that the screws don't come out completely.
- Insert the hex rod into the receptacle of the coil adapter. Make sure that a flat section of the rod is

aligned with the set screw(s). and using the 1/16" hex tool, tighten the set screw(s).

- Insert the tracker onto the other end of the hex rod. Make sure that a flat section of the rod is aligned with the set screw(s). and using the 1/16" hex tool, tighten the set screw(s).
- Check that the hex rod is secure at both ends by lightly trying to twist the tracker.

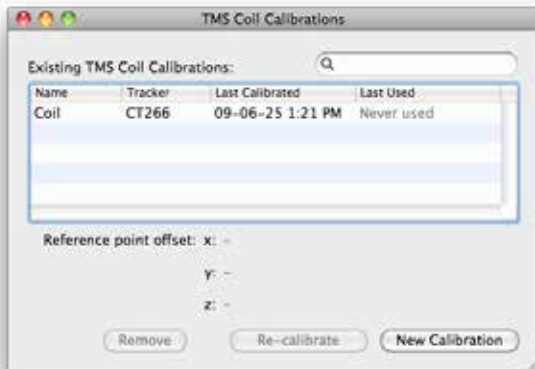
MANAGING COIL CALIBRATIONS

Brainsight 2 manages the coil calibrations with an internal database. You do not need to worry about file names or locations. You simply need to give the coil a name that fits your needs, and match that to the tracker attached to the coil. Select **Window->TMS Coil Calibrations** to open the coil calibration manager window (Fig. 4-2). The calibration manager allows you to create new coil calibrations, re-calibrate existing ones and remove old calibrations.

- To remove one or more calibrations, select it from the list of existing calibrations and click **Remove**.

Fig. 4-2

Coil Calibration Manager.



- To re-calibrate, select the calibration from the list of existing calibrations and click **Re-calibrate**.
- To create a new Calibration, click on **New Calibration**.

PERFORMING A COIL CALIBRATION

As with earlier versions of Brainsight, you calibrate your coil using the calibration block provided with your Brain-

sight tools. While the user interface has been improved, the calibration procedure is relatively unchanged. If you clicked on either Re-calibrate or New Calibration, the window illustrated in Fig. 4-3 will open.

Fig. 4-3

Coil calibration window.

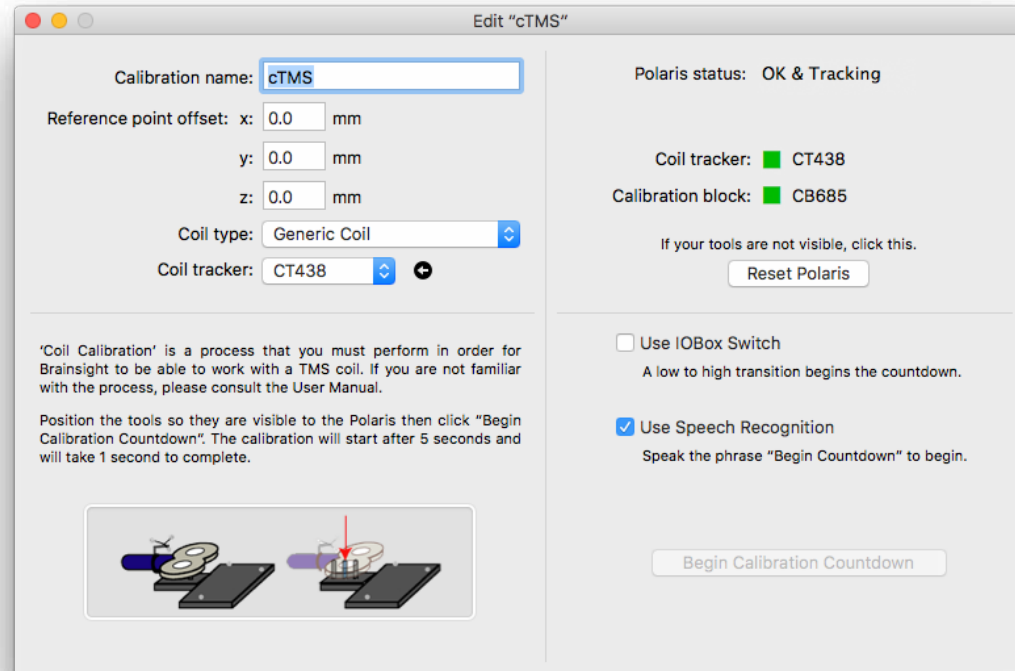
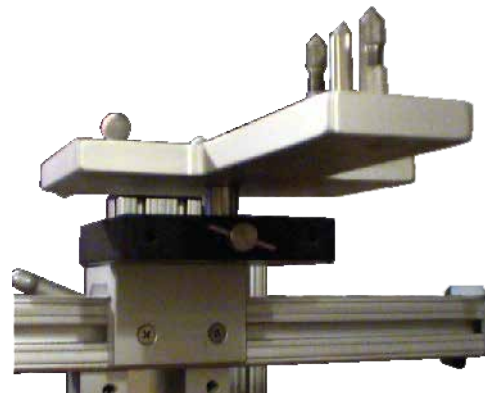




Fig. 4-4

A: Mounting pin to allow you to mount the calibration tool to the chin rest receptacle.

- Make sure you have a tracker fixed to the coil, and that the orientation of the tracker will be optimum for the expected orientation of the coil during the TMS session with regards to the camera orientation (Fig. 4-4).
- Place the calibration block on a table and move the Polaris camera to ensure that the block's spheres are in the camera's field of view. Alternatively, if you are using the head and coil holder apparatus, you can install the mounting pin on the bottom of the calibration block, and place the block in the receptacle used for the chin rest (Fig. 4-4). This has the advantage of already being within the camera's field of view (or relatively close) as the camera would typically be placed to see the subject's head.
- Examine the alignment pins on the block (Fig. 4-5)



B: Calibration block in the chin rest receptacle.

Fig. 4-5

Close-up of the reference indicator pin and the two stabilizer pins. Note that new types of stabilizer with wider depth stops were introduced and are used for the recently introduced calibration jigs (see next page).



to make sure the two outer stabilizing pins are well adjusted for the shape of the coil.

- Referring back to the calibration window, give the calibration a name, which will be used to refer to it in the software (e.g. “fig 8 coil”, or simply “coil” , or if you plan on tracking two coils at the same time, “coil A”).
- If you have one coil tracker, the correct one should already be displayed in the **Coil Tracker** popup button. If you have multiple trackers (to track 2 coils at once, for example), select the tracker that is attached to the coil from the popup menu.
- If desired, enter an x, y, z offset for the reference point. This would allow you, for example, to move the reference point to a location other than the location touched by the reference indicator pin. See Fig. 4-7 for an illustration of the coordinate system for the offset.

If you have a calibration jig for your coil (Fig. 4-6)

- Ensure that the depth stop screws are the ones with the wide, flat section (see Fig. 4-5), and that they are screwed all the way down as they act as the platform to support the jig.
- Select the calibration jig appropriate for your model of TMS coil, and insert it on the jig.
- Place the coil onto the jig.

Fig. 4-6

Rogue Research recently introduced calibration jigs to simplify the calibration procedure. They consist of plastic inserts that fit into the calibration block and have coil specific shapes etched on the surface. The coil simply slips into the jig and can easily be held in place with one hand. Contact Rogue Research for more information.

A: Calibration jig for a common coil (Magstim 9925 or Alpha coil) on the adapter.



B: Coil placed in the jig for calibration.



If you do not have a calibration jig:

- If you have an assistant, have one person hold the coil and place it on the calibration block such that the centre pin (the reference spot indicator) is touching the “hot spot” of the coil. Take care to ensure that the coil is straight and level.

The orientation of the coil on the calibration block will dictate the orientations of the inline and inline-90 view planes (see Fig. 4-7). Alternatively, use the articulated arm to hold the coil and place the coil as described on the reference indicator. **It is very important to be precise. Any error in positioning will translate into a systematic error in coil positioning.**

The next step will be to initiate the calibration measurement. Once the calibration has been triggered, a 5 second countdown will occur to give yourself time to steady the coil. The countdown can be initiated using one of 3 methods:

- 1: enable the voice recognition (click **Use Speech Recognition**) and say “begin countdown”;
- 2: On older iMac computers and laptops that support the IR remote, enable the Apple remote (by clicking **Use Apple Remote**; and pressing the Play button. Note that the remote works best when not in the field of view of the position sensor camera, or having the camera face the computer as the camera’s IR output can interfere with the reception of the remote’s signal.

3: Click **Begin Calibration Countdown**. The software will count down 5 seconds to give you time to steady the coil (helpful if you are alone and have to click and then quickly place the coil). After the countdown, the appropriate measurements will be performed (will take about a second) and the calibration will be complete.

- Close the window by clicking the close button (the top left button).

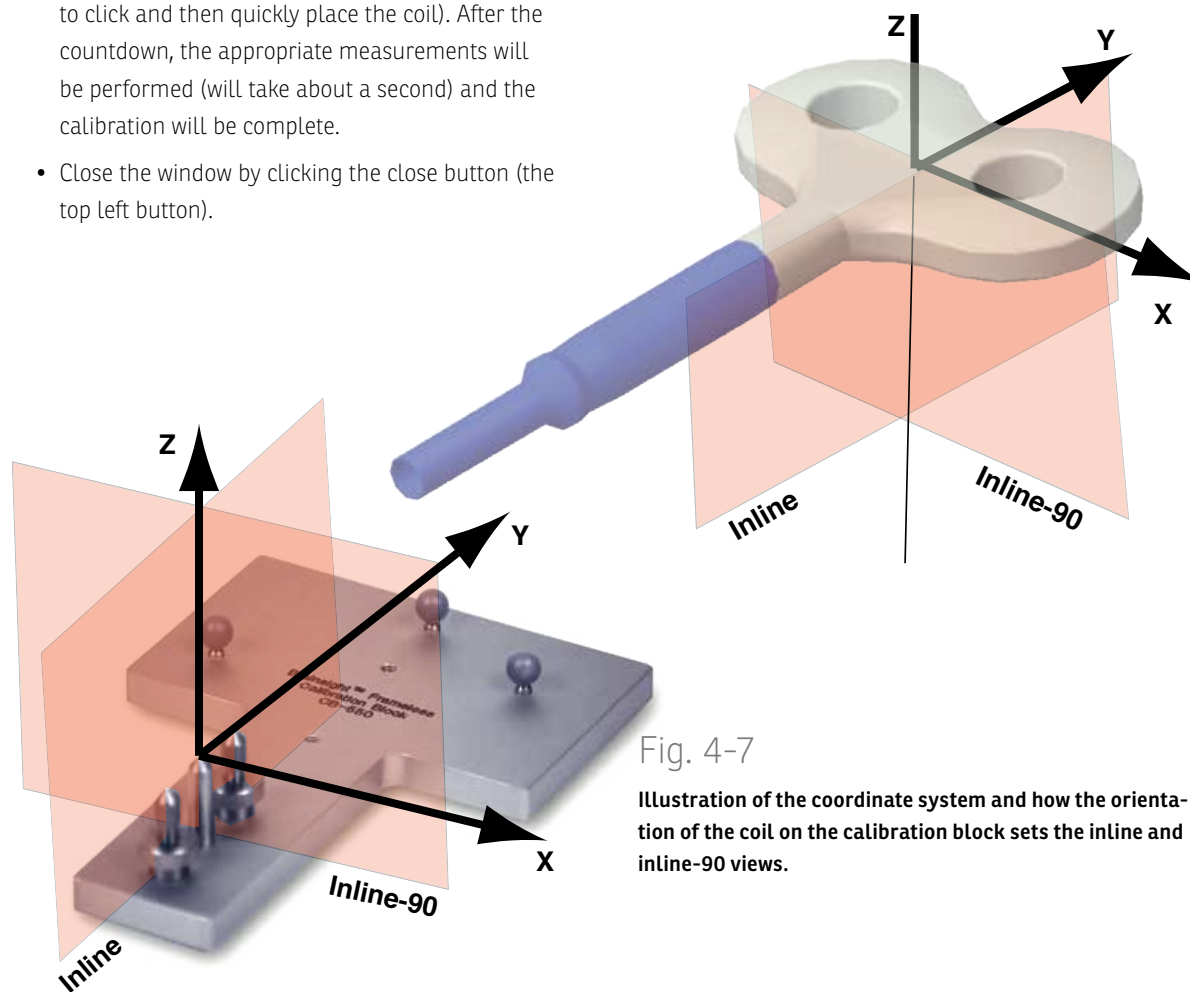


Fig. 4-7

Illustration of the coordinate system and how the orientation of the coil on the calibration block sets the inline and inline-90 views.

Chapter 5: Importing Brainsight 1.7 Projects

The internal file format for Brainsight projects has changed significantly since version 1.7. Brainsight 2 supports opening these older projects so you can both visualize the data acquired with 1.7 and use the data for new TMS sessions. When opening an older project, it will be converted to a Brainsight 2 project, leaving the original project unchanged.

MAPPING THE OLD TO THE NEW

When opening an old project, all the data is mapped from the old representations to the new ones, which can take a few minutes, particularly if the project has several curvilinear reconstructions and your computer does not have a lot of RAM (e.g. less than 2 GB). The good news is that this needs only be done once for a project.

Importing the Project into Brainsight 2

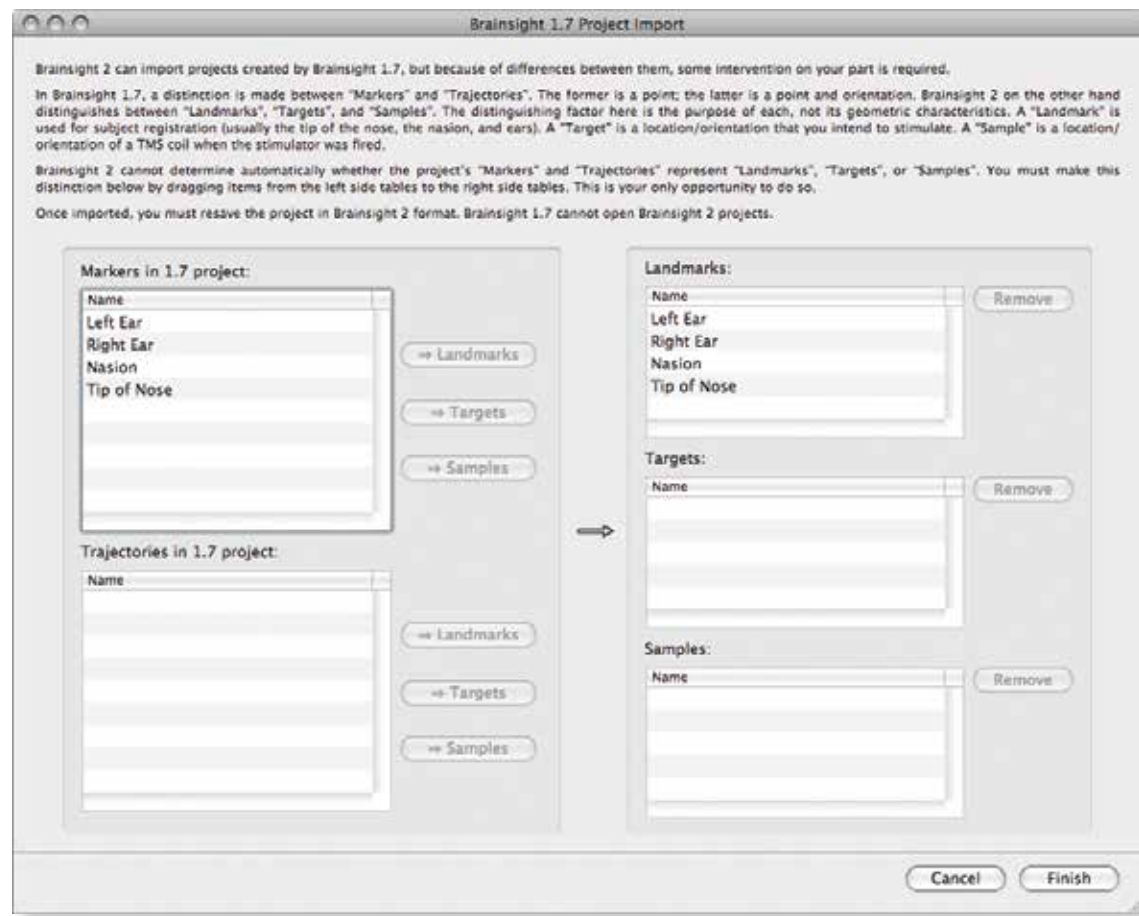
- Launch Brainsight 2.
- Select Open Project from the File menu, and select the Brainsight 1.7 project.
- After a period of time, the project importer window will appear (Fig. 14).
- Markers and trajectories from the old project will be listed on the left, and receptacles for anatomical landmarks, targets and samples will be shown on the right. All the markers and trajectories on the left need to be sorted into landmarks, targets and samples for Brainsight 2 projects (review chapter 4 for these concepts). If you used standard names for the anatomical landmarks, they will automatically be copied into the landmarks list on the right. Otherwise, select the landmarks from the list on the left and click **>Landmarks** to copy them over, or simply drag and drop them from one list to the other.

- Select any targets from the list on the left, and click **>Targets** to copy them to the target list (or drag and drop them).
- Select any samples from lists on the left and click **>Samples** to copy them to the samples list (or drag and drop them). These will be placed in a single TMS session entry in the new project.

Note that Brainsight 2 removes the ability to set the highlight colour as it is always red. Any highlight colours from the 1.7 project will be ignored.

Fig. 5-1

Brainsight 1.7 project importer window.



Chapter 6: Loading Anatomical Images

The anatomical images form the basis for the coordinate system onto which all data is registered to. For example, fMRI data is co-registered to it and overlaid. The subject's head (in the lab) is co-registered to the images to allow the display of the TMS coil on the images. For this reason, loading anatomical images is the first step in preparing your project.

Brainsight supports the use of your subject's specific MRI (recommended), or in the cases where the subjects MR images are not available, a template Brain (MNI 152 average brain). The subject-specific MR images are preferred because they will be the most accurate for targeting, however in some cases, using the model brain may be sufficient, particularly when reproducibility is the main goal. This may be the case when the target is found during a pilot TMS session rather than from the images directly (e.g. motor based target).

INTRODUCTION

When Brainsight is launched and you click "I agree" to the licence statement, a new project assistant window will appear. You can either open an existing project, create a new empty project (empty in that there are no pre-loaded template images) or create a new project pre-loaded with the MNI head images. You can by-pass the assistant window at any time by selecting the same options from the file menu.

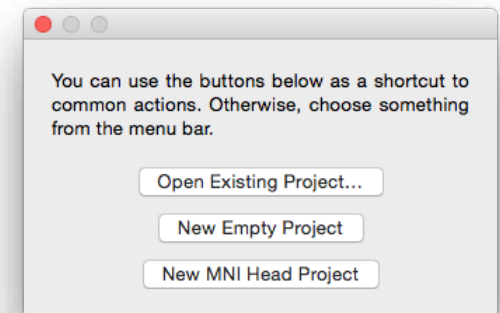


Fig. 6-1

New Project Assistant Window

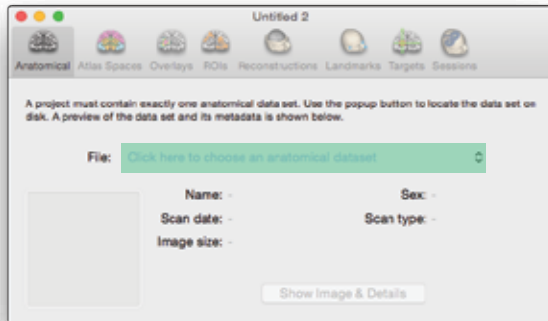


Fig. 6-2

Click on the file selector box (highlighted in green) and select "Choose..." from the popup menu.

OPENING A PREVIOUSLY SAVED PROJECT

Click **Open Existing Project...** in the New Project Assistant Window, or select **File->Open Project...** . When the file selector window opens, navigate to, and select the desired project to open. If the project was recently opened in Brainsight, you can use a shortcut by selecting the project file directly from the **Open Recent Projects** menu.

CREATING A NEW PROJECT USING SUBJECT-SPECIFIC IMAGES

Click **New Empty Project** in the New Project Assistant window, or select **File->New Empty Project**. A new, untitled project window will appear.

- Click the file chooser (the section highlighted in green in Fig. 6-2) and select "**Choose...**", from the popup button. A file selector dialog will appear. Note that you do not need to identify the file format as Brainsight will figure this out automatically. Do the following for each supported file format:
 - MINC: Select the MINC file by either clicking on the file and clicking **Open**, or by double-clicking the file.
 - Analyze (and hdr/img type NIFTI files): These files come in pairs. The header (using the .hdr extension), and the image data file (with a .img extension). Select either file by either clicking on one of them and clicking **Open**, or by double-clicking the file. The image file will be opened automatically.
 - NIFTI files (using the .nii extension): Select the NIFTI file by either clicking on the file and clicking **Open**, or by double-clicking the file.
 - DICOM CD: If your DICOM images came on a DICOM CD, use the free application "Osirix" (<http://www.osirix-viewer.com/>) to read the CD and extract the desired scan. Follow the Osirix instructions for more details, or follow the instructions in).
- DICOM files: All the files for the data set must be in the same folder prior to opening the images. Select any slice of the volume and click **Open**. Brainsight will search the folder for remaining slices from the scan and load them.
- PAR/REC: These files come in pairs. The header (using the .par extension), and the image data file (with a .rec extension). Select either file by either clicking on the file and clicking **Open**, or by double-clicking the file. The image file will be opened automatically.
- BrainVoyager VMR (versions 1-4): BrainVoyager typically performs several image processing steps to convert the native space images into normalized (MNI) space and stores intermediate images. Use the AC-PC aligned images (but not scaled) by selecting the appropriate .vmr file.

Note about DICOM CDs. It is common to receive DICOM files on a CD-ROM formatted in a common DICOM standard. The CD often contains multiple scans and it is difficult to extract the files associated with the desired scan. We recommend using a free application called OsiriX to read the DICOM CD. The software will read the CD and display a list of scans on the CD (it may take a few minutes to scan the disk and build the catalogue. Simply select the scan from the list, click the "Export" button and select the destination for the scan on your hard disk.

Once the images load, a thumbnail of the scan will appear on the project window along with some details extracted from the header (Fig. 6-3). You can proceed to the next step, or view the metadata in the header as well as the image volume by clicking the **Show Image & Details** button, which will open a viewer window (Fig. 6-4). The last section in this chapter will describe the image view window in detail. The example window is taken from a later step in the data processing workflow (the skin segmentation step) as it shows tools that are normally found throughout the software, with the exception of the anatomical detail view (due to its simplicity).

Fig. 6-3

Project window with the anatomical MR scan loaded.

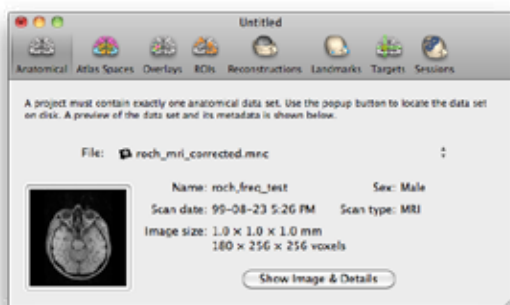


Fig. 6-4

Anatomical Image Detail View

In addition to showing the usual tri-planar images, the files header information is also kept and shown in detail.

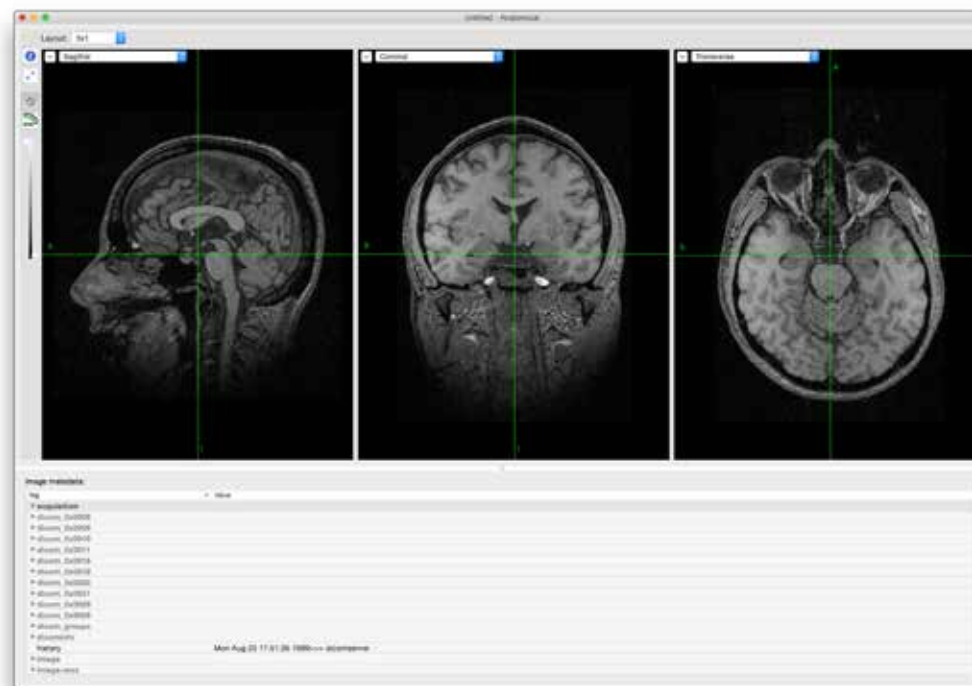


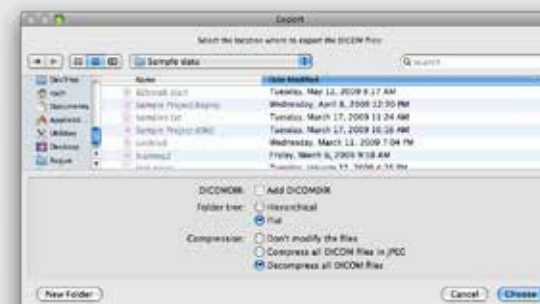
Fig. 6-5

Typical steps for importing DICOM images from a DICOM CD using Osirix.

A: Launch Osirix and insert the DICOM CD. Wait for the CD to be read, or press the CD button at the top of the screen to have Osirix scan and load the images from the CD (or drag the CD icon from the desktop onto the Osirix window). It may take a few minutes to scan the CD and load the images.



B: Select the scan that you wish to use (make sure it is selected in the list view and that the thumbnail images from the scan appear in the lower left view box) and click Export.



C: Select "Flat Folder" and "Decompress all DICOM files". Navigate to your image folder, and press Choose. Osirix will extract and save the scan in a folder using the subject's name and scan number.

CREATE A NEW PROJECT USING THE MODEL HEAD IMAGE SET

When MR images are not available, it may be appropriate to use a template head. Brainsight (as of version 2.3) incorporates the MNI 152 average brain for this purpose (<http://www.bic.mni.mcgill.ca/ServicesAtlases/ICBM152Lin>). Be sure to have downloaded and installed the “TMS support files” (version 1.3 or newer) from our web site (the same way you download Brainsight updates). The MNI 152 is a template based on the average of 152 individual subject MR images that were co-registered to the MNI coordinate space and averaged.

To use the average brain template:

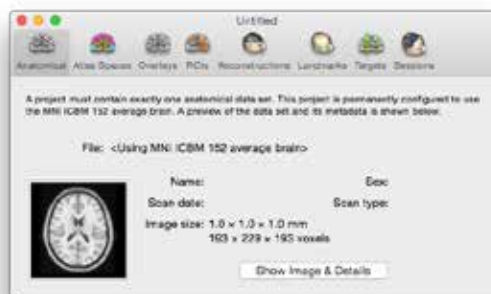
- Click **New MNI Head Project** from the New Project Assistant window, or select **File->New MNI Head Project**. The data set resides in a special place and will be loaded automatically.

Note that the data summary pane shows the image resolution and voxel count, but not the name (there is no name stored in the MNI 152 average brain image file).

The MNI Head project already has a 3D skin, brain surface and brain curvilinear reconstruction, so unless you wish to create additional surfaces, you can skip to “Chapter 12: Selecting Targets for Stimulation”.

Fig. 6-6

Project window with model head selected



WHEN TO USE THE MODEL HEAD VS. SUBJECT-SPECIFIC MRI?

Making the choice between using (and often paying for) subject-specific images vs. a model head can have significant impact on the accuracy and reliability of your study. In general, using a model head is best reserved for the following cases:

- The target will be based on a pilot study or by observing an external response (not by interpreting the anatomical images).
- Reproducibility is the main goal of using navigation (reproducibility vs. specificity).
- Anatomical targeting accuracy of about 10 mm is sufficient.

Subject-Specific MR images should be considered in cases where:

- Targets are based on subject-specific anatomy.
- Targets are based on functional overlay (e.g. fMRI).
- No external measure of target correctness is available.
- Anatomical targeting accuracy of about 3 mm is required.

THE IMAGE DISPLAY WINDOW

The image display window, as the name implies, is the main method of displaying image data. The exact configuration of the window depends on the context of the display (i.e., what step in the process you are in). The relevant controls are shown in Fig. 6-7. Different perspectives of the image data are displayed in individual views, called (to no surprise) Image Views.

Layout Control

Each display window starts in a default layout configuration. In the example of Fig. 6-7, it is a 2x2 layout. The layout can be changed using the layout control popup menu.

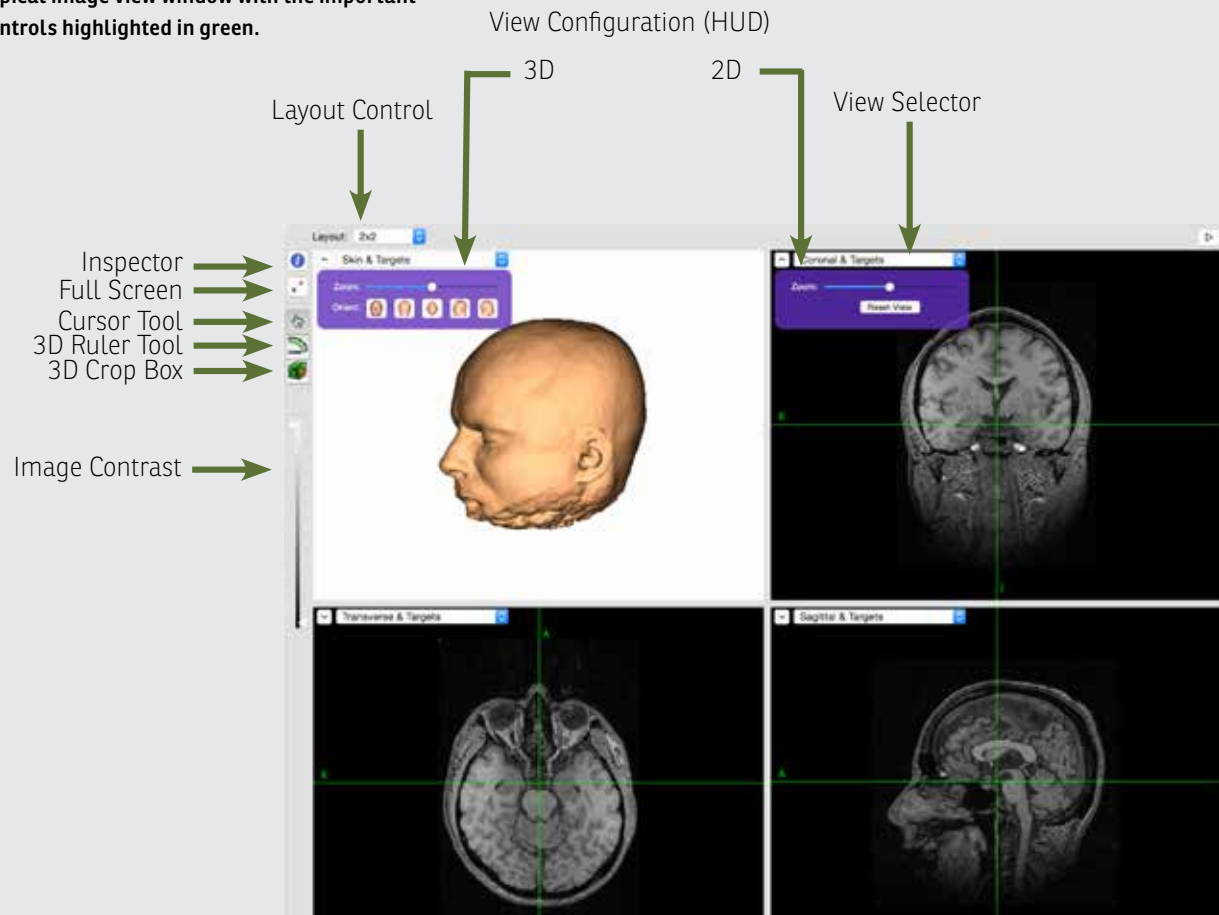
View Configuration (HUD)

Configure each image view (if desired) by clicking on the HUD button (We call it a HUD, for Heads Up Display because the window floats over the image view when invoked). When viewing a 2D image, you can change the zoom (note that the zoom applies to all 2D views); while viewing a 3D image, you can also change the view's orientation. In a graph view (e.g. EMG), a zoom controller allows you to set the vertical and horizontal scale.

Note: Many image manipulations are performed without needing to invoke the HUD. For example, option-click-dragging the image performs panning, while option-scroll wheel zooms the image. Zooming a 2D image view will apply to all 2D images, while zooming in a 3D or graph view only applies to that view. Panning always applies to the single view only.

Fig. 6-7

Typical image view window with the important controls highlighted in green.



View selector

You can change what is being displayed by clicking on the view selector. A series of common views and a customize option are listed, where you can select exactly what you wish to view from an array of options.

Inspector

Invoking the inspector opens a control window that allows you to change certain context sensitive window settings and the appearance of ROI (Fig. 6-10A) and overlay image data (Fig. 6-10B). From this window, you can also choose the peel depth of curvilinear reconstructions (Fig. 6-10C).

Full Screen Control

This button toggles the view window in/out of full screen mode. You can use full screen mode if you want to maximize the amount of screen space used for image display.

Cursor Tool

The new “smart” cursor tool replaces the multiple tools found in Brainsight 1 with gesture interpretation to determine your intent when clicking the mouse. When clicking the mouse on the images, one of several things may occur depending on the context of your motion:

- Single-clicking (without motion) on the image moves the cursor to that location (both for 2D and 3D views).
- In a 3D view, clicking and dragging rotates the image. Clicking inside the blue circle (it appears

when you click) rotates the objects in the direction you click. Clicking and dragging outside the circle rotates in a twist direction.

- Click-dragging with the option/alt (⌘) key down pans the image.
- Option-scrolling (using the scroll-wheel, or track-pad) zooms the image (both for 2D and 3D views)
- Click-dragging on a 3D object with the command (⌘) key down will trace the cursor along the surface of the 3D object.

3D Ruler Tool

You can measure the distance between two points in the 2D view, or create complex paths along a 3D surface (e.g. skin) and view the length.

In the 2D view, clicking on the start point, then dragging while holding the mouse button down will create a straight line whose end-point will follow the mouse. You can then move the start and/or end points by click-dragging either one with the mouse.

In the 3D view, you can create straight or complex curves on any 3D surface (Fig. 6-11). Clicking between anchor points will insert a point between them, while pressing the delete key will delete the currently selected (or last) anchor point.

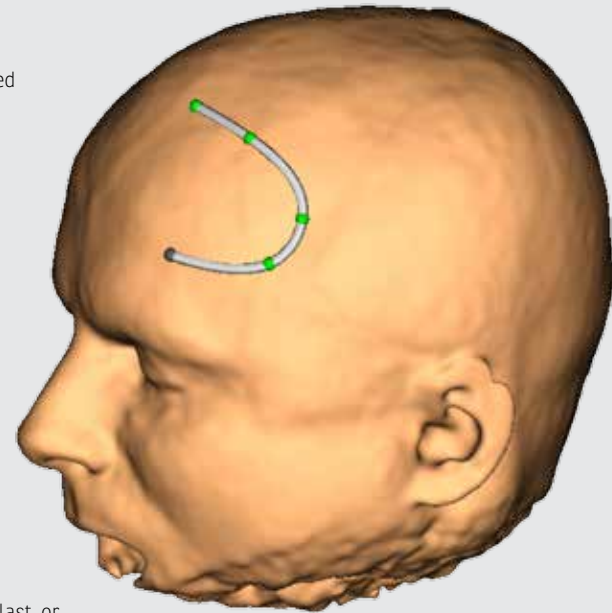
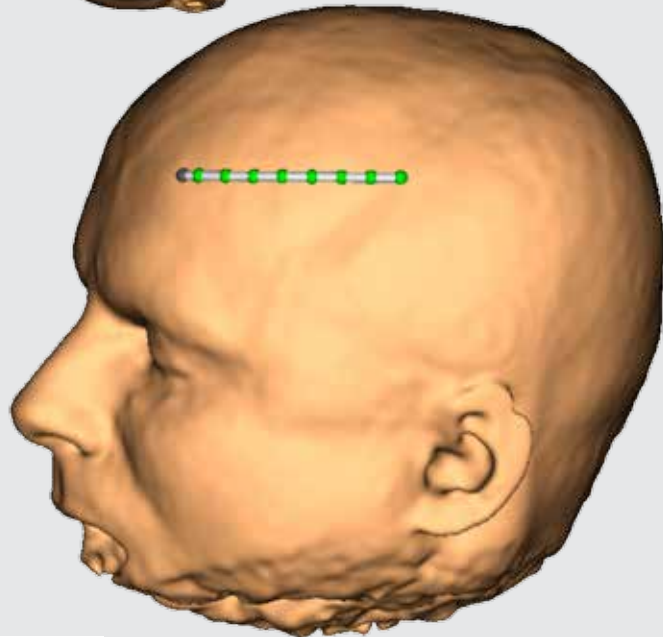
3D Crop Box

This mode works in conjunction with a 3D object (e.g. skin) displayed in a 3D view. When invoked, you can click

on a 3D surface (except the curvilinear objects) to activate the box (Fig. 6-11). You then move the walls of the box in and out by click-dragging the spherical handles to set a clipping plane location. Letting go of the handle updates the clipping of the object according to the clipping box. Once done, turn the box off by selecting the smart cursor again.

Fig. 6-8

A: 3D ruler tool in straight-line mode: Shift-click-dragging along a surface creates a curved ruler along the surface. Note the curve appears as a straight line from above, but follows the surface when viewed from another angle. The length is displayed at the bottom of the view, and anchor points are automatically placed at 1cm intervals for reference.



Other functions:

- Pressing delete will delete the last, or currently selected anchor. If a middle anchor is deleted, the previous and next anchors will automatically be joined.
- Clicking between two anchors will create a new anchor between the other two.
- Click-dragging any anchor will move that anchor along the surface

B: Spline mode:

Click on the surface to drop anchors at the location of each click to create complex curved splines. Each spline can be repositioned by click-dragging it.

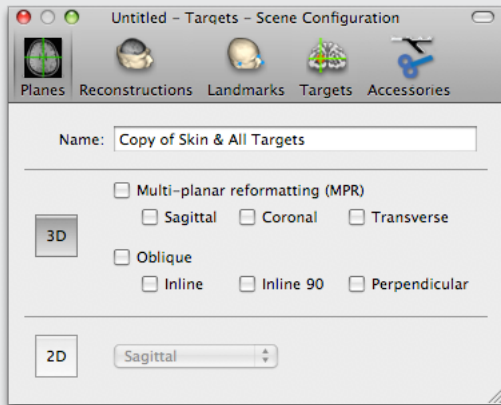


Fig. 6-9

Customize 3D display control window.

You can customize what is displayed in any 3D Image View using this control (accessed by selecting **customize...** in the view selector popup menu button):

Planes: Allows you to set the view in 2D or 3D mode, and to select one of the planar slices (in 2D mode) or multiple slices (in 3D mode).

Reconstructions: Allows you to select one or more 3D reconstructions generated from the 3D reconstruction step.

Landmarks: Allows you to select a subset, or all landmarks from the anatomical landmarks step.

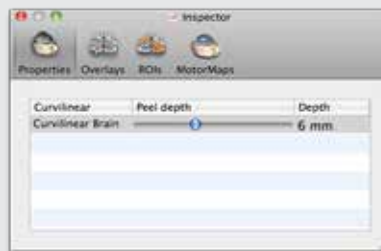
Targets : Allows you to select any or all of the targets form the select target stage.

Accessories (3D mode only): Allows you to add 3D representations of various objects, including the cursor, coil, trackers and the Polaris field of view.

Fig. 6-10

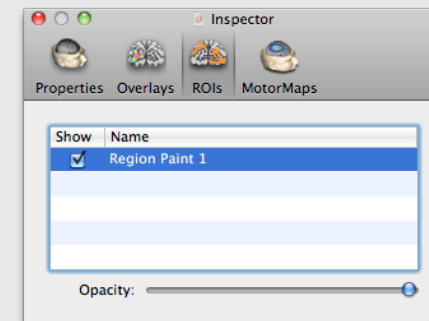
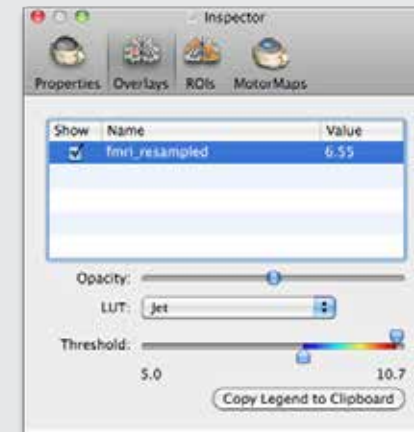
Inspector tool:

When creating overlays, curvilinear surfaces, ROIs and motor maps, it is often convenient to change certain properties at different times. For example, you may wish to change he curvilinear peel while picking a target, or changing the overlay opacity. Rather than having to go back to the relevant steps to change these, the **inspector** button allows you to bring up a window that allows you to access and change many of these settings at any time, in any step. Clicking on the Inspector button (the blue circle with the “i” in the middle) calls up the inspector window.



A: Curvilinear surface inspector

B: Overlay inspector



C: Region of Interest Inspector

(motor maps are described in Chapter 15)

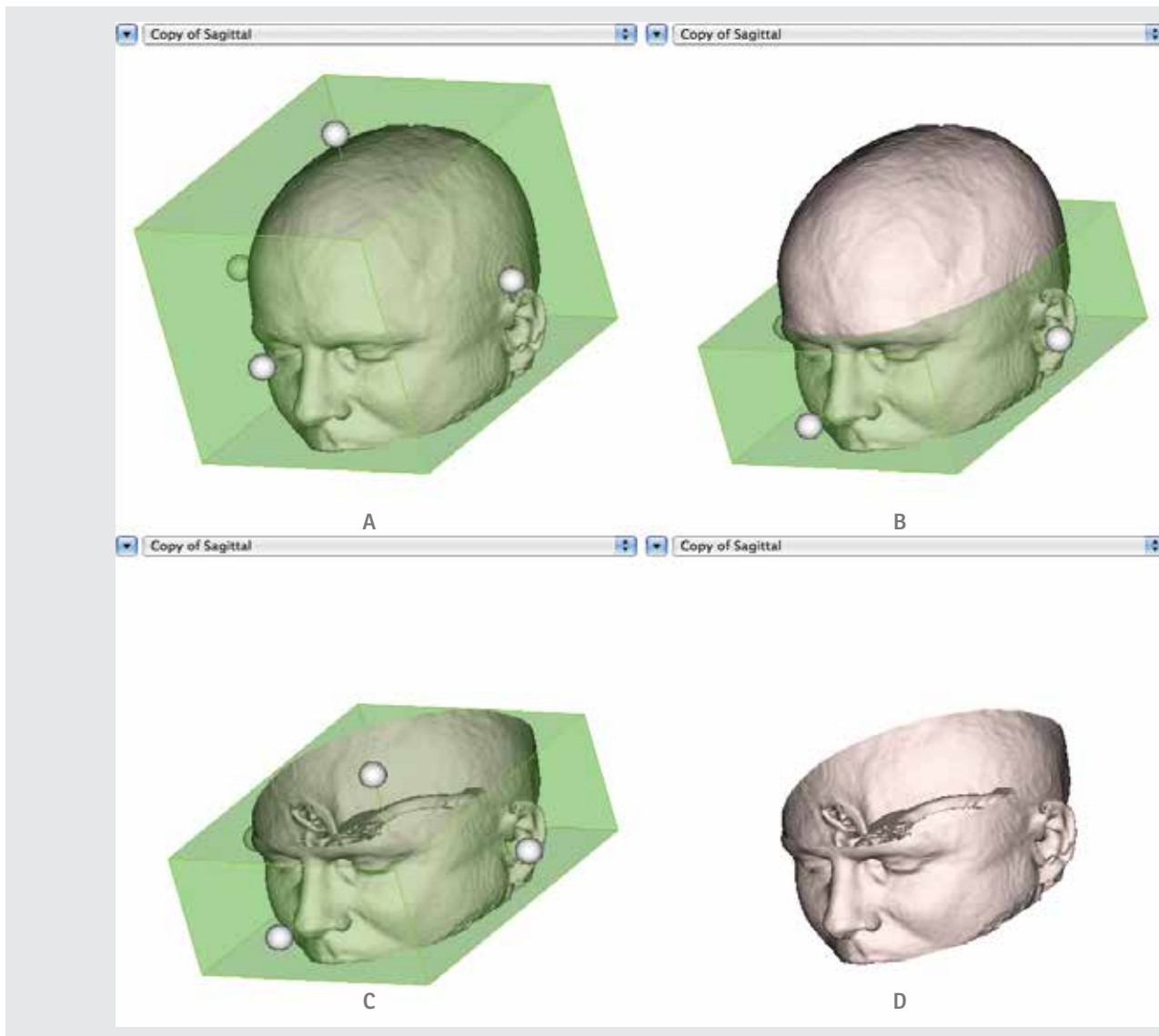


Fig. 6-11

Using the clipping box to clip an object (e.g. skin).

A: Move the walls of the box by dragging the spherical handles (click-dragging).

B: The upper wall was dragged down into the head.

C: The head is cropped according to the bounding crop box.

D: The crop tool is deactivated (by selecting the smart cursor tool) leaving the cropped object. Note that the box only applies to the object selected. Other objects inside the skin would remain whole unless another crop box is invoked and changed for it.

Chapter 7: MNI/Talairach Registration

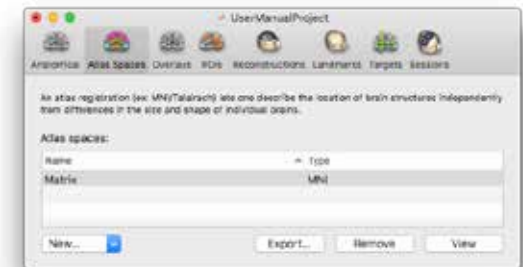
For many years, neuroscientists have used a common coordinate grid (often referred to as “stereotaxic space”) to localize their regions of interest (e.g. anatomical areas, or functional regions) so that data from multiple subjects could be combined or compared on a standard template. This is accomplished by mathematically aligning the coordinate grid of each brain using common anatomical references and using the brain’s size to scale the grid accordingly. The result is the ability to associate homologous anatomical regions of any brain to a common coordinate. The first stereotaxic coordinate system to gain mainstream acceptance was the Talairach and Tournoux atlas. They created an atlas from a single human brain specimen by cutting the brain into regularly spaced slices (and fixing them to slides), labelling the slices for various anatomical regions and superimposing a coordinate grid on them. Using coordinate space mapping techniques, any individual brain can be mapped to that common grid along with

any data recorded associated with that brain. More recently, an improved version of the Talairach brain, the MNI brain, was developed based on a model brain composed of an average of many individual brains mapped to that common space (instead of an individual brain). In many papers, it is common to report findings in “Talairach space” or “MNI space” to allow others to easily use these findings. The subtle differences between Talairach and MNI space is beyond the scope of this manual. Several reports exist in the literature that compare the two as well as the various methods that are commonly used to calculate these registrations (and how they are interrelated).

Brainsight provides tools to co-register your subject’s brain images to the MNI and Talairach coordinate spaces. This step is only required if you wish to use MNI or Talairach coordinates to define targets, or to export sampled coil coordinates in MNI or Talairach space.

Fig. 7-1

MNI/Talairach Atlas Registration Manager



The relationship between the native MR images and Talairach space can be represented in many ways, depending on the type of transformation. Currently, Brainsight supports a linear transformation (translation, rotation and scaling), which can be represented by a single 4x4 matrix. You can either use a pre-existing transform from another program (e.g. MINC tools or SPM), or perform the procedure manually here. If you have a pre-existing transform, then it is advisable to use it here instead of the manual tool to maintain consistency between the coordinates obtained using your favourite analysis software and Brainsight. Use the Brainsight tools only if you do not already have a registration matrix derived from your preferred software.

Note: As updates to Brainsight are released, transformations from a wider variety of software programs will be

added. Please let us know which ones are important to you. It is important to understand the utility as well as to temper expectations of the overall accuracy of employing a linear transformation for the mapping. In practical terms, one should not expect better than a few mm in mapping accuracy.

You can perform more than one registration, and select or change which one to apply at any time. If you have already performed this step using another software application (e.g. SPM or MINC tools), then you can save time and maintain consistency by using that matrix as described in "Loading a pre-existing matrix", otherwise, perform the manual registration.

MANUAL MNI REGISTRATION



Fig. 7-2

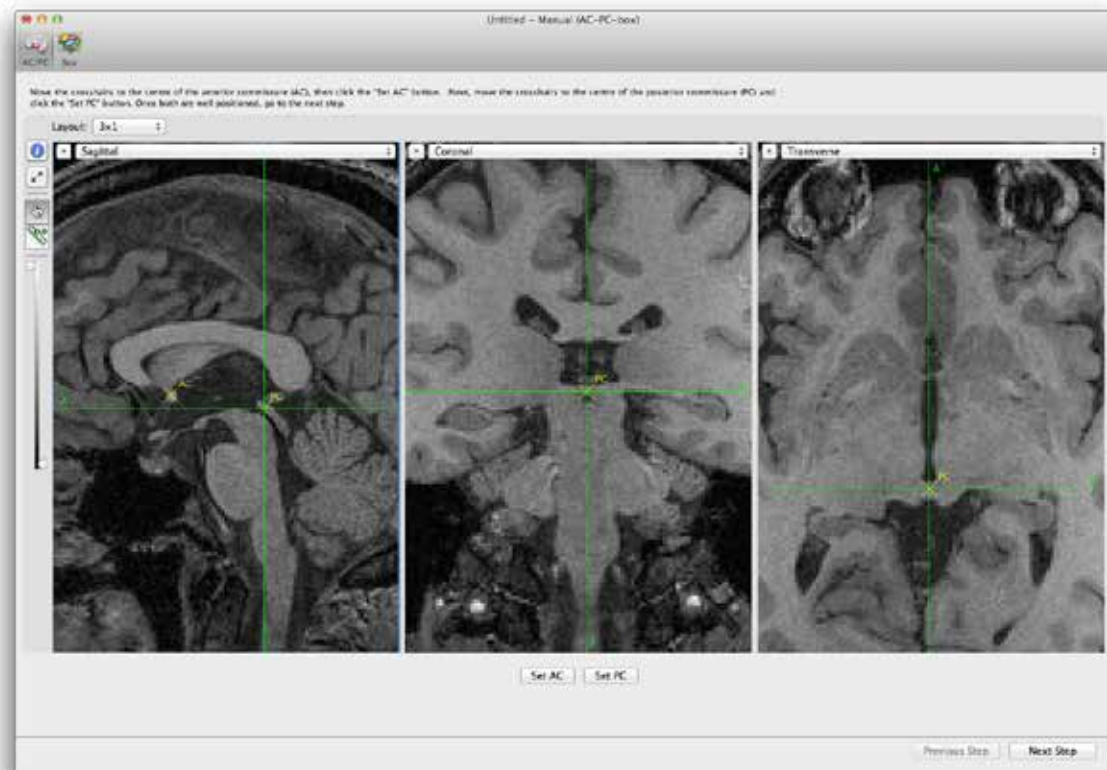
Initial Manual MNI Registration Window.

In addition to supporting registration from SPM and MINC tools, Brainsight includes a manual registration tool. The manual registration tool will require you to perform a few steps to enable the software to calculate a linear transformation to map between the subject's native MRI to the reference Brain (MNI Brain). In the first step, you will identify two well established brain structures, the anterior and posterior commissure (AC & PC). This will be used to rotate the brain image to align it along the

AC-PC plane (correcting for tilt and twist rotations). The second step will be to tell the software the overall size of the brain by moving the walls of a box to the edges of the brain in the lateral, vertical and anterior-posterior (AP) directions. These distances are compared to the width of the reference brain to calculate the correct scaling factors in the 3 directions. This information is enough to

Fig. 7-3

MNI registration step with AC & PC identified.



calculate a basic linear fit.

Select **Manual (AC-PC-box)** from the New... popup menu, the MNI registration task manager will appear (Fig. 7-2).

- Move the cursor to the centre of the anterior commissure (AC) and click **Set AC**.
- Move the cursor to the centre of the posterior commissure (PC) and click on **Set PC**.
- Adjust either (if needed) by moving the cursor to the desired location and clicking either **Set AC** or **Set PC** again (Fig. 7-3).
- Click on **Next Step**.
- Correct for head tilt (if any) by moving the Alignment slider while observing the coronal image. Set the alignment so that the vertical green line follows the midline between hemispheres.
- Set the size of the bounding box to the outer limits of the brain on the AC-PC axis. Pay special attention to the coronal view for setting the left/right and superior/inferior limits and the transverse for the anterior/posterior limits (see Fig. 7-4). **Note that the sagittal view is not helpful because the outer perimeter of the brain is surrounded by the sagittal sinus. The sagittal image should be ignored.**
- Click **Update**. In a moment, the registration will be calculated and the ICBM 152 average brain will be warped and overlaid on the MR images. Examine the quality of the fit visually by:
 - Drag the lower threshold control to the right a

bit to remove the background colour and better see the outer perimeter of the model brain) (displayed using the JET colour scale)

- Change the opacity back and forth repeatedly to better evaluate the fit. By swinging the opacity back and forth, you can flip between the original brain and the reference brain and gain an appreciation of the fit.
- You can interactively adjust the bounding box and click Update to adjust the fit until a reasonable fit

is obtained.

- Click **Finish** to complete the task.

Note: The registration procedure is meant to calculate the native to MNI space calculation. Both the MNI and Talairach coordinates can be used.

Fig. 7-4

MNI registration step with box set to brain bounds. Focus your attention in the areas highlighted in red.



LOADING A PRE-EXISTING MATRIX

If you have the file containing the registration matrix (MINC tools), choose **From .xfm...** from the **New** popup menu button, and select the file, otherwise choose **From Matrix**. Note that a window displaying anatomical images with the ICBM 152 average brain (warped using the loaded matrix) will appear (Fig. 7-5). The actual matrix is also displayed on the top left of the window.

Every transform matrix represents a transformation from one coordinate system to another. The matrix entered either by loading an xfm file or entering the matrix manually must be from the "World" space coordinate system as defined by your anatomical images (e.g. scanner coordinates), to the MNI space. For example, when using SPM, the .mat file does not work because it is from voxel space (whose definition changed over the years) to MNI space, while the PDF report works because it describes the world space to MNI space transform.

If the overlay does not match the anatomical data (particularly if it does not agree with how it looked in your other software), then you may need to manipulate the matrix. Currently, you can invert and/or transpose the matrix (by clicking the Invert or Transpose buttons) or edit the matrix manually by typing in the numbers directly.

A NOTE ABOUT MNI AND TALAIRACH SPACE

When using "normalized" space coordinates, it can be very easy to get confused. In the "old days", Talairach was

the coordinate space used. More recently, a modernized version of the normalized space was developed by the International Consortium of Brain Mapping (ICBM) to try to develop a brain more representative of the overall population (Talairach was based on a single individual brain). This group developed the "MNI" brain, which was created by co-registering multiple brains (imaged using MRI) into a common Talairach-like space.

In Brainsight, the entered registration, be it by matrix or performed manually is assumed to be to the MNI space. We have implemented the formula proposed by Lancaster, Fox et. al. (Lancaster et. al., "Bias Between MNI and Talairach Coordinates Analyzed Using the ICBM-152

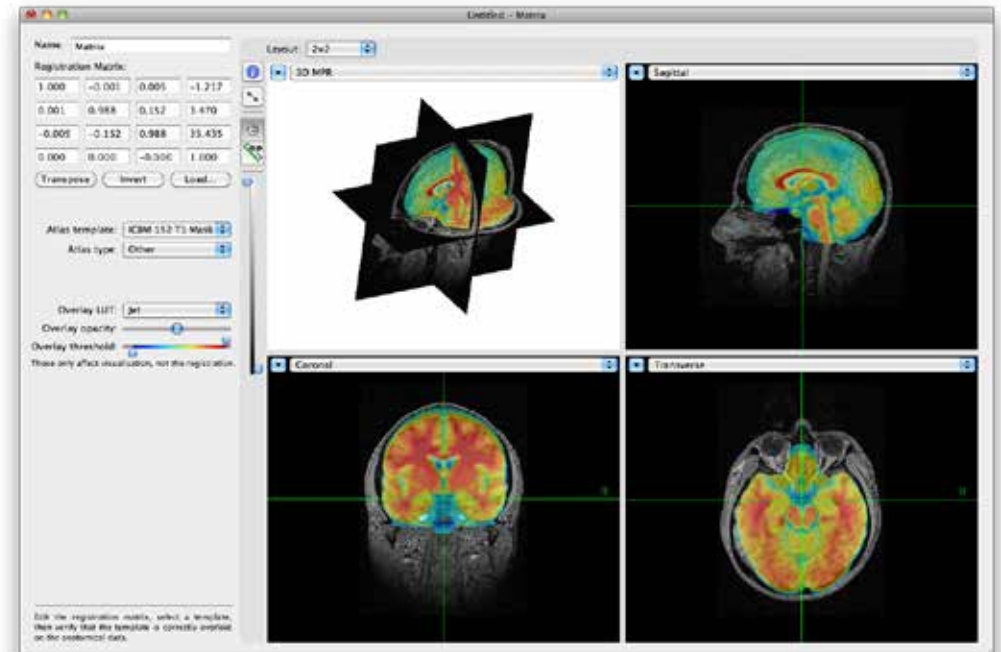
Brain Template", Human Brain Mapping 28:1194–1205 (2007) to convert from MNI to Talairach space for compatibility reasons.

Exporting the MNI Registration Matrix

In certain cases, you may wish to export the MNI registration created in the step for comparison with other methods or for use in other programs (to maintain consistency). To export the matrix into an ".xfm" formatted file (a simple text file used in MINC tools and easily converted to other formats), click **Export...** in the Project window (Fig. 7-1) navigate to the desired folder, enter a file name and click **Save**.

Fig. 7-5

Verification screen for MNI registration. Registration matrix is shown at the top left.

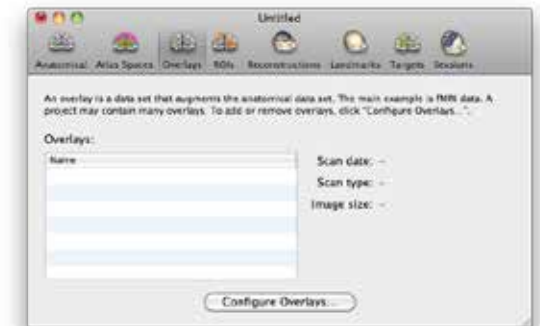


Chapter 8: Image Overlays

In addition to using MNI or Talairach coordinates, you can load functional or other anatomical data, (e.g. a T2 MRI) to overlay them on the anatomical MRI. You can also overlay an Atlas and warp it from its MNI reference space to the native shape of the subject.

Fig. 8-1

Overlay manager.



Click on **Configure Overlays...** to add or edit overlays.

ADDING FUNCTIONAL OR ANATOMICAL OVERLAYS

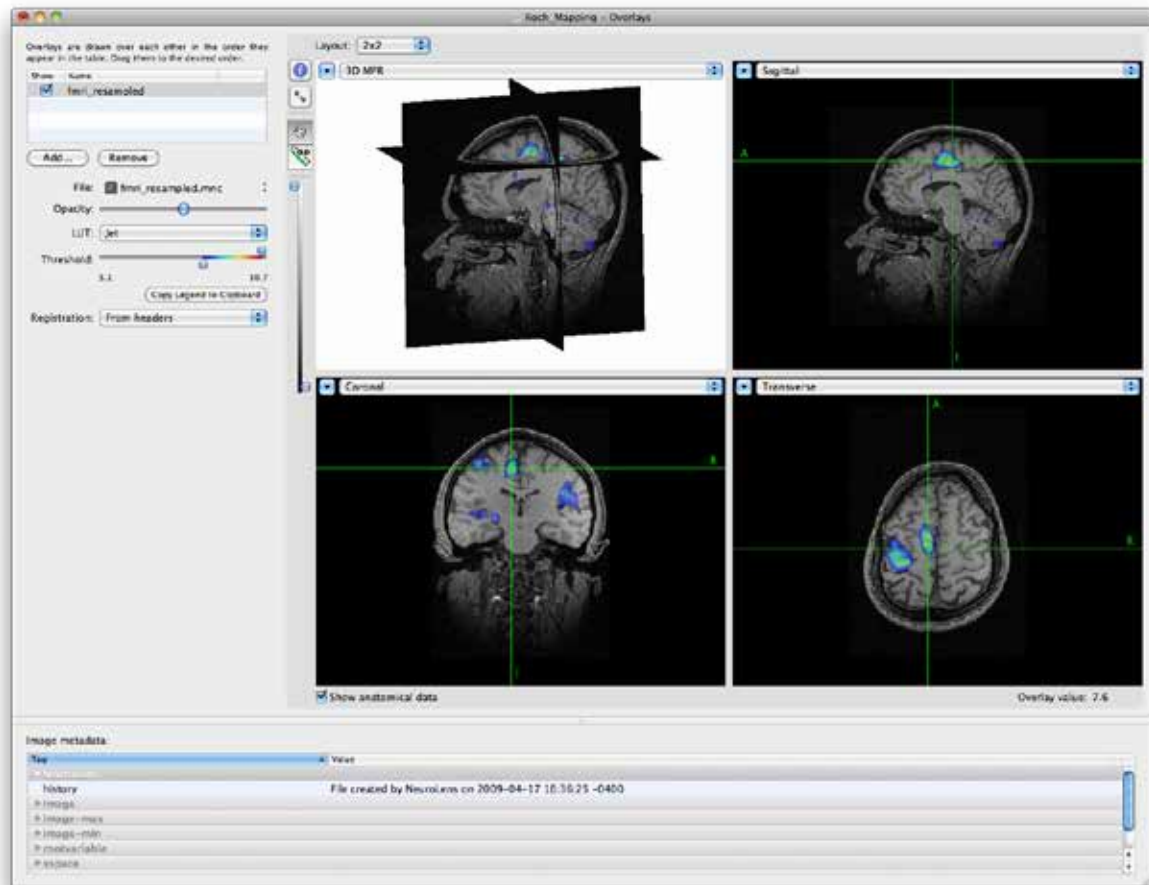
Overlays are simply volumetric data sets that have some intrinsic meaning to you. In the case of functional or anatomical data, the data should be in the native space of the subject.

- To add a new overlay, click **Add...** Select the image file (using the same rules for the different file formats as was applied for the anatomical image data as described in Chapter 6.
- The file needs to have been co-registered using another software program (and either re-sampled, or the registration matrix exported to be entered here). Select the registration method used:
 - If the data set was re-sampled to match the

Fig. 8-2
Overlay window

anatomical, select **"none"** as the registration.

- If the method stored the registration to the anatomical images in the header (as is sometimes done with MINC and NIFTI), select **"from headers"**.
- If a matrix is used, select **"Matrix..."** and enter the matrix manually, or by loading a supported matrix file format (only MINC .xfm files at the moment). When entering a manual matrix, take special care to ensure that the matrix is correct by observing the orientation and fit of the overlay on the anatomical images.
- For BrainVoyager images, select the .vmp (versions 1-6) file which has been co-registered to the anatomical images, and select **"from header"** as the registration. As with BrainVoyager anatomical images, use the AC-PC aligned (but not scaled to MNI space) images.
- For an atlas file, use From **current MNI registration** (see next section)
- Set the threshold of the images. Note that Brainsight does not support showing both positive and negative changes in response at the same time (yet). You can work around this limitation by loading the overlay twice and setting the thresholds to display the positive on one, and the negative on the other.
- Select the desired lookup table (LUT) using the **LUT** popup menu button.
- Set the desired opacity of the overlay using the



opacity slider.

You can load multiple overlays, and select which ones you want to be visible by default by enabling/disabling the visible checkbox next to each entry. You can also change the order of overlays by dragging the images in the list around to set the desired order. When finished, close the overlay window by clicking on the close button at the top left of the window.

LOADING AN MNI ATLAS FOR OVERLAY

You can load and overlay an Atlas however there are a few requirements:

- You need to perform an MNI registration (see Chapter 7) so the software knows how to transform space to/from MNI space.
- The Atlas file needs to have defined the transformation from the image voxels (voxel space) to the MNI space, stored either in the header or as a separate transformation file. Atlases in MINC format usually have this embedded so they should work. Other formats (e.g. NIFTI) will need to be validated first.
- In this version of Brainsight 2, the atlas must have 256 indexed regions or less. This will be improved upon in a future release.

To load an atlas as an overlay:

- Click add... and select the atlas file using the file selection dialog that is shown.
- Once loaded, select "Atlas" as the LUT (it is an

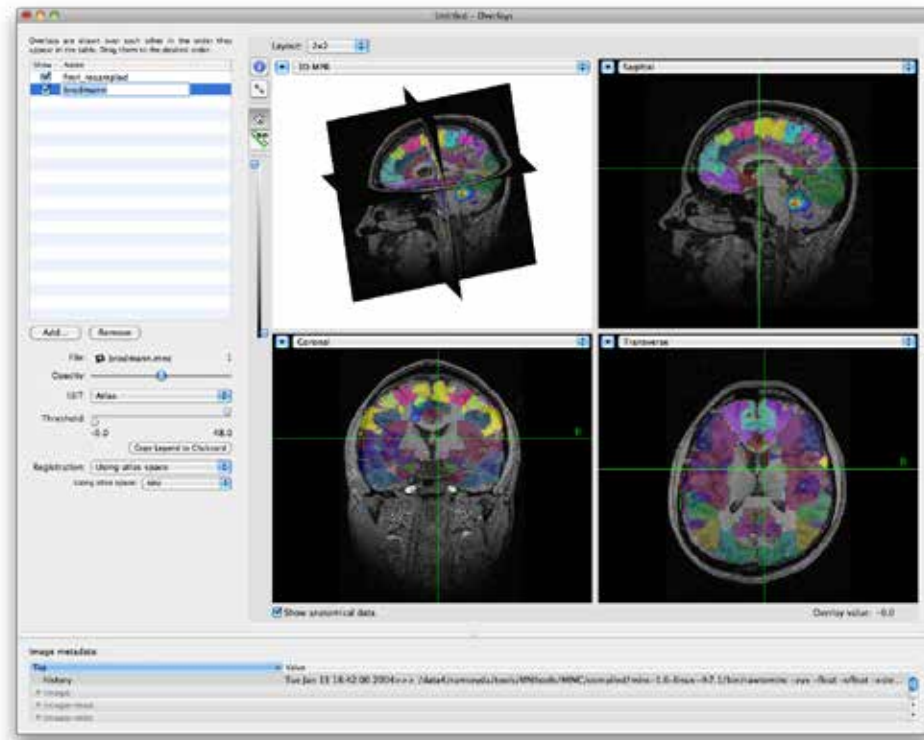
indexed colour table to maximize the contrast between adjacent atlas regions).

- Select "**Using atlas space**" as the registration method. This is disabled if you did not perform an MNI registration. If you performed more than one atlas registration, select it from the popup menu under the registration method popup menu.
- Select MNI or Talairach to identify the base coordinate system for the atlas.

- Verify that the Atlas overlays correctly on the anatomical images. Note that Talairach atlases may have a poorer registration quality as it undergoes an additional transformation from Talairach to MNI space before being transformed from MNI to the subject's native space.

Fig. 8-3

Overlay window with atlas



Chapter 9: Region of Interest (ROI) Painting

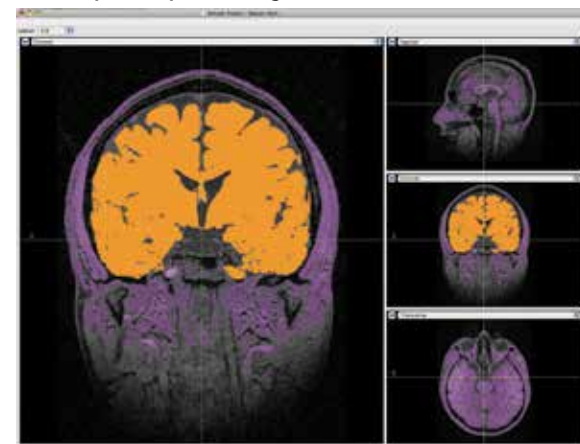
INTRODUCTION

In previous versions of Brainsight, the 3D segmentation tool combined two steps of building 3D representations of objects “painted” from the MR data: Region painting and 3D reconstruction. Brainsight breaks up these two steps to make better use of the voxel painting tool (ROI, or region of interest painting tool) for other purposes. For example, one might use the ROI tool to identify particular regions as seen on an atlas to highlight them in the 2D views. Once the region has been painted, it can be treated as any overlay and displayed in any of the planes. It can also be exported as a NIfTI file for use in other analysis and display software.

Region painting refers to the process of segmenting the region you are interested in (e.g. the skull, or a particular brain structure) from the surrounding data by labelling it somehow (e.g. painting image voxels) as illustrated in Fig. 9-1 A. 3D reconstruction method can take this labelled data and create a 3D surface (3D mesh) to be displayed and manipulated as a discrete object (Fig. 9-1 B).

Fig. 9-1

A: Example of a painted Region of Interest (ROI).



B: Example of a 3D surface representation of the edge of the ROI using the “Surface from ROI” described in the next chapter.



Brainsight currently supports region growing (we call it a threshold/seed operation) and manual painting to create and edit ROIs. The threshold/seed tool is useful if your structure of interest contains a distinct region that can be isolated by selecting an intensity range. Think of the seed tool as a persistent flood fill (often called a paint bucket) tool, which spreads “paint” to all connected voxels that fall within the threshold intensity range. You typically set an intensity range for your structure then drop a seed in the structure. The seed will initiate a fill operation (region growing) at the seed location. You then go to the next slice, and the seed will follow you to that slice, and initiate a fill again. The seed is smart enough to search a small area for the threshold if it lands on a new slice outside of the threshold area (this can happen if the shape of the structure changes from slice to slice).

The manual painting tools can be used to delineate areas that are not strictly intensity based, or where the seed/threshold either missed a spot, or filled into an unwanted area (despite being within the threshold bounds). For example, the skin reconstruction can usually be performed automatically because there is a large difference in intensity between the skin and surrounding air. The brain can also be isolated (mostly) except in regions where there might be structures with similar intensity ranges that exit the brain cavity into other areas (e.g. optic nerves). In these cases, you would let the seed(s) apply to the slice, and use the paint/erase tools to edit the results to conform to the structures.

CREATING AN ROI

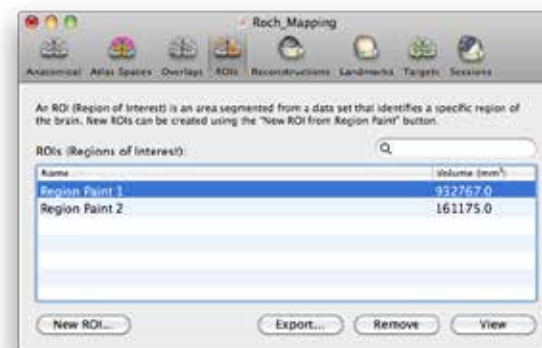
This section will cover creating an ROI and explain the use of the tools as they are needed. To create an ROI, select the ROIs tab at the top of the project window then click **New ROI from Region Paint**. The region paint window will appear (Fig. 9-3). The window will have a layout with 4 image view panes. The larger view is the painting view, while the other 3 are for location reference. Clicking in the 3 smaller views will move the cursor. Clicking in the paint view will perform an operation that depends on the currently active tool.

If your structure can be isolated by a range of image intensities, then:

1. Set the orientation in which to paint by selecting it from the orientation popup menu of the painting view. You can change orientations anytime and continue painting in the other slice (although that can get confusing).
2. Optionally, click on **Smooth data set** to apply a 5mm Gaussian smoothing kernel to paint from a smoothed version of the data. This will reduce sharp edges and noise, but will also blur out small structures.
3. Use the threshold sliders to set a range of intensities that help isolate your structure of interest. The voxels that fall within the upper and lower threshold

Fig. 9-2

ROI manager. Note that the volume is shown for each ROI.



bounds are referred to as the isolated voxels, and are displayed in purple (you can change that colour by clicking on the colour indicator box and selecting a new colour using the colour picker, and the opacity using the opacity slider). See Fig. 9-3.

4. Select **Seed** (among the painting tools as shown in Fig. 9-5) and click in the region of interest. The result will look like Fig. 9-4 B.
5. If the structure of interest consists of multiple disconnected regions that are isolated using the threshold values, add seeds to those regions by clicking in them.
6. If a region that is not isolated by the threshold values exists, you can use the Pencil and Fill Region tools to include it manually. Select **Pencil**, and draw the border of the region (Fig. 9-4 C). Select **Fill Region** and click in the middle of the region to fill the region (Fig. 9-4 D). Note that you can avoid clicking back and forth between the Pencil and Fill tools by remaining in the Pencil tool, and flood fill by option-clicking where you want to fill.
7. To exclude a region that was mistakenly included, select **Eraser**, and use it to delineate the unwanted part from the rest of the painted region, then use the Erase Region tool to clear the region by clicking on the isolated paint region. Note that as with the Pencil and Fill tools, you can remain in the Eraser tool, and option-click the region to apply the Erase Region to it.

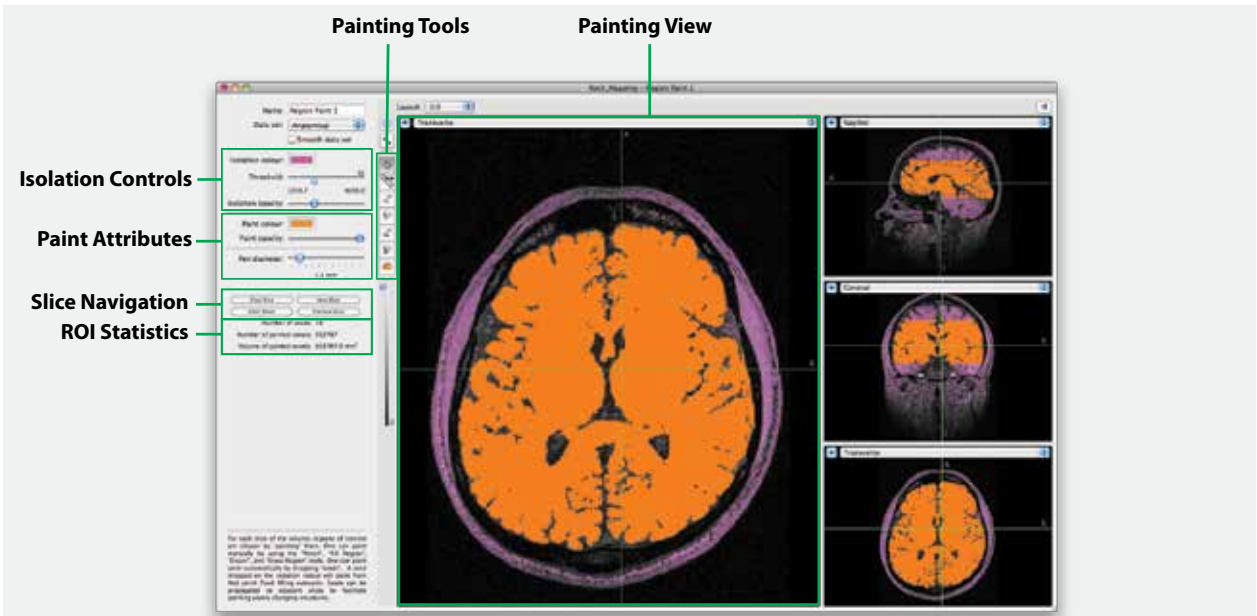
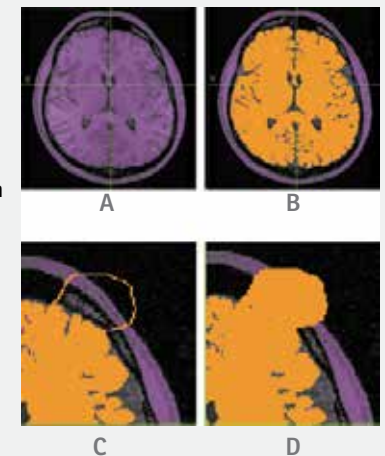


Fig. 9-3

Region paint tool. The area in purple is referred to as the isolated region. It represents the voxels in the displayed slice that fall within the threshold range set using the threshold sliders which are part of the isolation controls. The painted region is shown in orange (in this example) and is generated by a seed being dropped in a thresholded region.

Fig. 9-4

Region painting Tool, using seed/threshold and line pencil/fill region methods. eraser/clear region work the same way as the pencil and fill except they erase painted voxels. Note that the fill and clear region tools use the painted voxels to define the boundaries, NOT the thresholded voxels.



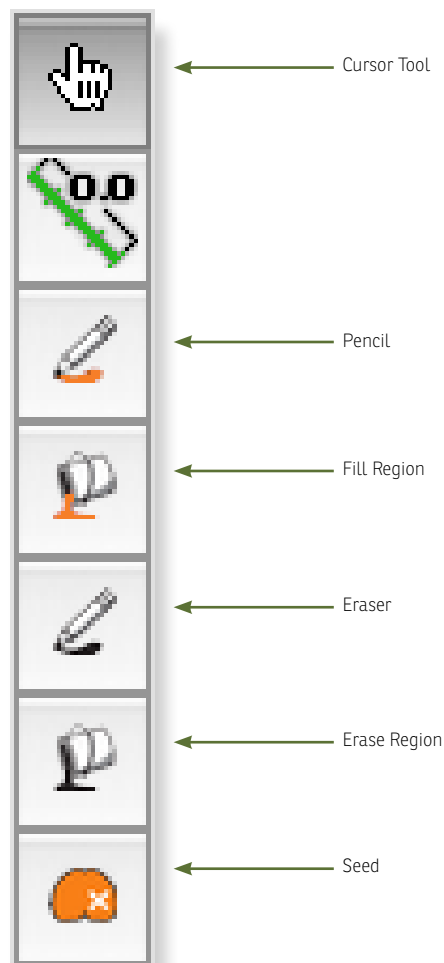
8. Once the region has been painted, proceed to the next slice by clicking **Next Slice** or **Previous Slice**.
9. Notice that any seed in the last slice is propagated to the new current slice and applied to paint the slice. Add seeds as needed and manually add/remove painted regions as in the previous steps.
10. If you find that after several slices that you have too many seeds (e.g. disconnected structures in previous slices are now joined, or the seeds have migrated to unwanted regions), click Remove All Seeds to clear the seeds, and then click Erase All Paint in Slice to clear the slice and start fresh.
11. Once you have painted the entire region, close the window. This is probably a good time to save your project.

Note that during this process, you will almost certainly click on something you did not want to, losing the work you just did. As of version 2.3, the Undo (a common function for many applications) has been implemented. Simply select **Edit->Undo (Cmd-Z)** to undo the last operation. You can backtrack several operations if needed.

EXPORTING AN ROI

Once you have created an ROI, you may find it useful to export it into a volumetric image file for use in other applications. For example, you might find the drawing tools to be useful in generating regions of interest for ROI-based analysis (e.g. for probabilistic tractography). Once the ROI is complete, click **Export....** Once the save

Fig. 9-5
Close-up of ROI tool listings.



file dialog appears, navigate to the desired folder, enter a file name (the name of the ROI is used as a default name) and click **Save**. The file will be saved as a NIFTI (.nii) file, using the anatomical data set as the template for the voxel size and image orientation.

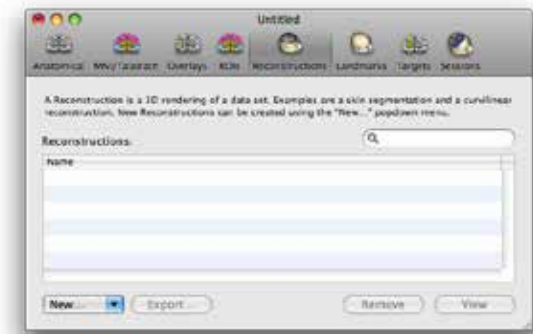
Conceptually, the Pencil/Eraser and Fill Region/ Erase Region tools are opposites of each other. The Pencil and Fill region delineate voxels while the Eraser and Erase Region clear voxels.

Chapter 10: 3D Reconstruction

3D reconstruction is the operation of creating a 3D surface for the purposes of display. These 3D objects can be painted with a solid colour or texture consisting of the image voxels intersecting the surface (see curvilinear reconstruction). Brainsight currently supports several reconstruction methods: The automatic skin, automatic curvilinear, and reconstructions derived from overlay data sets and ROIs. 3D surfaces generated from 3rd party software can also be imported and visualized.

Fig. 10-1

3D reconstruction manager.



3D reconstructions are performed for many purposes. First, a skin reconstruction is performed to simplify the identification of anatomical landmarks for the subject-image registration (Chapter 13). Second, a 3D brain reconstruction is performed to simplify target selection and provide a more intuitive view of the brain (and scalp) while placing the coil during a TMS session. Finally, reconstructions from regions of interests or ROIs can create 3D representations (e.g. functional activations, specific anatomical structures) of information that may be relevant to your particular protocol.

PERFORMING A SKIN RECONSTRUCTION

- From the reconstruction manager pane of the project

window (Fig. 10-1), click on **New...** and select **Skin**. An image view window will open.

- If needed, set the bounding box to encompass the whole head by dragging the boundaries with the mouse. Note to earlier Brainsight users, this is in contrast to previous versions where you were instructed to exclude the scalp. Include the scalp as the software uses it to evaluate the subject-image registration (Chapter 13) and you will crop it later using the 3D Crop tool (see “3D Crop Box” on page 33). You might leave part of the bottom out to have a “clean cut” bottom if the intensity of the MR image drops off. Otherwise, the head may look “ghoulish”, although this is an aesthetic recommendation (see Fig. 10-2).
- Set the colour to your desired setting by clicking on the colour box, and selecting the colour using the palette that appears.
- If needed, adjust the threshold to isolate the head vs. the surrounding air (and MR noise) as much as possible.
- Click Compute Skin. The skin object will appear in the top left view shortly (Fig. 10-3).
- If the results are not satisfactory, adjust the threshold and recompute the skin again.

Fig. 10-2

Skin segmentation step with head properly cropped.

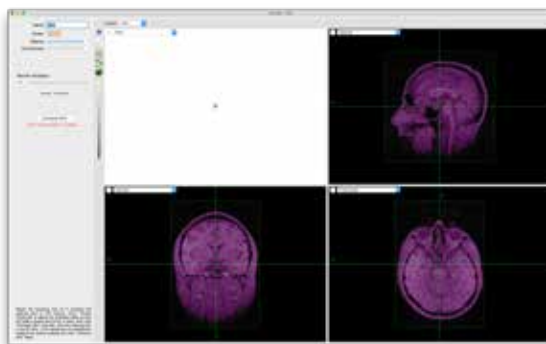
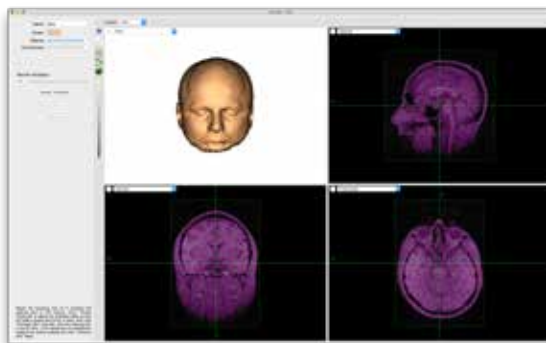


Fig. 10-3

Completed skin.



- Once the desired skin has been created, close the window by clicking the close button (top left button)

CREATING A CURVILINEAR RECONSTRUCTION OF THE FULL BRAIN

Many software programs represent a 3D brain as a surface mesh much in the same way we generate the 3D skin (see Fig. 9-1 on page 45). While this often provides a good representation of the brain surface, it has drawbacks in the context of TMS. First, TMS does not only stimulate the brain surface, but potentially the entire thickness (approximately) of the cortical ribbon. Second, if you want to use fMRI as a target, it is important to be able to visualize the location within the brain where the activation is recorded (many surface based models project the fMRI to the cortical surface, effectively moving the target).

The curvilinear reconstruction is designed to provide you with a 3D representation of the entire cortical ribbon, by creating a representation that can be interactively peeled to different depths, much like peeling the layers of an onion.

To create a curvilinear reconstruction:

- Click **New...** and select **Full Brain Curvilinear**.
- The default settings are typical values. You can change them if you wish. Note that in contrast with Brainsight 1, the settings here are a bit different.

Instead of start/stop depths and spacing, simply enter the end depth and spacing. (The start is now assumed to be 0 mm). Typical values are a stop depth of 16mm with a slice spacing of 2mm, however you are free to change them to your preference.

- Click **Compute Curvilinear** to generate the curvilinear surface. The process can take up to one minute depending on your computer.
- Once the brain has been generated, rotate it to examine the brain surface, and use the peel slider to peel the surface to different depths.

- If you previously loaded an fMRI overlay, you will also see it overlaid. Change the depth again to see where the peak occurs (Fig. 10-4).
- Close the window by clicking on the close button at the top left of the window.

IF THE RECONSTRUCTION DOES NOT WORK:
 The automatic curvilinear reconstruction is designed to work without requiring any user input. Occasionally though, the algorithm will fail. Without going deep into the implementation of the algorithms, one of the causes of failure is an error in determining the approximate centre of the brain (which is the starting point for the algorithm). This can be corrected by adjusting the bounding box to delineate the brain from the rest of the head.

Fig. 10-4
 Curvilinear surface "peeled" to reveal fMRI peak.

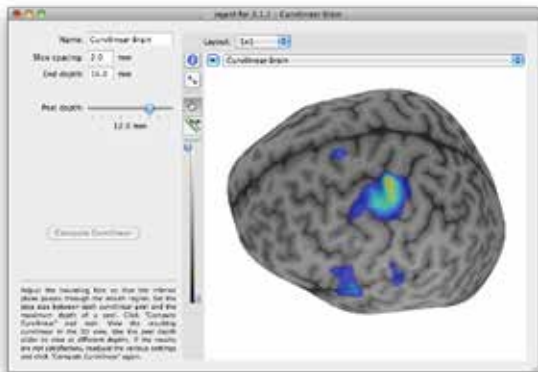
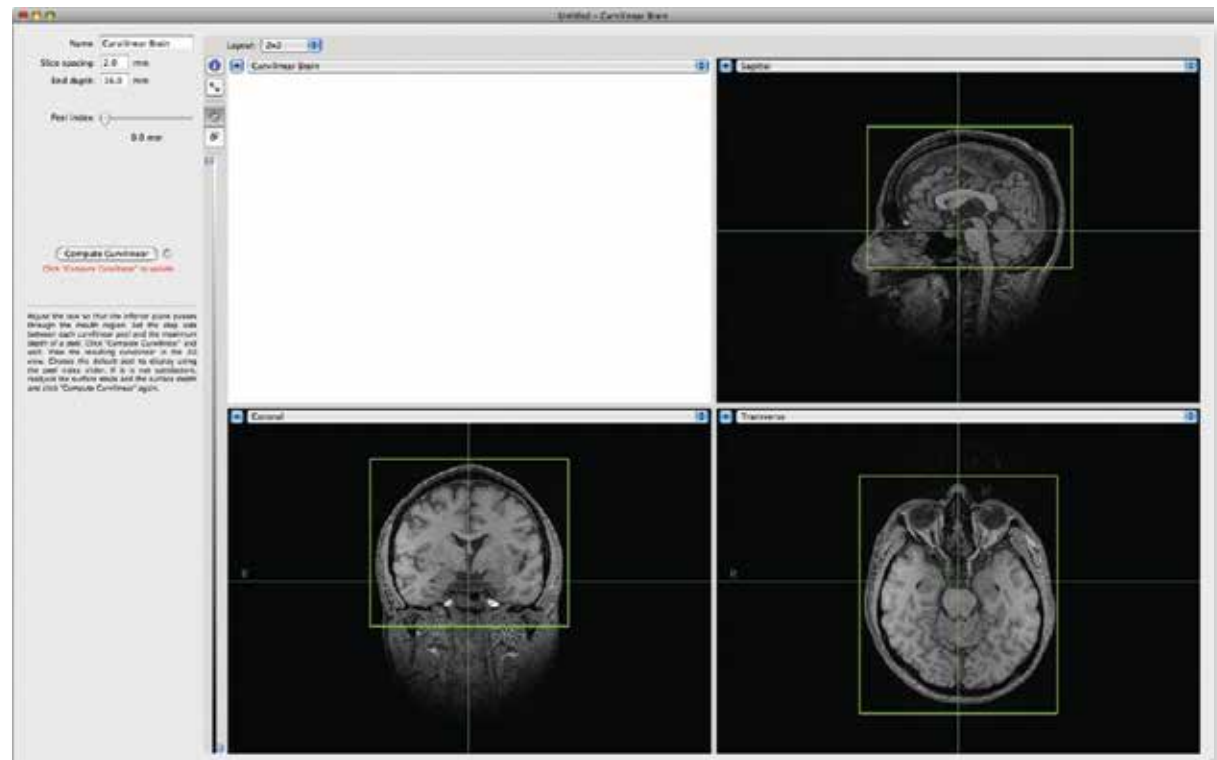


Fig. 10-5
 Adjusting the crop box to help the automatic curvilinear algorithm



This is particularly helpful in cases where the image acquisition is in the sagittal plane with large field of views (so there is a lot of neck in the field of view). To adjust the starting point:

- Move the edges of the box until the brain is delineated (Fig. 10-5).
- Click Compute Surface again and view the results.
- If this does not help, use a workaround procedure described in the next section.

CREATING A CURVILINEAR BRAIN RECONSTRUCTION USING A MODEL SHAPE

In certain cases, particularly when using the model brain or individual MR images of subjects whose scans contain artifact or lesions, the automatic curvilinear reconstruction may fail. In these cases, there is an alternate method to obtain a good curvilinear reconstruction. Consider how the curvilinear reconstruction works. The first step in the automatic algorithm is to attempt to generate a 3D shape of the brain by finding the brain boundary and generating a 3D mesh (and generating the concentric slices as additional meshes). The second phase is to "paint" the surface of this mesh with the values of the MRI voxels that touch the mesh. The failure in the curvilinear reconstruction is a failure in the first phase. Instead of attempting to interpret the subject's MRI to determine the shape, the MNI model head can be used as a reasonable substitute for the shape. By performing an MNI registration, the model head can be loaded as an overlay and

warped to "match" the shape of the subject's brain. That adjusted shape can be used to generate the 3D mesh for the curvilinear, then the original voxels can be used to paint this surface.

The workaround procedure is as follows:

- If the anatomical data set is a subject-specific MRI, then perform an MNI atlas registration to calculate the subject-MNI transformation (see Chapter 7). If the anatomical is the model head (see "Create a New Project Using the Model Head Image Set" in Chapter 6), skip this step.
- Select the overlay step (Chapter 8). Load an MNI model head as an overlay. An appropriate overlay image file can be found in the Sample Data folder that came with your Brainsight computer, or on your Brainsight software CD. Locate the file "icbm_avg_152_t1_tal_lin_masked.mnc" and load it.
- If the anatomical MRI is subject-specific, then select **Using atlas space** as the Registration method (by selecting it in the popup menu button) and MNI Atlas as the subtype. If the anatomical data set is the model head, select **From headers** as the registration method. Close the overlay window.
- Select **New->Curvilinear from overlay**, which will open the curvilinear creator window (Fig. 10-6). Select the MNI overlay as the overlay dataset (it is the default if you only have the one overlay). Set the

lower threshold to a value above 0 to highlight the brain.

- Set the slice spacing and end depth to your preferred values and Click **Compute curvilinear** to create the surface.
- Note that while the shape appears reasonable, the resulting surface as displayed in this window uses the model head voxels (and the threshold overlay) for the display. This is normal. When the same curvilinear is used in any other window (e.g. targets and perform), the original anatomical voxels will be used.

CREATING A CURVILINEAR SURFACE FROM AN ROI (FOR SMALLER STRUCTURES)

In most cases, the automatic curvilinear surface will meet your needs. In some cases however, it may be desirable to perform a curvilinear surface on a subset of the brain (e.g. cerebellum) or when the automatic curvilinear reconstruction failed. In these cases, you can create a curvilinear reconstruction based on a region of interest. For example, you can use the region of interest tool to paint the cerebellum.

To create a curvilinear surface based on an ROI:

- Use the ROI tool to segment your structure (see Chapter 9).
- Click **New...** and select **Curvilinear from ROI**.
- Select the ROI to generate the 3D surface from

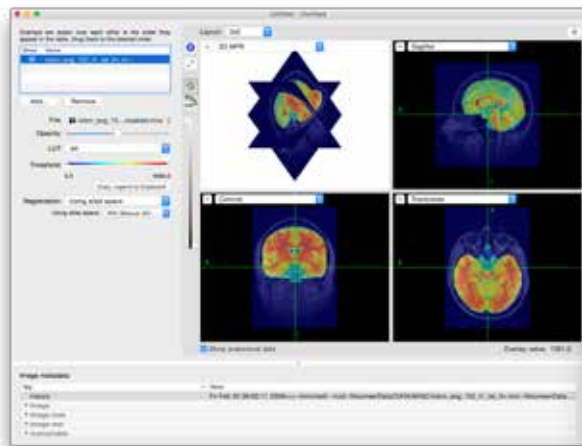


Fig. 10-6

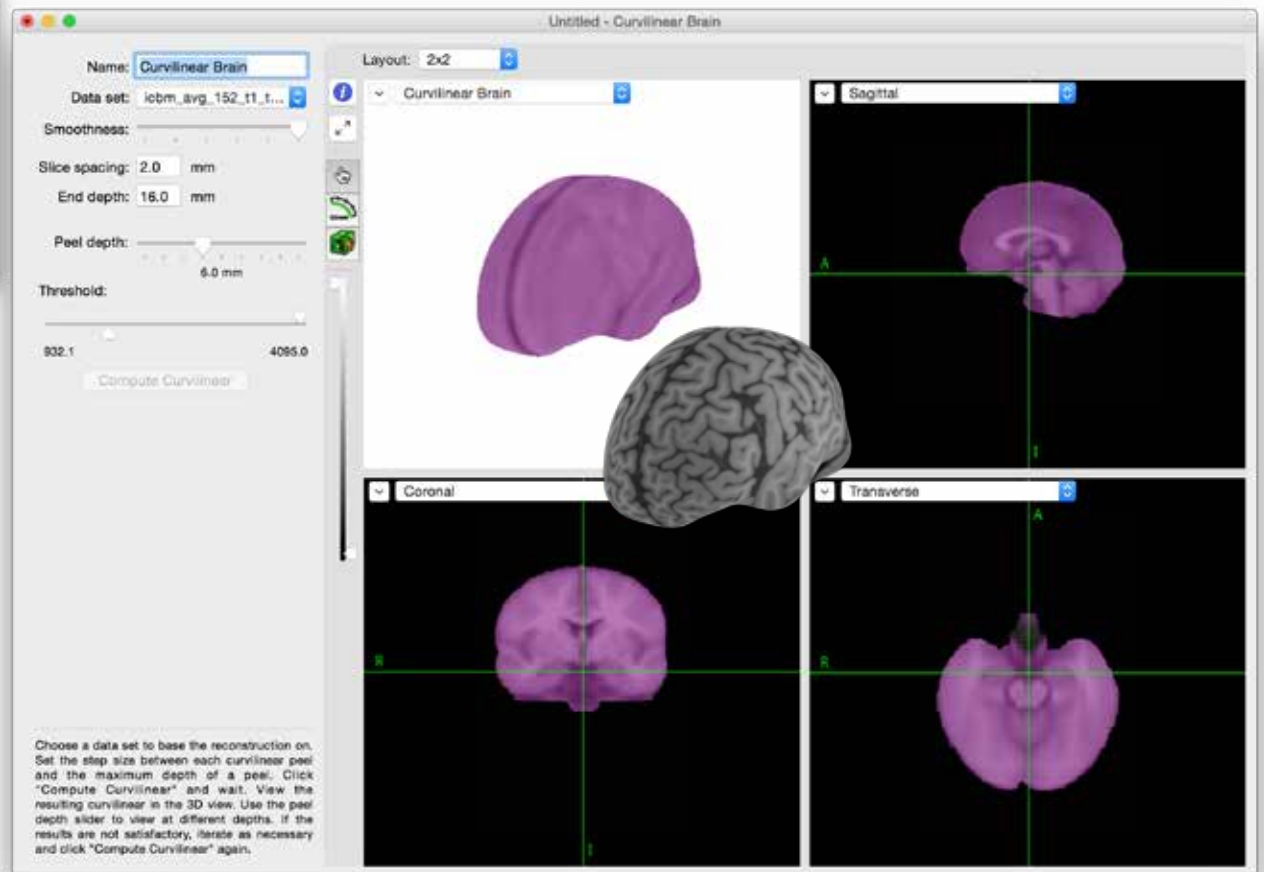
Curvilinear reconstruction using a model head for the shape.

A: Overlay step:

Load the model brain as an overlay and use an atlas registration to warp it to match the shape of the subject brain.

B: Create the curvilinear from overlay.

Note the voxels from the overlay are used to paint the surface in this step, but in subsequent steps (e.g. targeting), the anatomical image's voxels are used.



(if you have multiple ROIs) and set the step size and end depth. For smaller structures, a step size of 1mm and end-depth of 10mm might be more appropriate than the defaults values.

- Click **Compute Curvilinear**, wait for the process to complete, and view the results in the 3D view.
- If the surface appears too spherical (see left of Fig. 10-7), then the smoothing setting was likely too high. Lower it by dragging the smoothness slider to the left a couple of notches, then click **Compute Curvilinear**. After a moment, the change will appear in the 3D view.
- If the surface was too rough (middle of Fig. 10-7) then increase the smoothing by a notch or two by moving the smoothness slider to the right and click **Compute Curvilinear** again.
- The expected result is shown on the right of Fig. 10-7.

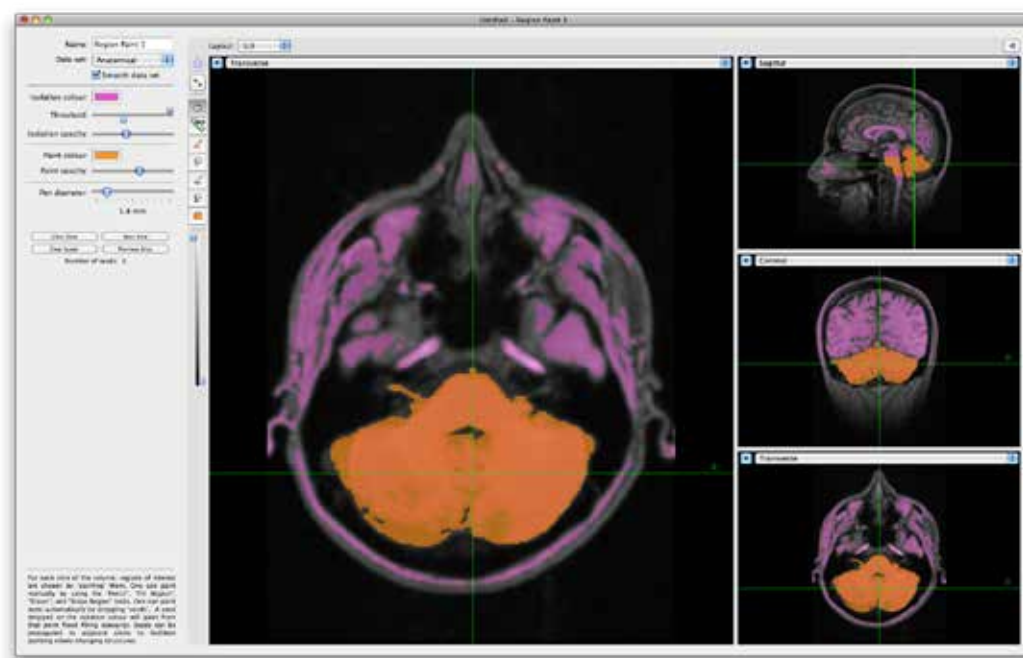


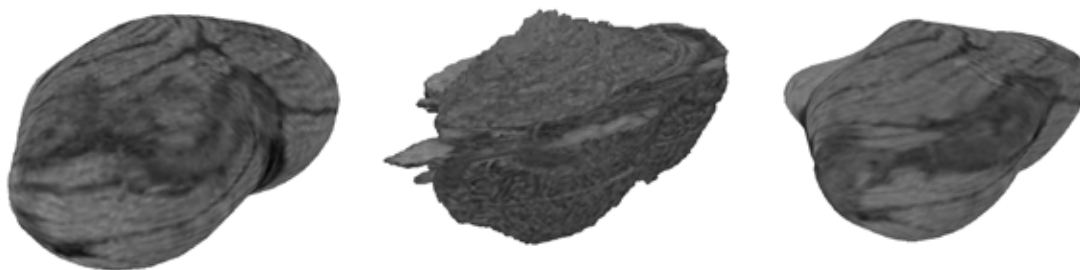
Fig. 10-7

ROI of a the Cerebellum (top) and the curvilinear surfaces derived from it (below) using various smoothness values.

CREATING A 3D SURFACE FROM AN OVERLAY

To create a 3D representation based on an overlay data set:

- Click **New...**, then select **Surface from Overlay** to open the surface creation window.
- Select the overlay to generate the 3D surface from (if you have multiple overlays).
- Set the lower and upper thresholds to the desired value to delineate the desired intensity range.



- Click **Compute Surface**, wait for the process to complete, and view the results in the 3D view.
- Verify that the surface is acceptable. Change the threshold or smoothness parameter if needed and click **Compute Surface** to update it.

If you cannot isolate your structure solely using an intensity range, cancel this process by closing the window (do not save the surface) and use the ROI tool to delineate your structure and see the next section on creating a surface from ROI.

CREATING A 3D SURFACE FROM AN ROI

Creating a surface from an ROI is simpler than creating a surface from overlay.

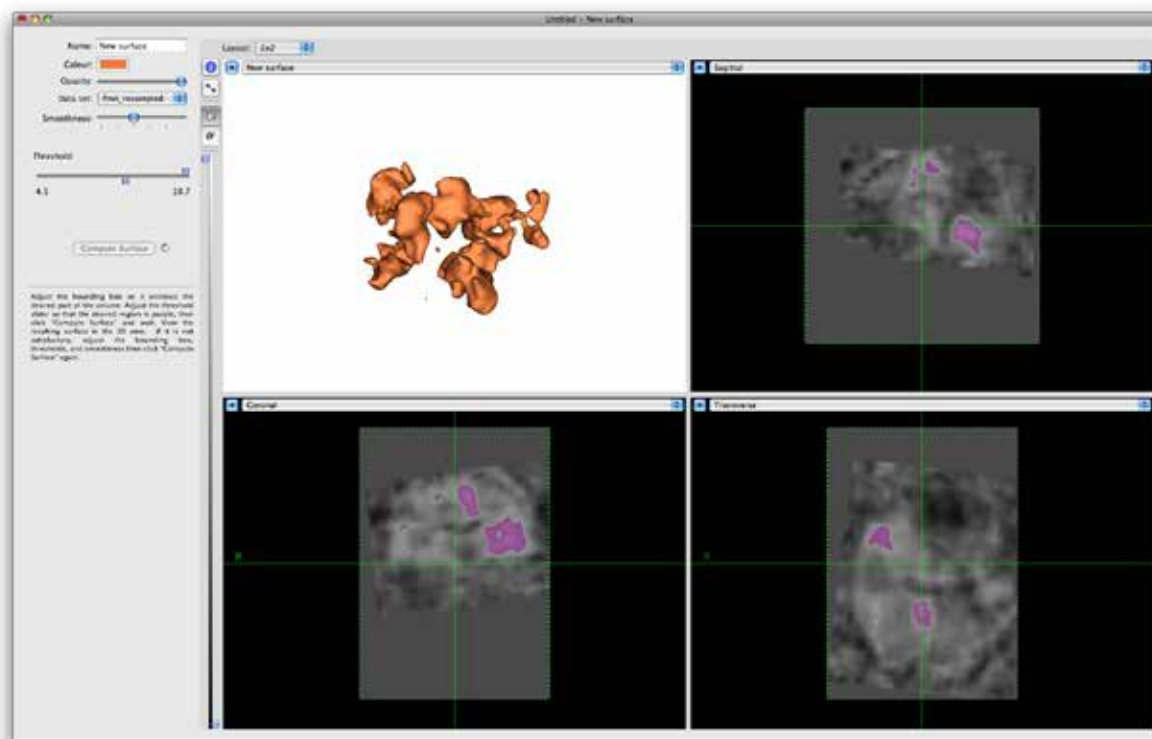
- Click **New...** and select **Surface from ROI** to open the surface creation window.
- Select the ROI to generate the 3D surface from (if you have multiple ROIs).
- Click **Compute Surface**, wait for the process to complete, and view the results in the 3D view.
- Verify that the surface is acceptable. Change the smoothness parameter if needed and click **Compute Surface** to update it.

IMPORTING 3D SURFACES FROM OTHER SOFTWARE

Brainsight can import surfaces saved in AutoCad (.dxf), polygon (.ply) and stereolithography (.stl) format. It is important that the coordinate system of the mesh be in the anatomical image's Brainsight coordinate system.

Fig. 10-8

Screenshot of the surface from overlay function.



Otherwise, the location of the objects will be incorrect. To import a surface:

- Click **New...** and select **Import from File...**
- Select your surface file from the file selection dialog and click **Open**.

Brainsight 1.7 users can take advantage of this by using the STL export feature in 1.7 to export a surface and import it into Brainsight 2.

EXPORTING 3D SURFACES

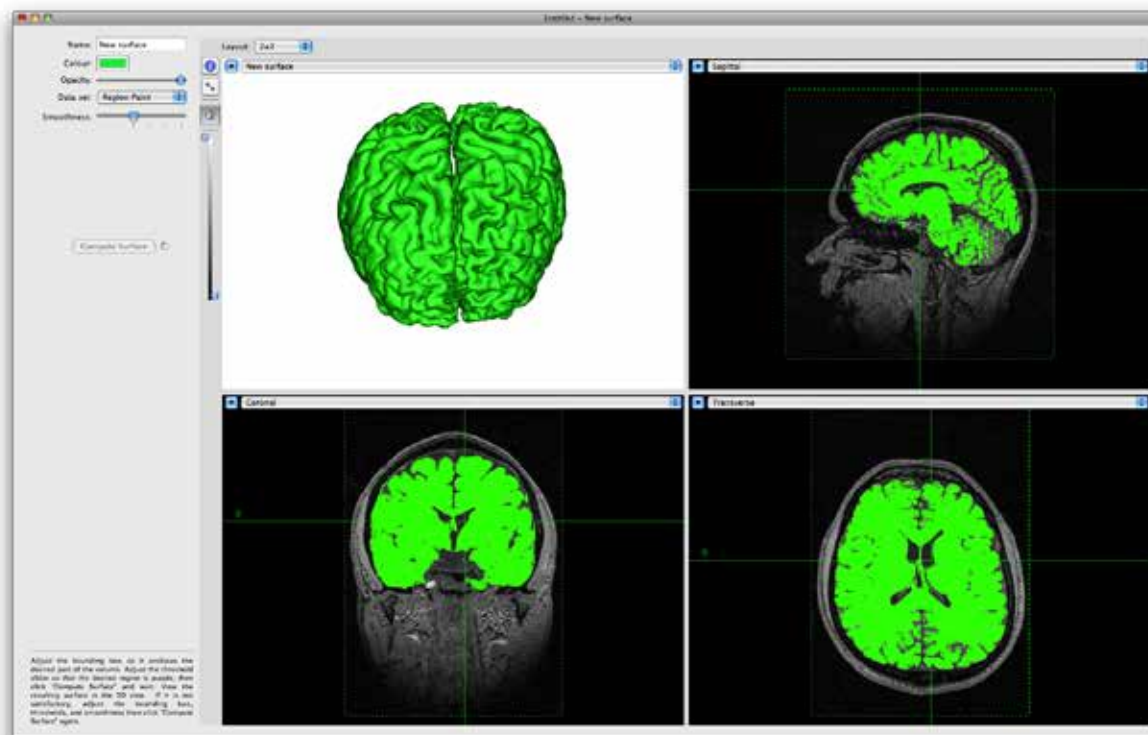
Although this function was mainly created for our veterinary neurosurgical application, it might be useful to note that any 3D surface created (except curvilinear surfaces) can be exported as AutoCad™ drawing interchange format (dxf), Polygon (ply) as well as in stereolithography (stl) file formats.

To export a 3D surface:

- Select it from the list surface of 3D surfaces shown in the reconstruction manager window.
- Click **Export...**
- Select the file format to use from the format popup menu, enter a file name, navigate to the desired folder, and press **Save**.

Fig. 10-9

Surface created from an ROI.



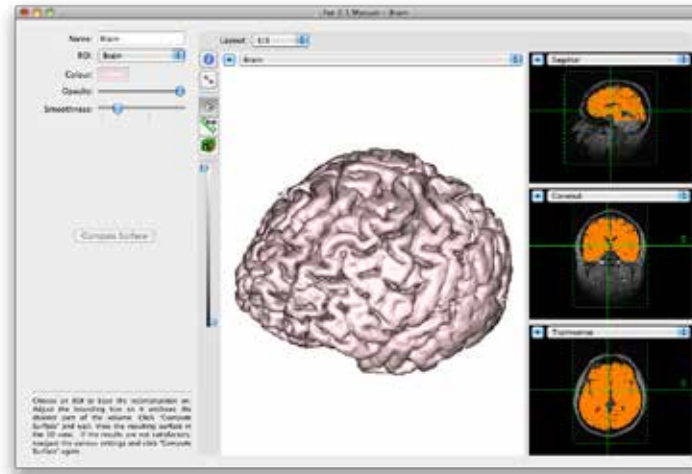
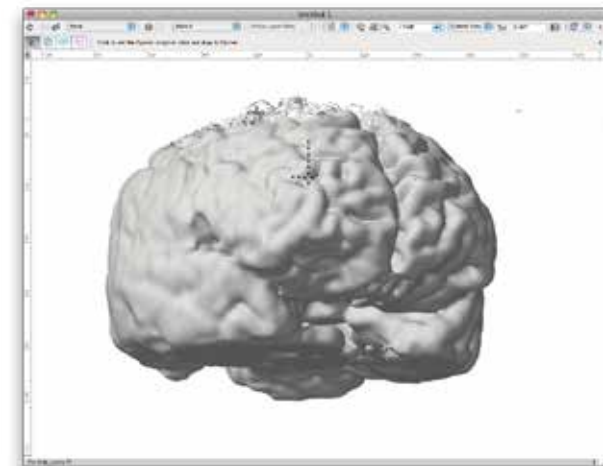


Fig. 10-10

Above: Surface created by an ROI.

Right: Same surface imported into a CAD application.



Chapter 11: Selecting Anatomical Landmarks

As explained earlier, the subject is co-registered to the images at the start of a TMS session. This is accomplished by identifying a series of anatomical landmarks on the images and on the subject. This chapter describes how to identify them on the images.

Good anatomical landmarks must abide by a few rules. First, they must be non-ambiguous, so a point in the middle of the forehead, for example, would not be good. They also have to be in the same location during the TMS session (with respect to the brain) as they were during the scan. That means they have to be rigid, so the chin would not be good. We recommend the following points as good landmarks:

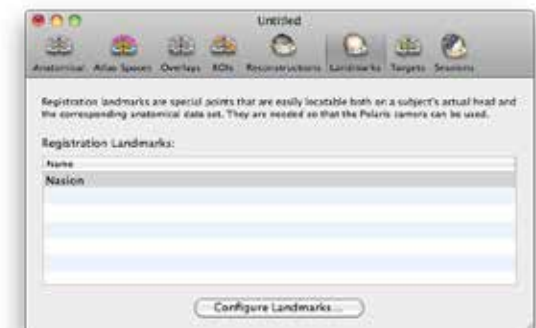
- Bridge and tip of the nose.
- The notch above the tragus of the ears.
- The outer canti of the eyes (if one of the above points are missing).

We do not recommend the tragus itself because earplugs may deflect it during the scan. To record the landmarks:

- Click **Landmarks** in the project window. The

Fig. 11-1

Landmarks manager

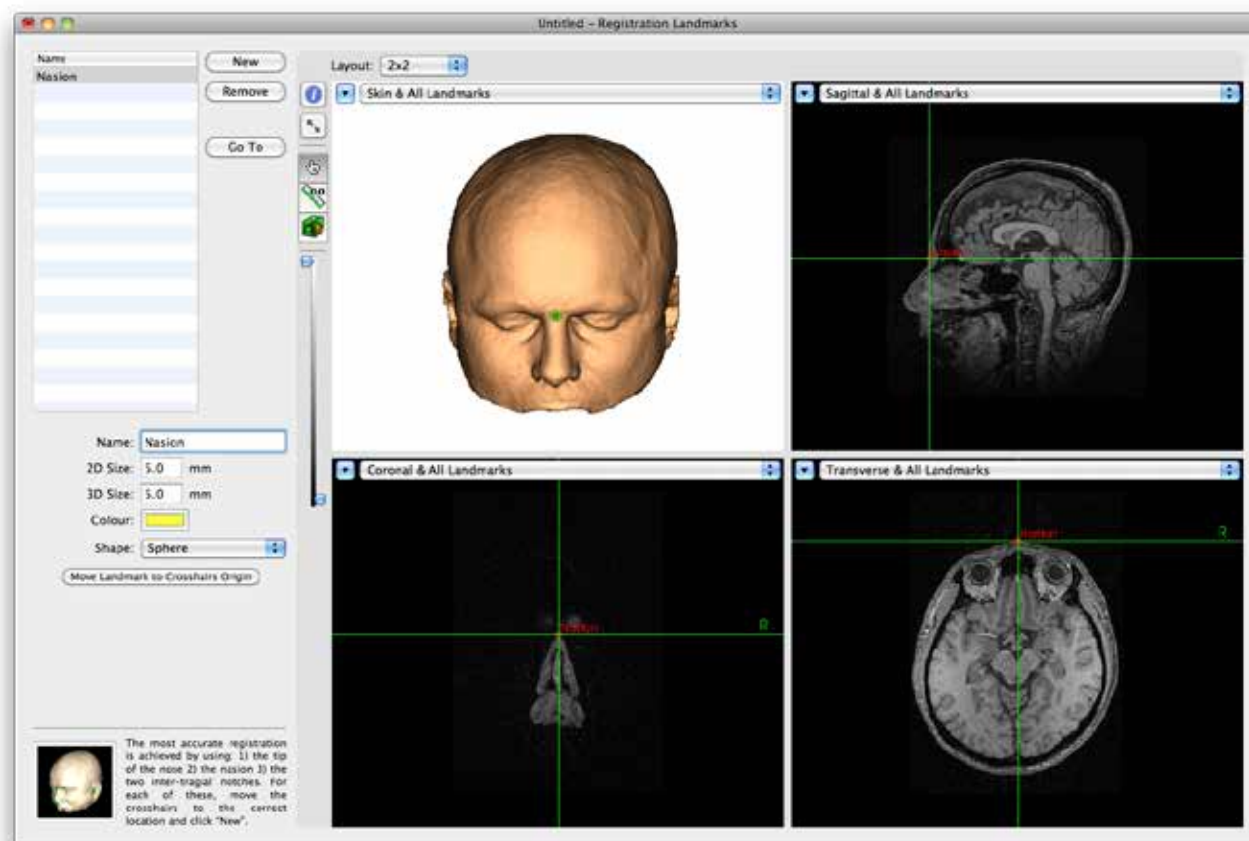


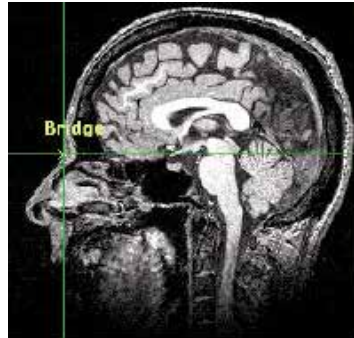
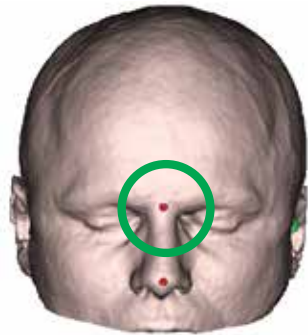
landmarks manager pane will display any landmarks created earlier, otherwise it will show an empty list (Fig. 11-1).

- Click **Configure Landmarks...** to open the landmarks window (Fig. 11-2).
- Rotate the 3D skin until you have a good view of the nose, particularly the nasion (top of the bridge). Click on it in the 3D view to move the cursor to that location. Note that a translucent green sphere identifies the cursor location in the 3D view.
- Observe the location in the transverse, sagittal and coronal views. Adjust the location by clicking in the 3D or any of the 2D slices until you are satisfied with the location.
- Click **New** to record the name.
- Note that the name field is highlighted so you can enter text that will overwrite the default name. Type in "Bridge of Nose", or "Nasion".
- If desired, you can change the colour, size or shape of the recorded landmark. For clarity, we recommend leaving it as is unless you have a reason to change it.
- Move the mouse to the tip of the nose, and perform the same steps as for the nasion. Call it "Tip of Nose" (the reason we use explicit, long winded names as opposed to TN or BN will be apparent later).
- Repeat for the left and right ears. Refer to Fig. 11-3 for examples of the landmarks.

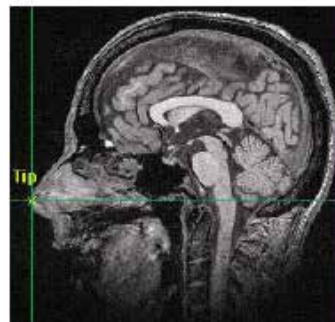
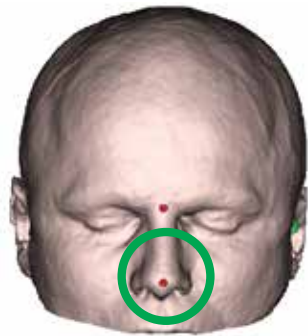
Fig. 11-2

Landmark entry window.

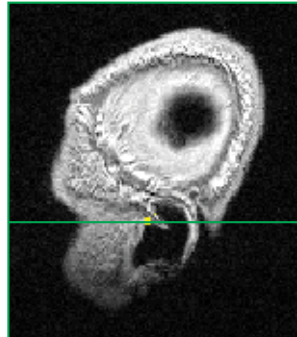




Bridge of Nose (Nasion)



Tip of Nose



Ear (notch above the tragus)

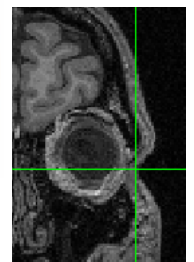


Fig. 11-4

Extra landmark: Outer canthi of the eyes.

Fig. 11-3

Examples of reliable landmarks.

Pay particular attention to the notch above the tragus.

- If one of the landmarks illustrated in Fig. 11-3 are missing, consider adding the outer canti of the eyes. They are relatively unambiguous and rigid (Fig. 11-4).
- Once all the landmarks have been recorded, close the window.

Chapter 12: Selecting Targets for Stimulation

The process of selecting your target is very similar to selecting the landmarks, except the nature of the targets themselves. How you pick the target depends on your protocol. You can select a target anatomically, using MNI/Talairach coordinates, or by picking them based on a functional overlay.

You can define a target as a discrete point, a point with approach angle, or even a grid of points.

To start the process, click **Targets** in the project window to bring up the target manager pane (Fig. 12-1) and then click **Configure Targets...** to open the targeting window.

Fig. 12-1

Targets manager.

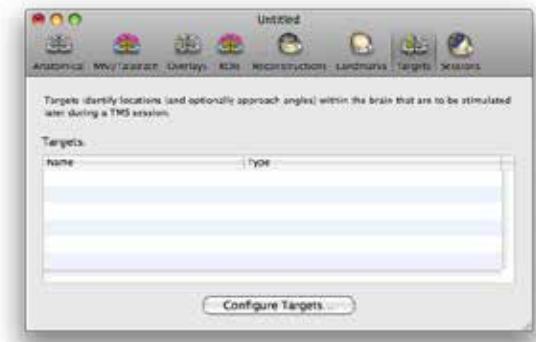


Fig. 12-2 shows a typical targeting window. In addition to the typical image views and list of targets on the left, there are additional controls on the right. The image views are set to the traditional transverse, coronal, and sagittal as well as the oblique inline, and inline-90 views. Finally, the 3D curvilinear surface (if you created one) is shown. As with all view windows, you can change these values as you like. The angle adjustment tool enables you to change the “approach” angles of the cursor, which is particularly helpful when defining trajectory targets.

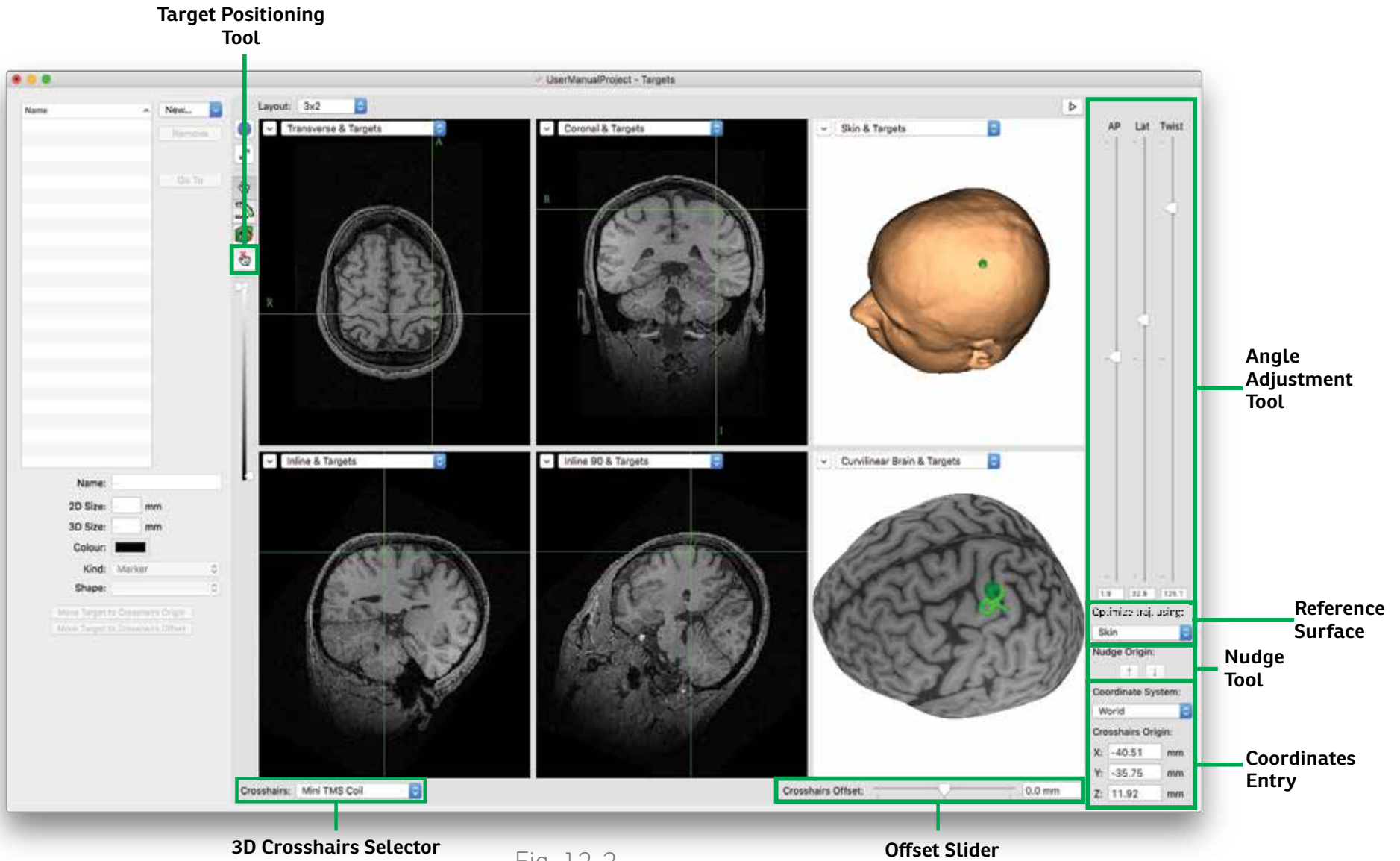


Fig. 12-2

Typical targeting window.

The targeting window introduces a few new tools (in addition to those described in Fig. 6-7). First, a new type of cursor tool, the target positioning tool, is used to adjust a target location. Second, the Angle adjustment tool provides a series of slider controls to alter the approach angles of a target. The **Optimize traj. using** is a tool to automatically optimize the coil orientation such that the orientation trajectory is normal to the selected reference surface. For example, if you select Skin as the reference surface, when you click on the brain to pick a stimulation target, the angles (as displayed in the image views and in the angle adjustment sliders) will automatically be determined to have the coil sit flat on the skin at the exit point. This optimization occurs each time you click in an image view. Note it does not do so when you enter coordinates of use the nudge tool. You can always

override it with the angle sliders. The nudge tool allows you to move the crosshairs up/down along the current trajectory in small increments. When used in conjunction with the target positioning tool, you can easily nudge any target up or down along its trajectory. The offset slider allows you to temporarily project the location of the crosshairs from the current location by moving the origin up and down along the current trajectory. In contrast to the nudge tool, the offset slider always keeps track of the original location of the crosshairs and the movement is relative to that original location. Note how the crosshairs shows the original location as a solid line, and the projected location as a dashed line. If you wish to make the projected location the new origin, click **Move Target to crosshairs offset**. The 3D representation of the crosshairs

can be changed to be of several preset shapes (Fig. 12-3) by clicking on the **Crosshairs** popup menu and selecting one of the shapes. Selecting the **Other...** item in that popup menu allows you to load and use a CAD file as the 3D crosshairs shape. The same file formats as described in the 3D reconstruction chapter (see "Importing 3D Surfaces From Other Software" on page 55) can be used here. The orientation of the object must match that described for the coil in Fig. 4-7. Finally, the coordinates entry tool allows you to select the desired coordinate system to view and set the location of the cursor using xyz coordinates.

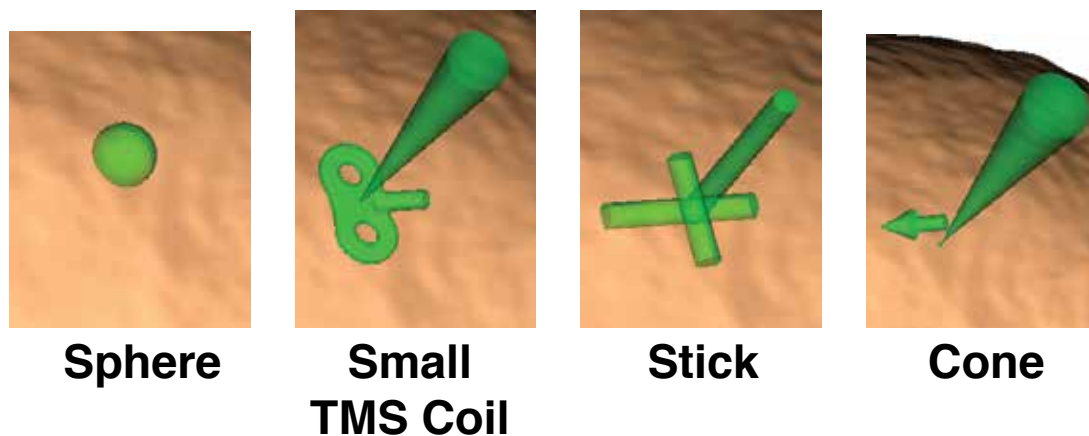


Fig. 12-3
The different ways to represent the 3D cursor

There are three types of targets that can be recorded. Marker targets (x, y, z only), trajectory targets (x, y, z and orientation), or grids (both round and rectangular, and based on markers or trajectories).

ANATOMICAL TARGETS (VISUALLY IDENTIFIED)

- Move the cursor to the desired location on the brain, using whichever image views are most helpful.
- **New to version 2.3:** Note that when you click on the 3D brain (or 3D skin), the orientation is set using the curvature of the 3D object set by the **Reference Surface** popup button to estimate a “reasonable” approach angle. For example, select “Skin” as the reference surface and when you click on the brain, the curvature of the brain will be used as the initial angle estimate, however the skin will be examined at that entry point and the angles will be automatically tweaked to ensure that the coil face will sit flat on the skin, ensuring a good coil orientation for that target in the brain. Use the angle adjustment slider controls to tweak the approach angles if needed.
- Click **New...**, and select the type of target to create (Marker or Trajectory).
- Enter a name for the target, and select the size, colour, and shape to suit your needs.
- If needed, tweak the location of the target by selecting the Target Positioning tool, and moving the cursor. As the cursor moves, the currently selected (active) target will move with the cursor.

MNI OR TALAIRACH BASED TARGETS

It is assumed that you performed the MNI registration described in Chapter 7. If not, perform it now.

- Choose the desired coordinate system by clicking on the popup menu button in the coordinates entry area of the window, and selecting it from the list.
- Enter the coordinates of the target in the X, Y, and Z entry fields.
- Verify visually (if possible) that the location appears correct anatomically.
- If you wish to record a trajectory-based target, adjust the approach angles using the angle sliders.
- Click **New...**, and select the type of target to create (Marker or Trajectory).

COORDINATE BASED TARGET

If you have derived a target in either Brainsight's coordinate space (see Fig. 17-3) or the anatomical MRI's World coordinate space (e.g. scanner coordinates found in DICOM images), you can move the cursor to that location by:

- Choose the desired coordinate system by clicking on the popup menu button in the coordinates entry area of the window, and selecting it from the list.
- Enter the coordinates of the target in the X, Y, and Z entry fields.
- Verify visually (if possible) that the location appears

correct anatomically.

- If you wish to record a trajectory-based target, adjust the approach angles using the angle sliders.
- Click **New...**, and select the type of target to create (Marker or Trajectory).

fMRI BASED TARGET

Functional based targets are similar to anatomical targets in that you create the target by clicking on the images and recording the location however the images include a functional overlay.

- If it is not already being displayed, display the functional data by opening the inspector and enable your overlay.
- Follow the steps outlined in the “Anatomical Targets” section to create and adjust your target.

CREATING A GRID OF TARGETS

In certain protocols, the target may not be a discrete point, but an array of points over a particular region (e.g. for mapping a region). Brainsight can create a series of points or trajectories called a grid. Two types of grids can be created, rectangular and circular, representing the method of distributing the nodes of the grid. Creating a grid is similar to creating markers and trajectories. The main difference is that you will select the location for the centre of the grid rather than for the discrete target, and lay out the grid based on that origin.

To create a grid:

- Select the Smart Cursor tool and move the cursor to the location that will be the centre of the grid. Make sure that the orientation of the cursor is normal to the brain (or scalp) curvature (as seen in Fig. 12-2). Remember to set the “twist” of the grid by setting the twist of the cursor location by adjusting the twist slider. The orientation is indicated by the little arrow at the base of the cursor (try zooming into the 3D view closely).
- Click **New...** and select either rectangular or circular grid. A grid will appear at the location of the cursor.
- Set the 2D and 3D node sizes and the other node attributes as you would for a singular marker or trajectory. These attributes will apply to all the nodes in the grid.
- If needed, adjust the location of the grid by moving the cursor (make sure you are using the Target Positioning tool) as needed. The centre of the grid will move with the cursor.

Rectangular grid (Fig. 12-5):

- Set the number of rows and columns.
- Set the grid node spacing.
- The grid will initially be flat. You can wrap the grid to any 3D surface (e.g. curvilinear brain) using the snap function. Once you have set the grid size, spacing and location, click (Fig. 12-6) **Snap To...** . In the sheet that appears, select the surface to wrap to

Fig. 12-4

Rectangular grid controls.

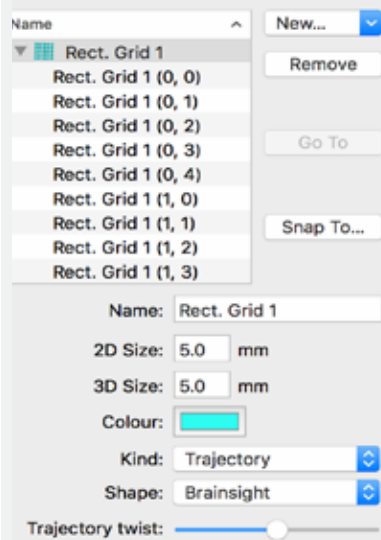


Fig. 12-5

Rectangular grid.

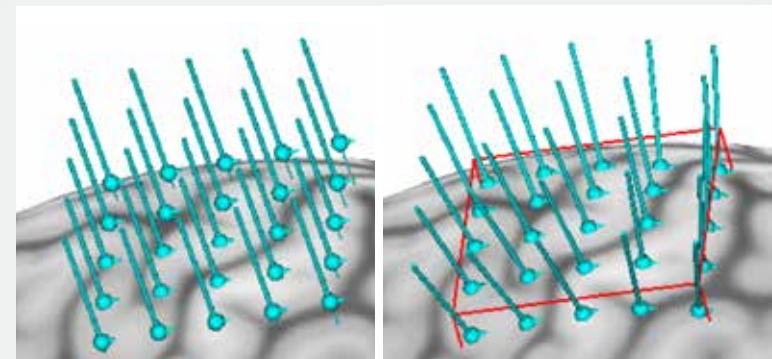
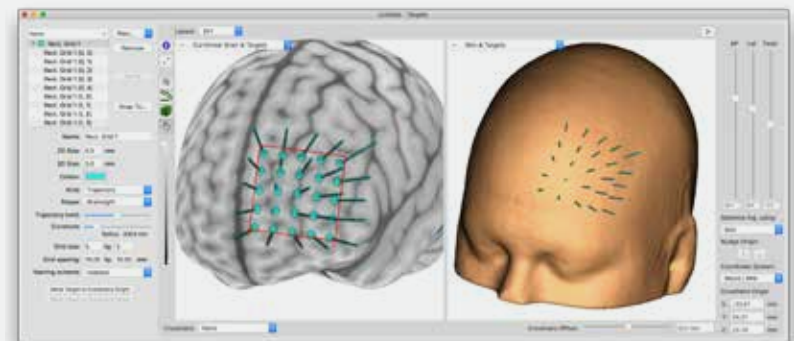


Fig. 12-6

Effect of adjusting the curvature slider.



and the surface to use to for trajectory optimization (see Fig. 12-6).

- After the grid has been placed, you can tweak individual grid nodes in the same way as any trajectory. To tweak a node, expand the node list by clicking the disclosure triangle, then select the node and use the same techniques described earlier to tweak the node location or orientation.

Each node of the grid will be labelled according to the name of the grid, and will have the row and columns appended. The indexing of the rows and columns will start at one corner of the grid, and use positive numbers towards the right and down. **Note that symmetrical indexing (as was available in Brainsight 1) will be provided in a future update.**

Circular grid (Fig. 12-8):

- Set the number of rings.
- Set the ring spacing.
- Set the space between the ring nodes by setting the arc length.

The circular grid consists of concentric circles. Nodes are placed at constant intervals around each circle. The distribution method can be set to one of two modes (see Fig. 12-9). Indexed mode will start around each ring and travel 360°, creating nodes at arc length intervals set by the arc length. Numbering will always be positive and increase with ring number, and for each node along

Fig. 12-7

Circular grid controls.

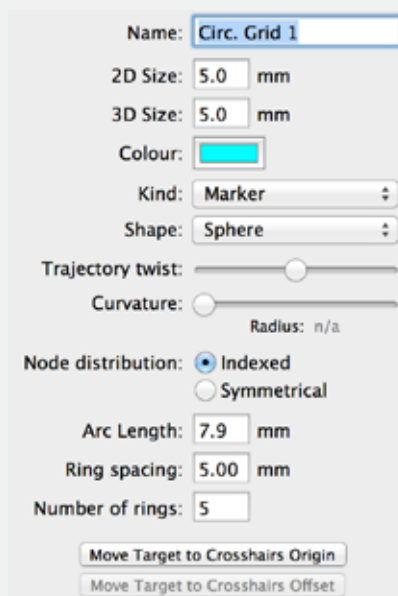


Fig. 12-8

A: Circular grid placed on curvilinear brain surface.

B: Circular grid placed on scalp.

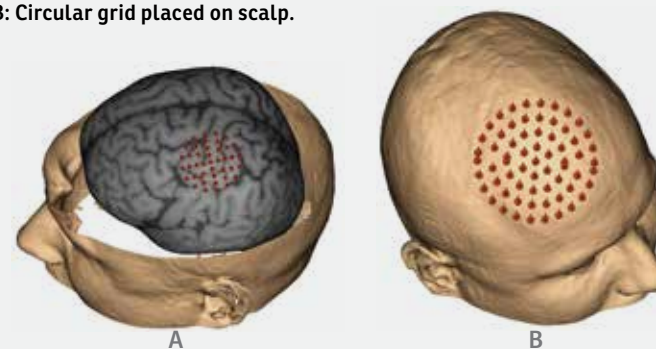
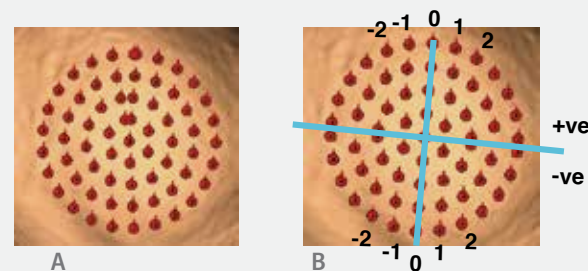


Fig. 12-9

Node distribution for indexed and symmetric grids.

A Indexed grid. Note that in the indexed version, a discontinuity exists where the distance between the last node on the ring and the first one is less than the arc length. B: Symmetric grid. Note that the nodes have discontinuities where the disks meet the horizontal, and that the index numbers are positive and negative.



the ring. Symmetric mode spacing defines quadrants as shown in figure Fig. 12-9B. Distribution of the nodes starts at the vertical axis (both at 0° & 180°) and arcs in both directions away from the starting point placing nodes at fixed intervals according to the arc length. Each node will be named according to the name of the grid, with the ring number (with +ve and -ve values, depending on the quadrant) and the index number along the ring appended (both +ve and -ve values depending on the quadrant).

CREATING A TARGET BASED ON A PREVIOUS SAMPLE

In some instances, you will want to define targets based on the results of a pilot study. The typical steps would be:

- Prepare the project file for the subject except to define a target, or to define a rough target to start.
- Perform the study (as described in the next chapter) and record the coil location along with the response measure that will be the criteria for selecting the ultimate target(s) for future session(s).
- After the study, follow the steps in Chapter 17 to review the study. In the review window, select the sample that you wish to use as a new target, and click **Convert to target**. Note that a copy of the sample will appear in the target list. Close the review window.
- Open a targeting window again. Select the new target in the list, and click **Go To**. Note that the target's origin is on the scalp, pointing into the

cortex.

- We recommend that targets be based in the cortex, rather than be on the scalp. To move the target into the cortex:
 - Click on the nudge tool to nudge the target down the trajectory.

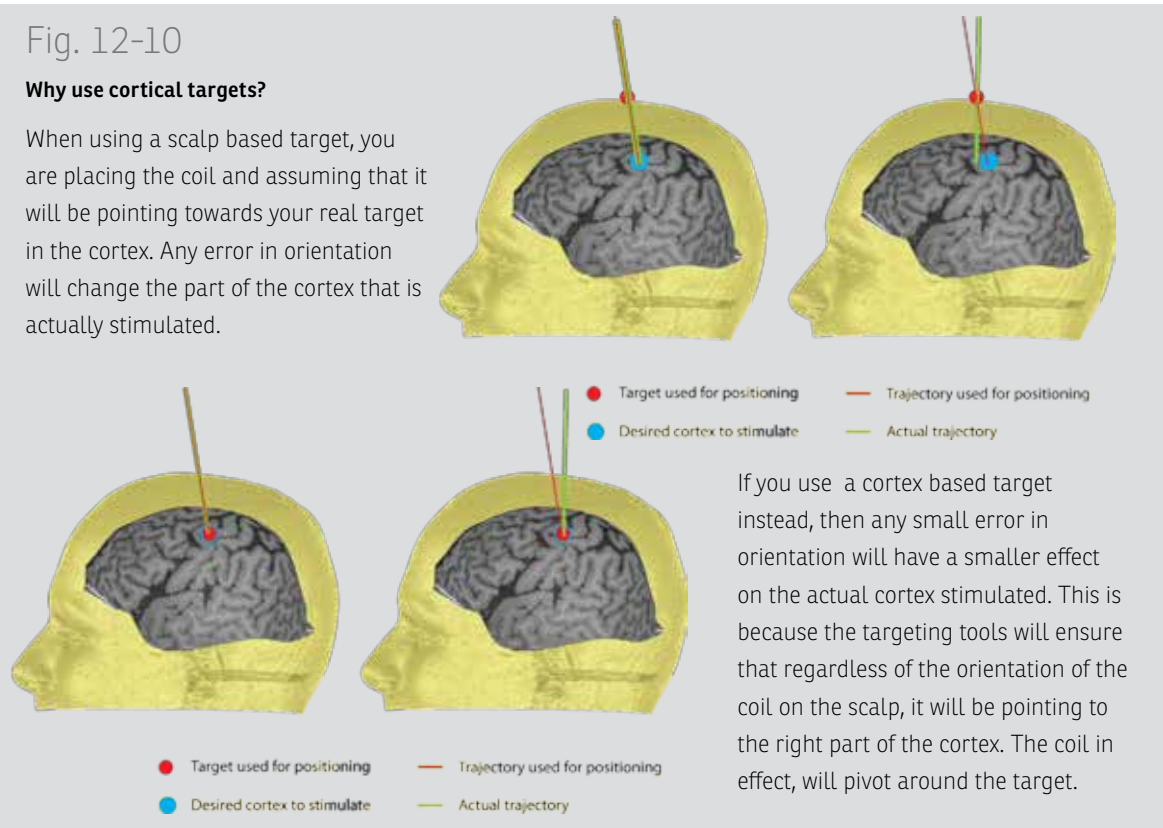
or

Move the offset slider to project the cursor down the trajectory into the cortex, then click **Move Target to Crosshairs Offset**. The target will move from the original location to the new location.

Fig. 12-10

Why use cortical targets?

When using a scalp based target, you are placing the coil and assuming that it will be pointing towards your real target in the cortex. Any error in orientation will change the part of the cortex that is actually stimulated.



If you use a cortex based target instead, then any small error in orientation will have a smaller effect on the actual cortex stimulated. This is because the targeting tools will ensure that regardless of the orientation of the coil on the scalp, it will be pointing to the right part of the cortex. The coil in effect, will pivot around the target.

Chapter 13: Performing the Study

Up to this point, you have spent several minutes or more preparing for this part, performing the TMS session. The description of many parts of this procedure will be deliberately vague because they depend on the nature of your experiment. Focus will be paid to the aspects that are relevant to neuronavigation, and the examples given to subject setup will use our subject chair and coil holder apparatus. Refer to the chapters regarding the computer trolley and TMS chair if you are using them.

Before you can start a session, you will need to have calibrated your coil (see Chapter 4) and performed the steps in preparing a project file (start at Chapter 6 and work your way back to here).

PREPARE THE TRACKED TOOLS

You will require the subject tracker, coil tracker and pointer for this section.

Caring for the reflective spheres

Make sure the spheres on the coil tracker, subject tracker and pointer are free of scratches, blemishes or dirt. If they are dirty, try using an alcohol wipe to gently wipe off the dirt, and allow the sphere(s) to dry before use. Take care not to rub too hard and rub off the coating of microspheres. If the sphere is too dirty to clean or scratched, replace it by:

- Removing the old sphere by firmly pulling it straight off the mounting post.
- Using a glove or plastic bag over your hand (to keep the oils of your fingers off the new sphere), take a spare sphere and push it onto the mounting post. You should feel a snap when it is correctly seated.

Both the subject's head and the TMS coil will be tracked by the position sensor camera. The TMS coil tracker should already have been fixed to the coil and calibrated following the instructions outlined in "Chapter 4: Calibrating Your Coil" on page 17.

PREPARE THE SUBJECT

The orientation of the subject will depend almost exclusively on your experiment. For example, if you are stimulating frontal areas of the brain, you will likely want the subject in a reclined position. Alternatively, if

your experiment involves visual stimulus presentation, an upright subject might be best.

Prepare and attach the subject tracker

As with the coil tracker, the subject tracker is held in place using a hexagonal rod. The diameter of the rod as well as the receptacles are smaller than that of the coil tracker to prevent confusing them. The subject tracker will be held to the subject's head using either an elastic head strap (with a flexible pad and hex rod receptacle) or the tracker glasses (Fig. 13-2).

Using the head-strap

Note that the receptacle in the head strap has two holes. One will orient the tracker horizontally and the other vertically.

- Decide which one to use based on the expected location of the camera. If the camera will be low (e.g. eye level), then use the vertical hole so that the subject tracker will be facing horizontally. If the camera will be high looking down, then use the horizontal hole so that the tracker will be facing up.
- Loosen the set screw in the receptacle and insert the hex rod. Tighten the set screw, taking care to ensure that the set screw comes into contact with a face of the hex rod.

Using the glasses

The glasses have receptacles on both ends of the frame.

- Select the one that will ensure that the tracker will

Fig. 13-1

A: Chair in a reclined configuration to provide convenient access to the frontal areas.



B: Upright configuration for access to parietal or occipital areas.

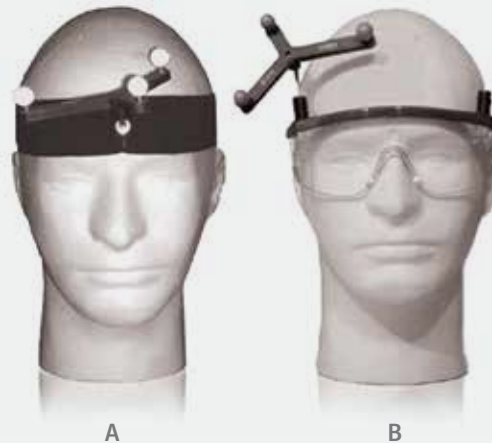


Fig. 13-2

A: Head strap for attaching trackers.

B: Glasses with tracker mounts.

be away from the coil.

- Loosen the set screws in the receptacle and insert the hex rod. Tighten the set screws, taking care to ensure that the set screws comes into contact with a face of the hex rod.

Fix the subject tracker to the hex rod by loosening the set screws in the receptacle, mount the tracker on the hex rod, and tightening the screws taking care to ensure that the set screws comes into contact with a face of the hex rod.

Ensure that the position of the subject tracker is such that the Polaris will be able to see the tracker, and that its location will not interfere with the coil location. You will have the opportunity to confirm the visibility of the tracker during the start of the TMS session.

PREPARE THE HARDWARE

If during the TMS session, you wish to automatically record the coil location using the TTL signal from the TMS device, connect the TTL output of the TMS device to the Brainsight computer. If you have a recent trolley-based iMac from Rogue Research that has a metal case at its base or a small metal box called an "I/O box", or a smaller box called and "Analog Receiver" (we often refer to it as the trigger box), connect the BNC cable from the trigger out of the stimulator to one of the "trigger in" ports (refer to Chapter 19 for more details). Note that there are two trigger in ports to allow you to monitor two coils at the same time.

If you do not have one of our interface boxes, or are using your own computer, contact Rogue Research to purchase a separate TTL trigger box. Note that the "X-Keys" box previously provided by Rogue is no longer supported. Contact Rogue Research to obtain the replacement trigger box.

Note: If you are using a Magstim system and using our early model I/O box (before fall 2010), you may need a special TTL output adapter to have access to the TTL signals. Magstim has released more than one version of this adapter, and some of them will not work. The only ones that will work reliably is the adapter with the TTL pulse extender (EMG Interface Module P/N: 3901-00) or the more recent round adapters by Jali Medical (USA only). The EMG interface module can be identified by the presence of small switches (DIP switches) that are used to configure the length and direction (trigger up or trigger down) of the TTL pulse. The reason is that the width of the TTL pulse (without conditioning) is too short ($\approx 50 \mu\text{s}$) for many electronic devices to detect. The pulse extender extends it to about 20 ms making it easier to detect. This issue is often encountered with EMG systems as well, hence the development of the EMG interface box. The most recent adapters from Jali medical also contain a built-in pulse extender, and can be identified by the connector style to the Magstim device. If the connector is a small circuit board, it has the pulse extender. If it is a grey, plastic connector, then it does not have the pulse extender.

Fig. 13-3

TMS Session manager window.



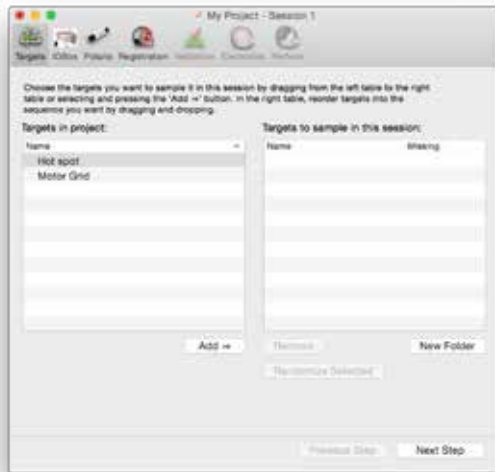
BEGIN A NEW TMS SESSION

- Launch Brainsight and open the subject's project file
- Click on **Sessions** to bring up the TMS session manager window (Fig. 13-3).
- To begin a new session, click **New->Online Session**. To resume a previously created session, select the session from the list and click **Resume**. A session window will appear (Fig. 13-4).
- The first window shows a list of all the targets defined earlier, and an empty list representing the targets to use in the current session. Either select the target and click **Add->** or, using the mouse, drag the targets to use in this session from the list of all targets to the list for the session. Note that you can

Fig. 13-4

Target selection screen.

Drag and drop the targets to use for this session from the pool of all targets on the left to the session target list on the right (or select the target on the left and click Move..

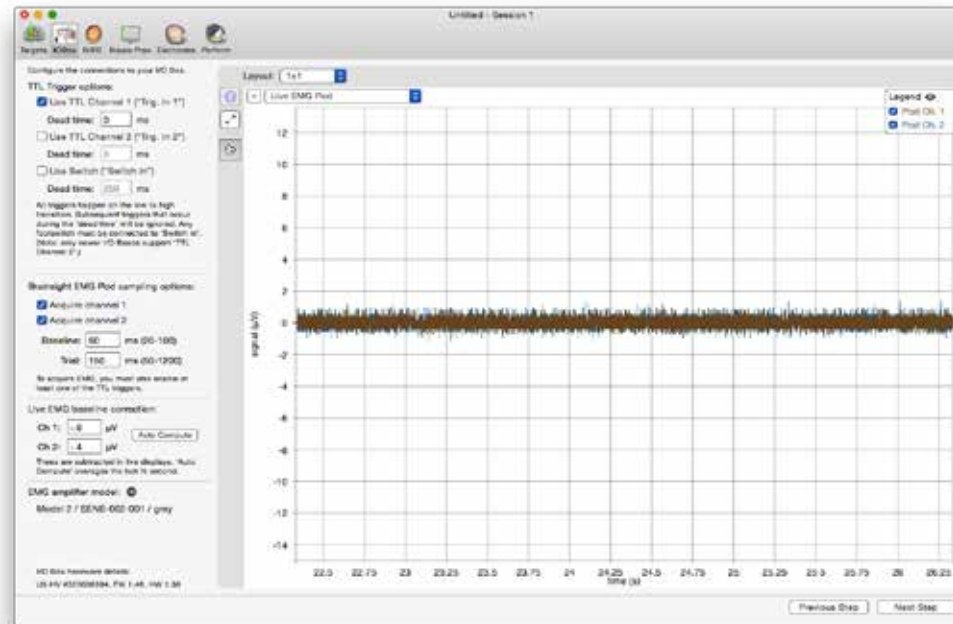


rearrange the order of session targets by dragging them up and down in the list. You can also add multiple instances of a target in the session list. This allows you to create a sequence of targets for a session that can include stimulating the same target more than once.

- Once all your targets are selected, click **Next Step**.

Fig. 13-5

I/O box configuration window



CONFIGURE THE I/O OR TRIGGER BOX

As of version 2.3, Brainsight has consolidated several hardware related functions into a new "I/O box" step. This step allows you to configure the trigger options (formerly the **Trigger Options...** Button in the perform step), the EMG acquisition (formerly the **EMG/EEG options...** button in the perform window) and provides a live EMG view (when present).

Set the trigger options

During the TMS session, you may wish to record the coil location manually. You can always do so by pressing the Sample button, but you can also do so automatically by connecting the stimulator's trigger out signal to the Brainsight computer (see previous section).

- If you have a Brainsight computer trolley with an I/O box (see Chapter 19) or LabJack™ interface box (specifically from Rogue Research) and have connected the TTL trigger output of the stimulator to the TTL trigger in of the I/O box (or connected a switch to the switch input), enable it by enabling the **Use TTL Channel x** checkbox (x=1 or 2). For rTMS, enter the pulse train length as **dead time** to have Brainsight use the first pulse in a train and ignore the rest (until the first of the next train). In certain models of the LabJack based trigger unit, you may select the type of trigger signal: Trigger on rising pulse, or falling pulse (e.g. 0->5 V or 5->0 V). Note that on early versions of the interface box, you need to ensure that the trigger pulse is at least 500 µsec long. In some stimulators, this will require a pulse extender. This limitation is also common when using EMG and EEG devices because the trigger is being recorded by an analog device with a sampling rate of 1-5 KHz. Contact Rogue Research or your TMS manufacturer for more details. Note that if you are using a recent Brainsight computer and I/O box (2010+), a pulse extender is incorporated into the

box, so a pulse extender is not required.

- You can also enable the switch input and connect that to a hand-held, or foot switch.
- Note that as described on page 86, you can open a second "perform" window to track a second coil, and set the trigger in of that window to any of the TTL channels. This allows you, for example, to set one window to track one TMS coil, and have the automatic trigger connected to that TMS device and have a second window track a second TMS coil and triggered by that second device.

Setting up the EMG

NOTE: A bug in Brainsight was discovered where the scaling of all EMG data acquired and stored was incorrect. As of Brainsight v2.2.13, any time an older project is opened that has the old scaling factor, Brainsight will issue a notification that all EMG data previously recorded will be automatically corrected and any new data acquired will have the correct scaling. The correction includes all EMG data, MEP values (unless they were overwritten manually) and the threshold values in motor maps. The error was in the scaling, not the raw data so any relative measure will not be affected.

Refer to Chapter 13 for safe and correct operation of the Brainsight EMG device. If you have not already done so, apply the EMG electrodes on the subject. The EMG data from both amplifiers will be displayed live in the EMG view on the screen. You can use this to ensure that you

have a good electrode contact.

To set up the EMG options:

- **Double-check that you have selected the correct amplifier model in the preferences.** Brainsight currently supports 2 models, each with different gain values so selecting the wrong one will result in incorrect EMG magnitude data. See "Setting your Preferences" on page 5 for details.
- Enable one or both channels using the checkbox next to each channel. Note that you can use either channel or both, and as described on page 86, you can enable either or both EMG channels in a second window while tracking two coils. This allows you, for example, to track two coils at the same time, and have one or both EMGs associated with one coil's samples or the other.
- Set the baseline (time prior to the stimulator trigger) and trial (time after the trigger) durations for recording. The baseline value is negative to represent time before the trigger (which is the 0 time). The maximum range for the EMG recording is -100 ms to 250 ms and the minimum is -20 ms to 50 ms.
- **NOTE:** The built-in EMG device is designed specifically for recording motor evoked potentials (MEPs). Its dynamic range is set to be able to visualize a 50 µv signal (for motor threshold). There are Its maximum range is approximately 5 mv peak to peak.
- Set the live EMG baseline correction. It is usually

easiest to simply click on **Auto compute** to have Brainsight calculate and set this value.

VERIFY PROPER POLARIS LOCATION

The next screen (after the target screen) is intended to ensure that the Polaris is correctly connected to the computer and that it is correctly positioned to view the relevant trackers.

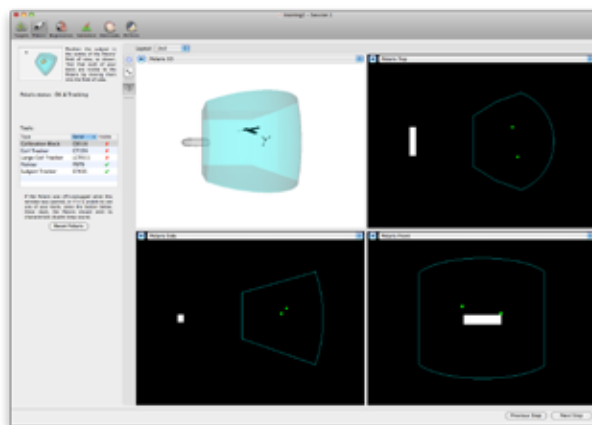


- Observe that a few seconds after the Polaris window opens, the Polaris will beep, and the red boxes describing the camera's field of view

view will change from red to blue. (If you have been using the Polaris, it may not have required a reset and the camera's field of view will already be blue).

- Make sure that the subject tracker (and any other tools in the field of view) is well within the boundary and that the tools you intend to use (as seen on the list) are present.
- Click **Next Step**.

Fig. 13-6
Polaris verification screen.



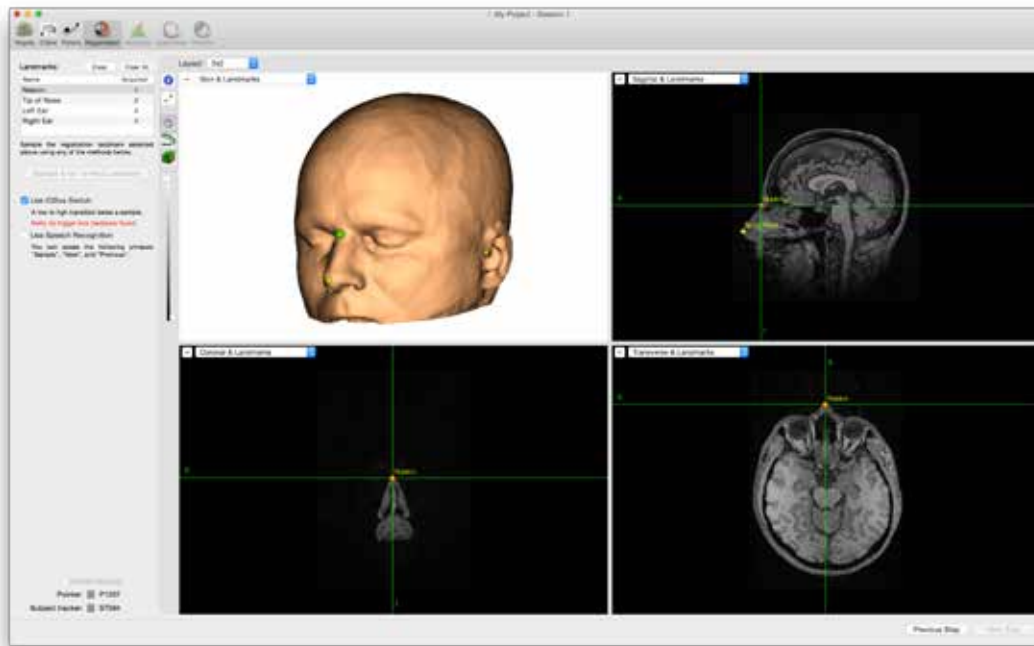
What if my tools are not visible?

If you are placing your tools in front of the camera and they are not tracked, one of several events may have occurred. Before contacting Rogue Research, here are a few things to try/examine (we will ask this if you contact us):

- Does it only fail to track one tool? If so, examine the spheres for scratches or dirt and make sure they are all seated properly on the posts.
- Does it track better (all tools) close to the camera, but not near the rear of the field of view? Has this been getting worse over time? If so, your camera may need re-calibration (required every few years)
- Are there any reflective objects (mirrors, windows, reflective pain in the IR spectrum) facing the camera? This can blind the camera.
- Was it a sudden failure to track all tools? Was the camera dropped or bumped (the Vicra and Spectra have a bump sensor). If so, it may require re-calibration or repair by Rogue Research.

Fig. 13-7

Registration screen.



PERFORM THE SUBJECT-IMAGE REGISTRATION (SUBJECT-SPECIFIC IMAGES)

Recalling Chapter 11, you selected a series of anatomical landmarks on the images. In this step, you will identify those same landmarks on the subject's head using the tracked pointer. The software will use these point pairs to calculate the subject to image registration (Fig. 13-7). This step requires close interaction with the computer as you identify the points and "tell" the computer when you are pointing to the requested landmark. Make sure that the volume on the computer is high enough to hear the

computer, as it will speak the names of the anatomical landmarks to identify. This step supports multiple input methods. Activate the voice recognition and/or the Apple remote by enabling the appropriate checkboxes. Alternatively, have an assistant present to operate the computer for this step.

Note that as of OS X 10.10 (and 10.11), the voice recognition has been severely degraded and unfortunately essentially unusable. We are working with Apple to regain this functionality. In the meantime, we have added support for the switch input of the interface box. Contact Rogue

Research to obtain a comparable foot switch.

- Note the location of the cursor on the screen (or click on the first landmark to begin).
- Carefully place the pointer tip on the same landmark on the subject's head, being careful to gently touch the skin surface (do not "poke" the subject) and to keep the pointer still. Make sure both the pointer and subject tracker are visible to the Polaris by making sure the boxes next to them in the window are green.
- Have the computer sample that point by either pressing the foot switch, speaking the word "sample" to the computer (using the speech recognition), or by pressing the **Play** button on the Apple remote (if using the remote), or by clicking **Sample & Go To Next Landmark**. Note that the remote works best when not in the field of view of the position sensor camera, or having the camera face the computer as the camera's IR output can interfere with the reception of the remote's signal.
- If you spoke the word sample (and you are using OS 10.9), you should hear a "whit" sound. If not, try again (sometimes, saying "Simple" rather than "Sample" works). Regardless of the input method, you should hear a beep and notice a green check mark appear next to the landmark in the list. If not, repeat the voice command, or press the Apple remote again. If you hear an "error beep" (it sounds different, one that is universally recognized as a

failure sound), the pointer and/or subject tracker were not visible. Make sure they are both visible and try again.

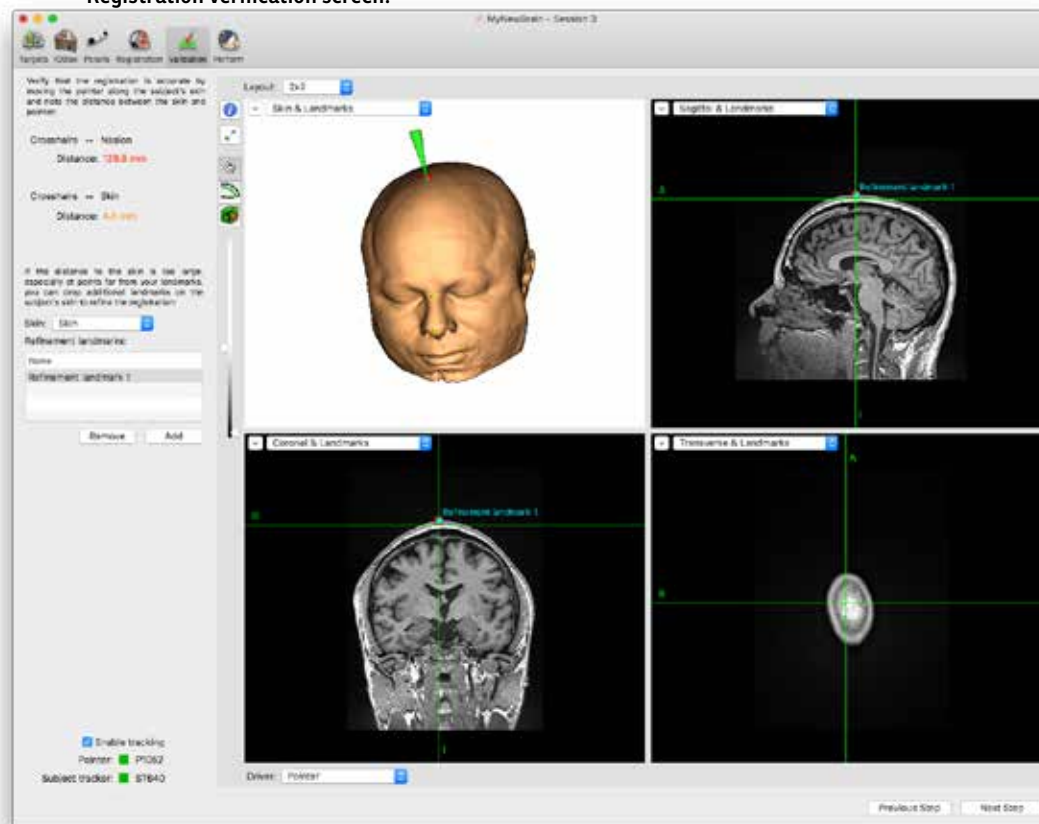
- Once you have sampled the point, it automatically goes to the next landmark and calls it out. Use the same technique to identify the landmark and have the computer sample the point.
- Repeat for all landmarks.
- You can repeat any point by either selecting it in the list (it will speak it out), or by speaking "previous" to the computer to change the current landmark to sample.
- Once all landmarks have been sampled, click on **Next Step**.

This step serves to verify and refine the quality of the registration obtained from the previous step. The cursor will automatically move based on the location of the pointer on the head (the pointer is "driving" the cursor). As of version 2.3, you have the option of recording additional points along the skin to attempt to improve the registration where the error is relatively small. While this can improve the registration in certain cases, it is no substitute for acquiring good quality points in the first step. In the long run, a good registration can be achieved a lot faster by paying attention during the previous step.

- Move the cursor to various locations on the scalp and observe the location of the pointer on the screen (Fig. 13-8). Make sure that the pointer is shown on

Fig. 13-8

Registration verification screen.



the scalp at the same location as that of the pointer. There will always be some level of registration error. Note the distance from the pointer to the skin (assuming you performed a 3D skin reconstruction) by looking at the number in the **Crosshairs->Skin**

display on the left of verification window. If the error value is consistently below 3 mm, it should be considered an excellent registration (the number is shown in green). Below 5 mm is often acceptable (shown in orange), particularly if it is below 3 mm

near your target, and 5 mm elsewhere.

- If the pointer is between 3 & 5mm from the skin, try adding refinement points by holding the pointer on the skin, being careful not to push into the skin, and create a sample by clicking **Add** or using the same method as in the previous step (e.g., foot switch or voice command). Repeat this for several points in the area where the error was observed. Notice that the error should reduce as you add points.
- Always go back and examine the rest of the head after adding refinement landmarks as they have a global effect on the registration. In some cases, the correction in one area may cause a larger error in others.
- Distances larger than 5mm are shown in red as a reminder that a better registration should be attempted (you decide based on your requirements what is actually acceptable and the colours are suggestions).
- If the registration is not acceptable, click **Previous Step** to repeat the registration. Otherwise, click **Next Step**.

If you have the EEG functionality enabled, then the next step will be the EEG electrode recording step. Refer to “Chapter 16: Special Application-EEG Recording” on page 103 for details on how to perform this step.

PERFORM REGISTRATION USING THE MNI MODEL HEAD PROJECT

If your project is based on the MNI model head template, then the registration procedure is a little different. The first step will consist of identifying three landmarks on the skin (the nasion, left & right ears) and the second step will be to record multiple landmarks on the scalp (the extremities) to help Brainsight measure the height, width and length of the subject’s head to calculate an additional scaling to help better match the model head to the individual’s head.

In this first step, you will identify those same landmarks on the subject’s head using the tracked pointer. The software will use these point pairs to calculate the subject to image registration (Fig. 13-9A). This step requires close interaction with the computer as you identify the points and “tell” the computer when you are pointing to the requested landmark. Make sure that the volume on the computer is high enough to hear the computer, as it will speak the names of the anatomical landmarks to identify. This step supports multiple input methods. Activate the voice recognition and/or the Apple remote by enabling the appropriate checkboxes. Alternatively, have an assistant present to operate the computer for this step.

Note that as of OS X 10.10 (and 10.11), the voice recognition has been severely degraded and unfortunately essentially unusable. We are working with Apple to regain this functionality. In the meantime, we have added support for the switch input of the interface box. Contact Rogue Research to obtain a comparable foot switch.

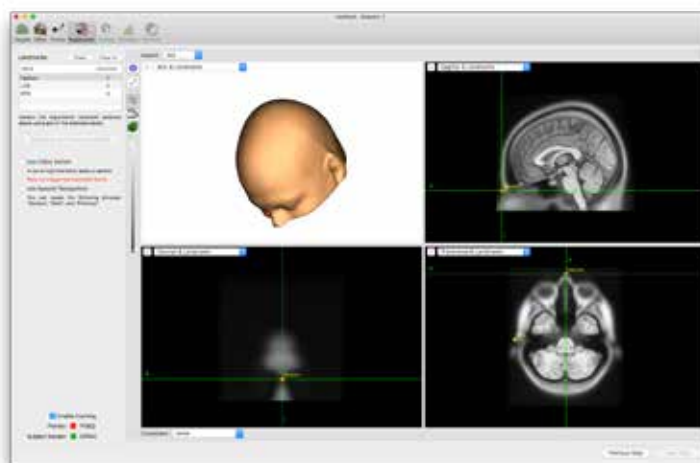
- Note the location of the cursor on the screen (or click on the first landmark to begin).
- Carefully place the pointer tip on the same landmark on the subject’s head, being careful to gently touch the skin surface (do not “poke” the subject) and to keep the pointer still. Make sure both the pointer and subject tracker are visible to the Polaris by making sure the boxes next to them in the window are green.
- Have the computer sample that point by either pressing the foot switch, speaking the word “sample” to the computer (using the speech recognition), or by pressing the **Play** button on the Apple remote (if using the remote), or by clicking **Sample & Go To Next Landmark**. Note that the remote works best when not in the field of view of the position sensor camera, or having the camera face the computer as the camera’s IR output can interfere with the reception of the remote’s signal.
- If you spoke the word sample (and you are using OS 10.9), you should hear a “whit” sound. If not, try again (sometimes, saying “Simple” rather than “Sample” works). Regardless of the input method, you should hear a beep and notice a green check mark appear next to the landmark in the list. If not, repeat the voice command, or press the Apple remote again. If you hear an “error beep” (it sounds different, one that is universally recognized as a failure sound), the pointer and/or subject tracker

were not visible. Make sure they are both visible and try again.

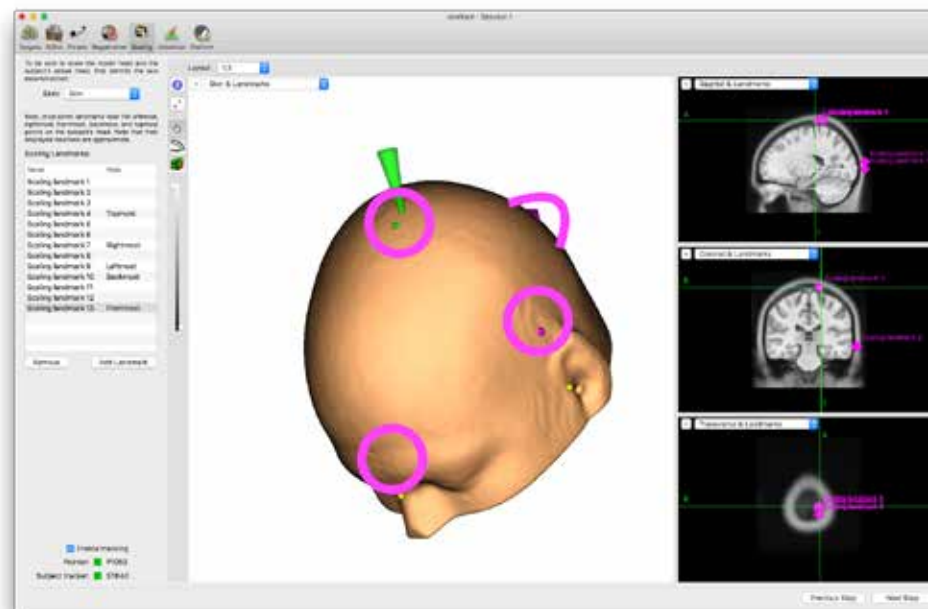
- Once you have sampled the point, it automatically goes to the next landmark and calls it out. Use the same technique to identify the landmark and have the computer sample the point.
- Repeat for all landmarks.
- You can repeat any point by either selecting it in the list (it will speak it out), or by speaking "previous" to the computer to change the current landmark to sample.
- Once all landmarks have been sampled, click on **Next Step**.
- Record landmarks on the top of the head by gently touching the top of the head with the pointer and clicking Add Landmark (Fig. 13-9B). Drop several landmarks so Brainsight can use the topmost of these for the scaling calculation (and you do not need to be very precise since there will be multiple landmarks to choose from).
- Repeat this for the left, right front and back of the head.
- Look at the list of landmarks and note that Brainsight has automatically selected and labelled the best landmarks as Frontmost, Backmost, Topmost, Leftmost and Rightmost. Click Next Step.

Fig. 13-9

A: Anatomical Landmark Identification



B: Scaling Landmark Recording



The final step is to verify that the registration was successful. Move the pointer on the head (Fig. 13-10), focusing on the same areas where the scaling landmarks were dropped in the previous step. Observe the numerical error displayed on the left of the screen (Crosshairs->Skin). It should be consistently at or below 3-4mm. Note that the error between these locations may be significantly higher. This is due to possible differences in curvature of the head shapes.

PERFORM THE TMS STIMULATION SESSION

The next screen (Fig. 13-11) is optimized for the final step, placing the coil over your target. You should see multiple 2D views, a 3D curvilinear brain and a bull's-eye view.

New controls in the perform window

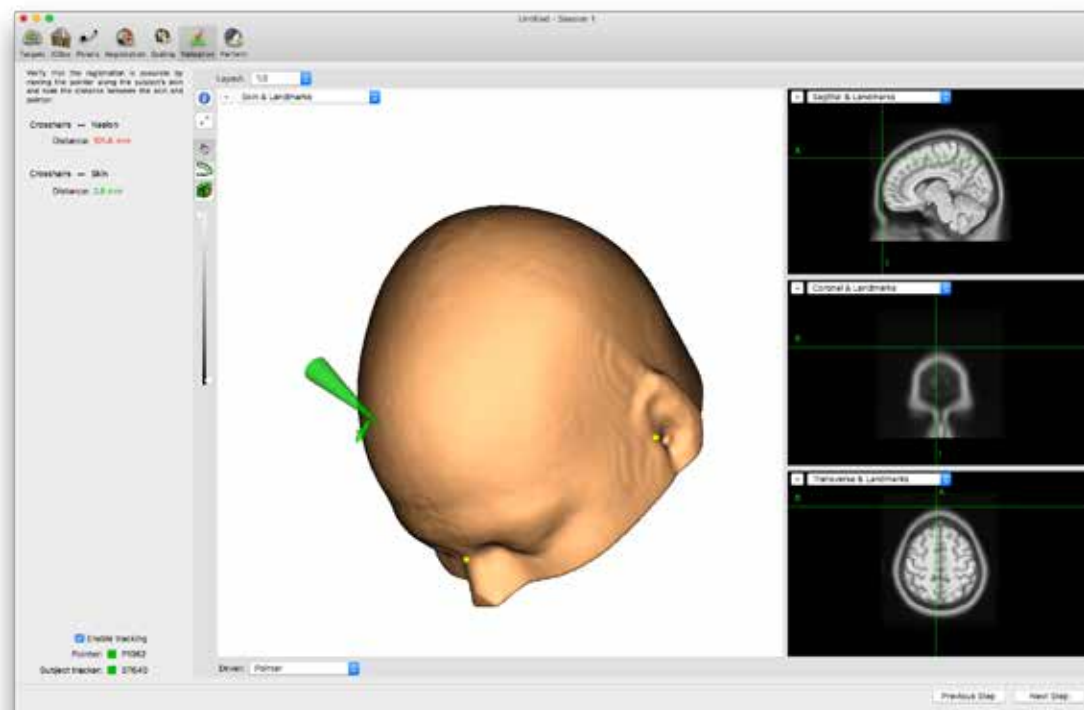
In addition to the controls introduced in previous chapters, the session perform window adds a few new ones.

The crosshairs **driver** popup menu allows you to select which tool is linked to (or driving) the crosshairs. You can select from mouse (so you can move the cursor by clicking in any view as usual) or you can select the pointer or any valid coil calibration. Once you select a coil, placing the coil within the field of view of the position sensor camera will make the cursor move.

If you have the EEG functionality enabled, you can toggle the display of the EEG electrodes using the **Electrodes**

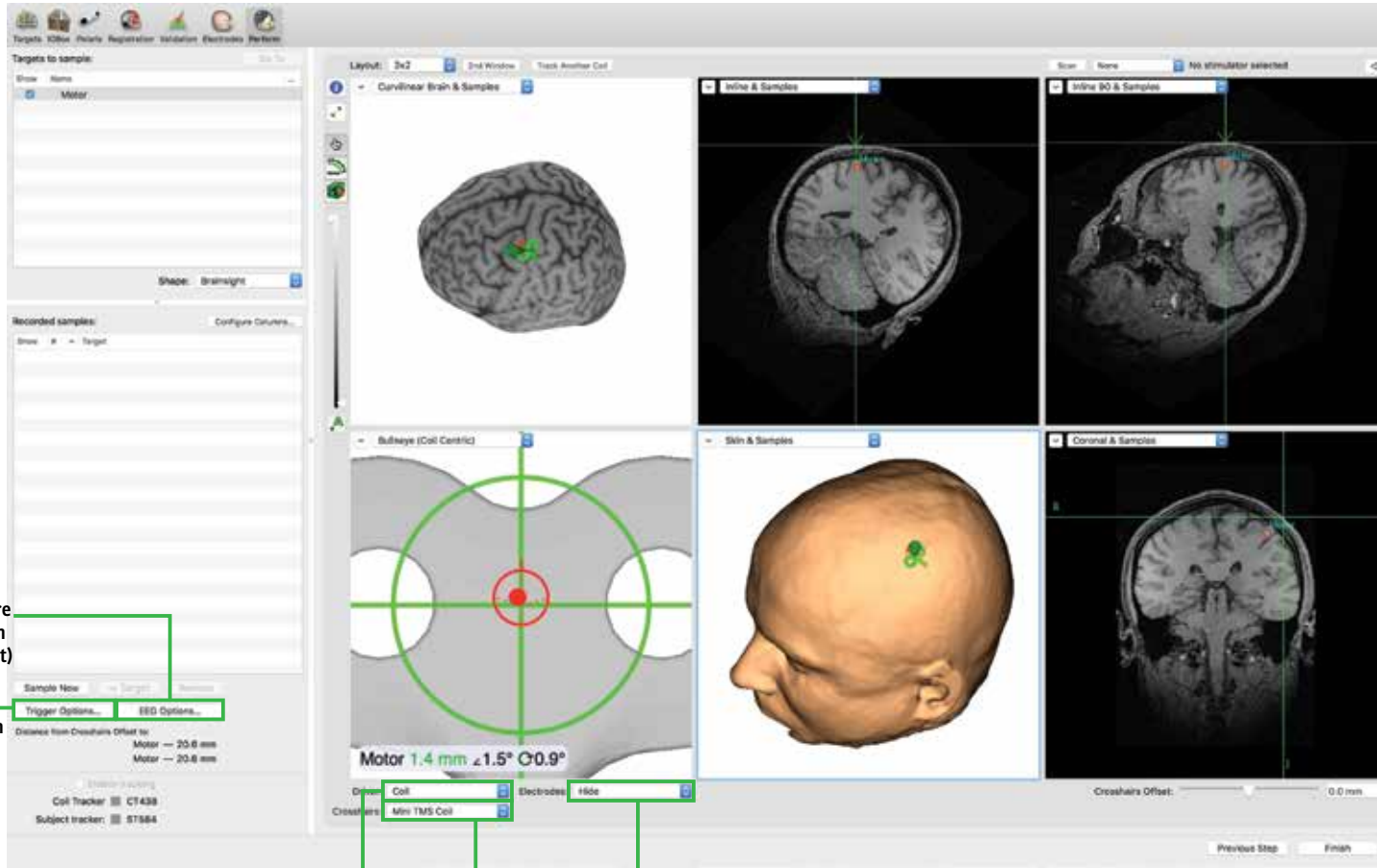
Fig. 13-10

Verification of the registration. Note that the agreement should be best at the poles (top, front, back, left, right) and that there may still be disagreement between these locations.



EEG Hardware Configuration (when present)

Trigger Configuration



Crosshairs Driver

Crosshairs Representation

EEG Electrode Display Toggle

Fig. 13-11

Typical Perform Session view window.

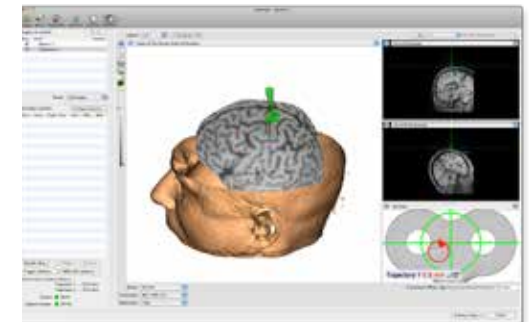


Fig. 13-12

Another example of a window layout effective for coil positioning.

popup menu.

As described in the targeting chapter, you can select the visual representation of the cursor for the 3D views using the **Crosshairs** popup menu.

Optimizing the view geometry

Brainsight configures the image view window according to the task currently being performed. In many cases, these are configured according to how we think it would be the most useful to you. The layout can be changed by selecting a new one from the Layout popup menu at the top of the window. Fig. 13-12 provides an example of a layout with one main view and 3 smaller complimentary views (1|3). Take some time to explore the options to find what you like best.

Note: The default representation of the crosshairs (and coil position when the coil is the active cursor crosshairs driver) in the 3D view is, as it has been in previous steps, a cone (or mini TMS coil). To augment this with a “realistic” graphical version of the coil: Click on the View Selector popup menu, and select “**Customize...**” to open the view configuration tool (Fig. 6-8 on page 34). Click on the “Accessories” button and select the coil representation you want to be displayed in the view. Close the window by clicking on the close button (the top left button of the window).

Setting user-trigger preferences

When placing the coil and throughout the session, it may be desirable to record the coil’s position and orientation

at certain times other than when the coil is fired (which is configured during the I/O box step. Note that if you are acquiring EMG, this can only occur when a TTL trigger is received as it is required to synchronize the EMG with the TMS pulse.

Each of these snippets of information recorded is referred to as a **sample**. Click **Trigger Options...** to open the options window (Fig. 13-13).

- During the TMS session, you may wish to record the coil location manually. You can always do so by pressing the **Sample** button, but you can also do so remotely using switch input (e.g. foot or hand-held switch) or voice recognition by enabling their respective check boxes.
- Close the window by clicking **OK**.

Visualizing and recording EMG

If you activated the EMG in the I/O box step, then you can visualize the EMG in any view pane, by selecting it from the view selector list of any view pane. Fig. 13-14 describes the EMG samples view.

In addition to the EMG recorded for each sample, you can also display the live EMG by selecting Live EMG in the view panes’s selector.

Now You Can Stimulate...

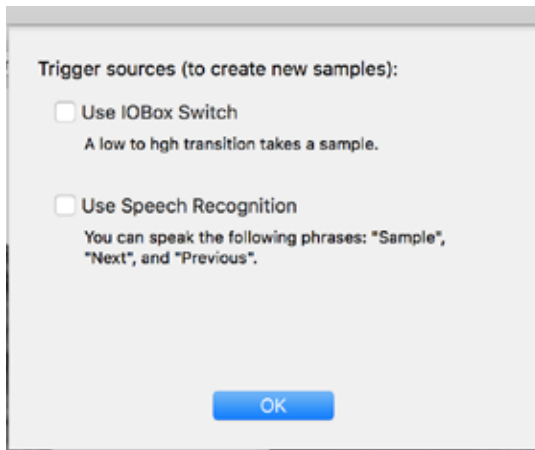
- Select the desired target by clicking on it in the list of targets, or if the voice commands have been activated, by saying the “next” or “previous”

commands to cycle to the target in the list.

- Select your coil as the input from the Crosshairs popup near the bottom left of the image views (recall Fig. 13-11).
- Move the coil on the head, observing the views on the screen. Many users have different preferences regarding how they use the views to place the coil. In general, the 3D views serve to help you get the coil close to the target. Once close, use the inline and inline-90 views to ensure that the coil’s orientation is normal to the brain surface and use the bull’s-eye to ensure that the coil is pointing to the target.
- If you are using the bull’s-eye view, you can also note the targeting error on the bottom-left of the view. This number represents the shortest distance from the target to the vector projecting from the coil’s reference spot along the coil’s trajectory (think of it as how far off a dart ends up from the center on a dart board). A value of 0 means that the coil is pointing directly at the target. Note that in practice, a value of 0 is not realistically achievable and you should decide what is an acceptable value (e.g. 1 to 1.5 mm). Note that the value will fluctuate continuously even if the coil and head are completely still, which is due to the normal fluctuation of the position sensor measurement of the tracker spheres.
- When using the bull’s-eye display for trajectories, the easiest way to use it is to break up the task into

Fig. 13-13

Trigger Options Window



two steps. First, move the coil over the scalp until the red circle is centered. The red circle can be thought of as the scalp entry point. Next, tilt the coil until the red dot is in the middle. The red dot represents the target w.r.t. the projection of the coil. If the red dot is in the middle of the green cross hair, it means that the coil is pointing towards the target (regardless of the trajectory). Note that this metaphor is less helpful for trajectories whose origin is in the scalp as the scalp entry point and target is the same place. In this case, the best use of the bull's-eye is in reverse. Move the coil so that the dot is centered (the coil is on the correct scalp location) and tilt the coil to get the

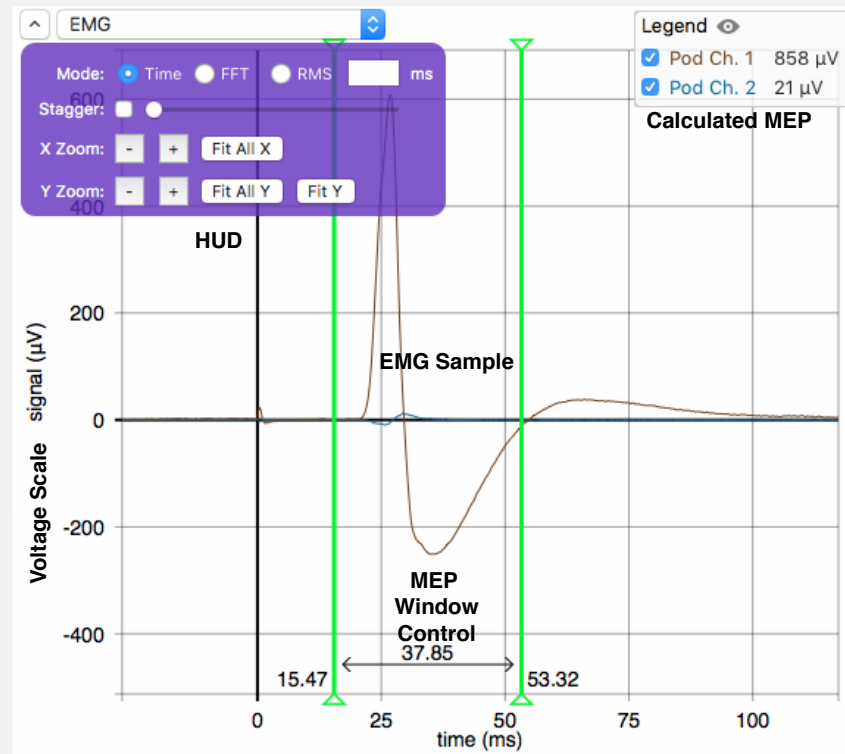


Fig. 13-14

Any view pane can be called upon to display the EMG acquired as part of a sample. Each EMG channel is drawn as a separate colour. The peak-to-peak of the EMG is calculated by examining the waveform between the two green vertical lines. Use the mouse to drag the lines left-right to set the correct window. Use the X & Y Zoom in/out buttons (available using the HUD) to change the scaling or use the mouse by option-scrolling in the horizontal direction to change the X zoom and vertically for the Y zoom. Click "Fit in X" or "Fit in Y" in the HUD to automatically fit the waveform in the view. As you change the zoom, the units automatically change to the appropriate units (e.g. mV to μ V). The graph can be panned in any direction using the same option-click-drag method used in the image views. If multiple samples are selected in the sample list, each sample will be drawn over each other, and the average of the selection will be drawn as a dotted-line.

Fig. 13-15

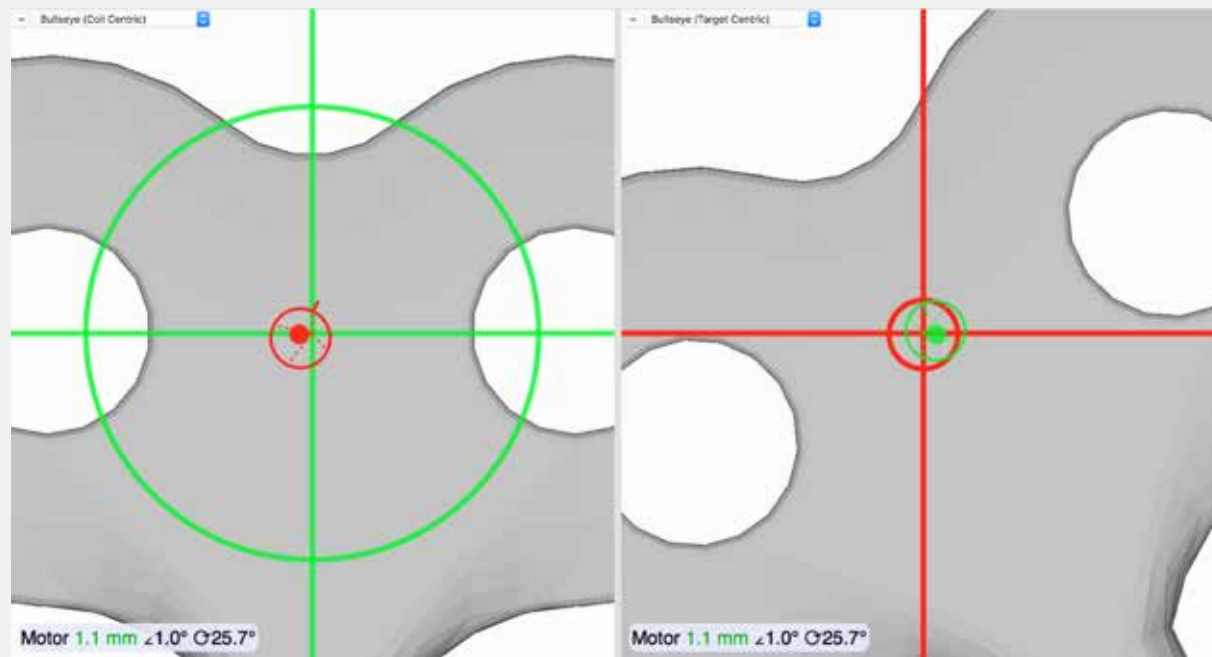
Bull's-eye display.

Interpreting the bull's-eye display

The bull's eye display has been improved in version 2.3. In previous versions of Brainsight, the bull's eye display has been implemented from the coil's perspective. That means that the coil remains at the centre of the image view and the target moves on the screen when the coil is moved. While many find this view intuitive, many did not. In version 2.3, we've added a new version of the bull's eye where the display is from the target's perspective. In this view, the coil moves and the task is to get the coil centred on the target.

In both modes, the numerical display at the bottom left indicates the targeting error and angular error, which is the distance from the target to the closest point along the line projecting from the coil's reference point into the head (along the coil's trajectory) and the angle of the coil w.r.t. the target trajectory angle. In general, a value of 1mm or less should be considered very good.

Note that when using scalp based targets, our metaphor of the target and scalp entry point breaks down. In this case, the circle will not move once the coil is on the correct scalp location (since the target is on the scalp) but the circle will move when the angle of the coil changes, so in the end, you still want the circle and dot in the middle, just align the dot first, then the circle.



circle in the middle (setting the angle).

- The real distance from the coil face to the current target and the closest targets are displayed on the bottom left of the window.
- If you wish to record locations within the cortex (instead of on the surface), add an offset to the coil location by sliding the offset slider (next to the crosshairs input) to the right. This offset is added to the coil location in the direction along the coil path, or in the case of the pointer, projected along the shaft into the head. Typically, 15 mm will place the cursor origin inside the cortex. The coil, as seen in the 3D view, will appear in the correct location, however the cursor will be projected into the head. This technique is particularly useful if you intend to use recorded coil orientations as targets for subsequent sessions as the bull's eye view works better when the target and scalp entry point are not the same point.
- Record the coil position and orientation by clicking Sample Now, or speaking the "sample" command. If your computer is connected to the TMS stimulator via the LabJack interface (or you have a recent Brainsight computer/trolley with the trigger input), the sample will be recorded automatically when the coil is fired.
- Once your TMS study has been completed, save the acquired data by selecting File->Save Project.

TRACKING A SECOND COIL SIMULTANEOUSLY

In more TMS studies, it is becoming more common to use two coils to perform simultaneous or near simultaneous stimulation on two sites. Brainsight allows you to track both coils at the same time, provided you have a second coil tracker (contact Rogue Research for more details). If you have the TTL trigger box (either the standalone unit, or the I/O box as part of our computer trolley), you can trigger the recording of each coil individually as well.

To track two coils, before starting a TMS session:

- If you have the required hardware for triggering from the TMS devices, connect the trigger out of TMS coil A into trigger in 1 on the Brainsight trigger box, and TMS coil B to trigger in 2.
- Attach a tracker to each coil.
- Follow the steps in Chapter 4 twice, once for each coil.
- Follow the instructions in this chapter to start a TMS session until you have performed the image-subject registration.
- Set the TTL trigger in to use trigger 1.
- Click **Track another Coil**. A second view window will open.
- Set the trigger options to use TTL trigger 2 of the I/O box. Note that you can only use the voice recognition and/or Apple remote for one window at one time.
- When you are ready to track the coils, set the

crosshair input of one window to the coil that is triggering the samples, and the input of the second window to the other coil.

- Place your coils and stimulate. Each time one coil is fired, the corresponding window will record the coil location.
- When the experiment is finished, close the two windows. Note that each window will be stored as a separate session.

OPENING A SECOND VIEW WINDOW (ONE COIL)

In certain cases, there may be more information that you wish to monitor than can be adequately displayed in one window. If your computer is equipped with a second monitor, you can open a second image view window and display additional information. For example, if you are performing complex EMG related experiments, it may be useful to open a second window and set the layout to 2x1 and display the live EMG in one image view and the event related EMG in the other.

Chapter 14: Special Application-Axilum Robot

One exciting new development in the field of TMS is the applications of modern robotics. Robotics can assist in the placement of the coil in many ways, including:

Consistent, accurate coil placement

Automatic compensation for head movement

Easy application of multiple targets (e.g. grid)

This chapter will cover the details of the Brainsight support for the Axilum robot. You are expected to be proficient with the other features of Brainsight and this chapter can be seen as an addition to the Perform Session chapter.

Additionally, review the "TMS-Robot User Guide" documentation provided by Axilum, and especially "Section 3 - General Safety Warnings and Precautions of Use" for important safety information.

INTRODUCTION

Neuronavigation applied to TMS has revolutionized the field of TMS by allowing more sophisticated definitions of the TMS target (e.g. based on anatomy or functional data), improving placement accuracy and recording of the coil position and orientation during the entire TMS session to ensure consistent placement.

Just like using a GPS, while the information may be useful, it is still only as good as the driver. Using a robot to hold and place the coil offers several additional advantages over navigation alone.

- Ensures correct application of the coil based on the navigator.
- Easier for the operator.
- Allows for compensation of head movement .
- Allows possibility of automation of common tasks.

Prerequisites

When performing a study using the Axilum TMS-Robot there are several additional prerequisites:

- Make sure that you have a Polaris camera with extended measurement volume and wide angle of view (e.g. Polaris Spectra), which are needed in this case to simultaneously track the robot tracker, subject tracker, and the custom coil tracker.
- Make sure that you have a coil that is supported by your version of the Axilum robot. To check which coils are supported refer to section 1.1 of the

"TMS-Robot User Guide".

SETTING UP BEFORE A STUDY

Many of the steps involved in using the robot are the same as for conventional TMS use. Refer to the relevant parts of this user manual to understand these tasks

Special notes in preparing a Brainsight project

When preparing a Brainsight project file, follow the steps in loading images, creating 3D surfaces and selecting registration landmarks as you normally would.

There are some considerations when selecting targets:

- All targets must be trajectories. The Axilum robot needs explicit instructions as to the desired position AND orientation of the coil.
- While the target can be set in the cortex as we would for manual TMS, the robot requires that Brainsight provide a scalp based target and orientation. At the time of the TMS session, there is a function in Brainsight to convert the cortical-based target (which is more intuitive and relevant for humans to define and understand) to the scalp based target more appropriate for the robot to accomplish. The scalp-based target will simply be the location on the scalp that lies along the vector (see Fig. 14-1).

Creating a grid of targets

Brainsight supports the creation of grids of various shapes and sizes. A current limitation in Brainsight is the inability to adjust the trajectory of grid based targets

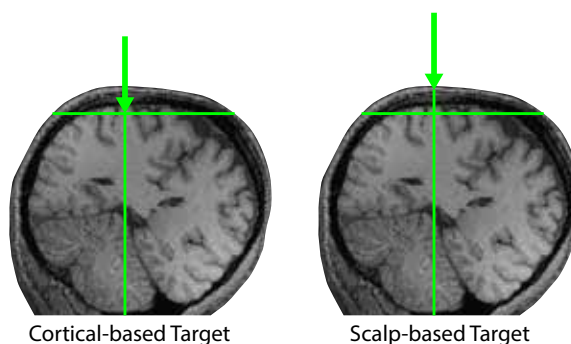


Fig. 14-1

Illustration of a cortical-based target and the equivalent scalp-based target.

individually. Brainsight currently allows for spherical approximations of the trajectory of individual grid nodes. This is not sufficient for use with the robot, so an additional procedure must be performed to convert the grid to a series of individual targets to allow Brainsight to optimize the trajectory of each one individually. The process takes a few minutes to perform and will be incorporated into a future version of Brainsight. To create a grid appropriate for use with the robot:

- Create a grid in the targeting step as you would for manual TMS (see "Creating a grid of targets" on page 66). Set the **Grid Kind** to marker (the trajectories will be generated later).
- Create a folder for the optimized trajectories (new

grid) by clicking **New...** and select **Folder**.

- Give the folder a name as you would for the grid (do not use the same name as the grid though).
- Display the list of grid nodes in the targets list by clicking on the disclosure triangle next to the grid's name.
- Make sure that you select **Skin** as the "Orient Exit Using..." (highlighted in green in Fig. 14-2).
- Set one of the image views in the image window to display the brain and grid. Orient the view to look at the grid from above. Set other image views to display the **inline** and **inline-90** views.
- Set the crosshairs display mode to Sphere (to make it easier to see the cursor location).
- Double-click on the first grid node to make the cursor jump to the first node's location on the images.
- With the cursor tool selected, carefully click on the selected grid node by clicking in the middle of the green sphere. The result should be that the location of the cursor should not change (a little movement is acceptable and unavoidable), but the click action will result in Brainsight calculating the optimal orientation based on the skin shape. If needed, use the AP, Lat and twist sliders to adjust the orientation while observing the inline and inline-90 views.
- Once the orientation is acceptable, click New->Trajectory to create a new trajectory based target. Set

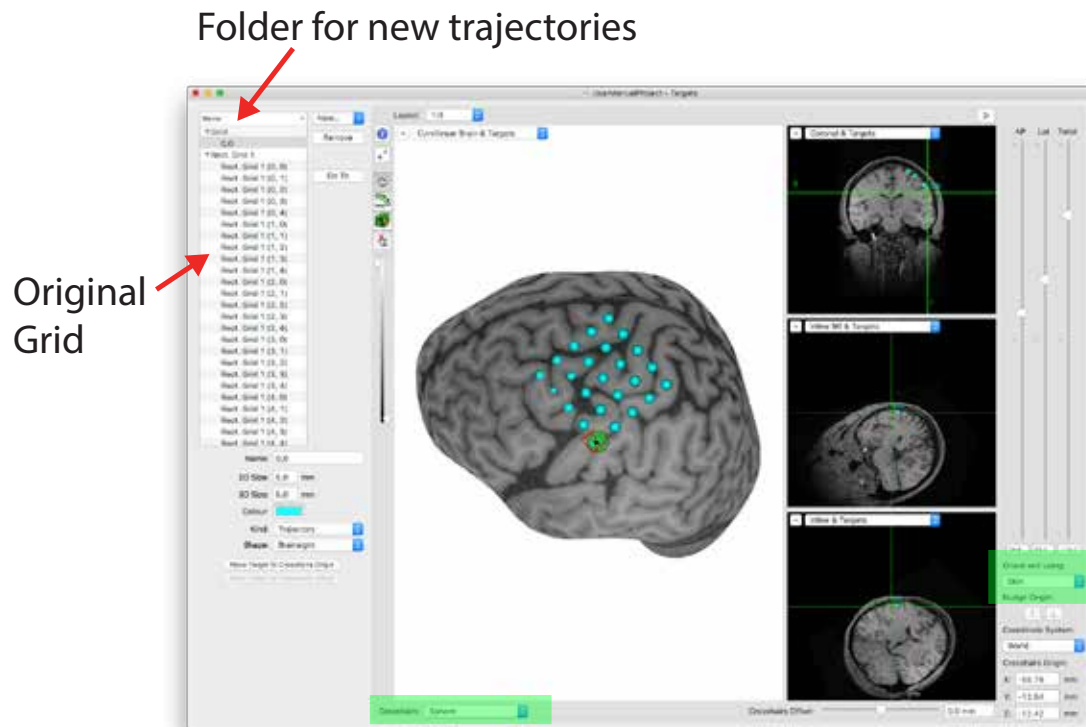


Fig. 14-2

Creating a grid with optimized trajectories

the name of the target to the index number of the original grid node. For example, if the original target was called G(0, 0), then a good name for the target would be "0, 0". Note that if you intend to make more than one grid, then to preserve the uniqueness of each target name by using naming convention

that starts with something unique (e.g. M 0, 0). The intent is to select a name similar to the ones used in the grid while remaining unique.

- Drag the new trajectory in the target list into the folder created earlier.

- Repeat the process of double-clicking on the next grid node, clicking on the node to set the orientation and creating a new trajectory for all grid nodes.
- Once all the new nodes are created, you can delete the original grid that was used as the template.

Preparing the hardware for a study

Similarly to a manual study, you will need the subject tracker, and the pointer.

Before proceeding with a TMS study:

- Prepare the pointer and subject tracker as you would for a manual TMS study.
- Mount the coil on the custom Axilum coil adapter with the coil cover (with tracking spheres) as shown in Section 9 of the "TMS-Robot User Guide".
- Calibrate the coil as described in "Chapter 4: Calibrating Your Coil". Recall that the coil tracker (and perhaps the calibration tool) are provided by Axilum. The main challenge in this step is to find a position to hold the coil so that the multi-faced tracker on the coil and calibration tool are visible to the position sensor at the same time. In some coil models, the size of the tracker on the coil may make this step challenging.

PERFORMING A STUDY

Many of the steps to perform a TMS study are identical to those for a manual TMS study. Before attempting a study using the robot, make sure that you are familiar with

performing manual studies in Brainsight so that you have a good understanding of all the steps (see “Performing the Study” on page 71).

Typical Additional Initial Steps for a Robot-based TMS Session

- Have the subject sit in the Robot chair
- Verify and if needed, adjust the location of the subject tracker to ensure it will be visible by the position sensor and not be near the intended location of the coil.
- In addition to the usual TMS hardware preparation steps described in Chapter 13, when using the Axilum TMS-Robot, one has to attach the coil cable to the cable holder as described in Section 9 of the “TMS-Robot User Guide”.

Begin the the Session

- Launch Brainsight and open a new online session or resume a previously created online session as described in Chapter 13.
- If Brainsight has been correctly installed and the correct serial number introduced, the session window should feature an Axilum tab (Fig. 14-1). Selecting that tab will display the Axilum control window (Fig. 14-4).

Verify Polaris Camera Position

When positioning the Polaris camera for a robot-assisted session we must make sure to satisfy the following conditions:

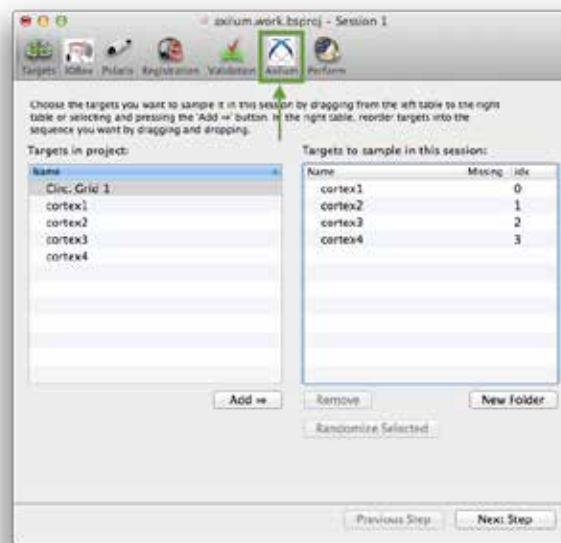


Fig. 14-3

Session Perform Screen with Axilum Step

- the camera field of view spans high enough to detect the Axilum Tracker which is located on the upper front side of the robot
- the camera field of view spans low enough to include the general area where the subject tracker will be positioned. Note that the robot seat can be moved up and down to accommodate for the subject’s height. An example of a good camera positioning is given in Fig. 14-4.

Prepare the robot (part I – before registration)

Prior to performing the subject registration/verification, certain robot-specific tasks should be performed to ensure that Brainsight is connected to, and controlling the robot.

- If the robot is not already powered on, follow the instructions in Section 10.4 of the “TMS-Robot User Guide” to boot the robot. Once the robot is on, Brainsight will detect it and its name will appear at the top of the Axilum screen, next to the Start and Stop buttons. If the robot is on but Brainsight fails to detect the robot, check that the robot is connected to the Brainsight system, or re-launch Brainsight.
- Once Brainsight has detected the robot, press **Start** to connect to the robot.
- If the **Arm status** and **Seat status** on the Axilum screen are “Not calibrated”, it means that the robot needs to be calibrated, i.e. initialized. There are two alternative ways to initialize the robot:

IMPORTANT: For either of the following methods, you might need to remove the back seat before starting the initialization process. Refer to the “TMS-Robot User Guide” for details.

- Initialize the robot by using its physical control panel, as described in Section 10.5 of the “TMS-Robot User Guide”.
- or
- Initialize the robot from Brainsight, by pressing the

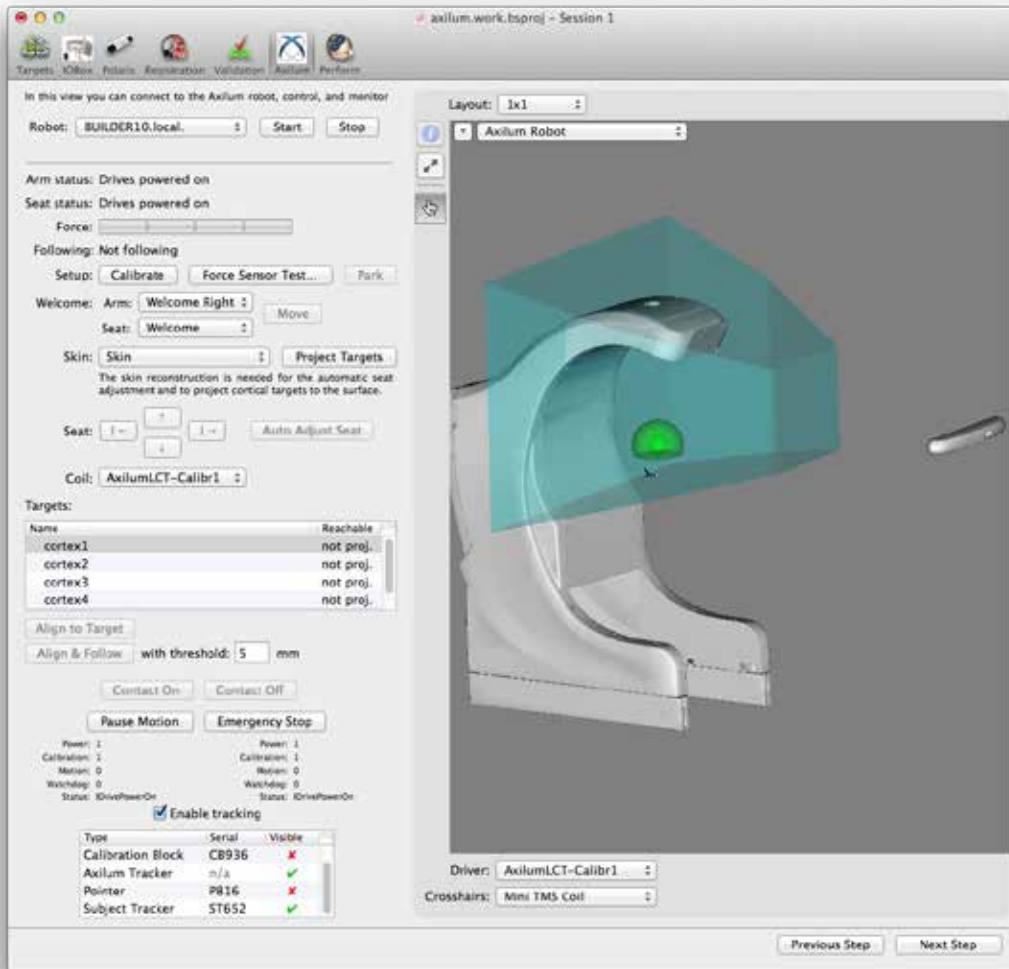


Fig. 14-4
Axilum Robot Controls (Axilum Step)

Calibrate button, and waiting for the robot arm and robot seat movements to complete.

Once initialized, the robot status flags displayed in the lower part of the Axilum screen should indicate that both the arm and the seat are powered and calibrated (see Fig. XX-3).

| | |
|---------------------|---------------------|
| Power: 1 | Power: 1 |
| Calibration: 1 | Calibration: 1 |
| Motion: 0 | Motion: 0 |
| Watchdog: 0 | Watchdog: 0 |
| Status: IHomingDone | Status: IHomingDone |

Fig. 14-5

Robot status flags after calibration (initialization)

The force sensor on the robot arm is a safety measure to protect the subject. It allows the robot arm to detect when it applies excessive pressure and to halt the movement.

- Perform the force sensor check by clicking **Force Sensor Test** in the Axilum view. This will bring up a window that will guide you through the check procedure. In order to pass the check, you must successively press with your finger on the focal point of the mounted coil, until you achieve all the required force levels in the described order (see Fig. XX-4). Once all the force levels are tested, the Finish button will activate, which indicates that the procedure has been successfully passed.

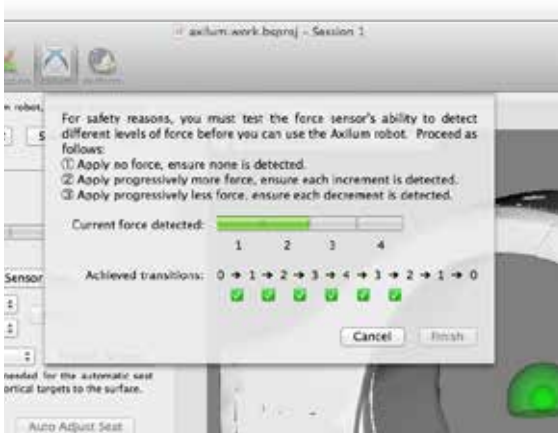


Fig. 14-6

Force sensor check procedure screen



IMPORTANT NOTE: Check the force sensor every time you replace or unmount the coil.

- In order to make it easy for a subject to sit in the robot seat, the robot arm and seat are moved to one of the "welcome positions". To do so, select a welcome position for the arm (either left or right) and for the seat using the appropriate popup buttons in the Axilum control window (recall Fig. 14-5), and press **Move**. You should observe the arm and chair move to the welcome position. Depending on which welcome position has been selected (left or right), the subject will be able to access the seat from the

respective side of the robot.

- Have the subject sit on the seat and adjust the headrest as directed in the Axilum documentation taking care not to place the headrest where it may interfere with the robot's motion (e.g. obscuring a TMS target).
- Make sure subject tracker is visible to the camera by observing in the 3D view on the Axilum screen where the Polaris field of view is displayed along with the visible trackers and a representation of the robot's range of motion (the green half-sphere). You can adjust the seat height to aid in ensuring that the trackers are visible by clicking on the appropriate seat movement buttons in the Axilum screen.
- Perform subject registration as done for a manual TMS session (see "Verify Proper Polaris Location" on page 76).

Steps After Subject Registration

Before proceeding, confirm sure that:

- The force sensor check has been performed.
- The robot is in one of the welcome positions.
- The subject is in the seat.
- The subject registration has been done.
- At least one target has been added to this session.
- At least one skin reconstruction has been created from the anatomical data (refer to Chapter 10).

Referring back to the Axilum control screen:

- If you created more than one skin reconstruction, select the one you wish to use for the robot-assisted TMS session. The skin reconstruction is needed for: (1) the seat auto adjustment functionality, and (2) the projection of the cortex targets to the scalp surface (see following steps for details).
- Click **Auto Adjust Seat**, which will automatically adjust the vertical position of the seat so that the subject head is falls in the robot working area, which is represented by the green hemisphere (recall Fig. 14-2)
- As discussed earlier in this chapter, any target needs to be projected onto the scalp to define the location for the robot to place the coil on the scalp. Instruct Brainsight to do this now by clicking **Project Targets**. Once this has been performed, examine the targets listed in the targets list to ensure that the robot can reach each one. This is indicated by a green check-box in the **Reachable** column in the target list (Fig. 14-1). For more details about the factors that

| Targets: | |
|----------|-----------|
| Name | Reachable |
| cortex1 | ✓ |
| cortex2 | ✓ |
| cortex3 | ✗ |
| cortex4 | ✓ |

Fig. 14-7

Example of a list of targets. Notice the cortex3 target is not reachable.

make a target reachable or not, see section “Robot workspace and target reachability” later in this chapter.

- Select the coil installed on the robot in the **Coil** popup button in the Axilium control screen. As in the case of a manual TMS session, selecting the wrong coil calibration can result in incorrect targeting.
- For visualization purposes, select the same coil from the **Driver** popup button.

Perform the stimulation

Before proceeding with this section, make sure that:

- The targets you are interested in are reachable by the robot, if not, review section “Robot workspace and target reachability” before continuing.
- You successfully performed the force sensor check
- The subject registration did not change (e.g. did not move head strap or tracker glasses)
- The subject is seated comfortably and ready
- Select the Perform step by clicking **Next Step** or by clicking the **Perform** icon at the top of the window.
- The perform step uses a default layout that we expect to be useful for the manual perform task. If desired, optimize the screen layout for a robot-assisted TMS session by:
 - Set layout to 1|3
 - Set the large image view to **Curvilinear Brain and Samples** (create curvilinear reconstruction if not

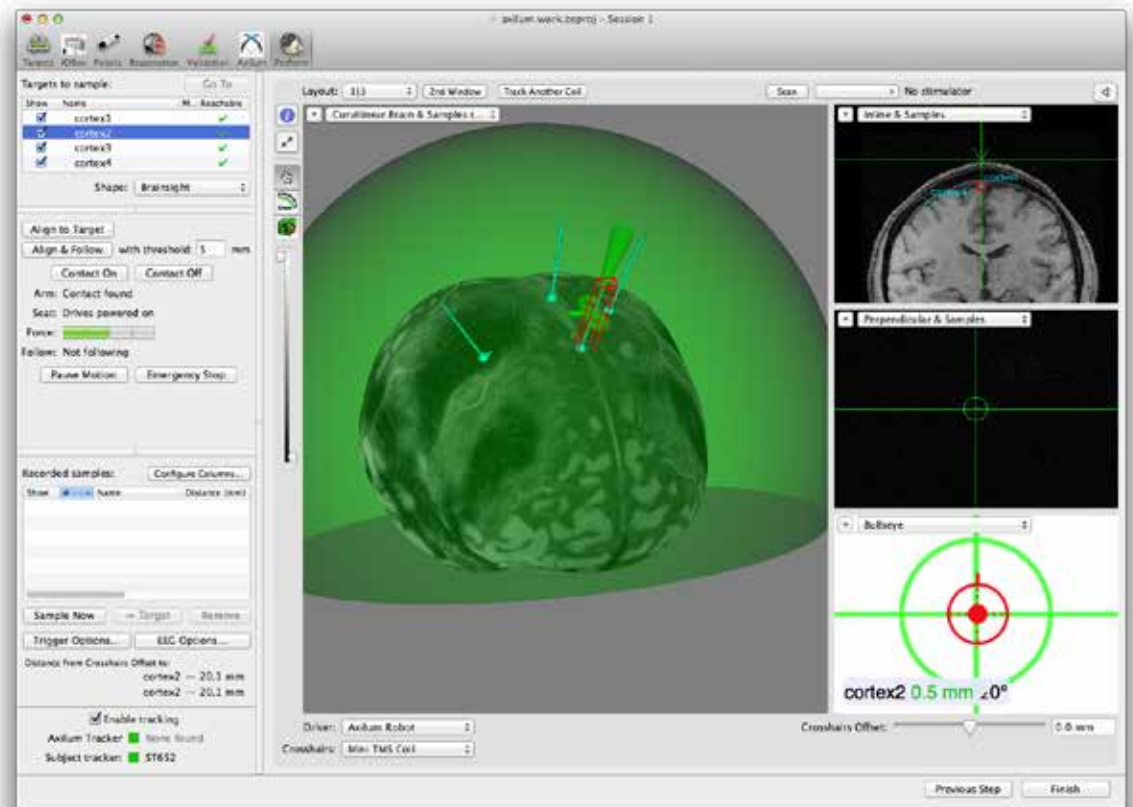


Fig. 14-8

Typical Perform screen for a robot-assisted TMS session

created yet)

- Set the smaller views to: Inline & Samples (or inline-90 and Samples), Perpendicular & Samples, and Bullseye.
- Customize the Curvilinear Brain and Samples view by clicking the list again and selecting the **Customise...** at the bottom of the list. The customize view selector window will appear ().
- Select “Curvilinear Brain” from the reconstructions list and optionally the Skin (best if the Skin’s opacity was set to something around 50% to see the Curvilinear Brain inside) then select “Axilum Working Space” from the Accessories list.
- Close the window (click on the red button)
- Select a reachable target in the “Targets to sample” list by clicking on it.
- Click **Align To Target**, which will perform the first stage of the robot movement, i.e. will align the robot arm with the target’s orientation and hover the coil roughly over the target. Wait for movement to complete.
- Once the alignment has been completed, click **Contact On**, which will perform the second stage of the robot movement, i.e. will move the coil towards the head and make contact with the head. Wait for movement to complete. Now the coil should be in contact with the head and targeting the selected target.

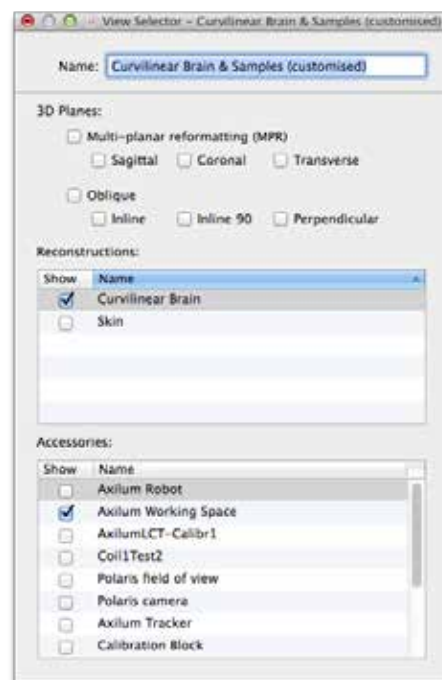


Fig. 14-9
Customize View Selector Screen

- You can verify the targeting error in the Bullseye view.
- If the subject moves their head after the robot motion completes, you can click **Align to Target** again (while keeping the same target selected) for the robot to re-align the arm to the target.
- If alignment is good, you can apply TMS stimulation as planned.
- If alignment error is unsatisfactory, check coil calibration, check that nothing obstructs the movement of the coil, and check the target position and orientation.
- Once TMS stimulation has been applied, the next target can be selected (if more than one target exists). There are two methods:
 - If the next target is close to the current target, i.e. within approximately 30mm, you can select the next target and click **Align to Target**. The robot arm will slide the coil along the head of the subject from the current target to the next one.
 - If the next target is not close to the current target, click **Contact Off** to move the coil back to its “orbiting” position, select the next target in the list, and click **Align to Target**. After the movement has completed, click **Contact On** to put coil in contact with head for the new target.
- Note that it is also possible to use the **Align & Follow** button, which moves the coil to a given target and

attempts to follow any subject head movement. This is accomplished by detecting if the head moves by more than the specified threshold, then re-positioning the coil to compensate for the movement.

ROBOT WORKSPACE AND TARGET REACHABILITY

The robot working space is the part of the 3D space that is reachable by the robot. We define a target to be reachable by the robot, and is displayed as such in Brainsight, when it falls within the working space. Targets that fall outside the space are not reachable.

In addition to the position, some targets can be unreachable due to their orientation being unreproducible (e.g. a target where the coil would need to be oriented upside-down, or would need to go into the head).

In Brainsight 3D views, the workspace is represented as a green hollow semi-sphere (see Fig. XX-Y). Depending on how the subject moves, the head might fall inside the working space, partially inside, or completely outside. In order to make as many targets reachable at any given time, it is recommended to position the head of the subject relative to the working space as shown in Fig. 14-10.

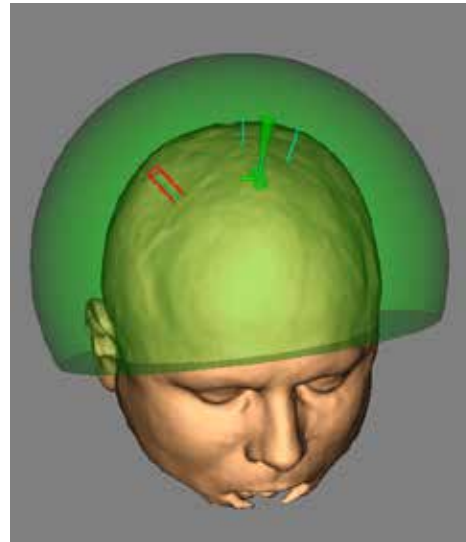


Fig. 14-10

Example of a head position that is well inside the robot's working space.

Chapter 15: Special Application–Motor Mapping

One common application of TMS is studying motor evoked potentials (MEPs). These are the signals sent to a muscle or muscle group from the brain resulting from a TMS pulse. One method of studying MEPs is to use EMG to record the MEP generated at the muscle while placing the coil over multiple regions of the brain. The resulting MEPs can be mapped back to the original stimulations locations on the cortex to generate a cartographic map on the brain.

This chapter describes how to use Brainsight to generate such a map. It would be a good idea to read this chapter prior to performing the TMS session to ensure that your protocol will provide the right data needed to generate the MEP maps.

INTRODUCTION

Brainsight allows you to generate two types of visual representation of MEP responses on the cortex. The first is a new method of color-coding the traditional 3D markers that are generated when the coil location is recorded, and the second is a method to generate an overlay that can be visualized on the brain much like a functional overlay.

The MEP data required to generate these maps can be provided in real-time using the built-in EMG acquisition pod now available from us (and come standard with new Brainsight systems that include the computer/trolley) or by entering the MEP peak-to-peak response manually derived from another EMG device.

There are many protocols to perform this procedure that are independent of the equipment used. For this reason, we only **suggest** a typical method in this chapter. It is important for you to understand what you are measuring and how you want to measure it. As consensus builds on how these become more standardized, we will continue to evolve this tool to simplify the process for standardized methods. In that spirit, we welcome your input in this area as we move forward.

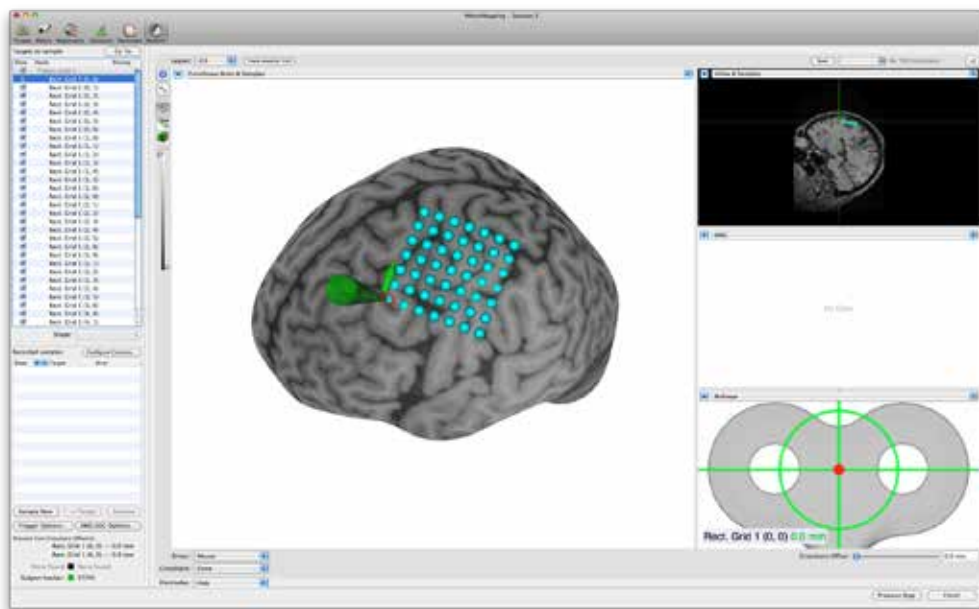
TARGET CONSIDERATIONS

If you plan on performing a motor mapping exercise, consider using a grid over your target area (see Fig. 15-1 for an example). This will ensure that you will acquire enough data without gaps that may effect the shape of

the map. It is also important to ensure that the map be bounded by values low enough to be below the threshold of significance. This will ensure that the intensities of the map will decay at the edges, increasing the confidence that the location of maximum value occurs within the

Fig. 15-1

Typical mapping setup with a grid surrounding the area to be mapped.



map.

INPUT EMG DATA

The peak-to-peak responses are used as the input to the mapping process. The peak-to-peak can be derived automatically from the EMG waveform acquired by the EMG pod, or entered manually. Manual entries are used when the EMG data is acquired by an external device OR to override a value derived from the EMG sample

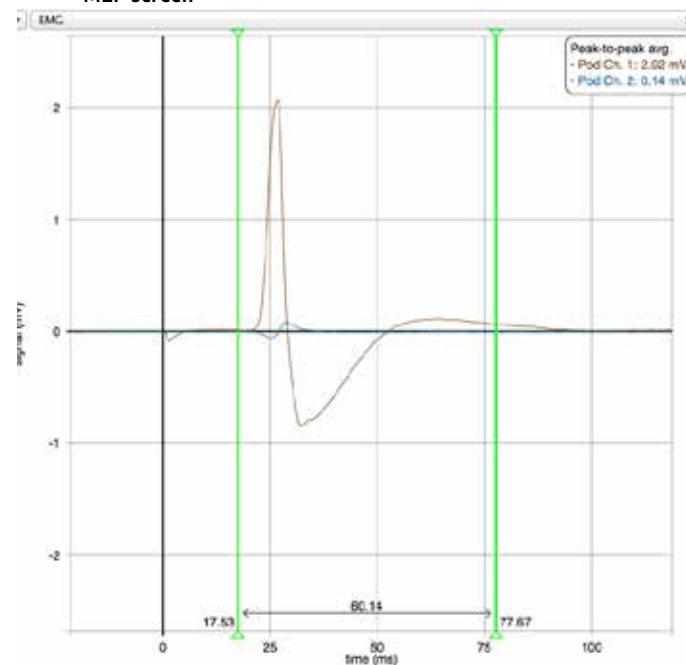
(you might do this for example, to set an obviously noisy sample to 0).

Built-in EMG Pod

If you are using the built-in EMG pod, set it up as described in "Preparing the EMG device for use" on page 133. You can view the EMG data in the waveform window (Fig. 15-2). After acquiring a few visible MEPs, set the MEP window (by moving the vertical green bars) to crop the waveform. The important point is to ensure

Fig. 15-2

MEP screen



that only the “real” EMG response is used to calculate the peak-to-peak response, not the artifact from the TMS pulse or other noise.

Ensure that you are using a TMS output setting high enough to generate supra-threshold responses (so you see the waveform) but not so high that you saturate the amplifiers (about 5 mv peak-to-peak). This may take some experimenting, or use a % of the motor threshold

Once set up, the peak-to-peak values will be used automatically for the mapping. Note that any time you change the MEP window settings, all the peak-to-peak values will be re-calculated.

Entering the values manually

- Make sure that the coil location is being acquired automatically when the coil is fired (or make sure you record the location manually).
- In the sample entries box (either in the perform window or the review window), click Configure Columns..., and enable Peak-to-Peak.
- After each sample is acquired (or at any time during the study), enter the peak-to-peak value derived from the external source into the field within the samples list box.

VISUALIZING MAP DATA

You can visualize the MEP map in two ways. First, the MEP values can be used to colourize the 3D representations (markers of trajectories) according to the MEP value

associated with that sample. Second, the samples can be projected into a 3D overlay data set and displayed on the curvilinear brain. The marker colourizing has the advantage of being real-time in that the colours are set as soon as the MEP value is entered (either automatically by the EMG pod or manually by typing the values in). The

overlay map has the advantage of being easier to interpret. Both methods can be used at any time or together, so one does not have to be chosen over the other.

Marker coloring

- In the Perform (or review) window, click the inspec-

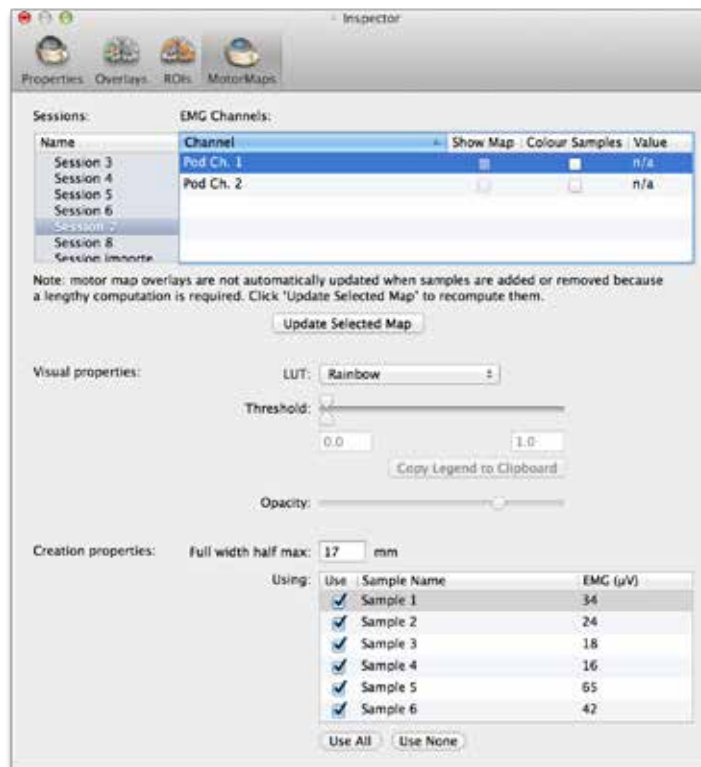


Fig. 15-3
MEP mapping configuration screen

tor button (the blue circle with the "i"). Click on **Motor Maps**.

- Select the session that contains the data to map by clicking on it in the sessions list on the left.
- Select the EMG Channel you wish to colourize.
- Enable the **Colour Samples** associated with that EMG channel.
- Select the desired lookup table, and set the upper and lower thresholds to obtain a map that displayed the desired data. Typically, the lower threshold is set to a voltage that is below what you consider to be significant (e.g. 50 μ V).

Creating the map as an overlay

The overlay map is designed to try to generate a smooth cartographic map that can be easier to interpret than the colored markers (see Fig. 15-4 for an example). Having a good understanding of the method we have implemented

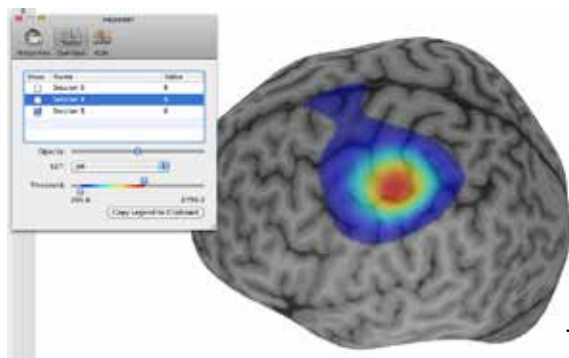


Fig. 15-4

Typical motor mapping result displayed on the curvilinear

is important in interpreting the display effectively. Refer to the next section for details on the algorithm.

Generating an MEP map overlay:

- Once you have collected your data, click on the inspector button, and select **motor map**.
- Set the FWHM value (see for recommended values for this parameter).
- Click **Update Maps**. After a moment, the map will be calculated.
- Enable the **Show Maps** check box to display the map.
- Select the desired lookup table, and set the upper and lower thresholds to obtain a map that has a smooth edge. Typically, the lower threshold is set to a voltage that is below what you consider to be significant.
- If you change the FWHM value, remember to click **Update Maps** to update the map. Changing the LUT selection or the upper and lower thresholds do not

require the map to be recalculated and the changes are updated in real time.

Detailed Description of the Mapping Algorithm

When each MEP value is acquired, it is associated with the position and orientation of the coil recorded in the sample. If you think of each sample as being a cylinder that runs along that trajectory, you can project that MEP value into the volume defined by the anatomical images. Any voxel that lies inside the cylinder is assigned the MEP value and a weighting factor. The weighting is 1.0 along the trajectory, and drops off the further away from the centreline using a Gaussian function. You can set the width of that cylinder by changing the full width at half maximum (FWHM) of the Gaussian. Fig. 15-5 illustrates the method.

Since many voxels will have multiple samples that intersect it, the MEP values at each voxel can be calculated by taking the weighted sum of all the samples that intersect the voxel. This method ensures that any voxel that is surrounded by MEP measurements will be assigned a weighed average of the neighboring MEP samples. Any voxel that lies along the periphery of the region of samples (since it is impractical and unnecessary to sample the entire head) will be assigned the value of the only sample that intersects it. This means that the MEP region will not smoothly drop to 0 as we exit the sampled region. It is important to ensure that the region sampled be larger than the region of interest so that the sampled values along the periphery of the region are below the

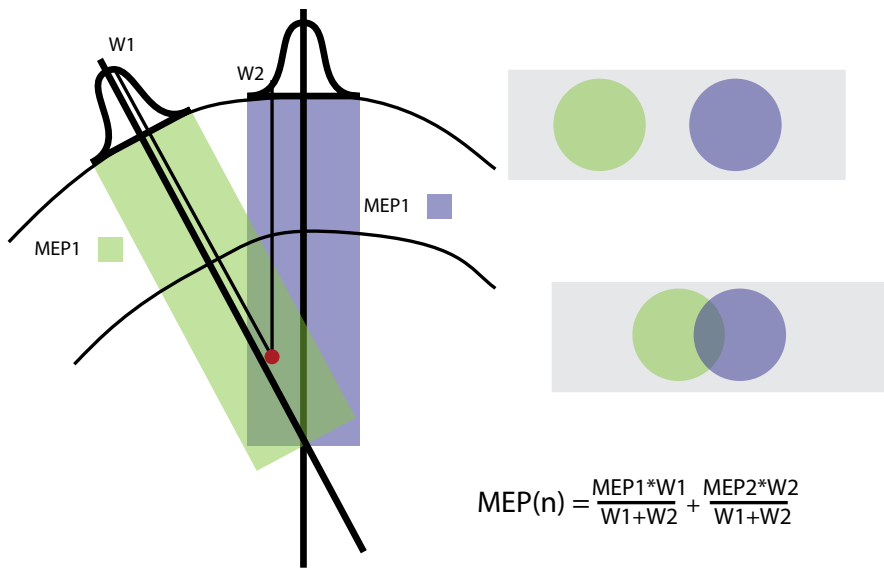


Fig. 15-5

Illustration of the algorithm used to interpolate the MEP values to generate a smooth map.

lower threshold.

Caveats in using the MEP display

The motor map display can be very a very useful tool in visualizing the MEP distribution, however there are several things to consider when using it.

Depth: The data display can be thought of as a 2D cartographic representation of the MEP data, and projected onto the curvilinear surfaces. The data is inherently NOT 3D data in that there is no real depth information, and the projection we perform is strictly a trick to paint the curvilinear surfaces. Viewing the 2D planes is not going to be helpful and **DO NOT INFER DEPTH INFORMATION FROM THE MAPS**. This would be reading more into the data than is there.

FWHM: The width of the cylindrical projections into the volume will have an effect on the appearance of the map display. If the FWHM is set too small when compared to the spacing between your samples, then the cylinders may not intersect each other, leaving gaps in the interpolation (, top image). As you increase the FWHM, the spread of each sample will widen and eventually overlap. This ensures that the interpolation will be continuous. This also has the effect of blurring the data as well. If you set the FWHM too high, you may blur out the peak. A good rule of thumb is to use a FWHM that is at or above the spacing between your samples. For example, if you created a sampling grid with 10mm spacing, then set the

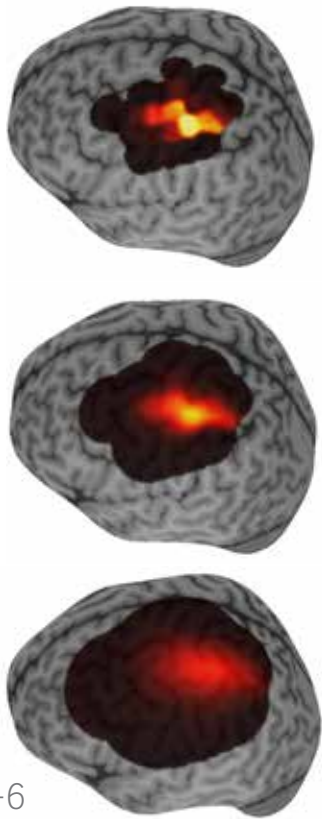


Fig. 15-6

Examples of different FWHM on the same motor map. The upper one used a 5mm FWHM resulting in gaps and a poor interpolation. Middle: 10mm FWHM, with improved appearance but still with a step interpolation. Bottom: FWHM of 20mm showing a better appearance. Note the higher FWHM has the side effect of lowering the peak value because it was blurred by the surrounding lower values.

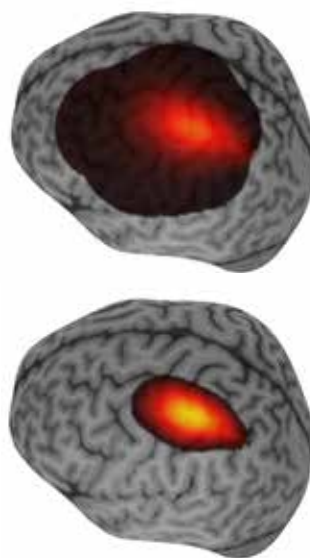


Fig. 15-7

Example of thresholded and non-thresholded MEP values. The appearance changes however the underlying values remain the same.

FWHM to at least 20mm.

Threshold: The threshold is used to mask out values that are below the threshold of significance. Typically this is a value that is above the observed noise value of the acquired data, or a task specific threshold. For example, many motor threshold exercises consider $50\mu\text{V}$ the threshold for resting motor threshold. Reducing the upper threshold often makes it easier to see where a peak

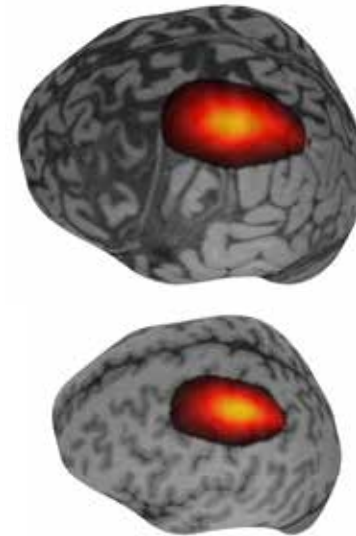


Fig. 15-8

Example of the motor map display at different curvilinear display depths.

may have occurred.

Curvilinear peel depth: The curvilinear peel depth is usually selected to allow you to see the gyral anatomy you are interested in. Note that since the trajectories of the coil placement are generally not parallel, the interpolated map will change slightly as you peel deeper. If you are comparing motor maps for the same subject across different mapping sessions, it is advisable to compare them using a constant depth.

Chapter 16: Special Application-EEG Recording

One of the most important trends in neuronavigation is integration with complimentary devices. One device where integration offers advantages is EEG. Adding EEG to neuronavigation, particularly in the context of EEG during TMS, offers new advantages including 3D localization of the electrode locations, real-time importing of the data synchronized to the TMS pulse and 3D visualization of the results along with the TMS coil locations. This chapter explains how to do this with the NEURO PRAX EEG system.

INTRODUCTION

Brainsight can communicate with the NEURO PRAX EEG system over an Ethernet network. Both neuroConn (the makers of the NEURO PRAX) and Rogue Research have implemented a new protocol for communications between the two applications. We hope that this protocol will evolve to include various “like minded” devices and have the following features: 1: Auto-discovery on a local network. 2: Real time sharing of configuration information, status and experimental data as it is acquired. The heart of this protocol has been around for years. The basic implementation of our protocol uses the same tools that allow your computer to automatically discover your new printer, or for your iTunes® library to be shared over a network.

While the Brainsight-NEURO PRAX integration is the first example of this new protocol, it will be at the heart of all new products from Rogue Research moving forward.

PERFORMING SIMULTANEOUS EEG/TMS RECORDING

Performing good EEG recording during TMS is still a bit of a challenge to do very well. With the NEURO PRAX hardware, it is relatively easy to acquire EEG data during TMS and to limit the artifact to under 20 msec. With a bit of care, that can be dropped down to about 5 msec. While the steps required for this are a bit beyond the scope of this manual, some of the key trick are:

- Be meticulous in your electrode preparations. Clean and scrape the scalp well.

- Minimize loops in the EEG wires

The main steps to perform integrated EEG recordings within Brainsight are:

- Connect both devices to the same local area network (LAN).
- Connect the TTL trigger out to both the Brainsight computer and the NEURO PRAX computer. You will need a TTL splitter (T connector) to share the trigger out.
- Use Brainsight normally until you reach the perform session step.
- Use the NEURO PRAX normally to set up the subject, until you reach the measurement step.
- Configure Brainsight to enable EEG recording.
- Acquire the list of electrodes from the montage in NEURO PRAX into Brainsight.
- Use the pointer to record the electrodes within Brainsight.
- Move the coil placement step in Brainsight and set up your visualization preferences.
- Begin recording in the NEURO PRAX software.
- Perform your experiment and monitor as the data are recorded.

Connect the Brainsight and NEURO PRAX computer to the same LAN

Both computers need to be on the same LAN and have been assigned valid IP addresses (presumably from the

Fig. 16-1

Typical LAN configurations to connect the Brainsight computer to the NEURO PRAX computer.

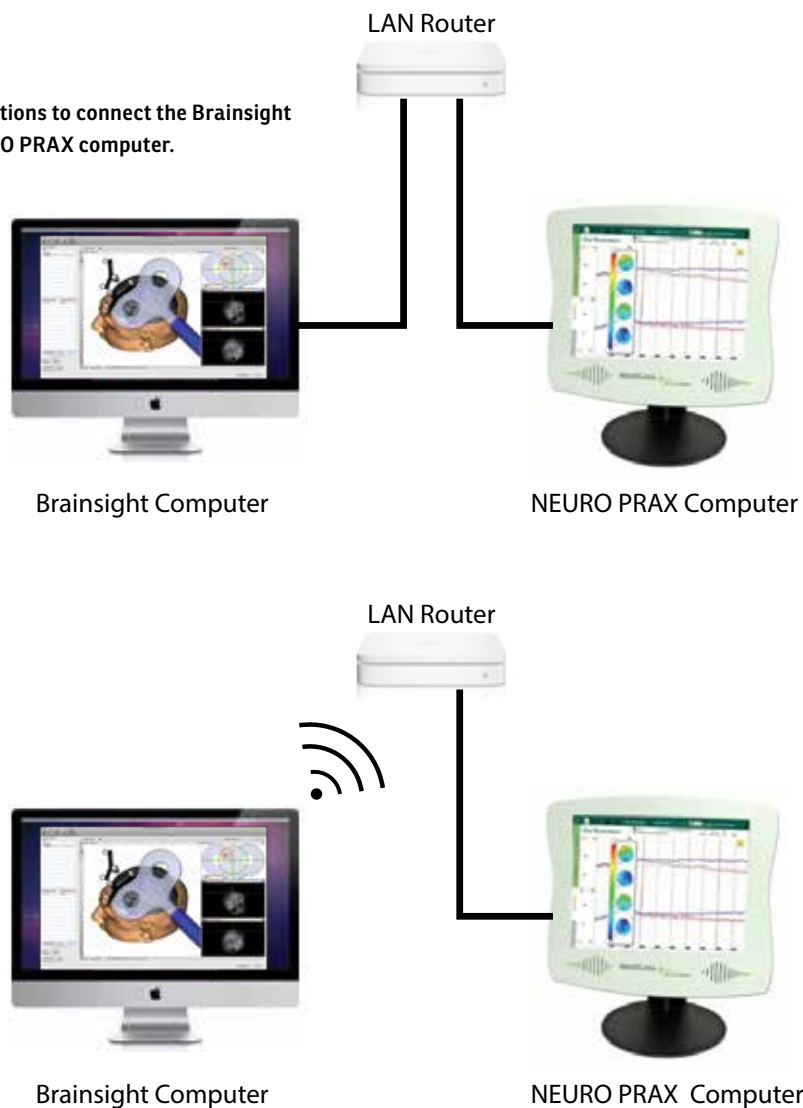
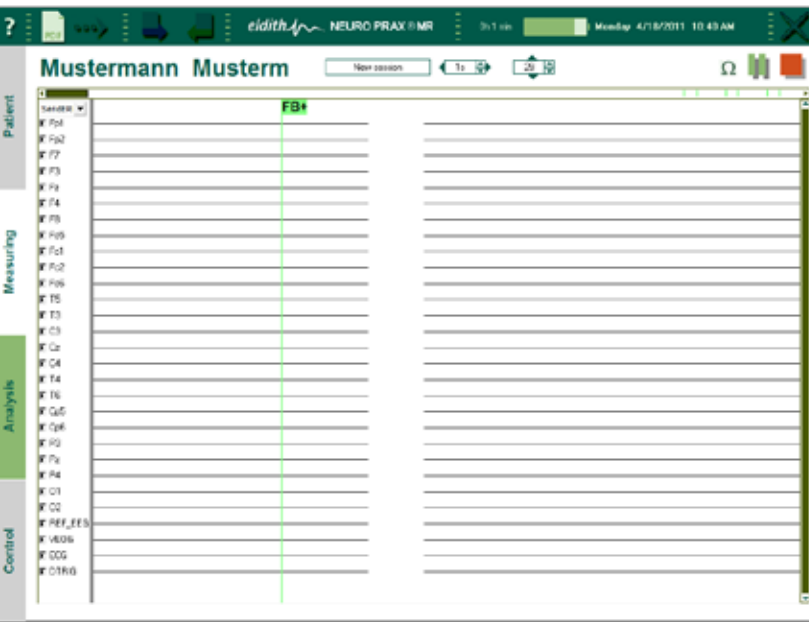


Fig. 1
Left: ne
Brainsig

16-2

neuroPRAX software in the "measure: mode. Right: screenshot in the Electrodes sub-step of the perform step.



DHCP server on your LAN). The NEURO PRAX computer supports the standard RJ45 Ethernet cable, while the Brainsight computer supports Ethernet and WIFI. If your router also supports WIFI then either configuration illustrated in Fig. 16-1 will work.

Discovering Each Other During the TMS session

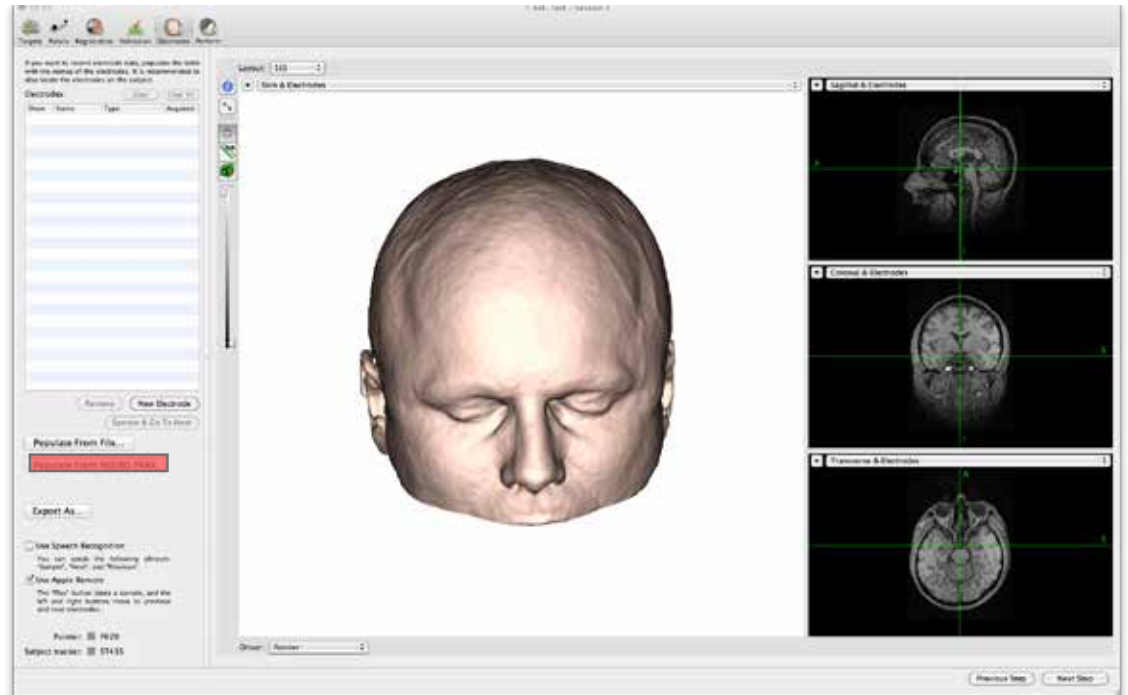
Set up both the Brainsight and NEURO PRAX systems as you normally would.

For the Brainsight procedure, perform all the steps up to and including the verify registration step. If you Brainsight

licence supports EEG functionality, then you will notice an additional step in the session perform window called **Electrodes**, immediately after the verify registration step (see Fig. 16-2).

For the NEURO PRAX system, perform all the steps until you reach the measurement step. Click the measurement step. NOTE: You must be using a montage that has the ERP protocol enabled. Contact neuroConn for more details.

If the two computers have discovered each other, you should notice in the Brainsight Electrodes step window



that the **Populate from NEURO PRAX** button is enabled (highlighted in red on the right of Fig. 16-2). If not, make sure that the NEURO PRAX computer is in the measure step and verify that your network is properly configured. Contact Rogue Research for further assistance.

Digitizing Electrode Locations

Once the two systems have discovered each other, you can obtain the list of electrodes from the NEURO PRAX computer, and use the Brainsight pointer to digitize them.

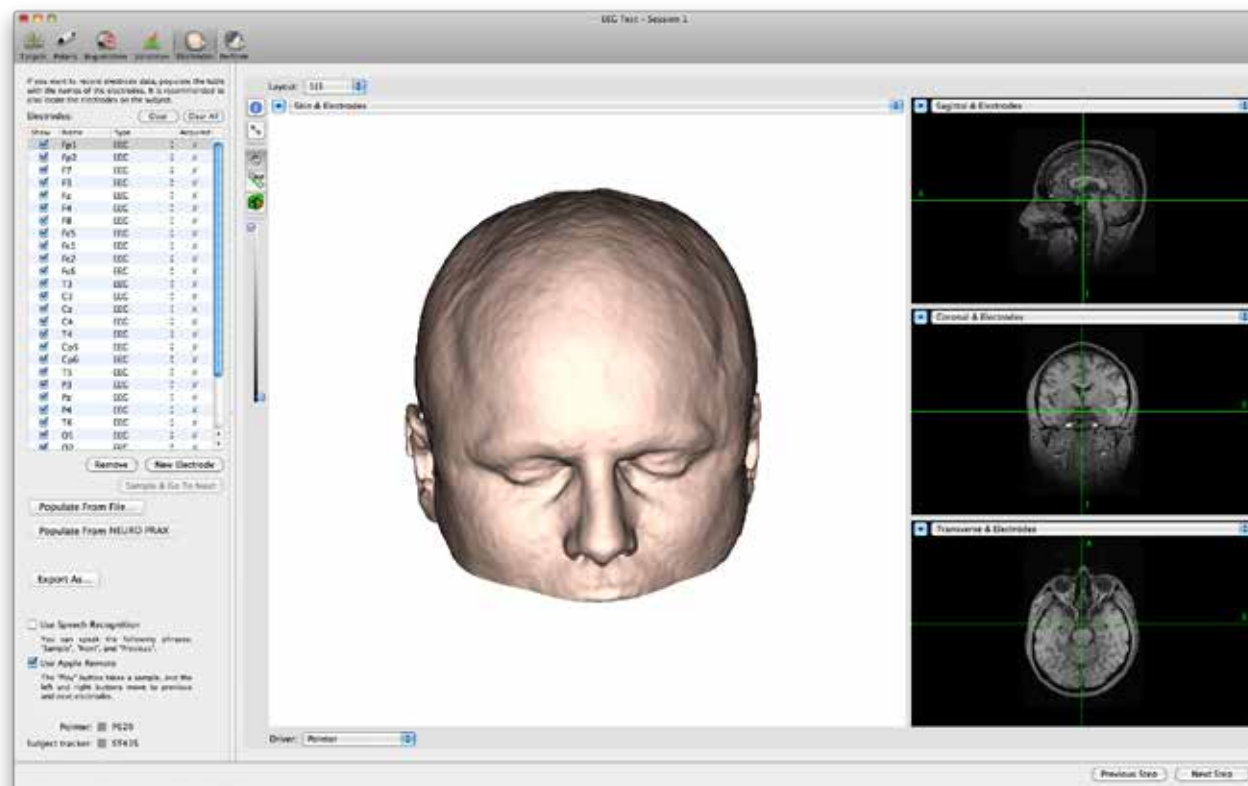
- In the Brainsight electrode step, click **Populate from NEURO PRAX**. After a few seconds, the electrode list should fill up and match the electrode names on the NEURO PRAX computer. NOTE, if instead you received an error message, try going back and forth from the **Measuring to Patient** and back to **Measuring** mode on the NEURO PRAX computer, then click **Populate from NEURO PRAX** again (there is a known issue that the connection is interrupted after an extended period).
- Once the electrode list has been populated, record them with the pointer by touching the electrode highlighted in the list with the pointer, and clicking Sample and Go To Next. You can use the Apple Remote or Voice recognition to sample in the same way as described in “Configure the I/O or trigger Box” from Chapter 13.

Recording EEG data during the experiment

Once the electrode locations have been recorded, **Click**

Fig. 16-3

Electrodes shown in the list populated from the NEURO PRAX (or loaded from a sequence file).



Perform to go to the next step. Follow the instructions from “Chapter 13: Performing the Study” to set up for the stimulation.

If you connected the TTL trigger out from the stimulator to both the NEURO PRAX and Brainsight computers, DO NOT enable **Use NEURO PRAX input**. Otherwise, duplicate samples will be created, one when Brainsight receives the trigger from the stimulator, and another one when it receives the trial from the EEG computer. When it is not enabled, Brainsight will create the TMS sample when it receives the trigger from the stimulator, and then when it receives the EEG trial from the EEG computer, it will associate that EEG data with the just created TMS sample. This ensures that the coil location is recorded at the time of the stimulation, and not at the end of the EEG trial acquisition.

If you only connected the TTL trigger to the NEURO PRAX computer, then enable **Use NEURO PRAX input**. During the experiment, each time the EEG system acquires an epoch of data (trial), it will automatically be sent to Brainsight and Brainsight will record the coil location and create a sample with it along with the EEG data. Note that there will be a delay between the time of the TMS pulse and the sample creation as Brainsight will only be notified of the sample after the EEG computer has acquired the sample and sent it to Brainsight. If the TMS coil is moved during that delay, the location of the coil at the end of the EEG trial (as opposed to at the time the coil was fired) will be recorded.

As the EEG is acquired, you can view the data in the Brainsight windows in a variety of ways. In any image view, you can select one of several EEG display methods. Take a moment to explore the different displays to find one that best suits your needs. You can also display the EEG

Exporting EEG Data

Once the experiment is complete and you are reviewing the session (see “Chapter 17: Reviewing Study Data”), you

can export the EEG data to EDF+ format for processing in your favorite EEG analysis program. EDF+ is the most commonly accepted EEG file format and enables you to use the EEG data acquired in Brainsight for analysis using other software. Brainsight supports two variants of EDF+, the discontinuous (event related) and the continuous versions. Brainsight stores the data in an event related format, so the continuous export is re-constructed using the timing information and the gaps between the samples (if there are any) are padded with 0s. To export the EEG data, (in the session review window), click **Export EDF+**, and follow the prompts.

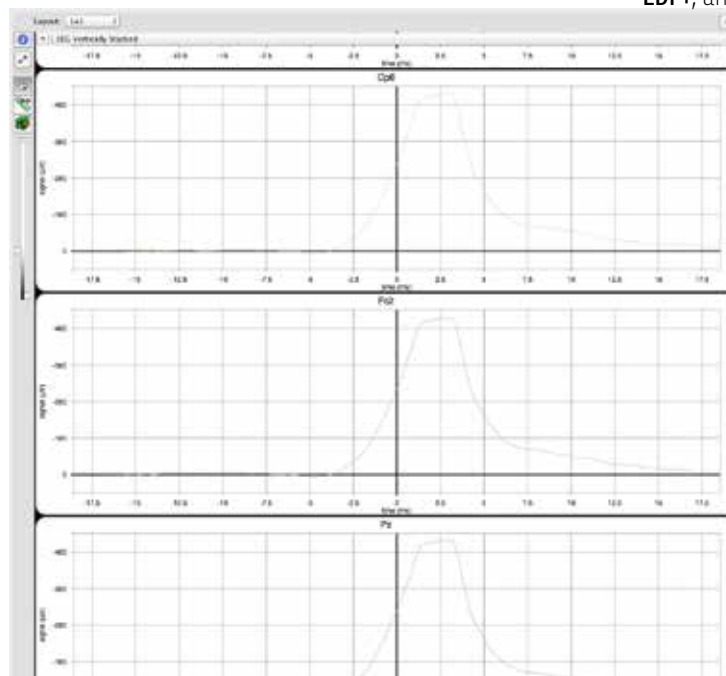


Fig. 16-4
One of the methods of displaying EEG data.

Chapter 17: Reviewing Study Data

After one or more TMS sessions, it is often useful to review the data acquired. Brainsight 2 has several tools to help review the results of the TMS session as well as export these to external files so you can perform more detailed analysis.

The usual purposes for review are:

- To verify that the targets to be stimulated were indeed stimulated.
- To sort through the data and export relevant information for further analysis.
- To pick recorded locations and convert them to targets for subsequent sessions.
- To configure the display window and take screenshots for publication.

Review is initiated from the Session manager pane. Click on the Sessions tab and then click **Review**, which will open a new display window (Fig. 17-1).

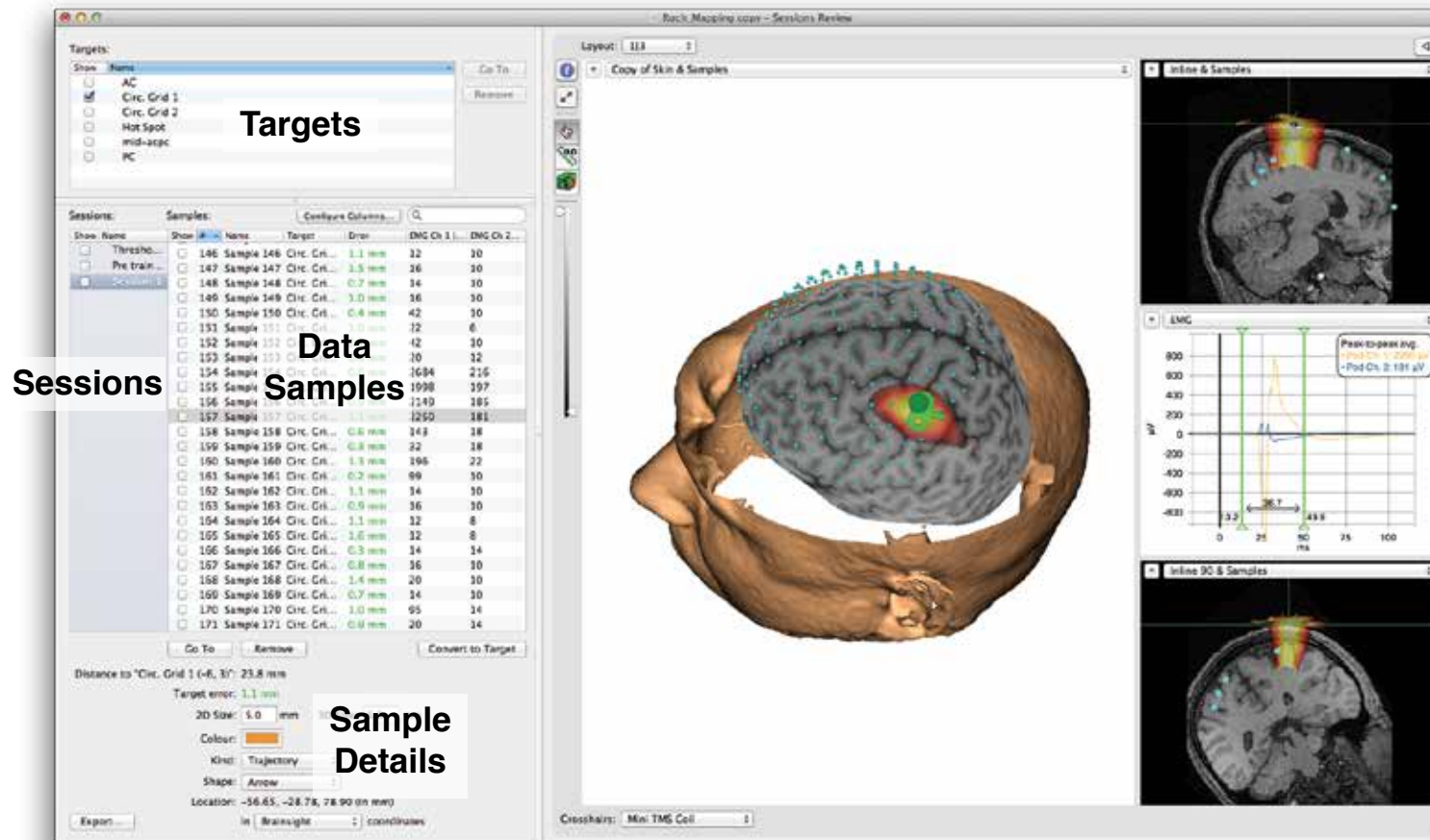
DISPLAY WINDOW

The review display window uses a similar layout the perform window with a few changes.

- A new list, the session list, can be seen next to the samples list. You can show or hide all the samples from a particular session as a group in the image views by enabling the **show** checkbox. You can show one or multiple sessions by clicking on their respective **show** boxes.
- The samples list displays all the samples from a session selected from the sessions list. Selecting multiple sessions in the sessions list will add all the samples from each highlighted sessions into the samples list. This is distinct from showing or hiding a sample in the image views. The samples list is to

Fig. 17-1

Session Review window.



allow you to selectively view the attributes of one or more samples. Selecting another session in the sessions list will affect what is shown in the samples list, but not what is being displayed on the images. Clicking **Configure Columns...** opens a window where you can enable or disable the display of any attribute in the samples list to simplify sorting on any one of them.

- The target list will have all the targets created in this project. You can display any of the targets in the image views by enabling their respective **show** checkbox.

EXAMINING THE DATA AND CHANGING ATTRIBUTES

Samples can be made visible or hidden using the show checkbox. To show or hide all of the samples quickly, select any sample, press **⌘-a** to select the entire list (or shift-click or **⌘**-click to select a group from the list), then **cntrl-click** or right-click on the list and select **Show Selected Samples** or **Hide Selected Samples** from the popup button.

When a sample is selected (and visible on any of the image views), the sample will be highlighted by a red bounding box. When multiple samples are selected, each one is highlighted.

Selecting a sample in the samples list will display its attributes under the samples list. Many of these attributes were acquired when the sample was recorded, such as the current target at the time and the EMG waveform (if you

were recording EMG). Many attributes are user selectable, such as the colour and shape of the sample. These can be changed at any time. Selecting multiple samples will display the common attributes. Changing any of these will be applied to all the selected samples.

One noteworthy attribute to describe is the peak-to-peak response from the EMG. This value is not recorded but rather it is derived from the raw EMG sample and the EMG window set with the movable green lines in any EMG display. If you move the MEP window controls (see Fig. 13-13), the MEP values will be recalculated. You can also change the MEP peak to peak manually by selecting the value in the list, and editing it directly. This new value will be used in any subsequent motor map calculation and will be exported when the Data Export option is selected. This can be handy to remove outlier values known to be noise or to replace the values with values from a third party EMG device (and used to create a motor map display). Note that if you change the MEP window controls, any modified MEP values will be overwritten with the newly calculated value, so take care when changing the window.

The samples list represents a union of the samples from the selected sessions. You can manipulate content of the list display by clicking **Configure...**, and enabling and/or disabling the available fields. You can display the samples in the image views for comparison by clicking the show checkboxes in the lists. You can also change the display layout (as in any display window) to your preference by

clicking in the list headings to change the display order.

As was possible during the TMS session, you have access to the inspector tool to customize the image view, change the display attributes of the 3D surfaces as well as use the motor maps feature.

CONVERTING A SAMPLE TO A TARGET

It is common for a TMS target to be derived from the results of a previous TMS session. You can easily convert (copy) a recorded sample into a target by dragging the sample from the sample list into the target list. The **Convert to Target...** button present while performing the TMS session performs the same function as dragging and dropping them.

It is common for the recorded sample locations to have a scalp point as its origin while it is often preferable to have the target's origin set somewhere in the cortex (see Fig. 12-10). After creating the target as described above, use the target positioning tool and nudge tool to nudge the target into the cortex as described in "Creating a target based on a previous sample" on page 69.

EXPORTING THE DATA

You can also export the targets or acquired sample data to a text file for more detailed analysis. The file format is essentially a tab-delimited text file where each row is a sample (or a landmark or target if you chose to export those as well) and each attribute is separated by a tab character. Attributes with multiple values are separated

by a semicolon.

To export the data, select the samples you wish to export from the list (if you want to export a subset of the samples), then click **Export...** to open the export dialog box (Fig. 17-2). You can choose to export the samples as well as the targets and registration landmarks. If you selected a sub-set of samples to export, click **Selected samples only**, otherwise, select All or none. Among the samples, targets and landmarks, you can select which attributes for each type of entry to export. You can also select the coordinate system to use for all coordinates. The default is Brainsight's internal coordinate system illustrated in Fig. 17-3. If the anatomical data set contained a transform to a reference coordinate space ("world space"), you can select that if you choose. If you performed an MNI registration, you can use MNI or Talairach coordinates. Enter a file name (and navigate to the desired folder), and then click **Save**.

Exported Data Format

The text file begins with a short header describing the fields and the order in which they are saved, followed by the targets (if you chose to export them), then the landmarks (if selected) and finally the samples. If you chose to export the landmarks, each one consists of two points (in the same coordinate space). The first is the image-based location (the one identified on the images in the landmarks step) followed by the coordinate sampled by the pointer during the registration.

Fig. 17-2

Data export box.

The selected attributes of each sample will be exported as a text file. The format is a straightforward tab-delimited text file.

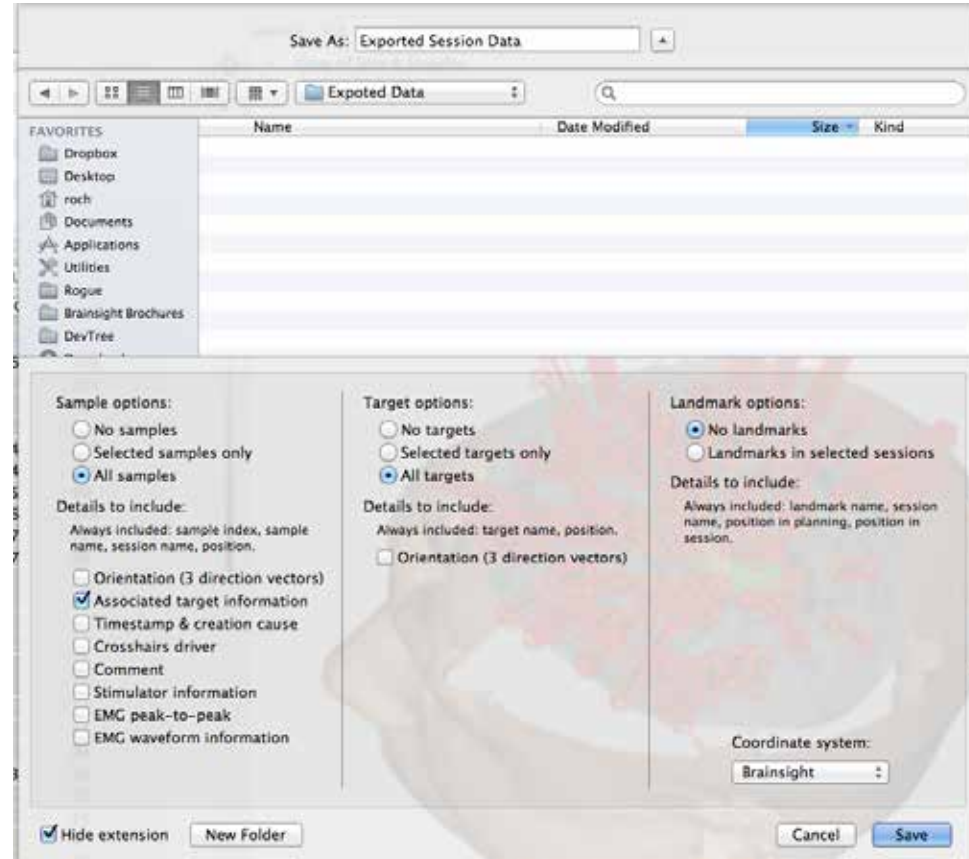
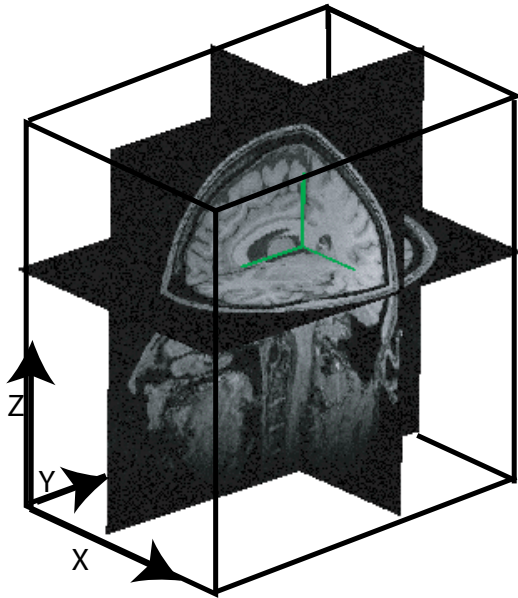


Fig. 17-3

Brainsight's internal coordinate system.



Attribute description

All data are written as strings. If it is described as an integer, it is implied that this is the format of the string. Note that some attributes were added with newer versions of Brainsight. If you are exporting a session that was acquired with an older version, the newer attributes may not be included since they were not recorded at that time.

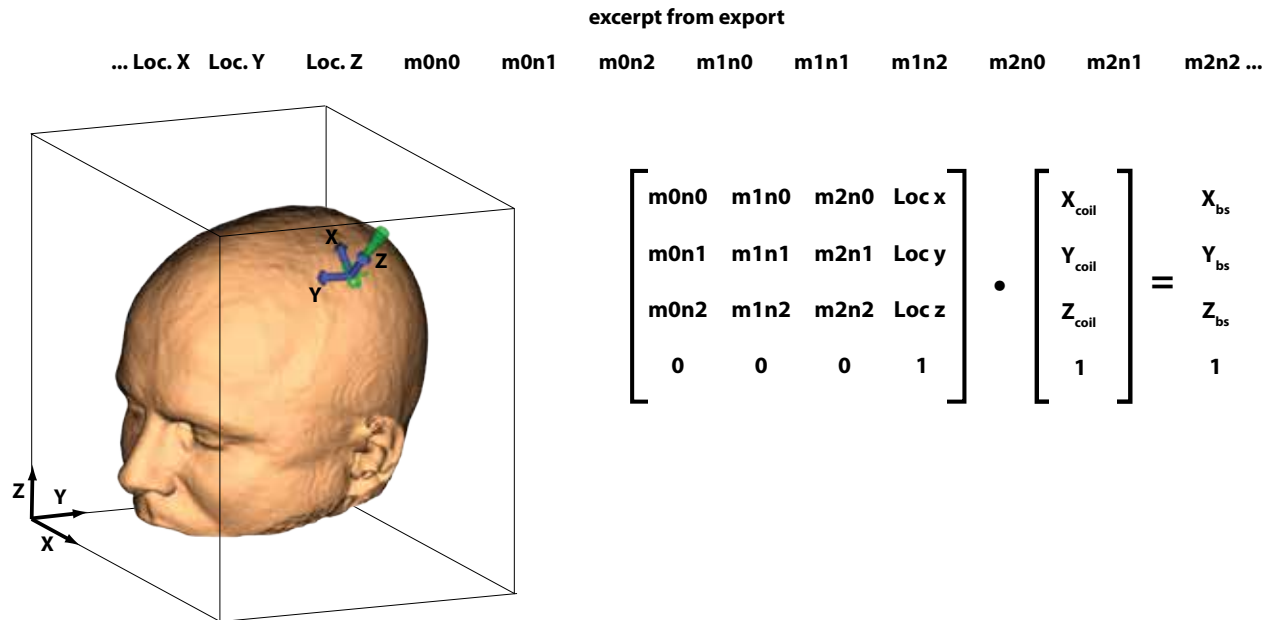
- **Sample name** [string.]: the name of the sample.
- **Index** [integer]: The index of the sample assigned in the order of the creation of the samples. If samples are deleted after they were created, the indexes are not reused.
- **Assoc. Target** [string]: the name of the target that was current at the time of the sample.
- **Crosshairs driver** [string]: Name of the tool that was being tracked when the sample was generated. Possible values are Mouse, Pointer or the name of the tracked tool given when it was calibrated.
- **Lox X (Loc Y & Loc Z)** [float]. X, Y and Z values of the location of the tracked tool at the time the sample was taken.
- **m0n0 m0n1 m0n2** [float]: The orientation (direction cosine) of the x axis of the tracked tool in the host coordinate space. See for a description of the tracked tool coordinate system and how to use the location and direction cosines to assemble the tool to image transform. This transform can be used to convert points relative to the tool to points in the image space (e.g. projections along the coil's z axis into the head).
- **m1n0 m1n1 m1n2**: [float]: The orientation of the y axis of the tracked tool in the host coordinate space.
- **m2n0 m2n1 m2n2**: [float]: The orientation of the z axis of the tracked tool in the host coordinate space.
- **Dist. to target** [float]: The straight line distance from the coil reference point to the target.
- **Target Error** [float]: The shortest distance from the line projecting into the head along the coil's path as described in Fig. 13-15.
- **Angular Error** [float]: The tilt error of the coil as described in Fig. 13-15.
- **Date** [string]: The date the sample was acquired in YYYY-MM-DD format.
- **Time** [string]: The time (according to the system clock) in HH:MM:SS.XXX where HH is the hour, M is the minute, S is the second and XXX is the millisecond.
- **EMG Start** [float]: Time in msec before the sample time (e.g. when the coil fired) when the EMG recording started. Also referred to as baseline. Always a negative number.
- **EMG End** [float]: End time in msec of the EMG sample (trial duration)
- **EMG Res.** [float] Time in msec between samples.

- **EMG Channels** [integer]: Number of active channels during the session (usually 0, 1 or 2).
- **EMG Peak-to peak N** [float]: N is the channel number. Peak to peak value in μV calculated between the EMG window at the time the data was exported. Note that for multiple EMG channels, the order of the data output is EMG Peak to Peak 0, EMG Data 0, EMG Peak to Peak 1, EMG Data 1 and so on.
- **EMG Data N:** [float;float;...float]. EMG samples in μV , separated by a ";". The number of samples can be calculated by $(\text{EMG End}-\text{EMG Start})/\text{EMG Res}$

You can perform the export more than once and switch coordinate systems between exports to export the data in multiple coordinate systems.

Fig. 17-4

Illustration of the relationship between the coil position and orientation described by the Loc and direction cosine values. They can be assembled into a matrix to convert coordinates relative to the coil into Brainsight, world or MNI/Talairach coordinate spaces. For example, to find the Brainsight coordinate of a point 15mm under the coil, multiply the transform matrix by the vector [0, 0, 15, 1].



Chapter 18: EEG Electrode Recording

Many Brainsight users also happen to use EEG for many of their experiments. If you are one of them, then you can make more productive use of your Brainsight position sensor hardware to digitize the locations of the EEG electrodes and of the scalp. This often renders the need for the Polhemus system (and the Locator software) redundant.

There are literally dozens of EEG data acquisition and analysis programs in use today. Some of these use standardized configurations of the EEG electrodes (e.g. 10-20 grid) to estimate the locations of each electrode. Other programs use a 3D position sensor (not unlike the Vicra used by Brainsight) to digitize the exact locations of the electrodes and sometimes the scalp to either create a more realistic model of the head, or to co-register the EEG data to MR images of that subject. In addition to EEG, many NIRS-DOT systems employ the same techniques to localize the NIRS optode locations.

Brainsight supports two methods to represent the EEG electrodes. One is a free form method where the three anatomical landmarks are recorded, followed by the electrodes in no particular order. The second method uses a sequence file (commonly used by BESA) to define a sequence of electrodes that can be loaded to prompt you to digitize the electrodes in that order. In either case, you may also want to digitize a random sampling of scalp points to characterize the shape of the head.

It is important to note that you do not need the MR images of your subject for this procedure. Strictly speaking, you are not performing any neuronavigation, you are simply using Brainsight to talk to the position sensor and take some measurements.

Once the measurements have been taken, you can save them in one of a few file formats, depending on the accepted formats of your EEG software.

GETTING STARTED

- Launch Brainsight and dismiss the splash screen. To open the EEG window, select **Window->Electrode Recording** (Fig. 18-1). Enter the name of the subject in the field at the top of the window.

Setting up

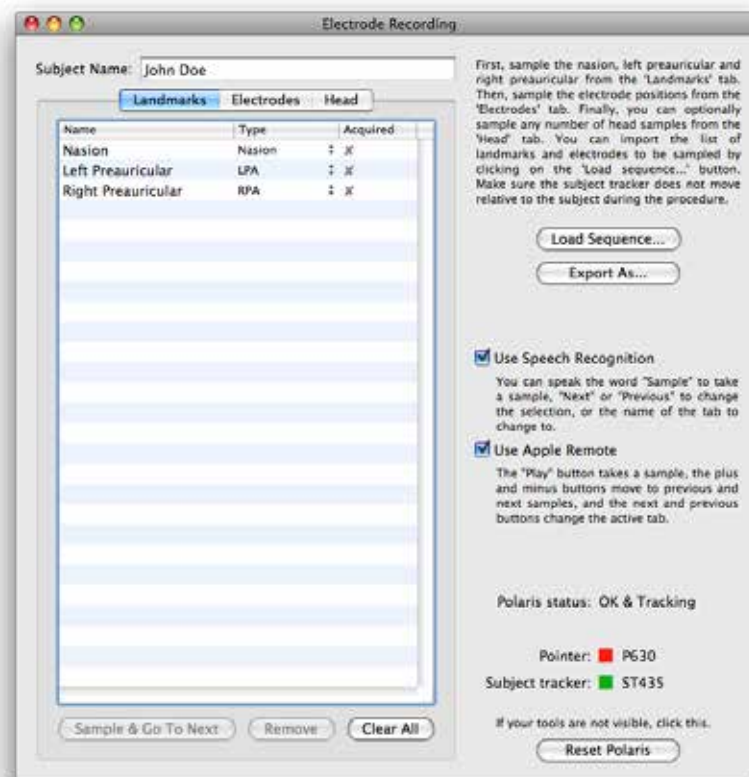
- Before starting, set up the trigger method(s) to notify the computer whenever you are touching a landmark. Optionally turn on the speech recognition or Apple Remote by enabling or disabling their respective checkboxes.
- Put the subject tracker on the subject's head and place the subject in the view of the Polaris position sensor (review how to prepare the subject and use the Polaris by looking at "Prepare the Subject" on page 71).

USING A SEQUENCE FILE

- If you are using a sequence file, load it here by clicking **Load Sequence...**, and select the file using the file dialog box. Refer to your EEG software documentation regarding the file format specification for a sequence file (which has a .seq extension), or contact Rogue Research for an example file. Once the sequence file has loaded, the electrode references will appear in the **Landmarks** and **Electrodes** tab (when you get to the next step). Note that loading a sequence file clears any pre-existing samples.

Fig. 18-1

First step of electrode recording.



DIGITIZE THE ANATOMICAL LANDMARKS

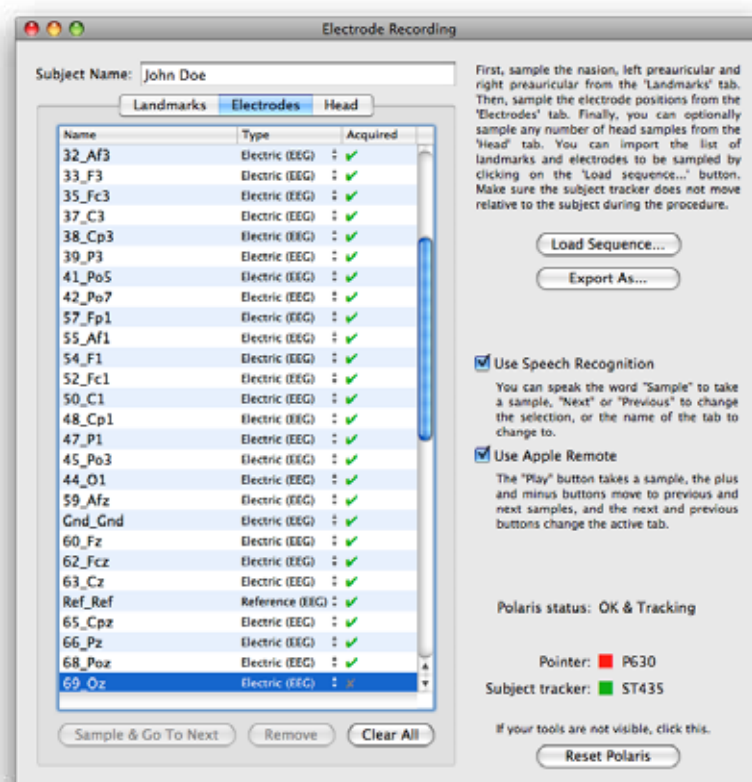
- If not already the active tab, click the **Landmarks** tab to bring it up (or, if you have speech recognition activated, say "Landmarks").
- Place the tip of the pointer on the first landmark and either say "Sample", press **Play** on the Apple Remote or have an assistant click on **Sample & Go To Next**. The software will sample the location of the pointer and associate it with the currently selected landmark in the list. The green check mark confirms this.
- If there is another landmark, the software will automatically go to the next one and speak the name of the electrode (assuming you have the volume turned up). Take note of this, and touch it with the pointer and repeat the sample process.
- Continue for all landmarks.

Once you sample the last landmark, no landmarks will be selected. If you wish to add additional landmarks, continue to sample landmarks (as you did before) and new unnamed ones will be created. You can change the names as you go, or select them in the list after you have finished and rename them at that time.

You can re-sample a landmark by selecting it in the list and sampling it with the pointer again. You can remove entries by selecting them in the list and clicking **Remove**. Finally, you can clear all the samples by clicking **Clear All**, which removes the sampled data but leaves the

Fig. 18-2

Electrode digitizing screen



entries so they can be re-sampled.

DIGITIZING ELECTRODES

- Click on **Electrodes** or say “Electrodes” to bring up the electrodes tab (Fig. 18-2). If you are using a sequence file, then all the electrode names should be visible in the list. Otherwise, the list will be empty and any new sample will automatically be named “Electrode-1, Electrode-2...”.
- Touch the first electrode (either the one highlighted in the list, or if there are no entries in the list, your first electrode) and either say “Sample”, press **Play** on the Apple Remote or have an assistant click on **Sample & Go To Next**. The software will sample the location of the pointer and associate it with the currently selected electrode in the list.
- If there is another electrode, the software will automatically select to next one in the list and speak it. Take note of this, and touch it with the pointer and repeat the sample process.
- Continue for all electrodes.

Once you sample the last electrode, no electrodes will be selected in the list. If you wish to add additional electrodes, continue to sample them (as you did before) and new unnamed ones will be created. You can change the names as you go, or select them in the list after you have finished and rename them at that time.

You can re-sample any electrode by selecting it in the list and sampling it with the pointer again. You can remove

entries by selecting it in the list and clicking **Remove**. Finally, you can clear all the samples by clicking **Clear All**, which clears the sampled data, but leaves the entries so they can be re-sampled.

DIGITIZING HEAD SHAPE (OPTIONAL)

The purpose of the head sampling function is to generate a “cloud” of samples that will help define the shape of the scalp. This is used by many EEG applications to generate a subject specific head model or to co-register the EEG electrode coordinate space to the subject’s MR space.

To begin acquiring scalp samples:

- Click on **Head** or say “Head” to bring up the Head sampling tab (Fig. 18-3). Note that the list will be empty as there are no pre-defined head points.
- Touch the pointer tip gently on the subject’s scalp, making sure that the pointer is visible to the Polaris and either say “Sample”, press **Play** on the Apple Remote or have an assistant click on **Sample & Go To Next**. The scalp location will be recorded and the entry will be appended to the list in the window.
- Move the pointer tip to an adjacent location on the scalp and sample again (using the same options as in the previous step).
- Continue to sample scalp locations throughout the head according to the needs of your EEG software. Typically, at least 20–30 points will be required. make sure that you obtain samples all over the head

to obtain a reasonably good representation of the head shape.

SAVING THE DATA

Once you have sampled the anatomical landmarks, electrode locations and head shape cloud (if needed), you can save this information to a variety of file formats.

- Click **Export As...** to open the save file dialog (Fig. 18-4).
- Select a file format from the popup menu (see below), enter a file name and click **Save**.

FILE FORMAT DETAILS

The file format chosen for export will influence two things: The format of the text and the coordinate system of the samples. Choose the right one for your EEG software. **Take special care to fully understand the coordinate system used for each format as they can be confusing!**

Text (.txt)

This is the simplest file format. The coordinate system uses the subject tracker as the origin and the coordinate axes, which are arbitrary depending on the orientation of the subject tracker. All samples are in this coordinate system. The coordinate system details are irrelevant as the anatomical samples would presumably be used to co-register all the samples to your specific coordinate system.

Fig. 18-3

Head Sampling Screen

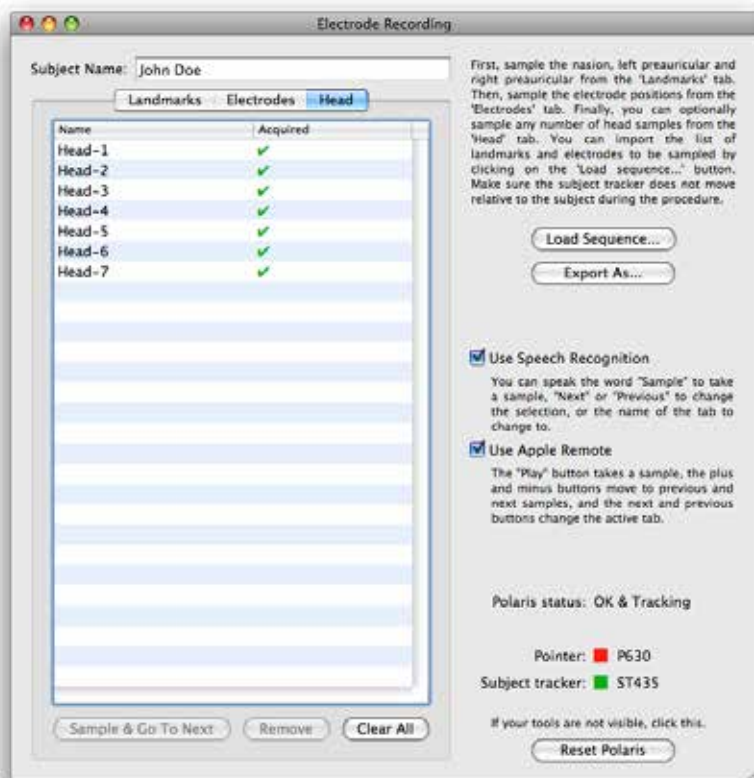


Fig. 18-4

File Export Dialog



Locator

The coordinates are transformed according to the Locator coordinate system (sometimes referred to as the CTF coordinate system). In short, the X axis is defined as the line starting at the midpoint between the RPA and LPA and passing through the nasion. The Z axis is taken as the cross product of the X axis and the RPA-LPA line and the Y axis is the cross product of the Z and X axes, which is close, but not necessarily exactly along the RPA-LPA line (read that again 3 times!).

BESA

The BESA file format structure is similar the Locator, except that the coordinate system is slightly different (and sometimes confused with the Locator coordinate system!).

The origin is the point along the LPA and RPA line where the line from that point to the nasion would be perpendicular to the LPA-RPA line (near the middle, but not necessarily exactly the middle due to head asymmetry). The X axis is along the LPA-RPA line. The Y axis goes from the origin to the nasion and the Z axis is the cross product of the X and Y axes.

As more Brainsight users become familiar with EEG, we would be happy to include additional file formats to the list. Please do not hesitate to contact us.

Chapter 19: Hardware Reference-Computer Trolley

The Brainsight computer trolley is designed to provide a large screen computer, required input/output ports as well as an integrated 2 channel EMG device in a small footprint, mobile platform. The updated version of the system will be released shortly along with an updated version of this user manual. This chapter will cover the version of the computer without the 2 channel EMG device.

The mobile computer (Fig. 19-1) consists of three main parts: The computer, the trolley itself, and the I/O box. Some early versions of the trolley did not have an I/O box. We intend to upgrade all trolleys to the same I/O box in the near future, so contact us to arrange the upgrade.

COMPUTER

The computer is an iMac (24" or 27" screen, depending on the purchase date) with Intel processor. It is mounted to the trolley via three fixation screws that screw the base to the top of the trolley, or by a base platform, that itself is screwed to the cart via the three fixation screws.

TROLLEY

The trolley allows you to move the computer anywhere you need it. The keyboard and screen's height can be adjusted by pushing the foot pedal at the base of the trolley, and lifting/pushing the computer up and down.

I/O BOX

The current I/O box (Fig. 19-2) contains a power bar, cabling and the acquisition device that serves to monitor the TTL and switch interface as well as provide the analog inputs for our 2-channel EMG device. The box has a rear panel that provides the BNC interface jacks for the TTL trigger in and the foot switch (or hand switch), the analog input connector, the mains switch and the Vicra power switch..



Fig. 19-1

Overall picture of the computer/trolley



Fig. 19-2

Close-up of the rear panel.

The Vicra switch also allows you to turn the Vicra on or off without affecting the computer to allow you to use the computer for project preparation or data analysis without having to have the Vicra on.

ASSEMBLY INSTRUCTIONS

Parts:

- Trolley Wheel Base
- Main Tube
- Foot Pedal
- Keyboard tray
- Trolley handle kit (handle, front bracket, 2 insert brackets)
- Computer base
- I/O box
- 2x hex bolts w. yellow threadlock (usually on the bottom of the Main Tube.
- 2x hex bolts w. blue thread lock
- 2x hex bolts (longer)
- 3x counter-sink hex headed screws
- White Power Cable
- Medical grade power cable
- 2x 2m USB cable
- 2x long cable-tie
- 6x short cable tie
- 1x 3/16" hex key

- 1x hex key (bronze)

Tools required:

- Phillips (star) screwdriver
- Scissors or cutters for cable-ties

Instructions

1. Unpack all parts and make sure they are in good condition.
2. Place a piece of flat "bubble-wrap" material on the floor, and place the I/O box on it upside down to expose the mounting holes.

3. Place the trolley wheel base upside down on the I/O box, and carefully align the holes in the wheel base to the holes in the I/O box as illustrated in Fig. 19-3.
4. Insert the two hex bolts into the holes of the wheel-base and carefully tighten the bolts to secure the I/O box to the wheelbase using your fingers first, then with the included xx hex key. Take care to ensure that the bolts are straight into the mounting holes of the I/O box and carefully tighten the bolts to not strip them (i.e. if the bolt goes in crooked).
5. Flip the wheelbase back upright.

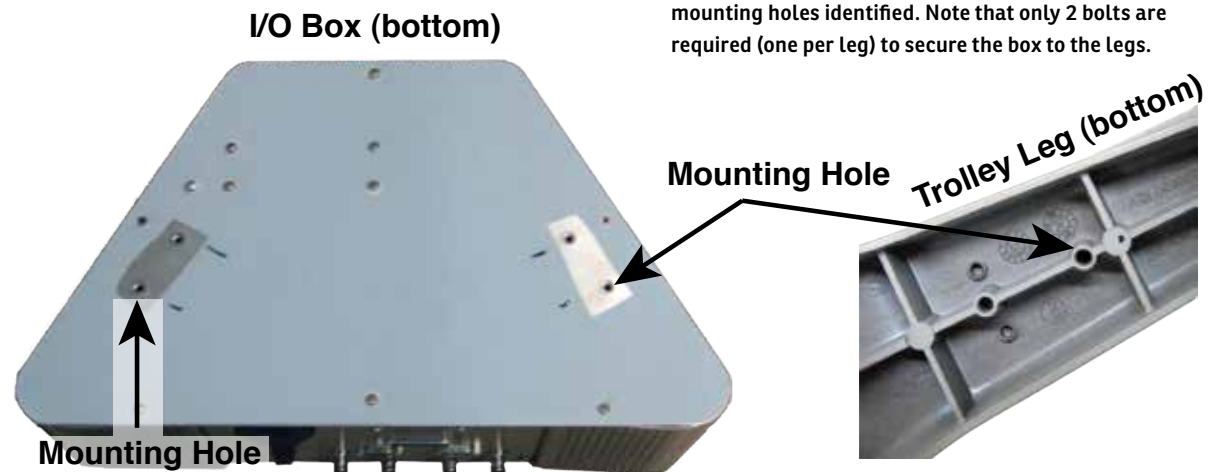


Fig. 19-3

I/O box and trolley leg, seen from underneath with the mounting holes identified. Note that only 2 bolts are required (one per leg) to secure the box to the legs.

6. If present, remove the two hex bolts (yellow thread-lock) from the bottom of the main tube.
7. Fit the main tube into the hole in the middle of the wheelbase, taking care to align the tab of the main tube with the notch in the wheelbase.
8. Carefully tilt the wheel base/tube onto its side to expose the bottom, while keeping the tube in the hole (you may need an assistant for this step).
9. Closely examine the two mounting holes at the center of the wheelbase (underneath the base). You should see the holes of the main tube roughly



Alignment Pin

Fig. 19-4

Pole in the receptacle in the base. Note the alignment pin on the pole and the slot in the base.

- aligned with the holes. Gently twist the main tube to make sure the holes are properly aligned (this will prevent the mounting bolts from binding and/or stripping later).
10. Take the pedal, and align the two mounting holes of the pedal base with the 2 holes in the center of the wheelbase. Make sure the foot pedal is between two of the wheel base spokes (and NOT under a spoke). If it is under a spoke, rotate the pedal 180° and align the holes again. Hold the pedal in place.



Fig. 19-5

Correct placement of the pedal.

11. Using the 2 hex bolts with the blue thread-lock on the tips, bolt the foot pedal, wheel base and main tube together. Use the included hex key to tighten the bolts. Take care that the bolts go in straight and do not bind (see Fig. 19-6).
12. Place the assembly back on its wheels.
13. Partially assemble the handle by fitting (snapping) the two insert sleeves into the two halves of the



Fig. 19-6

Example of a bolt that was not correctly inserted (pedal omitted for clarity).

handle assembly.

14. Fix the handle to the top of the inner tube of the main tube by screwing the two halves of the handle

assembly around the tube using a #2 Phillips (star) screwdriver.

15. Take the computer base platform, and disassemble it by removing the two thumbscrews at the bottom, and separate the two halves. The half with the 3 holes will be mounted on the trolley along with the keyboard tray.
16. Take the keyboard tray and the bottom half of the computer base (the half with the three holes) and align them to the three holes on the top of the main tube. Rotate the keyboard tray and/or the computer base to ensure that the keyboard tray is over the



Fig. 19-7

Assembly of the computer base and keyboard tray. The tray sits between the computer base and the top of the pole. The

foot pedal and that the front of the computer base is over the foot pedal. The keyboard tray should be on the tube and the computer base should be on the keyboard tray.

17. Using the 3 counter-sink screws, secure the computer base and keyboard tray to the top of the main tube. Tighten the screws using your fingers first (and ensure they are not binding) and then tighten them using the included hex key. Make sure the assembly is well secured and that there is no wiggle between the computer base and the tube.



three screws go through the computer base and then the keyboard tray and are fixed into the three holes in the pole.

18. Unpack the iMac computer and remove the plastic film covering the base.
19. Place the computer on the computer base, ensuring that the base fits into the cutout in the base. The base should not protrude past the height of the cutout.
20. Place the two foam spacers on the front part of the iMac base.
21. Place the upper part of the computer base on top of the lower part (sandwiching the iMac to secure it), and secure the upper part to the lower part using the two thumbscrews.
22. The power cable and 2 USB cables come as a harness (cables in a spiral wrapper). Plug the white power cable into the power outlet in the front of the I/O box (the part against the main tube of the trolley). Plug the two USB cables into plugs labelled USB 1 and USB 2. Run the cable up the tube, through the handle (the handle should be facing the rear of the trolley), through the hole of the iMac base into the iMac power receptacle in the rear.
23. Plug the power cable and the two USB cables into the receptacles at the rear of the computer. NOTE that it does not matter which USB ports are used, but using the ports towards the middle will minimize the clutter.
24. Press the foot pedal, and raise the iMac as high as it will go.

25. Tilt the iMac back to pull as much cable as will be required to tilt fully through the hole in the iMac base.
26. Take one long cable-tie to be used to fix the cable harness to the trolley handle in a way to take the weight of the cable of the connectors on the iMac: Observe where the harness comes close to the trolley vertical pole, between the trolley handle and the bottom of the iMac base.
27. Run the cable-tie through the spiral wrap of the power/usb cable harness and then around the pole at the location described above. Secure the cable-tie.
28. Plug the power cable into the rear panel of the I/O box, and into a power outlet.
29. Remove the twist-ties that secure the Vicra cable at the rear of the I/O box.
30. Follow the instructions in the Brainsight user manual to connect the Vicra to the Vicra cables.

Using the computer

1. Make sure that the mains switch at the rear of the trolley is set to ON.
2. Press the power button at the rear of the iMac. After a few seconds, you should notice it start up.
3. Once booted, follow the instructions in the Brainsight User Manual to operate the Brainsight system.

Software Updates

Like all modern computers, you Brainsight computer and software require regular software updates, which are supplied via the internet. Make the appropriate arrangements with your IT dept. to allow regular access to the internet by the computer.

Chapter 20: Hardware Reference-EMG Pod

The Brainsight 2 channel electromyography (EMG) acquisition device is designed to measure the voltages generated by muscle activity and provide that information to your Brainsight system. The voltages are measured on the skin using disposable, self-adhesive surface electrodes. Typically, it would be used to measure the muscle evoked potential (MEP) generated by a TMS pulse, for example during motor mapping.

DECLARATION OF CONFORMITY



Rogue Research Inc.
206-4398 boul. St-Laurent
Montreal, Quebec
Canada
H2W 1Z5

EC DECLARATION OF CONFORMITY

The EC directives covered by this Declaration

2004/108/EC Electromagnetic Compatibility Directive
2006/95/EC Low Voltage Directive

The Products Covered by this Declaration

MEPP002001 or higher MEP Pod system when used with:

- NTBX002002 or higher IOBox system, or
- ANAR002002 or higher Analog Receiver device.

The basis on which Conformity is being declared

The product identified above complies with the requirements of the above EC directives by meeting the following standards:

| | |
|-------------------|--|
| AAMI ES60601-1 | Issued: 2006/03/09: 2005 Version (R2012) Medical Electrical Equipment, Part 1: General Requirements for Basic Safety and Essential Performance; with AMD C1; 2009, AMD 2; 2010 |
| CSA C22.2#60601-1 | Issued: 2008/02/01 Ed: 2 Medical electrical equipment - Part 1: General requirements for basic safety and essential performance; COR 2: 2011/06/01 |
| IEC60601-1-6 | Issued: 2006/12/08 Ed: 2 Medical electrical equipment - Part 1-6: General requirements for basic safety and essential performance - collateral standard: usability |
| IEC 60601-1-2 | Issued: 2007/03/01 Ed:3.0 Medical Electrical Equipment - Part 1-2: General Requirements for Basic Safety and Essential Performance - Collateral Standard: Electromagnetic Compatibility - Requirements and Tests |

The technical documentation required to demonstrate that the product meets the requirements of the above directives has been compiled by the signatory below and is available for inspection by the relevant enforcement authorities. The CE mark was first applied in 2014.

The products described above comply with the essential requirements of the directives specified.

Signed: _____

Date: Feb 12, 2014

ATTENTION!

The attention of the user is drawn to special measures and limitations to use, which must be observed when the product is taken into service to maintain compliance with the above directives. Details of these special measures and limitations to use are available on request, and are also contained in the user manual.

SAFETY NOTES

Statement of intended use

This device is intended for use in teaching and research applications only. This device is not intended nor should be used for medical applications. It is not intended to treat, diagnose or monitor a subject.

The EMG device comes pre-calibrated. No adjustment is needed throughout the life of the device.

Safety Symbols

The following symbols are used throughout this manual to highlight important safety information, or information that is especially important to obtain best results in using the apparatus.



This symbol is used to denote advice to refer to the user manual for proper operating procedures and safety information.



Attention! This symbol denotes information regarding the safe use of the equipment to prevent injury or damage to the equipment.



This symbol is used to denote advice to obtain the best results using your Brainsight EMG system.



Type BF Applied part. This means that the input connectors are suitable for connection to humans. There is no direct electrical connection to the earth.



This symbol is used to denote a high voltage warning.

Safety Tips

Keep the subject out of reach from the computer or any other non-isolated device or other person touching non-isolated parts. The subject should only be able to reach and touch all BF applied parts including electrode leads, the differential sensor and isolation unit.



Use disposable surface electrodes. Do not use implanted electrodes.



Make sure the cables are well managed to prevent the subject or others around the subject from tripping on them.



Make sure that the position of the computer enables easy access to the main power cord in case immediate disconnection is required.



To avoid temporary discomfort when applying the electrodes, snap the disposable electrodes to the electrode leads prior to applying the electrodes to the skin. Otherwise, the pressure required to snap the leads to the electrodes while on the skin may cause minor, transient discomfort.



The equipment is not protected against liquid spills. Do not immerse any parts in water or any other conductive liquid. If any liquid is spilled on the equipment, unplug the analog cable from the I/O box or analog receiver box.



If the equipment fails to perform as expected, immediately discontinue use and contact Rogue Research for customer support or repair/replacement of the unit.



If using the I/O box, a medical grade isolation transformer has to be used. Make sure fuse rating of both parts are correctly set to your local voltage. Failure to do so may result in damage to your equipment, or loss of protection.



This device may cause electrical disturbances in sensitive equipment within its operating environment



Connecting a subject to high-frequency surgical equipment while using EMG system may result in burns at the site of the electrode contacts



Do not modify the equipment in any way. Modifying the equipment in any way may lead to data quality degradation, introduce potential safety hazards and void conformity to safety standards.



Ensure that all components are kept away from sources of electromagnetic radiation. Failure to do so may result in data with additional noise.



The computer is plugged into the electrical mains. Use caution when connecting or disconnecting the computer power cable.

Contraindications

- Do not use on patients with implanted electronic devices of any kind, including pacemakers, implanted defibrillators, electronic infusion pumps, implanted stimulators or any similar electronic assistive devices.
- Do not use on irritated skin or open wounds.

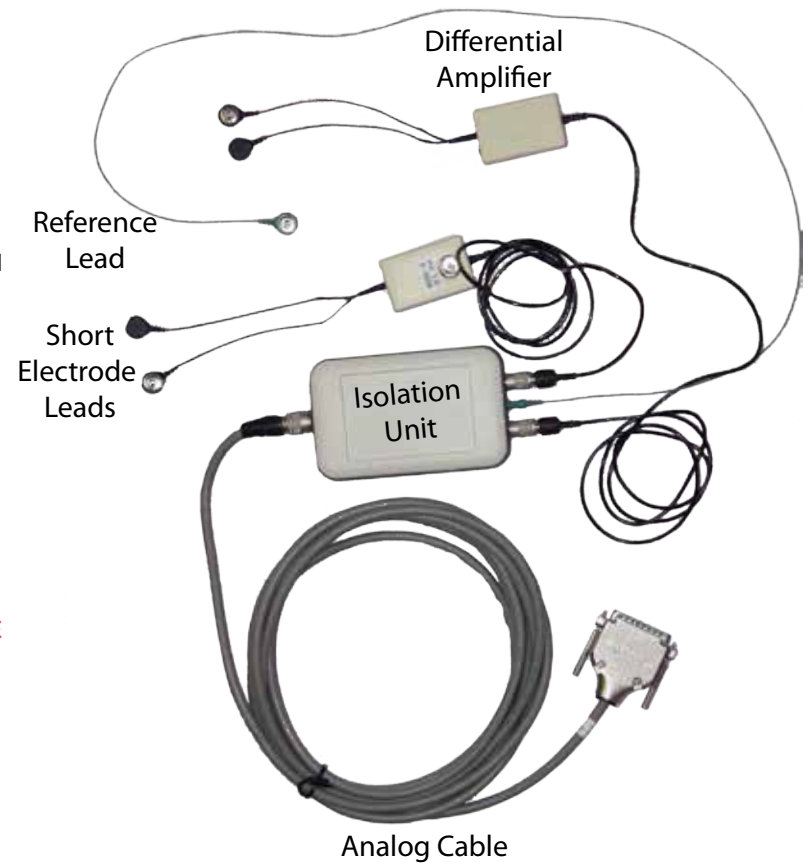
OPERATING, TRANSPORT AND STORAGE ENVIRONMENT

Operating

- Temperature Range: min=15°C, max=30°C
- Humidity Range: 40%-60%
- Use indoors

Fig. 20-1

Device overview: Parts used near the subject.



- Keep away from direct sunlight

Transport

- Temperature Range: min=-20°C, max=40°C
- Maximum humidity: 95%, non-condensing
- Handle with care

Storage

- Temperature Range: min=15°C, max=30°C
- Humidity Range: 40%-60%
- Store indoors
- Keep away from direct sunlight

Expected Product Lifetime

- 5 Years

MAIN COMPONENTS:

The EMG device consists of several components. Some of which are to be used near the subject and are electrically isolated while some are near and connected to the computer. The two are linked by an analog cable.

Differential amplifier.

The differential amplifier has a shielded 3-pin mini connector to accept a twin electrode lead. A cable connects the amplifier to the isolation unit via a Push/pull-style connector. It performs an analog subtraction of the signal from one surface electrode from the other. The amplifier is small enough to be worn near the measurement site (e.g. wear it on the wrist to measure finger muscles). A snap connector is fixed to the case to

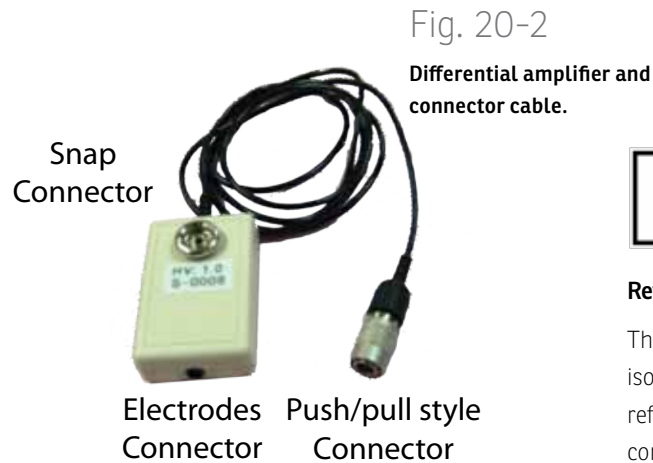


Fig. 20-2

Differential amplifier and connector cable.



Reference electrode lead

The reference electrode lead is connected directly to the isolation box using a 1.5mm mini-din connector. The reference electrode is connected to the lead by a snap connector. You can use the same surface electrode as with the other electrodes, however a larger reference electrode is preferred when available. You can also use disposable reference electrodes (e.g. Ambu® Neuroline Ground electrodes)

allow you to snap it to a velcro strap (e.g. to be worn on the wrist).



Short electrode leads

The electrode lead is specially designed to minimise signal contamination from external electrical sources (e.g. 50-60 Hz mains). It is shielded and uses a single mini 3-lead plug for the two electrode signals and the shield ground. The electrode connector is a standard snap style to ensure compatibility with a variety of surface electrodes (e.g. MEDI-TRACE™ Mini 130 Pediatric Foam Electrodes or equivalent).



Fig. 20-3

Twin-electrode lead.



Fig. 20-4

Reference electrode lead



Isolation unit.

The isolation box can accommodate the signals from two differential amplifier pods. The top of the box has two push/pull style connectors, one for each amplifier pod and a 1.5mm mini-din receptacle for the reference lead. The top of the box (Fig. 20-5, right) has a larger push/pull connector for one end of the analog cable which links to the analog receiver.



The connectors leading to the amplifier and the reference lead are Type BF applied parts.

Analog Receiver

The Analog receiver can either be a standalone box, or incorporated into a Brainsight computer trolley inside the "I/O Box".

The standalone receiver includes the receiver and a medical grade power supply. The front of the standalone box has a DB-25 connector (labelled "analog Input") to connect to the isolation box, a USB connector to connect to the Brainsight computer and a power input jack for the medical grade power supply. The rear of the box has three BNC connectors, two for TTL triggers (from up to two TMS devices) and one for a switch.



Fig. 20-5

**Isolation unit: Left: viewed from the top.
Right: Viewed from the bottom.**

Brainsight computer I/O Box

Many models of the Brainsight computer include the functionality of the analog receiver built-into a more general I/O box. In addition to the analog receiver functionality, it also includes power leads for the position sensor and computer as well as additional serial and USB ports. See Chapter 19 for more details.

CLEANING THE EMG DEVICE

If you need to clean peripherals likely to be in contact with different subjects, they can be cold-sterilised with an appropriate sterilizing agent. No part of the system can



To maintain compliance with IEC 60601-1 regarding the earth leakage current, the computer connected via the USB cable must conform to IEC 60601-1 standard for medical device safety. If the computer does not conform to this standard, the computer and/or the IOBox mains must be connected to a medical grade isolation transformer (e.g. ISB-100W from Toroid Corporation of MD). In any case, the subject must always be kept out of reach of the computer and any peripheral connected to it in order to prevent touch current.

be placed in an autoclave. Shut down and disconnect all cables before cleaning. Use a damp, soft, lint-free cloth and mild detergent, with isopropyl alcohol swabs, or with a 70% isopropyl alcohol solution to clean the exterior of the enclosures. Avoid getting moisture in any openings. Do not spray liquid directly the enclosures. Don't use aerosol sprays, solvents, or abrasives.

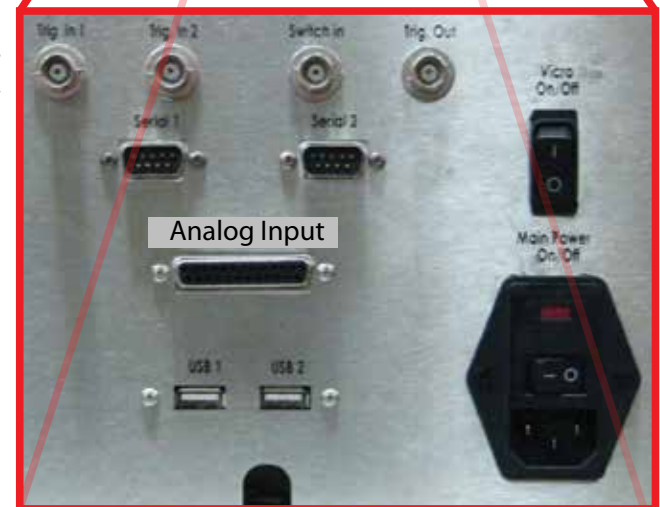


Fig. 20-6

Standalone Analog Receiver with power supply: Left: Front of unit with analog input connector, USB connector and the DC input connector. Lower left: Medical grade power supply. Below: Rear of receiver with trigger inputs. Right: I/O box as Brainsight computer trolley.



INSPECTING THE EMG DEVICE

All components should be visually inspected before each use to ensure that no mechanical deterioration has occurred. It is important to periodically visually examine the cables covering for cuts tears as well as checking the connectors for bent pins, exposed wires or any other damage.

PREPARING THE EMG DEVICE FOR USE

Before using the device, make sure that you have enough unused surface electrodes (two per channel) and a reference electrode. Review Fig. 20-1 for a complete wiring diagram.

If you have the standalone analog receiver:

Connect the analog receiver to the Brainsight computer:

1. Plug the medical grade power supply to a main power outlet.
2. Using the included USB cable, connect the USB port on the analog receiver to a USB port on the computer.
3. Connect the medical grade power supply to the DC input on the front panel of the analog receiver to activate the receiver. To deactivate the receiver, either unplug the DC input at the receiver, or unplug the medical grade power supply from the main outlet.
4. Using a cable with BNC connectors, connect the output trigger of the TMS device to one of the trigger-in ports of the analog receiver.

If you have the I/O box:

1. Make sure the main switches on the rear panel of the I/O box and the isolation transformer are set to off.
2. If this is the first time the I/O box is being used, verify that the fuses on both the isolation transformer and on the I/O box are set to the appropriate voltage for your area. Use two T10A fuses for 120VAC or use two T5A fuses for 240VAC on the I/O box and for the isolation transformer follow the user guide provided by the manufacturer. If it is not already properly set, contact Rogue Research before connecting the I/O box to the computer, or the mains outlet.
3. Connect the medical grade isolation transformer to a wall outlet. To ensure reliable grounding plug the



Always connect the cable to a USB port directly on the computer, or powered USB hub. Connecting it to a secondary USB port (e.g. a keyboard USB port) may result in unreliable operation, or a USB current overload error message on your computer.

isolation transformer into an hospital grade wall outlet. Make sure the outlet is capable of providing 1000VA.

4. Connect the I/O box to the medical grade isolation transformer.



Do not connect any thing else than the I/O box to the medical grade isolation transformer, doing so may cause over charge to the system and result in a non-safe operation of the system.

5. If not already done, using the 2 USB cables, connect the 2 USB ports at the front of the I/O box to 2 USB ports on your Brainsight computer. The upper port (USB 1) connects the analog receiver (inside the box) while the lower port (USB 2) connects the Polaris Vicra, the 2 serial ports (via a USB-Serial adapters) and the two utility USB ports on the rear panel of the I/O box.
6. If not already the case, connect the included power cable between the power connector of the front of the I/O box to the Brainsight computer. This is helpful for computers that are placed on mobile trolleys as it consolidates all power to the single power cable connected to the main switch.



Only computer compliant to IEC60950 should be used as part of the system.

Connecting the EMG Parts to the Analog Receiver

1. Connect one or both amplifiers to the isolation box by plugging in the connector(s) into the receptacle(s)

labelled “CH 1” or “CH 2” on the isolation box by holding the connector by the black plastic portion, gently pushing the connector into the receptacle while rotating the connector until it clicks into the receptacle (i.e. they are correctly aligned).

2. Connect the analog cable to the isolation box by plugging the larger connector into the receptacle of the isolation box labelled “To Analog Receiver” using the same method as with the amplifier connector above.



Always connect the cable to a USB port directly on the computer, or powered USB hub. Connecting it to a secondary USB port (e.g. a keyboard USB port) may result in unreliable operation, or a USB current overload error message on your computer.

3. Connect the other end of the analog cable (DB-25 connector) to the analog receiver (either the standalone box, or the computer I/O box) by pushing it into the connector labelled “Analog Input” and secure it by tightening the two thumbscrews on either side of the connector.



If only one channel is used, unplug the unused channel to prevent accidental contact with non-isolated device or undesirable voltage source.

USING THE EMG DEVICE.

1. Make sure the subject is kept far enough away from

the computer to prevent touching it.

2. Decide on your measurement location. Typically one electrode goes on a muscle and the other on a bony location near the first electrode. Fig. 20-7 shows a typical electrode configuration.
3. Place the isolation box near the subject. The box comes with a belt clip to allow the subject to wear it on the waist.
4. Using the Velcro strap, attach the differential amplifier to the subject close enough such that the short leads can reach the electrodes. The Velcro strap has a snap on it that snaps into a receptacle on the amplifier. For a finger twitch (using TMS) exercise, placing the strap around the wrist is a good choice.
5. Connect the snap end of the short electrode leads to the surface electrodes, and the shielded mini-din into the amplifier pod. **Note that disposable electrodes should only be used once. A “flat line” may result if the electrodes are reused or have expired.**
6. Prepare the skin surface according to the instructions that came with the surface electrodes.
7. Apply the electrodes to the skin following the instructions that came with the electrodes.
8. Repeat steps 4-7 for the second channel if you are planning to use it.
9. Attach the reference lead to the subject, usually on a bony surface or other reasonable neutral location (e.g. away from muscle).



Fig. 20-7

Example of electrode placement (the electrode on the index finger would actually be better if it were on the knuckle).

10. Connect the other end of the reference lead into the reference connector on the isolation box.
11. Follow the instructions included with your Brainsight system to configure the software to record the data from the EMG unit and perform your experiment according to your protocol.

Examine the paths of all the wires, particularly the ones from the amplifier to the isolation box, and from the isolation box to the analog receiver. Try to avoid loops in the wire as they may pick up noise. Keep the wires away from the TMS coil. To minimise noise from the input, short electrodes leads can be twisted. This will reduce the loop area and it's likely to induce less noise on



the inputs.

SAFELY TERMINATING USE OF THE EMG DEVICE

The Brainsight EMG device was designed to operate in a safe and reliable manner. If for any reason, the use of the device needs to be terminated quickly and safely, simply do ANY of the following:

- Remove the electrodes (both the signal electrodes and the reference electrode) from the subject. The electrodes are self adhesive and are easily removed. They can be removed at any time.
- Disconnect the differential amplifier and reference lead. You can either disconnect the electrode cable from the amplifier by pulling out the connector, or the amplifier from isolation unit by pulling out the connector. Disconnect the reference lead cable from the isolation unit by pulling the connector out of the receptacle.
- Disconnect the isolation unit from the Brainsight computer. You can disconnect it by pulling the cable connector out of the receptacle of the isolation box.

ERROR MESSAGES

Error messages related to the EMG device are displayed in the trigger options window (Fig. 13-12). The following is a list of error messages and remedies:

No trigger box hardware can be found

See the Troubleshooting section for instructions on verifying that the hardware is connected properly.

TROUBLESHOOTING

Your EMG unit was designed to be easy to use and to provide accurate results. Nevertheless, some problems may occur.

The EMG (or anything else) is not sampled when the coil is triggered.

This can occur if the trigger pulse from the TMS device is either not reaching the trigger-in is the analog receiver, or if the trigger signal is not compatible with the I/O box. First, make sure the trigger cable is correctly plugged in (and that the cable is not damaged). Next, verify that Brainsight is correctly configured to trigger an event recording using the correct trigger in. Finally, the trigger pulse itself must be a rising pulse (0-5V) and must last longer than 5ms.

The EMG is being triggered, but the resulting waveform is flat, random noise.

Check that the surface electrodes and reference electrode are properly fixed to the subject's skin, and in the case of disposable electrodes, that they are fresh. Make sure that the electrode leads are correctly plugged into the amplifier and that the reference lead is correctly plugged into the isolation box. Check that the amplifier(s) are plugged into the isolation box and that the isolation box is connected to the analog receiver. Make sure you are stimulating an area that should elicit an MEP response in the muscle being monitored. Check that you have configured Brainsight to sample the same amplifier (e.g.

channel 1 or 2) that you are using.

The EMG is being triggered and we see a waveform, but we are also getting a lot of noise.

Make sure that the electrodes are well secured on the skin, and that the skin was prepared before fixing the electrodes (e.g. rubbed with an alcohol wipe etc...). Make sure the locations of the electrodes are correct. Make sure that the reference lead is well placed and properly fixed to the skin. Make sure that the cables are not near the TMS coil when in use. Keep the cables away from large sources of electromagnetic radiation and prevent loops in the cables.

Further Assistance

If your problem was not solved with the above information, you can contact us directly by visiting our user forums (www.rogue-research.com/forums) or e-mail us at support@rogue-research.com. Finally, we can be reached at +1 514 284-3888 (or toll free in North America at 1-866-984-3888).

ELECTROMAGNETIC COMPATIBILITY

Medical electrical equipment requires special precautions regarding EMC and needs to be installed and put into service according to the EMC information provided in this manual.

Portable and mobile RF communications equipment can affect Medical Electrical Equipment.

The EMG unit should not be used adjacent to or stacked with other equipment and that if adjacent or stacked use is necessary, the EMG unit should be observed to verify normal operation in the configuration in which it will be used.

The use of Accessories, transducers, and cables other than those specified by the manufacturer, may result in increased Emissions or decreased Immunity of the EMG unit.

EMG SYSTEM SPECIFICATIONS

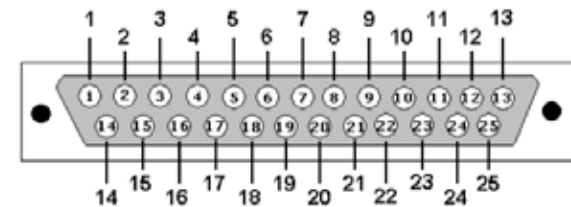
Overall System:

- Overall EMG Amplification:
Models 1 & 2 amplifiers 13500 V/V:
Model 3 amplifiers 4444 V/V:
- Input range: **Models 1 & 2:** 1.5mVpp,
Model 3, 4.5 mVpp
- Overall Bandwidth: 16-470 Hz
- Overall Noise: **Models 1 & 2:** <5.33 μ Vpp (R.T.I),
Model 3: <10 μ Vpp (R.T.I)
- ADC resolution: 12 bit
- ADC sampling rate: 3kHz per channel
- Power Consumption: 9Vdc, 1.5 A and USB 5Vdc, 500mA
- BF Applied part Isolation Voltage: 5300 VRMS

Sensors

- Bandwidth: 16-550 Hz
- CMRR (60Hz): -115 dB (typical)
- Input Impedance: 300 (minimum), 1250 (Typical) G Ω //1.6pF

| Pin | Description | Pin | Description |
|-----|-------------------|-----|-------------------|
| 1 | 5V USB bus | 14 | 0V USB bus |
| 2 | Ch1+ | 15 | 0V USB bus |
| 3 | Ch1- | 16 | Ch2+ |
| 4 | 0V USB bus | 17 | Ch2- |
| 5 | Ch3+ | 18 | 0V USB bus |
| 6 | Ch3- | 19 | Ch4+ |
| 7 | 0V USB bus | 20 | Ch4- |
| 8 | 5V USB bus | 21 | NC |
| 9 | NC | 22 | NC |
| 10 | NC | 23 | NC |
| 11 | NC | 24 | NC |
| 12 | NC | 25 | 0V Medical Supply |
| 13 | 9V Medical Supply | | |



Guidance and manufacturer's declaration –electromagnetic emissions

The EMG unit is intended for use in the electromagnetic environment specified below. The customer or the user of the EMG unit should assure that it is used in such an environment.

| Emissions test | Compliance | Electromagnetic environment – guidance |
|--|------------|--|
| RF emissions CISPR 11 | Group 1 | The EMG unit uses RF energy only for its internal function. Therefore, its RF emissions are very low and are not likely to cause any interference in nearby electronic equipment. |
| RF emissions CISPR 11 | Class A | The EMG unit is suitable for use in all establishments other than domestic and those directly connected to the public low-voltage power supply network that supplies buildings used for domestic purposes. |
| Harmonic emissions IEC 61000-3-2 | Class A | |
| Voltage fluctuations / flicker emissions IEC 61000-3-3 | Complies | |

Recommended separation distances between portable and mobile RF communications equipment and the EMG unit

The EMG unit is intended for use in an electromagnetic environment in which radiated RF disturbances are controlled. The customer or the user of the EMG unit can help prevent electromagnetic interference by maintaining a minimum distance between portable and mobile RF communications equipment (transmitters) and the EMG unit as recommended below, according to the maximum output power of the communications equipment.

| Rated maximum output power of transmitter W | Separation distance according to frequency of transmitter m | | |
|---|--|----------------------|-----------------------|
| | 150 kHz to 80 MHz | 80 MHz to 800 MHz | 800 MHz to 2,5 GHz |
| | $d = 1.2\sqrt{P}$ | $d = 1.2\sqrt{P}$ | $d = 2.3\sqrt{P}$ |
| 0,01 | 0.12 | 0.12 | 0.23 |
| 0,1 | 0.38 | 0.38 | 0.73 |
| 1 | 1.2 | 1.2 | 2.3 |
| 10 | 3.8 | 3.8 | 7.3 |
| 100 | 12 | 12 | 23 |

For transmitters rated at a maximum output power not listed above, the recommended separation distance d in meters (m) can be estimated using the equation applicable to the frequency of the transmitter, where P is the maximum output power rating of the transmitter in watts (W) according to the transmitter manufacturer.

NOTE 1 At 80 MHz and 800 MHz, the separation distance for the higher frequency range applies.

NOTE 2 These guidelines may not apply in all situations. Electromagnetic propagation is affected by absorption and reflection from structures, objects and people.


Guidance and manufacturer's declaration –electromagnetic immunity

The EMG unit is intended for use in the electromagnetic environment specified below. The customer or the user of the EMG unit should assure that it is used in such an environment.

| Immunity test | IEC 60601 test level | Compliance level | Electromagnetic environment – guidance |
|---|---|---|--|
| Electrostatic discharge (ESD) IEC 61000-4-2 | ±6 kV contact ±8 kV air | ±6 kV contact ±8 kV air | Floors should be wood, concrete or ceramic tile. If floors are covered with synthetic material, the relative humidity should be at least 30 %. |
| Electrical fast transient/burst IEC 61000-4-4 | ±2 kV for power supply lines ±1 kV for input/output lines | ±2 kV for power supply lines ±1 kV for input/output lines | Mains power quality should be that of a typical commercial or hospital environment. |
| Surge IEC 61000-4-5 | ±1 kV differential mode ±2 kV common mode | ±1 kV differential mode ±2 kV common mode | Mains power quality should be that of a typical commercial or hospital environment. |
| Voltage dips, short interruptions and voltage variations on power supply input lines IEC 61000-4-11 | <5 % U_T (>95 % dip in U_T) for 0,5 cycle 40 % U_T (60 % dip in U_T) for 5 cycles 70 % U_T (30 % dip in U_T) for 25 cycles <5 % U_T (>95 % dip in U_T) for 5 sec | <5 % U_T (>95 % dip in U_T) for 0,5 cycle 40 % U_T (60 % dip in U_T) for 5 cycles 70 % U_T (30 % dip in U_T) for 25 cycles <5 % U_T (>95 % dip in U_T) for 5 sec | Mains power quality should be that of a typical commercial or hospital environment. If the user of the EMG unit requires continued operation during power mains interruptions, it is recommended that the EMG unit be powered from an uninterruptible power supply or a battery. |
| Power frequency (50/60 Hz) magnetic field IEC 61000-4-8 | 3 A / m | 3 A / m | Power frequency magnetic fields should be at levels characteristic of a typical location in a typical commercial or hospital environment. |
| NOTE U_T is the a.c. mains voltage prior to application of the test level. | | | |

Guidance and manufacturer's declaration –electromagnetic immunity

The EMG unit is intended for use in the electromagnetic environment specified below. The customer or the user of the EMG unit should assure that it is used in such an environment.

| Immunity test | IEC 60601 test level | Compliance level | Electromagnetic environment – guidance |
|--|--|-------------------------|--|
| <p>Conducted RF IEC 61000-4-6</p> <p>Radiated RF IEC 61000-4-3</p> | <p>3 Vrms 150 kHz to 80 MHz</p> <p>3 V/m 80 MHz to 2,5 GHz</p> | <p>3 V</p> <p>3 V/m</p> | <p>Portable and mobile RF communications equipment should be used no closer to any part of the EMG unit, including cables, than the recommended separation distance calculated from the equation applicable to the frequency of the transmitter.</p> <p>Recommended separation distance</p> <p>$d = 1.2\sqrt{P}$</p> <p>$d = 1.2\sqrt{P}$ 80 MHz to 800 MHz</p> <p>$d = 2.3\sqrt{P}$ 800 MHz to 2,5 GHz</p> <p>where P is the maximum output power rating of the transmitter in watts (W) according to the transmitter manufacturer and d is the recommended separation distance in metres (m). Field strengths from fixed RF transmitters, as determined by an electromagnetic site survey, ^ashould be less than the compliance level in each frequency range. ^b Interference may occur in the vicinity of equipment marked with the following symbol:</p> <div style="text-align: center;">  </div> |

NOTE 1 At 80 MHz and 800 MHz, the higher frequency range applies.

NOTE 2 These guidelines may not apply in all situations. Electromagnetic propagation is affected by absorption and reflection from structures, objects and people.

^a Field strengths from fixed transmitters, such as base stations for radio (cellular/cordless) telephones and land mobile radios, amateur radio, AM and FM radio broadcast and TV broadcast cannot be predicted theoretically with accuracy. To assess the electromagnetic environment due to fixed RF transmitters, an electromagnetic site survey should be considered. If the measured field strength in the location in which the EMG unit is used exceeds the applicable RF compliance level above, the EMG unit should be observed to verify normal operation. If abnormal performance is observed, additional measures may be necessary, such as re-orienting or relocating the EMG unit.

^b Over the frequency range 150 kHz to 80 MHz, field strengths should be less than 3 V/m.

ANALOG CABLE PINOUTS

Note that only Channels 1 & 2 are used

PARTS LIST

Standalone

| | |
|--|-----------------|
| 1x Power cord for AC input Medical grade for North America | CA-0001 |
| 1x USB 2.0 Cable 6FT long | CA-0005 |
| 1x BNC Coaxial Cable 10FT long for trigger port | CA-0006 |
| 1x Analog Cable | ANAC001001 |
| 1x Reference electrode Lead Green 1.5mm DIN | 441273X25036001 |
| 2x Short electrode Leads Black 1.5mm DIN | 444222X05003V01 |
| 1x Medical Grade Power Supply 9Vdc 1.5A | MW170KB0903F01 |
| 2x Differential amplifier | SENS001002 |
| 1x Analog Receiver Unit | ANAR001001 |
| 1x Isolation unit | BELT001002 |

I/O box

| | |
|--|-----------------|
| 1x Power cord for AC input Medical grade for North America | CA-0001 |
| 1x IEC 60320 Sheet E to C13 Power cord | CA-0004 |
| 2x USB 2.0 Cable 6FT long | CA-0005 |
| 1x BNC Coaxial Cable 10FT long for trigger port | CA-0006 |
| 1x Analog Cable | ANAC001001 |
| 1x Reference electrode Lead Green 1.5mm DIN | 441273X25036001 |

2x Short electrode Leads Black 1.5mm DIN
444222X05003V01

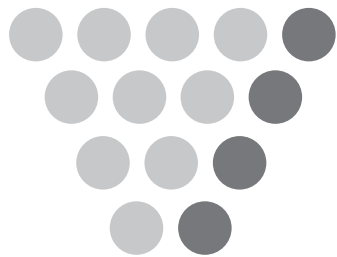
| | |
|---|------------|
| 2x Differential amplifier | SENS001002 |
| 1x Isolation unit | BELT001002 |
| 1x I/O box includes Medical Grade Power Supply and Analog Receiver Unit | NTBX001001 |
| 1x Medical grade isolation transformer | ISB-100W |

DISPOSAL

Dispose of the product in accordance with your local government requirements. Contact your local recycling centre for more information. For more information about product content contact Rogue-Research inc.

Brainsight[®]

TMS



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