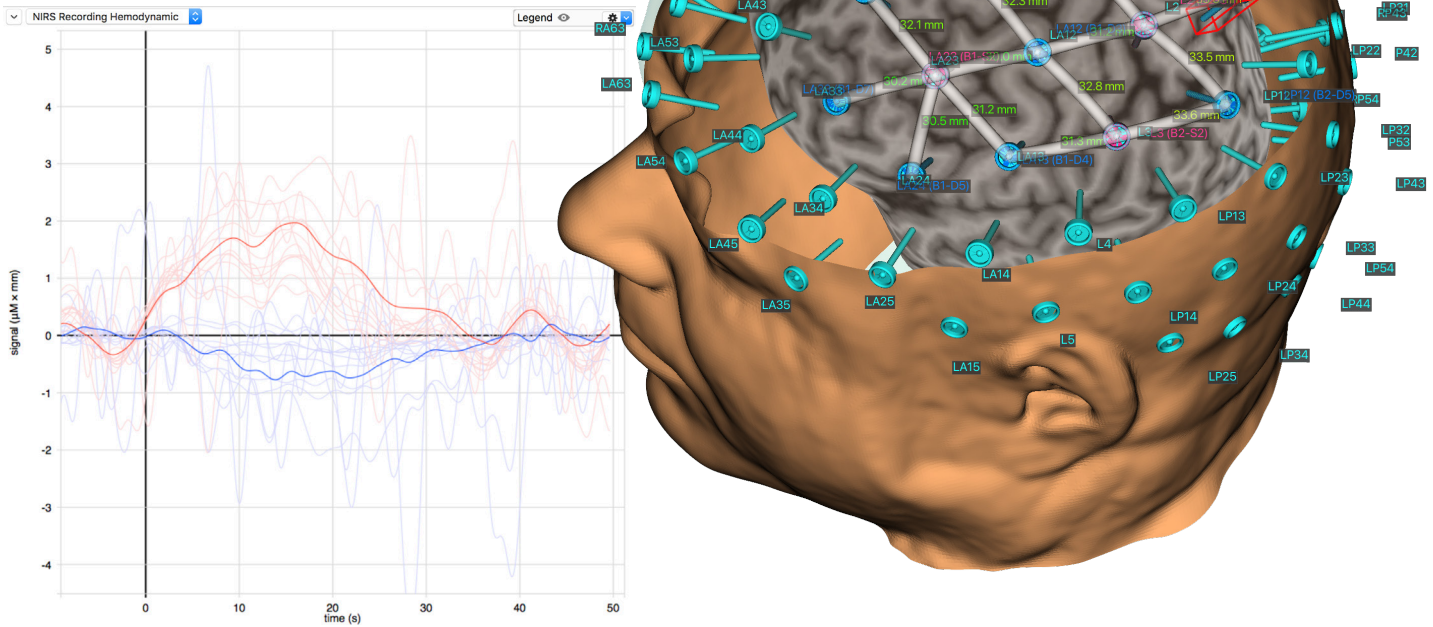
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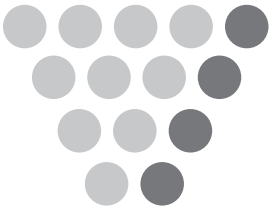
NIRS

USER MANUAL

v2.5.14

(Nov 2026)





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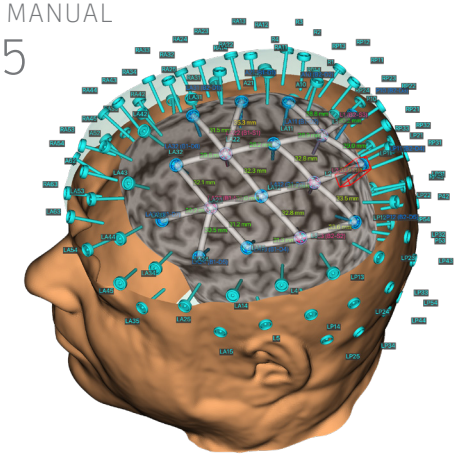
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Labjack exodriver

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CocoaAsyncSocket

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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

Note: the project file format has changed (if migrating from 2.4 or earlier). Brainsight 2.5.x can open documents created by older versions of Brainsight, but older versions of Brainsight cannot open documents created by Brainsight 2.5.x.

Changes in version 2.5.14 (since 2.5.13): (2026-11-06)

- Fixed a bug in VetRobot tool calibration where unexpected robot arm movements could occur when using the cartesian movement controls.
- Fixed a bug exporting tool calibrations to .xfm files where the resulting file would have garbage values, but only if the calibration procedure was not actually completed, now it will refuse to export until the calibration procedure is completed.
- Fixed a bug in the Session Axilum window where the Polaris camera body and its field of view were not being displayed in the 3D view.
- Fixed a cosmetic bug in offline Session Perform windows where a horizontal line was being drawn through some buttons near the bottom left of the window.
- Fixed miscellaneous bugs.

Changes in version 2.5.13 (since 2.5.12): (2026-05-27)

- Fixed a bug exporting .nirs files where the correspondence between the detector optode names (SD.XXX field) and their corresponding names (SD.YYY field) would be incorrect, but only if proximity detectors were involved.
- Fixed miscellaneous bugs.

Changes in version 2.5.12 (since 2.5.11): (2026-04-02)

- Worked around a bug where Brainsight would freeze (on macOS 10.13 only) when trying to activate speech recognition, for example when opening a tool calibration window. Activating speech recognition

manually will still freeze, and this is a macOS bug. If you are still using macOS 10.13 (released 2017), please update.

- Added a warning about the fact that Polaris Vicra cameras are now end-of-life. Units with serial number P6-01513 or older are unfortunately already not serviceable, and newer units are serviceable until 2030.
- Performing simulations with SimNIBS and BabelBrain is no longer allowed for markers, since they have no orientation. Trajectories must be used instead.
- Added a new option for Vet Robot stereo calibration to support the new 45 degree marmoset configuration.
- Fixed a bug where cloning a session did not preserve visualisation settings for vector fields.
- Fixed miscellaneous bugs.

Changes in version 2.5.11 (since 2.5.10): (2026-02-06)

- Fixed a bug where speech recognition did not work on macOS 26 Tahoe.
- Improved the network server feature to provide more information related to the currently selected target. A new packet named 'request:get-current-target-in-session' can be used to get the current target information at any time, and the existing 'response:create-sample' and 'response:list-session-targets' packets were updated to also include information about the current target.
- Fixed a bug where if an inline, inline 90, or perpendicular view was first panned and then zoomed, portions of the crosshairs were drawn in the wrong place.
- Fixed a bug where the (subtle) direction indication in the disc shape for targets was rotated 90 degrees.
- Fixed miscellaneous bugs.

Changes in version 2.5.10 (since 2.5.9): (2025-11-27)

- Fixed a bug where invoking BabelBrain to compute a TMS simulation would fail if the anatomical NIfTI file did not contain a qform.
- Added a new button to attempt to clear error conditions reported by the Vet Robot. This is mostly to use in response to the 'critical motion error', should it occur.
- Improved error messages when the Vet Robot reports an error.
- Made the green dots representing Polaris tools in 2D views a little bit bigger, thus easier to see from farther away.
- Fixed a rare bug where 2D and 3D MPR slices could sometimes appear blank. This only happened with certain datasets with particular spacing.
- Fixed a cosmetic bug where the NIRS wavelength selection buttons were still visible even if the legend was collapsed.
- Fixed miscellaneous bugs.

Changes in version 2.5.9 (since 2.5.8): (2025-07-04)

- Various text fields (particularly those related to coordinates or matrices) now allow entering more decimal digits.
- Exported Brainsight .txt files (from Review window, or file streaming feature) now use many more decimal digits, for more exact results.
- When invoking SimNIBS, a custom coil file can now be specified (instead of only being able to choose from a fixed popup list).
- Improved Vet Robot stereo calibration results when using 50 mm lenses.
- Improved Vet Robot tool calibration quality, especially for unusual tool shapes and orientations.
- When creating Vet Robot tool calibrations, the user interface now gives more information on the quality of the calibration.
- Fixed miscellaneous bugs.

Changes in version 2.5.8 (since 2.5.7): (2025-03-28)

- Fixed a bug in the 'response:select-target-in-session', 'response:list-session-targets', 'response:create-sample', 'stream:sample-creation', and 'stream:sample-emg' packets where the 'coordinate-system' field behaved as intended, but the 'position' field was always in Brainsight coordi-

nates instead of the indicated coordinate system.

- Fixed miscellaneous bugs.

Changes in version 2.5.7 (since 2.5.6): (2025-02-26)

- Fixed a bug in the 'create-target-at-location' packet in the network protocol where the reported index path of the created target would (usually) be incorrect if there were any folders amongst the session's targets.
- Changed the 'create-target-at-location' packet in the network protocol to allow the target position to be unspecified, in which case the target will be positioned at the current crosshairs position in the Session Perform window.
- When exporting curvilinear reconstructions to a file, they are now always coloured using the anatomical's voxels. For curvilinears created from ROI, this is a bug fix because previously they weren't being coloured at all. For curvilinears from overlays, this is a behaviour change as they were previously coloured from the overlay they were created from.
- Fixed miscellaneous bugs.

Changes in version 2.5.6 (since 2.5.5): (2025-01-24)

- Brainsight can now act as a TCP/IP network server, and accept connections from one or more client applications. Clients can request that Brainsight perform certain actions, and Brainsight can inform clients when certain events occur. We provide documentation for the network communication protocol and sample Python code. (This feature requires at least macOS 10.14, and 10.15 for full functionality.)
- Oblique images (inline, inline 90, and perpendicular) use a better interpolation algorithm and thus now appear less grainy.
- Fixed a bug where long EMG channel names (from NEURO PRAX) were sometimes truncated in the legend.
- Improved error messages when connection to a network-based Polaris fails.
- Fixed miscellaneous bugs.

Changes in version 2.5.5 (since 2.5.4): (2024-11-22)

- Made substantial improvements to Vet Robot tool calibration. The workflow is mostly the same except that you no longer need to identify the tool tip and shaft in both cameras simultaneously, you can instead do so in one camera at a time, which is helpful as the camera field of view is small and it can be hard to position a tool to be visible in both simultaneously. The algorithm that calculates the tool calibration is also much improved, giving more accurate tool calibrations.
- Improved Vet Robot tool-relative movement user interface to be more intuitive, and consistently move and rotate the tool around its axes: injection/retraction, left/right, forward/backward. Previously, the behaviour was not predictable.
- Vet Robot target reachability checks now have the option of checking that not only is the target itself reachable, but that a few millimetres deeper is also reachable. A new textfield in the Perform window allows setting this amount.
- Improved Vet Robot stereo calibration for small animal systems, to better cover the cameras' field of view.
- Fixed a rare bug where Vet Robot stereo calibration could get stuck in an infinite loop.
- When importing targets from a text file, if the coordinate system name is set to "Relative", the positions in the file can be interpreted as relative to another (already-existing) target.
- Fixed a bug where projects based on a SimNIBS .gmsh file could get the NIfTI sform and qform confused and result in an error message when invoking BabelBrain to perform a TMS simulation.
- Fixed a bug where Polaris tool tracking could sometimes show the subject tracker move with respect to the subject's head. This was merely a visual glitch, and did not affect correctness.
- Improved performance working with many targets (example: big grids).
- Improved performance working with many electrodes (example: big EEG/NIRS caps).

- Improved performance opening .dxf files.
- The Polaris firmware version number is now shown in the Polaris Configuration window.
- In waveform views, when in staggered mode, you can now click a waveform to get a tooltip showing the channel name.
- Fixed a crash opening corrupt project files.
- Fixed a bug where recalibrating a NIRS block would program an incorrect version number into the block's memory.
- Fixed a bug where the bullseye view would show a TMS coil in the background when a fUS tool was being used.
- Fixed a bug where the Vet Robot firmware version number would sometimes be displayed incorrectly.
- Fixed a bug where changing a sample's EMG peak-to-peak value or its "contribute" checkbox would fail to refresh the sample's colour in 2D and 3D views.
- Fixed a bug where changing the time index in a 4D overlay would sometimes fail to refresh 2D and 3D views.
- Fixed a bug where, if there were multiple surface reconstructions, changing the colour or other attribute of one would sometimes fail to refresh 3D views.
- Fixed a bug where, if there were multiple curvilinear reconstructions, changing the peel depth of one would sometimes fail to refresh 3D views.

Fixed miscellaneous bugs. Changes in version 2.5.4 (since 2.5.3): (2024-06-26)

- Moved some user interface controls from the bottom to the top of the window, namely the 3D Crosshairs and Driver popup buttons. This gives more vertical space for images and makes the contents of the popup menu less likely to overflow.
- Added a new option in the Trigger Options window to allow creating samples even when the relevant Polaris tools are not visible (by default samples cannot be created when, for example, the coil tracker is not visible.)
- Now default to looking for SimNIBS 4.1 (newest at time of writing), instead of 4.0. If you have an older (or newer) version, adjust the path in Brainsight > Settings.
- Added a fourth set of tool-relative Vet Robot movement controls that only have buttons to inject and retract the tool. The controls that allow the more dangerous tool-relative rotations are now separated in a different pane.
- No longer allow Vet Robot to move to a marker-type target, only to trajectory-type targets. This is a safety precaution because, although markers technically have an orientation, it's not displayed, and so the robot risks moving in an unexpected direction.
- Fixed a bug where Vet Robot subject registration would fail if the skull reconstruction was not watertight and consisted of several disjoint pieces and one of the initial registration landmarks was touching a secondary piece.
- For Vet Robot sessions, the default threshold range in the Validation step was tightened from 0.5 to 0.3 mm, reflecting recent improvements in system accuracy.
- Made various improvements for Axilum Robot / Cobot support:
  - An error message is now shown if the Cobot is not in MCP (manual control panel) mode.
  - Added functionality to switch Cobot sides.
  - The force sensor check procedure must now be redone if the coil is changed.
  - Coil names are now partly anonymized, to no longer reveal if a sham coil is being used (to help with blind studies).
  - Extended the range of the contact sensor sensitivity.
- The Polaris Lyra is now configured to track at 30 Hz instead of 20 Hz.
- Fixed a bug where a bumps to a Polaris were not reported.
- Fixed a bug that could result in a failure to read some valid NIfTI files, for example those generated by BabelBrain.

- Fixed a bug where vector field arrows (for TMS simulation for example) sometimes did not display when then should have.
- Fixed a bug where 4D datasets with exactly 4 time components would be interpreted and drawn as vector fields.
- Added a new fUS transducer option for 3D Cross-hairs shape.
- Added a new button next to the scene selection popup menu to quickly customize a view.
- A TMS coil is no longer shown in bullseye views when the selected tool calibration is fUS-type.
- Creating a surface/skin reconstruction is now about 25% faster.
- Creating a curvilinear reconstruction is now about 35% faster.
- Fixed various crashes that could occur opening corrupt files.
- Fixed miscellaneous bugs.

Changes in version 2.5.3 (since 2.5.2): (2024-03-01)

- Brainsight can now simulate the acoustic effect of transcranial focused ultrasound (fUS) at a target location. It does this by interacting with BabelBrain, a third party software that must be installed separately. The Targets window now allows invoking BabelBrain, wherein simulation parameters can be set. The resulting simulation appears overlaid in 2D and 3D images, and can be customized from the Inspector window.
- When writing to our .txt file formats, we now use slightly different coordinate system names for NIfTI files, which may require updating code that reads these files. The coordinate system name now includes whether it's from the file's sform or qform. So, for example, where we used to use a string like "NIfTI:Scanner" we now use "NIfTI:Q:Scanner". For this reason, exported .txt files increased from version 13 to 14, and .txt files created by streaming increased from version 6 to 7.
- Improved performance when creating hundreds of samples. There should be noticeably less latency between the trigger that creates a sample and its appearance in the application.
- Substantially improved accuracy of Vet Robot subject registration, thus improving accuracy results overall.
- Fixed a bug, introduced only in 2.5.2, where selecting two or more samples was not showing the average waveform for EEG and NIRS views (but was for EMG views).
- Fixed a bug where EMG waveform views sometimes did not show the visual indication (crosshatching) of when a waveform has exceeded the EMG pod device's maximum range of 2.25 mV.
- Fixed a bug in EMG views where the line indicating the EMG latency would sometimes not redraw after the time range was changed (with the green vertical bars).
- Fixed a bug where electrodes could still be clicked in 3D views, even when all electrodes were hidden.
- Fixed miscellaneous bugs.

Changes in version 2.5.2 (since 2.5.1): (Sept. 2023)

- Added calculation and display of EMG latency using the SHTE algorithm (by Šoda, Vidaković, Lorincz, Jerković, and Vujović). The Perform and Review windows now have a new optional table column that can show the latency for each sample. In addition, waveform views now draw a vertical line at the latency time. This line can be dragged to adjust the automatically computed value if it seems incorrect. Latency can also be exported to .txt files from the Review window.
- Each reconstruction can now be configured to participate in overlay blending or not. If the option is off, overlays will never be blended on that reconstruction. If the option is on, overlays will be blended atop that reconstruction, provided the overlay is enabled in the Inspector window (as usual). This option is on by default for curvilinear reconstructions, and off by default for surface reconstructions.
- A tool calibration's 4x4 matrix can now be exported to a MINC .xfm text file.
- The Vet Robot can now be moved relative to the currently used tool.

- The Session Polaris window now allows selecting the Polaris, and also has a button in bring up the Polaris Configuration window.
- More windows now have the option of showing the crosshair's numerical coordinates (at the bottom right).
- Fixed a bug where some projects with corrupt NIRS data would fail to load.
- Fixed a longstanding bug where the brightness/contrast slider did not work in the Curvilinear From Overlay and Surface From Overlay windows when an overlay was used as the source of the reconstruction.
- Fixed a bug where Brainsight would not automatically connect to a Polaris, even if it was detected.
- Fixed a bug where some image views would stop drawing after Brainsight was running in the background.
- Fixed a crash creating motor maps on old Macs with Nvidia GPUs .
- • Improved performance creating motor maps on Macs with Apple Silicon processors.
- Fixed several crashes that could occur when opening corrupt files of various formats.
- Fixed miscellaneous bugs.

Changes in version 2.5.1 (since 2.5): (2023-06-27)

- Fixed a crash in the Tool Calibrations window when using a TTL trigger to start the calibration procedure.
- There is now a user-resizable box in the ROI window to constrain the extent of the seed flood fill.
- There is a new disc shape option for targets and samples.
- Added support for the new Polaris Lyra® position sensor.
- Fixed a bug where vector fields from SimNIBS simulations were sometimes not shown correctly in the Session Perform and Session Review windows.
- Fixed a bug where the Park and Welcome buttons to move the Axilum robot/cobot were disabled when they shouldn't have been.
- If a sample cannot be created, a brief error message is now shown.
- Improved the robustness of the Vet Robot stereo calibration procedure.
- Fixed an error in the header comments of the stream-to-file feature.
- Fixed a bug where zooming a waveform image view sometimes did not work.
- Fixed a bug where the time index of 4D datasets was not shown correctly.
- Fixed miscellaneous bugs.

Changes in version 2.5.0 (since 2.4.11): (2022-03-24)

- Note: macOS 10.13 High Sierra is now the minimum requirement, increased from macOS 10.11 El Capitan in Brainsight 2.4. For a free update, visit https://support.apple.com/macos/upgrade. Contact us if you need to upgrade your Mac hardware.
- Brainsight can now simulate the induced electric field due to a TMS stimulation at a target location. It does this by interacting with SimNIBS, a third party software that must also be installed. The Targets window now allows associating a TMS coil model and stimulation strength with each target. The resulting simulation appears overlaid in 2D and 3D images, and can be customized from the Inspector window.
- 3D reconstructions (like the skin reconstruction) are now coloured by blending any enabled overlays atop the reconstruction's own colour.
- Overlays now support time series data (though only from NIfTI and MINC2 files, not other formats). The Overlays window and Inspector window now have a new slider to choose the time offset.
- Very large datasets (with more than 2^31 voxels) can now be used.
- Made various accuracy improvements to Vet Robot stereo calibration and subject registration, resulting in more accurate targeting during surgery.
- In the Session Perform window, creating new samples is now disallowed if the relevant Polaris tools are not visible.

- In the Session Perform window, the 'stream to file' feature now includes EMG waveform data and the coordinate system for selected targets and created samples.
- In the Session Perform window, the 'Sample Now' button is now disabled if the required tools are not visible to the Polaris camera.
- When working with the Axilum robot/cobot, a new 'scalp offset' distance can be specified to keep the TMS coil a few millimetres above the scalp to account for the thickness of an EEG cap for example.
- EMG waveform views now visually indicate when a waveform has exceeded the EMG pod device's maximum range of 2.25 mV.
- Added support for the Cornell University (Johnson, Philippa J; Barry, Erica F) canine atlas.
- Fixed various bugs with some DICOM datasets, where images would appear split in half, have gaps, or have missing slices.
- Fixed a longstanding bug where reconstructions based on ROIs would claim that re-computation was necessary, even though the ROI hadn't changed. (This was partly fixed in 2.4, but still occurred for re-opened projects.)
- ROIs can now be created by importing from a medical image file (DICOM, NIfTI, MINC, etc.).
- Fixed a bug in the ROI window where the pencil and eraser tools would not work correctly at the edge of view, especially when moving the mouse quickly.
- NIRS waveforms can be imported from a .nirs file, thus allowing importing data from other manufacturers' NIRS devices.
- Fixed a bug (introduced in Brainsight 2.4.11) where the SD.SrcPos and SD.SrcPos3D fields in exported .nirs files were swapped.
- Fixed a bug (introduced in Brainsight 2.4.5) where the SD.SrcPos field in exported .nirs files were in decimetres instead of centimetres. (The SD.SrcPos3D field was exported correctly in millimetres though.)
- Assembly Lists and Cap Layouts can now be created by importing from a .nirs file.
- Calibrating a TMS coil or other tool now allows for the tool tracker and calibration tracker to move together (relative to the camera), instead of failing if either tool moved relative to the camera.
- Polaris tool visibility status now uses a larger coloured area, making it more visible from father away.
- The enabled/disabled state of Polaris tools in the Polaris Configuration window are now remembered across quit/relaunch.
- Landmarks, targets, electrodes, and samples can now be clicked in 3D image views to select the corresponding item in the related table view.
- Targets can now be exported to a text file from the Targets window (export was previously possible, but only from the Session Review window).
- In the Targets window, if a reconstruction is chosen in the 'optimize traj. to' popup menu, clicking in 2D views no longer reorients crosshairs.
- Exporting curvilinear reconstructions in the PLY format now includes the voxel values in greyscale, whereas previously no colour was exported, only the shape.
- When exporting reconstructions as STL, VTK, and PLY you can now choose between the ASCII and binary variants of these file formats.
- • When importing a reconstruction from file, the object can now be placed relative to a chosen target (useful for placing chambers for example).
- The crosshairs in 2D image views now have a small gap in the middle so as not to obscure the very thing being targeted.
- Wherever 4x4 matrices can be imported from a file, a new file format is now supported namely plain text files with 16 numbers within.
- The crosshairs offset slider now allows a large range.
- When opening a project file, if there are referenced external files (datasets, CAD files) that can't be found, the dialog that asks to find them now (by default) disables files with different names, thus making it much easier to find the correct file.

- A new preference allows changing the colours of the bullseye views, especially useful for colour blind users.
- A new preference allows changing the font size of the bullseye views.
- A new preference allows specifying default EMG baseline and trial durations that will be used when creating new sessions.
- Native support for Apple Silicon processors.
- Improved support for macOS 11 Big Sur, macOS 12 Monterey, and macOS 13 Ventura.
- Various performance improvements:
- Exporting DXF files is now much faster, especially for large reconstructions.
- Updating an atlas space template overlay is now much faster.
- Reorienting the anatomical dataset is now much faster.
- Creating curvilinear reconstructions is now much faster.
- Creating skin and other surface reconstructions is faster.
- Fixed miscellaneous bugs.

Changes in version 2.4.11 (since 2.4.10): (2022-07-12)

- Fixed a longstanding (but rare) crash that occurred when closing a window that contains image views.
- Fixed a bug where the name of proximity detectors was not exported correctly in .nirs files.
- Fixed a bug where macOS could warn of an expired certificate by updating our Developer ID code signing certificate.
- Updated support for newest iterations of our Vet Robot hardware, notably for the NHP 45 degree inclination setup.
- Fixed a bug where the date/time metadata from MINC1 files would sometimes not be shown.
- Improved error checking when communicating with a Magstim TMS stimulator.
- Fixed miscellaneous bugs.

Changes in version 2.4.10 (since 2.4.9): (2022-03-01)

- Fixed a crash that could occur when computing the distance from a point to a surface, which occurs in several places, like the Targets and Session windows.
- Fixed a bug where importing a dxf file resulted in the colours being read incorrectly.
- Updated support for newest iterations of our Vet Robot hardware, notably the 50 mm lens.
- Fixed a small inaccuracy in the visual positioning of an LCT (large coil tracker) object in 3D images. (This did not affect the actual measured position of the tracker.)
- Fixed miscellaneous bugs.

Changes in version 2.4.9 (since 2.4.8): (2021-10-18)

- There is a new checkbox in the Session > IOBox step to indicate if you want to save or discard the live/full EMG waveform. It's usually not necessary to save it, because samples contain a copy of the EMG waveform just before and after the TMS pulse, and as it can grow very large it slows performance, especially saving and opening project files.
- Resuming a session no longer overwrites any existing live/full EMG waveform, instead it now appends new data to the end.
- Fixed a bug where the EMG pod was sometimes not detected between closing and resuming sessions or when disconnecting and reconnecting its USB cable.
- Fixed a bug where exporting .nirs files would fail if the project did not contain any NIRS Aux data.
- When stopping an Axilum session, we now perform an extra movement to make sure the robot arm stays in the working space.
- Fixed miscellaneous bugs.

Changes in version 2.4.8 (since 2.4.7): (2021-06-25)

- The Polaris Configuration window now has a new popup menu where you can choose which Polaris device to use. This is especially useful for network-based Polaris cameras, of which you may have several on your network.
- Fixed a bug where the application would sometimes

become unresponsive when communicating with a Polaris Vega.

- The 'extended pyramid' volume shape supported by some Polaris Spectra and Vega cameras is now supported and will be used automatically if available.
- Fixed a bug where the NIRS Configuration window would indicate a firmware update was available when in fact no update was available.
- The Vet Robot stereo calibration procedure was improved to capture slightly more points.
- The 'Mini TMS Coil' 3D crosshairs shape now has a slightly longer shaft.
- Fixed miscellaneous bugs.

Changes in version 2.4.7 (since 2.4.6): (2020-12-23)

- Added support for the new macOS 11 Big Sur, notably communication with Polaris cameras now works.
- Numerous changes to Axilum Robotics support:
- A new feature in the Session Perform window now allows visiting a sequence of targets, pausing for a specified number of TMS pulses, with a specified duration between them, and then moving to the next target.
- The "Align" buttons have changed behaviour in several notable ways:
- They now only act on the sole selected target. They no longer can be used for a folder of targets.
- They now move in whatever path is necessary to ultimately reach the target and always descend the coil to contact the skin. (Previously, there were two behaviours: if the coil was already on the skin, they would only try to slide along the skin, and if the target was too far, no movement would result at all. If the coil was in orbit, they would align above the new target, but not descend to the skin.)
- To signal this behaviour change, the buttons have been renamed from "Align" to "Move".
- The "Stop" button now moves the robot arm away from the subject's head, if it was in contact.
- Closing a session window now warns if you are connected to a robot, instead of just closing.
- Added tooltips to most of the Axilum-related buttons, to help understand what they each do.
- Added a second kind of subject registration for Vet Robot sessions. Instead of using two landmarks and the laser grid, you can now use three or more landmarks for a classic rigid body registration. This requires being able to accurately locate such landmarks both on the anatomical scan and in the camera images.
- The Targets window now allows importing target names and coordinates from a text file.
- Fixed a bug where older documents sometimes failed to convert to the newest format with the message "crosshairs is a required value".
- Fixed a bug where the "switch" input on the IOBox was triggering from high to low voltage instead of low to high voltage, resulting in presses of the foot switch being recognised upon releasing the pedal instead of upon depressing the pedal.
- Fixed a crash that could occur choosing some colours in the ROI window.
- Fixed a crash importing some SPM12 .mat files.
- Fixed a crash on macOS 10.14 and older that could occur if a TTL trigger was received while editing the peak-to-peak value in the Inspector > Motor Maps window.
- Fixed various bugs with macOS dark mode, where some things were drawn with incorrect or illegible colours.
- Fixed a bug where landmark/electrode names that contained two parts, like "LA43-LA44", would only have the first half spoken.
- The Session Validation window now allows choosing the crosshairs shape, like most other steps in the Session window.
- Fixed an old bug where the first use of the Apple Remote after booting the Mac resulted in the first button press being reacted to twice.
- Fixed a bug where the Apple Remote up and down buttons did not work on macOS 10.13 and newer.

- Fixed a bug where the Apple Remote did not work at all on macOS 10.15 and newer.
- Fixed miscellaneous bugs.

Changes in version 2.4.6 (since 2.4.5): (2020-10-21)

- The Vet Robot subject registration procedure no longer requires manually cropping the skull reconstruction, it is now done automatically.
- Vet Robot stereo calibration and subject registration calculations are now much faster.
- Judging the quality of the Vet Robot stereo calibration procedure is now easier because we now show a graphical representation of the quality of the results.
- SPM12 .mat files can now be loaded everywhere a 4x4 matrix can be loaded from file; notably this can be used for atlas space registrations.
- When exporting .txt files from the Session Review window, the option to snap samples to a reconstruction previously only snapped inwards but now it will now snap in either direction, thus working for samples created inside the head (due to use of 'crosshairs offset' slider for example).
- Fixed a bug where the NEURO PRAX impedance check failed to update the electrode colours.
- Fixed miscellaneous bugs.

Changes in version 2.4.5 (since 2.4.4): (2020-06-29)

- Fixed a crash that could occur opening projects created by older versions of Brainsight, where the project once contained NIRS data that was subsequently deleted.
- Exporting .nirs files can now include the results of any analysis that was performed.
- Exported .nirs files now contain metadata indicating that centimetres are used for positional information. This will prevent Homer2 from having to ask.
- The Vet Robot Configuration window no longer shows a ring around the flange in the camera views because the concept does not apply to the newest hardware.
- The newest version of the FTDI device driver (2.4.4) is now installed (this controls communication with RS-232 serial devices like the Polaris camera and Magstim TMS stimulator).
- Improved compatibility with macOS 10.15 Catalina by supporting 'notarization'. This eliminates the "Brainsight can't be opened because Apple cannot check it for malicious software" error message.
- Fixed miscellaneous bugs.

Changes in version 2.4.4 (since 2.4.3): (2020-04-09)

- Fixed a bug where the newly-released macOS Catalina 10.15.4, but not earlier versions, caused Brainsight to crash.
- Added support for the Logothetis / Saleem D99 Macaque atlas. (You also need to install Support Files Vet 1.3.)
- Fixed miscellaneous bugs.

Changes in version 2.4.3 (since 2.4.2): (2020-01-23)

- Reverted the updated FTDI device driver that was included in Brainsight 2.4.2 because it does not work correctly on newer versions of macOS. Now the same version that Brainsight 2.4.1 and earlier included is once again included.

Changes in version 2.4.2 (since 2.4.1): (2020-01-20)

- When performing coil (or tool) calibrations, relaxed the check for how much the calibration block and tool tracker moved (it became too strict in Brainsight 2.4, resulting in calibrations sometimes failing even when the trackers were reasonably still).
- When using the 'target positioning tool', targets are once again drawn semi-transparent (this broke in Brainsight 2.3.4).
- The driver for the KeySpan USB-serial adapter is no longer installed because it does not work well with recent versions of macOS. If you have the driver already installed (from a previous version of Brainsight), it won't be uninstalled, so you can continue to use it, however, we recommend contacting us for a free replacement.
- The newest version of the FTDI device driver is now installed (this controls communication with RS-232 serial devices like the Polaris camera and Magstim TMS stimulator).

- Fixed miscellaneous bugs.

Changes in version 2.4.1 (since 2.4): (2019-12-23)

- Improved compatibility with macOS 10.15 Catalina by supporting 'notarization'. This eliminates the "Brainsight can't be opened because Apple cannot check it for malicious software" error message.
- Fixed a bug where some Analog Receivers / EMG Pods were not detected. We discovered that a small number of such devices were not correctly programmed by us. If this is the case for your device, when you open a session window you will receive a message explaining the situation with a button to reprogram the device correctly.
- Fixed miscellaneous bugs.

Changes in version 2.4 (since 2.3.12): (2019-12-06)

- Important: Brainsight 2.4 now requires Mac OS X 10.11 (El Capitan) or newer. If your Mac is reasonably recent (~2008 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 2.4 can open documents created by older versions of Brainsight, but older versions of Brainsight cannot open documents created by Brainsight 2.4.
- Added various Homer2-equivalent NIRS analysis features:
- Support for multiple conditions.
- Onset creation:

  From existing samples already created in the session window.

  By pulse detection in auxiliary data (low to high, high to low, threshold with dead time).

  By manual time entry of onsets.
- Optical density calculation and visualization, both unfiltered and with low-pass, high-pass, or band-pass filtering.
- Concentration calculation and visualization of HbO, HbR, and HbT for:

  Whole recording.

  Block averages, with optional error bars.

  Fast and easy recalculation when adding/removing onsets, changing baseline param eters, etc.
- Easy selection and visualization of NIRS data:

  Clicking on 3D representation of optodes on subject head shows corresponding waveform data.

  Clicking on waveform label selects corre sponding optodes in 3D image views.
- Made many improvements to Vet Robot support:
  - Significantly improved the overall accuracy of the system.
  - Region painting of the skull in sessions is now both saved in the project and undoable.
  - In the Session window, camera image views can now be zoomed and panned like other views.
  - Vet Robot sessions can now be cloned.
- Made many improvements to Axilum Robotics support:
  - Added support for the Axilum Robotics TMS-Cobot.
  - The skin reconstruction is now shown in the Session>Axilum step.
  - Greatly improved performance of projecting targets to the skin reconstruction.
- Added support for the Polaris Vega® position sensor.
- The Session > Polaris window now shows the exact field of view shape for the Polaris Krios and Polaris Spectra, where previously it was showing the shapes of their respective predecessor models.
- Instead of a generic 'diagnostic pending' message, more exact messages are provided for various Polaris error conditions (ex: bump detected, battery fault, temperature high, etc.).
- If your Polaris' bump detector is triggered, Brainsight itself can now clear the error, obviating the need for

the NDI Toolbox application.

- If the Polaris reports a dead battery or a temperature error, tool tracking will now work regardless. (You should still schedule a repair of your Polaris, as tracking accuracy may be reduced.)
- In the Session>Perform window, changing the active coil/tool calibration (from the 'driver' popup menu) now disables/enables the corresponding Polaris tools. For example, changing from a calibration that uses CT-123 to one that uses CT-456 will stop the camera from tracking the former and start tracking the latter.
- Changed the legend in NIRS views to have a global wavelength toggle button, that applies to all pairs, instead of per-pair control of wavelength visibility.
- In 3D image views, clicking a tube that represents a NIRS pair now selects the corresponding channel in the legend of waveform views.
- Selecting a NIRS channel in the legend table or rectangles view now selects the corresponding NIRS tube in 3D image views.
- Selecting an EEG/EMG/ECG/EOG channel in the legend table now selects the corresponding electrode in 2D/3D image views.
- In sample-based waveform views, when selecting multiple samples, error bars can now optionally be shown for averages (for EEG/EMG/ECG/EOG and NIRS data).
- In sample-based waveform views, clicking a waveform now shows a tooltip that indicates which waveform the sample is from or if it is an averaged waveform.
- Waveform views now default to showing a better range of data in both the x and y axes.
- Creating an Assembly List from a .txt file now gives the option of linking it to an existing Cap Layout or creating a new Cap Layout.
- When creating a reconstruction, you can now choose to keep only the largest piece (as opposed to previously, where all pieces were kept). This can be useful for skin reconstructions, where you don't want artifacts.
- Overlays can now be configured to colour values above/below the threshold to be either transparent (as previously) or to repeat the hi/low colour of the lookup table.
- When exporting samples into DICOM files, you can now optionally project the sample along its axis to the intersection of a chosen reconstruction (ex: the brain surface).
- The 'Manual (AC-PC+scale)' atlas space window now shows resizable lines (instead of a box) to scale the template to the subject head. This better indicates how it is meant to be used.
- Added marmoset, pig, and sheep atlases.
- Added much more information to the text file streaming feature. In addition to raw Polaris tool locations that it output before, it now logs when: the selected target changes, a TTL trigger occurs, a sample is created, the crosshairs move.
- Added buttons to the Targets and Session Perform windows to navigate up/down/left/right on a rectangular grid.
- Added a button to reorient the crosshairs to be perpendicular to a chosen surface.
- All threshold sliders now have text fields below them so that exact ranges can be specified.
- Added a new preference to disable sounds played when creating samples or sampling landmarks.
- Partly fixed a longstanding bug where reconstructions based on ROIs would always claim that re-computation was necessary, even though the ROI hadn't changed. (This will still occur for re-opened projects though.)
- Fixed a longstanding but minor bug where the threshold mask in an ROI window did not exactly match the effect of flood fill.
- Fixed a longstanding bug where converting a sample to a target made all hidden targets become visible. Now the visibility of targets is unaffected.
- In an ROI window, the up and down arrow keys and up and down mouse wheel now move by exactly one slice, instead of by the 'slice increment size' of the Preferences window.

- In image views, the name of a landmark/target/sample can now be shown/hidden using a new button below the brightness/contrast slider.
- Changes to .txt format export:
  - The .txt file format has been changed from version 8 to 12 due to some minor changes to the file format. If you have scripts/code that reads such files, you may need to adjust them slightly.
  - When exporting EMG data, the time range used for peak-to-peak calculations is now included.
  - When exporting TMS stimulation information, the Magstim® BiStim² inter-pulse duration and second power are now included.
- Fixed a bug where Magstim® BiStim² inter-pulse duration confused µs versus ms.
- Trackpad gestures are now supported in image views. You can now zoom with a two-finger-pinch gesture, and rotate with a two-finger-rotate gesture.
- Greatly improved performance snapping targets, grids, and electrodes to a reconstruction surface.
- Improved performance working with the Polaris.
- Improved support for non-admin macOS accounts. An admin account is still needed to install, but non-admin users can now run Brainsight.
- Improved support for macOS 10.14 Mojave and 10.15 Catalina, particularly their 'dark mode' feature.
- Fixed miscellaneous bugs.

Chapter 1: Introduction

Welcome to Brainsight NIRS! Brainsight NIRS represents the fruition of over a decade of effort in design and development in both hardware and software. Brainsight NIRS builds on our experience in neuronavigation and multimodality acquisition as well as feedback from our hundreds of customers. We hope that you find this new generation of neuronavigation based image acquisition tools 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 NIRS. 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. For popup menu buttons (buttons that, when clicked, present a short menu list of actions to pick from), the instruction "click **New->Surface**" will be used. The verb click implies that you are asked to click on a button and the arrow implies that the click will allow you to select the item from the list.

MULTIMODALITY USE

Brainsight is designed from the start as a multimodality neuronavigation system. While the focus in this manual are the features specific to NIRS imaging, you may intend to use Brainsight to record NIRS along

with electroencephalography (EEG), or while using a transcranial magnetic stimulator (TMS), or both. When relevant, this manual will describe how to perform some of these together, however it will be assumed that you have familiarized yourself with the specific functionality by reading the Brainsight user manual specific to that functionality (e.g. Brainsight NIBS).

SYSTEM REQUIREMENTS

Brainsight 2.5 requires a recent Macintosh computer with the following minimum characteristics:

- Mac OS X 10.13 or greater
- Intel or Apple Mx CPU
- 8 GB RAM (16+ recommended)

If you are contemplating a new computer purchase, we recommend a computer with the latest Apple M-series CPU at least 32GB 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 a shortcut to our support e-mail address.

- **e-mail support@rogue-research.com.**
  As with the crash reporter, several experienced people get the support e-mail so you should get a reply as soon as possible.

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 perform NIRS 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 (infor@rogue-research.com) for upgrade information.

SAFETY

Safety Symbols

The following symbols may be used throughout the user manual

	Attention! This symbol denotes information regarding the safe use of the equipment to prevent injury or damage the equipment.
	Advice. This symbol denotes advice to obtain the best results using the system.
	Consult instructions for use.

	Do not trash. Dispose of this product according to the disposal instructions described in this manual.

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 shall not be used for any treatment, diagnosis or monitoring on a patient.

It's the user's responsibility to design and validate safeness of their stimulation protocols.

The output of the Brainsight fNIRS device with the 705nm and 830nm configuration using flat-lensed optodes is consistent with type 1M lasers. Do not attempt to view the output directly from the optode using optical focusing equipment (e.g. microscope or additional lenses).

Warnings and Cautions

Follow these warnings and cautions to ensure safe use and maximize signal quality.

	Do not look directly into a source optode during operation. Doing so may cause eye damage. It is recommended to wear protective glasses if manipulating the optodes while the lasers are on.

	The NIRS system includes a key-based interlock to prevent unauthorized use of the lasers. Remove the key from the interlock when not in use.
	In the case of a damaged optical fiber, do not touch exposed glass fibers. Doing so may introduce glass splinters into the skin.
	Do not step on the optical fibers. Doing so may damage the fibers and reduce the signal quality.
	While the Brainsight computer controls the acquisition settings of the NIRS device, the acquisition system is autonomous. If the Brainsight software halts unexpectedly during the acquisition, the device is designed to continue operating until the planned acquisition completes. The lasers will remain on as indicated by the laser on light on the front panel. Touch the “Stop Lasers” button on the touchscreen to abort the acquisition if needed.

Chapter 2: Introduction to NIRS Imaging

INTRODUCTION

This chapter is intended for those that are new to NIRS imaging and/or neuronavigation. The general concepts of NIRS imaging will be explained followed by a brief description of the typical steps on how to perform a NIRS experiment. Each step will be covered in more detail in subsequent chapters.

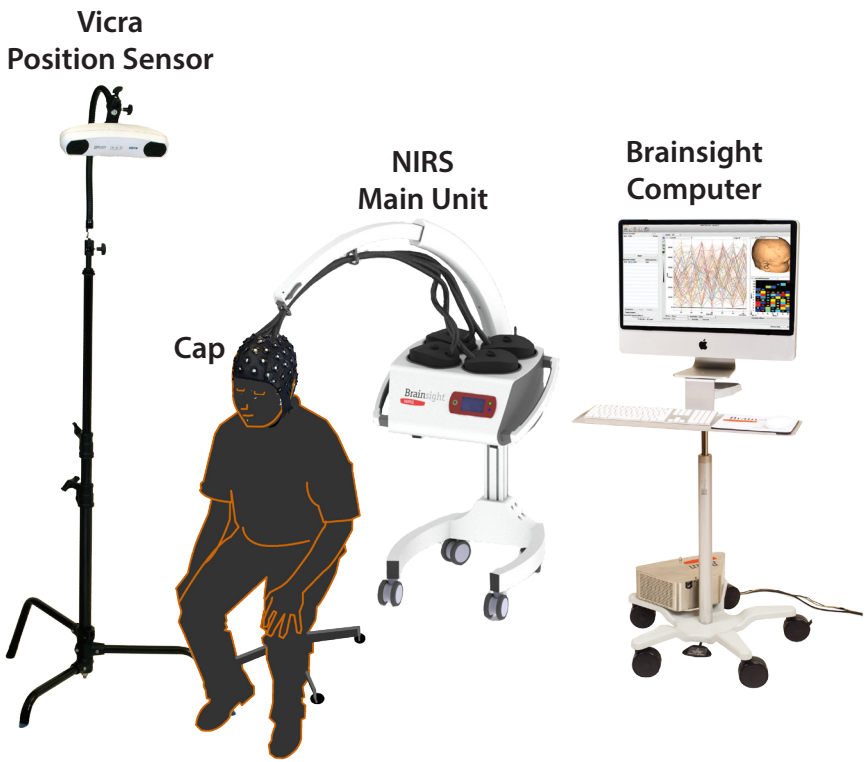


Fig. 2-1

Typical Brainsight NIRS system

NIRS PRIMER

In NIRS, infrared (IR) light is sent into the head using small lasers in the NIRS device. The lasers create a high intensity beam (not high enough to be harmful) of two or more distinct wavelengths. This light is channeled into a fibre optic cable (see Fig. 2-2), which has a small lens on the one end (called an optode, similar to an electrode for EEG, except it measures optical light instead of electrical current). That lens is put in contact with the scalp so the light enters the head (see Fig. 2-3). Some of it is absorbed by the head (scalp, skull, brain etc...) and some of it is scattered. One of the materials that absorb light is the hemoglobin in the blood within the brain. The amount of oxygenated and de-oxygenated hemoglobin in the blood will influence the amount of light absorbed. Changes in the amount of oxygenated and deoxygenated hemoglobin in the blood will thus lead to very small changes of light absorbed within the brain. A second set of optodes and optical fibres are placed on the head to collect some of that scattered light that exits the head. The fibres channel that collected light into sensitive detectors inside the NIRS device and this signal is digitized for analysis. Mathematical algorithms are applied to process the collected data to calculate the changes in oxy and deoxy hemoglobin concentration. These changes can be associated in changes in brain function (as the brain works, it consumes oxygen in the blood), so in the end, a map of brain activation can be created by the NIRS device.

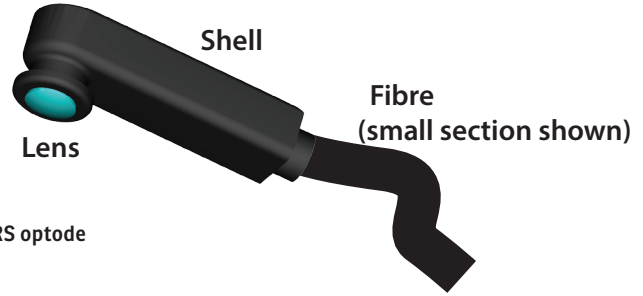


Fig. 2-2

Close-up of a NIRS optode

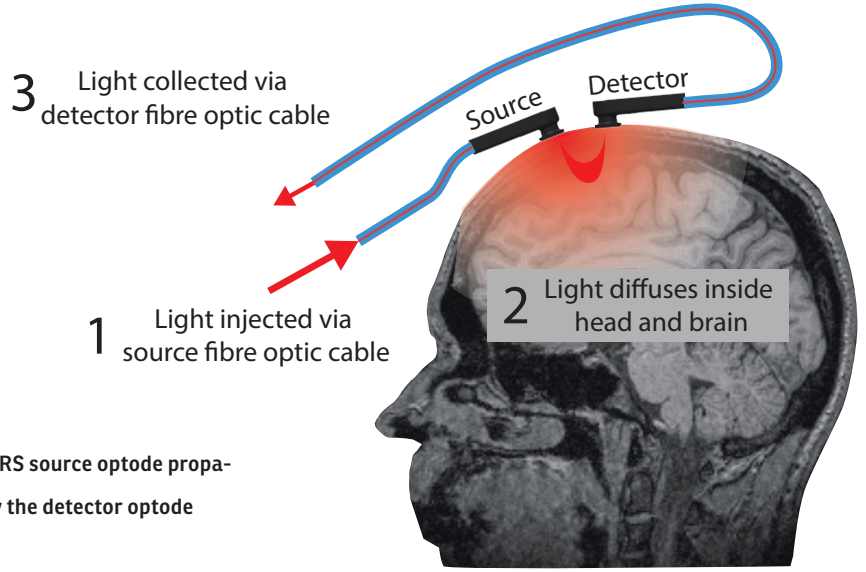


Fig. 2-3

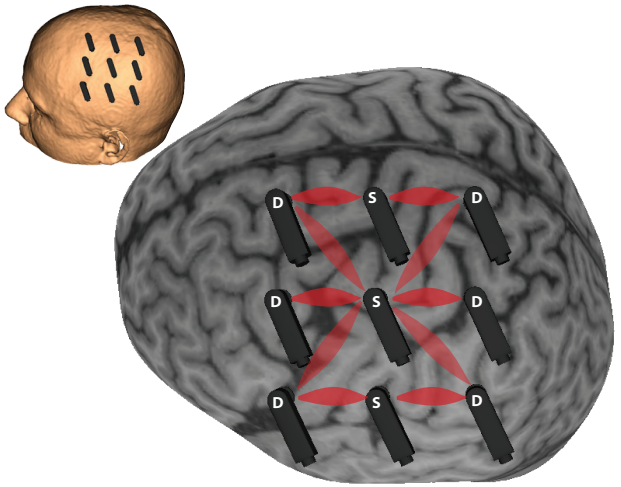
Illustration of how light from the NIRS source optode propagates in the head and is collected by the detector optode

Multiple sources and detectors are placed close to each other on the head, usually about 3cm apart (see Fig. 2-4). In most cases, a specific detector optode will collect light from more than one source. In order to tell them apart, each source injects the light at a specific frequency (Fig. 2-5). The signal recorded by each detector will have a spectrum of all the frequencies associated with the sources that were close enough to be recorded. The software then separates each signal, creating a set of signals that represent the light from each specific source to each specific detector.

After the NIRS session, the data is analyzed by the computer software, where the changes in measured signal strength are examined and converted into changes in brain activity. The results are displayed on the subject's MRI images (or that of a standard brain) for interpretation and analysis.

Fig. 2-4

Illustration of a common 3x3 array of optodes. S indicates sources and D indicated detectors. The red regions illustrate the region of the brain that is imaged between each source and detector pair. Light from each individual source may travel to multiple detectors, conversely, each detector may record light from more than one source. Note the signal strength will be greater for the source detector pairs that are closest to each other.



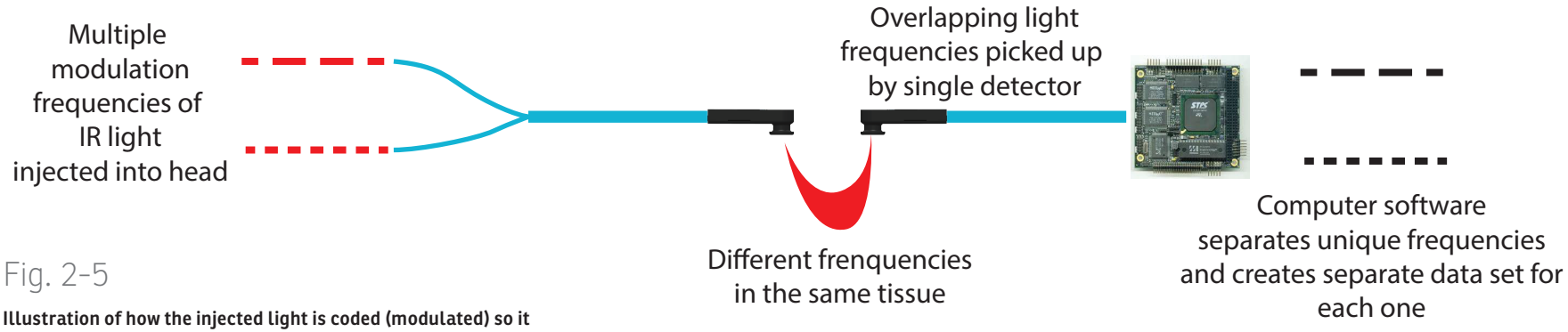


Fig. 2-5

Illustration of how the injected light is coded (modulated) so it can be separated out after collection by the detectors.

MAPPING THE DATA TO THE BRAIN

The ultimate goal of NIRS is to measure brain function. When the data is acquired, it must be associated with a corresponding region on the brain. Brainsight has multiple methods of associating each source and detector with a region of the brain. In short, we include a neuro-navigation system to localize each optode with respect to the brain.

INTERPRETING THE NIRS DATA

The NIRS Signal

Interpreting the NIRS signal requires careful consider-ation and is an active field of research in of itself. The signal being recorded (refer back to Fig. 2-3) is a sum of multiple contributions including:

- photons that were scattered/reflected within the cortex that vary with changes in brain activation as well as physiology (e.g. pulse)
- photons that were scattered/reflected within the scalp and CSF that change with physiology and in some cases due to other factors correlated with the experimental task (e.g. movement during task)
- outside light (with IR content and high frequency flicker)
- Noise generated by the electronics of the NIRS instrument including cross-talk from other optode signals occurring within the instrument

These signals are converted from light intensity to optical density and then converted to relative changes in oxy and de-oxygenated concentrations.

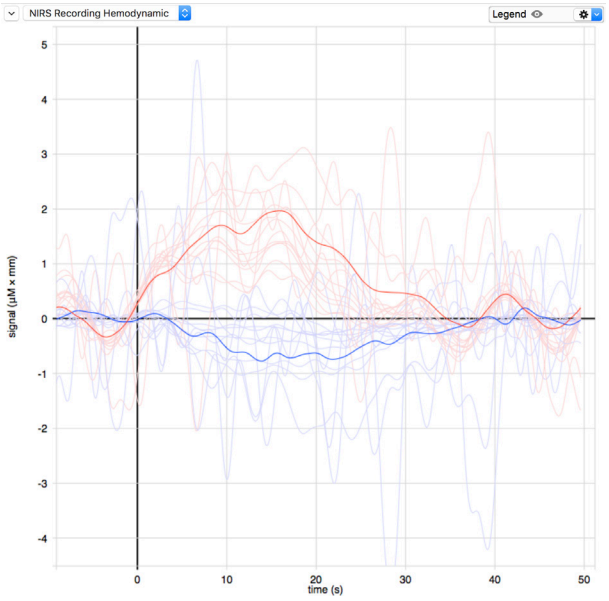


Fig. 2-6

Typical activation curves. Red is the change in oxi haemo-globin and blue de-oxi haemoglobin

NEURONAVIGATION

Neuronavigation (often referred to as frameless stereotaxy or Image-guided *something*) has it's roots in modern neurosurgery. It can be described like a GPS system for the brain. 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, or a hand-held pointer. The map is replaced by anatomical images (usually MR images) of the subject. The naviga-tion software communicates with the position sensor to obtain the location of the pointer or trackers (perhaps one of them on a NIRS patch 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 tracked object from the real world to the image space. Once calculated, a representation of any tracked object can be displayed on the images. Points of reference, be they targets for

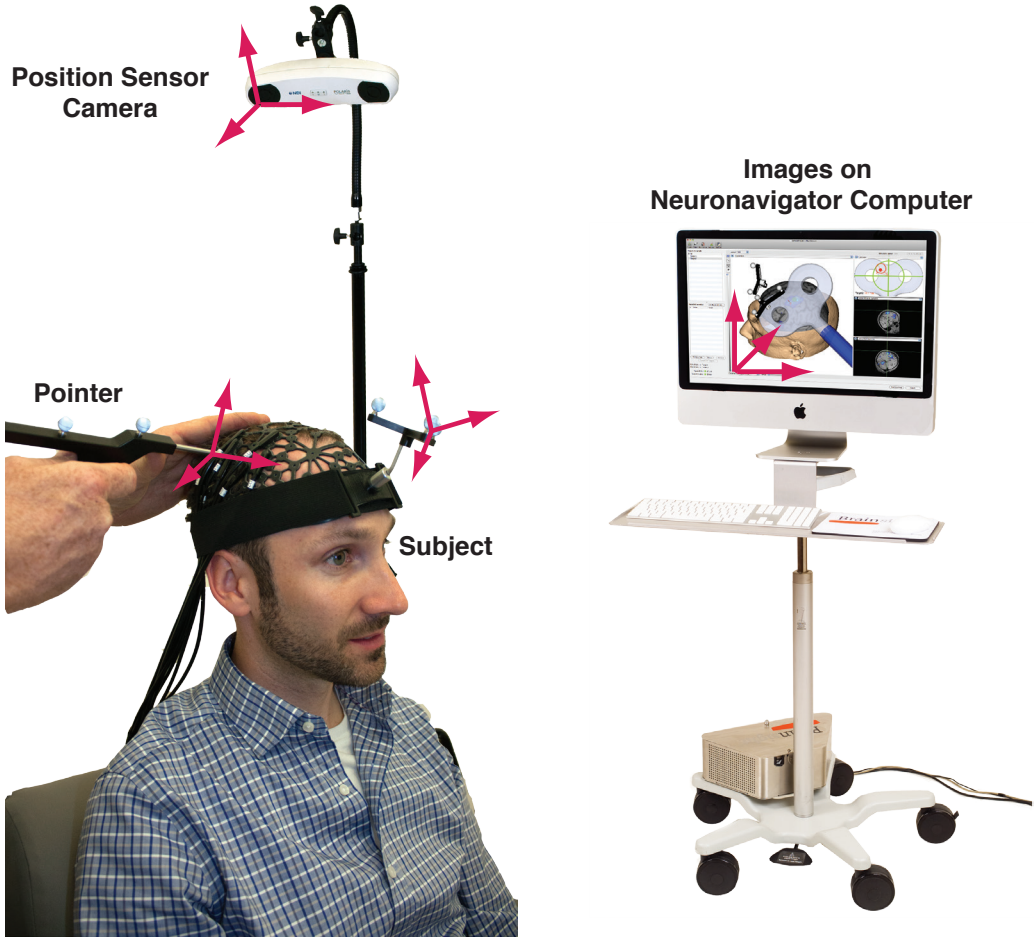


Fig. 2-7

Main components of a neuronavigator

imaging or stimulation can be identified in advance and the navigator can help you get the NIRS patch, EEG electrode or TMS coil over the target, or record the location of the NIRS optodes and/or EEG electrodes and map them to the subject's images.

The steps involved to operate the system can be separated into two classes: System maintenance/ preparation and subject-specific information entry. The system specific operations that relate to the software are accessed by various menu items when running Brainsight. The subject specific steps are accessed via the Brainsight project file window.

The overall layout of Brainsight project window is designed to follow the typical steps involved in preparing and ultimately performing a NIRS study, each tab along the top of the window represents one step in the process of getting ready for or carrying out a NIRS 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 NIRS 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.

TYPICAL STEPS FOR IMAGE-GUIDED NIRS: SYSTEM SPECIFIC STEPS

Define your NIRS cap(s)

The optodes used to inject (sources) or collect light (detectors) must be placed on the head, and held in close contact to the skin in order to work properly. While that sounds simple, it is likely the most challenging and potentially frustrating part of NIRS. There are a wide variety of layouts for optodes to image different portions of the brain. There are a wide variety of approaches and each of them have their strengths and weaknesses.

When you purchase a Brainsight NIRS system, it will come with one or more caps and one or more sets of fibres. For the purposes of this user manual, a **cap** is defined as an apparatus that is worn on the head with the purpose of rigidly holding one or more NIRS optodes and/or EEG electrodes on the head. The caps may be similar to EEG caps (where full head coverage is desired) or smaller patches that are fixed to the head in one way or another. A cap definition in Brainsight consists of a name for the cap itself, a list of the names of each receptacle (referred to simply as holes) onto which optodes and electrodes may be fixed and optionally, the location of the holes within the cap in a standardized coordinate system (e.g. MNI coordinates). Using EEG as an analogy, a cap might have holes in it that are labeled according to anatomical locations using a standard grid system (T1, FP2 etc...). These locations are cap specific and do not assume anything is attached in any given receptacle; it is the list of all possible places where an optode or electrode may be attached.

There are several methods to arrange and hold the optodes on the head. One of the most common is to use an EEG-style fabric cap with plastic receptacles for the optodes. Rogue Research has developed a novel cap layout where the receptacles are evenly (relatively) spaced from each other to offer flexibility in generating good montages. The naming convention of the optode holders uses an L-R (for left and right side) for the column of receptacles that are roughly over the motor cortex to the ear with numbers going from the midline in the inferior direction (e.g. L1, L2 etc...). Receptacles anterior to this line are labelled LA (LA11, LA12, LA21, LA22 etc...) and those posterior are labelled LP (LP11, LP12, LP21, LP22 etc...). Since the receptacles are equidistant, any source and detector adjacent to each other become a potential source-detector pair.

Brainsight contains a software based cap manager, where your physical caps are defined for use later.

When a cap is to be used, optodes and/or electrodes must be attached to the cap at one or more of the receptacles. This list of cap holes and associated optodes is called a connection list. It defines what specific optode (be it a detector or source) from the NIRS device is fixed to which hole on the cap. One can use this list list to physically insert the optodes into the receptacles in the cap prior to a scan (and may be stored this way for re-use for subsequent scans when the configuration does not need to change). This enables Brainsight to associate the data acquired by each source-detector pair with a specific region of the brain. This cap-connection list association is called an assembly. A cap may be associated with multiple connection lists and thus have multiple assemblies, but a connection list can only be associated with a single cap. Thus an assembly is a unique pair of a cap and connection list.

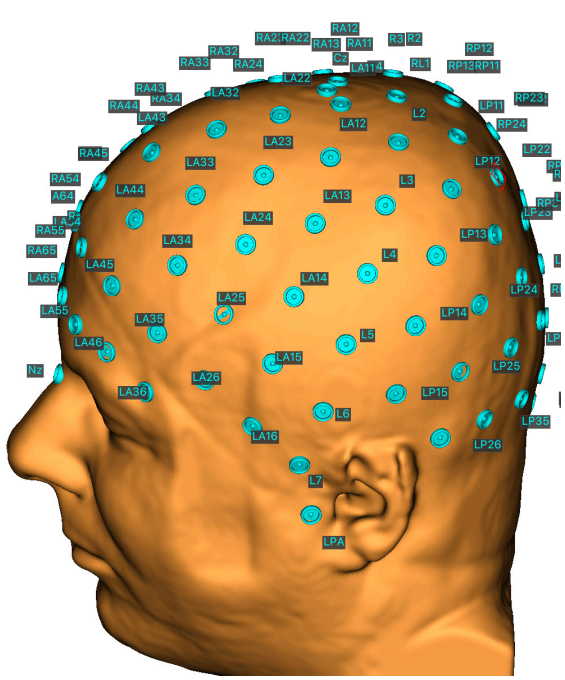
Brainsight includes a software tool to define one or more caps. The purpose is to be able to quickly assign each optode to a pre-determined location on the images.

Define a cap assembly

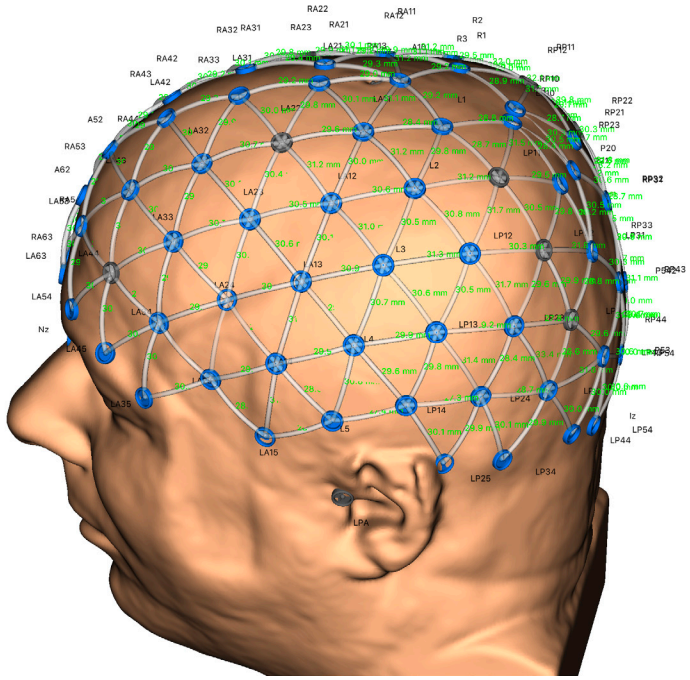
The cap defines the name and location on the head onto which an optode can be placed. The NIRS system must know what optode is attached to each specific hole in the cap. In contrast to each cap hole being associated with a specific anatomical region, each optode is attached to a specific channel number on the NIRS module. In order to associate the recorded NIRS signal to a specific anatomical region, a connection list must be defined to map the anatomical location to the NIRS detector channel.

NEURONAVIGATION: HOW MUCH OF IT WILL YOU USE?

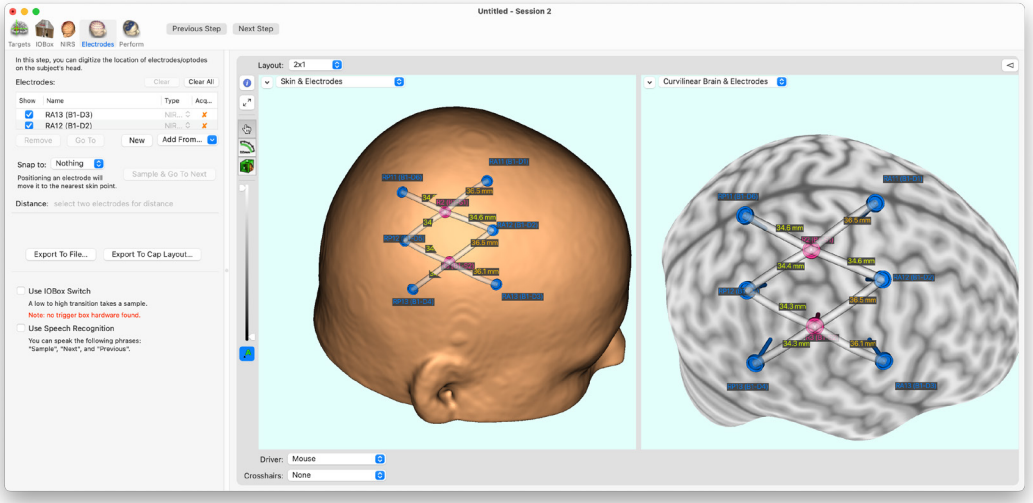
When using Brainsight, you have multiple options in how much you wish to use the neuronavigation. The main purposes for neuronavigation are to be able to ensure that the optodes are placed over the regions you wish to image and to associate the locations of the optodes



A



B



C

Fig. 2-8

A: Brainsight cap applied to subject MRI

B: All potential source-detector pairs for the cap

C: A simple montage (assembly) using a subset of the cap pairs

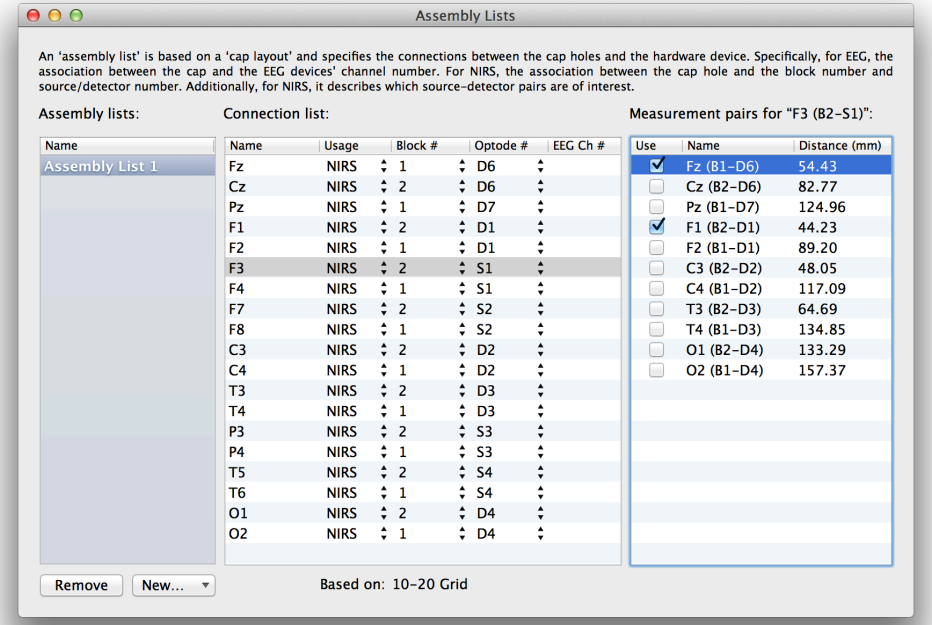


Fig. 2-9

Assembly list manager

(and associated NIRS data) with the subject's anatomy (as defined by their MR images). How much of this is needed (or how accurately you need to record the optode locations) for your particular application is up to you to decide. Essentially, there are two decisions to make: First, are you going to use the subject's MR images, or are you going to use a model date set (e.g. MNI head)? Second, are you going to rely on the pre-recorded estimates of the optode locations (either on the MNI head, or warped to the subject's head) or will you use the position sensor to record the optode locations?

The least accurate, but simplest is to use the MNI head and estimated optode locations. In this case, the anatomical images are based on a standard brain like the ICBM152 average brain or the MNI-based "super" brain. Both MNI brains are in the same coordinate system. The average brain is a composite data set taken from averaging 152 normal subjects. The super brain is a composite date set of several T1 anatomical scans of a single individual, warped to the same MNI coordinate system. Both can be referred to as an MNI brain since they share the same shape. The average brain gives you an idea of the relative variability of the different brain regions (structures that vary a lot are blurrier than ones that are relatively constant), while the super brain is a clear, high contrast example of an individual brain in MNI space. We tend to use the superbrain more often because it happens to have a better defined skin for the recon-struction (the top was not clipped). The optodes are on a cap whose receptacle locations were pre-measured in the MNI coordinate system. Assuming the cap was correctly placed, a reasonable estimate of the optode locations is provided. This may be sufficient for illustration purposes.

The next level up is to use the subject's MR images, but still rely on the estimated locations of the optodes. This requires that you first obtain an anatomical MRI data set of the subject, and that you perform the MNI registration step (see...). This allows Brainsight to take the initial estimate of the optode locations in the MNI coordinate system and transform them to the subject's native coordinate system as defined by the subject's MRI. The accuracy is limited by the assumption that the cap is well placed on the subject's head and by the accuracy of the subject->MNI registration.

Finally, the most accurate way to determine the optode locations on the subject's head is to actually record them using the position sensor. In this case, you would place the subject tracker on the head and use the Polaris camera and traced pointer to record the optode locations at the start of the NIRS recording session.

TYPICAL PREPARATION STEPS FOR IMAGE-GUIDED

NIRS: SUBJECT SPECIFIC STEPS

Before performing a NIRS acquisition session, a Brainsight project file needs to be created and completed. This is typically done only once for a particular subject and the project file is recalled for each NIRS session.

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 your caps included MNI coordinates defining their locations, then you need to co-register the individual subject's MR to the MNI coordinate space. This will allow Brainsight to map the initial locations of the optodes to the subject specific MRI 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 wish ot overlay one or more data sets (e.g. other MRI scans, or functional data), 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 neuronavigation 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 represented as a series of triangles generated by segmenting the raw MRI voxels (see Illustration of how light from the NIRS source optode propagates in the head and is collected by the detector optodea 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 NIRS.

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 Illustration of how light from the NIRS source optode propagates in the head and is collected by the detector optodeb).

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 NIRS SESSION

Once all the "homework" has been done, a NIRS 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 and the pointer in the various positions required to identify the landmarks.
2. **Connect the equipment.** The NIRS main unit communicates with the Brainsight computer via Ethernet network (wired or wireless). The position sensor camera is connected to the computer
3. **Sit the subject, apply the NIRS cap and fix the subject tracker.** Once the apparatus is set, you are ready to begin the experiment. Apply the cap (with the optodes in place) on the head. Try to move any hair that might be between the optode and the skin out. 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. **Turn on the NIRS and ensure that the optodes are acquiring data.** Now, turn on the lasers and observe the data as it is being acquired. Make any adjustments to the laser power or detector gain.

Review the acquired data

After the NIRS session, you may want to review the data acquired. For example, you may wish to look at the recorded data to ensure that the acquisition is free of artefacts. After you have reviewed the data, you can export it in the .nirs format for analysis on your favorite NIRS processing software.

ANALYZE THE DATA

Refer to the instructions that come with the analysis software (e.g. Homer).

Chapter 3: Brainsight System Overview

Your Brainsight NIRS system comprises of many parts, including hardware and software. Brainsight NIRS is a distributed system, with functions spread over multiple devices. This increases flexibility on the setup as well as the data acquisition. This chapter will introduce you to each component of the hardware and how to set it up.

MAJOR SYSTEM COMPONENTS

The Brainsight NIRS system comprises of multiple parts and was designed as a distributed system. For example, the NIRS unit itself has no major user interface. Instead of the traditional computer/screen incorporated into a device, the NIRS unit is connected to the control computer ("client") via Ethernet network. This enables

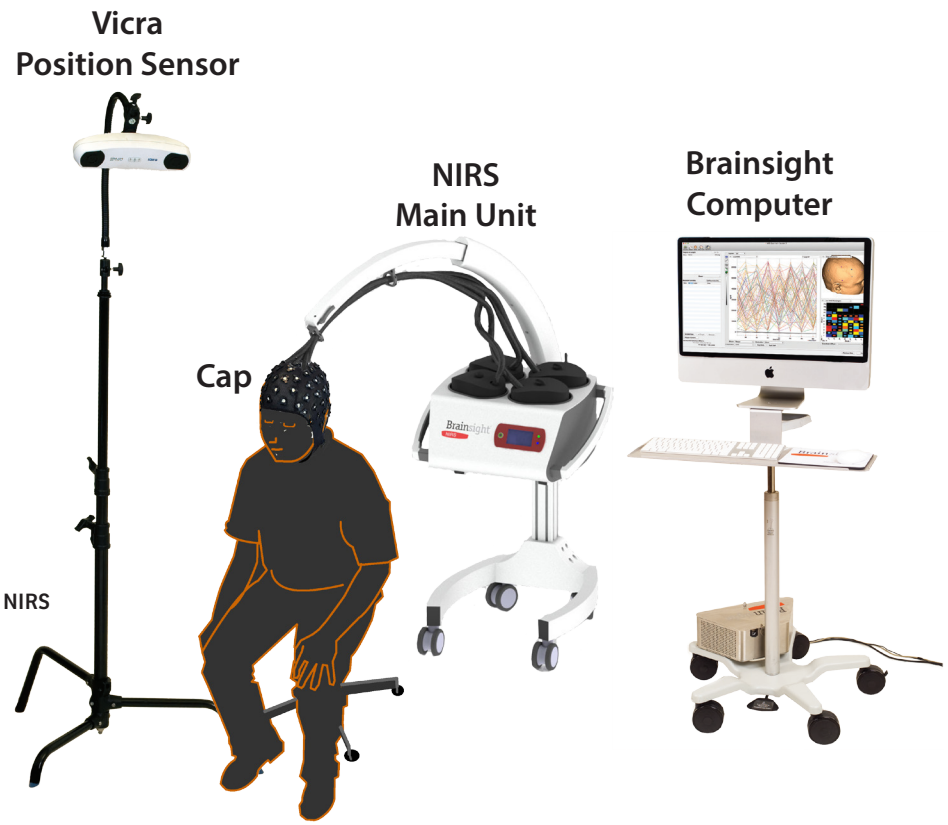


Fig. 3-1

Main Components of Brainsight NIRS

you to have the NIRS device close to the subject while having the control computer near the operator, be it next to the subject, or in the next room. This client-server model also enables you to have more than one device communicate with the NIRS device at one time, much like how a printer in your office can communicate with more than one computer. This enables more flexibility in sharing data during complex, multi-modality experiments where, for example, in addition to the Brainsight computer, you may need another computer running Matlab™ or similar program to be fed the NIRS stream in real time during the experiment.

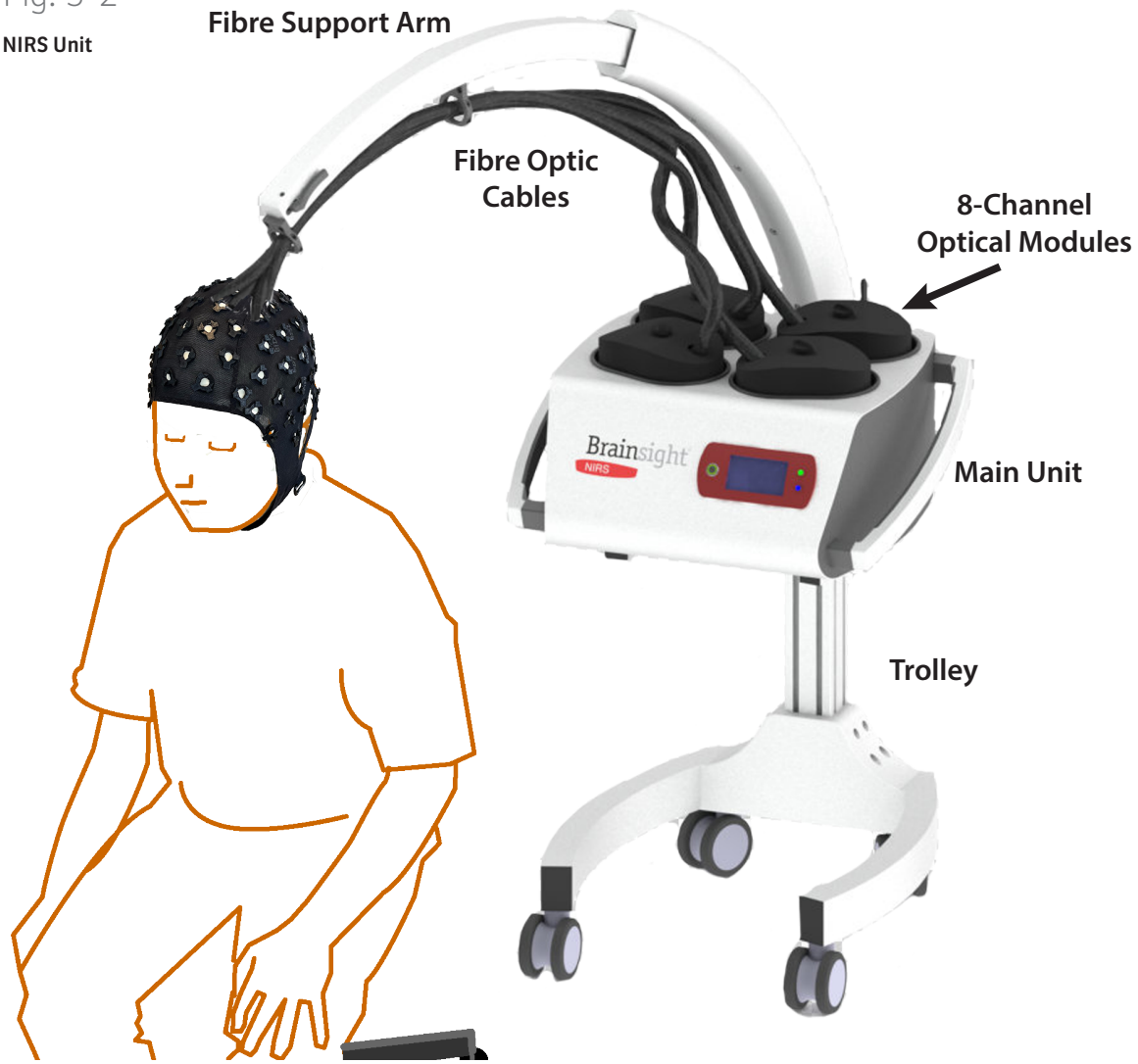
This section will describe each component, including how to assemble, set it up and maintain them. How they work together as a system and how to perform experiments will be presented in later chapters of this manual.

NIRS UNIT

The NIRS unit contains most of the hardware required to acquire NIRS data (see Fig. 3-2). The Brainsight NIRS system is modular in that the electronics and optical components have been separated into the "main unit" and 8 channel optical modules. This simplifies upgrading the system in the future. For example, you can purchase additional 8 channel modules to increase the number of channels you have (up to 32), or use modules with 3-wavelength sources instead of two. Switching modes would be achieved easily by swapping the block. You could also purchase longer fibres (for use in MEG or MRI

Fig. 3-2

NIRS Unit



scanners) and either switch the fibres connected to the block, or purchase an optical module along with the fibres to simplify switching back and forth. The unit is held on a mobile trolley that incudes an articulated arm to hold the fibres.

Main Unit

The main unit contains the electronics that are required to manage the optical modules, acquire and process the data and interface with external clients, including the Brainsight computer. The unit has four bays to receive the optical blocks and the necessary ports to connect it to the network as well as to record up to 8 channels of auxiliary analog data.

The main unit body has arms on either side to allow you to move it, either by lifting it (if it is not on a trolley), or by pushing it on the trolley.

On the top of the unit, there are four bays for optical modules. The system can function with one or more modules connected, and the presence of the modules is detected when the system it turned on (boots up).

The front of the unit contains the LCD touch-screen, power button and status display lights. The power button is used to boot the system. Once the system has booted, a power down and stop laser button will appear on the touch screen (Fig. 3-4). Touch the power down button to shut the system down. Since there is a computer built-into the device, it is important to use this to shut down the device to allow the embedded control computer

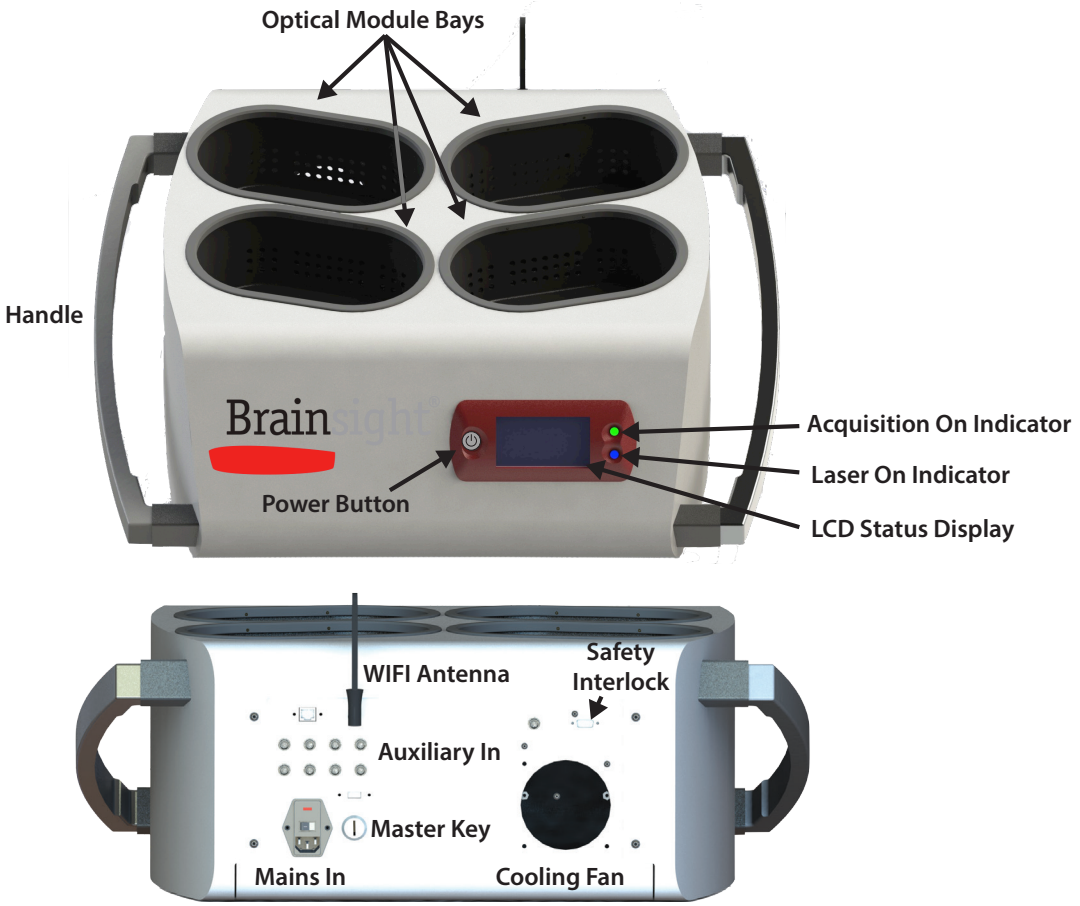


Fig. 3-3

Main Unit Details.

to perform its shut-down sequence.

Next to the LCD screen are two status lights. The upper (green) light indicates when the system is on. Once the system has completed its startup sequence, the Brain-sight logo will appear on the LCD screen.

On the rear of the main unit, you will find the input connectors for analog channels. These are used to record external data, including physiological data (heart rate, respiratory etc...) as well as experiment state information. These data channels are synchronized to the NIRS data for analysis and the sampling frequency can be set up to 8kHz. The connectors are standard BNC connectors.

Just above the analog input connectors, you will find the Ethernet port. This is used to connect the device to a network to allow it to communicate with the control computer (which must also connected to the network). Connecting and configuring the network will be described later in tis chapter.

One the rear, you will also find the safety interlock. This interlock prevents unwanted activation of the lasers. The interlock must be in place before the experiment starts. The interlock is activated by connecting the interlock key to the interlock port. It is a good practice to remove this key when the system is not in use.

Finally, the main power switch/fuse module can be found on the rear. The power switch enables power to the system, but does not boot the interface computer. Conversely, the power button on the front of the unit



Fig. 3-4

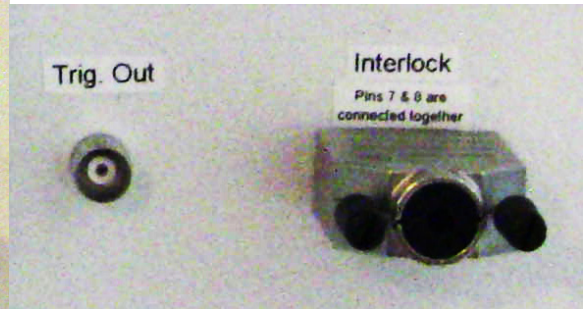
Touch screen display



Fig. 3-5

Closeup of the rear panels.

auxiliary (analog) channel input connectors, the main switch and the two interlocks.



will not function unless the main power switch is on. Before using the unit for the first time, make sure that the correct fuses are installed. The correct fuses for your local power voltage are listed on the label on the rear panel. The main power cord is connected to the main power switch/fuse module. Use the included power cord to connect to the appropriate power outlet.

Optical Module

The optical module contains the electronics and optical components to generate the IR light that is channeled into the head and measure the resulting light scattered within the brain.

On the bottom, you will find the electrical connector to interface the module to the main unit. The receptacle for this connector is in one of the four module bays on the top of the main unit. The connector is divided into two sections, the emitter (red portion) and detector (black portion)

If you open the module, you will expose the optical connectors. The connectors are standard SMA connectors commonly used for fibre-optic cables. They are divided into two sections, one for the sources and one for the detectors. Each source fibre can have two or three wavelengths enabled (depending on the module) however there are always 3 connectors per source. The source labelling scheme 1-1-1 for source one, with the wavelength of each connector beneath the number, so for a 2 channel module, under the 1st "1", you would

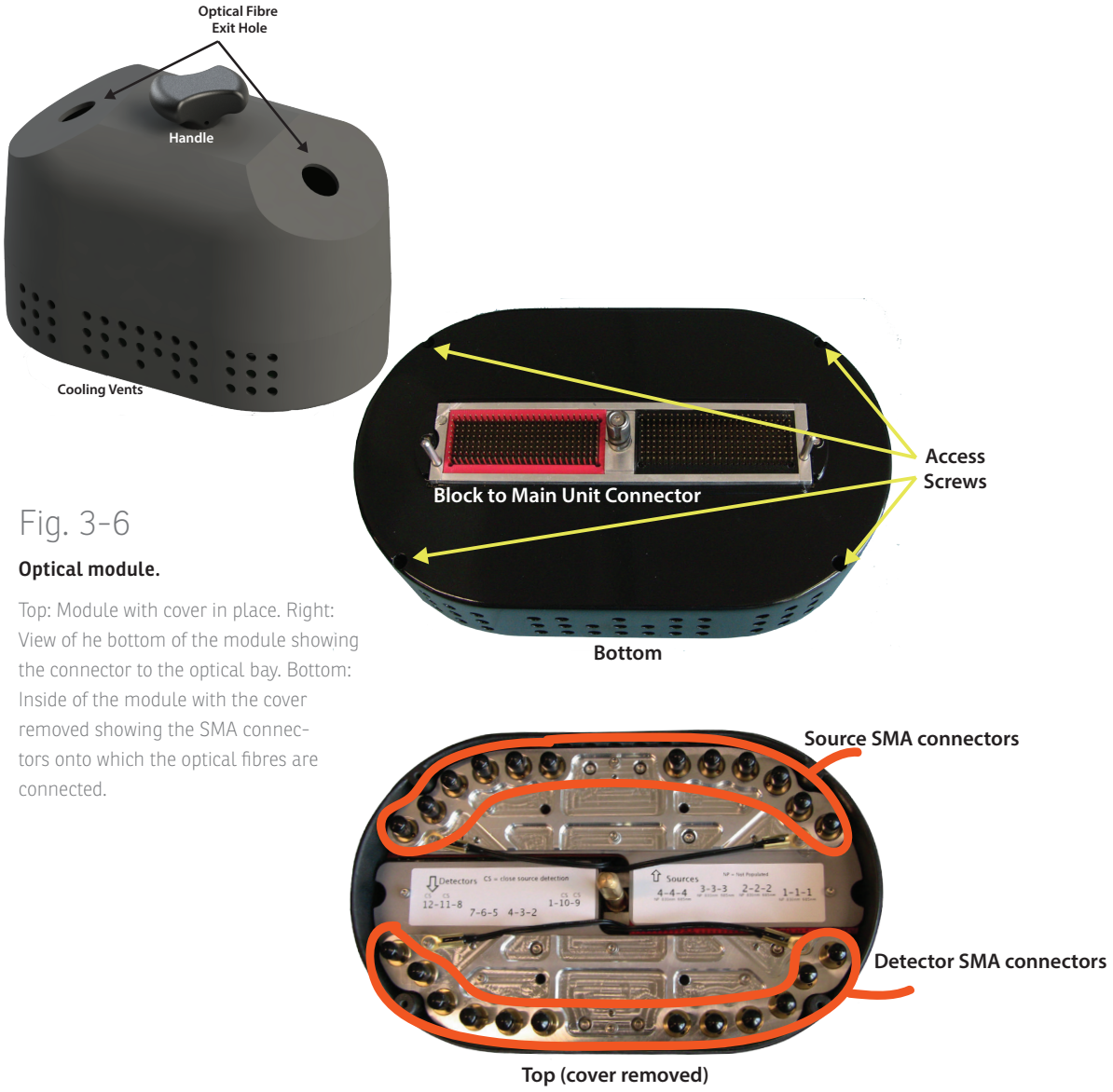


Fig. 3-6

Optical module.

Top: Module with cover in place. Right: View of he bottom of the module showing the connector to the optical bay. Bottom: Inside of the module with the cover removed showing the SMA connectors onto which the optical fibres are connected.

see N/A, since it is not used, and under the second , you would see 830nm (the 830nm laser) and under the third, 685nm for the 830nm laser.

The module is secured into the bay using the twist handle at the top. Inside the module, you will find the optical connectors with the corresponding red/black sides. To connect the module to the main unit, insert the module into a free bay taking care to align the red and black sides. As the module reaches the bottom, you should feel the center post enter the receptacle. Once in, twist the handle clockwise until you feel it click (approximately X turns).

Optical Fibre

The optical fibres serve two purposes. First, they conduct the light from the laser sources in the optical module to the head and second, conduct the scattered light from the head back to the light sensors (avalanche photodiode, or APD) for measurement and recording. Brainsight uses two type of fibers that are optimized for the purpose. We refer to them as source and detector fibres. Both fibres types have a unique serial number and are character-ized at the factory prior to shipment to ensure that they conform to specifications, especially in their ability to conduct light.

The detector fibre uses a bundle style fibre optic cable which has hundreds of small fibres in a tight bundle. This provides a large surface area for light collection (particularly for diffuse light) as well as good flexibility. It

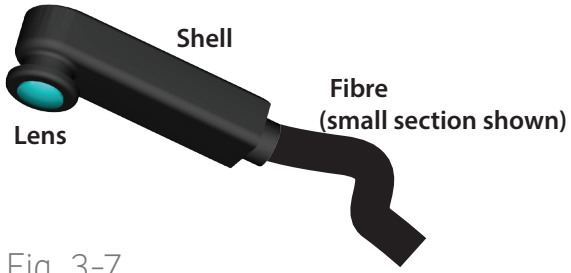


Fig. 3-7

Optical Fibres

has a single optode at one end that is placed in contact with the scalp, and a single SMA connector at the other end that is connected into a detector receptacle in the optical module.

The source fibre is used to carry the light from the laser diodes to the scalp. It has the same optode at one end as the detector fibre (that is placed in contact with the scalp), but uses two or three single core fibres to conduct the light, depending on whether it is a two or three wavelength fibre. At the other end of the fibre, there are two or three SMA connectors. The purpose is to take the light from two or three laser diodes (each using a different wavelength and modulation frequency) and emit the light into a single, common point on the scalp via the optode lens. The fibre diameter is smaller than the detector fibres, but a little stiffer.

Support Arm

The support arm is a n articulated, telescoping arm to support the weight of the fibres between the NIRS main unit and the subject's head. It is designed to be easy to position so that an optimal orientation can be found to have the fibres securely supported, reducing the weight carried by the subject's head and reducing the forces exerted on the optodes themselves to minimize movement during acquisitions.

The arm has two ring shaped receptacles to hold the fibres. The rings have magnetically closed latches that open to allow you to insert or remove the fibres.

The arm is attached to the mobile trolley and an adjustable piston is used to set the vertical resistance if the arm. This ensures that the arm stays in a constant location while holding the optodes while allowing easy movement by the operator.

The arm is telescopic. It can be extended and retracted by grasping the end of the arm, and pressing the brake lever. Once pressed, pull the arm to extend it, or push it in to retract it. Take care when doing so as changes in position will change the weight carried by your hand.

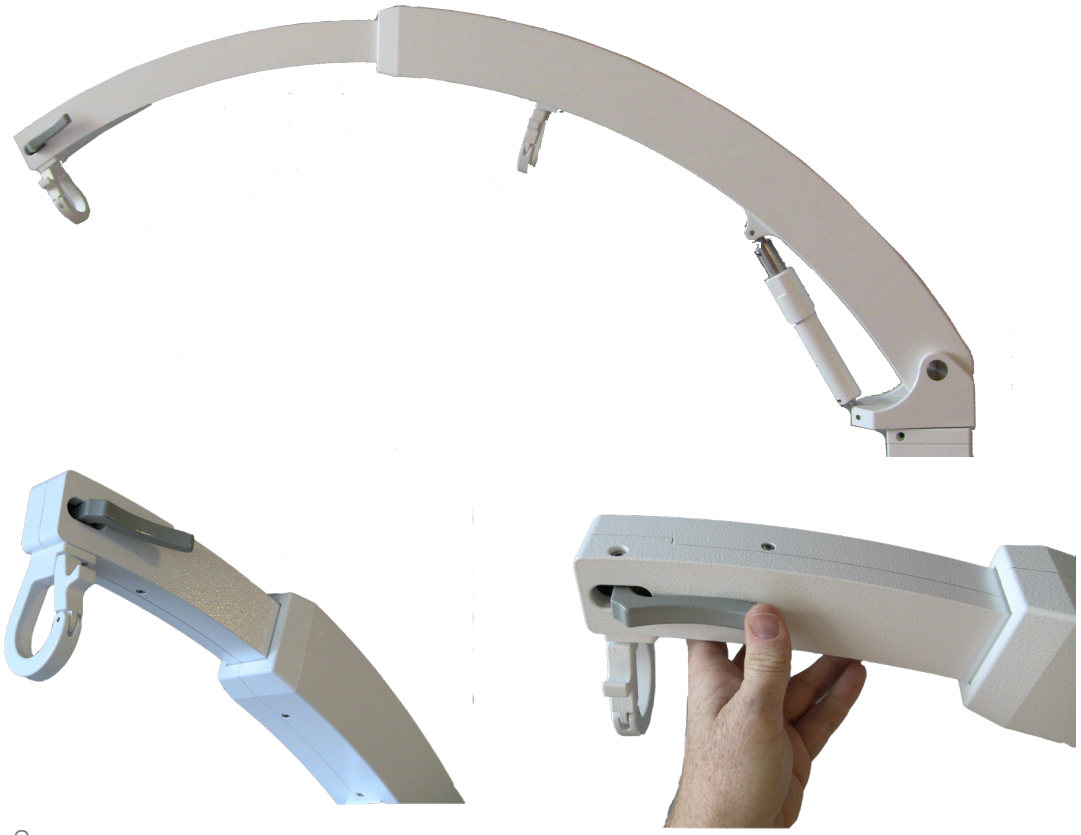


Fig. 3-8

Support Arm

Trolley

The Brainsight NIRS unit may be placed on the trolley to simplify placement of the NIRS unit next top the subject (to allow a simple path for the fibres to get to the head) and to use the articulated arm to support the fibres (assuming the arm is attached to the trolley). The main unit is fixed to the trolley by placing it on the wishbone-shaped support (that is fixed to the trolley back-bone) and secured using the 4 bolts that go through the wishbone into the bottom of the unit.

The trolley base uses 4 large swivel caster wheels to allow easy movement of the trolley. The trolley may be secured at any time by locking the front wheels. This is done by gently stepping on the break levers on the wheels to push them down, into the locked position. The wheels are unlocked by placing the foot under the brake lever, and pulling up.

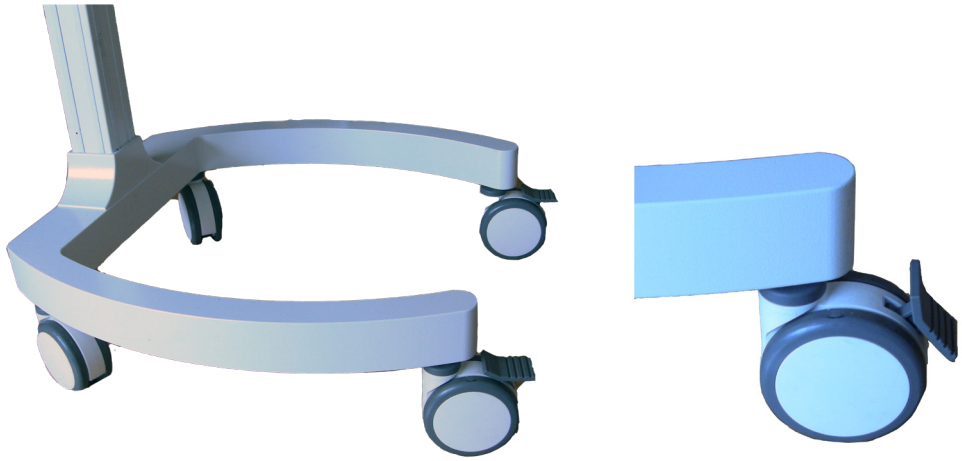


Fig. 3-9

NIRS trolley

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 (dongle), a power supply and camera stand. If your Brainsight system included the mobile computer trolley, then refer to Chapter 20 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 120º 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.

Fig. 3-10

Right: 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.

Middle: 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.

Bottom:

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





- 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 intermittently, or cause USB-over current error messages. If you are lacking ports, use a USB 2.0 (or higher) 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 20), so turn it on when you need to use the Vicra.

Physical Setup (Vega)

The Vega uses the same camera stand however instead of the flexible gooseneck, it includes a ball mount that can support the weight of the Vega.

- Unscrew the thumbscrew on the side of the cylindrical mount protruding from the bottom of the ball mount adapter enough for it to fit on the top of the camera stand. Place the ball mount on the camera stand and tighten the thumbscrew to secure the ball mount to the pole.
- The top platform of the ball mount (from which you removed the flat plate in the previous step should have a thumb lever that lock intop place when the flat plate is replaced into position. Pull the lever out so the flat portion (with the screw that attaches he camera to it) of the top of the ball mount can be removed. The thumb lever should remain open to receive the plate again.
- Attach the flat plate to the mounting hole of the rear of the Vega. Note the arrow indicating the side of the mount that should face the bottom of the Vega.
- Carefully attach the Vega to the ball mount by presenting the front edge of the plate into the receiver (see instructions that came with the ball mount for more details) and when it is inserted, tilt the camera to bring the plate flat into the receiver. When it is inserted correctly, the thumb lever should snap into place to lock the plate in the correct position. Verify that the camera is locked into place.
- Connect the supplied Ethernet cable (that supports the POE standard) to the Ethernet jack on the rear of the Vega. Connect the other end to the supplied power supply to the jack labelled Ethernet out.
- Connect an Ethernet cable from the Ethernet in of the power supply to your Ethernet router or directly to the Ethernet port of the Brainsight computer.

To turn on the Vega, plug the Power adapter to a suitable outlet. Note that there is no power switch.

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.

INSTALLING THE SOFTWARE

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

Double-click on the installer package to initiate the install process (Fig. 3-1).

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. 3-2), simply click "Install" and all 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.

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 NIRS support files. These include sample data (which will be installed on your desktop) as well as the files needed for MNI atlas support.

Double-click on the **NIRS Support Files.mpkg** icon to launch the installer. Follow the same steps described in "Installing the Software" on page 25 to complete the installation.

QUICKLOOK PLUGIN

One of the software components installed is a Quick-look™ 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)

Brainsight keeps files that describe each of your tracked tools in a private folder on the hard drive, and manages those files directly. In order to "tell" brainsight about the existence of one of your tracked tools, you only need to open the tool file in Brainsight once and it 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 (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.

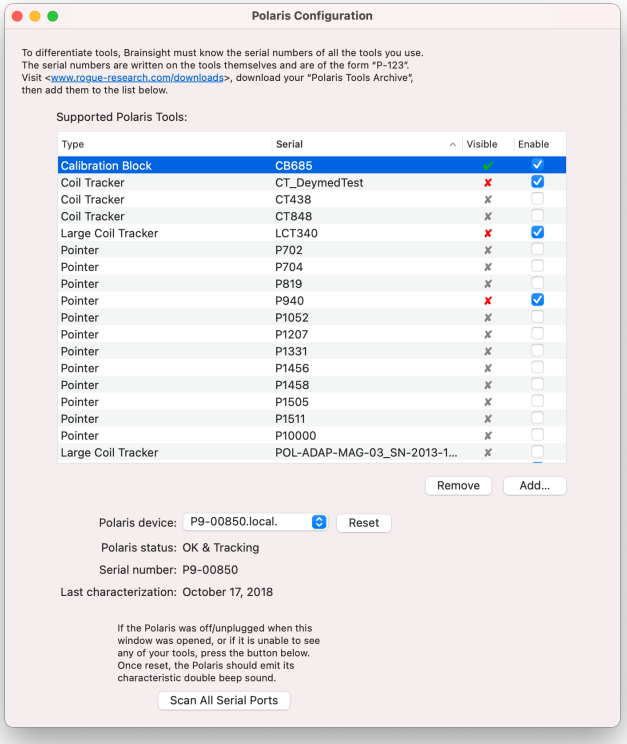


Fig. 3-11

Polaris Configuration Screen

2. Select **Window->Polaris Configuration** to open the Polaris window (NIRS Unit).
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 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.

Newer models of the Polaris camera (e.g. Vega) have changed from a serial/USB cable to Ethernet. This opens the possibility of having more than one camera visible on the Ethernet network. If you have more than one camera, select your camera from the popup button. This selection will be used throughout the software where interaction with the Polaris camera is required. You may need to

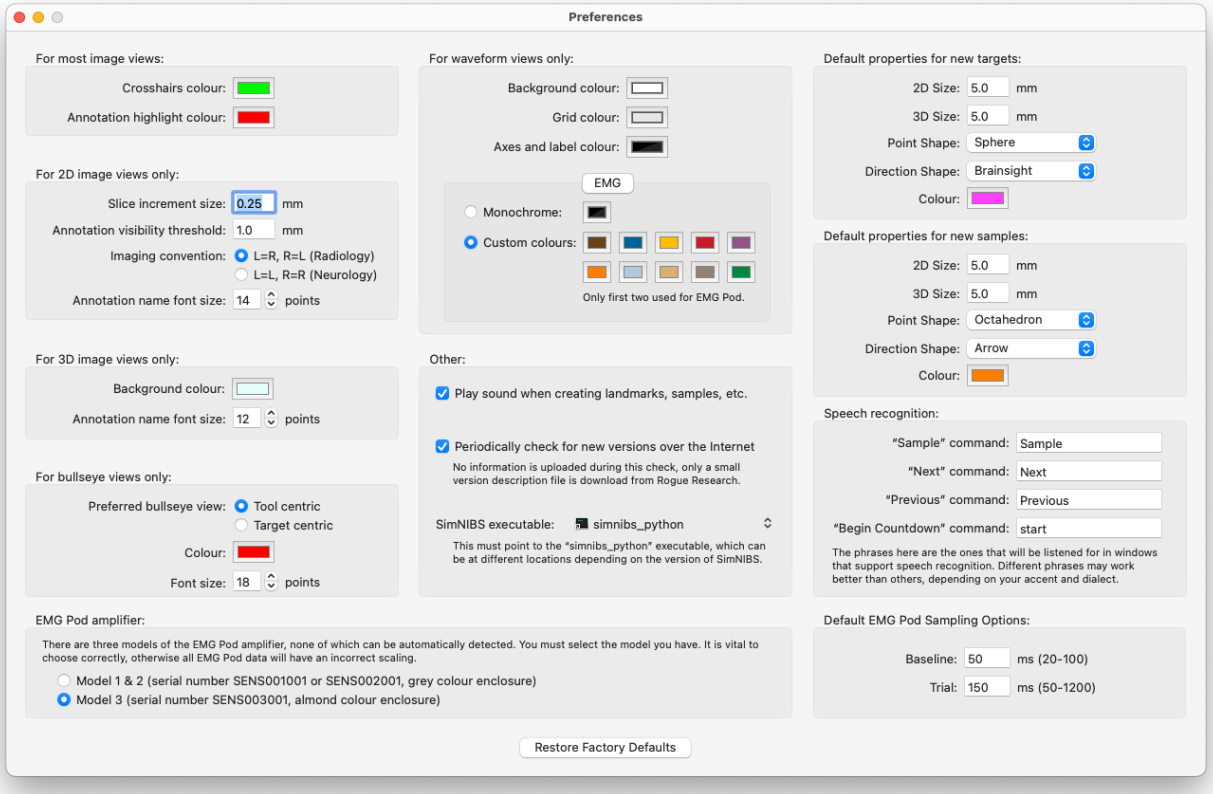


Fig. 3-12

Preferences Screen

come back to this screen after you have assembled and turned on your Vega

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. 3-12).

Crosshairs colour: Refers to the colour of the crosshairs that indicate the location of the cursor. Click on the colour to open the colour picker to pick a colour.

3D Background colour: When Brainsight renders a 3D scene, the surrounding space (background) requires a colour. Change it by clicking on the colour to open a colour picker to choose your colour.

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.

Default properties for new targets: If you are using Brainsight along with TMS, you may 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.

EMG Pod amplifier: Brainsight currently supports two models of EMG amplifier. Model 2 (in small grey enclosures) and Model 3 (in almond colored enclosures). These amplifiers have different, hard-wired gain settings. Make sure you select the correct ones here to ensure that the recorded EMG data is correctly scaled.

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.

Chapter 4: Cap and Assembly Manager

When you perform a NIRS acquisition, optodes are placed on the head of your subject. In many instances, the optodes are held on the head using a standard cap. Brainsight includes tools to define and save your NIRS caps and how the optodes on your NIRS are attached to the cap for use during the NIRS session. This saves time at the start of the NIRS session and simplifies the process of mapping the location of the optodes to the subject specific MR images by providing a reasonable estimate on where the optodes will end up on the head. This chapter will explain how to use the cap and assembly managers to define your caps and assemblies.

INTRODUCTION

When you purchase a Brainsight NIRS system, it will come with one or more caps and one or more sets of fibres. For the purposes of this user manual, a **cap** is defined as an apparatus that is worn on the head with the purpose of rigidly holding one or more NIRS optodes and/or EEG electrodes on the head. The caps may be similar to EEG caps (where full head coverage is desired) or smaller patches that are fixed to the head in one way or another. A cap definition in Brainsight consists of a name for the cap itself, a list of the names of each receptacle (referred to simply as holes) onto which optodes and electrodes may be fixed and optionally, the location of the holes within the cap in a standardized coordinate system (e.g. MNI coordinates). Using EEG as an analogy, a cap might have holes in it that are labeled according to anatomical locations using a standard grid system (T1, FP2 etc...). These locations are cap specific and do not assume anything is attached in any given receptacle; it is the list of all possible places where an optode or electrode may be attached.

When a cap is to be used, optodes and/or electrodes must be attached to the cap at one or more of the receptacles. This list of cap holes and associated optodes is called a **connection list**. It defines what specific optode (be it a detector or source) from the NIRS device is fixed to which hole on the cap. One can use this list to physically insert the optodes into the receptacles in the cap prior to a scan (and may be stored this way for re-use for subsequent

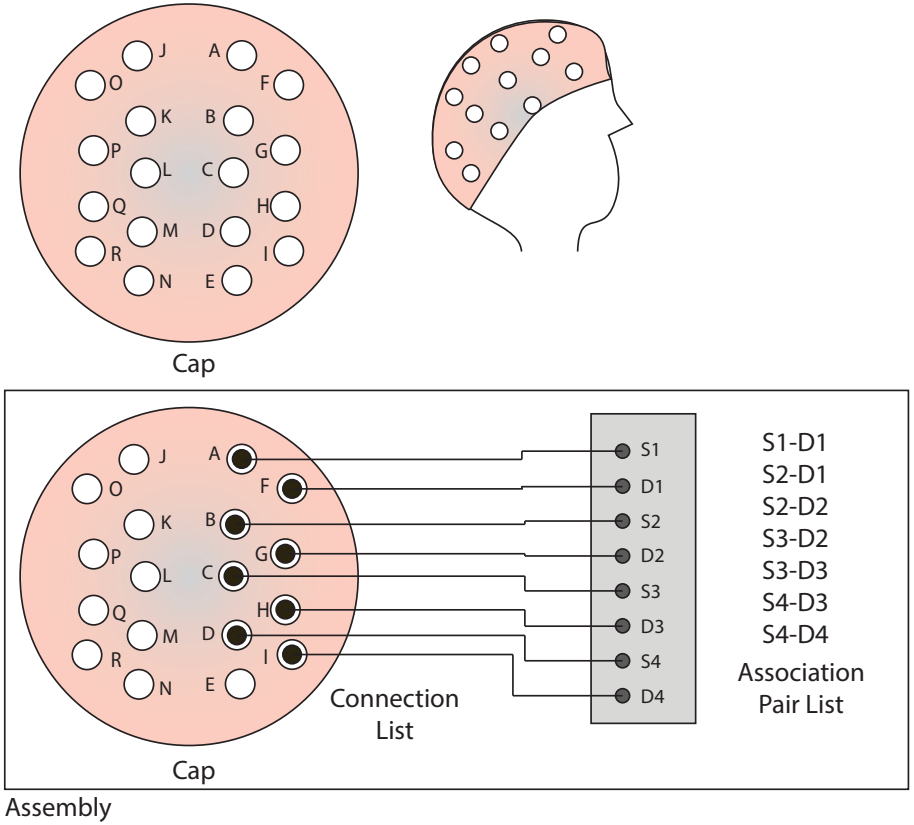


Fig. 4-1

Illustration of the relationship between a cap and an assembly.

scans when the configuration does not need to change). This enables Brainsight to associate the data acquired by each source-detector pair with a specific region of the brain. This cap-connection list association is called an **assembly**. A cap may be associated with multiple connection lists and thus have multiple assemblies, but a connection list can only be associated with a single cap. Thus an assembly is a unique pair of a cap and connection list.

The data that is being recorded in NIRS is the light collected by the detectors. In theory, each detector may be collecting light from every source optode on the head. Each source may have 2 or more separate wavelengths of light, so the number of potential sources of light that any given detector may be recording is the number of source optodes times the number of wavelengths per source. For a 32 channel system, each detector may record data from 16 source optodes. Assuming two wavelengths per optode (32 light sources) and 32 detectors, you can create 32x32, or 1024 data streams. This can quickly become difficult to manage. While it is theoretically possible to for a detector to collect light from all sources, in practice, only sources within a reasonable distance from the detectors will contribute enough of light worth recording, so each detector can be associated with sources close enough to matter. We call these **association pairs**.

Brainsight includes software tools to define your collection of caps, and tools to use caps to generate connection

lists and lists of association pairs. A cap, connection list and association pair list is referred to as an **assembly**. The tools in Brainsight to create and manage there are the cap manager and assembly manager.

USING BRAINSIGHT WITH DIFFERENT NIRS HARWARE

While the Brainsight navigator is used often with the Brainsight NIRS hardware, you can use it with different NIRS hardware as well. You can define cap layouts and assembly lists for any NIRS system, use the navigation system to place the cap and record the optodes and even import the NIRS data into Brainsight for visualization.

One difference between the Brainsight and other hardware is our use of block#s to define up to 4 modules that may be present in the system. When defining assembly lists for other hardware, simply use Block 1 for all source and detector channels.

USING THE CAP MANAGER

When you obtain a cap, either from Rogue Research or other source, you need to enter the information associated with the cap into your Brainsight system in order to be able to use it with a subject.

Open the cap manager by clicking **Window->Cap Manager.** This will open the cap manager widow (Fig. 4-2). To create a new cap from scratch, click on **New->New Cap.** To create a new cap based on a pre-existing cap, select the cap to use as a starting point in the list (e.g. different caps with similar geometry), then click **New->Cloned cap**.

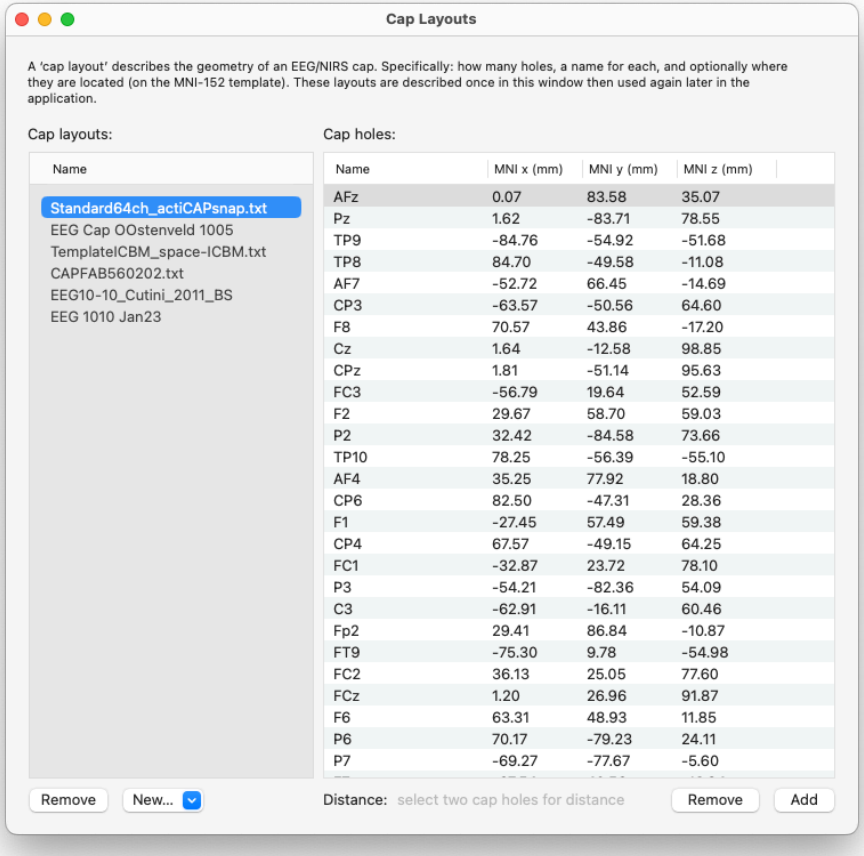


Fig. 4-2

Cap Manager

Finally, to edit an existing cap, simply select it in the list to highlight it.

- To create a receptacle, click **Add**, and a new entry will be created. The name field will automatically be highlighted. Enter a name for the receptacle. For whole head caps, this is usually an anatomical location (e.g. EEG caps), while for smaller patches, these are usually a node identifier (e.g. row and column name). These names are for your reference, so you can choose them as you wish. In addition to the name, you can also enter the 3D location of the receptacle in the MNI coordinate system (if you have this information). This location will be used to estimate the location of the receptacle when placed on the subject's head. If available, enter the X, Y & Z values.
- Repeat the previous step for every receptacle on the cap.
- You can select any receptacle on the list and edit the information, or delete it altogether by selecting it and clicking **Remove**.
- Once you are finished, you can close the window.

MANAGING ASSEMBLIES

A assembly list is a way to define, prior to the subject being there, a specific configuration of a cap and NIRS optodes (and optionally EEG electrodes). It represents a list of what optodes are to be connected to what receptacles in the cap, as well as which source-detector pairs will be recorded. By creating these templates in advance, you can eliminate repetition by having to enter the same information each time you want to record some NIRS data and reduces the setup time once the subject is present for the scan.

When using this assembly during a scan, Brainsight will only activate the sources that are included in this connection list.

To create a new, or edit an existing assembly:

Open the Assembly list manager window by clicking **Window->Assembly Lists**.

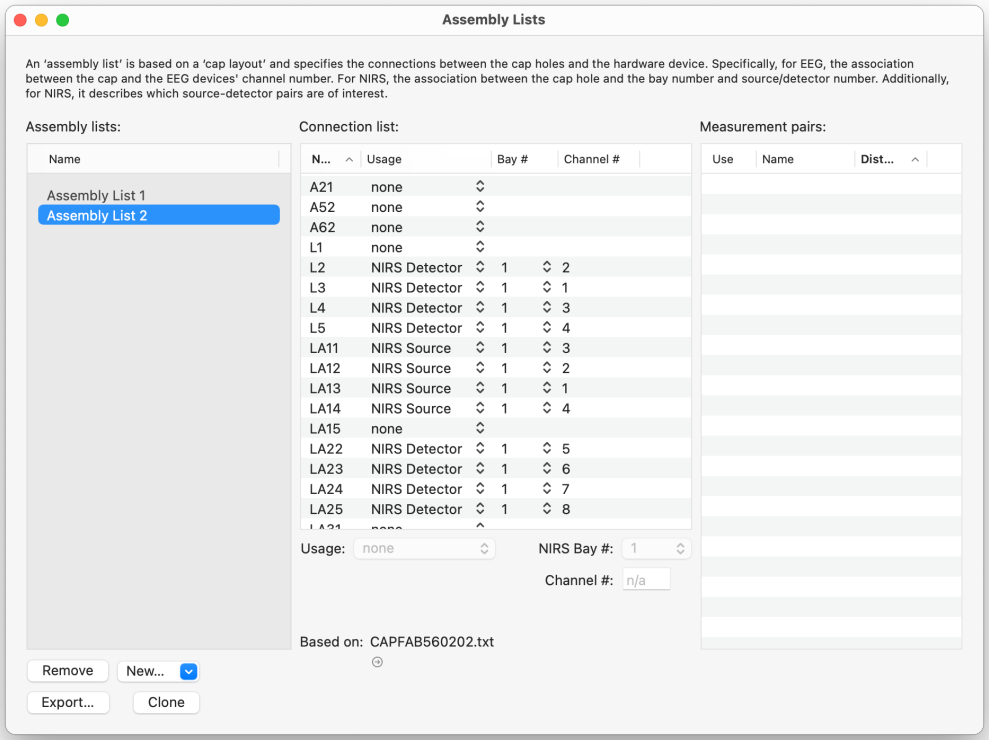


Fig. 4-3

Assembly Manager

- To create a new assembly from scratch, click **New->[cap],** where cap is the cap you want to use in the assembly.
- The connection list will populate itself using the the cap holes. For each cap hole that you wish to assign something to, click on the **Usage** popup entry field (it is set to none by default) and select either NIRS for a NIRS optode, or EEG for an EEG electrode.
- If the entry is a NIRS optode, select the NIRS block# in the block# popup field to assign an optical module number (1-4). Next, select the source or detector number, by clicking the Optode popup field, and selecting the appropriate source or detector number. Remember to use block# 1 for NIRS systems other than the Brainsight NIRS device.
- If it is an EEG electrode, select the electrode number that corresponds to the amplifier channel number.
- Repeat the previous steps for each optode and/or electrode. Recall that you do not need to use all the receptacles or optodes and electrodes. You need only define the ones you wish to use when applying this assembly.

VISUALLY CREATING AN ASSEMBLY FOR AN EEG-STYLE CAP

The process of determining the optimal locations for the placement of optodes on the head is one of the most complicated yet important steps in successful NIRS acquisitions. While an assembly is what we call the list of cap locations and associated channels on the hardware, the overall layout of optodes on the head is often referred to as a montage (similar to EEG). The main goals of the montage are to cover the region of the brain you wish to record from with a set of optodes that are spaced equally apart (e.g. 30mm). Brainsight can be used to display the assembly as the assembly is built to make it easier to intuitively arrive at the best montage for yuor particular application.

This section will cover the steps to crate a montage/assembly list using the Brainsight EEG-style cap with the hexagonal type array of optode holders. Before proceeding, it is advisable to familiarize yourself with several of the "Prepare" steps following this chapter. Specifically, you need to be familiar with creating a Brainsight project based on the ICBM brain and manipulating the display of 2D and 3D images.

If you have not already done so, download the cap layout for the cap you intend to use and add them in the cap manager. Contact Rogue Research if you do not have any cap layout files for the caps you possess. Note that we have cap layouts for several sized caps, however the hexagonal-style caps have essentially the same layout for all caps except for minor variations along the midline where on the larger caps, one might find two adjacent receptacles (on either side of the midline) and on smaller caps, they may have been merged into one if they were too close together. In these cases, instead of RA1 and LA1 (for example), the merged receptacle would be labeled A1. For the purposes of planning layout, any of the same class of cap can be used (note the cap size, e.g. 58cm) and the assembly can be re-applied to the other homologous cap sizes.

Overall, the procedure will be to load the ICBM brain and apply a blank cap layout to display the locations of all the receptacles and then to interactively build an assembly while viewing it on the images as you go until you ave completed the assembly. The process may seem cumbersome at first, but becomes easy once you have acquired some experience.

Launch Brainsight and create a new project from template brain.

- Click on **Sessions** in the project window and then click **New->Offline Session...** from the **New** popup button.
- Click on the **Electrodes** tab.
- Arrange the screen layout to something similar to Fig. 4-4. Specifically, select the 2x1 layout and display the scalp in one view, and the curvilinear brain in the other. You are free to change the layout however this layout is likely the most useful.
- Select **Window->Assembly list** to open the assembly list manager.
- In the Electrodes step window, click Add From... and select a cap that will be the template for your layout (e.g. CAPFAB560202) from the list, set the coordinate system to "World/MNI" and Snap to: Skin

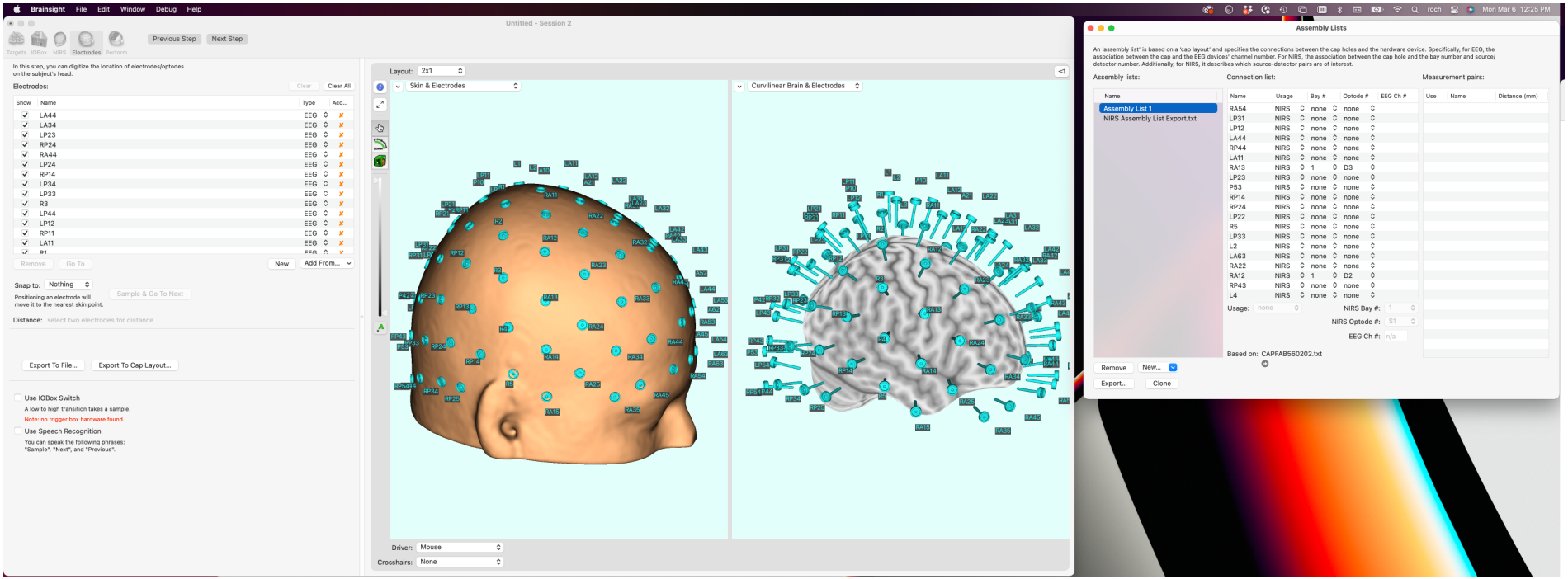


Fig. 4-4

Suggested layout if images and windows to interactively built an assembly list.

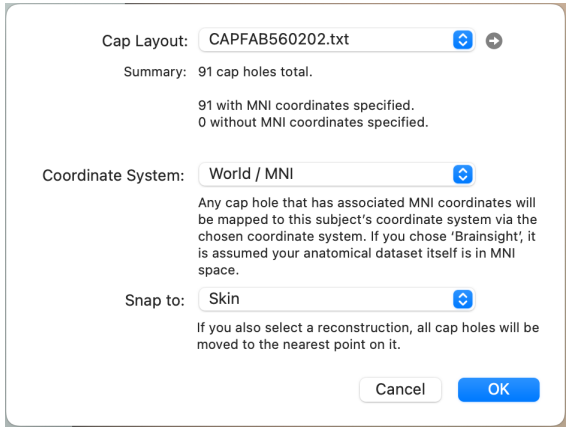


Fig. 4-5

Apply cap to head configuration

(see Fig. 4-5). You should see the optode receptacles appear on the scalp of the skin and float over the curvilinear brain as shown in Fig. 4-4.

- Create a new blank assembly by clicking the **New** popup button and selecting the same cap layout as you used in the previous step.
- Looking at the images, decide where to place the first source and note the receptacle label. Select that receptacle in the assembly list and assign the first source (e.g. Bay 1, S1) to it.
- Looking at the images, decide on the receptacle to place the first source (ideally, a receptacle immediately adjacent to the source you just assigned). Select that receptacle in the assembly list and assign a detector (e.g. Bay 1, D1) to it. Notice that the possible pair (B1S1-B1D1) appears in the Measurement Pairs list and the distance between the two is shown. We expect that distance to be around (+/- a few mm) 30mm (or slightly more for larger heads). Note these distances are on the MNI head and will be slightly different when applied to different sized heads. Enable this pair using the **Use** checkbox.
- Notice that nothing has changed in the image views. You can display an update of the progress by applying the partially built assembly. In the image window, select **Add...->From Assembly List...**. Instead of the cap layout selected at the start, select the assembly list. B esure to keep the **Coordinate System** as MNI and the **Snap To:** as Skin. Notice that the source-detector pair is displayed on the images (Fig. 4-6).

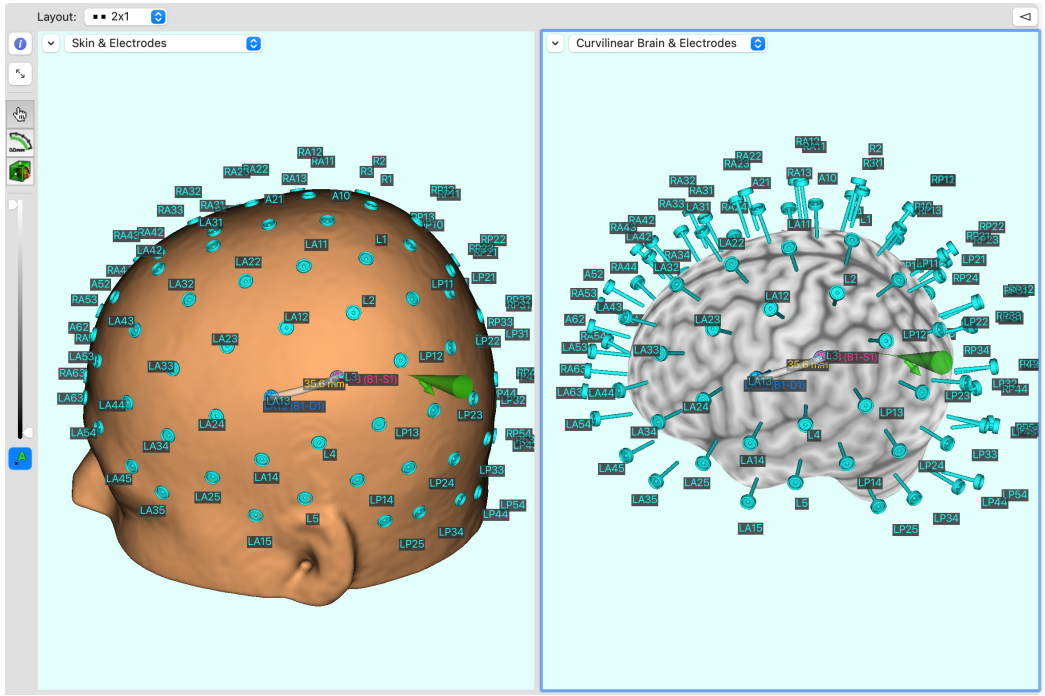


Fig. 4-6

First source-detector pair displayed on the images

- Continue adding sources and detectors to the assembly list and repeating the **Add From Assembly List...** every time you want an updated view of your progress.
- Once complete, close the Assembly manager window and the offline session.
- You can re-apply the assembly list to other cap sizes by opening the Assembly list manager again, selecting the assembly and clicking **clone**. Note that you can change the underlying cap layout of the cloned assembly by clicking the arrow beneath the cap layout listed under "Based On". If any of the cap nodes used in the assembly are missing from the new cap, you will need to edit the assembly list to correct it. This will occur when changing cap sizes where adjacent receptacles are merged (or vice versa where a single mid-line receptacle is split into two, one on each side of the midline).

DETERMINING 3D COORDINATES OF CAP HOLES USING THE POSITION SENSOR

If you have a custom cap and wish to digitize it to add it to the cap manager (to be used in creating assemblies), see "Using a single subject to create a NIRS cap definition" on page 98.

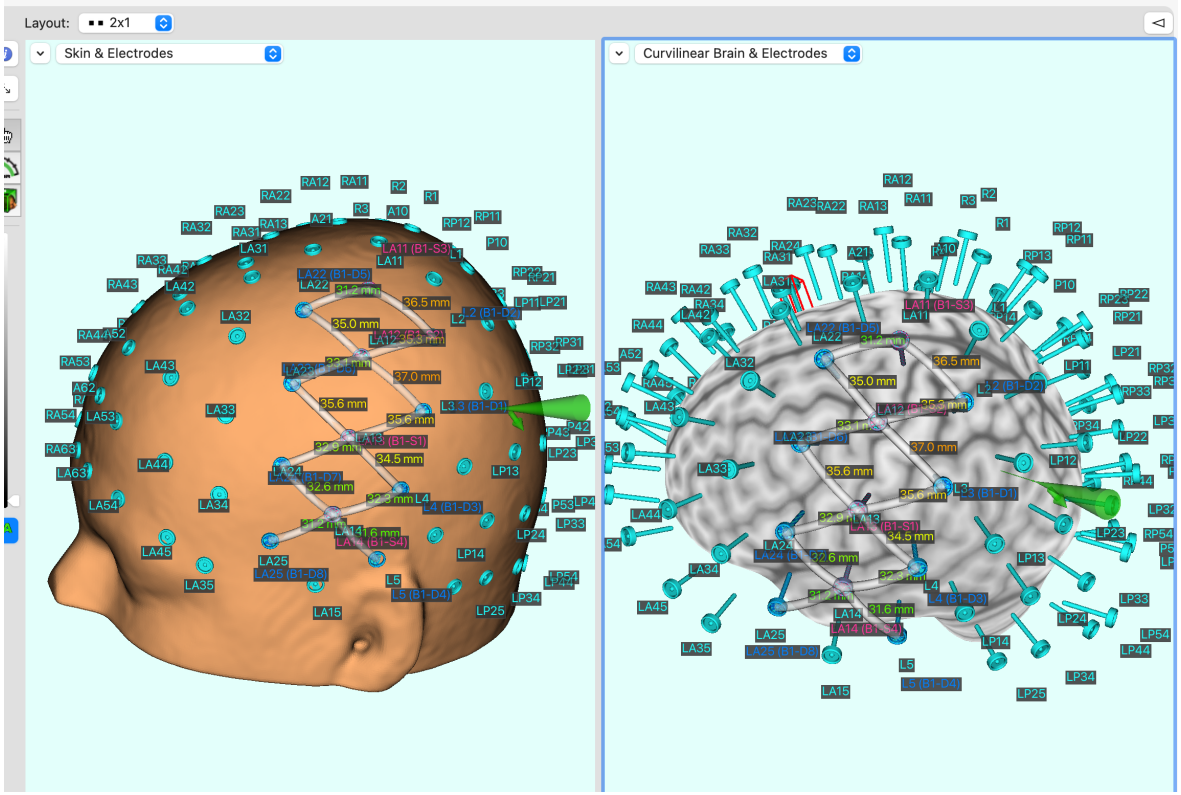


Fig. 4-7

Simple assembly list montage over the motor strip

Chapter 5: Loading Anatomical Images

One of the unique features of Brainsight is the ability to bring the NIRS data directly into the subject-specific MR images. This makes it easier to ensure that the optodes are well placed on the scalp to image the desired brain regions and to use this data to perform more sophisticated analysis and display of the results. If subject specific anatomical images are not available, you retain the option of loading a relevant model head (e.g. MNI brain) with a slight loss on accuracy. This chapter will cover the first step required to prepare a subject specific project file so it will be ready for a NIRS acquisition: loading anatomical images. The next steps, will be covered in the next chapters.

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).

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.

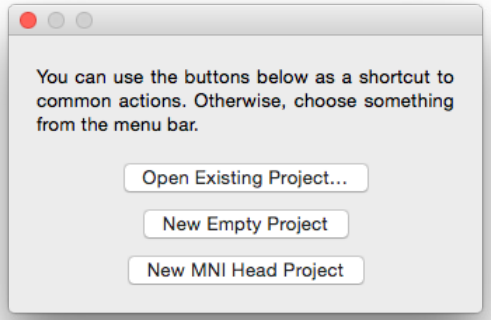


Fig. 5-1

New Project Assistant Window

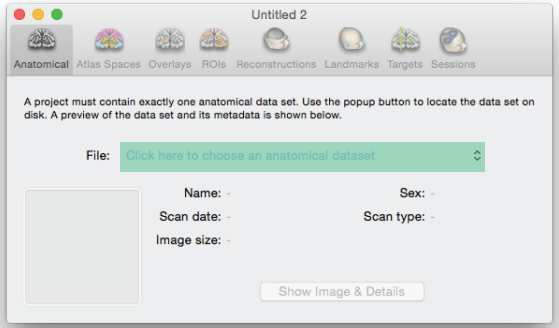


Fig. 5-2

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. 5-2) 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:// 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. 5-3). 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. 5-4). 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. 5-3

Project window with the anatomical MR scan loaded.

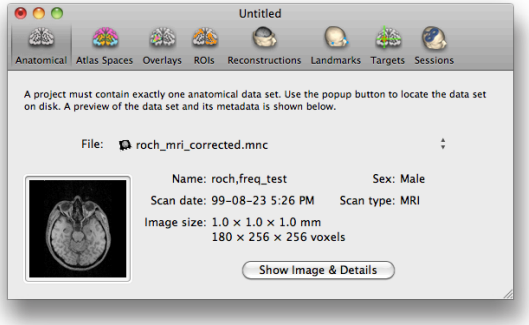


Fig. 5-4

Anatomical Image Detail View

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

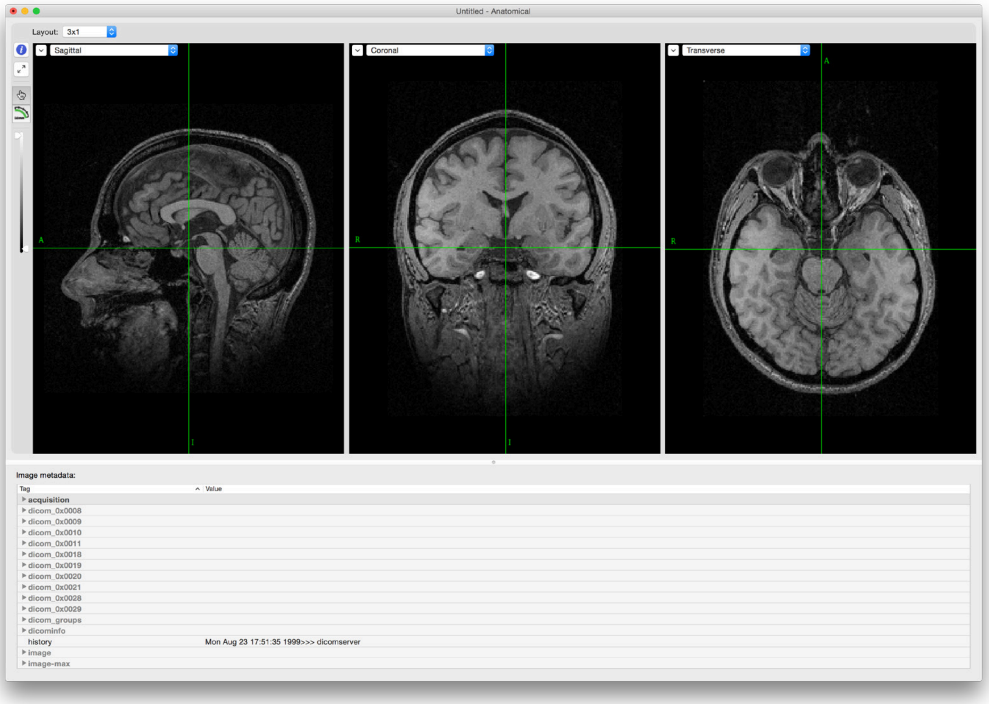
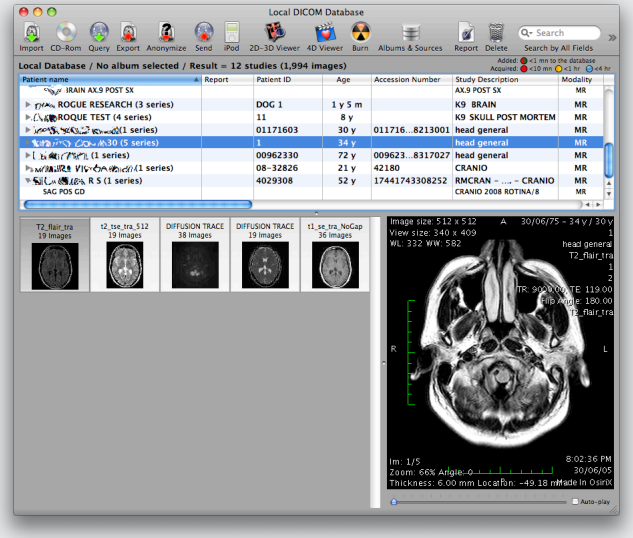
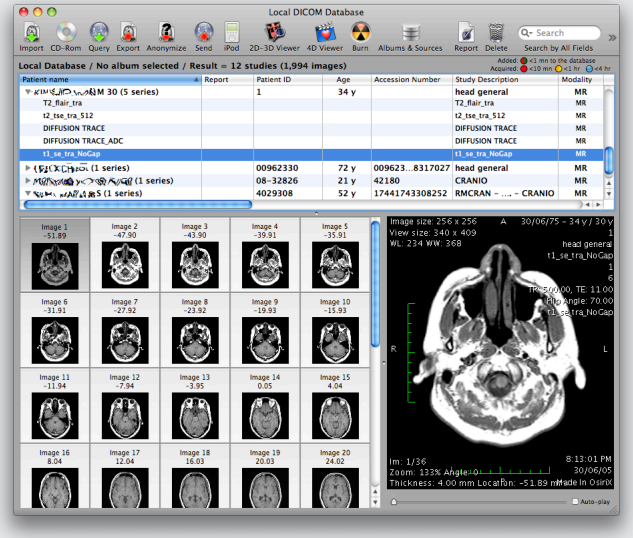


Fig. 5-5

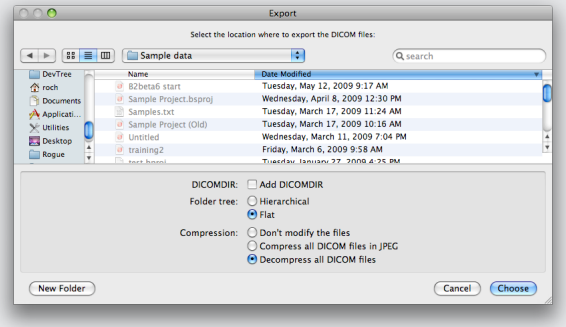
Typical steps for importing DICOM images from a DICOM CD using Osirix.

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 imaged 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 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:

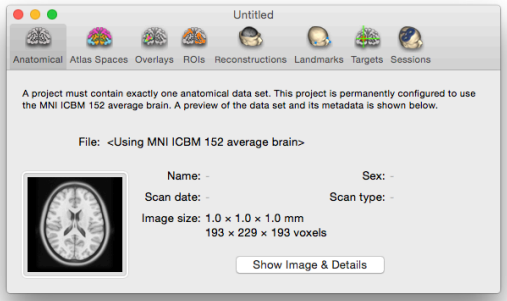
- Click **New MNI Head Project** from the New Project Assistant window, or select **File->New MNI Head Project**. The data set resides in a special place and will be loaded automatically.

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 11: Selecting Targets for Stimulation".

Fig. 5-6

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 and 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 1mm 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.

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. 5-7. 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. 5-7, it is a 2x2 layout. The layout can be changed using the layout control popup menu.

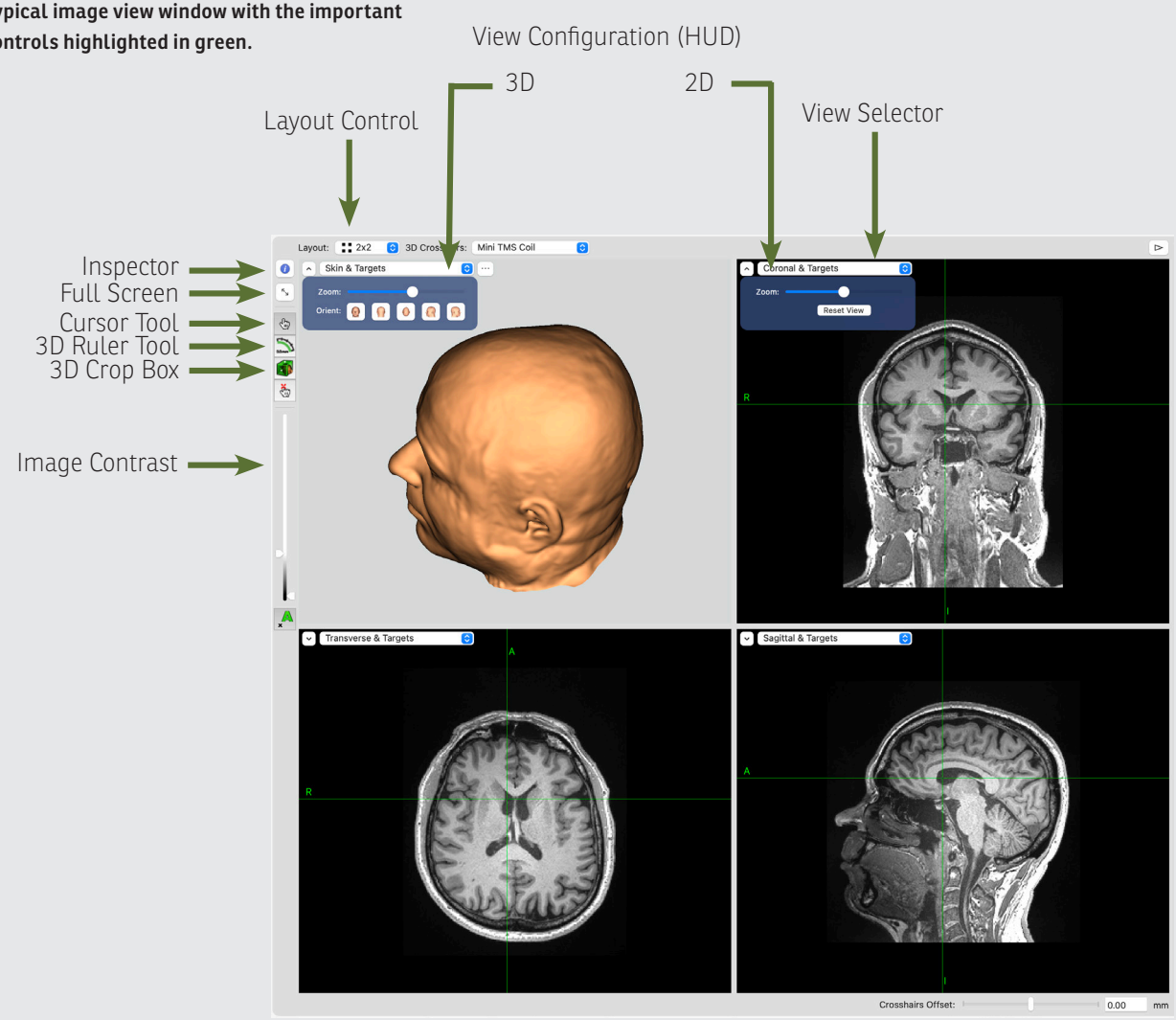
View Configuration (HUD)

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. 5-7

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. 5-10A) and overlay image data (Fig. 5-10B). From this window, you can also choose the peel depth of curvilinear reconstructions (Fig. 5-10C).

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.

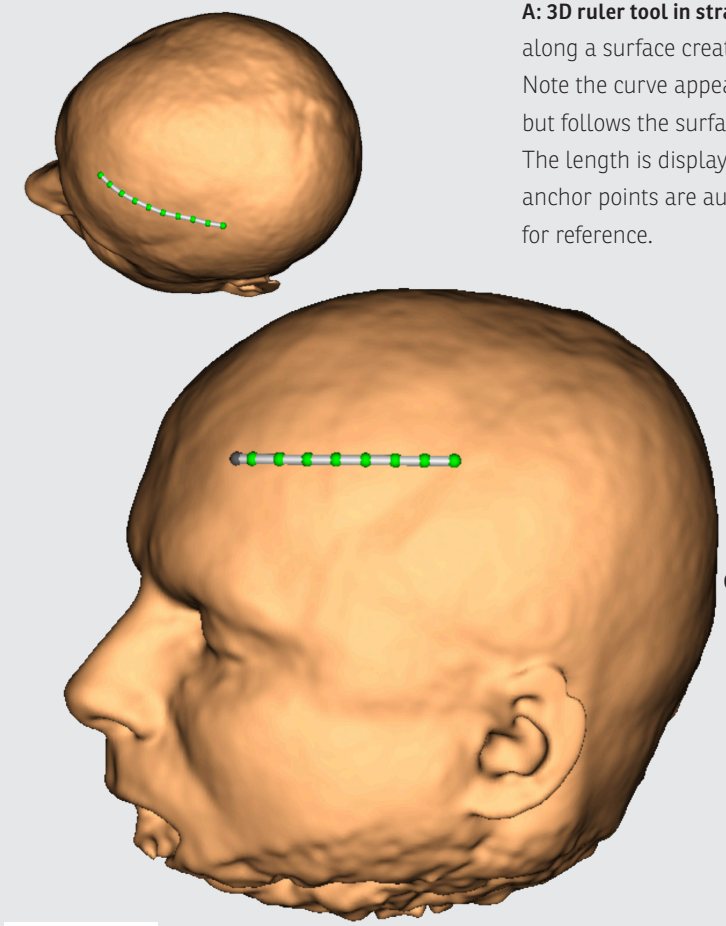
In the 2D view, clicking on the start point, then dragging while holding the mouse button down will create a straight line whose end-point will follow the mouse. You can then move the start and/or end points by click-dragging either one with the mouse.

In the 3D view, you can create straight or complex curves on any 3D surface. 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 to activate the box (Fig. 5-11). 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.

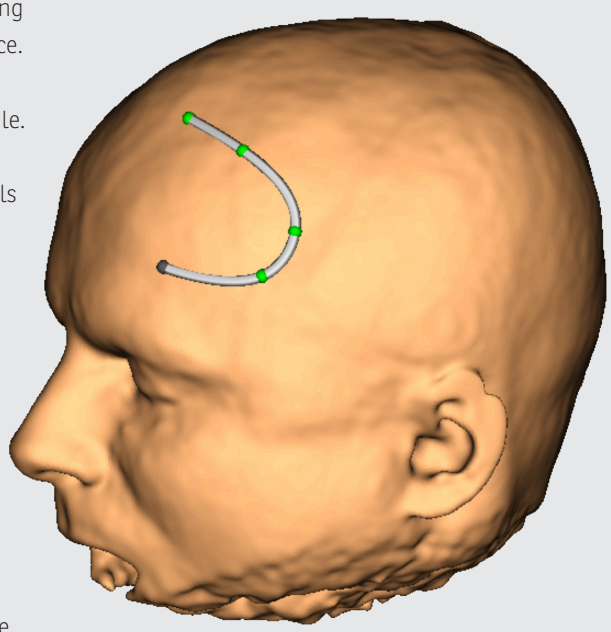
Fig. 5-8



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. 5-9

Custom View control window:

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

3D Planes: Allows you to view the brain through one or multiple 3D planes.

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

Accessories (in an Online Session): Allows you at add and track 3D representations of various objects, including the cursor, coil, trackers and the Polaris field of view.

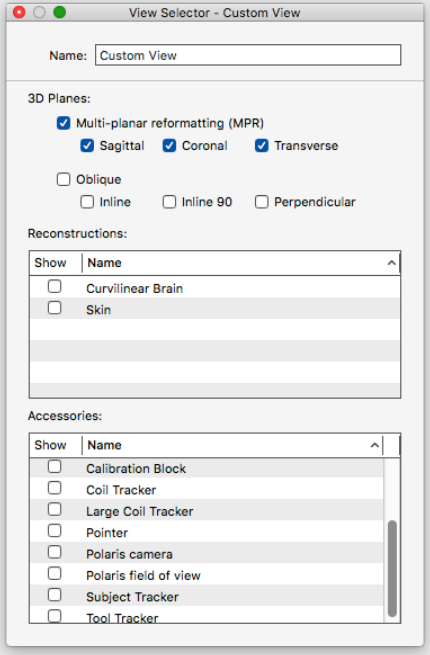
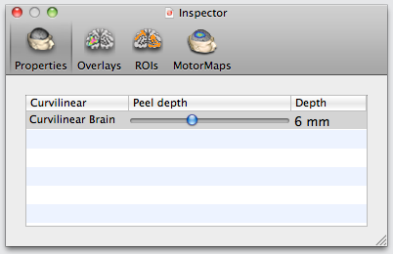


Fig. 5-10

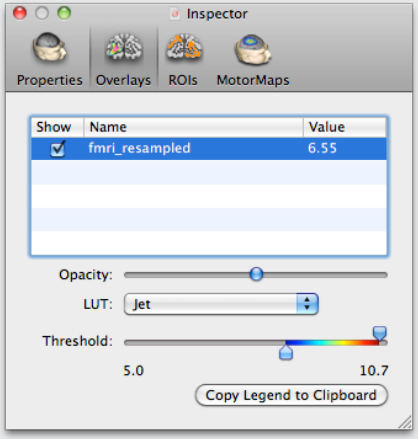
Inspector tool:

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

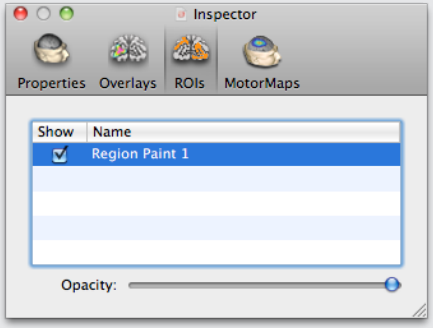


B: Overlay inspector



C: Region of Interest Inspector

(motor maps are described in TMS manual)



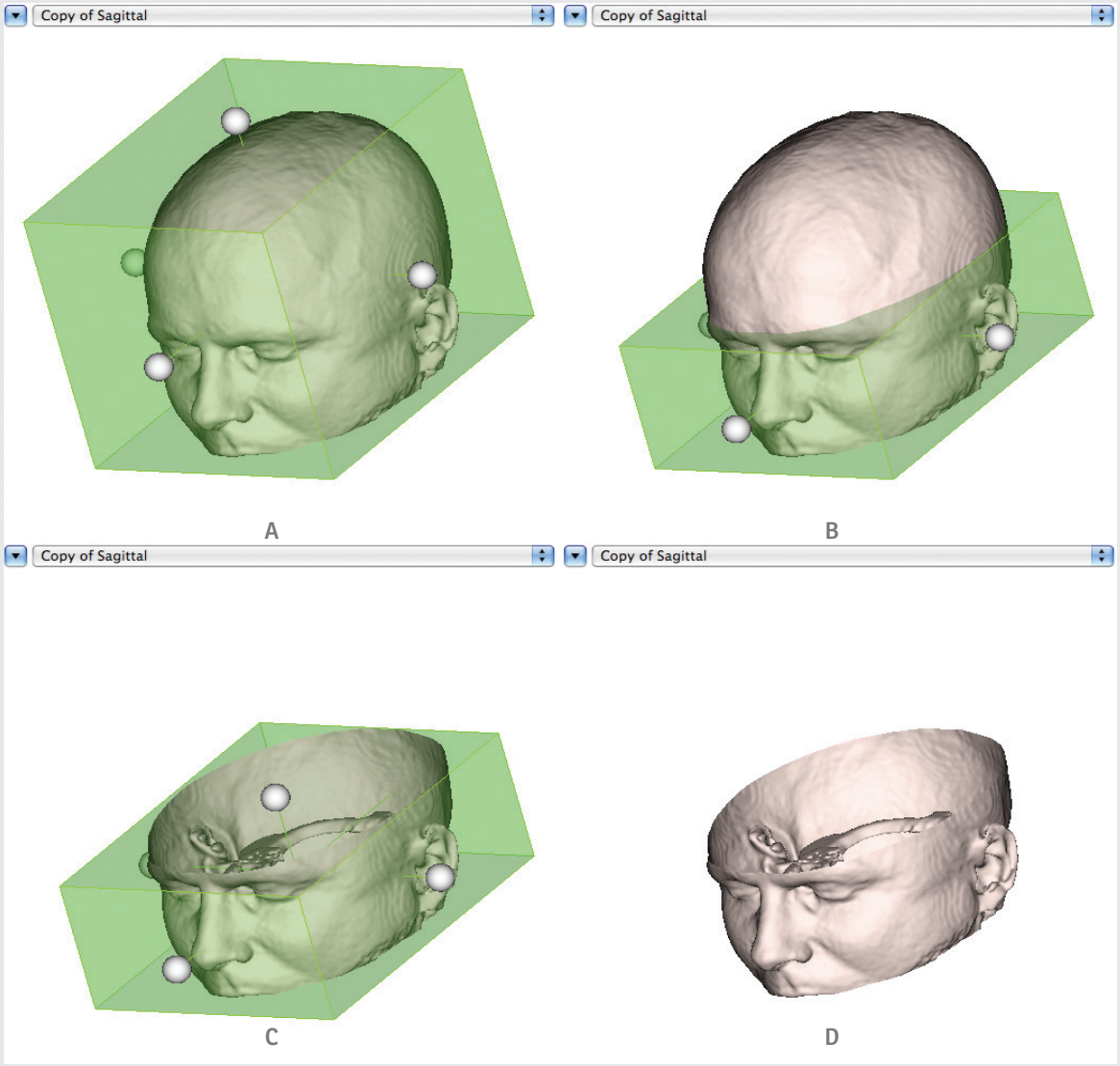


Fig. 5-11

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 (be 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.

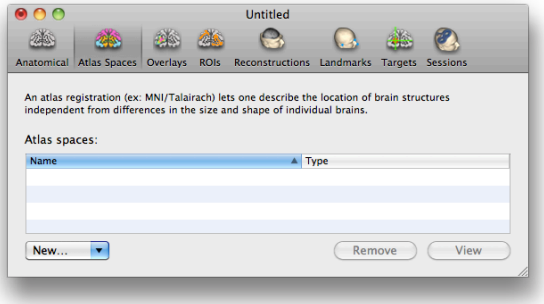
Chapter 6: Prepare: MNI/Talairach Registration

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 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. 6-1

MNI/Talairach Atlas Registration Manager



INTRODUCTION

This step is only required if you are using subject specific MR images. This step will allow Brainsight to map the initial 3D coordinates of any NIRS cap (which are stored in MNI space) to be mapped to the subject's scalp as seen on the MR images.

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-exiting 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.



Fig. 6-2

Initial Manual MNI Registration Window.

MANUAL MNI REGISTRATION

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 commisure (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

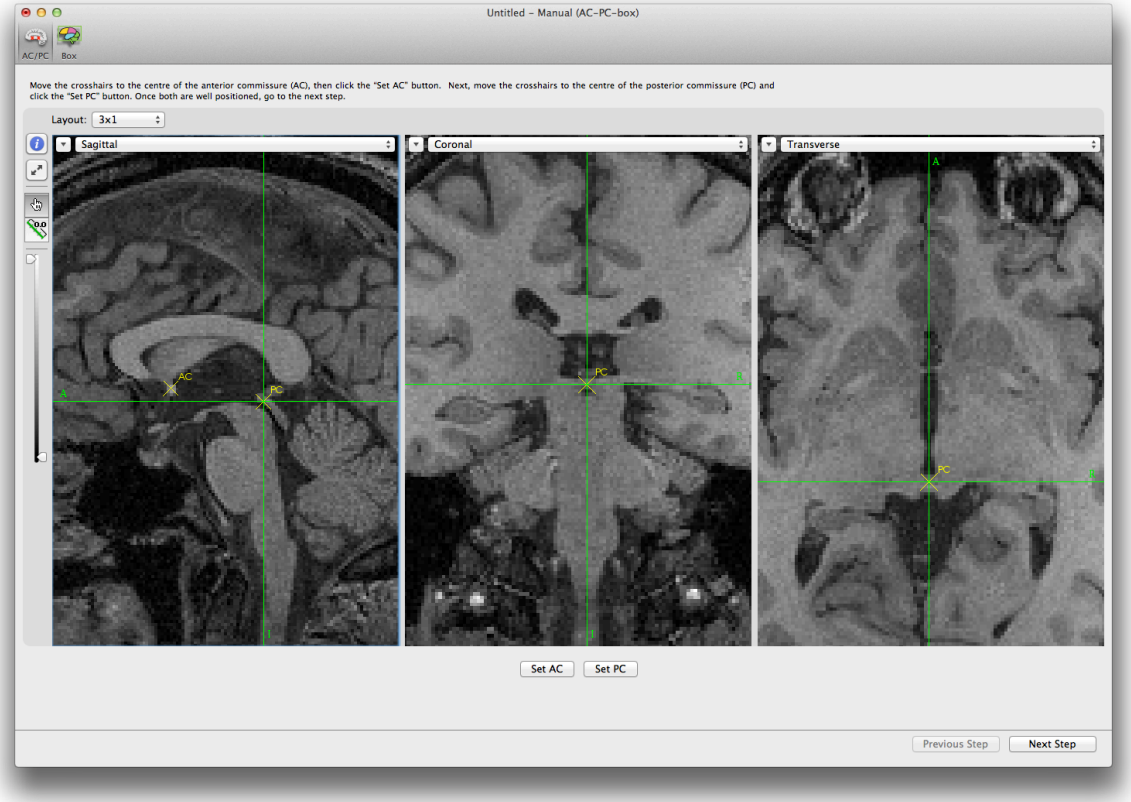


Fig. 6-3

MNI registration step with AC & PC identified.

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 calculate a basic linear fit.

Select **Manual (AC-PC-box)** from the New... popup menu, the MNI registration task manager will appear (Fig. 6-2).

- Move the cursor to the centre of the anterior commisure (AC) and click **Set AC.**
- Move the cursor to the centre of the posterior commisure (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. 6-3).
- 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. 6-4). **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

Fig. 6-4

MNI registration step with set brain boundaries. Focus your attention on the upper, lower and lateral bounds of the coronal slice, and the anterior and posterior bounds of the transverse slice.



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.

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. 6-5). The actual matrix is also displayed on the top left of the window.

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 Fox et. al. (ADD REF!) to convert from MNI to Talairach space for compatibility reasons.

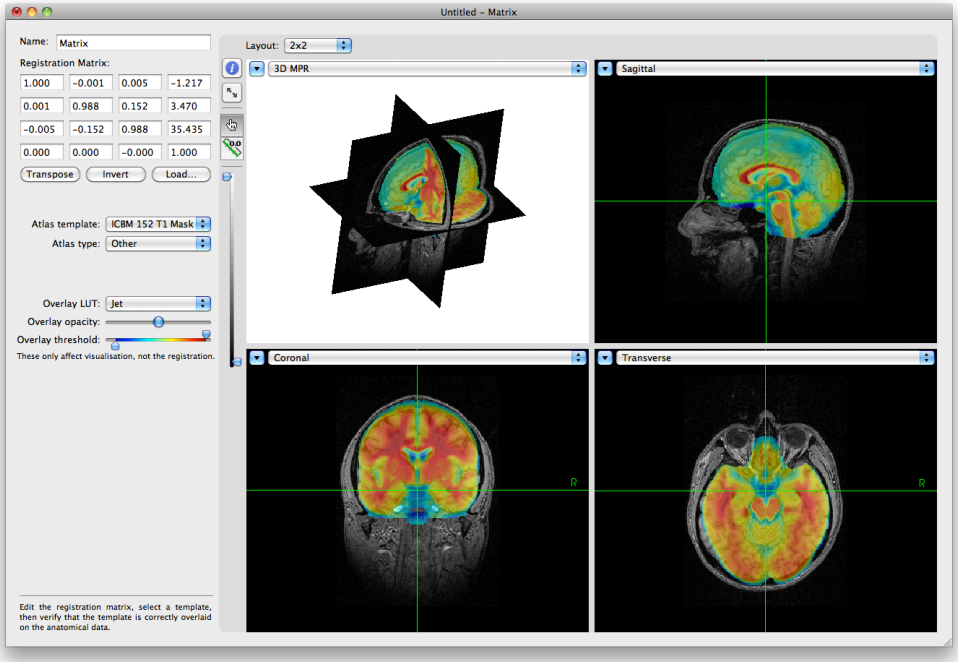


Fig. 6-5

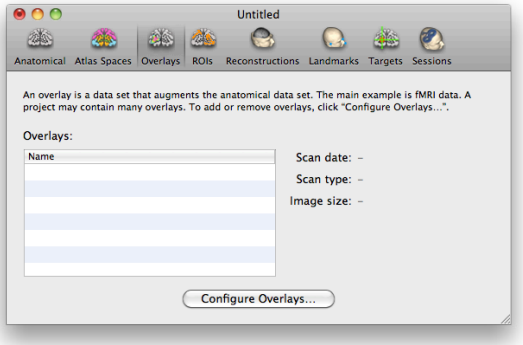
Verification screen for MNI registration. Registration matrix is shown at the top left.

Chapter 7: Prepare: 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 it's MNI reference space to the native shape of the subject.

Fig. 7-1

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 5.
- 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

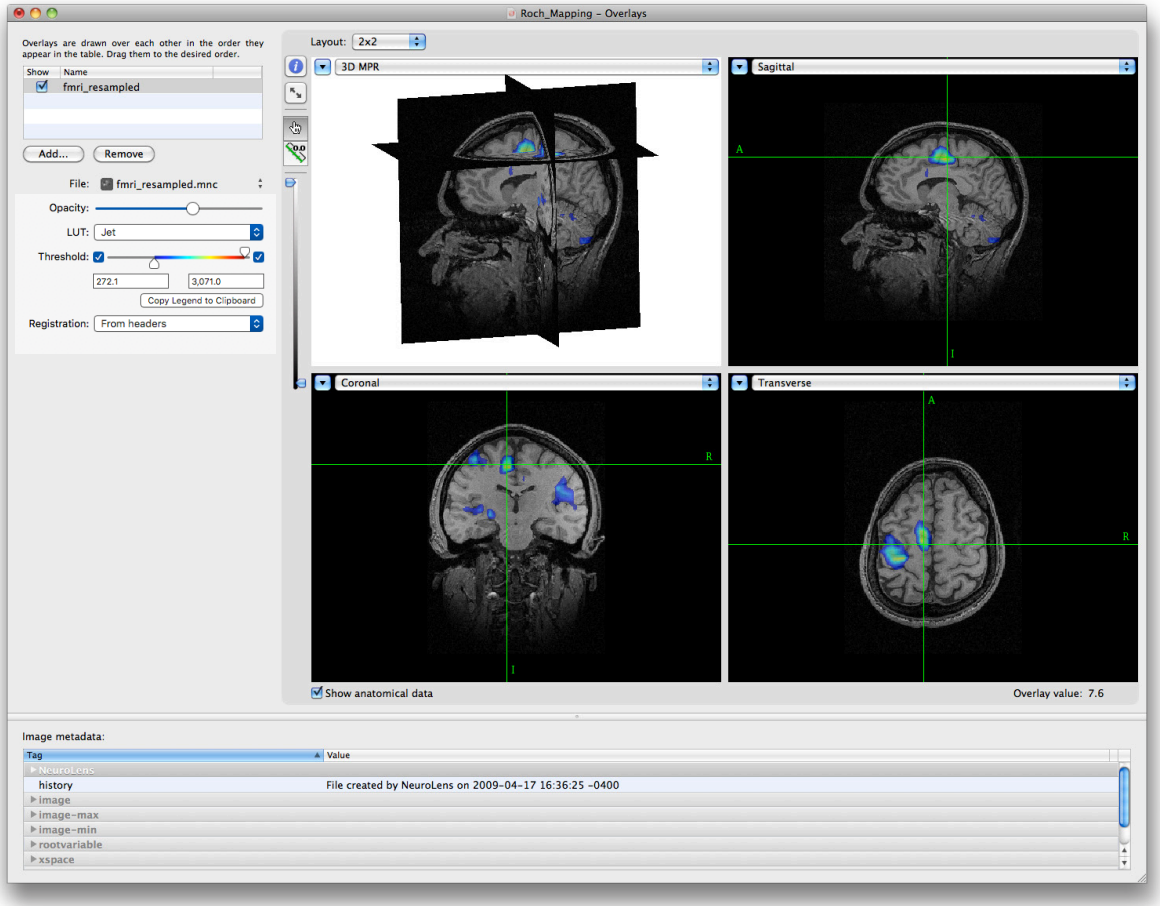
anatomical, select **"none"** as the registration.

- 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. The checkboxes at either end of the Threshold slider allow you to either show or hide the data beyond your set threshold. If shown, what is either above or below your threshold level (depending which checkbox is unchecked) will be shown as a solid colour from the extreme ends of your LUT (e.g. blue would represent all data below the chosen threshold, and red would represent all data above a chosen threshold). Note that Brainsight does not support showing both positive and negative

Fig. 7-2

Overlay window



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:

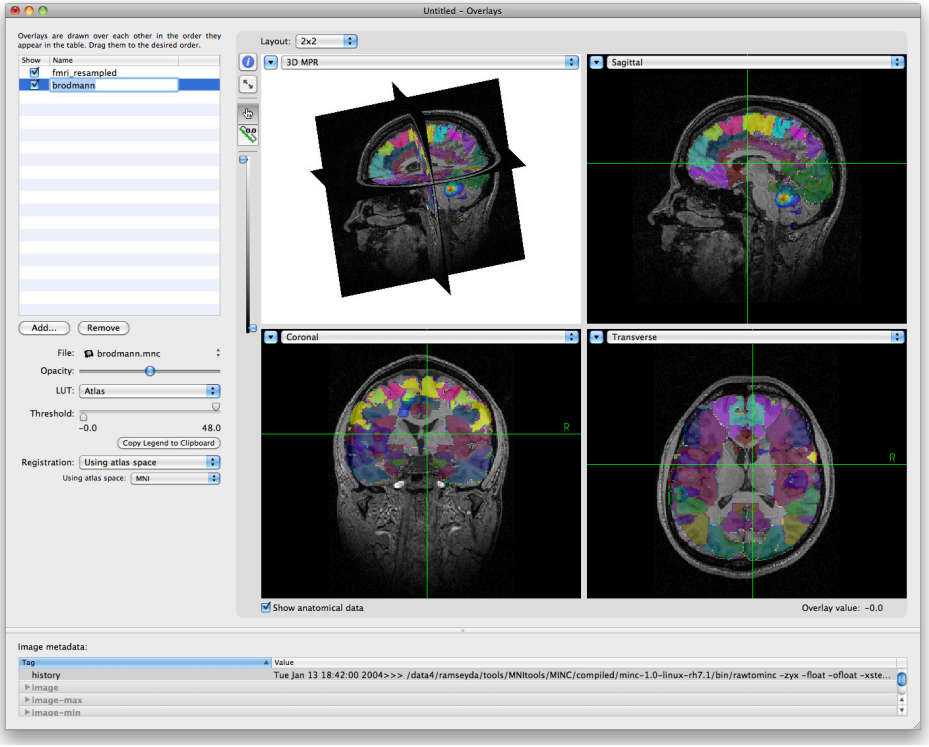
- You need to perform an MNI registration (see Chapter 6) so the software knows how to transform space to/from MNI space.
- The Atlas file needs to have defined the transformation from the image voxels (voxel space) to the MNI space, stored either in the header or as a separate transformation file. Atlases 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.

Fig. 7-3

Overlay window with atlas



- Select MNI or Talairach to identity 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.

Chapter 8: Prepare: 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 2 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.

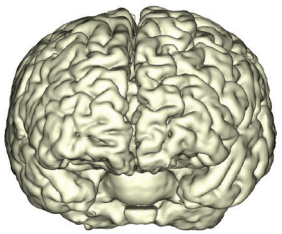
Region painting refers to the process of segmenting the region you are interested in (e.g. the skull, or a particular brain structure) from the surrounding data by labelling it somehow (e.g. painting image voxels) as illustrated in Fig. 8-1 A. 3D reconstruction method can take this labelled data and create a 3D surface (3D mesh) to be displayed and manipulated as a discrete object (Fig. 8-1 B).

Fig. 8-1

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 2 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

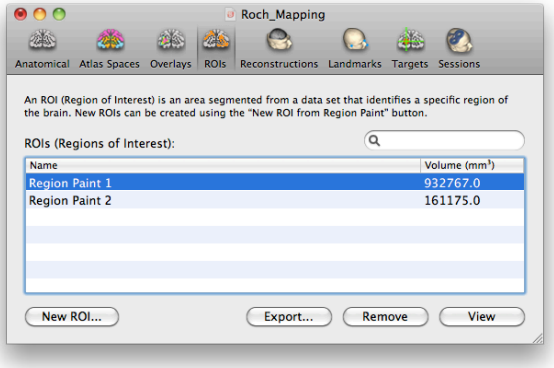
This section will cover creating an ROI and explain the use of the tools as they are needed. To create an ROI, select the ROIs tab at the top of the project window then click **New ROI from Region Paint**. The region paint window will appear (Fig. 8-3). The window will have a layout with 4 image view 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 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 bounds are referred to as the isolated voxels, and are

Fig. 8-2

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



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. 8-3.

4. Select **Seed** (among the painting tools as shown in Fig. 8-5) and click in the region of interest. The result will look like Fig. 8-4 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. 8-4 C). Select **Fill Region** and click in the middle of the region to fill the region (Fig. 8-4 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 "offending" 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.

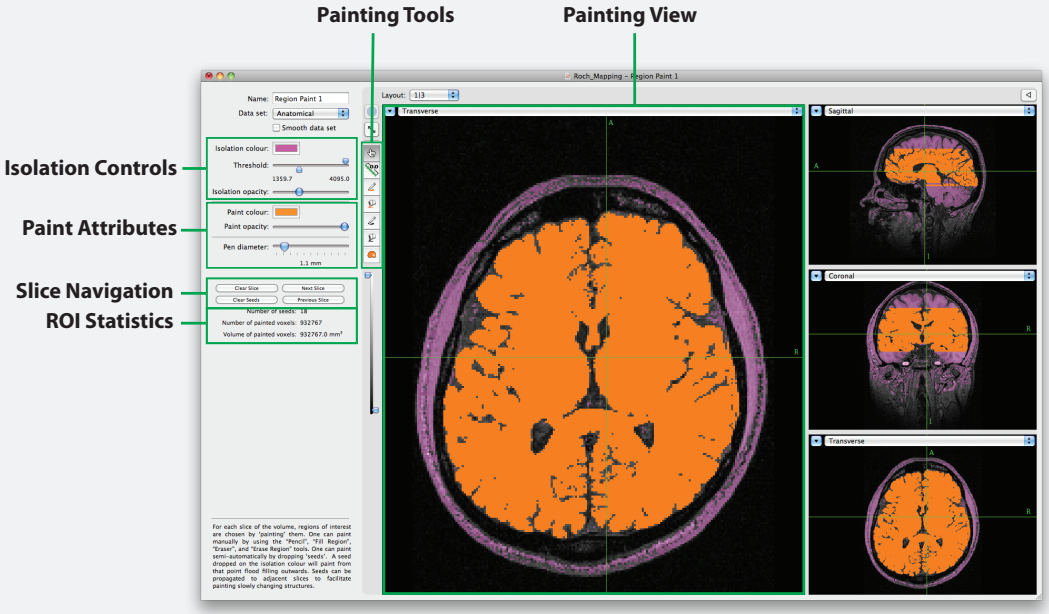


Fig. 8-3

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.

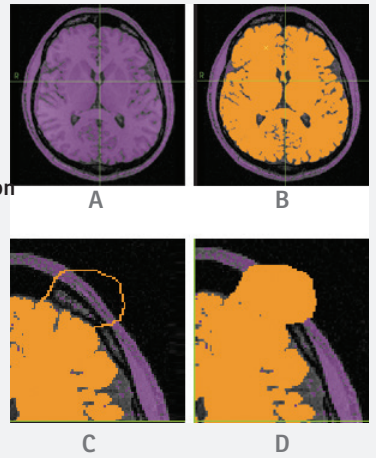


Fig. 8-4

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 thresholed 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.

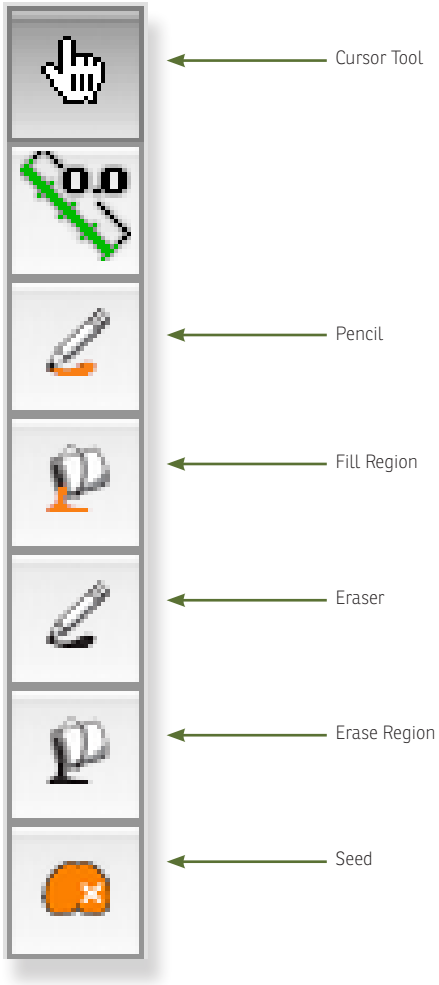
Note that during this process, you will almost certainly click on something you did not want to, losing the work you just did. To Undo the last operation, simply select **Edit->Undo** (**Cmd-Z**). You can backtrack several operations if needed.

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 tactography). Once the ROI is complete, click **Export...**. Once the save 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.

Fig. 8-5

Close-up of ROI tool listings.



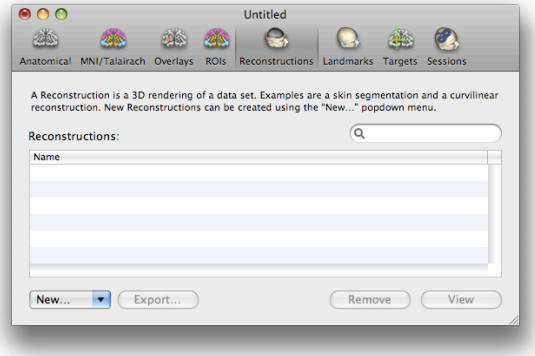
Conceptually, the Pencil/Eraser and Fill Region/ Erase Region tools are opposites of each other. The Pencil and Fill region delineate voxels while the Eraser and Erase Region clear voxels.

Chapter 9: Prepare: 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. 9-1

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 16). 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. 9-1), 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 16) and you will crop it later using the 3D Crop tool (see "3D Crop Box" on page 42). 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. 9-2).
- 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. 9-3).
- If the results are not satisfactory, adjust the threshold and recompute the skin again.
- Once the desired skin has been created, close the window by clicking the close button (top left button)

Fig. 9-2

Skin segmentation step with head properly cropped.

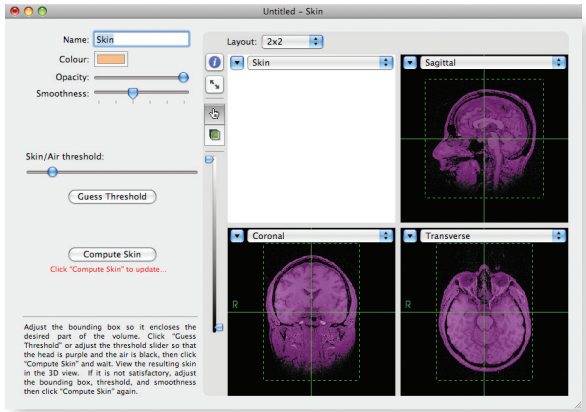
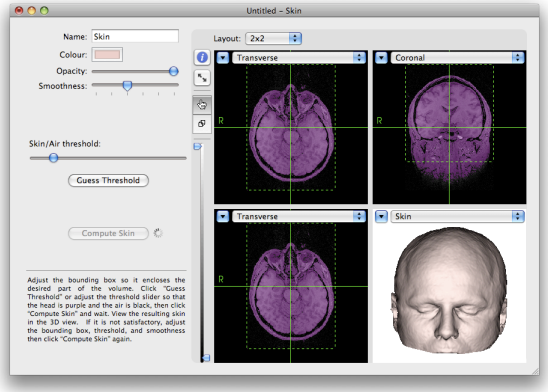


Fig. 9-3

Completed skin.



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 59). While this often provides a good representation of the brain surface, it has drawbacks in the context or 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. 9-4).
- Close the window by clicking on the close button at the top left of the window.

Fig. 9-4

Curvilinear surface "peeled" to reveal fMRI peak.

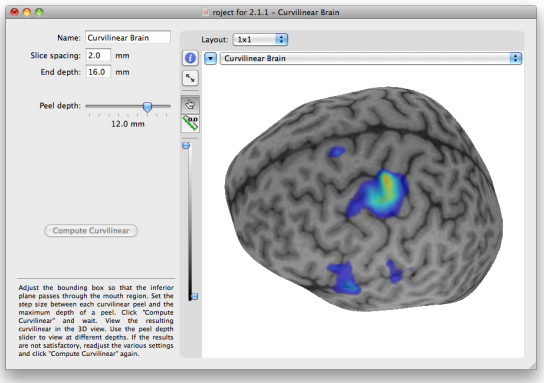
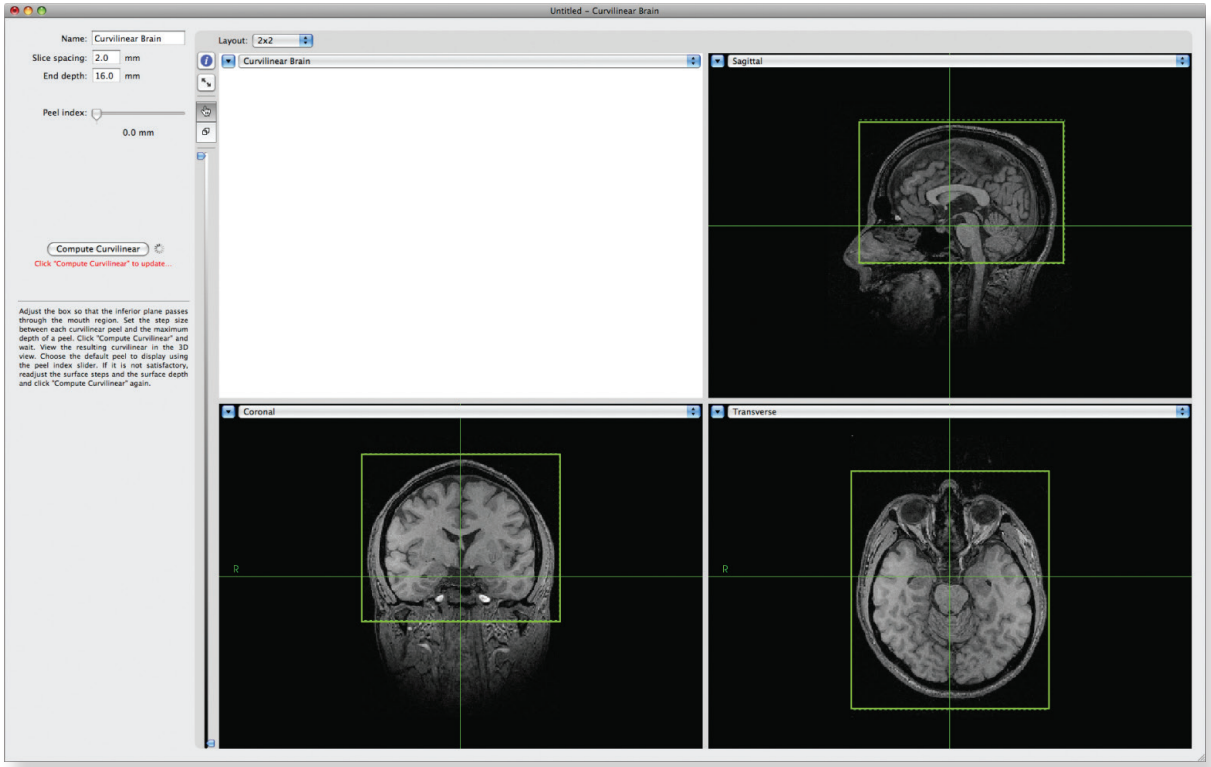


Fig. 9-5

Adjusting the crop box to help the automatic curvilinear algorithm



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.

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 de-lineated (Fig. 9-5)
- Click Compute Surface again and view the results
- If this does not help, you can create a curvilinear from an ROI; see the next section

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 8).
- Click **New...** and select **Curvilinear from ROI**.
- Select the ROI to generate the 3D surface from (if you have multiple ROIs) and set the step size and end depth. For smaller structures, a step size of 1mm

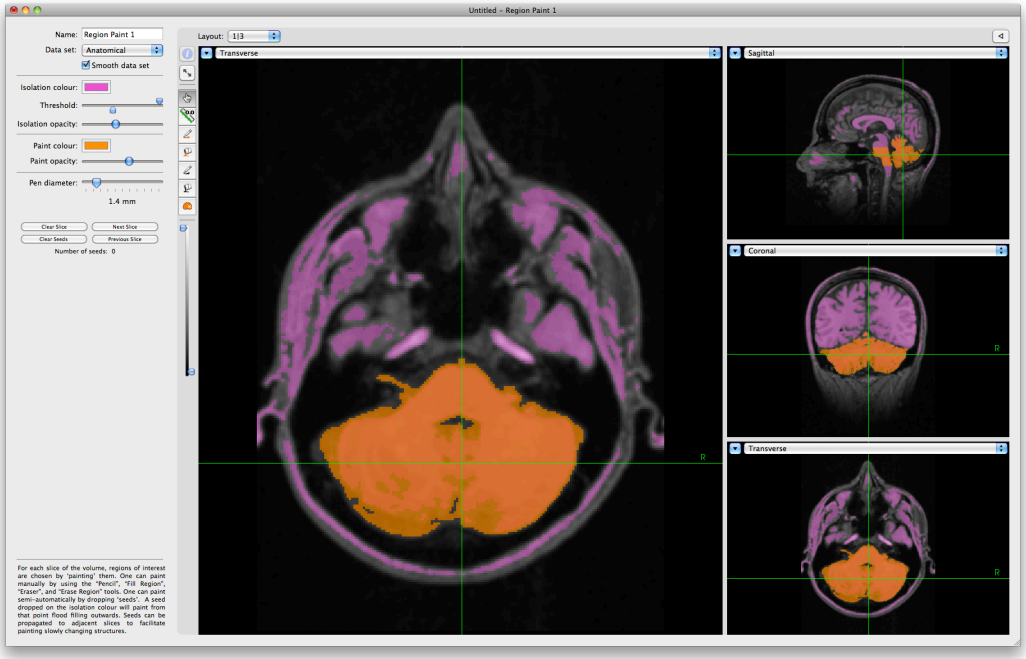
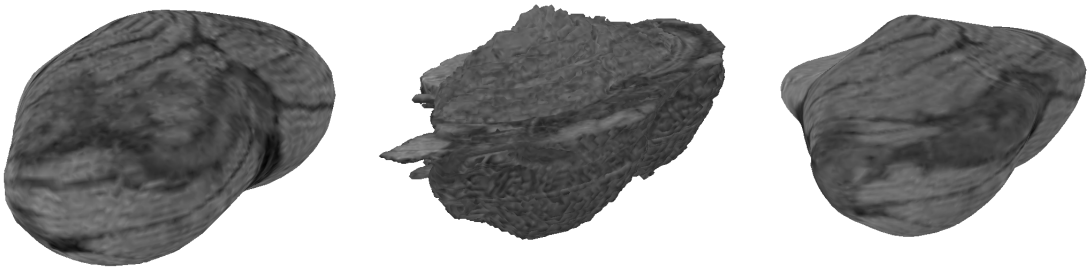


Fig. 9-6

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



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. 9-6), 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. 9-6) 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. 9-6.

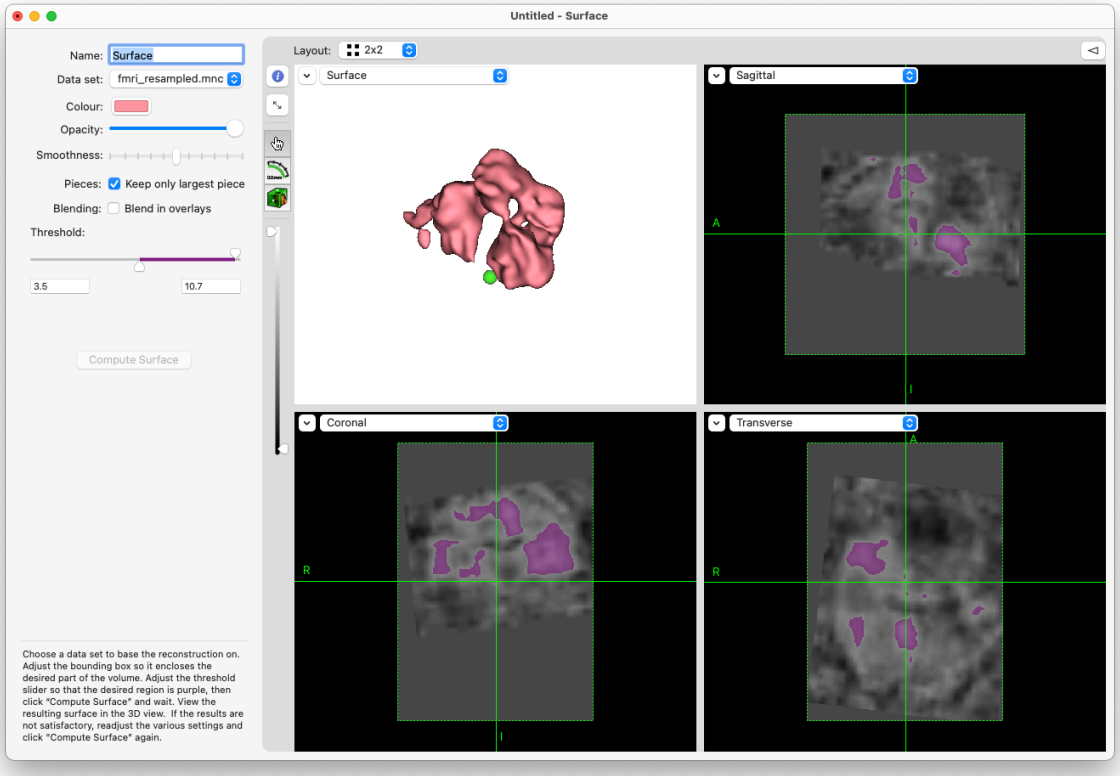
CREATING A 3D SURFACE FROM AN OVERLAY

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.

Fig. 9-7

Screenshot of the surface from overlay function.



- Verify that the surface is acceptable. Change the threshold or smoothness parameter if needed and click **Compute Surface** to update it.
- If the overlay is noisy and you obtain a lot of small objects and only expect (want) the largest one, enable **Keep only largest piece** and click compute again.
- The colour can be selected by clicking the colour button and then the colour from the resulting colour picker window. Enabling **Blend in overlays** will have any overlays turned on be painted on the surface.

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.

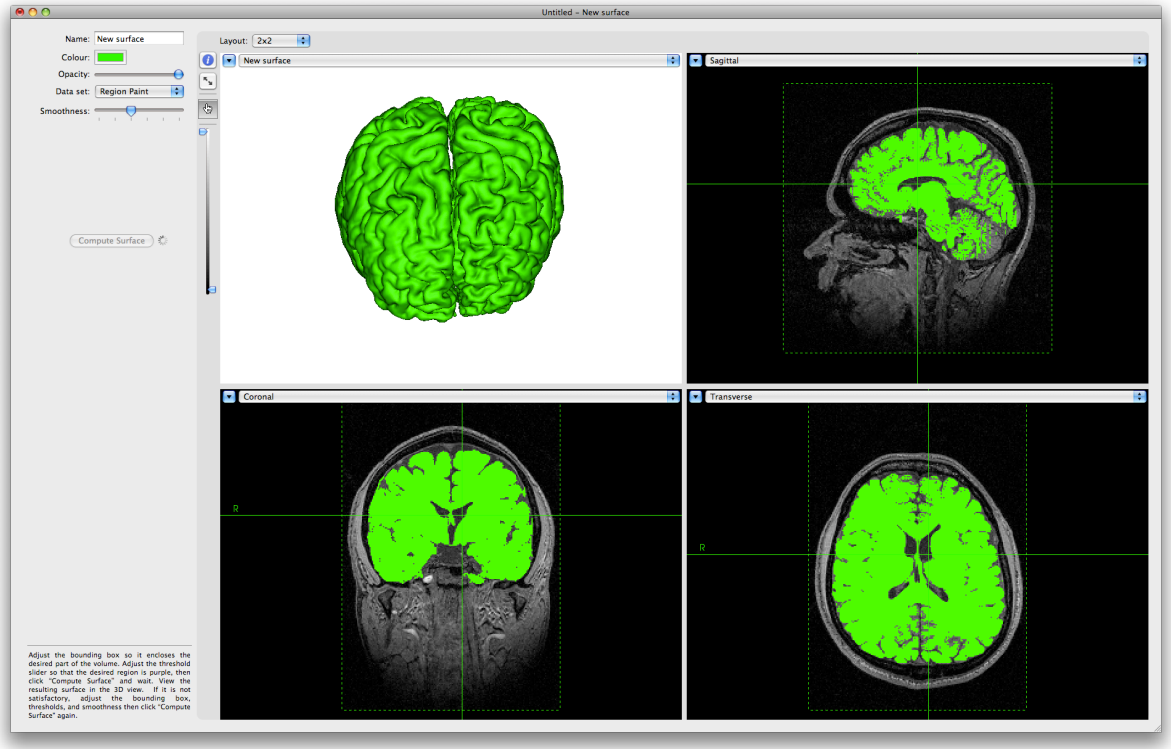
CREATING A 3D SURFACE FROM AN ROI

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.

Fig. 9-8

Surface created from an ROI.



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. 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**.

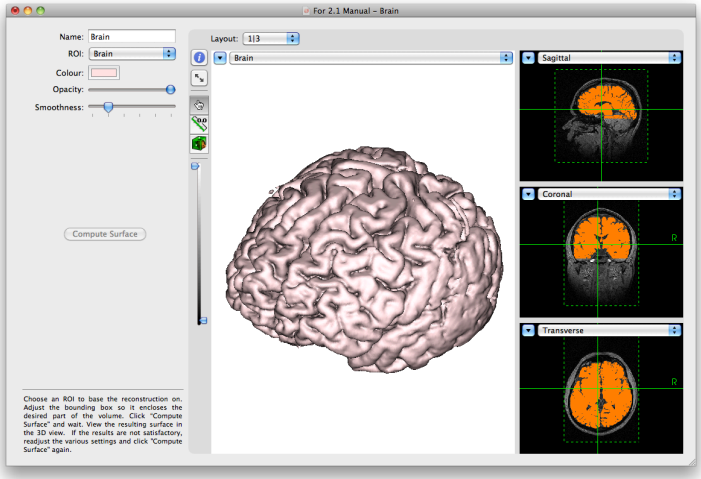
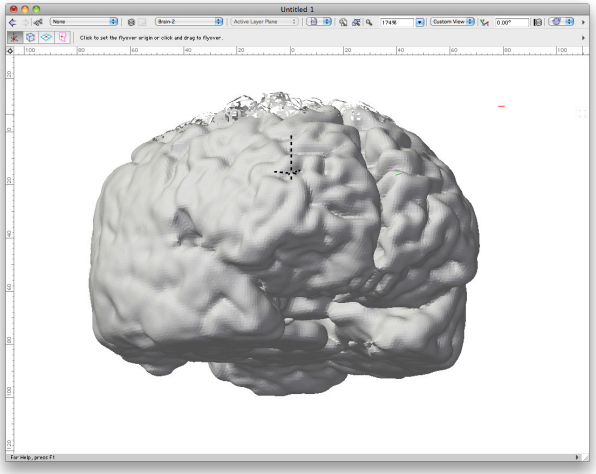


Fig. 9-9

Above: Surface created by an ROI.

Right: Same surface imported into a CAD application.



Chapter 10: Prepare: 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:

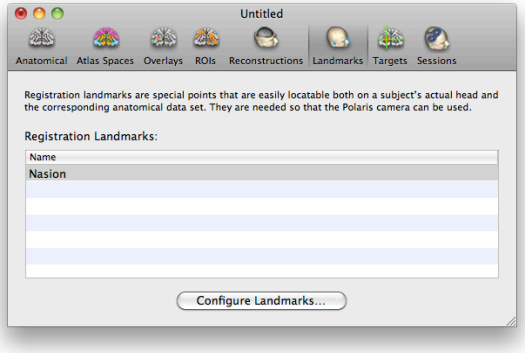
- Bridge and tip of the nose.
- The notch above the tragus of the ears.
- The outer canti of the eyes (if one of the above points are missing).

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. 10-1

Landmarks manager

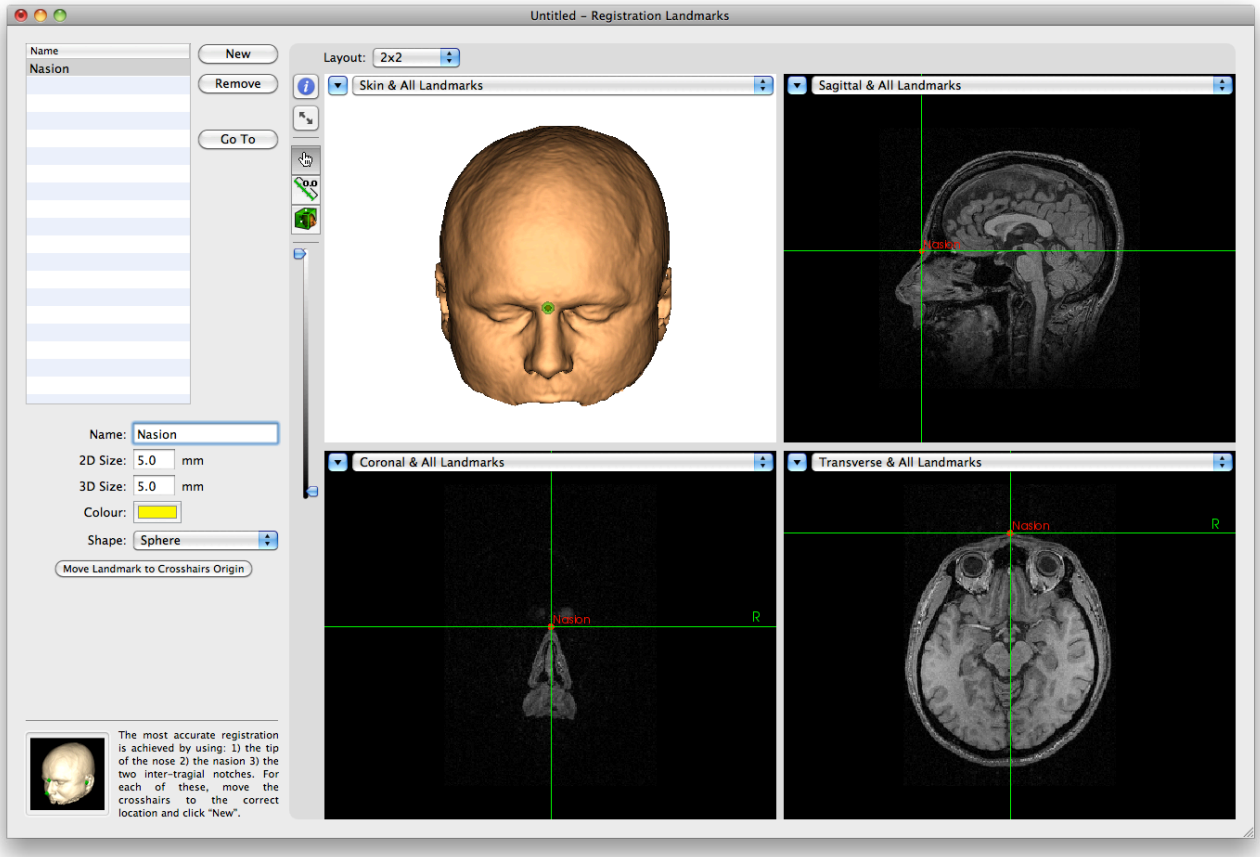


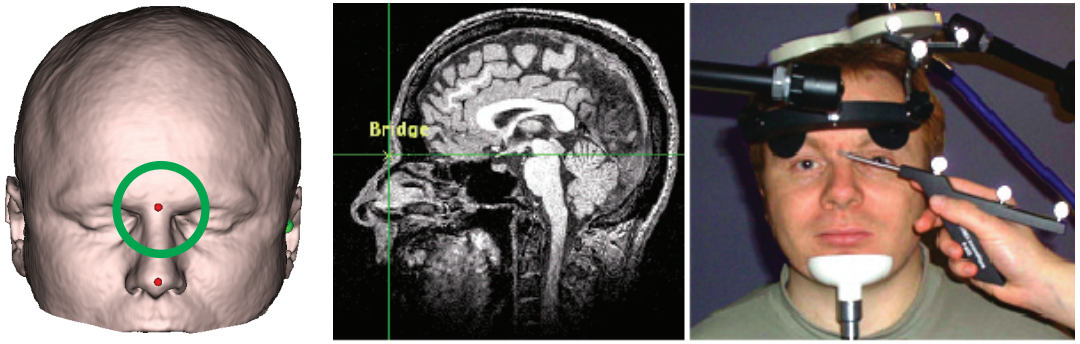
landmarks manager pane will display any landmarks created earlier, otherwise it will show an empty list (Fig. 10-1).

- Click **Configure Landmarks...** to open the landmarks window (Fig. 10-2).
- 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. 10-3 for examples of the landmarks.

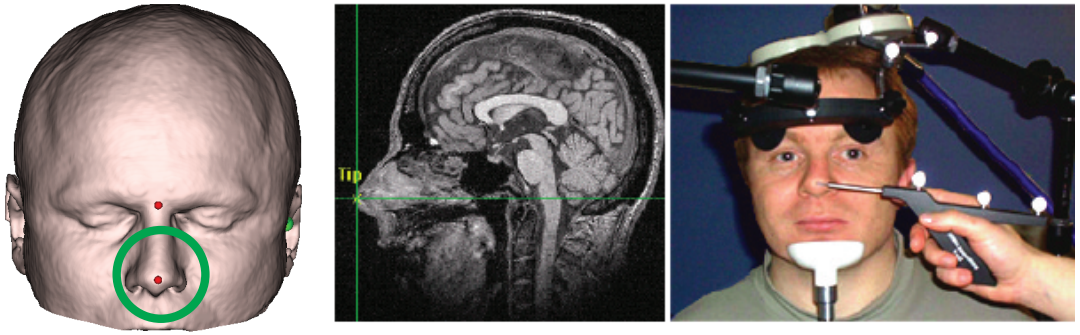
Fig. 10-2

Landmark entry window.

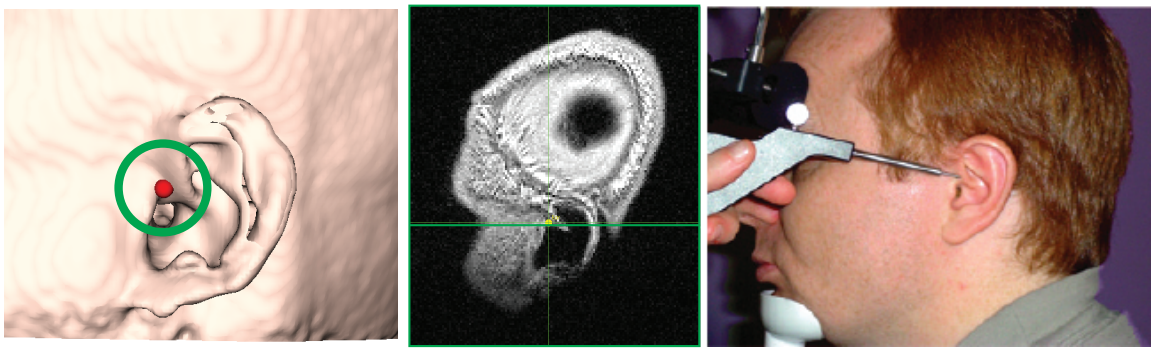




Bridge of Nose (Nasion)



Tip of Nose



Ear (notch above the tragus)

- If one of the landmarks illustrated in Fig. 10-3 are missing, consider adding the outer canti of the eyes. They are relatively unambiguous and rigid (Fig. 10-4).
- Once all the landmarks have been recorded, close the window.

Fig. 10-3

Examples of reliable landmarks.

Pay particular attention to the notch above the tragus.

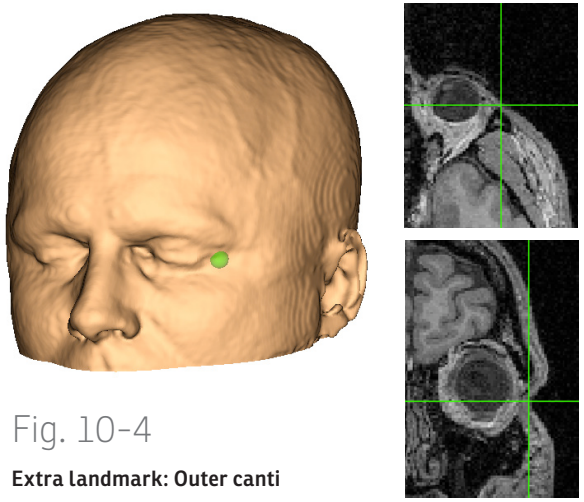


Fig. 10-4

Extra landmark: Outer canti of the eyes.

Chapter 11: Selecting Targets for Stimulation

The targeting step is optional in NIRS, and has more roots in our neuronavigation for TMS than for NIRS. Nevertheless, there may be occasions where defining a specific point or array of points on the cortex or scalp may be useful in judging the best locations for optode placement. In addition, you may be performing a combined NIRS and TMS experiment. For both these possibilities, this chapter describes how to define targets based on anatomy, image overlays of MNI coordinates and to use the grid tool to simulate the placement of a patch to hold an array of optodes. This array can be used as targets for optode placement at the start of the NIRS session to ensure that the optode patch is placed correctly.

To start the process, click **Targets** in the project window to bring up the target manager pane (Fig. 11-2) and then click **Configure Targets...** to open the targeting window.

Fig. 11-1

Targets manager.

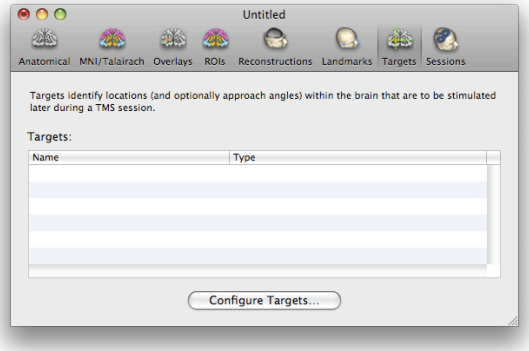


Fig. 11-2 shows a typical targeting window. In addition to the typical image views and list of targets on the left, there are additional controls on the right. The image views can be set to the traditional transverse, coronal, and sagittal views, as well as to oblique, inline, and inline-90 views. Finally, the 3D curvilinear surface (if you created one) is shown. As with all view windows, you can change these views as you like. The angle adjustment tool enables you to change the "approach" angles of the cursor, which is particularly helpful when defining

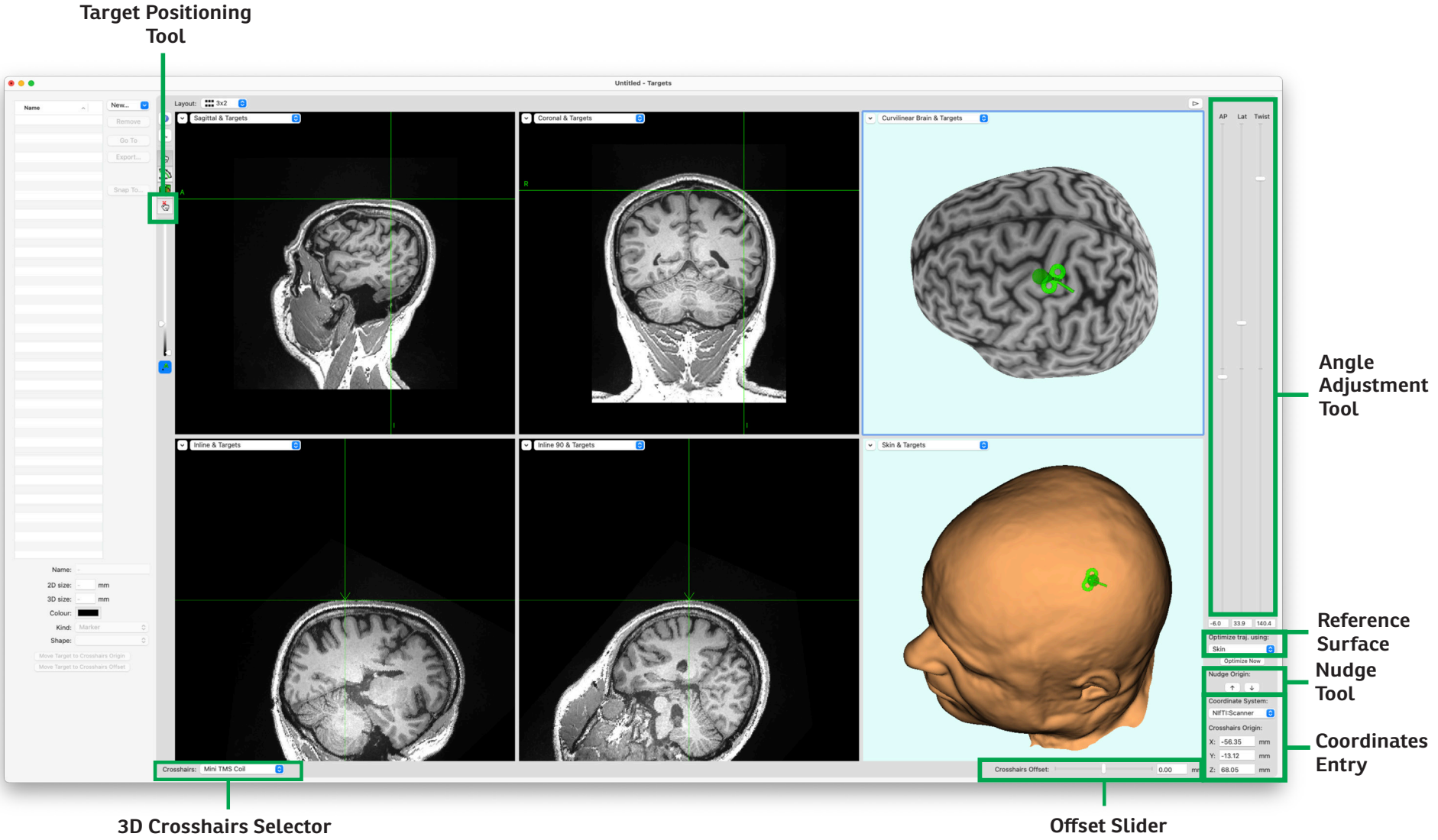


Fig. 11-2

Typical targeting window.

trajectory targets.

The targeting window introduces a few new tools (in addition to those described in Fig. 5-7). 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 to 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 calculated 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 or use the nudge tool. In this case, click **Optimize Now** to invoke the optimizer. You can always override the optimizer 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 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. 11-3) 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 65) can be used here. The orientation of the object must match that described for the coil in . 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.

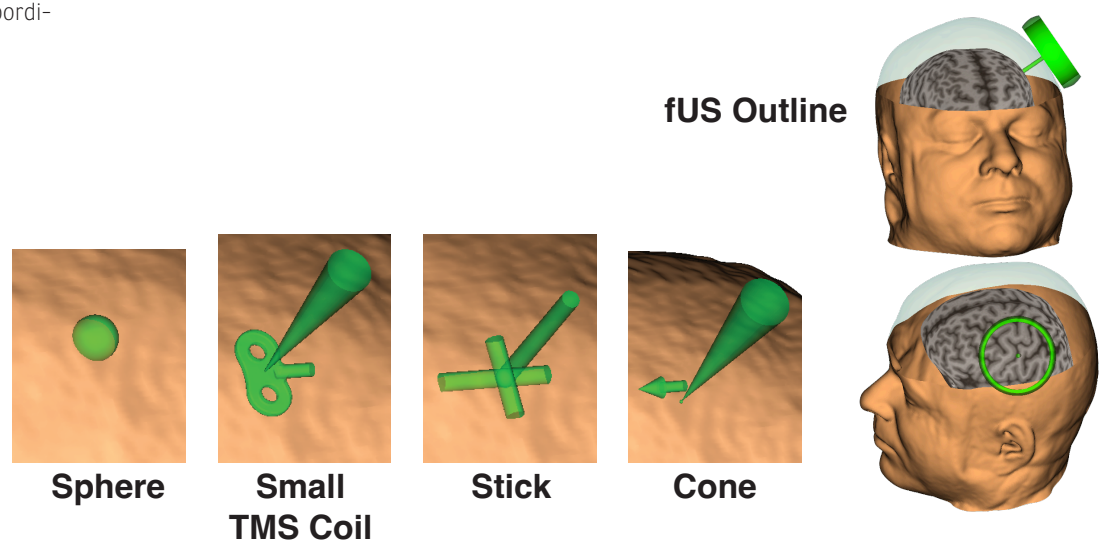


Fig. 11-3

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.
- 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 orientatoin 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 6. 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. 18-3) or the anatomical MRI's World coordinate space (e.g. scanner coordinates found in DICOM images), you can move the cursor to that location to create a target:

- 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 displayed 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. 11-2). Remember to set the "twist" of the grid 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 as needed by moving the cursor, using the Target Positioning tool. The centre of the grid will move with the cursor.

Rectangular grid (Fig. 11-5):

- Set the number of rows and columns.
- Set the grid node spacing.
- Set the naming scheme. You can select **indexed** where the topleft has index (0,0), **Symmetrical** where the middle of the grid has index (0,0) with +ve and -ve indexes, or **Alpha/Numeric** where the rows are numeric and columns are letters as found in a spreadsheet.
- The grid will initially be flat. You can wrap the grid

Fig. 11-4

Rectangular grid controls.

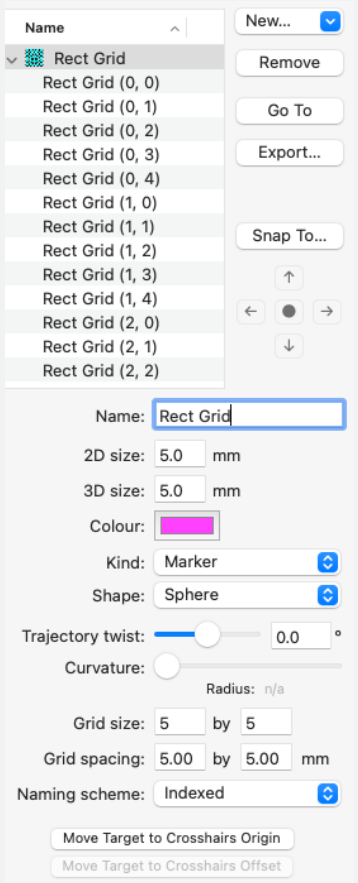


Fig. 11-5

Rectangular grid.

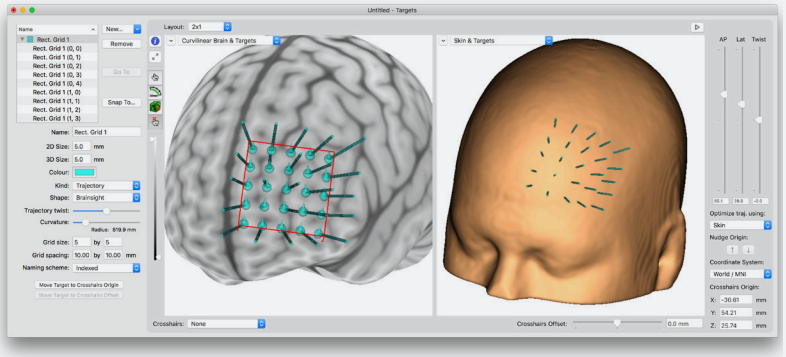
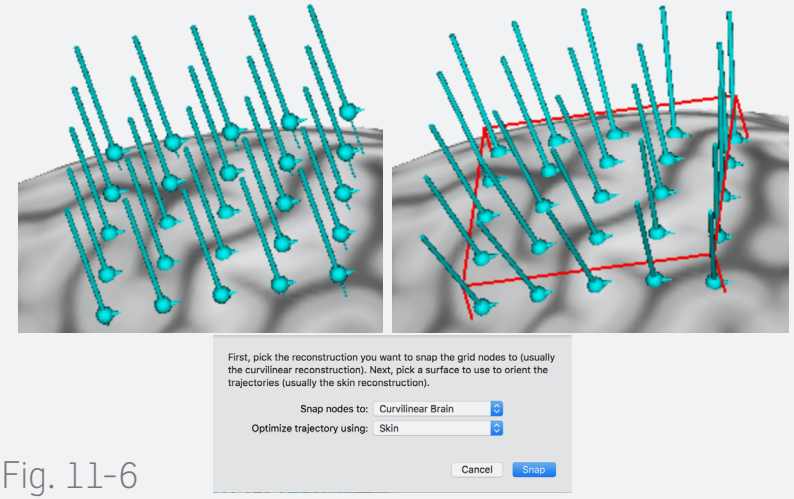


Fig. 11-6

Effect of adjusting the curvature slider.



to any 3D surface (e.g. curvilinear brain) using the snap function. Once you have set the grid size, spacing and location, click (Fig. 11-6) **Snap To...** . In the sheet that appears, select the surface to wrap to and the surface to use to for trajectory optimization (see Fig. 11-6).

- 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.

You can move navigate the grid by selecting a node in the list and clicking **Go To**, double-clicking the node in the list, or by cliking the navigation arrows.

Circular grid (Fig. 11-8):

- 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. 11-9). 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 the ring. Symmetric node spacing defines quadrants as

Fig. 11-7

Circular grid controls.

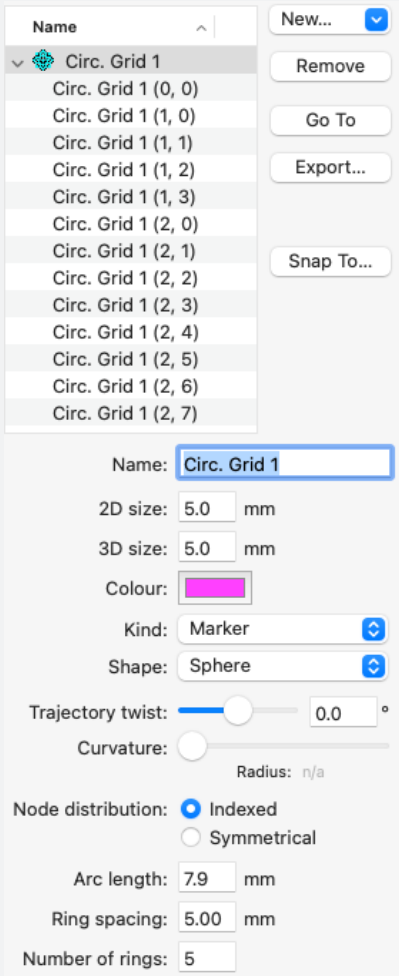


Fig. 11-8

A: Circular grid placed on curvilinear brain surface.

B: Circular grid placed on scalp.

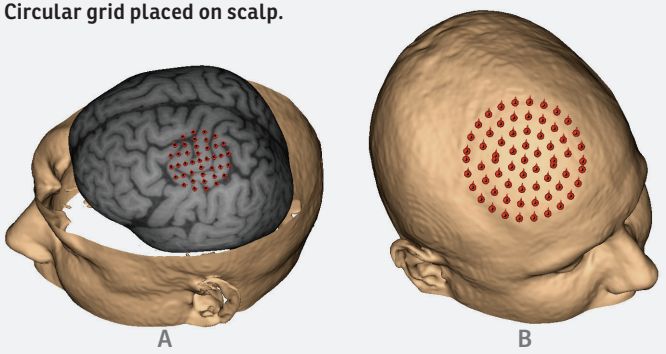
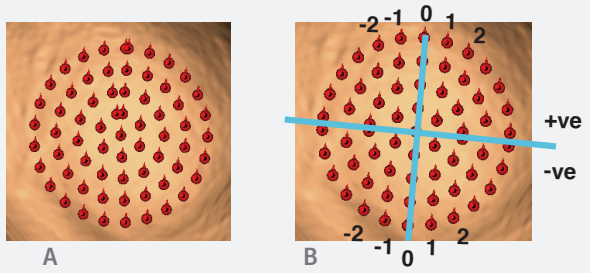


Fig. 11-9

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.



shown in figure Fig. 11-9B. 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 withe 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 18 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.

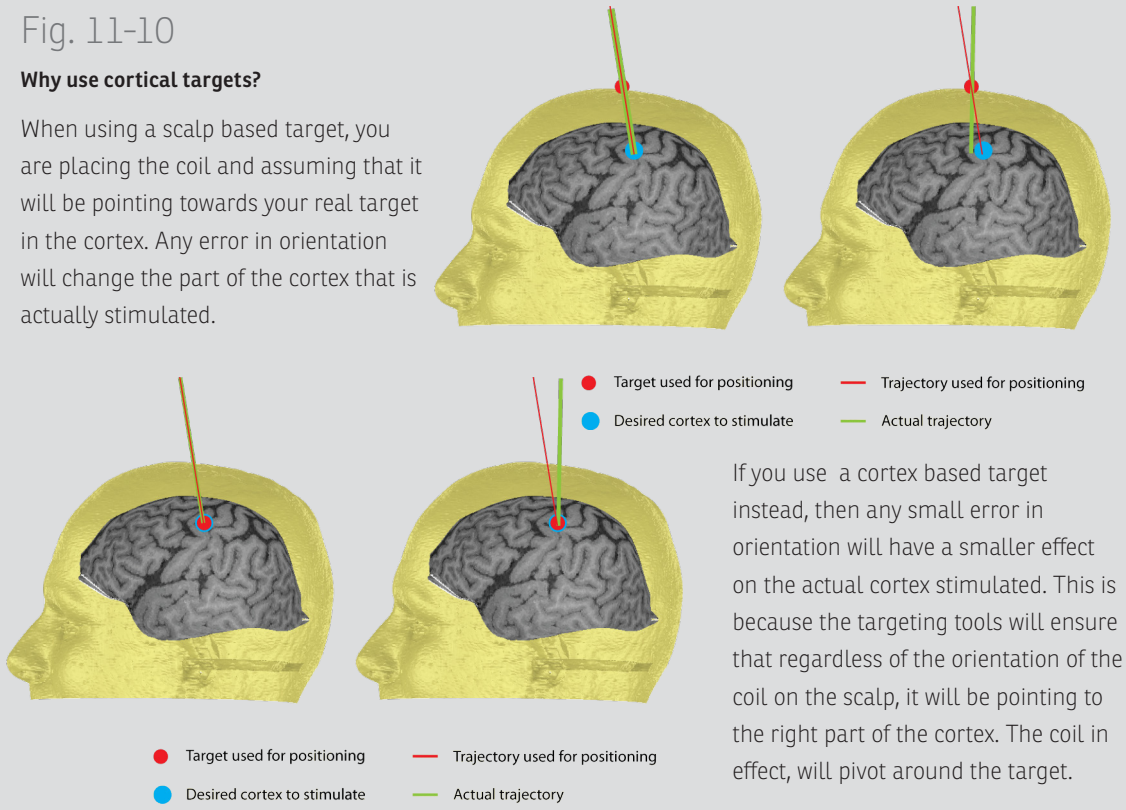
  or

  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. 11-10

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 12: Perform: Initial Setup

Up to this point, you have spent several minutes or more preparing for this part, performing the NIRS session. This chapter will show how to perform the initial setup required to prepare the system and subject for the session. Many of the steps required for the NIRS session will depend on the nature of your experiment. For example, you may use the MNI coordinates as the final location of the optodes, or you may wish to use the position sensor to digitize the optodes. In the latter case, you will need to set up the position sensor and perform the subject-image registration. In the former, you will not need to. These options will be presented as they become relevant. The next steps are presented in the next chapters, whose names are prefixed with "Perform:".

OVERVIEW

Before you can perform a NIRS experiment, you will need to prepare the equipment.

PREPARE THE NIRS SYSTEM

NIRS Unit

- Move the unit close to the subject and ensure that the optode fibres can reach the subject, and if the support arm is used, that it can reach over the subject's head without obstructing the subject's freedom of movement.
- Make sure that the unit is connected to the mains for power and a correctly configured network to allow communication with the Brainsight control computer. Review Chapter 3 for more details on how to assemble and connect the hardware.
- If the position sensor will be used to digitize the optode locations, make sure the Vicra camera is placed in such a way as to have an unobstructed view of the subject head tracker and the pointer while in use (see fig XX).
- If not already done so, connect the fibres to the optical modules, and insert the optodes into the receptacles of the cap or patch. Use the connection list of the planned montage as a guide to the correct placement for the optodes. Refer to Chapter 3 for details on assembling the fibres and optical modules and Chapter 4 for more information on connection

lists.

- Turn on the NIRS unit by ensuring that the unit is plugged into appropriate mains, that the main switch on the back of the unit is on and finally by pressing the power button at the front of the unit.
- The machine will take a moment to boot. Once booted, the Brainsight logo will appear on the front.

PREPARE THE BRAINSIGHT COMPUTER

- Move the Brainsight computer to a location that allows easy access by the operator. It does not need to be close to the NIRS device itself, it only needs to be near a power outlet and reachable by the same Ethernet network that the NIRS unit is connected to.
- Turn on the computer, launch Brainsight and ensure that the computer is connected to the same network that the NIRS device is.

PREPARE THE SUBJECT

Place the NIRS cap on the head

There are multiple options to hold the optodes on the head, each method having advantages and disadvantages. The key to obtaining good data is to pick the option that best suits your needs.

If you are using the Brainsight cap (plastic ring and elastomer straps):

The Brainsight cap consists of several components.

- Loosen the elastic strap at the rear of the cap and place the cap in the head.
- Take care to ensure that the rear section of the cap strap goes below the transverse bone (under the inion) and that the strap is not touching the ear.
- Gently tighten the strap. It takes some practice to learn the correct amount of tension required to secure the cap while not being overly uncomfortable. The cap may feel ok at first but become uncomfortable after wearing it for several minutes. If this occurs, loosen the strap a bit.
- Attach the sagittal strap on the front centre rivet and guide the strap along the midline of the head. Secure the rear using the two straps, one to a rivet on each side of the cap. Take care to use a hole on the rubber strap that provides the desired tension in the sagittal strap.
- Using your assembly list as a guide, add straps to the cap by inserting them onto the appropriate rivet of the sagittal strap. Use the hole labelled "0" on the strap with the even numbers going to the subject's right and odd numbers to the left. Secure the other end of the straps to the appropriate rivet on the cap perimeter.
- Use the articulated arm (if available) to support the fibre optic cables and bring the optodes near the subject head (Fig. 12-1).
- Insert the optodes into the strap holes, taking care to rotate the optodes so that the fibres run away from the head in an orderly manner.
- Inspect each optode and part the hair under each optode to ensure a good contact with the scalp.

Prepare and attach the subject tracker

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 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

Fig. 12-1

Typical arrangement for the NIRS.



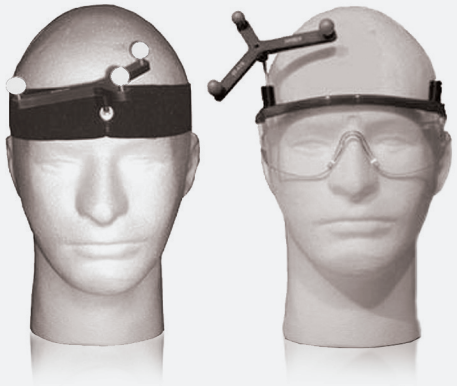


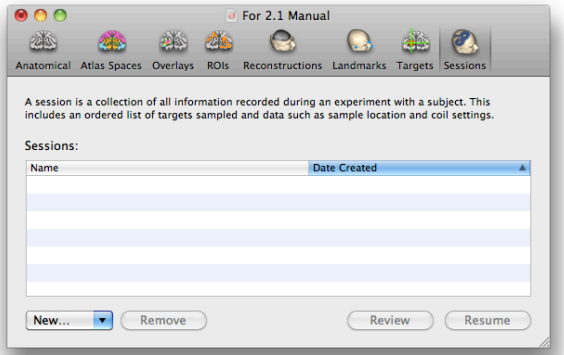
Fig. 12-2

A: Head strap for attaching trackers.

B: Glasses with tracker mounts.

Fig. 12-3

TMS Session manager window.



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 you are planning to use the navigation functionality, ensure that the Vicra camera is connected as described in Chapter 3.

BEGIN A NEW NIRS ACQUISITOIN SESSION

- Launch Brainsight and open the subject's project file
- Click on **Sessions** to bring up the session manager window (Fig. 12-3).
- If you are using the navigator to confirm/adust the optodes and/or to record their final location, proceed to the next section . If you are not using the navigator, skip to the following section .

Acquiring NIRS Data Using the Navigator:

- If you are using the navigator, begin a new session by clicking **New->Online Session**. If you are not using the navigator, click **New->Offline Session**. To resume a previously created session, select the session from the list and click **Resume**.
  A session window will appear (Fig. 12-4).
- 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 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 then once.
- Once all your targets are selected, click **Next Step.**

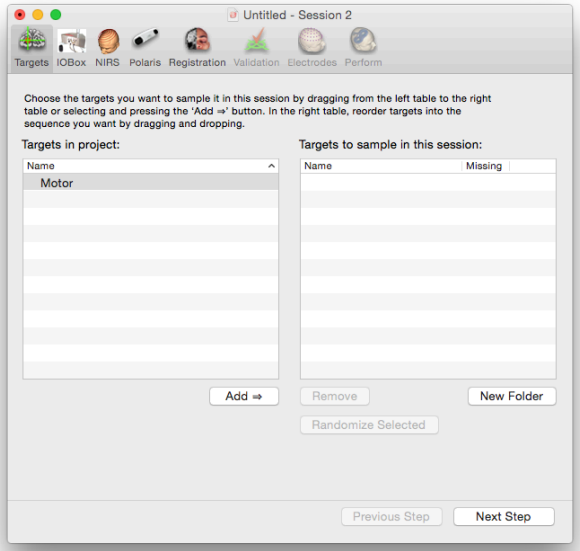
Fig. 12-4

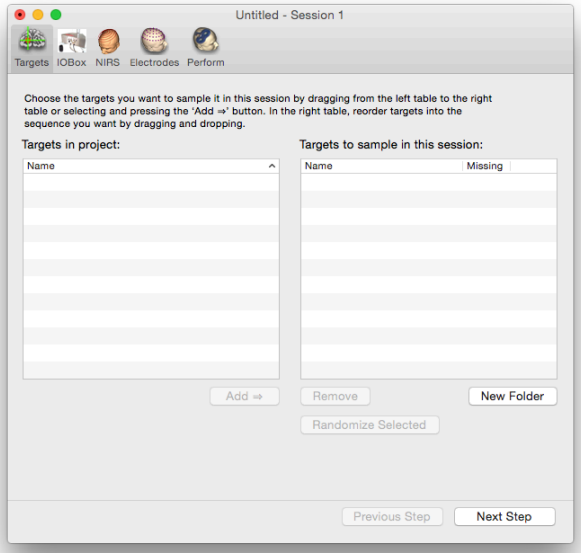
Session start screens:

A: On-line session where the navigator will be used

B: Offline session where the NIRS acquisition will be performed without navigation

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..





Chapter 13: Perform: Trigger and EMG Setup

One common use of NIRS is to record event related data (e.g. repeating a task multiple times to allow for averaging of the signal). If you are performing an event related acquisition, the events are typically generated by an external trigger (e.g. stimulus presentation computer). This chapter will describe how to connect the trigger to your Brainsight computer and/or the NIRS device and configure the software to use the trigger to acquire the event related data.

INTRODUCTION

Event related data recording is a common method used in cognitive neuroscience. In general, an event related experiment involves multiple repetitions of an event, either exposure to a stimulus, or the performance of a short task. The onset of the event may be synchronized using a trigger. For example, many stimulus presentation systems (e.g. E.Prime) provide a TTL trigger signal to synchronize the acquisition.

The NIRS data is acquired in a continuous file both in the NIRS device and in the Brainsight software. If at the same time, a trigger signal is sent to the Brainsight computer, the trigger times can be recorded to allow the acquisition to be broken up into a series of epochs, one for each trigger event. This allows for easy averaging during the acquisition and these event triggers can be exported as part of the NIRS data file for use in HoMER for data processing.

USING THE STIMULUS TRIGGER OUT TO AUTOMATICALLY RECORD EVENT RELATED NIRS SAMPLES

This section will describe how to enable one or more methods to trigger the recording of a NIRS event related sample. In addition to acquiring NIRS data epochs, if you are acquiring EMG data, the trigger recording will also apply to the EMG. Because the Brainsight I/O box has a built-in digitizer for EMG, the trigger configuration window will display the live data. Ignore this and focus on the trigger options on the top left of the I/O box window.

Click **Trigger Options...** to open the options window (Fig. 13-1).

- During the NIRS session, you may wish to create an event manually. You can always do so by pressing the **Sample** button.
- If you have a Brainsight computer trolley with an I/O box (see Chapter 20) or Trigger box (called an analog receiver) and have connected the TTL trigger output of the stimulus software (or other hardware generating a TTL trigger for you) to the TTL trigger in of the I/O box, enable it by enabling the **Use TTL Channel x** checkbox (x=1 or 2). If the trigger is coming from an rTMS device, 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 pulse of the next train).

Setting up the EMG

Refer to the Brainsight NIBS user manaual 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.

As of v2.4.9, you can record EMG as event related (as always) where a short duration of the EMG can be recorded and associated with each sample. You can now record continuous EMG as well, where one or both

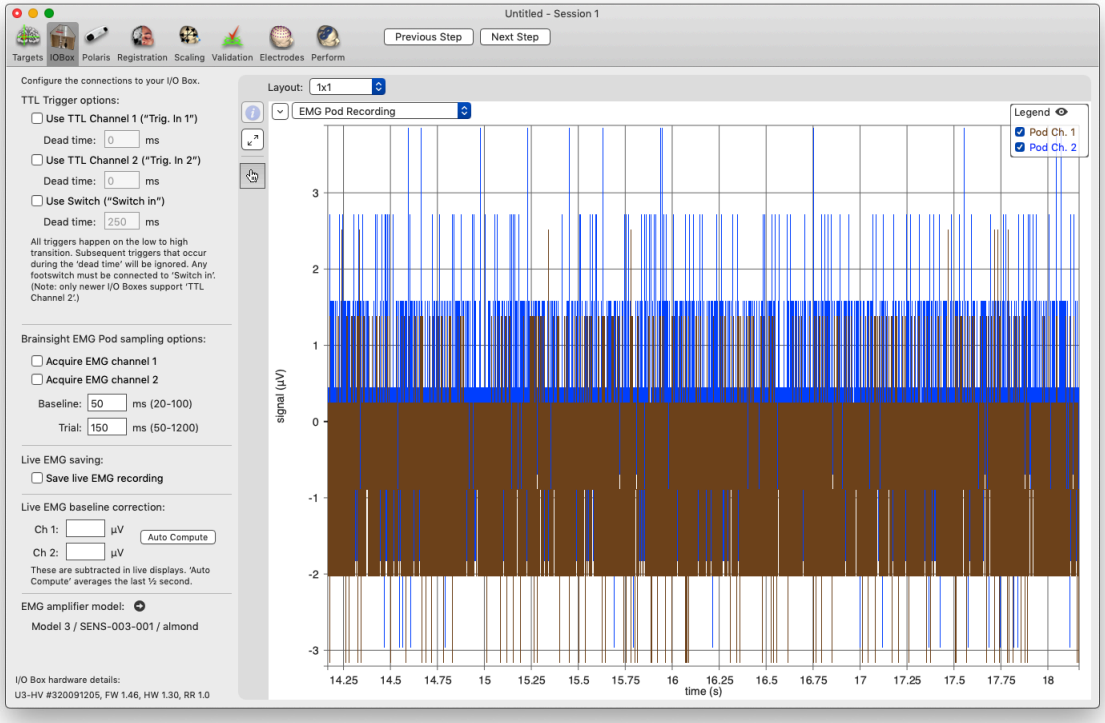


Fig. 13-1

Trigger Options Window

channels can be recorded for the entire duration of the study.

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 up the EMG" on page 84 for details.
- Enable the recording of the Live EMG (both channels) by enabling the checkbox.
- 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 83, 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). 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.

Chapter 14: Perform: Optimize NIRS Parameters

Acquiring a good quality NIRS signal requires the optimization of several settings. What settings produce the best results depends on some real-world factors including the distance from the source to detector, the presence of hair and the quality of the optodes and fibres. This chapter will describe the fundamental relationships between these factors, and how to optimize the acquisition settings to obtain the best possible signal prior to recording the NIRS data.

WARNINGS



Do not look directly into the source optode during operation. Doing so may cause eye damage. It is recommended to wear protective glasses if manipulating the optodes while the lasers are on.

QUICK STEPS

It is assumed that you have reviewed and have a basic understanding of the NIRS configuration window, specifically the different NIRS display elements, the detector chain and how the various settings at each stage of the chain can effect the quality signal acquired . If you are not familiar with these, then skip this section and familiarize yourself with the remainder of the chapter before manipulating the NIRS settings. While the NIRS system will be in operation in this section (to allow you to view the signal and manipulate the NIRS settings for the upcoming study), no data will be stored. Data collection occurs during the perform step.

Setting the NIRS Acquisition Parameters

By this time, the subject should be wearing the NIRS cap and optodes. It is not necessary that the subject-image registration be performed at this point. The NIRS device should have been connected to the same TCP/IP network as the Brainsight computer and turned on (and its boot sequence complete).

If you have not already done so, select the NIRS step in the session window. The window will look like that in Fig. 14-1.

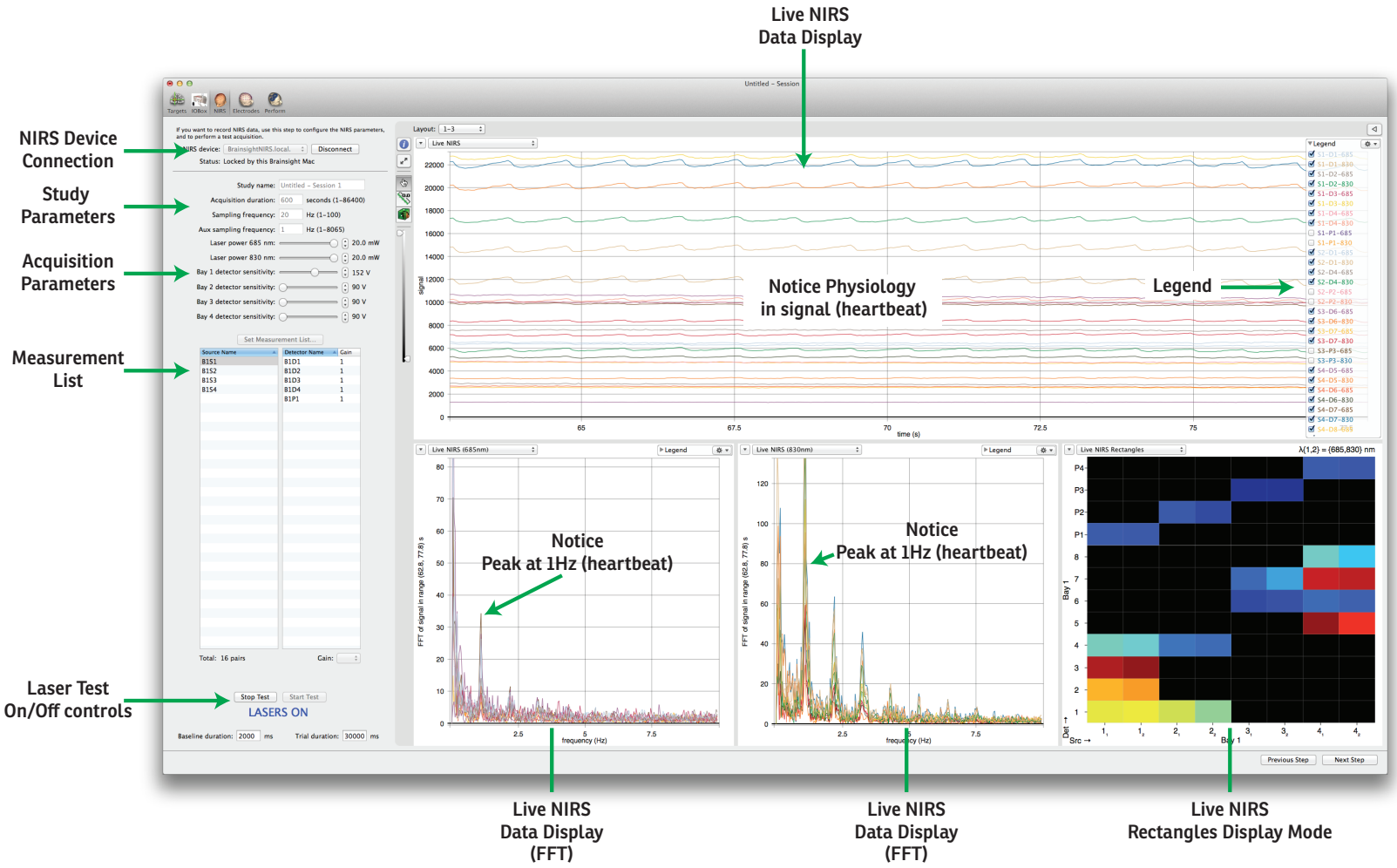


Fig. 14-1

Typical screenshot of the NIRS step

The most useful views here are the live NIRS, Live NIRS FFT, and live NIRS rectangles view.

- Connect the computer to the NIRS device by selecting it from the NIRS device popup menu button, and click **Connect**. After a moment, you should see the status message should change from "Not connected" to "Locked by this Brainsight computer" (you may see an interim message saying "unable to connect", but ignore that for a few seconds while it establishes a connection. If the unable to connect message persists for more than a few seconds, proceed to the connection trouble shooting section. There may be a delay of several seconds while the connection is established and then the system locked.

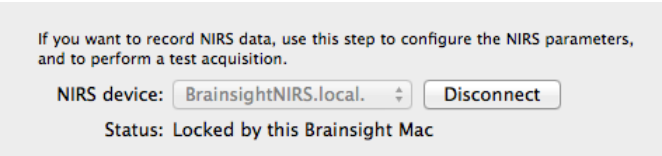


Fig. 14-2

Close-up of the NIRS connection manager portion of the NIRS step.

- Enter a name for this NIRS study. This will be used as the file name on the NIRS computer for the data to be acquired in the study.
- Select the cap and assembly that describes the cap on the subject using the Measurement list popup menu button.
- Once you have selected the measurement list, you should see the individual detector channels appear in the list.

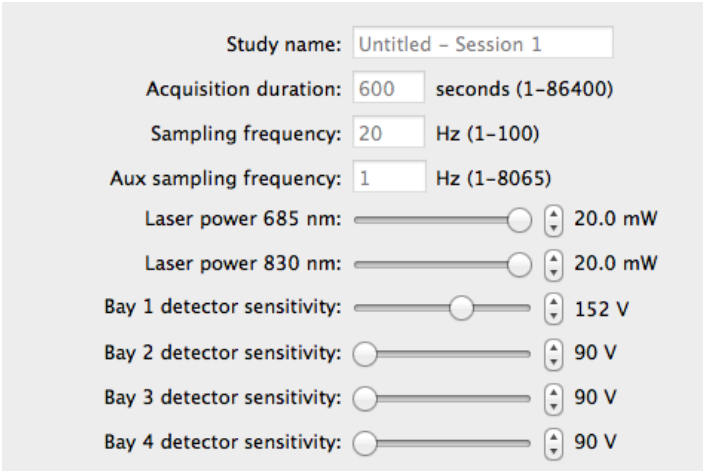


Fig. 14-3

Close-up of the acquisition parameters pane. The slides control the laser power as well as the high voltage that determines the gain of the avalanche photodiode detectors (APDs).

- Prepare a short acquisition to observe the incoming NIRS signal. Set the acquisition time to a reasonable length (e.g. 300 seconds).
- Set the sampling frequency to the desired value (e.g. 10Hz). You can sample up to 100 Hz. Keep in mind that lower sampling rates will result in higher signal quality (at the expense of temporal resolution), so pick the lowest rate that meets your needs.
- Set the laser power (all sources, both wavelengths) to the initial desired value by selecting the all sources in the sources list and sliding the power sliders all the way to the right (Fig. 14-7) . It is often best to start at the maximum power. If you notice a lot of signal saturation once you are acquiring, you can lower the laser values. Remember to review how the laser power, detector gain and digitizer gain relate to each other to obtain the cleanest signal (described later in this chapter).
- Set the initial detector sensitivity values for each block using the sliders. Start at the halfway point.
- Make sure the operator and subject are wearing their safety glasses, then click on the start button to start the acquisition.
- Set one of the views to **Live NIRS** and another to **Live NIRS Rectangles** to allow you to evaluate the quality of the incoming signal.

- Watch the live NIRS signal. The main characteristics to watch for are:
  - Presence of physiology in the signal (heart and respiration) with a good amplitude (it is a topic of discussion as to how well the presence of physiologic signal is a predictor of good NIRS data, but this will evolve over time).
  - Lack of saturation of the detectors (shown as red underlines beneath the live data and an S symbol in the NIRS rectangles.
- If the data is saturated, lower the detector sensitivity until you notice a good signal. If the signal looks poor when the saturation stops, try raising the sensitivity again, but first lowering the laser power. If one of the wavelengths is producing a much stronger signal (it is expected that the 830nm is stronger than the 685 or 705nm because of the lower absorbance of that wavelength by the tissue), lower that one first until all wavelengths are producing a similar amplitude for a given source-detector pair. The goal is to get the best dynamic range without saturating the detector. Review "The NIRS Detector Chain" section of this chapter to learn more about optimizing the components of the detection chain.
- Watch the Live NIRS rectangle views to ensure that all the detectors on the head are returning a good signal. If one or more of them look dimmer than others (and the distance between the source and detectors is similar to other pairs that are returning a better signal), then examine the optodes on the scalp for problems including the presence of hair under the detector, or poor coupling of the detector on the scalp. If the detector is not staying on the scalp reliably, consider another means of holding it in place, including an elastic wrap to push the detector down onto the scalp (see section xx for tips on applying the cap and optodes onto the scalp).
- If you find that you have a few individual channels with weaker signals (and raising the detector voltage causes saturation), then you can select that detector and try increasing the detector gain. This does not add new signal, but makes better use of the digitizer range to maximize the sensitivity of the analog-digital (ADC) conversion.
- Once you are satisfied that the signal is acceptable, click **Stop Test** to end the acquisition. If you need more time and the test has timed out, click **Start Test** again to repeat the process.
- If your study will be event related (using an external trigger), then set the baseline and trial duration values in the associated text fields. This is not required for continuous acquisitions. Make sure to set the connect and enable the associated trigger signal in the trigger and EMG step (if needed).
- Once you have completed the setup, click on **Next Step** to proceed to the subject registration step if you are performing an on-line session, or to the

THE NIRS DETECTOR CHAIN

The NIRS data undergoes several steps of detection, amplification and digitization before any data is displayed on the computer screen. Each of these steps can be optimized to ensure the best quality of data is being recorded. While it is a relatively straightforward process, some understanding of each step is helpful.

Overview

The chain has several steps: Laser power, Avalanche photodiode bias voltage, signal amplifier and finally the digitizer.

Light Intensity

The starting point for NIRS is the injection of light into the head. As the light enters the scalp, it will be diffused and absorbed in the various tissues in the head. A small fraction of this light will make its way to one or ore detectors. When considering the path of the light that leaves the source optodes and is picked up by a detector diode, the shape is generally described as an arc into the head and out again (banana shaped). The wider the gap between the two, the deeper the arc goes into the head (and thus the deeper we are scanning into the head). As source-detector spacing increases, we see deeper into the head but at the same time, the path length increases and thus more photons scatter somewhere else other than in the detector, so the amount of collected light decreases. The generally accepted "sweet spot" for source-detector spacing, the balance between scanning deep into the

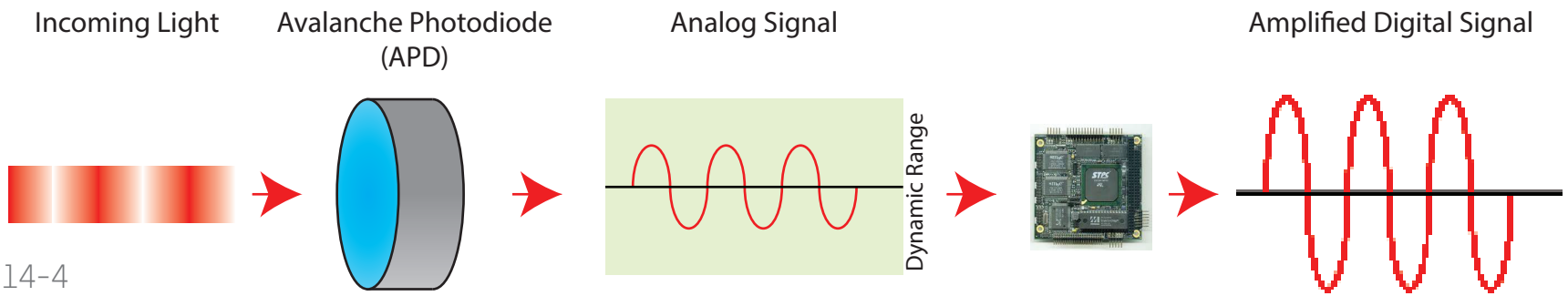


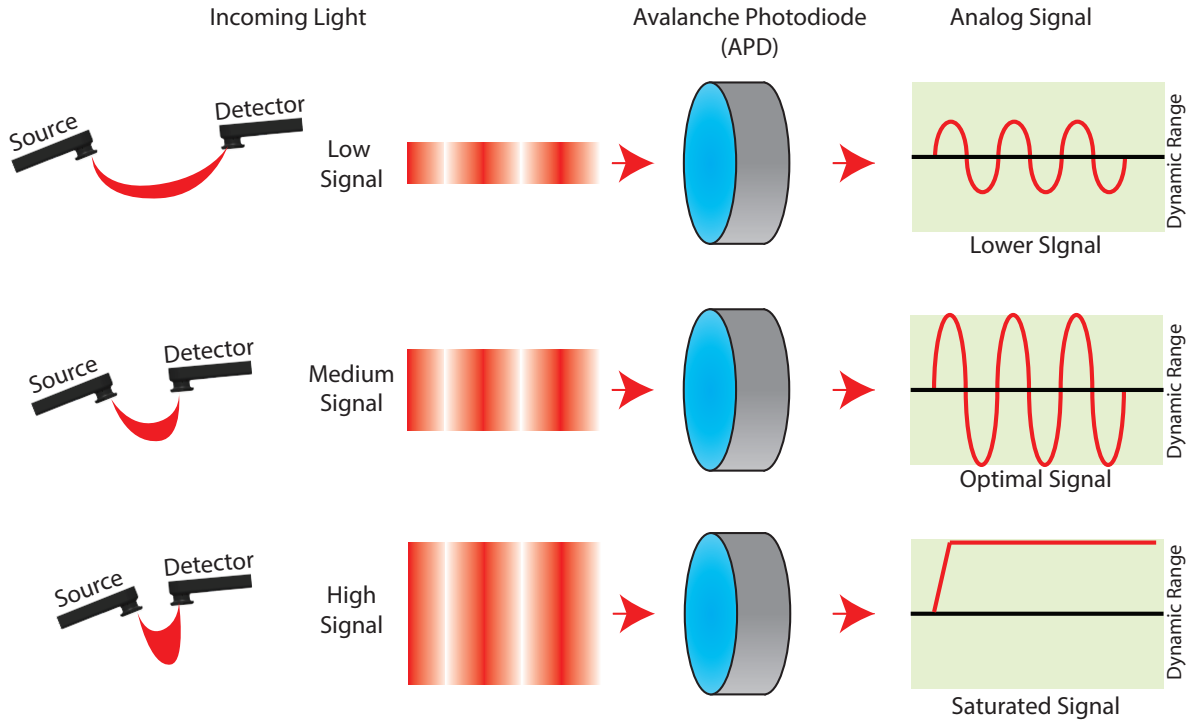
Fig. 14-4

Illustration of the effect source-detector spacing and APD bias voltage has on the APD output signal.

brain but still getting enough light out again to form a good signal is a separation of about 3cm.

Each detector may pick up light from one or more sources (and in fact, from each distinct wavelength. Since at this stage, the detector cannot distinguish the light from any specific detector (or wavelength within a source optode) it is recording the sum of all light from all sources and all wavelengths.

At this stage, the parameters that should be optimized are to ensure that all sources within range of the detector (say between 28mm & 32mm, for example) contribute a fair share of the signal, so no one source dominates too much. The strategy to help this is to find source-detector distribution patterns that try to have similar spacing. This is somewhat of an art and the actual layout vary



a lot depending on the region to be imaged and how densely you wish to image a region.

Each source may be emitting two or more distinct wavelengths of light. As the light travels through the tissue, some of it is scattered and some of it is absorbed. The amount of light absorbed in the tissues depends on the tissue and the wavelength. For example, two common wavelengths used is 685nm and 830nm. Tissue tends to absorb 685nm more than 830nm, so it may be advisable to keep the total distribution of light relatively even. **This can be done by selecting the source(s) in the assembly list, then using the laser power sliders.**

Detector Sensitivity

The avalanche photodiode (APD) converts the NIRS signal from photons to analog electrical signal (which can then be amplified and digitized later in the chain). Think of it as converting photons to one or more electrons. Once the light input has been optimized (in the previous step), the detector sensitivity can be adjusted to optimize the conversion to electrical signal. The sensitivity is adjusted by setting the bias voltage. The sensitivity of the APD depends on the total amount of light hitting the detector and the bias voltage setting. If either too much light reaches the detector or the bias voltage is set to high, the detector will reach a saturation condition where is simply sends out a continuous, high signal regardless of the input. The goal of optimizing the detector settings is to detect as much light as possible and for the detector to send as strong an analog output

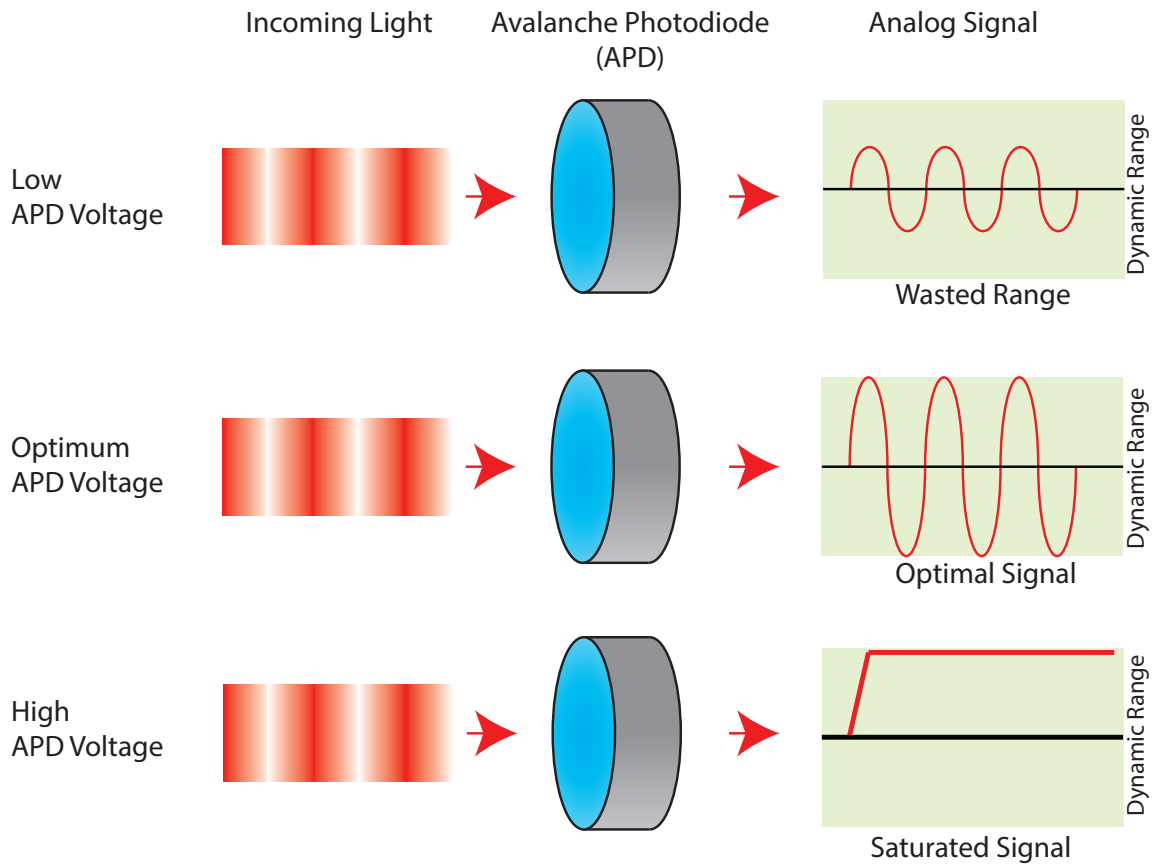


Fig. 14-5

as possible. A strong signal here means less artificial amplification will be needed in the next step prior to digitization.

The setting is relatively simple to adjust. While acquiring NIRS signal, simply raise the APD voltage bit by bit and observe the incoming signal. As the voltage increases, the signal amplitude will increase. At some point, the APD will saturate and the saturation indicators (an "S" will be displayed in the Live NIRS rectangles, and the live waveforms will have an line along the bottom. When saturation is observed, back the voltage down again until the saturation disappears.

Analog Amplifier and Digitizer

The goal of the previous steps are to ensure that the signal reaching this stage has as much signal (as opposed to noise) as possible. The final stage is to digitize the analog signal for further processing and storage. The digitizer itself has a set dynamic range, so the best digitization occurs when the incoming signal takes the most advantage of that range. If the range of the signal is a small fraction of the digitizer range, then some of the range is wasted. To help maximize the range in this step, the signal goes through one final amplification step. The default amplification is set to 1, but that can be increased. If the amplification is set too high, then the signal may be clipped and the extremes of the data will be lost.

The detector gains can be set individually, or as a group.

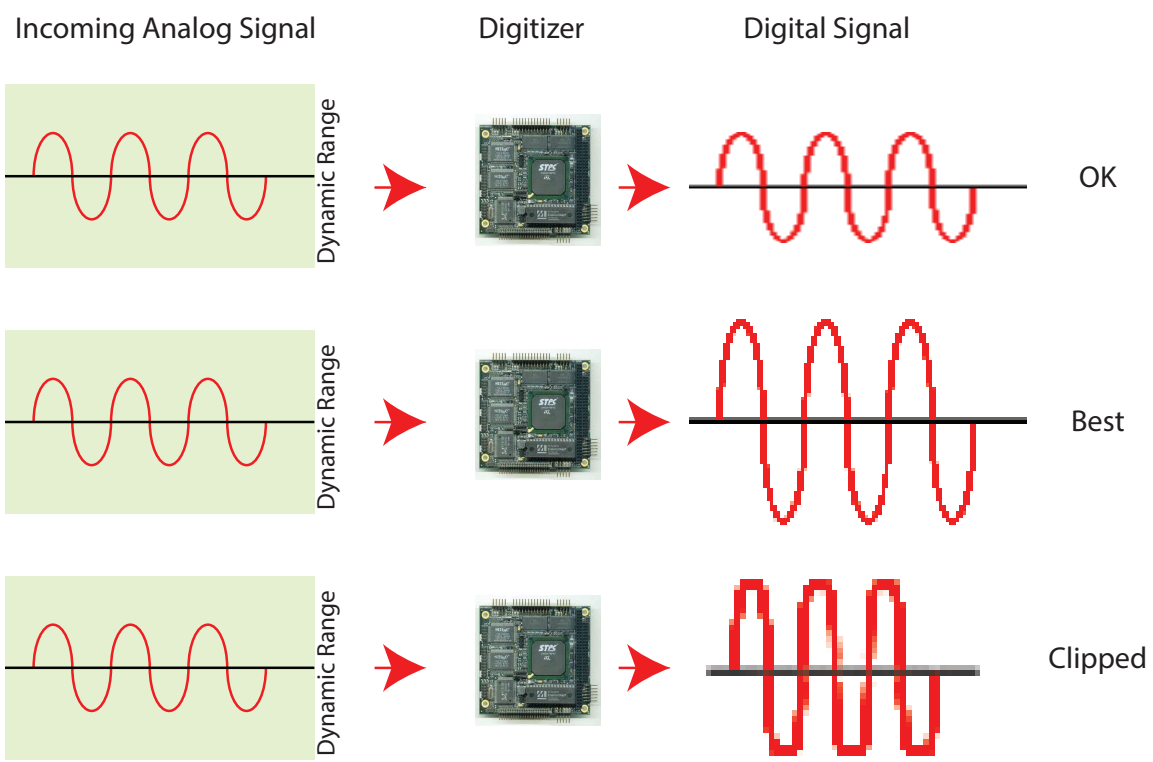


Fig. 14-6

Illustration of the digitizer gain and the resulting signal.

Typically, you may find one or a few detectors returning a weaker signal than the others (consistently across all wavelengths). The amplification gain may be used to boost that signal to something more consistent with the other detectors. Note that this will not "create" new signal, but will optimize the digitization of that detector, so at least you are not losing out on the dynamic range of the digitizer because that detector happened to be a bit further from the sources than the others). When looking at the assembly list, select all the sources on the left side (select the top one, then shift-click on the bottom one to select all sources. Observe that on the right list, all detectors are now shown. Select the detector whose gain you wish to set, and change the value on the bottom using the gain popup button.

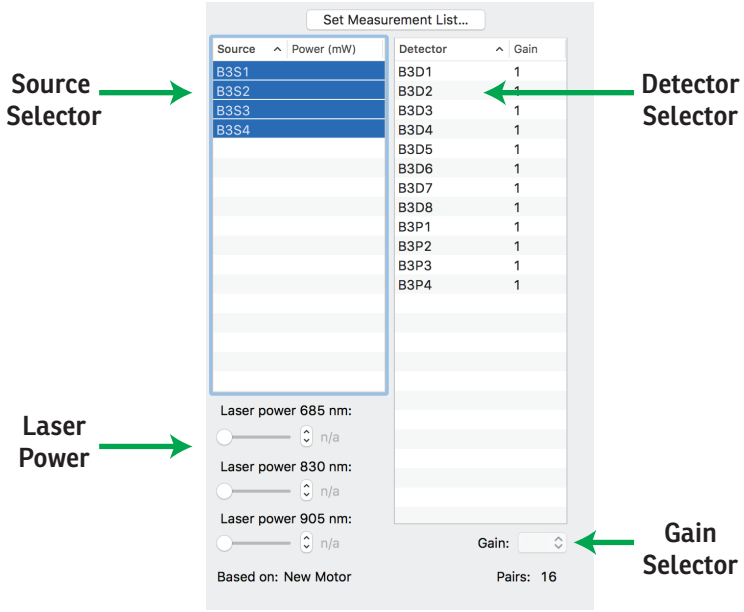


Fig. 14-7

Measurement list display with the Source selector, laser power controls, detector selector and digitizer gain controls.

Chapter 15: Perform: Localizing Optodes

One of the key features in Brainsight is the ability to associate the NIRS signals with the actual locations of the optodes on the subject's scalp and to map these locations to either a standard image-based model for the brain or the subject's specific MR images. This chapter describes how to associate the locations of the optodes, either using the estimates provided by the cap manager (mapped to either a model MNI brain, or the subject's MRI) or by actually digitizing them using the tracked pointer.

INTRODUCTION

One of the benefits of having an integrated navigator with the NIRS is the ability to accurately place the optodes using the subject's anatomy as a guide and/or to export the location of the optodes along with the data for use in more sophisticated analysis. The level of use of the neuronavigation is optional and generally falls into the following categories:

- No navigation and no estimated optode locations
- No navigation but using estimated optode locations based on a model head or subject's MRI
- Estimated optode locations and placement using navigation on a head model or subject's MRI
- Estimated optode locations and placement using navigation and recording of final locations on head model or subject's MRI

The simplest way of acquiring NIRS data (which is how systems without navigation do it) is to simply create an assembly list that defines the optode relationships from a functional perspective (which source-detector pairs to record) and to omit any information regarding their locations.

A slightly more sophisticated way is to define a NIRS cap with the MNI coordinates of each optode and the list of source-detector pairs to record (as described in "Managing Assemblies" on page 32). This will provide an estimate of the relative positions of the optodes and provide the possibility of visualizing the results overlaid

on the standard brain (MNI head model) for interpretation. This information can also be warped onto the subject's MRI by co-registering the subject-specific MRI to the MNI model head.

The next step in incorporating navigation is the ability to verify that the optodes are placed according to the plan. This typically involves mapping the MNI-based optode location template to the subject-specific MRI images, co-registering the subject to those images and using the tracked pointer to verify that the optodes are at the expected locations. Adjustments can be made to move the optodes to the correct locations. If the subject's MR images are not available, the MNI model head can also be used, albeit with lower accuracy.

Finally, the pointer can be used to digitize and record the final location of the optodes on the head. This step does not require that there be an original estimate of the optode locations and in fact can be used to create an initial estimate of the optode locations for future use with this, or other subjects (see "Using a single subject to create a NIRS cap definition" on page 98).

APPLYING AN ASSEMBLY LIST

If you are applying an assembly list that includes MNI coordinates and this project is using subject-specific MR images, you will need to have co-registered the MRI to the MNI coordinate space first (see "Chapter 6: Prepare: MNI/Talairach Registration"). If the assembly list does not have MNI coordinates, then proceed as instructed

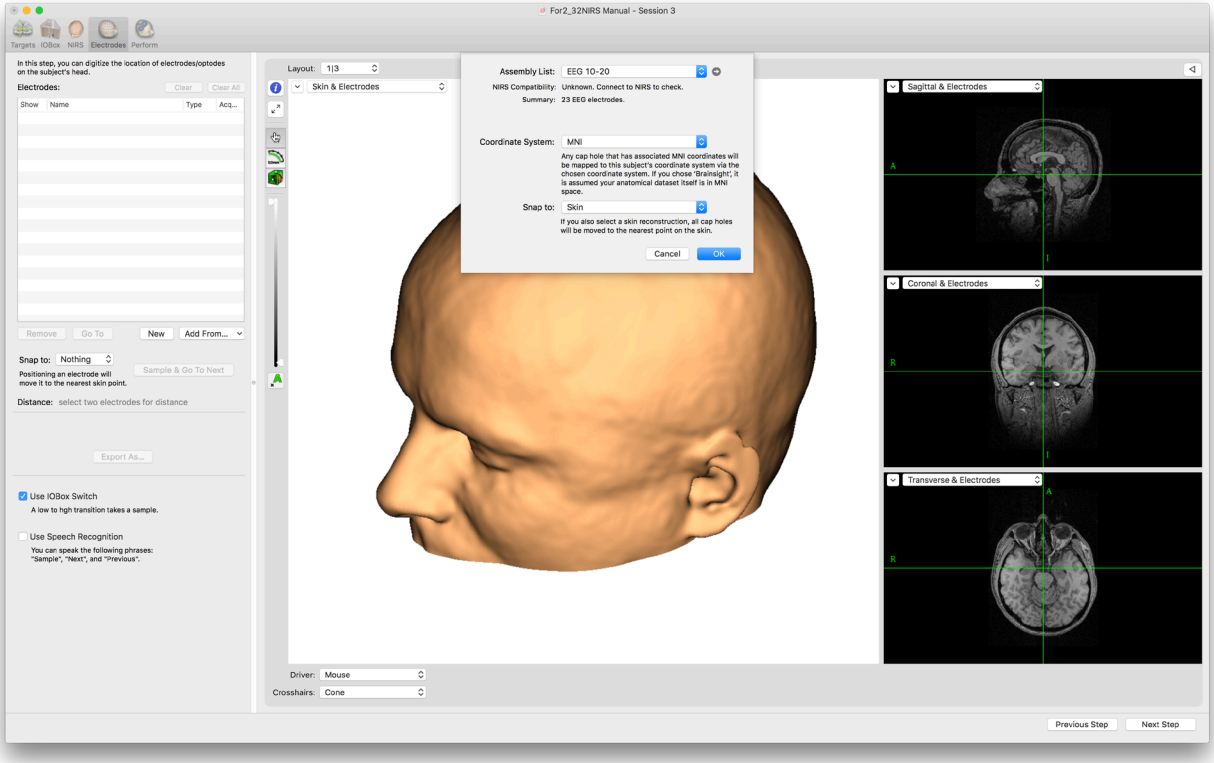


Fig. 15-1

Applying a pre-set assembly list

however disregard the reference to the coordinate system as they are only needed to convert MNI coordinates to the subject coordinate space.

- If you have not applied an assembly list yet in the NIRS step (“Perform: Optimize NIRS Parameters”), Click **Add From->Assembly List...** and an assembly list selection sheet will appear (Fig. 15-1).
- Select the assembly list from the popup list button
- Select the coordinate system registration to apply (the one you created in the Atlas step, or World/MNI is you are using the MNI head)
- Select **Snap to: Skin** (you should have created a 3D skin already as described in “Chapter 9: Prepare: 3D Reconstruction”)
- Click **OK** to place the optodes.

Verify Correct Cap Placement

If your assembly list used a cap with initial location estimates, then the image display should show the estimated locations of the optodes (and electrodes, if present) on the subject head. Assuming that you have performed the subject-image registration, you can now move the pointer around the head, touch the optodes and electrodes on the head and visualize how well the cap, actually on the head, agrees with the estimate. If there are discrepancies, you have the choice of either moving the cap on the head until it agrees with the plan, or digitize the final locations of the optodes to record the true locations on the head. Typically, you end up doing a

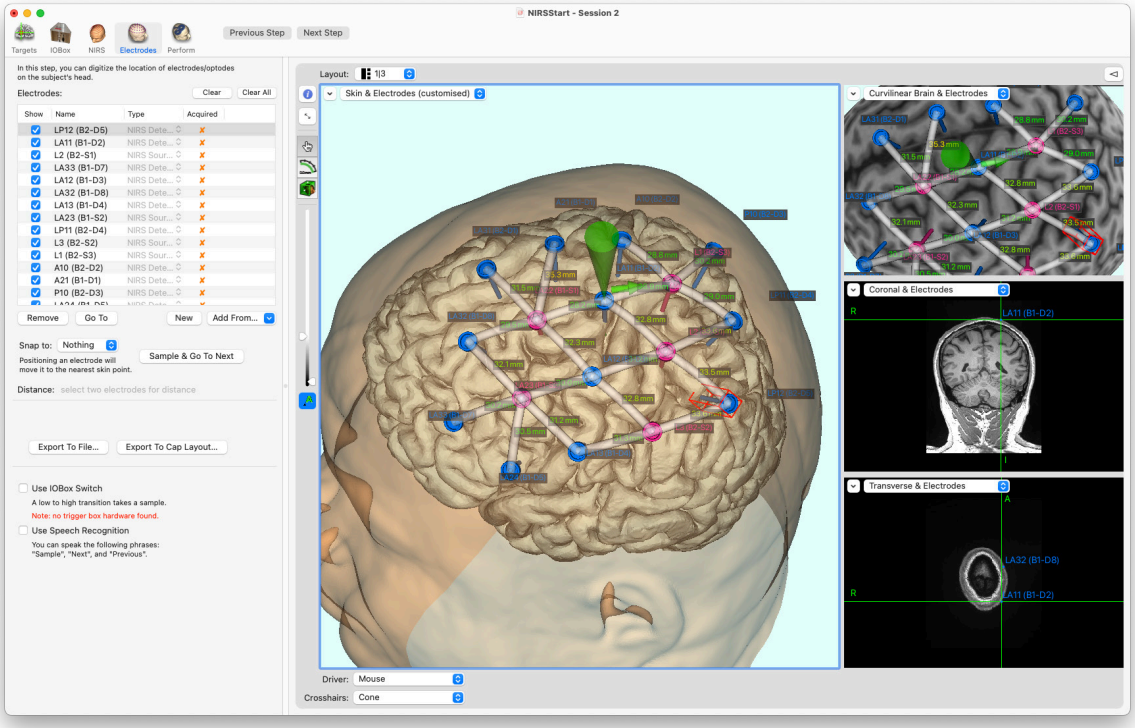


Fig. 15-2

A set of optodes from an assembly list applied to the subject-specific MRI.

bit of both. Tweaking the cap and in the end, digitizing the final location of the optodes.

To digitize the final locations of the optodes:

- Select **Snap to: Skin** in the popup button beneath the optode list. This will tell Brainsight to project the pointer tip to the closest point on the skin while digitizing the optodes. This will compensate for the optode thickness and ensure all locations are on the skin, not floating over the skin by the thickness of the optode. It will also use the skin to orient the optodes on the skin so the 3D representations of the optodes point into the brain (useful for visualization purposes).
- If you are using the foot-pedal connected to the Brainsight I/O box or trigger input box, then select it now by enabling the **Use I/O Switchbox** checkbox.
- Select the first optode in the list. Note that the computer will read out the optode/electrode name.
- Touch the optode with the pointer and depress the foot switch or click **Sample & Go Next**. The location of the optode as displayed on the skin should update itself. The next optode in the list should have automatically been selected (the computer voice will call it out).
- Go to the next optode and sample it as in the previous step. Repeat for all optodes/electrodes in the list.

USING A SINGLE SUBJECT TO CREATE A NIRS CAP DEFINITION

As noted earlier, the NIRS configuration step requires a valid assembly list (the list of source-detectors to use for the acquisition). In order to create an assembly list, one needs a cap layout. This creates a bit of a "chicken and the egg" problem in that we need MNI coordinates of the cap "holes" in order to create the definition needed for the assembly list, but need a subject to wear the cap to measure them. This section will outline the steps to use a single subject to measure the locations of the cap holes and to convert these to MNI coordinates to use to define the cap.

The overall process will consist of:

- Preparing a Brainsight project for the subject (including an MNI registration in the Atlas step)
- Applying the cap to the subject (whatever the cap may be, patch, EEG cap or elastomer straps)
- Initiating a session and co-registering the subject to their MR images
- Using the electrode step to record the optode hole locations.
- Exporting the sampled list of electrodes to a text file (in the MNI coordinate space)

At this point, we assume you have done all the preparation and have a subject with the cap on, the images loaded, the on;ine session has been initiated, the subject-image registration already performed and are at the Electrodes step. To digitize the new cap layout:

- Select **Snap to: Skin i**n the popup button beneath the empty optode list. This will tell Brainsight to project the pointer tip to the closest point on the skin while digitizing the optodes. This will compensate for the optode thickness and ensure all locations are on the skin, not floating over the skin by the thickness of the optode. It will also use the skin to orient the optodes on the skin so the 3D representations of the optodes point into the brain (useful for visualization purposes).
- If you are using the foot-pedal connected to the Brainsight I/O box or trigger input box, then select it now by enabling the **Use I/O Switchbox** checkbox.
- Place the pointer on the first optode/electrode and click **New**. This will create a new entry in the optode list using the current pointer location (projected to the skin).
- Note that the optode name in the list will be highlighted. You can quickly overwrite that default name (Electrode XX) by typing a new name (it is best to have 2 people at this point, one sampling the optodes and the other typing). You can leave the default names for now as well and change the names later.
- Move the pointer to the next optode and click New again (and repeat the naming process). Repeat for all optodes.

- Once all the optodes have been digitized and named, click **Export As...**, select TEXT as the file type and MNI as the coordinate system, provide a name (a name describing the proposed cap is a good name)and click **OK**.
- Return to the Cap Layouts Manager (described in Chapter 4 on page 29) and select **New->From FIle...**. Select the text file created in the previous step and it will be added to the caps list.
- Change the name of the new cap layout (at least remove the ".txt extension)
- Return to the Assembly Lists manager (also in Chapter 4) and create a new assembly by selecting N**ew->YOUR CAP NAME**.
- Configure the Usage-Bay-Optode information for each channel used and the assembly list will be ready for use in any project in the future.

Chapter 16: Perform: Subject-Image Registration

The Subject-Image registration step is where we establish the link between the real world and the image world. Once this link is established, it will be possible to track any object of interest in the real world (e.g. pointer) and display the representation of it on the images. This will simplify the task of ensuring the optodes are placed accurate;y according to plan and to record their final location.

The registration procedure varies a bit depending on your project type (subject-specific MR images vs. MNI model head). It is good to familiarize yourself with both techniques.

VERIFY PROPER POLARIS LOCATION

The next Polaris step 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 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. See
- Click **Next Step.**

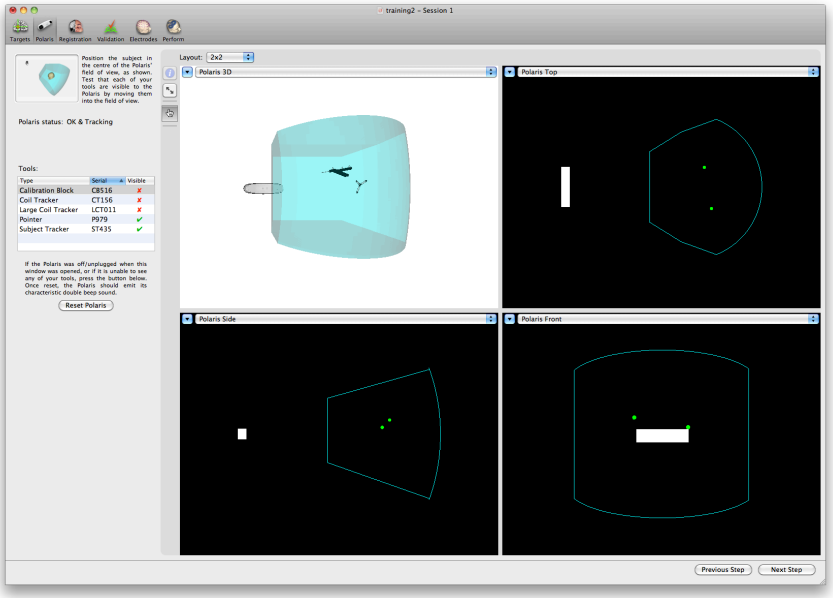
If you are using a subject-specific MR-based project, proceed to the next section. If you are using an MNI model head based project, skip to the next section:

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

Recalling Chapter 10, 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. 16-4). This step requires close interaction with the computer as you identify the points and "tell" the computer when you

Fig. 16-1

Polaris verification screen.



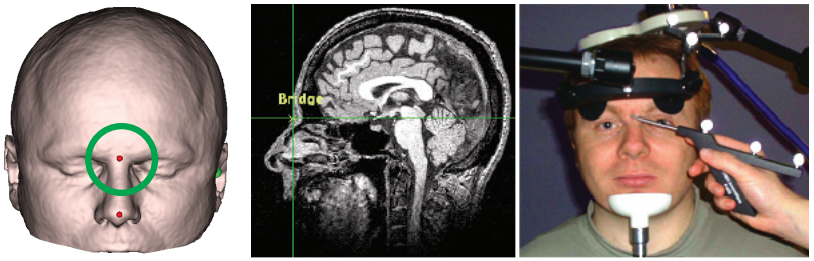
What if my tools are not visible?

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):

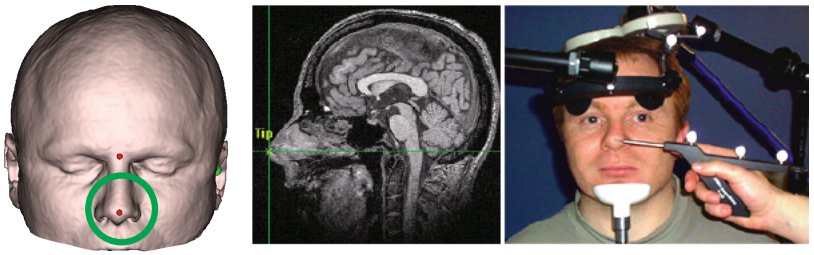
- Does it only fail to track one tool? If so, examine the spheres for scratches or dirt and make sure they are all seated properly on the posts.
- Does it track better (all tools) close to the camera, but not near the rear of the field of view? Has this been getting worse over time? If so, your camera 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.

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 switch input by enabling the appropriate checkboxes (Fig. 16-3). Alternatively, have an assistant present to operate the computer for this step.

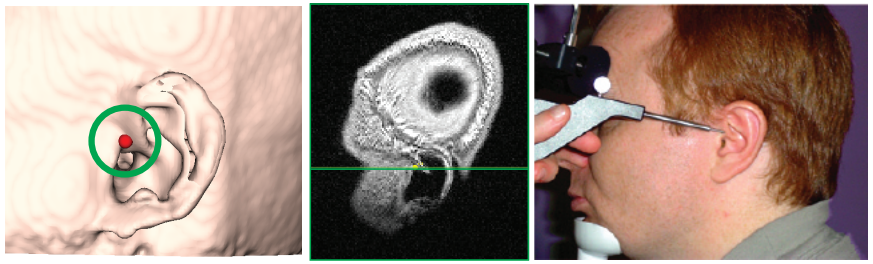
- Note the location of the cursor on the screen (or click on the first landmark to begin).
- Carefully place the pointer tip on the same landmark on the subject's head, being careful to gently touch the skin surface (do not "poke" the subject) and to keep the pointer still. Make sure both the pointer 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 clicking **Sample & Go To Next Landmark**.
- 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 foot switch 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



Bridge of Nose (Nasion)



Tip of Nose



Ear (notch above the tragus)

Fig. 16-2

Typical landmarks for registration.

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

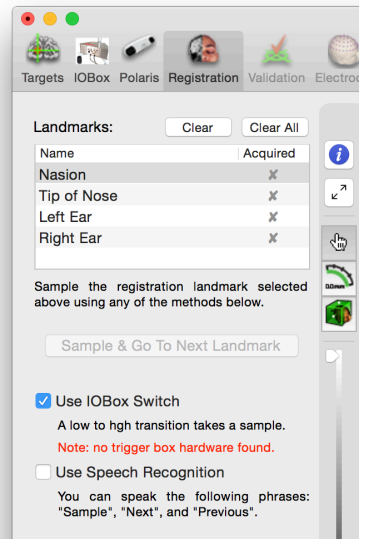


Fig. 16-3

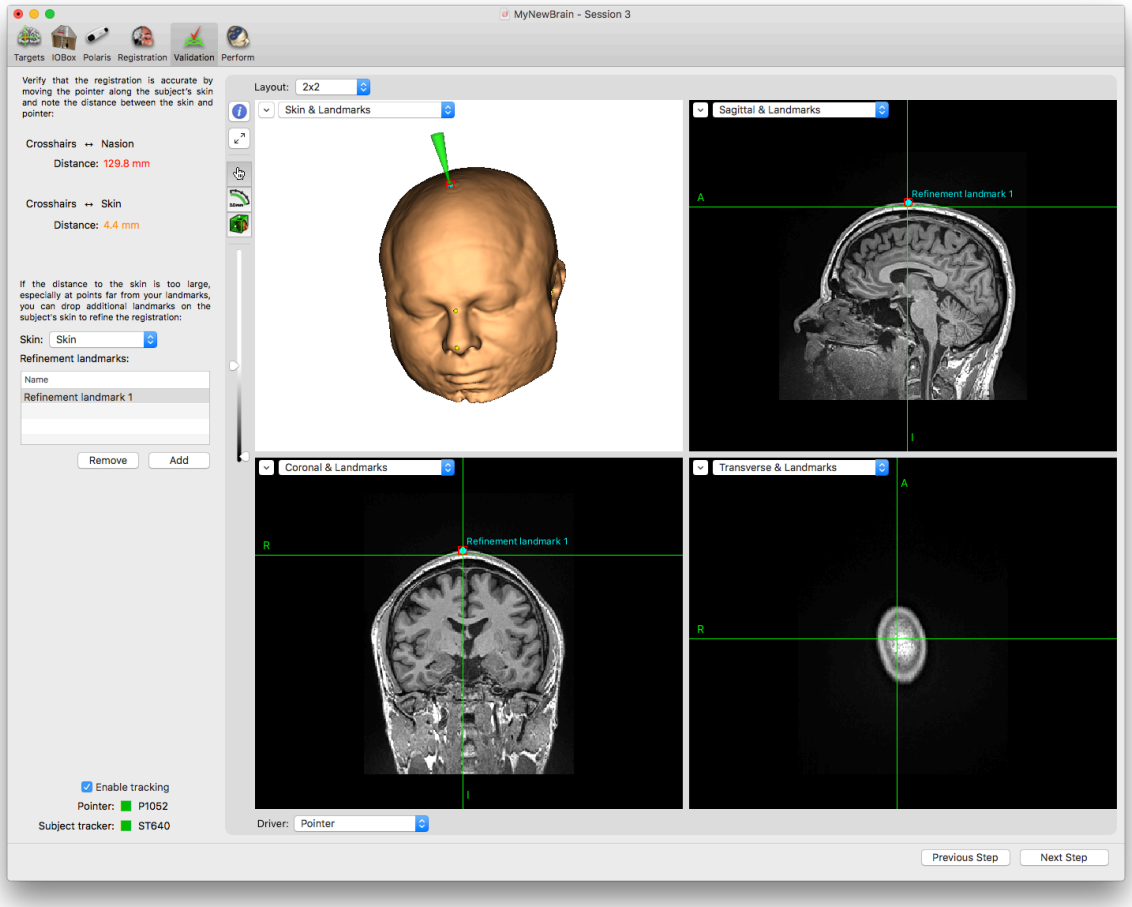
Selectors to activate the switch input and/or speech recognition. Note that these settings persist on subsequent steps.

pointer on the head (the pointer is "driving" the cursor). You have the option of recording additional refinement 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. 16-4). Make sure that the pointer is shown on 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

Fig. 16-4

Registration verification screen.



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 than 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.**

The next step will be to apply the NIRS cap and verify/digitize their locations. Proceed to "Chapter 15: Perform: Localizing Optodes" on page 95.

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. 16-5). 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 switch input (see Fig. 16-3). Alternatively, have an assistant present to operate the computer for this step.

- 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 clicking **Sample & Go To Next Landmark**.
- 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 switch 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. 16-6). 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

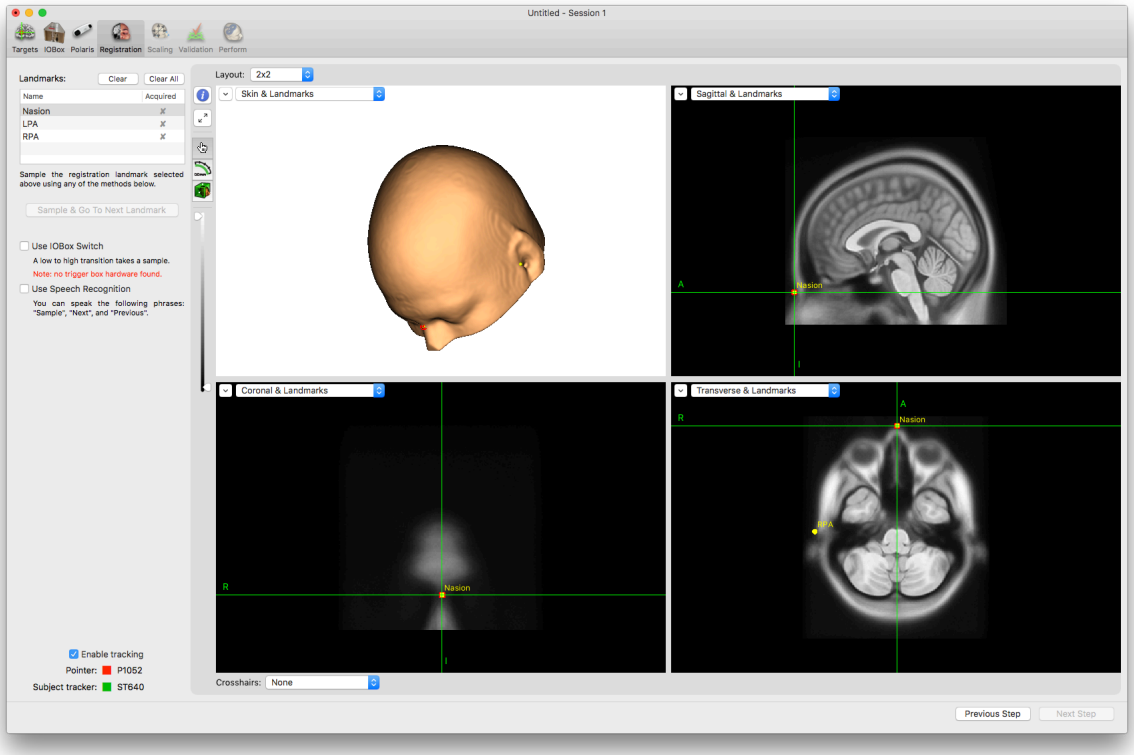


Fig. 16-5

Anatomical Landmark Recording

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.

The final step is to verify that the registration was successful. Move the pointer on the head (Fig. 16-7), focusing n 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.

The next step will be to apply the NIRS cap and verify/digitize their locations. Proceed to "Chapter 15: Perform: Localizing Optodes" on page 95.

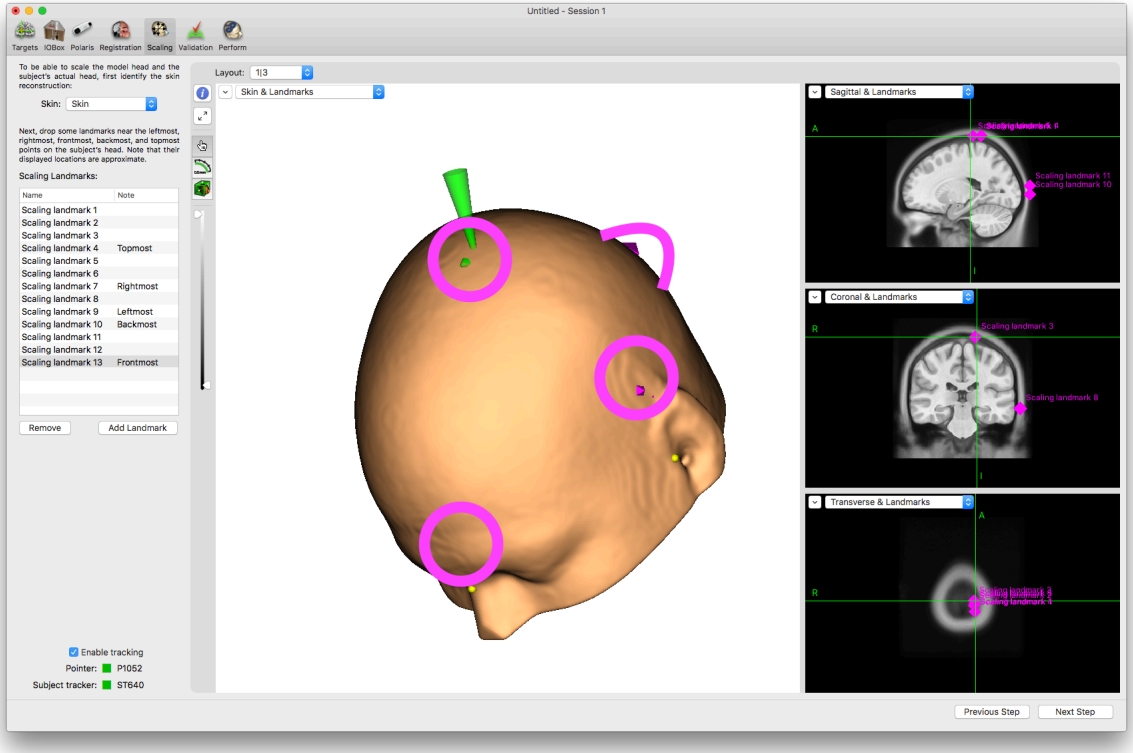


Fig. 16-6

Scaling Landmark Recording

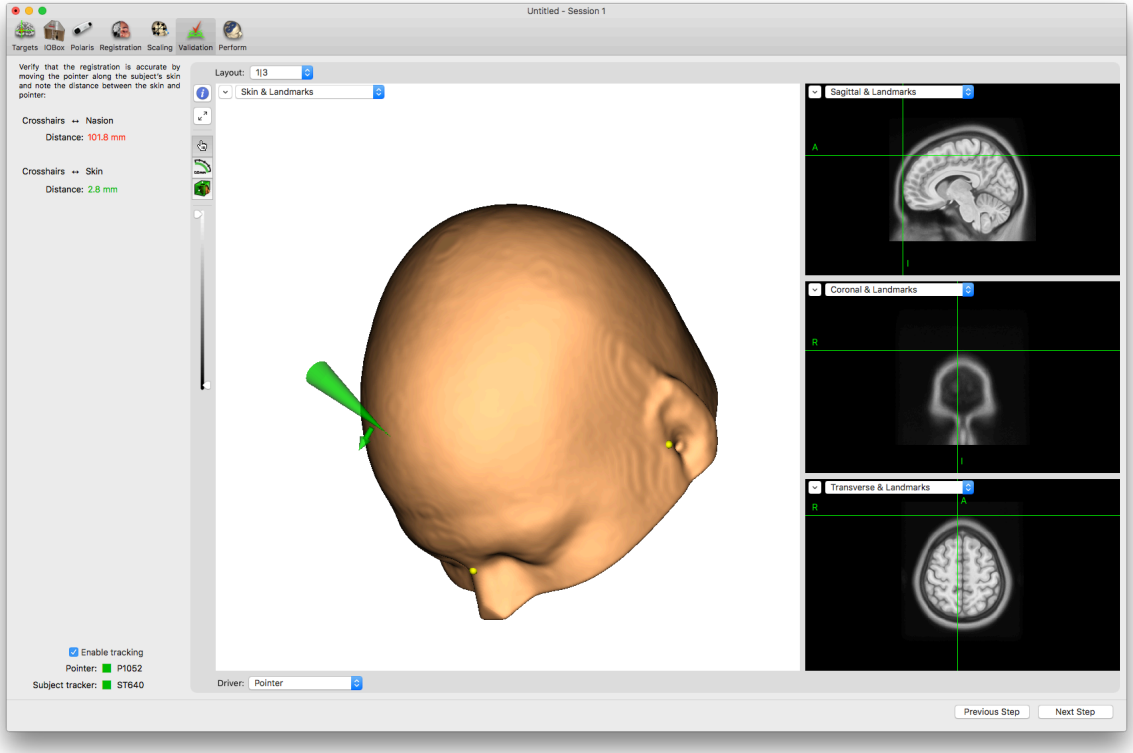


Fig. 16-7

MNI Registration verification step.

Chapter 17: Perform: Acquire The Data

Once all the parameters have been decided on, it is time to perform the actual study. This chapter will describe the steps needed to acquire the NIRS data during the experiment.

INTRODUCTION

A lot of preparation work has led to this step. Relatively speaking, there is little work to do. It is assumed that prior to reaching this step, you have connected to the NIRS, selected an assembly list and run the system to ensure that the optodes are well placed (see "Chapter 14: Perform: Optimize NIRS Parameters"). At this point, there is little left than to click the record button and perform the experiment.

There are a few types of NIRS experiments

NIRS-ONLY EXPERIMENT

- Ensure that the parameters for the NIRS study were entered and tested in the NIRS hardware step (see "Chapter 14: Perform: Optimize NIRS Parameters")
- If you intend to acquire event-related epochs, enter a baseline and trial duration. The baseline is the amount of data before the trigger and the trial length is the amount of data after the trigger to record.
- When you are ready to start the acquisition, click **Start NIRS**.
- If the acquisition was event related and you enabled an external trigger, you should notice samples accumulate in the samples list during the acquisition.
- If you wish to stop the acquisition at any time, click Stop NIRS. Otherwise, the acquisition will continue

for the time set in the **Acquisition Duration** field of the NIRS step.

MULTIMODAL ACQUISITION

In some experiments, you may wish to acquire other data in addition to the NIRS. For example, you may be performing a TMS NIRS experiment where you are using TMS to stimulate a brain region and using NIRS to observe the results. In this case, you may wish to use Brainsight's TMS navigation features to track your TMS coil and record its location while acquiring EMG.

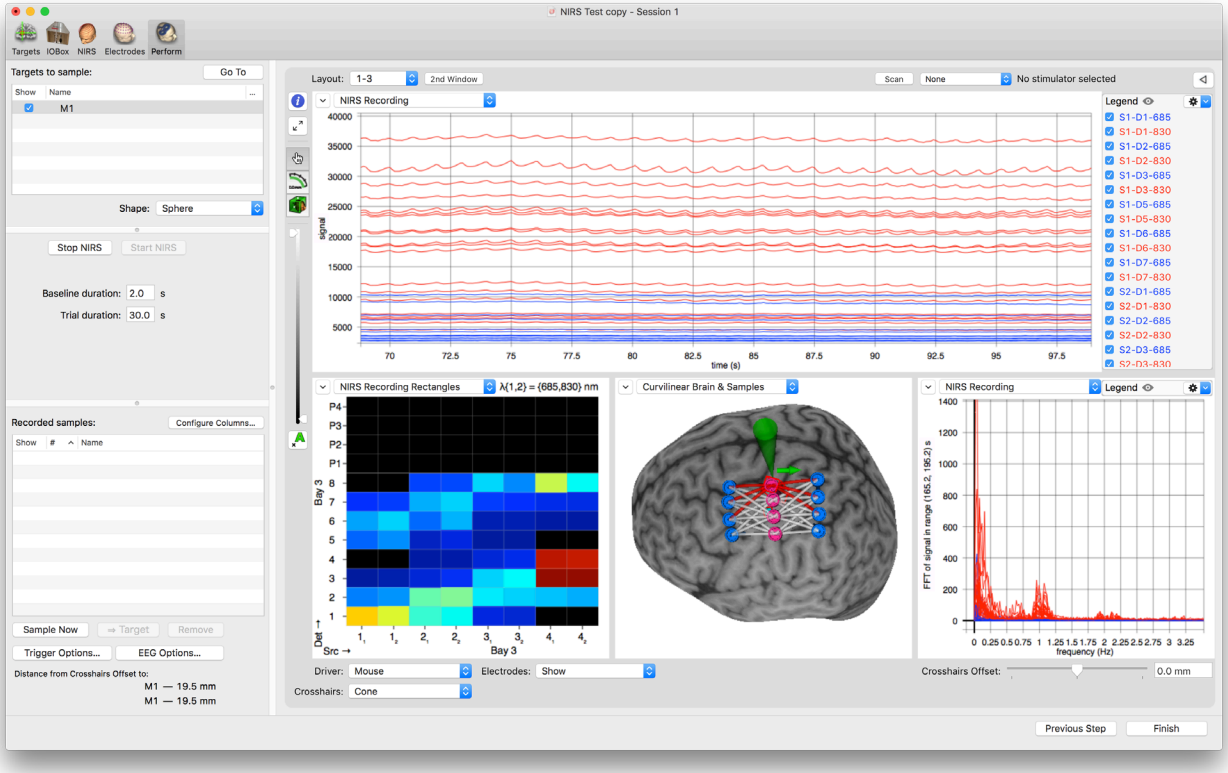


Fig. 17-1

Perform Step

Chapter 18: Reviewing and Analyzing Study Data

After a NIRS session, it is often useful to review the data acquired in the session, compare and contrast it with other NIRS sessions, analyze the data, and/or export the data for analysis. Brainsight has several tools to help review and analyze your NIRS data, and the option to export the session data in the common ".nirs" format for further processing.

REVIEWING SESSION DATA

The usual purposes for review are:

- To verify that the data acquired was reasonable (e.g. no significant artifacts).
- To sort through the data and export relevant information for further analysis.
- To configure the display window and take screen-shots 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. 18-1).

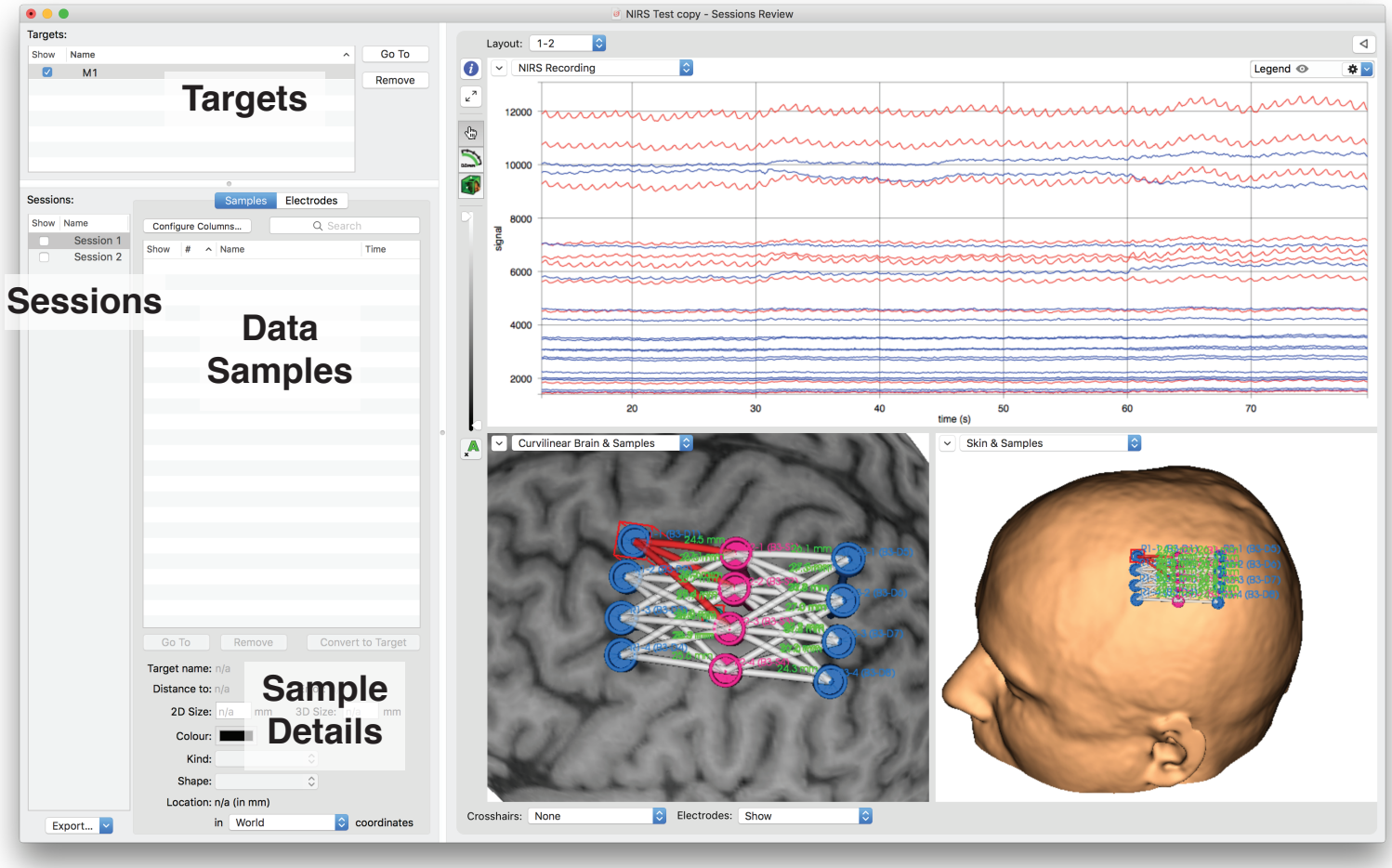
Display Window

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 allows you to selectively view the attributes of one or more

Fig. 18-1

Session Review window.



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 ctrl-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 the Brainsight NIBS user manual for details onthe EMG display), 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.

EXPORTING THE DATA

You can 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. 18-2). 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. 18-3. 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.

Attribute description

All data are written as strings. 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

Fig. 18-2

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.

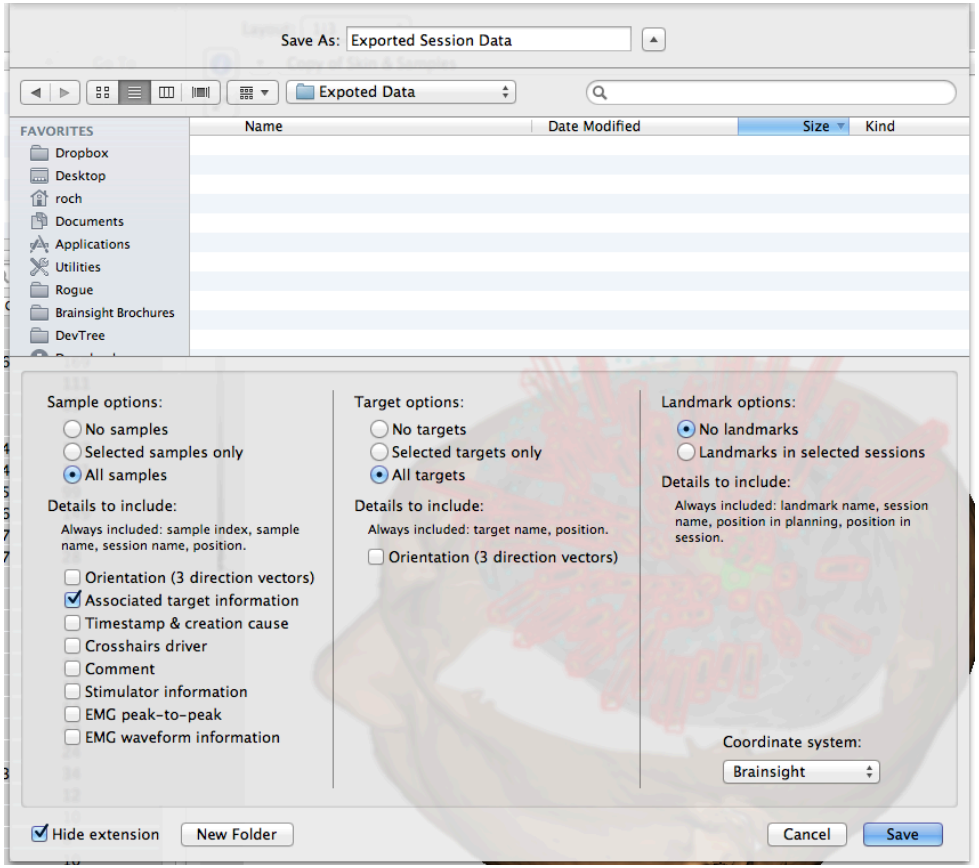
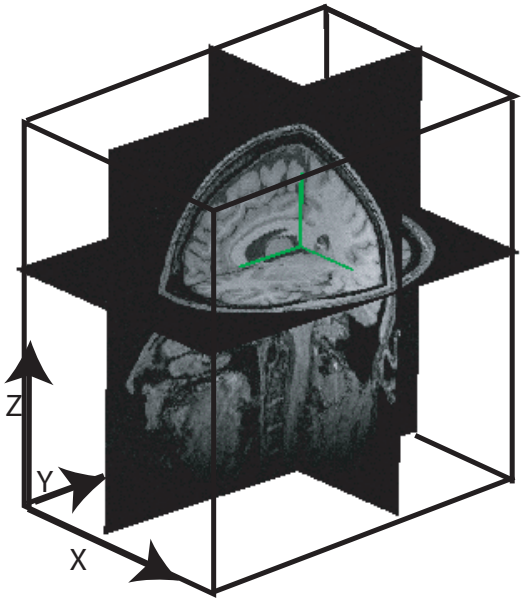


Fig. 18-3

Brainsight's internal coordinate system.



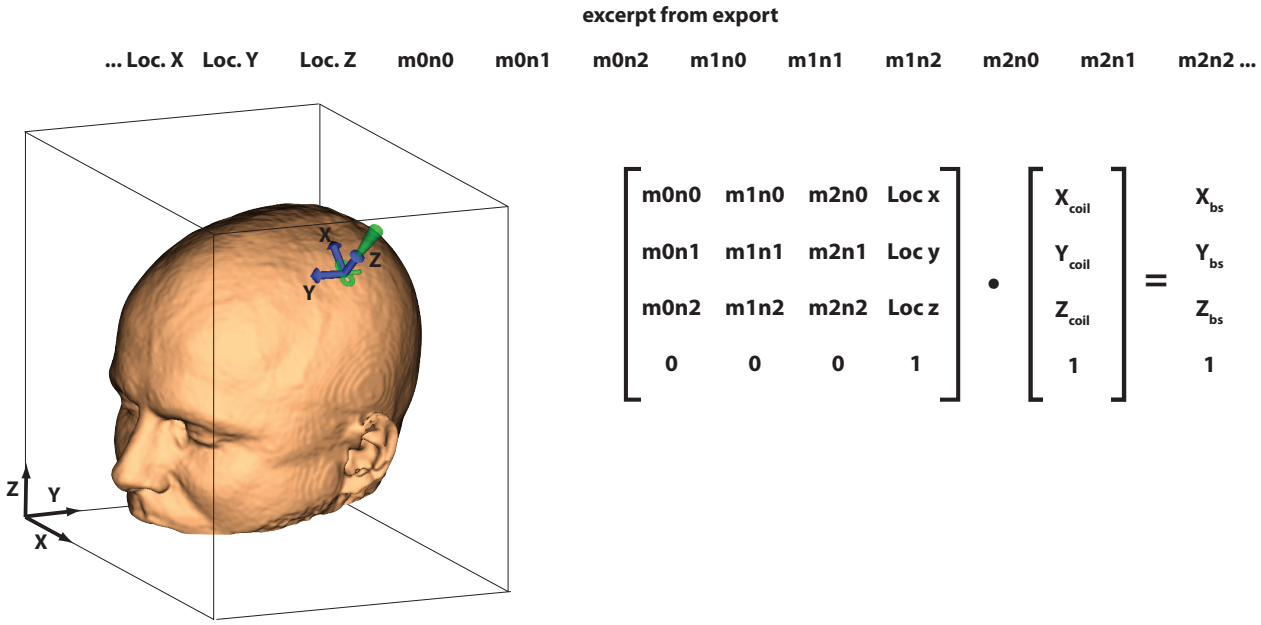
the tracked tool given when it was calibrated.

- **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.
- **Angular Error** [float]: The tilt error of the coil.
- **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 were HH is the hour, M is the minute, S is the second and XXX is the milisecond.
- **EMG Star**t [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
  (EMG End-EMG Start)/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. 18-4

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].



ANALYZING SESSION DATA

Data analysis of your acquired NIRS session can be performed within Brainsight. From the Sessions tab, select the session you wish to analyze, then click **Analyze**, which will open a new display window with four tabs (Fig. 18-5).

Import

If your data was acquired by a Brainsight NIRS system (the NIRS device), the NIRS data is already part of the project, so you can skip this step. If your data was acquired using another NIRS device, it is possible to import the .nirs file here and match it to the assembly list that was used to estimate and/or digitize the location of the optodes. It is important that an assembly list was used during the navigated session in order to have a valid mapping from the channels of the NIRS data file to the channels defined in the Brainsight project to project them to the correct location on the head.

Onsets

In the Onsets step, you can define your conditions (or events) and extract the onset times for each type of condition.

- Under “Conditions”, name a new condition by selecting “Add...”.
- In “Onsets for condition “Condition Name”:”, select “Add From...” and select your desired method for setting your onset times to use for analysis:

- **NIRS Aux Channel Data**: extracts onset times using a threshold to detect voltage spikes recorded from an auxiliary channel connected directly to your NIRS device. This method will result in the most precise synching of triggered events and the data.
- **Existing Session Samples**: extracts onset times by using samples acquired during the session (i.e. manual samples or triggered samples received by the I/O box).
- **Manual Time Indexes**: manually create a comma-separated list of onset times for the duration of the session (e.g. 10,40,70,100, etc.).

The list will now be populated with onset times for your chosen condition.

Processing

In the Processing tab, the optical density is calculated as an intermediate processing step using the raw NIRS data, the absorption coefficient of the tissue and the distance travelled by the light from source to detector. To remove any extraneous noise in the data, including respiration and heart rate, you can apply either a low pass, a high pass or a band pass frequency filter to the data. Select the type of filter you wish to apply and click "Compute".

Concentration

The Concentration tab allows you to display your analyzed data. Average HbO, HbR and HbT concentrations from a chosen condition for each source-detector pair are displayed in the Image View of "NIRS Average Δ Concentrations". HbO is displayed in red, HbR is displayed in blue, and HbT is displayed in green. To set the parameters to visualize your analyzed data, input the following:

- In "Time range around onsets", input the desired time to be used for baseline data (the time before a condition, as a control) and input the length of time to be analyzed for the trials. Ensure to not have trial times overlapping when performing your analysis (e.g. do not enter a trial time value that exceeds your intertrial interval), as this may make your resulting data difficult to interpret.
- Select the condition you would like to view. Ensure the correct onsets in the condition are checked. Then click "Compute".

The average concentration data can now be seen in the Image View.

The individual trials used to calculate the averages are shown in the "Onsets for Condition "Condition Name":" window. In a condition, if one or more particular trials are unsuitable for analysis, the trials can be unchecked in the "Contribute" column and new averages will automatically be calculated and displayed for that condition.

In the Legend of "NIRS Average Δ Concentrations", you can select which source-detector pair to highlight in the graph by clicking on it once; you can remove a source-detector pair from the graph by unchecking it; and you can choose to view HbO, HbR and/or HbT by clicking or unclicking their respective buttons at the top of the legend. You can also highlight a particular source-detector pair by clicking on a tube on the "Skin and Electrodes" Image View.

Fig. 18-5

NIRS data import window

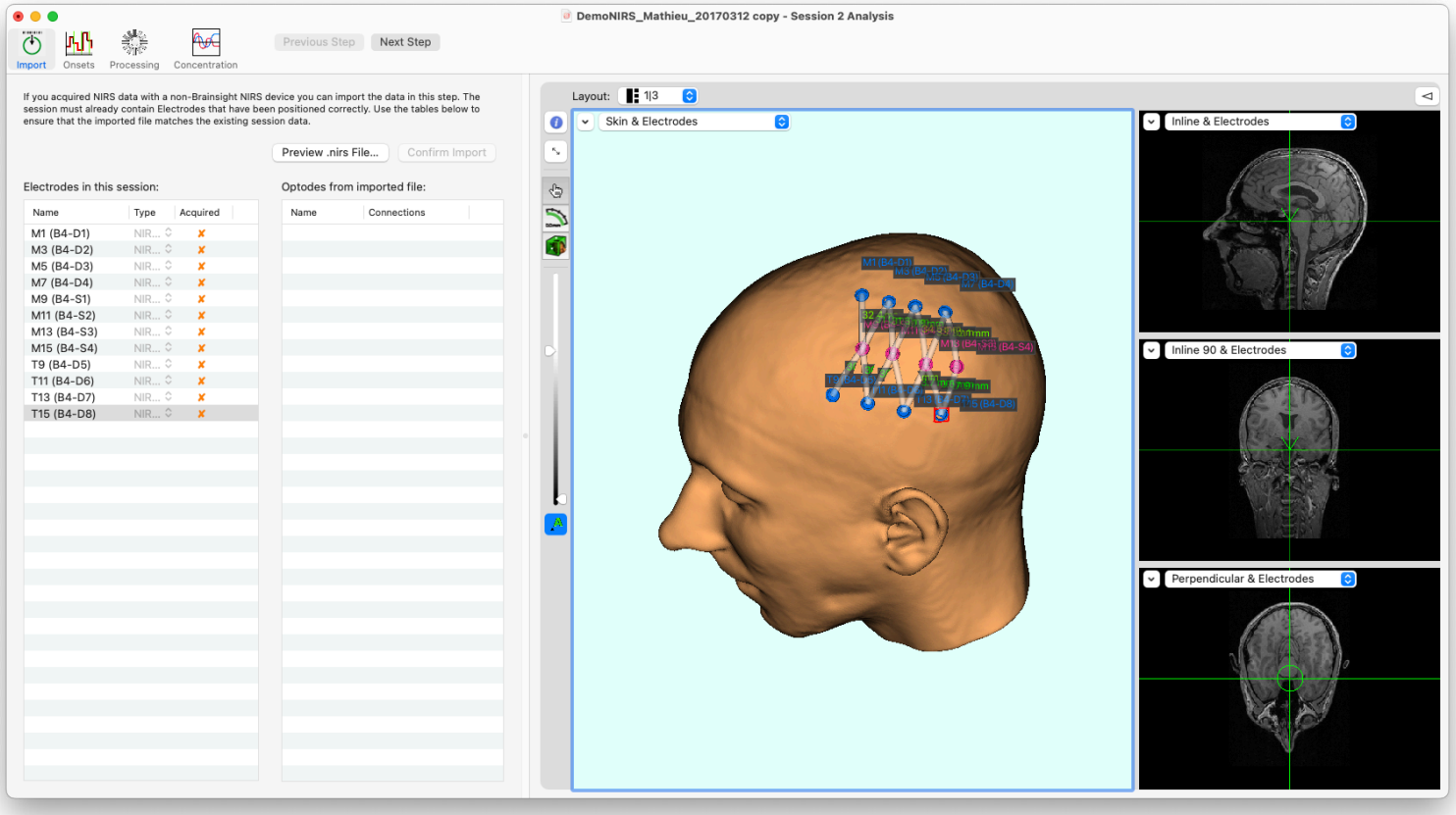


Fig. 18-6

Analysis window: Onsets tab

Add conditions and then add the event onset times for each condition using "Add From...".

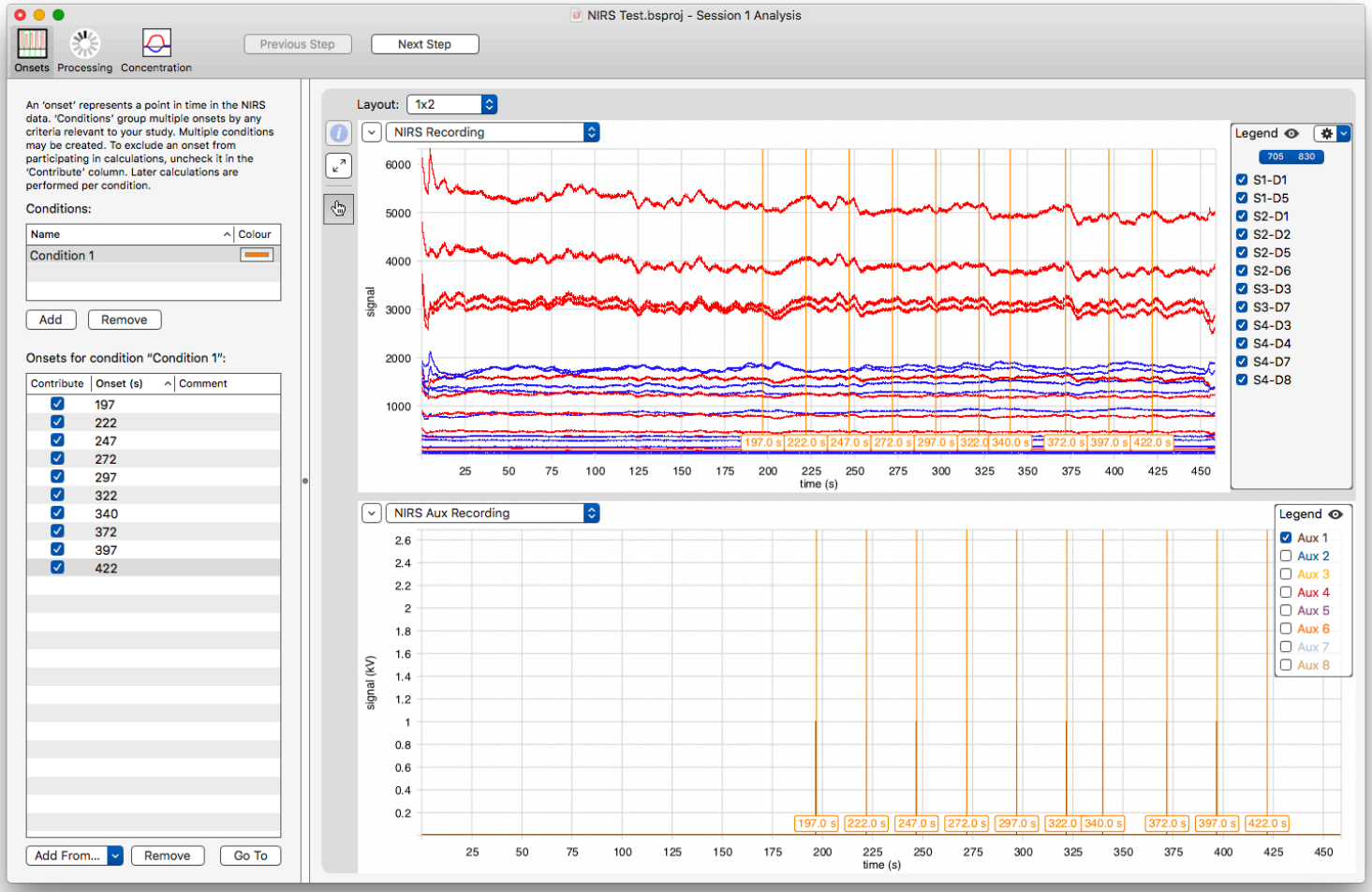


Fig. 18-7

Analysis window: Processing Tab

Compute and view optical density data and the filtered data.

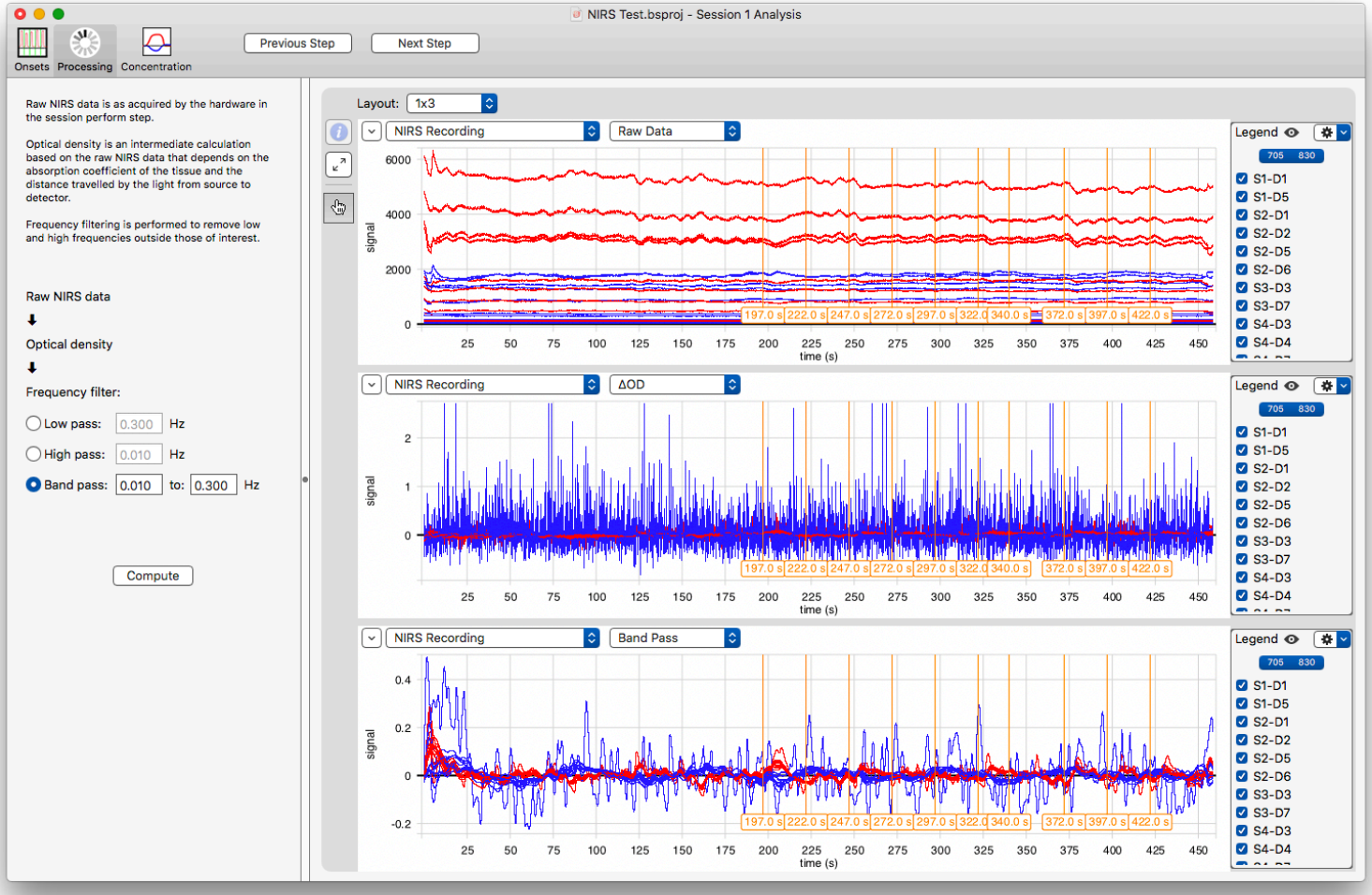
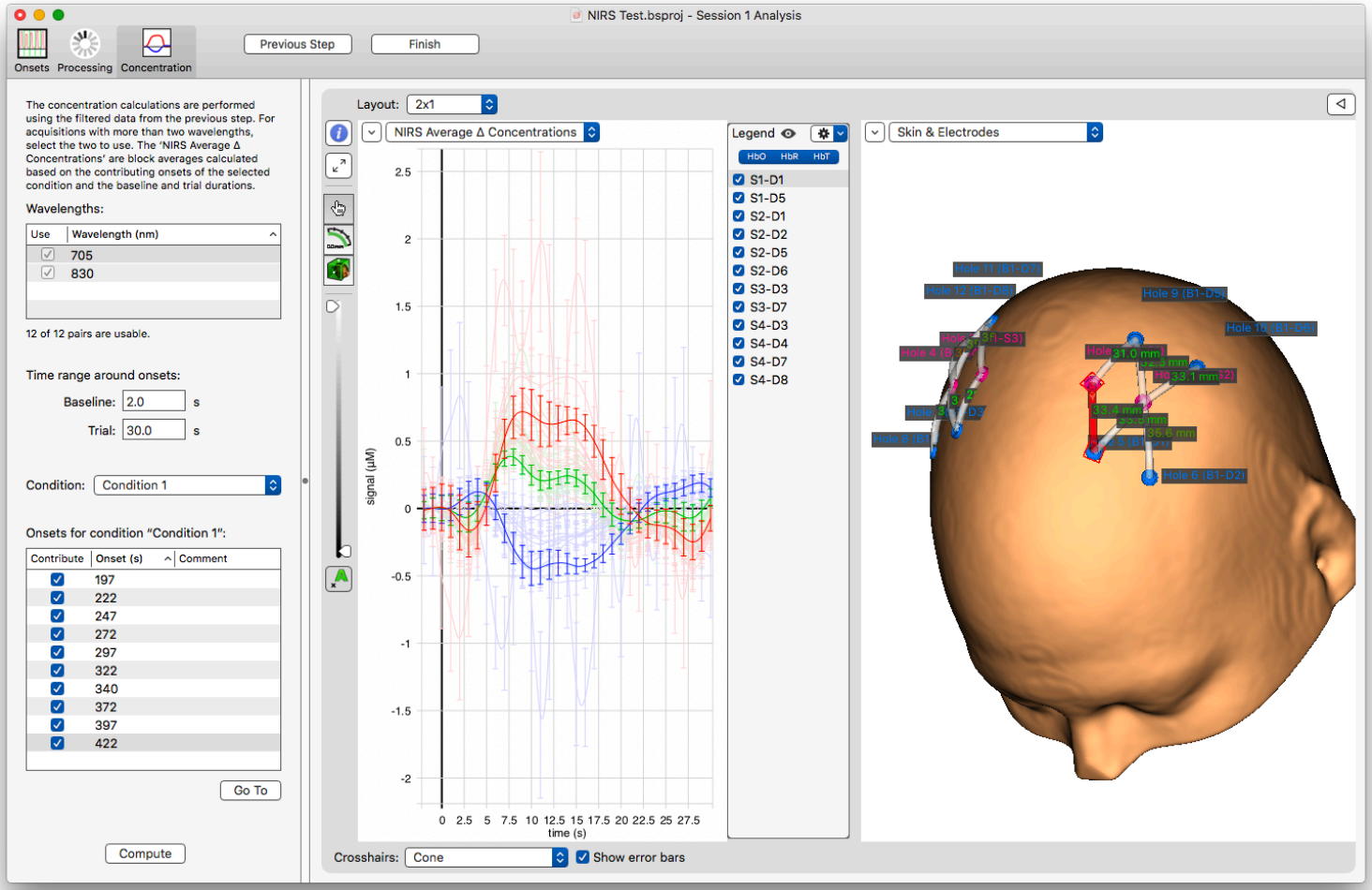


Fig. 18-8

Analysis window: Concentration tab

For a selected condition, displays average changes in concentrations for HbO, HbR and HbT for each source-detector pair.



Chapter 19: 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. 19-1). Enter the name of the subject in the field at the top of the window.

Setting up

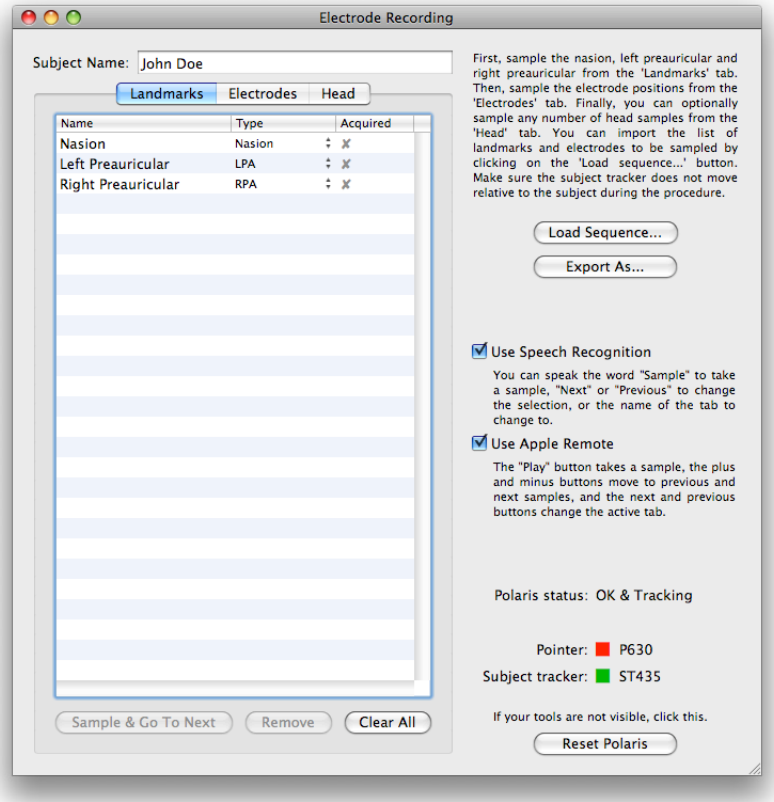
- Before starting, set up the trigger method(s) to notify the computer whenever you are touching a landmark. Optionally turn on the speech recognition or Apple Remote by enabling or disabling their respective checkboxes.
- Put the subject tracker on the subject's head and place the subject in the view of the Polaris position sensor (review how to prepare the subject and use the Polaris by looking at "Prepare the Subject" on page 80).

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. 19-1

First step of electrode recording.



DIGITIZE THE ANATOMICAL LANDMARKS

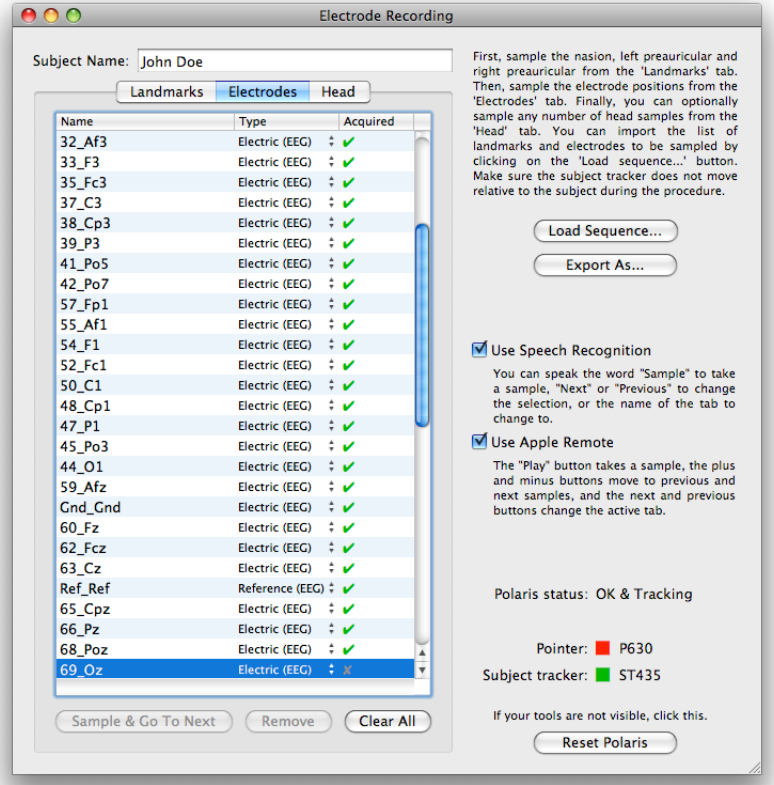
- If not already the active tab, click the **Landmarks** tab to bring it up (or, if you have speech recognition activated, say "Landmarks").
- Place the tip of the pointer on the first landmark and either say "Sample", press **Play** on the Apple Remote or have an assistant click on **Sample & Go To 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. 19-2

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. 19-2). 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. 19-3). 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. 19-4).
- 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. 19-3

Head Sampling Screen

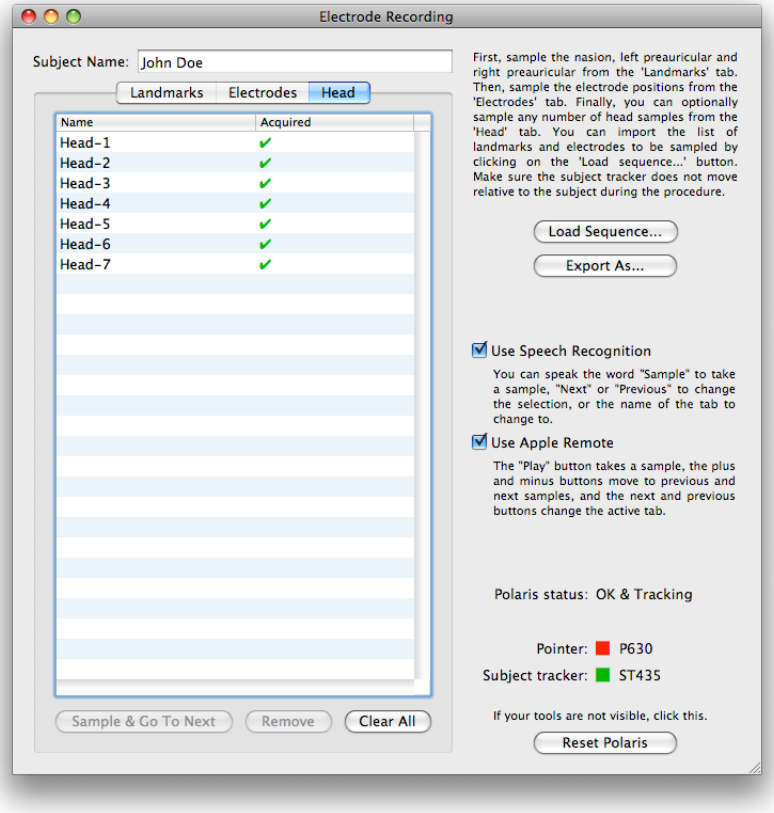
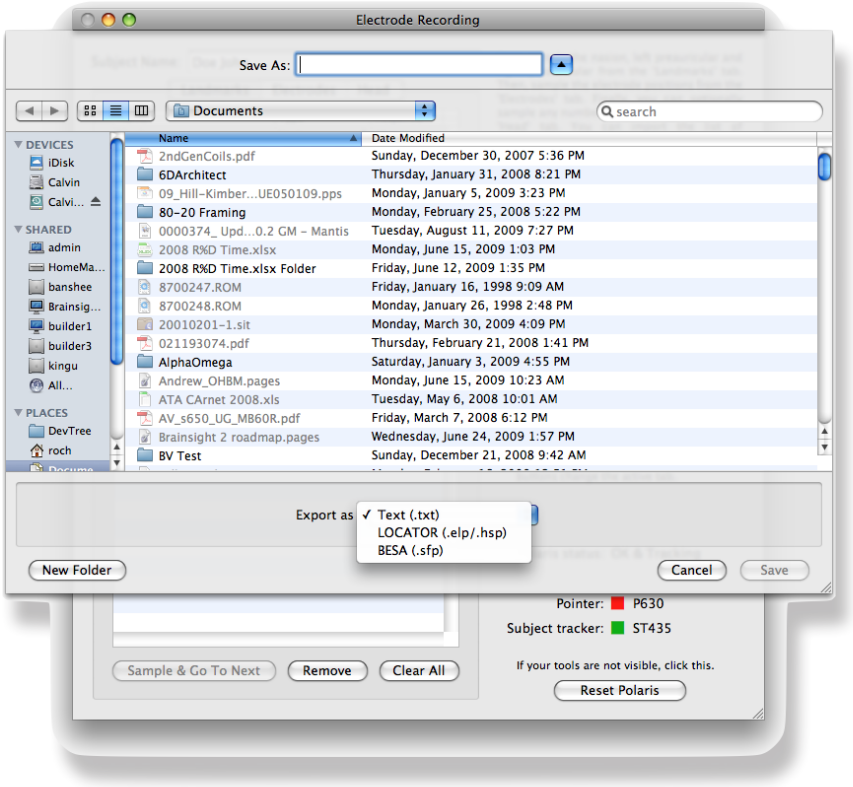


Fig. 19-4

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 assymetry). 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 20: 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. 20-1) 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. 20-2) 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..

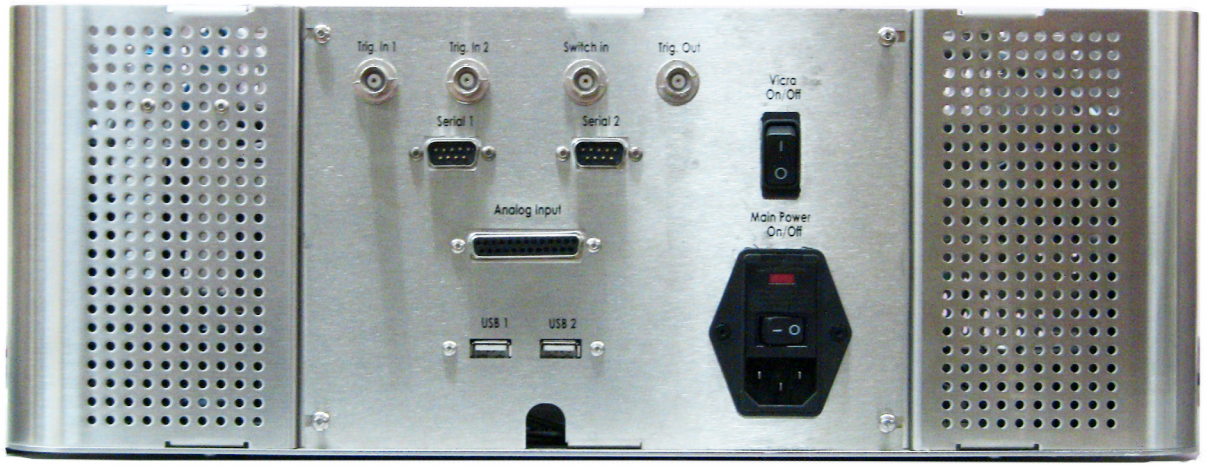


Fig. 20-1

Overall picture of the computer/trolley

Fig. 20-2

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:

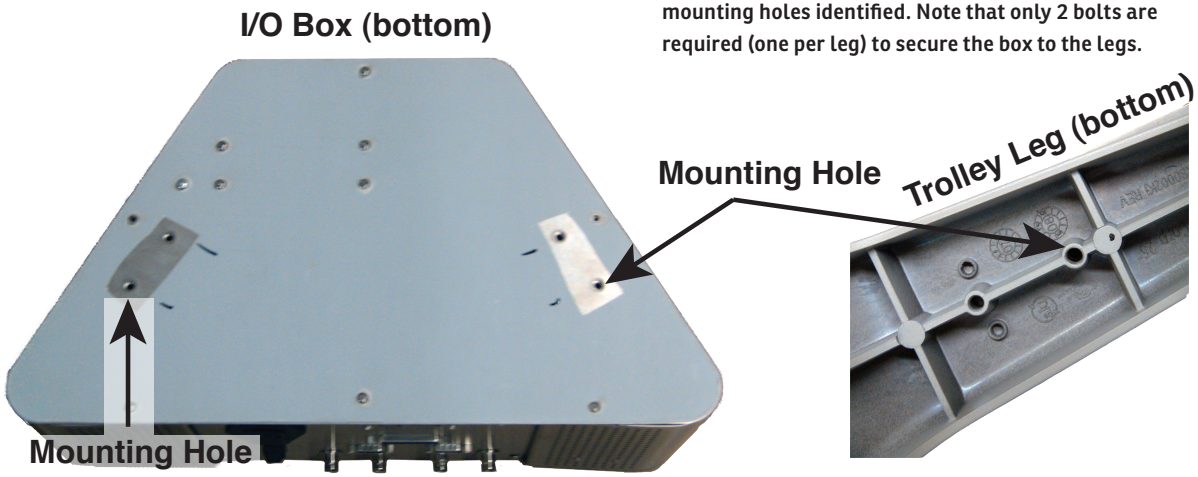
- Phillips (star) screwdriver
- Scissors or cutters for cable-ties

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. 20-3.
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. 20-3

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 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.
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. 20-6).
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 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

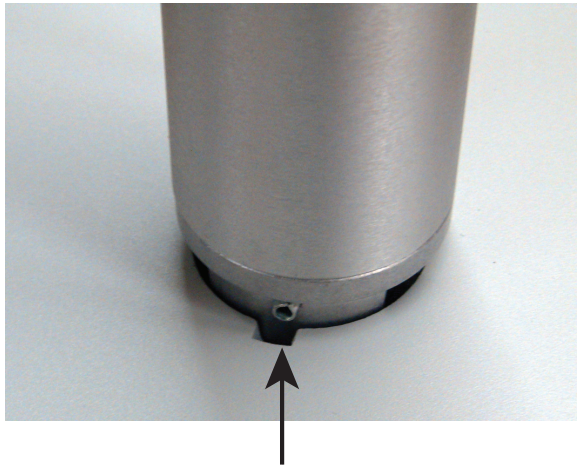


Fig. 20-4

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



Fig. 20-5

Correct placement of the pedal.



Fig. 20-6

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

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 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.



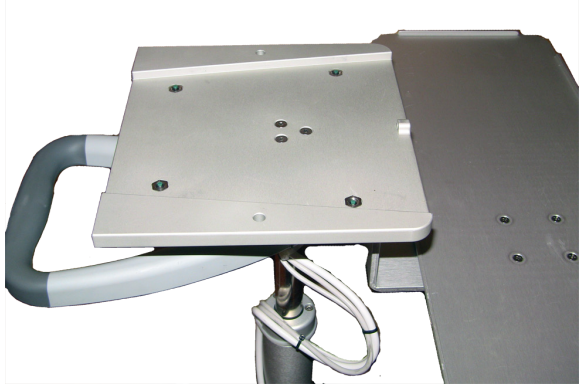


Fig. 20-7

Assembly of the computer base and keyboard tray. The tray sits between the computer base and the top of the pole. The three screws go through the computer base i 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

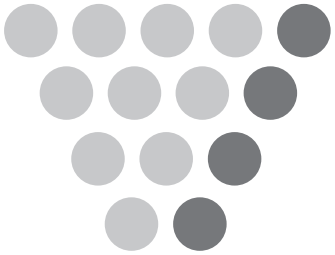
1. Make sure that the mains switch at the rear of the trolley is set to ON.
2. Press the power button at the rear of the iMac. After a few seconds, you should notice it start up.
3. Once booted, follow the instructions in the Brainsight User Manual to operate the Brainsight system.

Software Updates

Like all modern computers, your 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.

Brainsight®

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