# Aurora fNIRS

User Guide

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# NOTICE OF INTENDED USE:

NIRx NIRS imaging systems are NOT intended for use as a clinical diagnostic or treatment guidance tool. Neither the system hardware (NIRSport2) nor system control software (Aurora fNIRS) has FDA Approval. Use of these resources is for **investigational use only** and requires IRB approval **prior** to performing measures on human subjects.

## Intended Readership

Familiarity with this document is strongly recommended for operators of the NIRx NIRS NIRSport2™ imaging device, to avoid instrument misuse that potentially can lead to hardware malfunction or data corruption.

We furthermore recommend this document to any user involved with planning experiments with or with analyzing data from NIRSport2 measurements.

Critical notes and alerts are indicated with this symbol throughout the document.

## Walkthrough Video

A video walkthrough of the Aurora fNIRS software may be viewed here:

https://www.youtube.com/watch?v=LtPx89eDuNQ

## Related Documents

The following user manuals and documents may contain additional information pertinent to the topic matter of this user manual:

- NIRSport2 User Guide – For proper hardware operation
- NIRXWINGS User Guide – For proper hardware operation
- NIRSite 2020.07 (or Later) – For custom montage creation

## Problem Reporting Instructions

You may use the following ways of contacting NIRx for additional training, support, or bug reporting:

E-mail: support@nirx.net

Web: https://nirx.net/technical-support

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# 1. Release notes

## 1. 1. Aurora fNIRS 2021.9

### New features and improvements

- Display of Wings data
  - Manual and auto scale of plots
  - Low- and bandpass filtering of signals
  - Ability to switch of single plots
- Storage of Wings data
  - in .wings and .snirf format
  - Aligned with nirs signal to max. 1 ms offset, 2 ms jitter
- Offline review mode for Wings data

## 1. 2. Aurora fNIRS 2021.04

### New features and improvements

- Support of single device split Hyperscanning in Hyperscan application. Ability to choose two different (max. 8x8) configurations to run from one NSP2 device, support for short channels and accelerometer. Independent visualization of data, separate storage of data.
- LSL stream update: Inclusion of subject information (name, age etc.) in LSL stream metadata.
- Full accelerometer data in LSL stream.
- Full accelerometer data (100 Hz) in SNIRF file.
- Accelerometer samples (in LSL stream, *.acc, and SNIRF file) are corrected for drift of clock between NSP2 and accelerometer.
- More default montages & configurations included when Aurora is initially installed.

### Bug fixes and changes

- Better error messages/handling when write access to Documents folder is denied by Windows
- Validation of "Data root directory" and "Configuration directory" on settings page (i.e. errors when directory does not exist or Aurora can't write to it)
- Hyperscan data now saved in the *Hyperscan* folder instead of the *Data* folder.
- Better validation of custom channel names/labels

## 1. 3. Aurora fNIRS 2020.07

### New features and improvements

- Support of infant head models. NIRSite 2020.07 now allows the user to select, besides the already available adult MNI ICBM 152 adult head model, among three infant head models (from newborns to 8-month age). The same head models are also supported for visualization in Aurora 2020 fNIRS. The SD distances used for the computation of the Beer-Lambert's law are based on the distances calculated over the chosen head model.
- Aurora fNIRS now fully supports the new SNIRF file format. The feature does not need to be enabled, data will be automatically exported in the SNIRF format as well. More info on the file format can be found here.
- The signal optimization algorithm has been made significantly faster, without effecting the outcome. No action is needed to enable this feature. A continuous signal optimization routine has also been implemented. This allows a continuous update of the signal quality indicators while the setup of the optodes on the subject's head is being improved. A new signal quality indicator, the coefficient of variation, has also been introduced.

- An offline review mode has been implemented. This allows the user to review previous recordings. Review of signal optimization results is available only for data recorded with Aurora 2020.07, while the review of the data is available for earlier versions as well.
- Stability of the Hypersan app has been significantly improved, in particular, if the NIRSport 2 devices are connected to a PC via USB or USB hubs.
- Users are now warned if newer versions of Aurora fNIRS are available, enabling an easy upgrade. Upgrades to newer versions are however not enforced.
- A new text data file (_config.hdr), that summarizes the device and configuration settings is now saved together with the data.

### Bug fixes and changes

- The Security Tab under Application Settings was missing in the earlier version and has been reintroduced.
- When undocking tabs from Aurora fNIRS, it was not possible to bring the main Aurora fNIRS window in front of the undocked tabs.

# 2. Introduction to fNIRS

### *fNIRS Fundamentals*

Near-infrared spectroscopy (NIRS) employs low-energy optical radiation for measuring absorption changes in sub-surface tissues of living organisms, in order to infer local concentration changes of oxy- and de-oxy-hemoglobin as correlates of cellular activity. fNIRS (functional NIRS) refers to the NIRS measurement of cortical tissue to assess neural activation and its corresponding mental function.

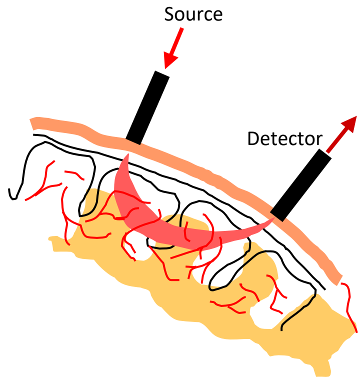



*Figure 2.1: Shape of average photon path between a source and detector on the cortex*

Each measurement channel is formed by an optical emitter ('source') and a receiver ('detector') placed on the tissue surface. Because of the scattering (light diffusing) properties of the tissue, a portion of the received light will travel through deep tissue structures, where it may interact with tissue chromophores such as oxygenated (HbO) and deoxygenated (HbR) hemoglobin. The penetration depth and shape of the probing volume is a complex function of the source-detector distance and other aspects of the measurement geometry and is also affected by the local tissue optical properties. As a general rule, measured fNIRS signals are estimated to originate from an area centered between the source and detector, and from a tissue depth no more than about half the source-detector distance (see Figure 2.1). Optical signals are heavily damped by biological tissue; the intensity will decrease several orders of magnitude over a few cm. The ideal source-detector distance is therefore a trade-off between achieving the greatest possible sensing depth while maintaining a sufficient signal quality (signal-to-noise ratio). Generally, a distance of 30-35 mm is considered optimal, and the sensing depth into the adult human head is on the order of 15-25 mm.

To achieve spatial mapping (or imaging) of brain activity, arrays of multiple source-detector pairs are placed over the area of interest. The NIRS imaging equipment developed by NIRx employs a unique measurement strategy in which EACH source channel forms a measurement channel with EACH detector channel. Therefore, a setup with X sources (S) and Y detectors (D) will always produce X*Y measurement channels. This is true irrespective of the source-detector arrangement or distances; however, only the channels that have S-D separation distances within a certain upper limit will produce signals having usable amplitudes and noise levels.

Because of this scheme, there is no restriction on how to place sources and detectors over the tissue. This affords a maximum of freedom and flexibility in realizing any desired experiment, but at the same time it demands that the user pay careful attention to experimental planning and take a few data-quality assurance steps during setup and also in the subsequent signal analysis.

To allow this degree of flexibility, NIRx imagers require operation prior to each experiment, during which the signal for each S-D combination is optimized. Depending on the amount of light reaching a given detector from a given source, the detector's light sensitivity is electronically adjusted to provide the optimal amount of signal amplification and therefore the best possible signal quality. This process is performed automatically during the calibration process initiated by the control software, as described in detail in section 6.4 of this manual.

# 3. Aurora 2021.9 Installation

## 3. 1. Recommended PC Configuration

Aurora fNIRS is compatible with Windows 8 & 10, as well as Macintosh, from macOS Mojave 10.12.6. Note that there is a separate installer for the mac application.

## 3. 2. Aurora Installation Steps

A. Obtain the Aurora 2021.9 fNIRS installer. This can be downloaded on the NIRx support site on the following page: [https://support.nirx.de/aurora/](https://support.nirx.de/aurora/)

B. Close all other applications before starting the installation. This will make it possible to update the relevant system files without having to reboot the computer.

C. Run the Aurora fNIRS installer by clicking on the Aurora_Install_1.4.exe file.

D. Confirm that the application is allowed to make changes to the device, if requested by Windows.

E. Read each dialog box as they appear, as in Figure 3.1, and click *Next/OK/Install* as requested. It is recommended to choose the default installation folder.

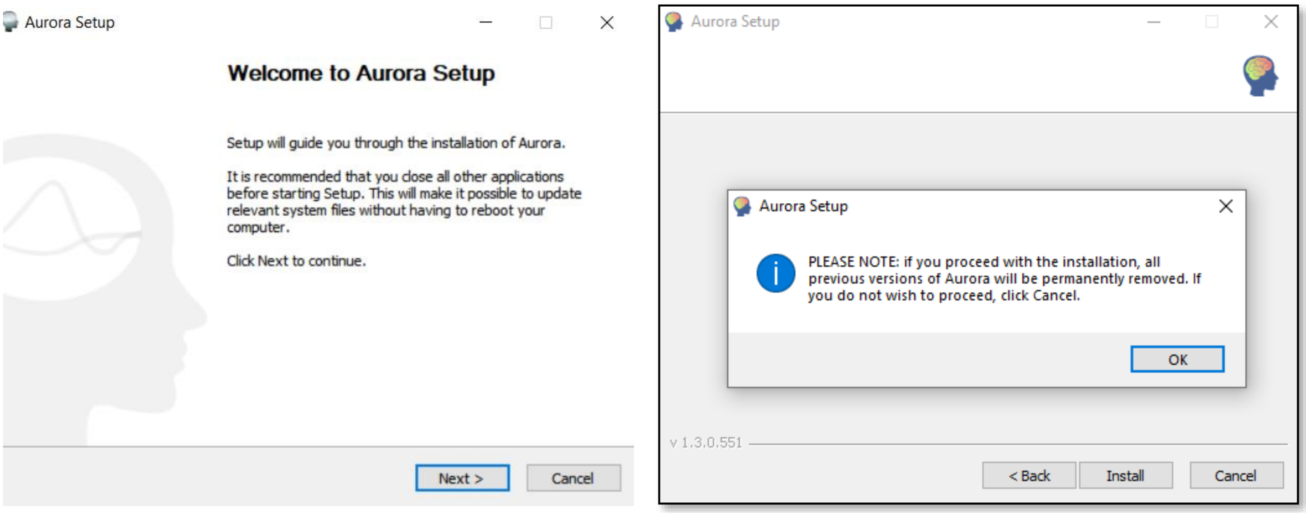



***Figure 3.1: Aurora installation dialog boxes***

F. Complete the installation by clicking the *Finish* button. Note: Please refer to the next section "Before Launching Aurora fNIRS 2021.9" before running the software.

G. Upon first running Aurora fNIRS, verify that the software is allowed full network access through the Windows Firewall. To do so, navigate *to Control Panel>Systems and Security>Windows Defender Firewall>Allowed Apps*. If aurora.exe does not have private or public access, select change settings, click the respective boxes, and click *OK*.

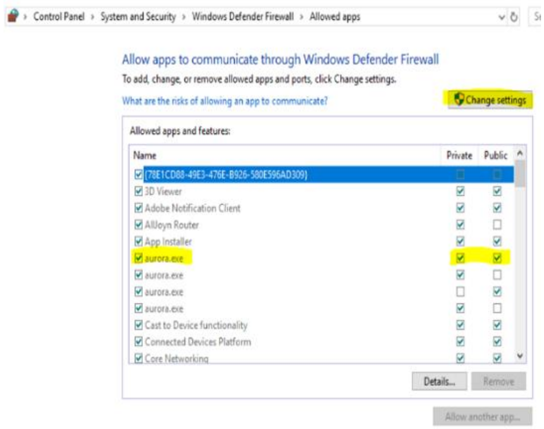



***Figure 3.2: Verify that Aurora is allowed through the Windows Firewall.***

# 4. Basic Device Operation with Aurora

***See the NIRSport2 Hardware Manual for more information on device hardware.***

The NIRSport2 device can connect to Aurora fNIRS either via USB or via Wi-Fi. Regardless of mode, ensure that the device is powered on by holding the power button for several seconds. A bright green light will indicate the device is turned on.

The device may be powered either by battery or from wall power. If the power cable is plugged in during data acquisition, the battery will be bypassed, and the device will be powered by wall power. If the user decides to run on battery power, ensure that there is enough charge for the full measurement. See the NIRSport2 Battery Sheet for more information on the capability of the NIRSport2 Battery.


*Figure 4.1: The rear panel of the NIRSport2; the power button is circled in red*

## 4. 1. USB Mode

Connect the NIRSport2 device to the PC running Aurora with the provided USB cable (USB end to computer, micro to device). When data is recorded via USB, it is recorded directly onto the data acquisition computer. When the device is connected via USB for the first time Windows will automatically download and install the necessary drivers. A working internet connection is needed at this time.

## 4. 2. Wifi Mode

When powered on the NIRSport2 device will generate a Wi-Fi network. This is indicated by the F2 LED on the device turning from blue to green. The network SSID and password are printed on the bottom of the device. See Figure 4.2, depicting a NIRSport2 Wi-Fi network that is available for selection from the Windows Network & Internet Settings Tab.

Note that the Wi-FI connection can drop during data recording. In Wi-Fi mode, the data is always recorded onboard the device, and continues even if the connection drops. The data can be retrieved in the process outlined in section 9. 2 of this manual.

If the user would like to increase the range and bolster the strength of the Wi-Fi connection, and intermediary access point may be used. The process for connecting with this access point is described in section 6. 3. 1. 1 of this manual.

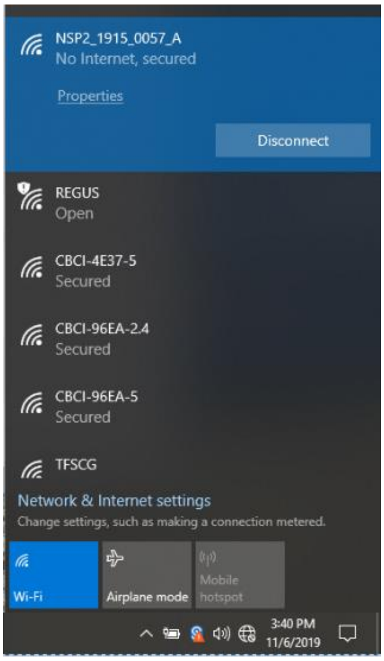



*Figure 4.2: The NIRSport2 network generated by a device (ID: 1915_0057_A) is connected to the data acquisition computer*

## 4. 3. Aurora Status Ribbon

The Aurora status ribbon on the bottom left corner of the screen gives the user up to date information on the status of the connected NIRSport2. From left to right, it tells the user the following about the device:

A. Wi-Fi range (if device is connected via Wi-FI)

B. The colors of the LEDs on the rear panel of the device

C. The battery level

D. The device ID

E. The temperature

F. The fan speed

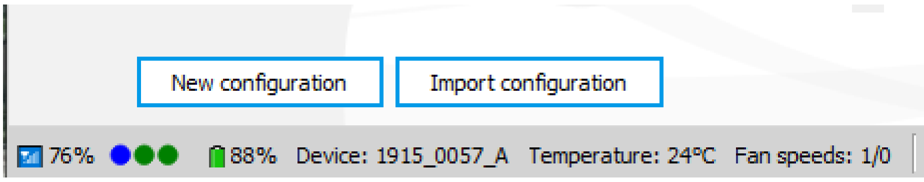



*Figure 4.3: The Aurora status ribbon indicates the status of the NIRSport2 that it is connected to*

# 5. Aurora Layout & Directories

## 5. 1. The Navigation Panes

The Aurora fNIRS 2021.9 navigation pane is structured in two main parts: (1) The main navigation pane, which guides the user through the main steps of the recording session and (2) The supporting navigation pane, which guides the user through different options or sub-steps for each step of the recording session:

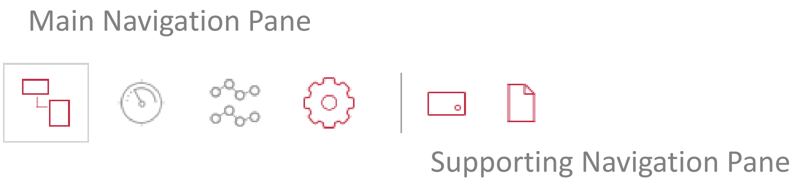
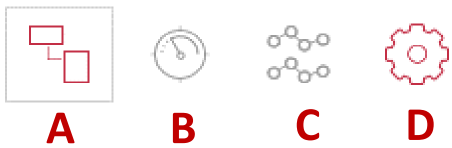



*Figure 5.1: (Above and below) the navigation panes in Aurora. Note: The options available in the supporting navigation pane are dependent on the step that is currently active within the main navigation pane.*

## 5. 2. The Experiment Workflow




A. **Setup**. This step consists of two sub-steps:
   a. Device Selection
   b. Configuration Selection
B. **Signal Optimization.** Before running a measurement, Aurora fNIRS runs a signal optimization routine that identifies the best source intensity for each channel and gives the user feedback on the quality of each channel in the probe layout.
C. **Record.** This step lets the user start and stop recording.
D. **Settings.** The main application settings can be accessed here.

## 5. 3. Aurora File Directories

When Aurora is installed, it creates a folder called *NIRx* in the documents folder. This folder contains the following folders and sub folders, as depicted in Figure 5.2:

A. *Configurations,* with the subfolder *Montages*. When a new configuration is created in Aurora, it is automatically saved here. When a new montage in NIRSite is created, the user should save it to this location in order to be utilized in Aurora (option to automatically save here is available by selecting *Export for Aurora fNIRS* in the *Save Montage* pop-up box in NIRSite).
B. *Data*. Data files from Aurora are automatically saved here.
C. *Logs*. The Aurora log.txt file is saved here. This file keeps a record of all functions implemented in Aurora and is automatically updated. Should an error occur related to Aurora/NIRSport2, the NIRx support team may request a copy of this file for troubleshooting.
D. *Hyperscan*. with the subfolders *Data*, *Templates* and *Logs*. The data, log and template files from the Hyperscan application are saved here.

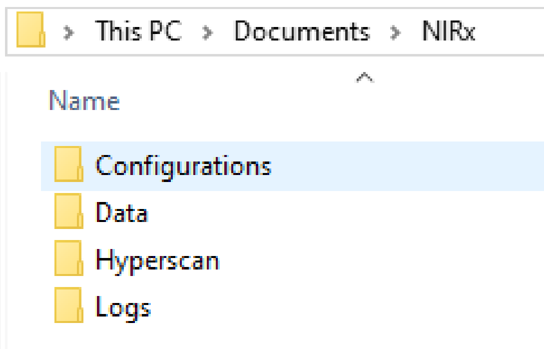



*Figure 5.2: The NIRx folder location and contents*

While the user may modify the location of the Configurations and Data folders, as described in section 6. 3. 1 of this manual, this is not recommended.

# 6. Running an Experiment

## 6. 1. Device Selection

When launching Aurora fNIRS, it will open to the *Setup > Device Selection* screen. This view will list all systems currently available for connection with Aurora. If the NIRSport2 device is not yet connected, it may be done now. Click the *Refresh List* button to find the device. Confirm the device by either clicking *Select Device* or double-clicking the device icon.

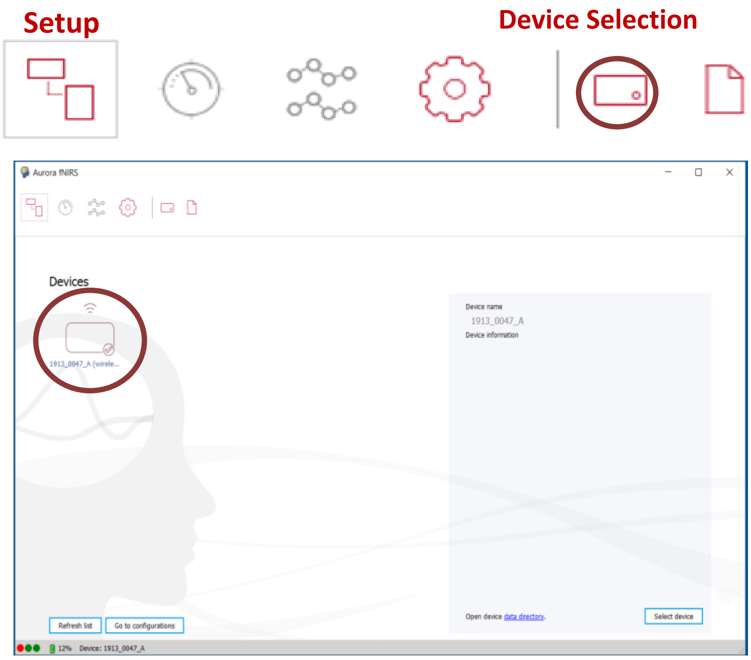



*Figure 6.1: The device selection page, recognizing an NSP2 via Wi-Fi*

Available devices will appear with their device ID and type of connection – either wireless or USB. Note that Aurora may automatically recognize the NIRSport2 device and skip the setup screen.

## 6. 2. Configuration Selection

Once the NIRSport2 device has been selected Aurora fNIRS will proceed to the next sub-step: Selecting the Configuration.


Aurora fNIRS allows for a quick and immediate setup of the hardware configuration, by allowing the user to select a configuration at the start of each experimental session. A configuration file contains information on the optode positions and the channels they form (i.e. the montage), as well as on the specific illumination pattern of the sources, the sampling rate, and other experimental parameters. By selecting a configuration, all information is automatically updated in Aurora fNIRS.

Importantly, it is not possible to start a recording session in Aurora fNIRS without selecting configuration.

The configuration selection window in Figure 6.2 shows available configurations on the left, and a configuration of choice selected on the right.

To select a configuration, the user can click on the *Select* button in the bottom right of the window and proceed with the experimental session.

Alternatively, configurations can be edited, copied or deleted, by clicking the respective buttons.

Existing configurations (located elsewhere on the PC) can also be imported into the configurations list by using the *Import Configuration* function in the bottom left corner of the configuration selection Page.

Unless altered, the default folder to store configurations is:

..\Documents\NIRx\Configurations.

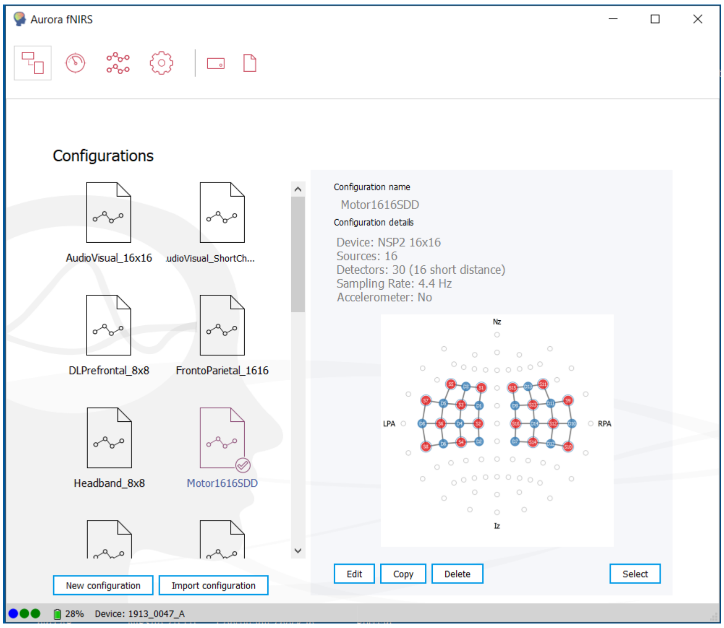



*Figure 6.2: The configuration selection window. Here, a configuration with a 16x16 motor montage with short channels is selected.*

When using Aurora fNIRS, the software will search for available configurations in the folder above.

The user has the option to change the default folder to store configurations. Change the default folder can be done at any time, by clicking the *Settings* button in the main navigation pane and changing the file path under *Configuration directory*, as described in section 6. 3. Note that configurations will not be copied from the previous folder to the newly defined folder.

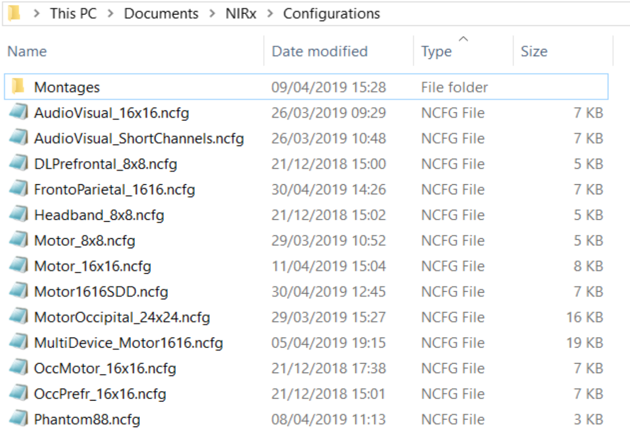



*Figure 6.3: Default location of configuration files. Configuration files are saved with the extension *.ncfg*

## 6. 2. 1. Creating a New Configuration

If Aurora fNIRS is unable to find an existing configuration, the user will be prompted to create a new configuration. Importantly, it is not possible to start a measurement in Aurora fNIRS without selecting a configuration. A montage is required to create a configuration (see section 6. 2. 2.). If a montage is available, the user can proceed to create a new configuration in Aurora fNIRS.

See steps for creating a new configuration below:

A. Click the *New Configuration* button in the bottom left corner of the configuration selection page (see Figure 6.4)
B. In the window that pops up, specify a name for the new configuration.
C. Select the type of device that will be used for this configuration.
D. **For short channel users:** declare how many short channel bundles are used.
E. **For accelerometer users:** enable the accelerometer by checking the box.
F. **For Borealis Users:** Check the box and supply the Borealis device serial number. See the NSP2 MRI Coupler guide for further instruction on imaging with Borealis.
G. Select a montage from the list of available montages (those available in the *Configuration> Montage* folder)
H. Click *OK* to save the Configuration.

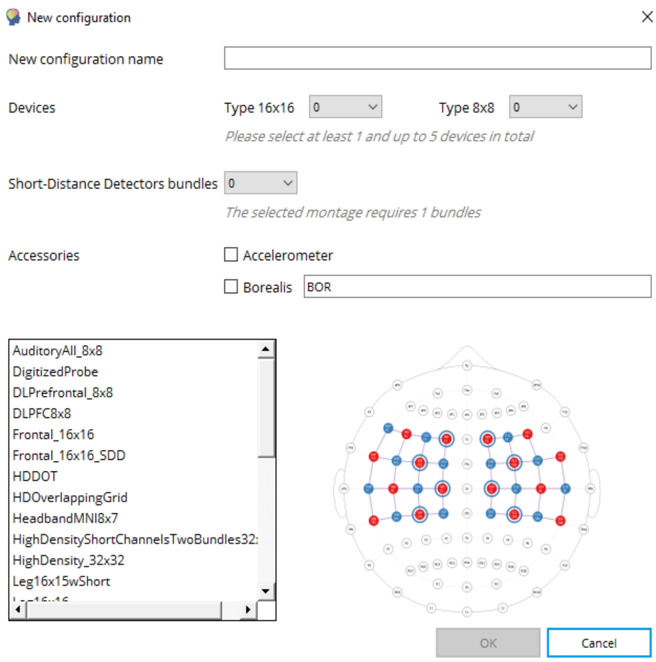



*Figure 6.4: The New configuration window.*

Multi-device recordings must be configured in the new configuration window using the *Device type* drop down menu. For more guidance on this feature, please see section 9. 5 of this manual.

If using short channel measurements, ensure that a montage with short channels is selected (depicted as rings around sources). Once such a montage is selected, declare the short channel bundle(s) in the *Short-Distance Detectors bundles* drop down menu. Failure to do so will result in an error dialog box.

The last detectors in a montage always host the short channel bundles. For example, with a 12x12 montage, detector 12 host short channel detectors 12-20. Note that a maximum of two short channel bundles per participant are allowed for.

If recording with short channels or accelerometers, they must be declared in the new configuration window. Failure to do so will result in data not being recorded properly, or at all, from these accessories.

### 6. 2. 2. Montages

To create a measurement configuration in Aurora fNIRS, it is necessary to have a probe layout, or montage, available. Montages make up for the most important information contained within a configuration file, as they specify the positions of optodes (sources and detectors) and channels.

Montages are created in NIRSite, and completely customizable to the user's interests. For more information on creating montages in NIRSite, please consult the corresponding Getting Started Guide. NIRSite, the NIRSite Getting Started Guide and sample montages can be downloaded from the NIRx help center on the following page: https://support.nirx.de/software/

In previous NIRx software (e.g. NIRStar) montages created with nirsLAB's Probe Setup Utility could also be used (by creating a probeInfo file). **Importantly, Aurora fNIRS only supports montages created in NIRSite.**

**Warning:** If measuring with short channels, do not forget to include short channels in the montage in NIRSite or accidentally select a montage (or configuration) that doesn't include short channels during the experiment.

Once a montage has been created, it should be placed in the *Montages* folder, which is located in the *Configurations* folder: *...\Documents\NIRx\Configurations\Montages.* Importantly, the folder must contain the probeInfo.mat file of the montage to be recognized in Aurora. Note that if the *Configuration* directory is changed, the *Montages* folder will be relocated too.

### 6. 2. 3. Editing a Configuration

A number of recording features are available by editing them. To access them, select a configuration from the available list on the configuration selection page, and click *Edit* in the bottom right corner. The features are listed in three different tabs and outlined in the following three subsection sections. To save any edits made in these windows to the open configuration, click the *Save* button in the top right-hand corner of the screen.

#### 6. 2. 3. 1. Basic Parameters – Data Visualization Features

In the *Basic parameters* tab, the user can adjust parameters of the configuration that contribute to making recorded data more insightful during data acquisition. See Figure 6.5 for illustration of this tab.

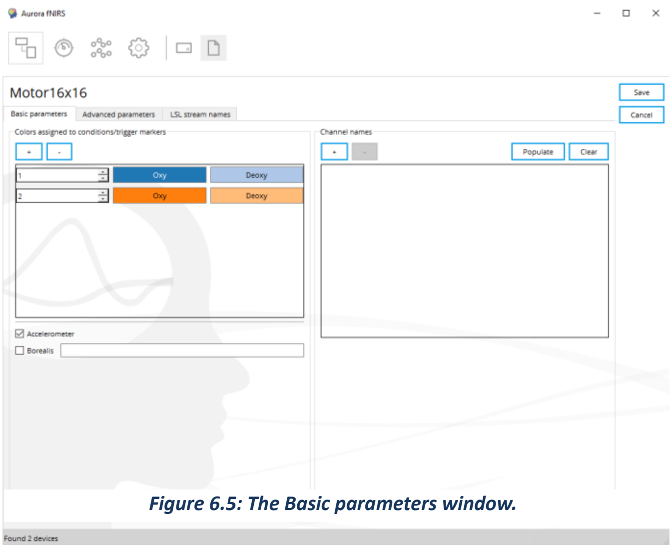



*Figure 6.5: The Basic parameters window.*

In the *Colors assigned to condition/trigger markers* section, the user can add or remove trigger markers, respectively by clicking the (+) or (-) button. For every marker added, the specific trigger marker number /mask can be set, as well as the display colors for the block averages of (online computed) changes in oxygenated hemoglobin and deoxygenated hemoglobin. The same color will be applied to the display of the corresponding trigger line in the line plots.

Important: please note that only trigger markers that are configured here will be displayed in the line plots and used for online block averages. Trigger markers that are not configured here will be recorded, but not displayed real time.

In the *Channel names* section, the user can assign names to specific measurement channels. Channels can be either added or removed manually, by clicking the (+) or (-) button, or the *Populate* button can be clicked, which immediately adds all available channels. The *Clear* button removes all channels from the list. Naming the channels can be particularly useful when working with short channels, as they can be all assigned the same identifier.

Selecting the *Accelerometer* feature creates an additional Accelerometer tab in the recording window, which enables the user to calibrate the accelerometer. This *must* be selected in order to view accelerometer data during data recording.

Borealis users must check the box and supply the Borealis device serial number in the *Borealis* field. See the NSP2 MRI Coupler guide for further instruction on imaging with Borealis.

#### 6. 2. 3. 2. Advanced Parameters – Illumination Pattern and Sampling Rate

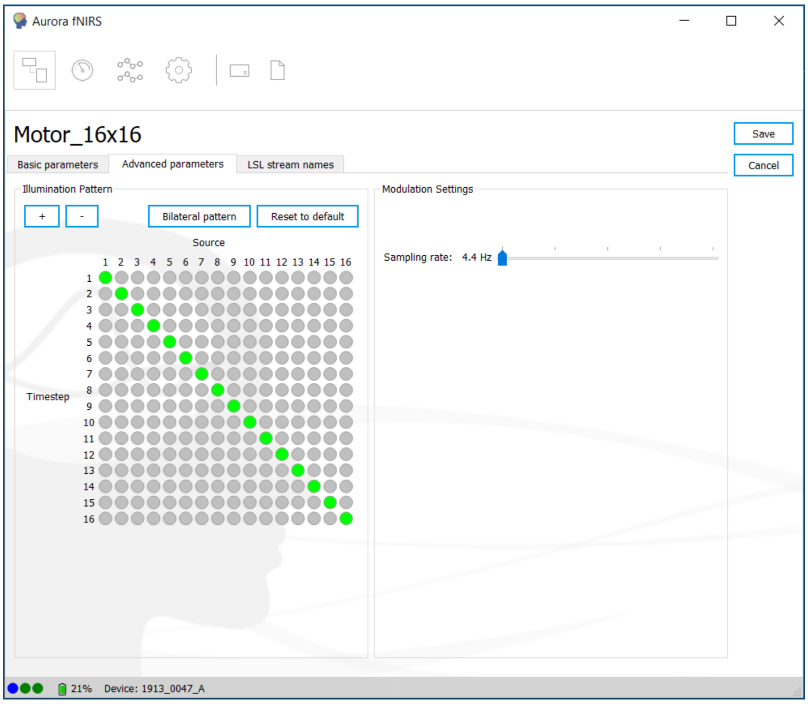



*Figure 6.6: The Advanced parameters window.*

In the *Advanced parameters* window, the user can alter the *Illumination Pattern* and *Sampling rate*. See Figure 6.6 for illustration of this window.

NIRx systems are time multiplexed, meaning that not all channels are recorded from at the same time. This is achieved by turning on sources at different times – the sequence in which the sources turn on is known as the illumination pattern. In Figure 6.6, each column represents a source (in consecutive order, from left to right, starting with source 1) and each row represents a sequential step in the scan.

Under *Illumination Pattern*, individual elements of the illumination pattern row *x* column *y* matrix may be toggled by clicking them with the mouse. If an element is highlighted (i.e. green), this indicates that this source (*x*) is activated at step *y*. The default pattern is a square matrix with the main diagonal highlighted, i.e. all sources light up in consecutive order. In a bilateral pattern, two sources are on at the same time, with a double diagonal pattern. For most experimental purposes, it is not advised to change the illumination pattern, as having multiple sources on at the same time can lead to cross-talk between channels. Nonetheless, in configurations with a high number of sources, it may be advantageous, in order to reduce calibration time and increase the sampling frequency. In this is situation, care must be taken to ensure that any sources that are on at the same time are as far apart on the head as possible.

Under *Modulation Settings*, the sampling rate of the configuration can be modified. The sampling rate is the inverse of how long it takes for each source to fire in the illumination pattern, and thus how frequently each channel is recorded from. By adjusting the slider, the sampling rate can be increased or decreased.

The duration of each LED (or source) pulse is determined by the number of steps and the chosen sampling rate. The relationship for determining this value is:

$$\frac{1}{(sampling\ rate)x(\#\ of\ steps)} = Duration\ of\ LED\ pulse$$

While there may be a natural inclination to increase the sampling frequency of the fNIRS measurement, this is not necessarily recommended. Doing so will decrease the LED pulse duration, and thus lower the amount of light seen at the detector. This may lower the overall signal quality seen in a subject, particularly in cases where a montage is over thicker parts of the skull, and in participants with thick hair. Furthermore, the frequency of the hemodynamic response is quite slow, and most analyses look at frequency content below 1 Hz.

Overall, when adjusting the sampling rate, the user should consider the experimental paradigm, subject population, montage and intended data analysis (e.g. offline vs. online, GLM vs. functional connectivity). When running pilot studies, the user may adjust the sampling rate to determine optimal settings. Importantly, after piloting a study, during the experimental phase (data collection) an identical configuration (with a constant sampling rate) should be used between subjects.

#### 6. 2. 3. 3. LSL Stream Names

Lab Streaming Layer (LSL) is available for use with Aurora by default. The *LSL stream names* tab allows the user to set up wireless communication with other software for real time data streaming and receiving triggers (or time stamps). The user can specify the names for the *Data out* and *Trigger in for* LSL streaming. The default names are Aurora and Trigger, respectively. These names must be exactly the same in Aurora and the third-party software in order for them to connect; any discrepancies (such as an uncapitalized letter) will result in a lack of connection. This is a common source of error with LSL usage.

Aurora 2021.9 is able to stream both raw data and hemoglobin values via LSL. For more information on this feature, please see section 9. 1 of this guide.

By clicking the *Test connection* button, the user can test whether Aurora fNIRS can receive triggers for the specified LSL parameter. If a trigger is received that is not an integer from 0-255, the *FallBack trigger number* will appear in the data. The default value for this occurrence is 12. For more information on triggering via LSL, please see section 6. 6. 1 of this guide.

### 6. 2. 4. Selecting a Configuration

To select a configuration measurement, simply double click the configuration on the selection page, or click the configuration once, then press *Select* the in bottom right corner of the screen.

## 6. 3. Application Settings

The main application settings can be modified here. There are two windows included under settings, and their features are detailed in the following three sections. Once selected, the settings remain, even after the application has been closed, until they are manually changed by the user.


### 6. 3. 1. Preferences

The *Preference* tab allows the users to set default data and configurations root directory. Additional options on this tab include:

*Plotting colors*: The user may choose colors of their preference for hemoglobin and raw data plots, as well as how the optodes are visualized.

*Detector type*: This drop-down menu sets the dark-noise thresholds for the type of detector used with the system.

*Power on device if connected via USB*: If connected via USB, the device will automatically switch on when selected in the Device selection window.

*Enable preview mode*: If enabled, this option adds a preview button to data recording pane. The Preview button allows a preview scan without saving any data, for test measurements, inspection of the data quality, and display optimization. The test scan may be stopped by clicking the *Stop* button. “Preview mode” alert will be displayed at the bottom of the screen during a preview scan.

**Caution:** Data measured during the preview cannot be saved! Data will only be saved from the instant of clicking the *Start Record* button during an ongoing preview.

*Ask for confirmation before closing the application:* To prevent accidental closing of Aurora, enabling this button will prompt a warning.

*Interrupt calibration in case of critical dark noise:* This option prompts a warning if critical level of dark noise is detected during a signal optimization routine and allows the user to stop the optimization and take measures to eliminate dark noise.

*Access point device connect to:* See more information on setting up an access point with Aurora in the next section.

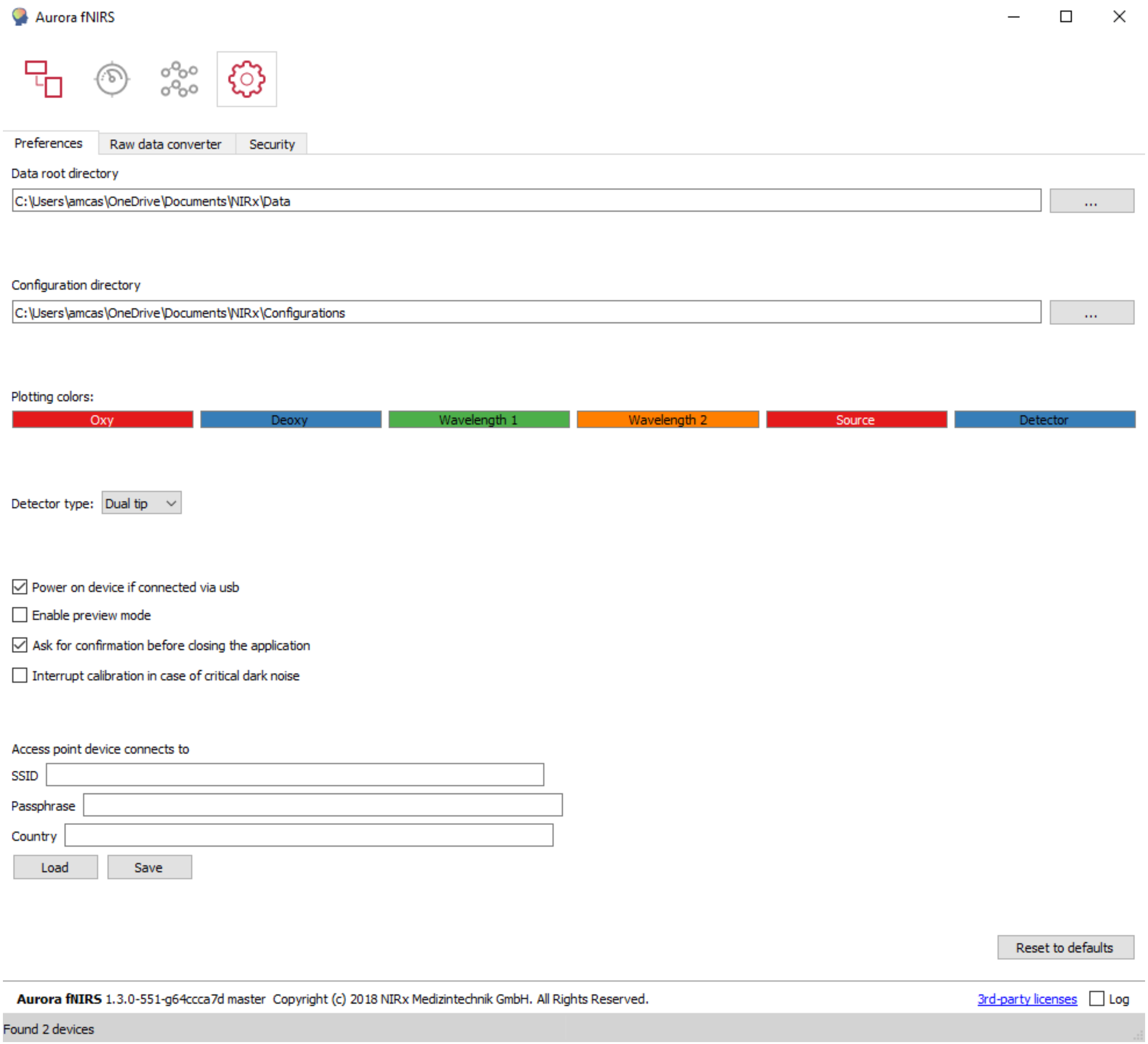



*Figure 6.7: The Preferences window*

### 6. 3. 1. 1. Connecting with an Access Point

As mentioned in section 4. 2, the range and stability of the Wi-Fi connection of the device may be improved by connecting the device to an access point. Furthermore, an access point allows the user to connect multiple devices to the data acquisition computer at once, which allows for wireless Hyperscanning.

The access point can manifest in a number of ways, such as the hotspot on a smart phone or a travel router (NIRx does have a recommended model; contact support@nirx.net for more information). The NIRSport2 can connect to a configurable access point in the 2.4 and 5 GHz Bands.

Warning: NIRx strongly recommends choosing an access point that can be turned off; once configured, the NIRSport2 will always connect to an access point when the access point is on! Furthermore, for data security, we recommend only using access points without internet access, such as a travel router or a mobile hotspot without data.

The steps for connecting the NIRSport2 to an access point are as follows:

A. Before attempting to set the NIRSport2 to connect to a different network, the computer must be connected to the NIRSport2 via its own Wi-Fi network (SSID and password are on the bottom of the device).
B. In Aurora fNIRS, under *Settings,* scroll down to access point settings and enter the SSID and password of the network of the access point that will be used (as in figure 6.7).
C. Enter the country of use. **Note that it is very important this information be correct,** because of colliding standards in different countries.
D. Press Save. This will prompt a device reboot. Once rebooted, the NIRSport2 device will connect to the network just configured, if available.
E. Connect the PC running Aurora fNIRS to the access point network. The device will now automatically appear under on the device selection page, anytime it is power on, its connection is stable, and the access point network is turned on.

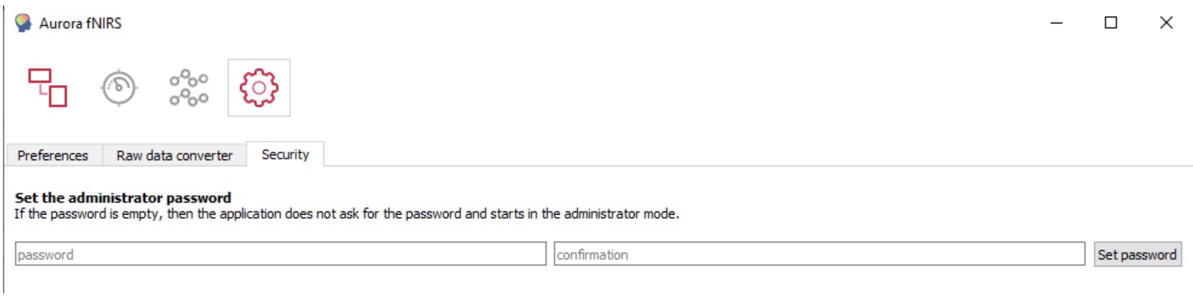
### 6. 3. 2. Security

In the security tab, the user can implement 'administrator mode'. Aurora distinguishes two types of user roles: Regular User and Administrator. The Administrator role is protected after defining a password. Once the Administrator role has been protected, Regular Users will not be able to edit/create new configurations and/or change settings. This can be advantageous if there are many people involved in data collection, and the admin does not want any configuration settings to be changed for the experiment.

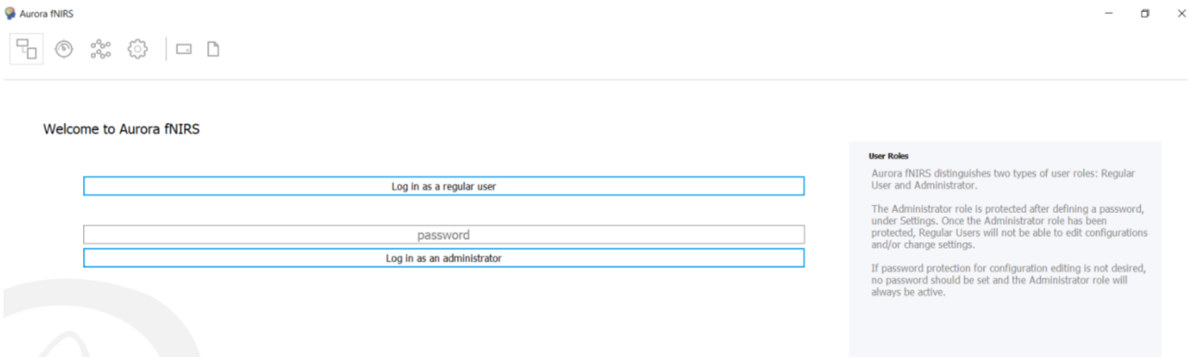
To set an administrator role, provide a password, click *Set password* and close Aurora. Any subsequent launch of Aurora will prompt to 'Log in as a regular user' or 'Log in as an administrator'.

To remove password protection, log in as an administrator and click *Set password*, keeping the password and confirmation tabs empty.

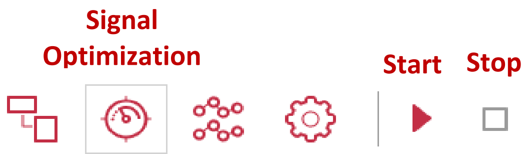
*Figure 6.8: (Below) The Security tab, where administrator mode is activated.*




*(Below) When administrator mode is enabled, this is the screen that appears upon launching Aurora*




## 6. 4. Signal Optimization




Once a configuration has been selected, the user can proceed to the signal optimization step. This step will optimize signal quality before data recording.

Before starting the signal optimization, ensure that the NIRScap is correctly placed on the subject, with all sources and detectors positioned as defined in the selected configuration, and configured for optimal optical contact with the skin. All sources and detector bundles should be connected to the NIRSport2 device. For instructions on how to place the NIRScap, please go to the NIRx help center and download the NIRScap getting started guide from the following page: https://support.nirx.de/documentation/

Ensure that the correct detector type is selected under the *Settings > Preferences* tab (single tip SiPD, dual tip SiPD, or APD). As seen in Figure 6.7, this can be selected in the drop-down menu next to *Detector type* in the middle of the page. The detector type affects the threshold set for dark noise measurements. Choosing incorrect type may lead to misinterpretation of dark noise results.

If all equipment is correctly set-up, the user may start the signal optimization routine by clicking the start button. The main interface of Aurora fNIRS will be disabled during the signal optimization routine. It is advisable that the subject remains still during this time. It is possible to stop the calibration at any point by selecting the stop button.

During the signal optimization routine, as depicted in Figure 6.9, the NIRSport2 increases the brightness of each source in a stepwise manner until optimal signal amplitude for each channel is obtained. The progress bar in the bottom of the screen is updated as the level at each detector with a certain source brightness is read. Currently, with a stable connection to the device, the process takes about 60 seconds for a standard 16x16 configuration.

This routine is equitable to the calibration procedure in NIRStar, though not quite the same, as detectors of devices

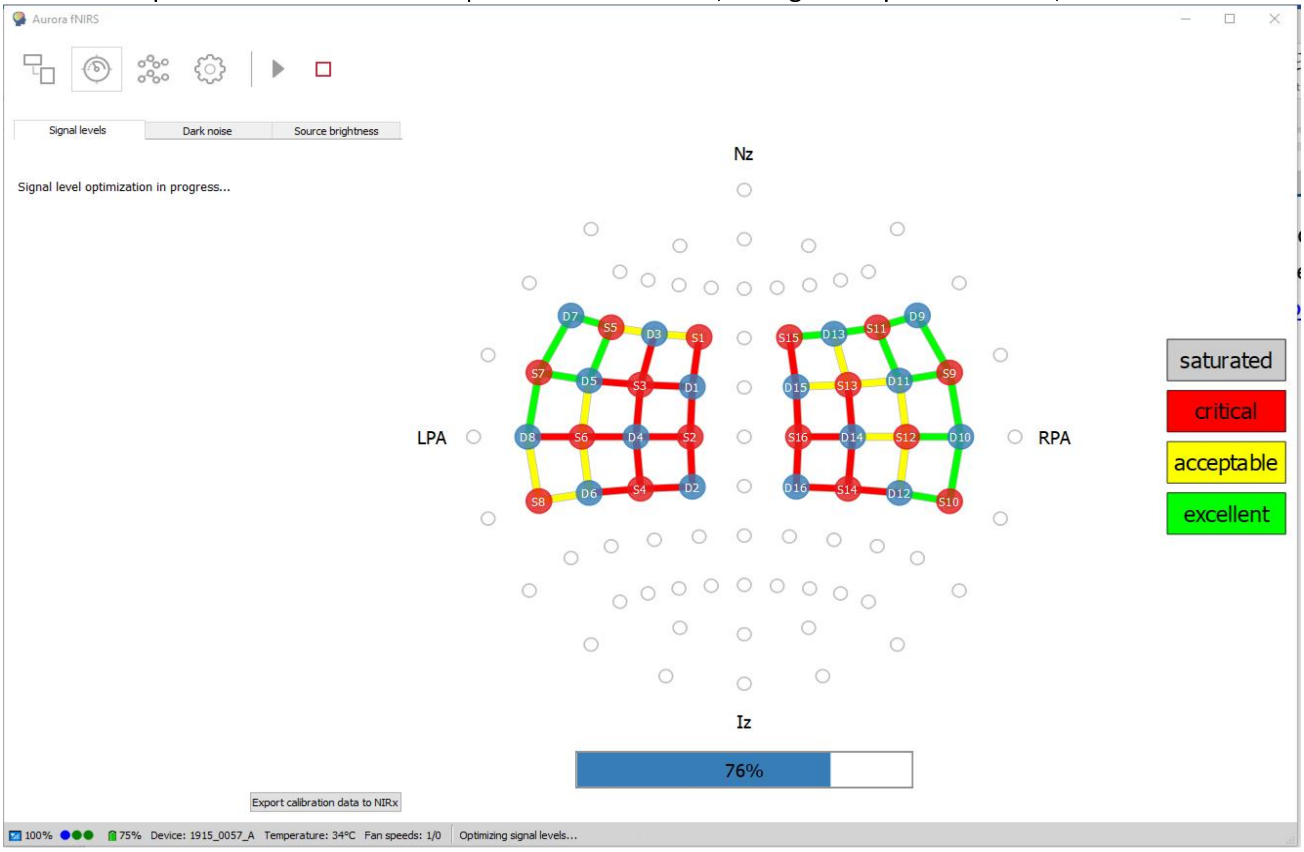



*Figure 6.9: The signal optimization window during the signal optimization routine. Montage orientation denoted by Nasion (Nz), Inion (Iz), Right & Left Preauricular (RPA & LPA) points.*

that run with NIRStar have variable gains – the NIRSport2 does not have variable gains, but rather variable source brightness (mW).

Furthermore, unlike in NIRStar, the signal quality reported is not a composite index. The four metrics presented – signal level, dark noise, source brightness and coefficient of variation- are related, but presented independent of one another. The user should check with signal level, dark noise and coefficient of variation results before proceeding with data collection. The implications of these metrics are discussed in the sections below.

### 6. 4. 1. Signal Level

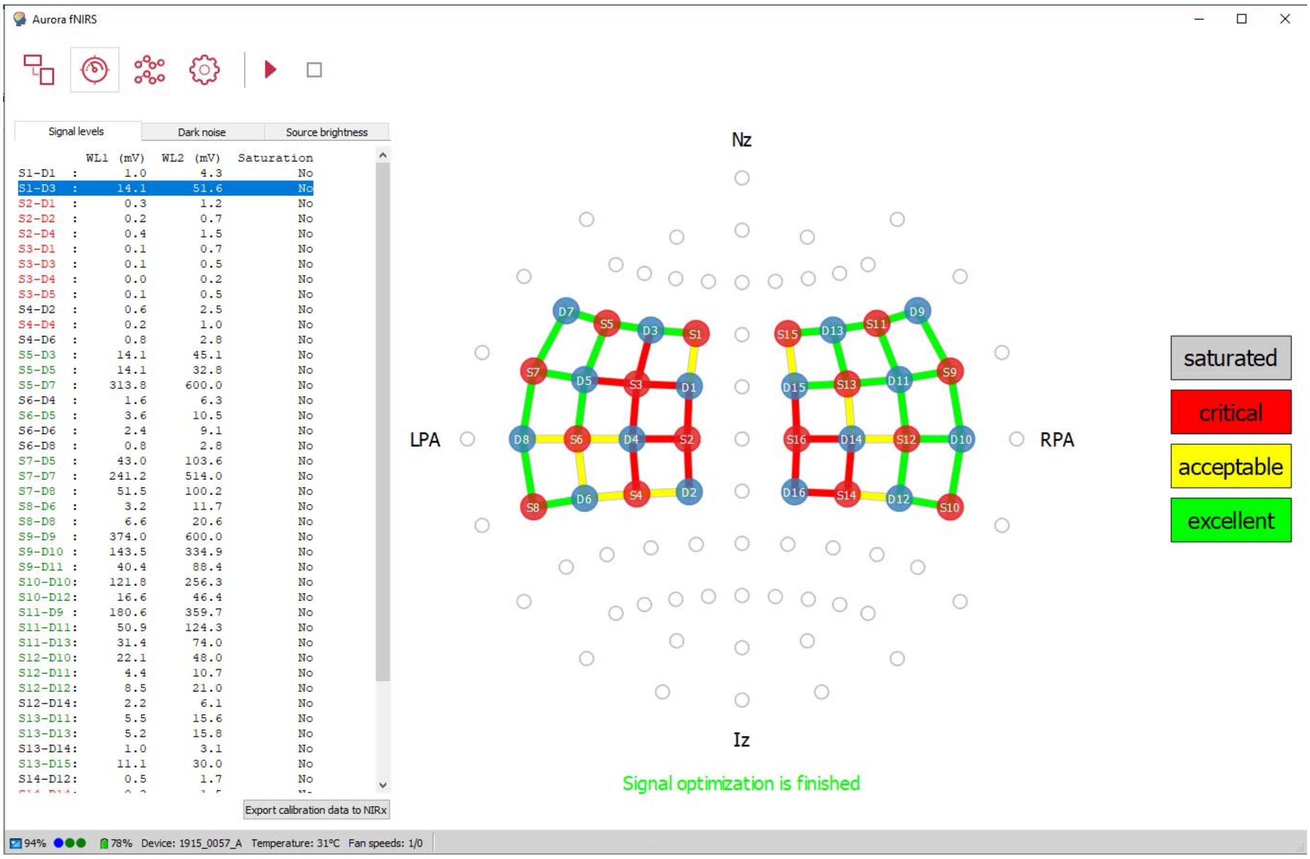



*Figure 6.10: Signal level results for each channel are accessible by clicking on the signal levels tab in the top left corner. Values (in mV) for each wavelength are noted.*

Signal level is the raw voltage reading at the detector. The signal level at a detector reflects how well light passes through tissue, from a certain source to the detector. If this average value is high enough, the signal level of the channel formed by this source and detector will be marked as excellent (green) or acceptable (yellow); if it is too low, it will be marked as critical (red).

| | |
|---|---|
| **critical** | **< 0.5 mV** |
| **acceptable** | **> 0.5mV and < 3mV** |
| **excellent** | **> 3 mV** |
| **saturated** | **Power at first harmonic of demodulated signal / Power at fundamental frequency > 5%** |

In regards to signal level thresholds and their implications, it is OK to proceed to recording with some yellow channels, but not advisable to proceed with red channels, as these will likely need to be excluded in later analysis for having high coefficient of variation (C.V.), or noise. Yellow and red channels may be due to poor optode-skin contact, presence of hair, improper cable placement, or improper source-detector arrangement i.e., optode arrangement not reflecting the chosen montage. Please consult with the Troubleshooting Signal Quality Guide for more guidance, which can be found on the NIRx help center from the following page: [https://support.nirx.de/documentation/](https://support.nirx.de/documentation/)

While the signal level is an objective measure assessing signal quality, it is important to visually assess signals. One can do so using the preview mode in the data recording step. To access this mode, the preview feature must first be enabled in device settings (see section 6. 3. 1 of this manual). After signal optimization, click on the *Data Recording* (  ) button. Then, click on the *Preview* (  ) button, which will give access to all Aurora data viewing windows without saving the data. The *Stacked line plot* and *Line plot* views will be most useful in assessing data quality.

In a high quality, unfiltered, cortical fNIRS signal, heart rate is clearly visible (a local peak with a frequency ~1 Hz), variations in HbO concentrations are ~5x greater than HbR, and the average values of HbO and HBR are negatively correlated. In general, fNIRS channels with excellent (green) signal level will look something like the left graph on Figure 6.11; in this graph, heart rate is visible, variation in HbO (red) is much larger than HbR (blue) and the two signals are somewhat negatively correlated. Clearly, a physiologically relevant signal is being recorded. In contrast, fNIRS channels with critical (red) signal level will look something like the bottom graph on Figure 6.11; this graph is clearly dominated by electrical noise rather than a physiological signal of interest, as shown by its rapid variations that are nearly perfectly equal and opposite.

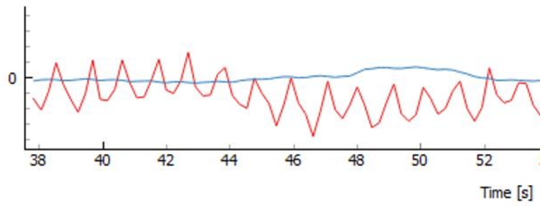
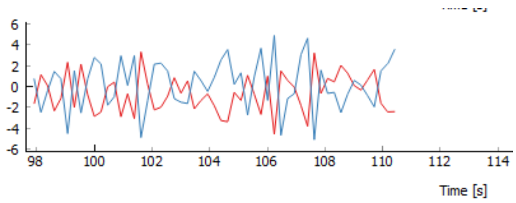



*Figure 6.11: (Top) A high quality fNIRS channel reading. (Bottom) A noisy fNIRS signal. These graphs were obtained from the Line plot of the data recording page.*



## 6. 4. 2. Dark Noise

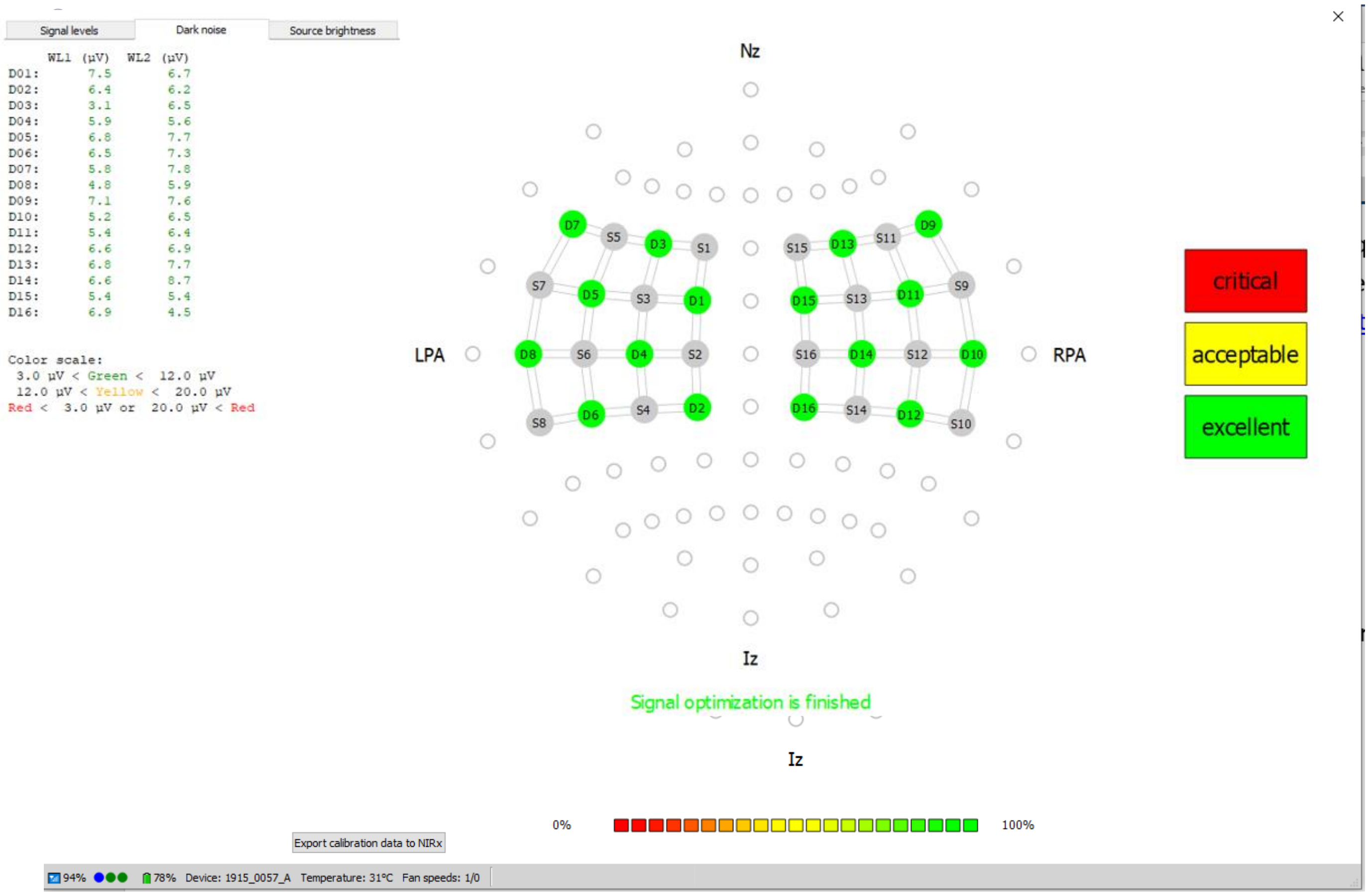



*Figure 6.12: Dark noise results. In addition to a topographic color scale on the right, values (in µV) for each wavelength are denoted for each detector on the left.*

The dark noise measure characterizes a detector's sensitivity, by evaluating the amplitude and variance of its reading when no input (i.e., zero incident light intensity) is present. High dark-noise levels (labeled as 'Critical') may be due to ambient light interference. High dark noise interference can impact a measurement.

Looking at the Dark noise tab as in Figure 6.12Figure 6.12, one can determine the dark noise value for each detector. There is also a topographic color scale for further illustration.

If critical dark noise is detected in any detectors, it is advisable to not only verify the optical contact of this detector, but also to remove any ambient light interference from the detector – a NIRx overcap or a common opaque shower cap can do so.

## 6. 4. 3. Source Brightness

The source brightness level is automatically adjusted according to the intensity of the received light - which in turn is dependent on factors such as skin-optode contact, density and color of hair, skin color etc. Source brightness is reported as a percentage of the total source power. One would expect to see greater source brightness in areas with more hair, thicker skull, etc. It is not a clearly actionable metric, and the user should refer to signal level and coefficient of variation readings over it.

### 6. 4. 4. The Coefficient of Variation (C.V.)

The coefficient of variation is calculated as the ratio between the standard deviation of the raw signal, for each wavelength, and its mean value and expressed in percentage. A higher standard deviation is an indicator of poor signal quality: the lower the C.V., the better the signal quality. The C.V. is calculated over 1.5 seconds of data (or at least 10 frames, depending on the frequency), acquired once the optimal brightness for each LED has been determined (at the end of the signal optimization). Because the C.V. is computed on unfiltered data, a SNR of around 1% is typical for physiological setups, owing to light-signal fluctuations associated with the cardiac pulsation. The C.V. is calculated for each channel, for both wavelengths.

A color scale is used to represent whether a calculated C.V. is acceptable or not. The C.V. thresholds have been determined based on experience and the ability of detecting the cardiac rhythm in a signal depending on the level of noise.

| | |
|---|---|
| **critical** | **> 7.5%** |
| **acceptable** | **> 2.5% and < 7.5%** |
| **excellent** | **< 2.5%** |

Signal level and coefficient of variation are closely related, though in some cases a channel may be marked as having good or acceptable C.V. while having critical signal level; this is particularly true of users with APD detector, which perform better than SiPD detectors with noisy signal. Ideally, one should ensure that both signal level and C.V. are at least at acceptable levels before moving on to recording; if pressed for time, if a channel has acceptable or excellent C.V. but critical signal level, the data will likely still contain useful information after being preprocessed, and the user may proceed with data collection.

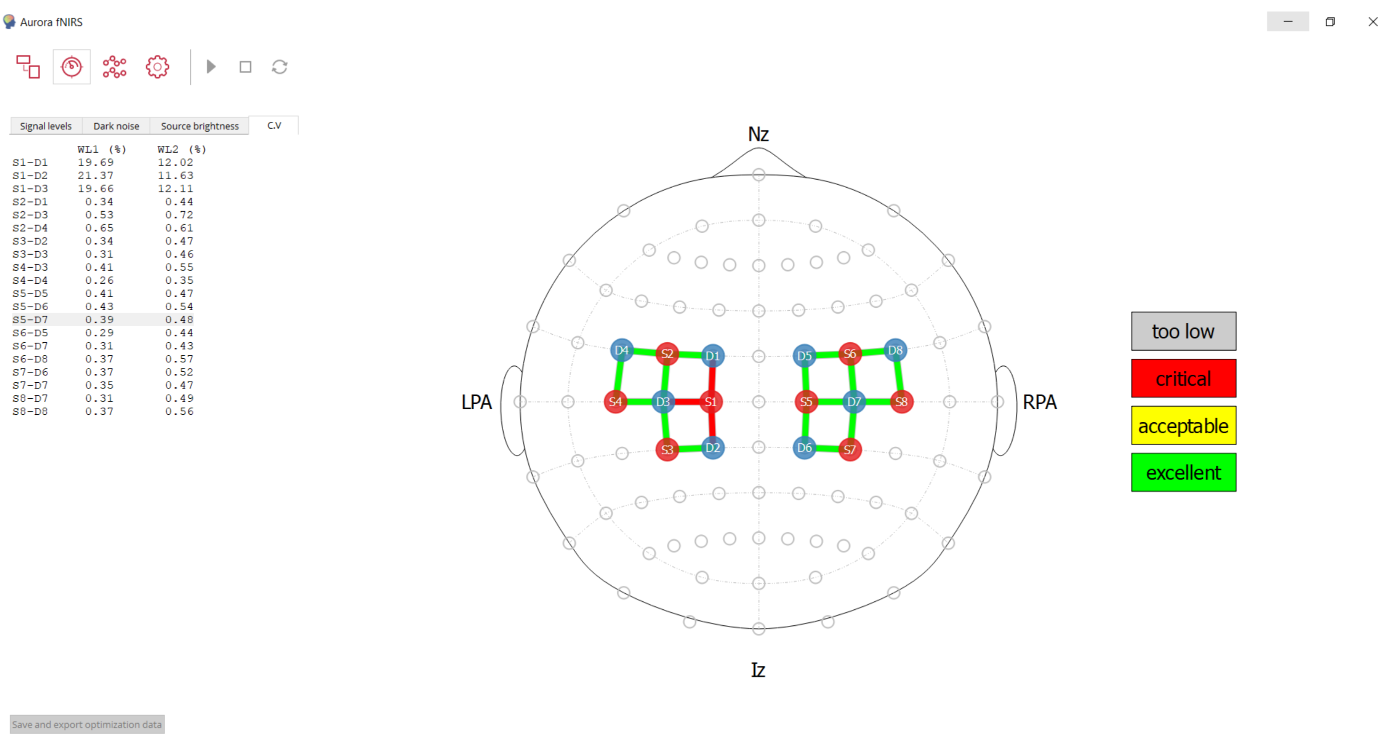



***Figure 6.13***– The coefficient of variation (C.V.) displayed after signal optimization. The exact values are plotted for each WL in the table, while the topoplot indicates each channel's C.V. through a color scale.

### 6. 4. 5. Signal Optimization with Short Channels

If short distance measures are setup, the short distance detectors appear as rings around their respective sources. Similar to the standard detectors, the short detector rings display signal amplitudes for the channels they form as well as dark noise values.

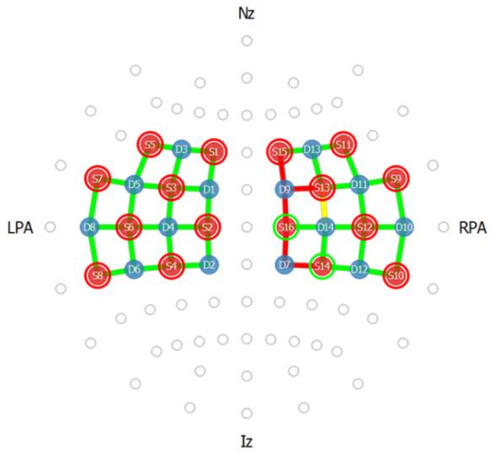



*Figure 6.14: Signal optimization with short Channels*

### 6. 4. 6. Continuous signal optimization

Aurora a mode with continuous update of the signal quality indicators. To enable this mode, the signal optimization has to be complete at least once.

The main goal of the continuous update mode is to allow the user to see in real time the update in signal quality while working on improving the optode setup on the subject's head. This is particularly useful in the case the signal optimization routine yielded bad signal quality for a few channels only.

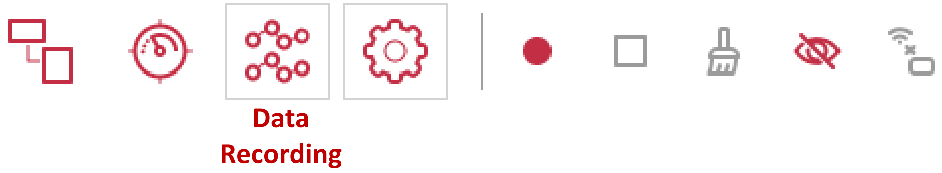
While keeping the source brightness at the levels as calculated during the previously completed signal optimization routine, Aurora fNIRS will keep recalculating the signal levels and the C.V. for all channels. **Please note that the dark noise values will not be recalculated**.


After completing the signal optimization routine, if there are channels with not acceptable or not excellent signal quality, you may enter the continuous update mode by clicking the *Start continuous update of signal amplitudes* button. The signal levels and C.V. indicators will now be continuously updated, with every new data sample. The time elapsed will also be displayed.

**Before proceeding the recording, please stop the continuous update mode by clicking the stop button.**

## 6. 5. Data Recording




Once the Signal Optimization routine is completed, proceed to the recording step by clicking the *Data Recording* ( ) button. The user may start to record data by clicking the *Record* ( ) button. Start of recording is also indicated by the F1 LED turning from blue to green. The recording may be stopped at any time by clicking the *Stop* ( ) button.

The supporting navigation pane to the data recording step is seen in Figure 6.15. Depending on the device settings, buttons A and G may or may not be available. The buttons are as follows:

A. Preview Mode. Visualize data without saving it. Must be enabled; see section 6. 3. 1.
B. Start Record.
C. Stop Record.
D. Clear Page.
E. Normalize Baseline (recompute the Beer Lamberts law with a new moving baseline).
F. Hide/View viewing features bar on the bottom of the screen.
G. Disconnect from the device via Wi-Fi connection.

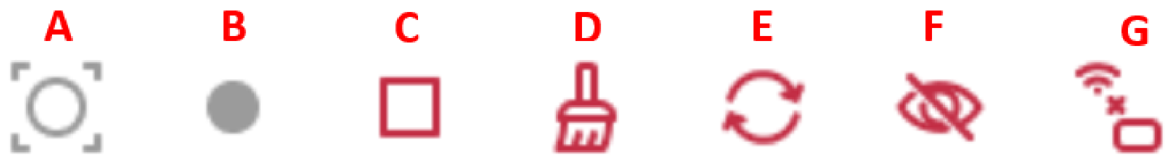



*Figure 6.15: The Supporting navigation pane to the data recording step*

During a recording, Aurora fNIRS has multiple display options for the data. Each has customizable viewing features on the bottom of the window, with their own set of features, as in Figure 6.16. The display options are illustrated in the following subsections. Please note that all tabs are detachable and may be moved to a second screen for better visualization or for concurrent viewing. Tabs are detached by double-clicking their header.

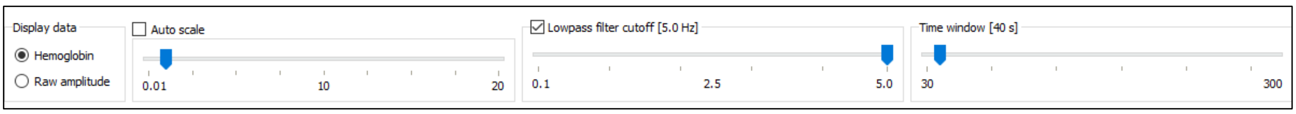



*Figure 6.16: Viewing feature options on the bottom of the line plot tab.*

Note that in each recording view, each channel is comprised of a source (**S#**) and a Detector (**D#**). The names of these channels may be changed to more intuitive conventions; see section 6. 3. 1. 1 of this manual to do so.

In every display option (aside from the raw amplitude option in the *Line plot*), data is displayed as changes in the concentration of HbO and HbR (µmol/L) over time. The unchangeable parameters for their calculation from raw voltage to concentrations changes, using the Modified-Beer Lambert Law, can be seen in section 9. 1. Any changes to the visualization of the data does not change how it is stored; data is always saved in its raw voltage (V) form in the *.wl1 and *.wl2 files.

### 6. 5. 1. Stacked Line Plot

The stacked line plot visualizes all channels in a single plot across time. Specific channels may be un-displayed by double-clicking on their respective labels on the left side of the screen. Viewing features in this plot include zooming, scaling, and setting the time window of the measurement. Changes in HbO Concentration are traced in red; HbR, blue. The x-axis is in units of µmol/L; however, the scale of these units is not displayed in this window. To see the scale of this variable, go to the *Line plot* view. **Error! Reference source not found.**

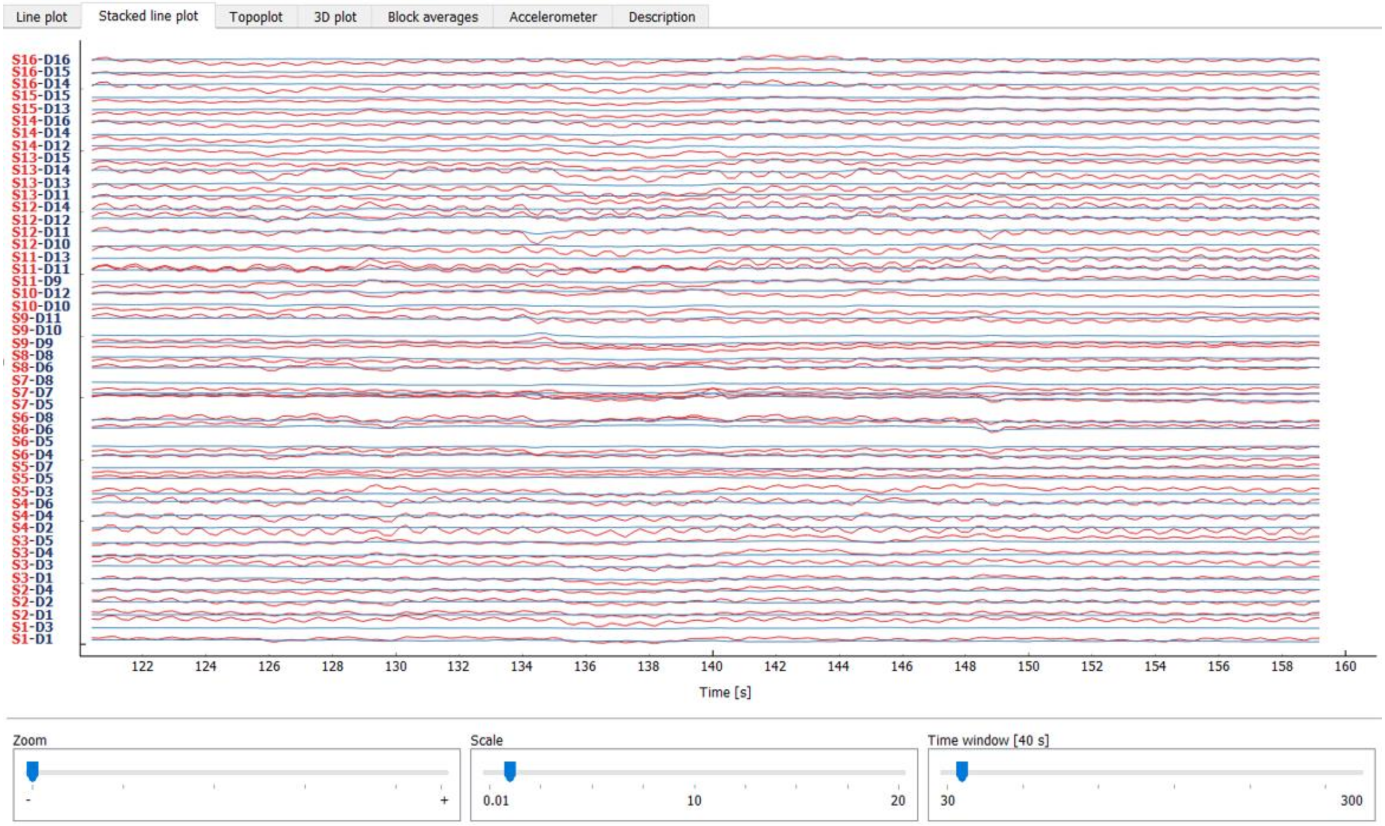



*Figure 6.17: Stacked line plot data viewing window*

### 6. 5. 2. Line Plot

The *Line plot* visualizes each channel reading in its own window across time. This tab is the only window where a low-pass filter can be applied (the filter applied here will be applied in all viewing windows). If the user double-clicks on a specific source-detector pair, the view will switch to the channel location on the *Topoplot*.

This is the only view where data can be displayed as either changes in hemoglobin concentration (µmol/L) or raw amplitude (mV). For hemoglobin, change in HbO concentrations are traced in red; HbO, blue. For raw voltage, the voltage reading from the 850 nm wavelength is displayed in orange; 760 nm, green.

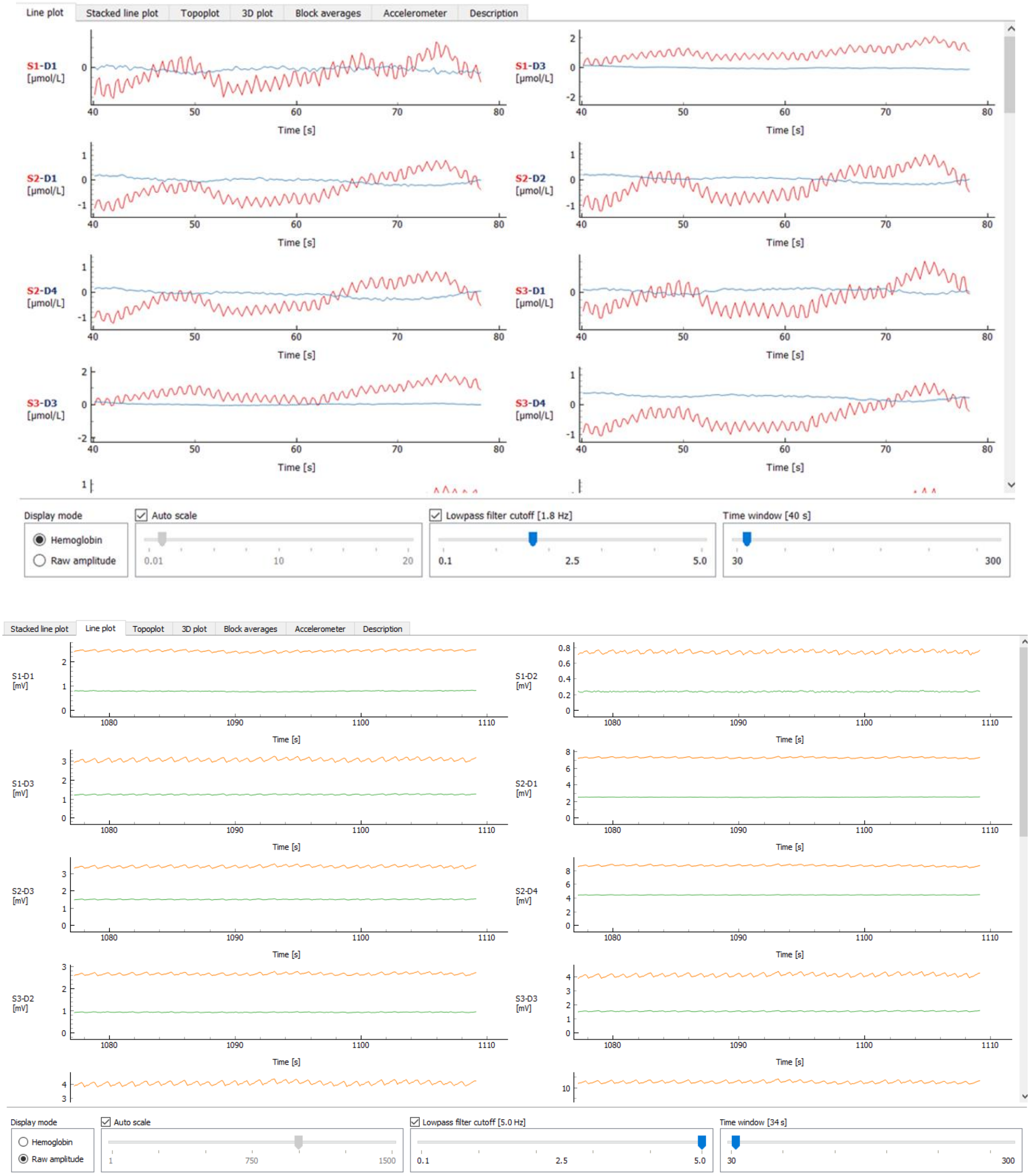



*Figure 6.18 : Line plot data viewing window, (top) displaying changes in hemoglobin concentrations, (bottom) displaying changes in raw voltage*

### 6. 5. 3. Topoplot

The Topoplot offers a 2D mapping of channel data for a chosen chromophore, HbO or HbR. Adjusting the sensitivity of the plot changes the range of concentration values plotted. Hovering over a channel will show the *Line plot* window of that channel, and double clicking it will switch the view to the *Line plot* tab.

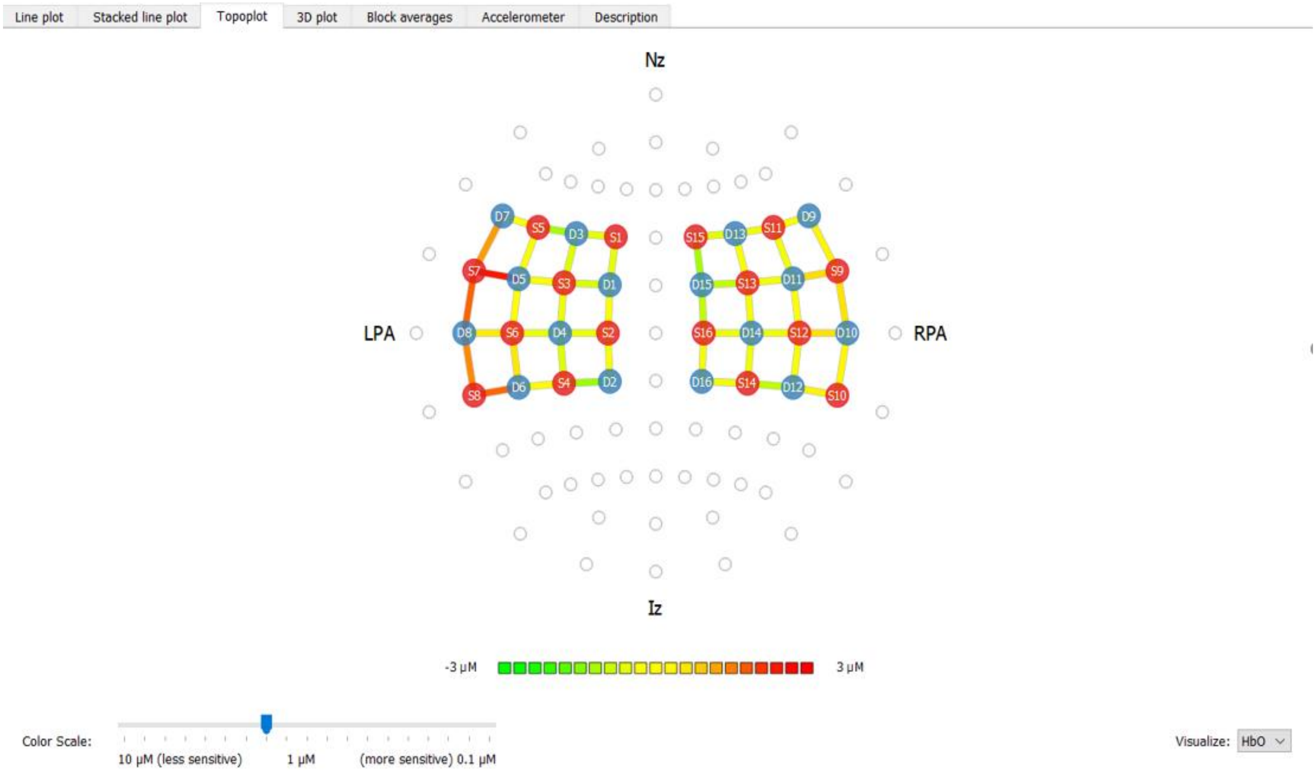



*Figure 6.19: Topoplot viewing window*

### 6. 5. 4. 3D Plot

The 3D plot offers a 3D mapping of channel data for a chosen chromophore, HbO or HbR, on a head model. Channels are represented as diamond shapes on the scalp, as seen in figure 6.20. As in the *Topoplot*, adjusting the sensitivity of the plot changes the range of concentration values plotted. The view of the plot may be changed by clicking and dragging in the plot or selecting a set angle from the view option buttons in the bottom right corner of the page. Furthermore, the user may decide whether or not to plot the location of the optodes and to make the brain visible or invisible using the options in the bottom left corner of the page.

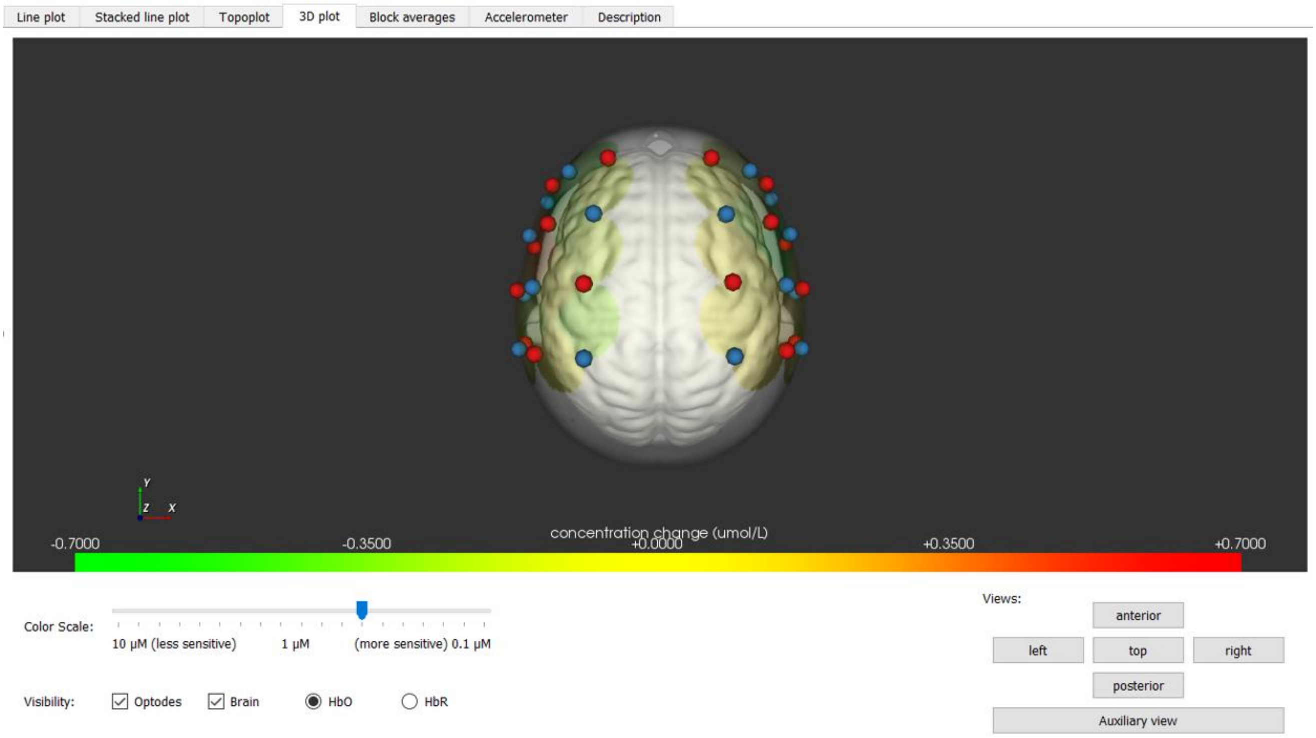



*Figure 6.20: 3D plot viewing window*

If the user hovers over a channel on the plot, the *Line plot* of the channel will appear in a popup, as seen in figure below.

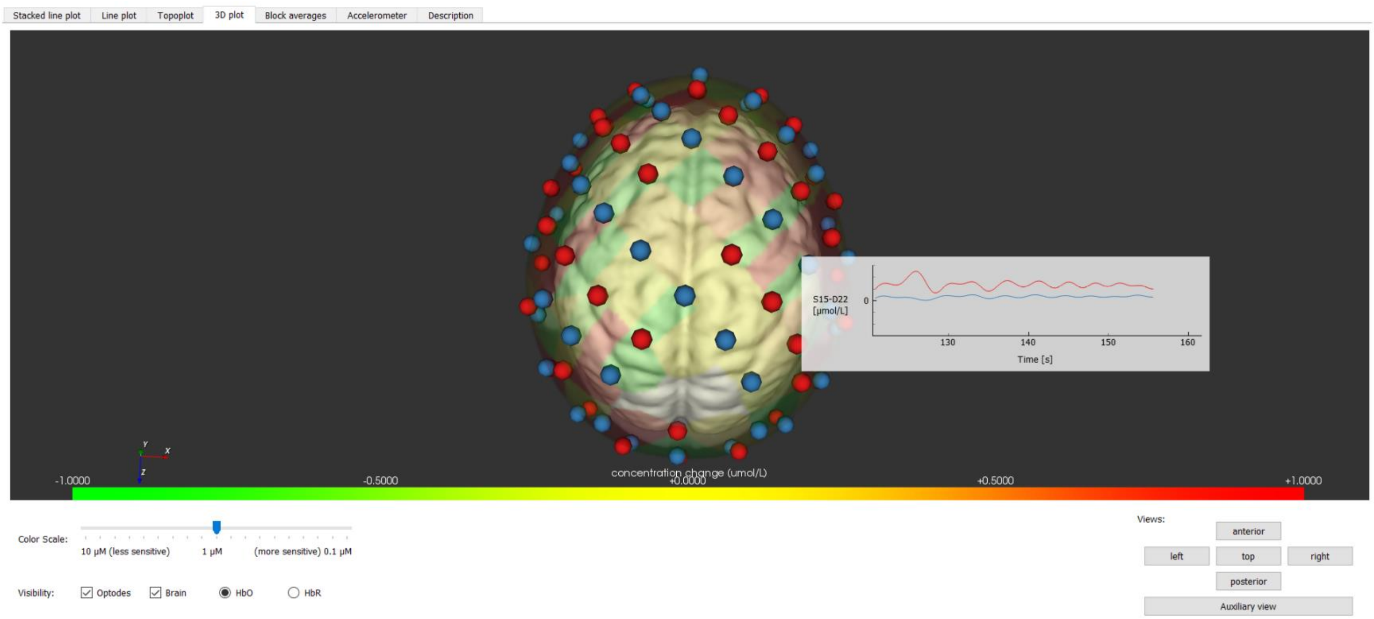



*Figure 6.21: 3D plot viewing window*

Aurora 2021.9 allows the user to have up to 4 independent, auxiliary *3D plots*, as depicted in Figure 6.22. This allows the user to view the recording of each chromophore, HbO and HbR, in a topographic context, in multiple locations across the head, at the same time. The additional views can be launched by clicking the *Auxiliary view* button located in the bottom right hand corner of the main *3D plot* window.

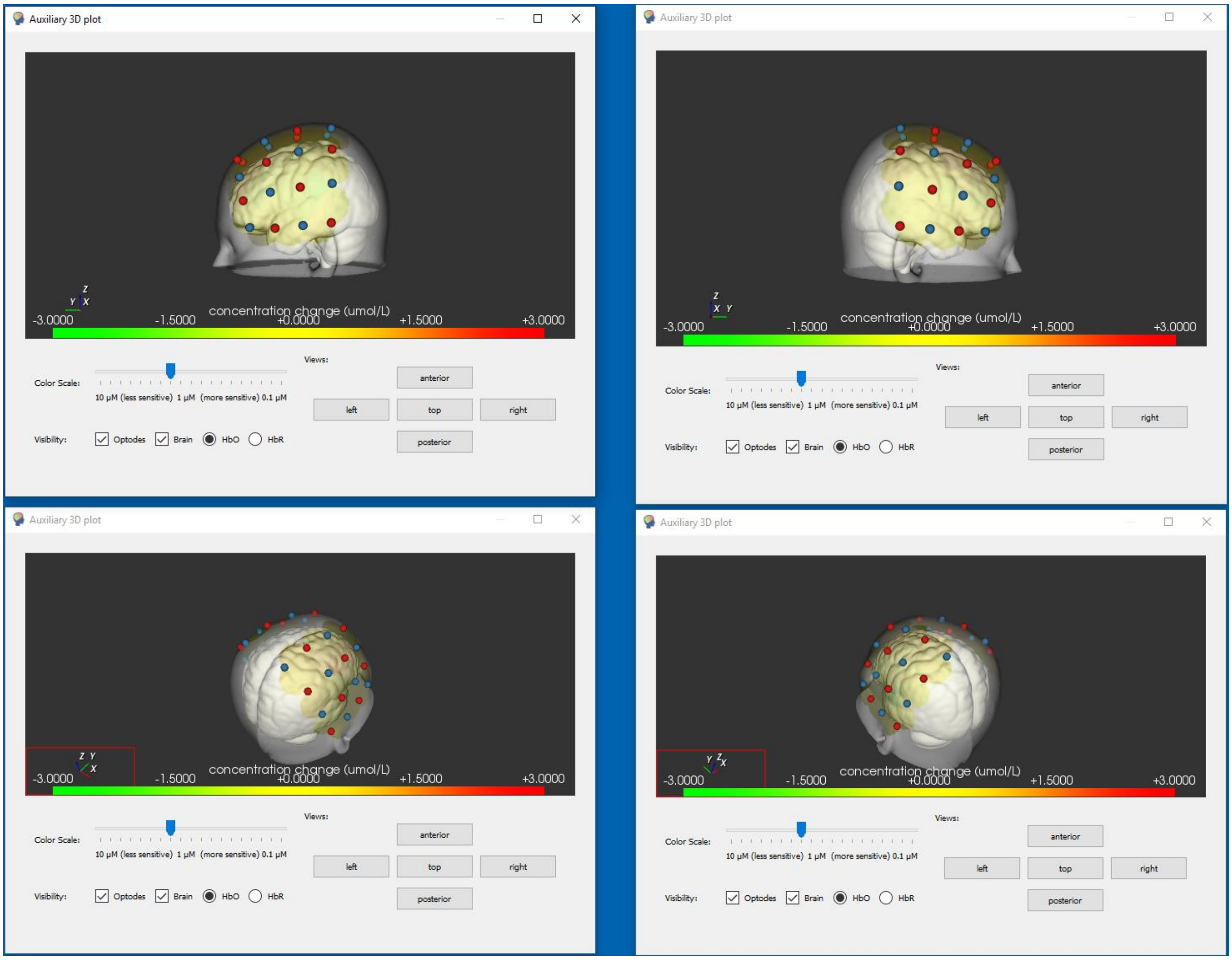



***Figure 6.22: 3D plot viewing window – four auxiliary views***

### 6. 5. 5. Block Averages

This data viewing tab allows users to view topologically arranged channel displays, averaged in epochs relative to trigger events. These average epochs are also known as block averages. Responses to multiple trigger types (conditions) can be displayed at the same time, as they arrive in real time. The responses are mapped onto the Standard EEG 10-10 coordinate system for reference, as seen in Figure 6.23.

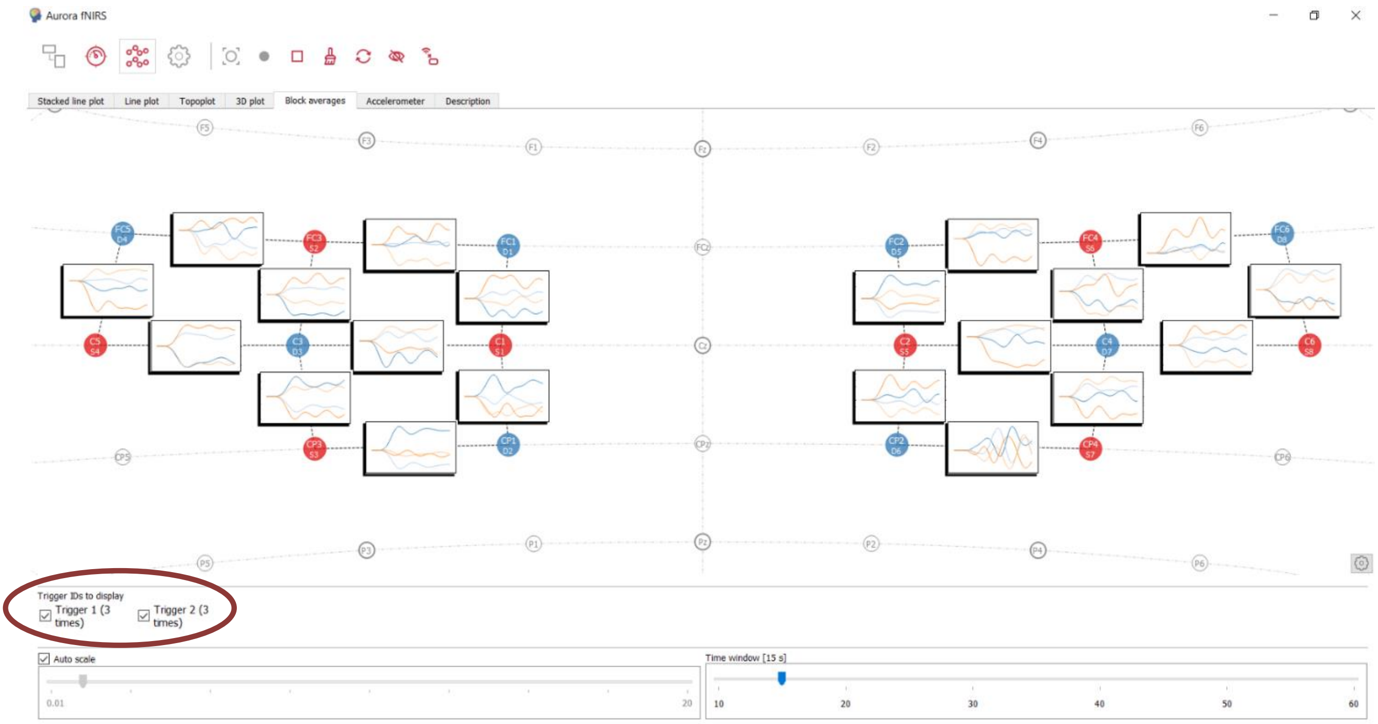



*Figure 6.23: Block averages viewing window – trigger counter highlighted*

The number of traces plotted in each block average window depends on the number of distinct triggers received, and how many triggers are selected under the *Trigger IDs to display* feature in the bottom left corner of the screen. Furthermore, the number of epochs averaged together for each trigger is indicated here as well. This number will automatically update as triggers are received, as will the plots.

For each trigger plotted, the bold trace indicates changes in HbO concentration (µmol/L), while the lighter trace indicates changes in HbR concentration (µmol/L). The colors of these plots can be changed, as denoted in section 6. 2. 3 of this manual.

Options for changing the scale and the time window are offered at the bottom of the screen. Note that the time window scale refers to the time of the block average after the trigger appears and can be anywhere from 10-60s. If an individual block average is hovered over, a pop-up of that block average in a larger scale will appear, as in Figure 6.24.

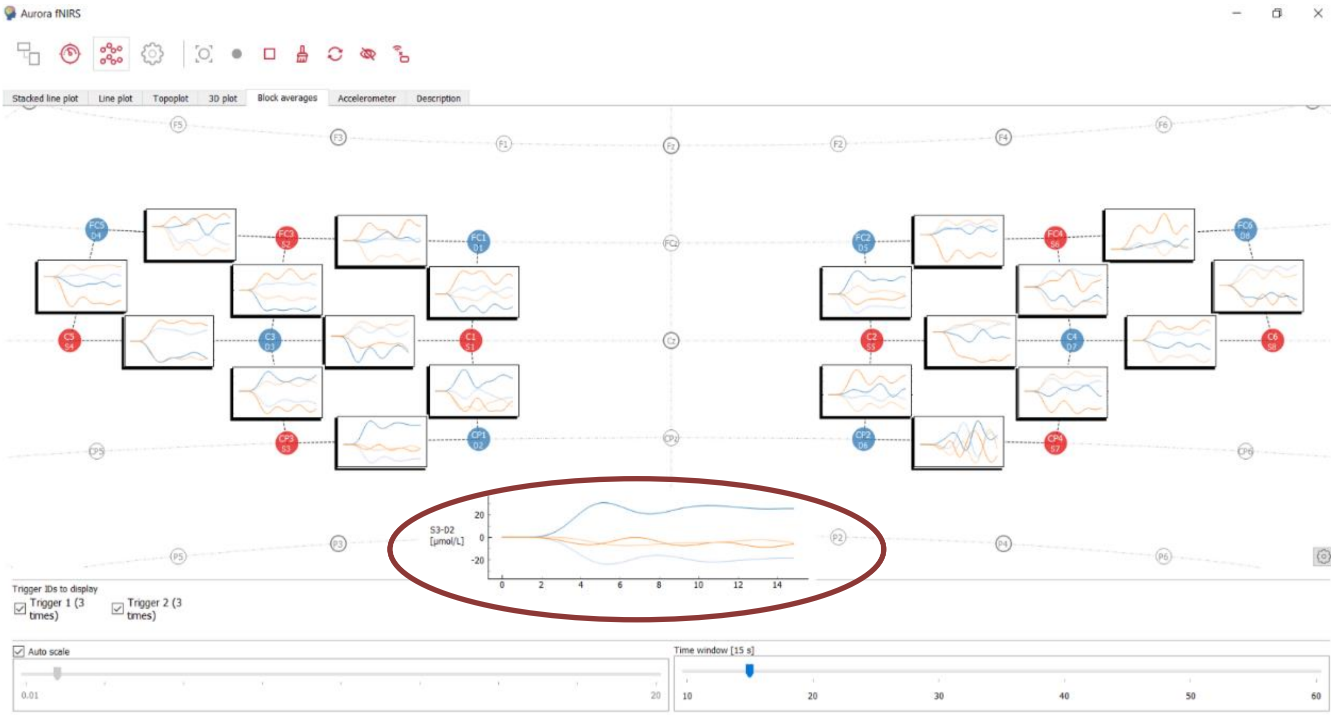


*Figure 6.24: Block averages viewing window. The Line plot of the channel between S3-D2 is highlighted by hovering the mouse over the block average.*

## 6. 5. 6. Accelerometer

The NIRSport2 features integration of up to 2 accelerometers, one per detector bundle. In Aurora, the Accelerometer feature must be enabled in the configuration in order to record from this sensor, as denoted in sections 6. 2. 1 and 6. 2. 3. When the accelerometer is properly declared in the configuration, an additional Accelerometer tab will appear in the recording window, as in **Error! Reference source not found.**.

While the accelerometer can technically be placed anywhere on the body, it will typically be placed on the head, and thus movement of the device is reflected as rotations and spins of a human brain model. The view of this head can be set with the view options in the bottom right corner of the tab.

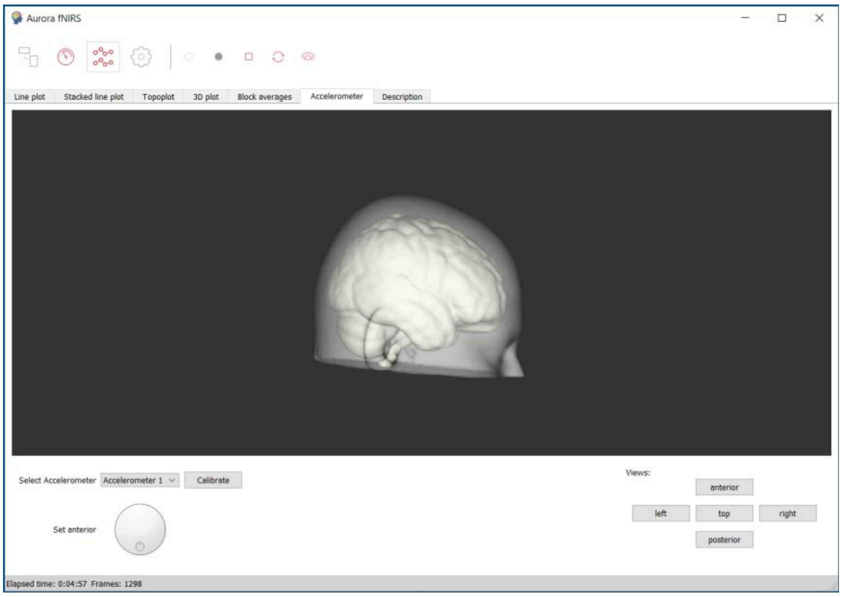
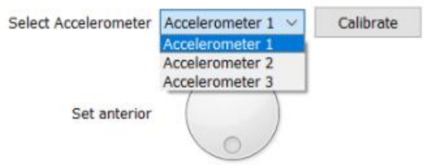


*Figure 6.25: Accelerometer viewing window*

The accelerometer can discern where it is in space on its own (X, Y, Z coordinates) and thus record accelerometry data without any kind of calibration. However, in order to properly view movement of the participants head in the *Accelerometer* tab, the software needs to know where the accelerometer is placed in relation to the human head (posterior or anterior, left or right). To do so, have the participant be relatively still. Click on the *Anterior* button under *Views*. Then, rotate the *Set Anterior* wheel, until the head model sits level on the screen. The process may need to be repeated once or twice more before getting stable, accurate viewing.

As multiple accelerometers can be recorded from, they can also be differentially calibrated and viewed using the *Set Accelerometer* drop down menu, as seen to the right.




## 6. 5. 7. Description

This tab allows the user to keep a record of participant information that will save with the data set. In addition to basic identifiers, the user may find it particularly helpful to take notes on the experimental session, such as room temperature, participant compliance, and any other characteristics that may be useful to look at when exploring the data.

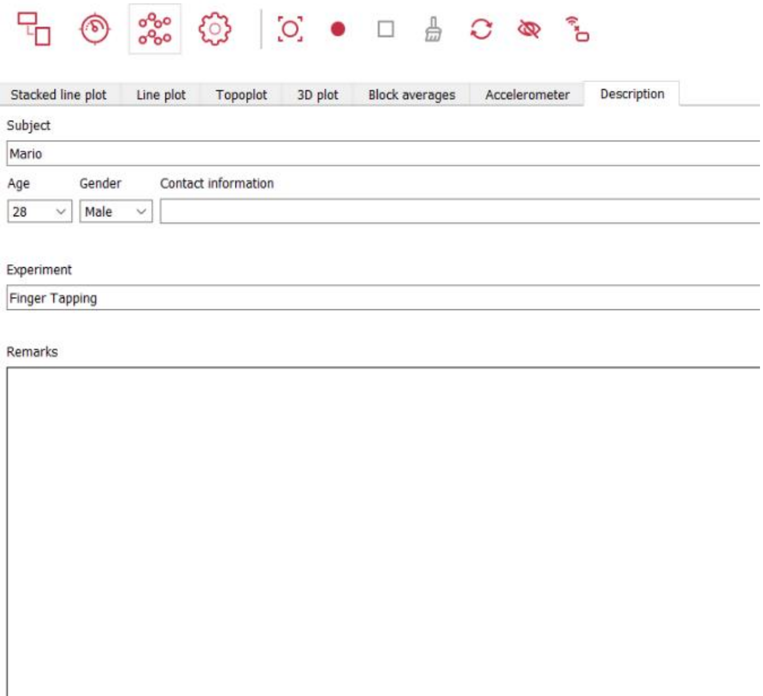



*Figure 6.26: Data recording Description tab*

## 6. 6. Triggering with Aurora

Currently, there are three possible methods for sending triggers (or timestamps) to Aurora. They are briefly touched upon in the following three sections; for a more information on the practical implementation of each method, please see the NIRSport2 trigger manual, available on the NIRx help center on the following page:

https://support.nirx.de/aurora/

When triggers are received by Aurora, they are stored in the *.tri file with the rest of the data.

Trigger inputs must be between 0-255 bits to be recognized in Aurora (aside from manual F keys).

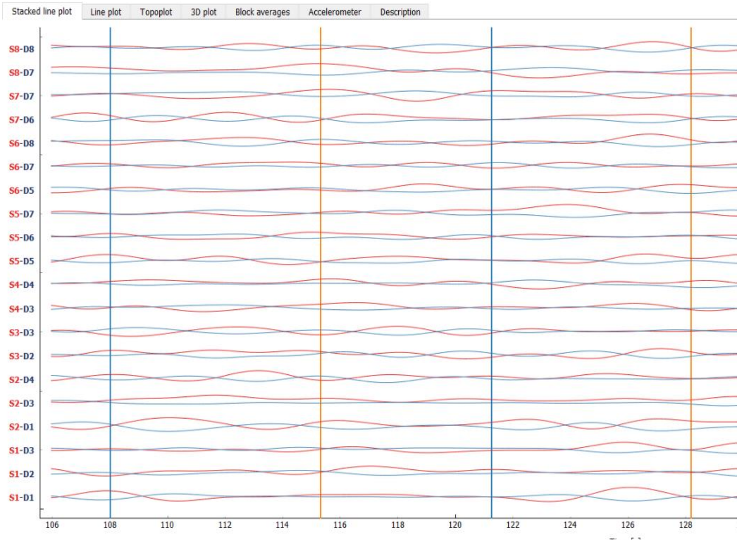


*Figure 6.27 : Example of trigger in a channel in the Stacked line plot window. The two different colors (blue and orange) indicate the timing of two different triggers/stimuli*

### 6. 6. 1. Lab Streaming Layer (LSL)

Lab Streaming Layer (LSL) is a protocol that allows for the sharing of both recorded data and for experimental triggers in real-time, meaning it can synchronize easily between stimulus PC – NIRx device.

Aurora allows for trigger input via LSL, given that the data acquisition computer and the trigger source share the same network and the *Trigger In* name is the same for both parties. See section 6. 2. 3. 3 for direction on selecting a *Trigger In* name in Aurora.

Note: Aurora sends out all the triggers it receives (TTL, LSL and Manual) via an LSL streams called "NIRStarTriggers". It has two columns, that contain the time since run start and the trigger ID.

For information on streaming data via LSL, see section 9. 1 of this document.

### 6. 6. 2. TTL Triggers

Hardware TTL (transistor-transistor logic) triggers can be sent to the NIRSport2 device and recorded in Aurora via a D-25 Parallel port and NIRSport2 Trigger In cable. If no parallel port is available a Cedrus C-pod (USB to Parallel port adapter), which comes with every NIRSport2 system, can be used. Contact NIRx support for more information.

### 6. 6. 3. Manual Triggers

In addition to generating trigger events through external signals, Aurora also allows the user to set trigger markers manually during the course of the measurements. A manual marker can be recorded by pushing the keys F1...F12 on the keyboard (this may require also pressing the Ctrl Key to enable the F keys). Note that manual triggers are not as reliable as triggers sent from a presentation software. They are mostly recommended for taking notes or starting a 'rest' recording.

## 7. Offline Review

Aurora fNIRS provides users the feature of reviewing previously recorded datasets. This can be done by clicking on the *"Start offline review"* button in the bottom part of the Aurora fNIRS main window.

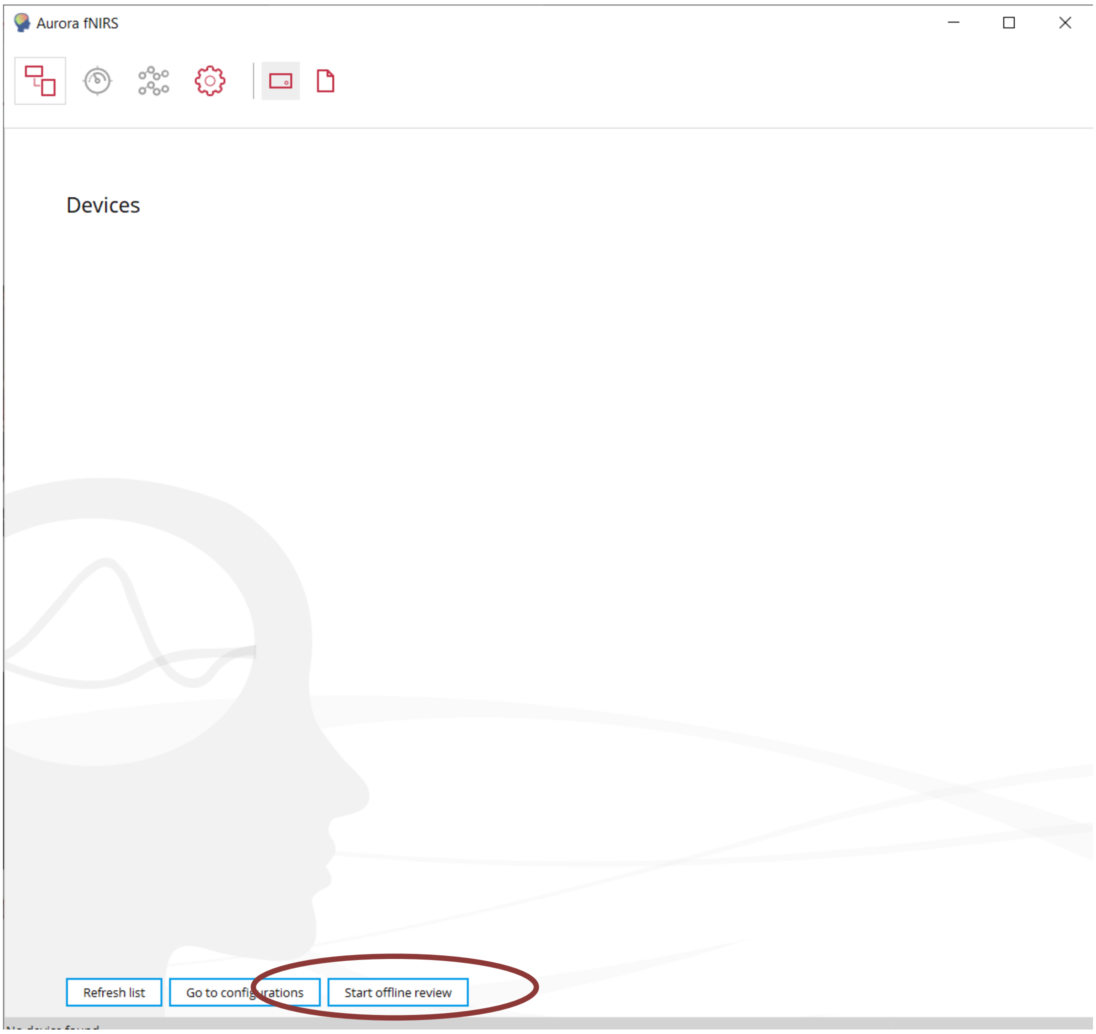



*Figure 7.1 – Opening the offline review mode*

By clicking on *"Start offline review",* you will be prompted to select the .nirs file of the dataset that is intended to be loaded and visualized. Navigate to locate the recording to be reviewed.

All views, except for accelerometry, will be available and visible as during recording.

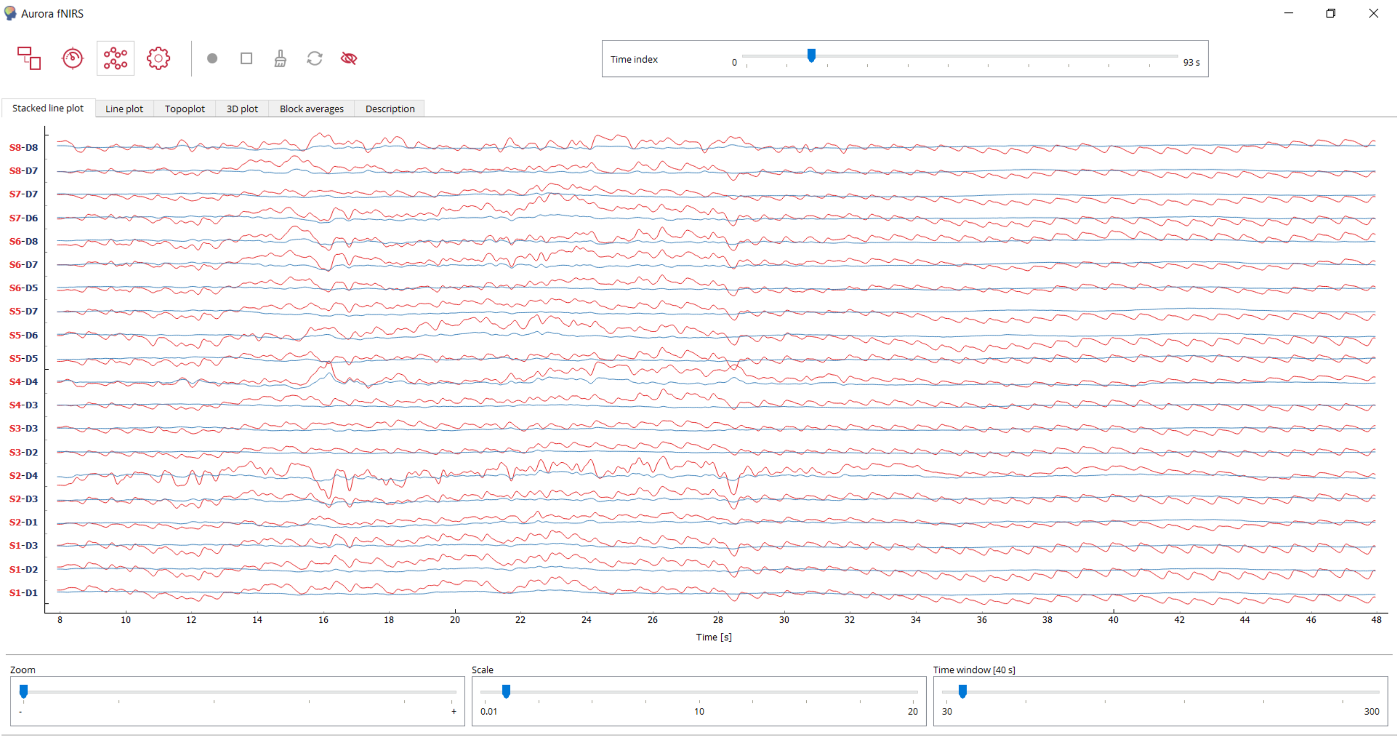


*Figure 7.2 – Stacked line plot opened in offline review mode*

In the *Stacked line plot,* the *Line plot,* the *Topoplot* and the *3D plot* views, you can navigate in time by using the *Time index* slider, at the top right corner of the Aurora main window. Two navigation modes are available:

- In steps of one second (left and right arrow keys)
- In steps of one minute (PgUp and PgDn keys)

Alternatively, you can click any time point within the time scale index. The resolution of the time scale is 1 second.

**The time point indicated in the time index slider corresponds to the last time frame as shown in the *Stacked line plot,* the *Line plot* views.**

In the *Block averages* view, the block averages are calculated at the very end of the recording, by taking into account all recorded triggers. **Moving the time index slider will not affect in any way the displayed block averages.**

# 8. Data File Format

The default folder in which Aurora fNIRS stores recorded data can be found under: *...\Documents\NIRx\data*. Here, data files are automatically named and organized, using the date of acquisition and recording session to define the target directory name and the common root of file names.

The general pattern is: prefix-yyyy-mm-dd_xxx.ext

In the following subsections, all files within the data folder are individually explained. Note that the *.nirs and SNIRF files created allows the user to open up Aurora data sets in the most common fNIRS analysis software such as nirsLAB, Homer2, Homer3 and the NIRS Toolbox, allowing them to seamlessly analyse their data in these platforms.

**Note: In order to make use of 3D anatomical features in NIRS Toolbox, such as drawing a 3D mesh, you must load in NIRx data with the nirs.io.loadNIRx function, NOT the nirs.io.loadDotNirs function.**

## 8. 1. Detector Readings: *.wl1, *.wl2

The recorded signals for both wavelengths are stored in two separate files, a *.wl1 file containing the data for wavelength 1 (760 nm) and a *.wl2 for wavelength 2 (850 nm). These data files contain the raw voltage readings recorded by the source-detector channels.

It is important to note that the saved raw data are never processed in any way. That is, pre-processing steps selected on the user interface, such as normalization or application of a filter, will not affect the recorded data in any way.

The file format of both the *.wl1 and *.wl2 files is a space-separated ASCII table, where columns represent **data channels specified in the topolayout** and rows represent time frames. The file contains no header, explicit row or column labels, or time stamps. The data structure is illustrated in the table below, where $S_i$ $S_i$ is the $i^{th}$ source; $D_j$: $j^{th}$ detector; $t_k$: $k^{th}$ scan, or time frame of measurement. See Figure 8.1 for illustration.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $S_1$-$D_1(t_1)$ | $S_1$-$D_2(t_1)$ | ... | $S_1$-$D_{max}(t_1)$ | $S_2$-$D_1(t_1)$ | ... | $S_2$-$D_{max}(t_1)$ | $S_3$-$D_1(t_1)$ | ... | $S_{max}$-$D_{max}(t_1)$ |
| $S_1$-$D_1(t_2)$ | $S_1$-$D_2(t_2)$ | ... | $S_1$-$D_{max}(t_2)$ | $S_2$-$D_1(t_2)$ | ... | $S_2$-$D_{max}(t_2)$ | $S_3$-$D_1(t_2)$ | ... | $S_{max}$-$D_{max}(t_2)$ |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| $S_1$-$D_1(t_{max})$ | $S_1$-$D_2(t_{max})$ | ... | $S_1$-$D_{max}(t_{max})$ | $S_2$-$D_1(t_{max})$ | ... | $S_2$-$D_{max}(t_{max})$ | $S_3$-$D_1(t_{max})$ | ... | $S_{max}$-$D_{max}(t_{max})$ |

*Figure 8.1 File Structure of *.wl1 and *.wl2 files. These files contain the raw voltage values recorded by the detectors, that are not modified in anyway. These are NOT optical density or hemoglobin concentrations.*

## 8. 2. Configuration File: *.config_json

This file contains the settings utilized by the NIRSport2 for data recording. It is actually a copy of the *.ncfg file that lives in the Configuration directory, which the user selects before optimizing the signal and recording data. This file is not intended for use by the researcher, hence the values in this file are not specified in this guide. Instead, the researcher may review the _config.hdr file to reference the recording parameters for their session.

## 8. 3. Header File: *_config.hdr

The header file contains important information about the general configuration and setup of the device, as well as experimental parameters. It is the user-friendly compliment to the more technical *.config.json file described above, and also contains the experiment notes specified by the user.

The file is structured into sections identified by a `[section header]` containing variables ('keywords'), to which to which parameter values are assigned according to a '`keyword=value`' scheme. The following explains the header file sections using exemplary values.

### General

Contains general information about the time and date of data recording and the filename.

```
[GeneralInfo]
```

| | |
|---|---|
| `Version=1.4.0-908-g4735fc3d master` | Aurora software version |
| `Device ID=1833_0012_A` | Device name |
| `Date=2020-06-25 15:46:35.967318` | Date of recording |
| `Sources=16` | Number of sources |
| `Detectors=16` | Number of detectors |
| `Sampling rate=5.086263020833333` | Sampling rate |
| `Amplitude details=100.0%, 100.0%, ...` | Amplitude details obtained during calibration |
| `triggers=[]` | Trigger timing |

### Experiment notes

Notes entered into the notes editor of the user interface are saved here.

| | |
|---|---|
| `experiment_name=` | Name of the experiment |
| `experiment_subject=` | Subject name/number |
| `experiment_subject_age=` | Subject age |
| `experiment_subject_gender=` | Subject gender |
| `experiment_subject_contact_info=` | Subject contact information |
| `experiment_remarks=` | Notes relevant to the experiment |

### Data Structure

This section records the arrangement of detector channels in the .wl1 and .wl2 files, and the channel masking pattern.

```
Channel Mask="#

1   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0

1   1   0   1   0   0   0   0   0   0   0   0   0   0   0   0

1   0   1   1   1   0   0   0   0   0   0   0   0   0   0   0

0   1   0   1   0   1   0   0   0   0   0   0   0   0   0   0

...

0   0   0   0   0   0   0   0   0   0   0   0   0   1   1   1

#"


Channel indices=

0-0, 0-2, 1-0, 1-1, 1-3, 2-0, 2-2, 2-3, 2-4, 3-1, 3-3, 3-5, 4-2, 4-4, 4-6, 5-3, 5-4, 5-5,

...
```

The channel mask stores the masking pattern in a table. Channels that are set not to be displayed are identified by '0' s, while channels set to be displayed are labelled with 1's. Counting from the upper left, the column number corresponds to the detector channel, and the row number corresponds to the source position.

The channel indices denote the order in which the columns of the data files (*.wl1, *.wl2) are assigned to source detector combinations. Each channel is denoted by the source number, a minus sign ('-') and the detector number. Each pair is followed by a comma and the next channel. This variable may be read to generate a table header for the data.

## 8. 4. Probe Setup File: *.probeInfo.mat

Aurora fNIRS will save the Montage (*.probeInfo.mat file) that has been used as part of the configuration selected for the recording. This file contains information about the positions of the sources and the detectors, and the channels they form. The probeInfo file contains an MNI coordinate system, providing the information necessary for 3D probe registration.

This file is created in the NIRSite Software. For more information on creating montages in NIRSite, please consult the corresponding Getting Started Guide which can be found on the NIRx help center on the following page: https://support.nirx.de/software/

## 8. 5. Subject Information File: *description.json

This file contains the descriptive information as entered in the subject Demographics dialog prior to and throughout data recording. The subject information file may help to identify datasets. The following is an example of the text structure:

```
{
    "subject": " John Doe",
    "age": "35",
    "gender": "Male",
    "contact_info": "email@server.domain",
    "experiment": " Go/No-Go",
    "remarks": " Right-hand subject "
}
```

## 8. 6. Trigger files

Please note that all triggers are always recorded in the .nirs file. The .nirs file allows to store triggers at a sampling rate only equal to the sampling rate of the fNIRS data. Triggers, however, are always recorded at 46875 Hz. To avoid information loss, trigger marker related information and their time stamps are saved in additional files as well, depending on the trigger source:

- *_lsl.tri for triggers received over LSL
- *.tri for triggers received over the TTL input port.

### 8. 6. 1. LSL & Manual Trigger Marker Information File: *_lsl.tri

This file records the received LSL and Manual triggers in a semicolon separated format. Each line has the following entries, in reference to when the trigger was received:

UTC time (year, month, day, 'T' , hour, minute, second, second fraction); data sample number; trigger marker

Data from an example *lsl.tri file, with the same color code as the labels above:

2019-05-03T08:25:29.544889;235;1

### 8. 6. 2. Hardware Trigger Marker Information File: *.tri

This file records the received TTL triggers in a semicolon separated format, such as the data from an example *.tri file:

2019-05-01T15:53:32.699768;332;7;4;1;345

Each line corresponds to the following entries, in reference to when the trigger was received:

UTC time (year, month, day, ‘T‘ , hour, minute, second, second fraction): 2019-05-01T15:53:32.699768
Data sample number: 332
Step within data sample: 7
Hardware ID: 4 (always 4, can be ignored)
Trigger marker: 1
Sample within step: 345

Note that while LSL and manual triggers are only precise to the sampling frequency, Hardware triggers (TTL) are precise to the step within the data sample – see section 6.2.3.2 for more information on data sample vs. data step.

## 8. 7. Atlasviewer file: digpts.txt

This file contains 3D coordinates and reference points obtained from the *.probeInfo.mat file. This file allows the user to import data processed by Homer2 (using the *.nirs file – see below) and import the results into AtlasViewer.

## 8. 8. Homer2 format file: *. nirs

Aurora fNIRS allows the user to directly export the data into a format that is compatible with the Homer2 fNIRS analysis platform. The *.nirs file is a Matlab file which contains information about the configuration used for the recording, and the recorded data. The *.nirs file can be directly imported into Homer2, the NIRS Toolbox and nirsLAB version 2019.04 version for further analysis.

Note: all triggers (LSL, TTL, Manual) are saved in the ‘s’ matrix of the *.nirs file.

## 8. 9. SNIRF format file: *.snirf

This format is a universal file format for storing and sharing NIRS data independently of any specific application-specific file format such as Matlab. Please see this page https://github.com/fNIRS/snirf for more details.

It may currently be loaded in data analysis software such as Homer3 and the NIRS Toolbox.

## 8. 10. Accelerometer Data File: *.ACC

The accelerometer data file is also saved in the zipped folder. The data is stored in a semicolon separated format where each line has the following entries:

start time of the frame; frame number; plan_entry_index; slot_index;  channel_index; internal counter;
acceleration x-component [m/s]; acceleration y-component [m/s]; acceleration z-component [m/s];
gyroscope x-component [deg/s]; gyroscope y-component [deg/s],;gyroscope z-component [m/s];
magnetometer x-component; magnetometer y-component; magnetometer y-component; hall resistance

## 8. 11. Aurora Raw Data Zip File *.roh

The raw data file stored in the compressed zip folder contains raw voltage data from all possible source-detector combinations. This file may be converted to standard file format using the raw data converter option, as described in section 6.3.2 of this document.

See Table 7.1 for an example of the first row of the *.roh file imported in MATLAB. The raw data file contained in the compressed zip folder has the following structure:

**Column 1 Date and time of a scan:** For a 16x16 configuration, a scan consists of 16 x 16 = 256 rows; to collect data from all possible source – detector combinations.

**Column 2 Scan number:** For standard illumination pattern, scan 0 would be:

*source 0 – all detectors* (16 rows)

*source 1 – all detectors (16 rows)*

*…………………………..*

*source 7 – all detectors (16 rows)*

Thus generating 256 rows of data for a single scan.

**Column 3 Source number:** For a given scan, the first 16 rows represent source 0. The next 16 rows represent source 1 and so on. Indexing of sources and detectors in raw data starts from 0 i.e. Source/detector numbers starts from 0 i.e. S0, S01, S02...S07.

**Column 4 Detector card number:** For a given source activation step the first 8 rows (all 1's) are detector card 1 and next 8 rows are detector card 2.

**Column 5** Detector number: For a given source activation step the first 8 rows correspond to detectors 0-7 from the detector card 1. The next 8 rows have detectors 0-7 from detector card 2.

**Column 6** WL1: Data file wavelength 1

**Column 7** WL2: Data file wavelength 2

**Column 8 – end** For Future: If light sources are modulated with any other frequency, the data will be stored here.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1 | 2018-11-30T18:19:58.573397 | 0 | 0 | 1 | 0 | 1.9300e-06 | 3.2300e-06 | 0 |

*Table 8.2 First row of the .roh file imported in MATLAB. It opens in Excel with columns separated with semicolons.*

## 8. 12. NIRxWINGS Raw Data File: *.wings

Present in the zip folder together with the *.roh file only if the Biosignals option is enabled in the configuration (see section 9.8 for more information). It is a CSV file that may be easily opened with a text processor. The data is stored in a semicolon separated format where each line has the following entries:

Timestamp; internal value (always 0); battery level; channel 1; channel 2; ....; channel 11

Channels refer to the different sensors connected to the device always with the following order: ExGa1...4 (mV); ECG (mV), Resp (Ω), PPG (ADU), SpO2 (%), HR (BPM), GSR (kΩ), Temperature (°C).

# 9. Advanced Features

## 9. 1. Real Time Data Streaming via LSL

Real time data streaming from Aurora is available via Lab Streaming Layer (LSL). This feature is enabled per default and offers the user both raw voltage and converted hemoglobin concentration values. With real time data, the user may implement real time analysis and neurofeedback paradigms, with any software package on the same network that can implement the LSL library. Turbo Satori, a dedicated real-time fNIRS analysis and neurofeedback platform is one such software; others include Matlab and Python.

Note that the values used in the Modified Beer-Lambert Law to compute changes in hemoglobin from changes in voltage are predetermined and cannot be changed. The actual values used can be found in Figure 9.1.

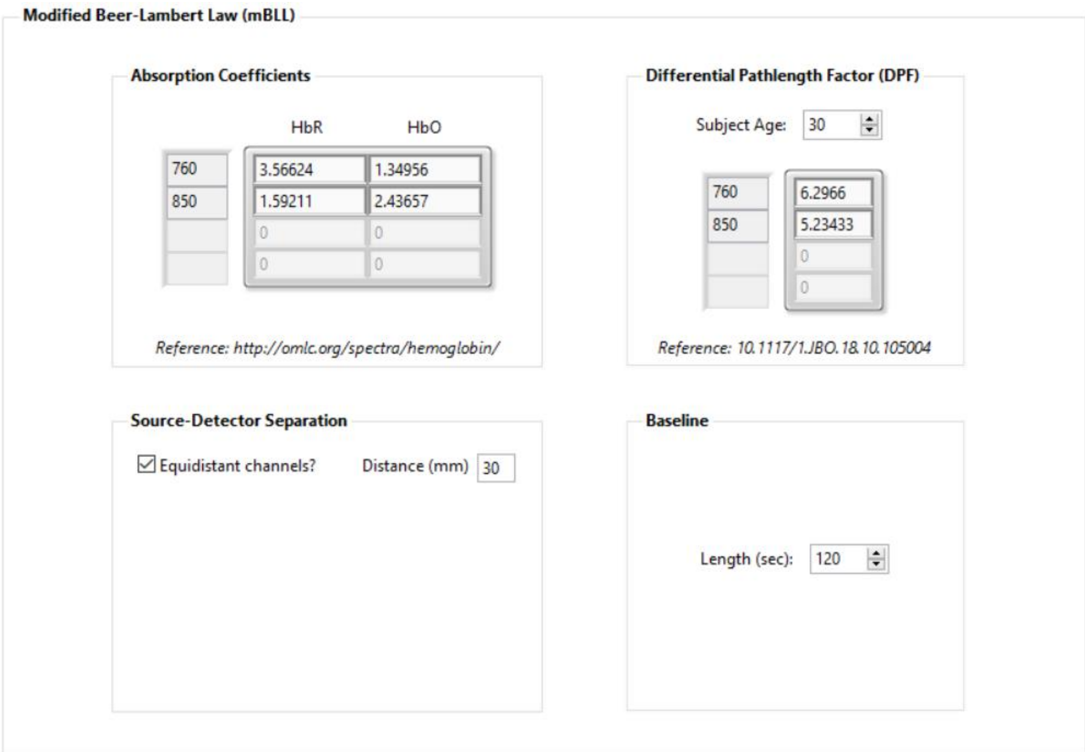



*Figure 9.1: The unchangeable, Modified Beer-Lambert Law parameters - used for the online computation and real-time streaming values of changes in concentration of HbO and HbR*

### 9. 1. 1. Aurora LSL Data Structure

The structure of streamed fNIRS data is as shown in the image below. Briefly, the first n columns in the stream represent the raw voltage data for wavelength 760 nm, where n = channels defined in the topolayout. The next n channels consist of the 850 nm raw voltage data (in Volts). The next set of columns contains the Oxyhemoglobin data, followed by Deoxyhemoglobin data from the topolayout channels (in µmol/L). Aurora also streams a timestamp, calculated by measuring the time at the first frame and then adding the known time difference between frames for each new frame. Due to the deterministic behavior of NSP2 hardware the relative timing between frames are precise.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Frame Counter | 760nm: S1 – D1 | .... | 760nm: S8 – D8 | 850nm: S1 – D1 | .... | 850nm: S8 – D8 | HbO: S1 – D1 | .... | HbO: S8 – D8 | HbR: S1 – D8 | .... | HbR: S8 – D8 |

*Figure 9.2: Layout of the LSL data stream from Aurora. Aurora only streams data from masked channels (those included in topolayout).*

Meta-data about the recording is also available in Aurora's LSL stream. This includes subject information as input by the user (information fields are the same as those given in sections 6. 5. 7 and 8. 5), optode locations, channel labels, sampling frequency and device serial number. For information on generic NIRS metadata format in LSL, see this post: [https://github.com/sccn/xdf/wiki/NIRS-Meta-Data](https://github.com/sccn/xdf/wiki/NIRS-Meta-Data) .

## 9. 2. Accessing Onboard Recordings

When operated in Wi-Fi mode, the NIRSport2 records the experimental data on the in-built device memory. While this data is normally stored on the acquisition PC at the end of the recording, should the Wi-Fi connection drop and the device does not get the opportunity to reconnect and transfer the data to the acquisition PC, it is necessary to manually retrieve the data. Furthermore, any data recorded via standalone mode (an advanced feature, described in section 9. 6 of this manual) must be manually retrieved.

The stored data files can be manually accessed from the device by connecting to the device via Wi-Fi.

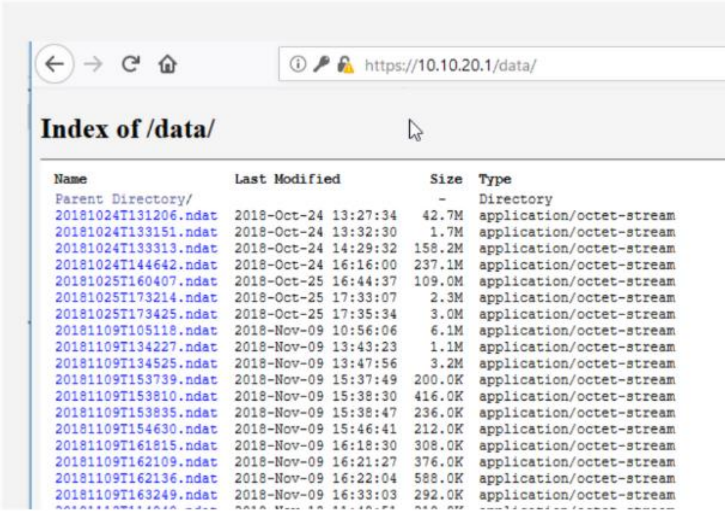



*Figure 9.3: Accessing onboard device data via Wi-Fi and an internet browser*

To access the device data:

A. Connect to the device via Wi-Fi, as described in section 4. 2.
B. Go to device page by writing **[https://10.10.20.1/data/](https://10.10.20.1/data/)** in an internet browser OR select *Open Device Data Directory* on the bottom right corner of the device selection page.
C. When prompted, enter *nsp2* as username and *dataaccess* as password.
D. Download the .ndat file corresponding to the date of interest.
E. Follow the directions for converting the native NIRSport2 data files in section 9. 3 below.

Please note that before starting a new experiment, the NIRSport2 will delete as many old files as necessary until it reaches ~1.5 GB of free space, starting with the oldest files. Ensure to download data BEFORE starting a new session, as Aurora might delete the previous files to make space for new experimental data.

## 9. 3. Converting Native NIRSport2 Files - NIRS Converter

In cases of Wi-Fi connection drop or intentional use of standalone mode, the *.ndat file must be retrieved from onboard the NIRSport2 and converted into the standard file format. To retrieve data, see section 9. 2 above. Alternatively, there may be an instance in which some of the data files are written to the data acquisition computer's data directory, but not all are written successfully. In this case the *.zip file in the data directory folder can be used to create all NIRSport2 data files using the NIRS Converter Application.


**Note: The *.ndat and the *.zip are complete data sets recorded in the native NIRSport2 format – they can then be converted into the various readable, useable file formats, such as the .nirs file, SNIRF file, .wl1 and .wl2 files using the NIRS Converter application.**

Once the raw data -which is in the native NIRSport2 format - has been retrieved, open the NIRS Converter Application to convert the data into the various readable, useable file formats. This application is installed with Aurora and should be available as an icon on the desktop – otherwise, search for it in your computer's applications list.

### 9. 3. 1. Raw Converter Tab

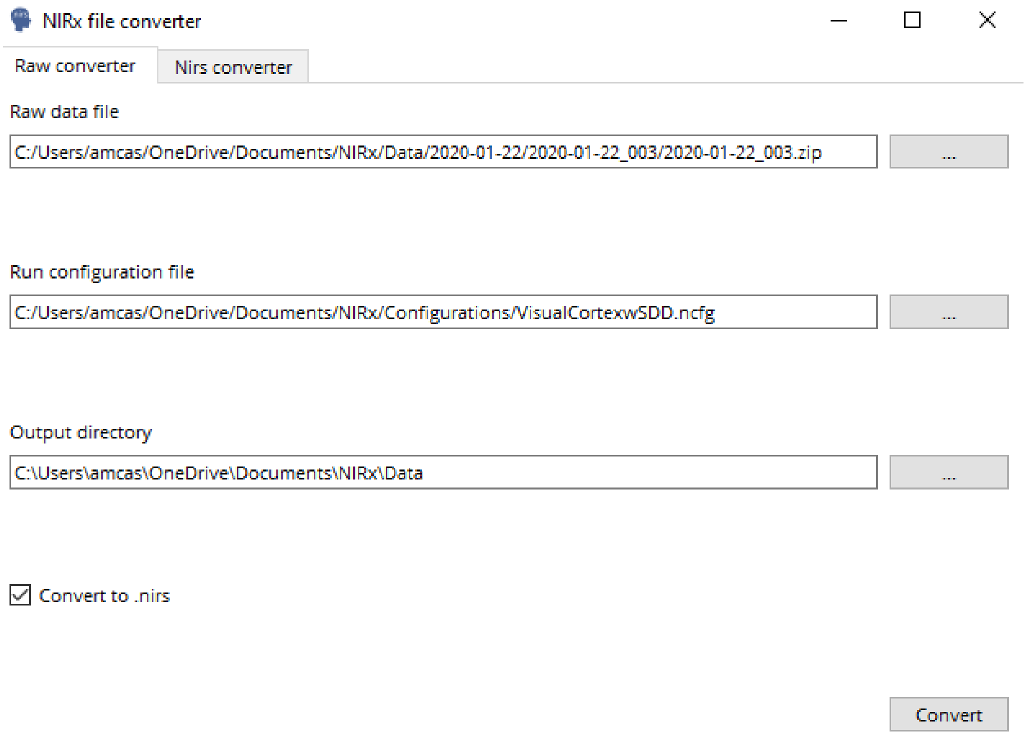



*Figure 9.4: Raw convert tab of the NIRS Converter Application*

In the raw converter tab, the raw data file path must first be specified. Either write the path in the empty field or locate it by selecting the ellipsis button. Select the *.ndat, *.roh file or *.zip folders as raw data- any will work. Next, the converter requires the configuration file selected by the user for the measurement in Aurora. The configuration file (*.ncfg) may be found in the Configuration folder of the NIRx directory in Documents, assuming the default path hasn't been changed by the user. Next, specify an output directory for the converted files. Finally, select whether or not to create a *.nirs (and SNIRF) file, selected by default. Press convert in the bottom right corner of the page, and the proper files will be written to the output directory.

### 9. 3. 2. NIRS Converter Tab

The NIRS Converter tab of the NIRS Converter application allows for the generation *.nirs and SNIRF files only. It is useful in the rare cases where Aurora writes all other files from the raw data properly (e.g. *.wl1, *.wl2, trigger files, etc) but fails to write the *.nirs or SNIRF files properly. To use it, simply specify the folder path of the NIRx data by clicking the ellipsis button or writing it directly in the empty field. Then, click Convert at the bottom, and the proper files will be written to the same data folder.

## 9. 4. Hyperscanning

Aurora offers a Hyperscanning application named Hyperscan to study functional neurovascular activation on multiple subjects simultaneously. This allows the user to connect different devices or split one through one single interface that will manage the normal functioning of Aurora. NIRSport2 devices may be connected, as usual, via USB or Wi-Fi (access point required for this application; see section 6. 3. 1. 1 of this document). All data and certain event trigger information (see section can be fully synchronized using Hyperscan. In order to proceed with Hyperscan, the desired configuration for each participant and application settings must be first be defined in Aurora.

### 9. 4. 1. Hardware setup

Each participant must have at least one NIRSport2 imager dedicated to their recording. It is possible to connect multiple NIRSport2s in cascade for each participant in order to increase the number of sources and detectors in a montage. First, the cascade configuration must be created in Aurora, as outlined in section 8.4. Then the user may proceed as with normal configurations in Hyperscan, making sure to connect to the primary device on the *Add Subject* step.

Starting from Aurora version 2021.04, one single NIRSport2 device can be split among different participants with same or different configurations.

### 9. 4. 2. The Hyperscan Application

The Hyperscan application is installed automatically together with the Aurora 2021.9 installer since it will work as an independent controller. The icon of this application can be seen to the left. When launching Hyperscan, it will open to the main page, as shown in **Error! Reference source not found.**

### 9. 4. 3. The Hyperscan Main Page

The Hyperscan main page has three main components:

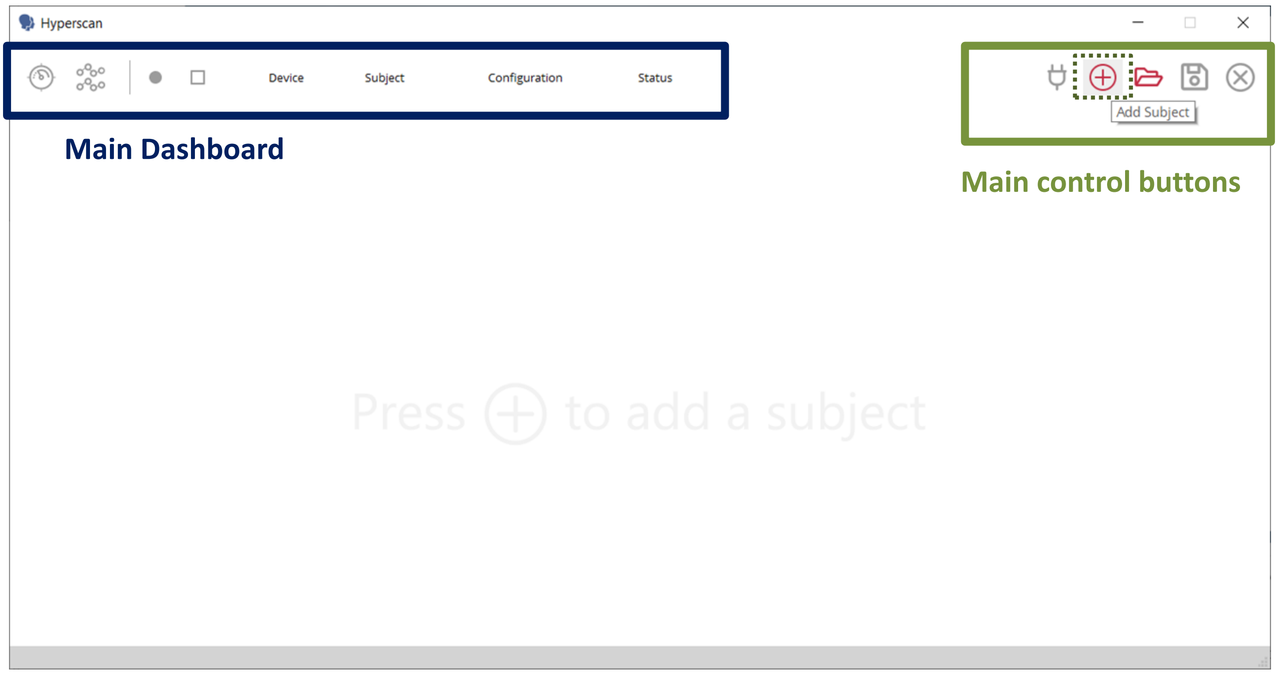



*Figure 9.5: Main page of the Hyperscan application when first opened.*

A. **The Main Dashboard,** as a single toolbar, which controls signal optimization and recording for all subjects.
B. **The Subject Dashboard,** with multiple toolbars, as many as subjected added. Allows for individual control of signal optimization and recording for each subject, as well as editing subject information and removing subjects from recording.
C. The ***Main Control*** buttons, in the top right corner of the page.

Both dashboards contain two navigation buttons (to go to signal optimization/recording) and two action buttons (start/stop signal optimization/recording). In addition to individual controls, each subject toolbar denotes the subject name, device ID, configuration, and status for each subject, as identified by the main dashboard.

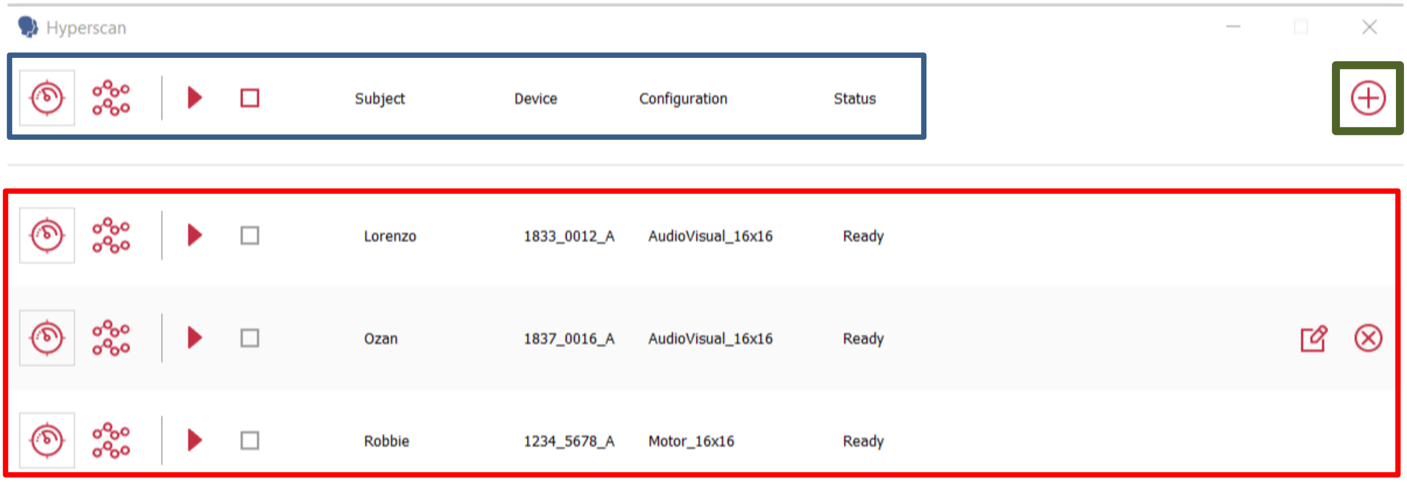



*Figure 9.5a: The main page, with 3 subjects added. The main dashboard is highlighted in blue, the subject dashboard with three subject toolbars in red, and the add subject button in green.*

### 9. 4. 4. Adding a Subject

In order to start the experiment, the user must add each subject individually by pressing the *Add Subject* button in the top right corner of the main page, leading to the *Add Subject* dialog pop-up as in **Error! Reference source not found.**6.

Here the user will fill out experiment information specific for every subject. If the NIRSport2 device for a subject is not yet connected, it should be connected now, and the *Refresh Device* button should be pressed.

Add subject offers the following fields *(*denotes mandatory field*):*

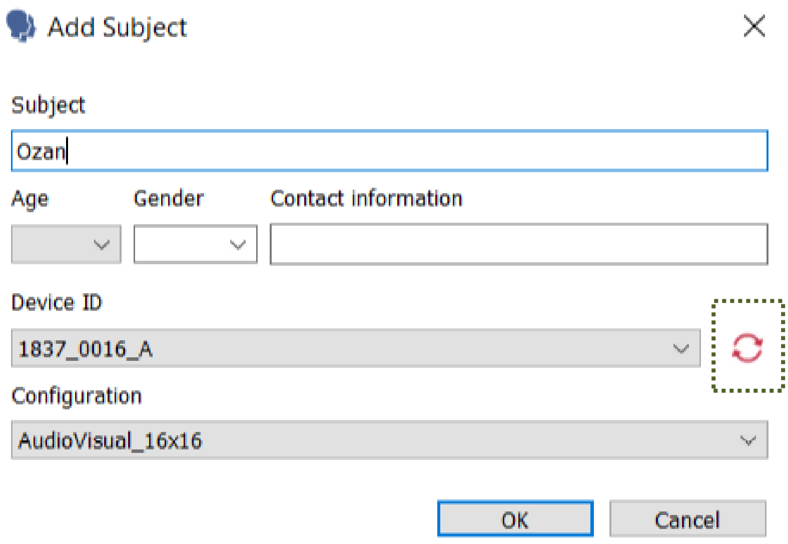



*Figure 9.6: Add subject dialog. The refresh device button is in green*

A. **Subject Name**
B. Other Identifiers: Age, Gender, Contact Info
C. **Device ID**
D. **Configuration**

Take special care of noting which device ID corresponds to which subject. This will ensure accurate subject data identification later during analysis.

All devices available will appear under the *Device ID* tab showing their device ID. Each device will be related to one single subject with its one single configuration, which you may select under the Configuration tab. There will be all the configurations available under the default folder to store them (unless altered): …*\Documents\NIRx\Configurations.*

Note that the configurations for participants do not have to be the same; each participant can have different configurations (including different montages or number of devices in cascade) if desired.

Importantly, it is not possible to add a subject without naming it or selecting a device and a configuration.

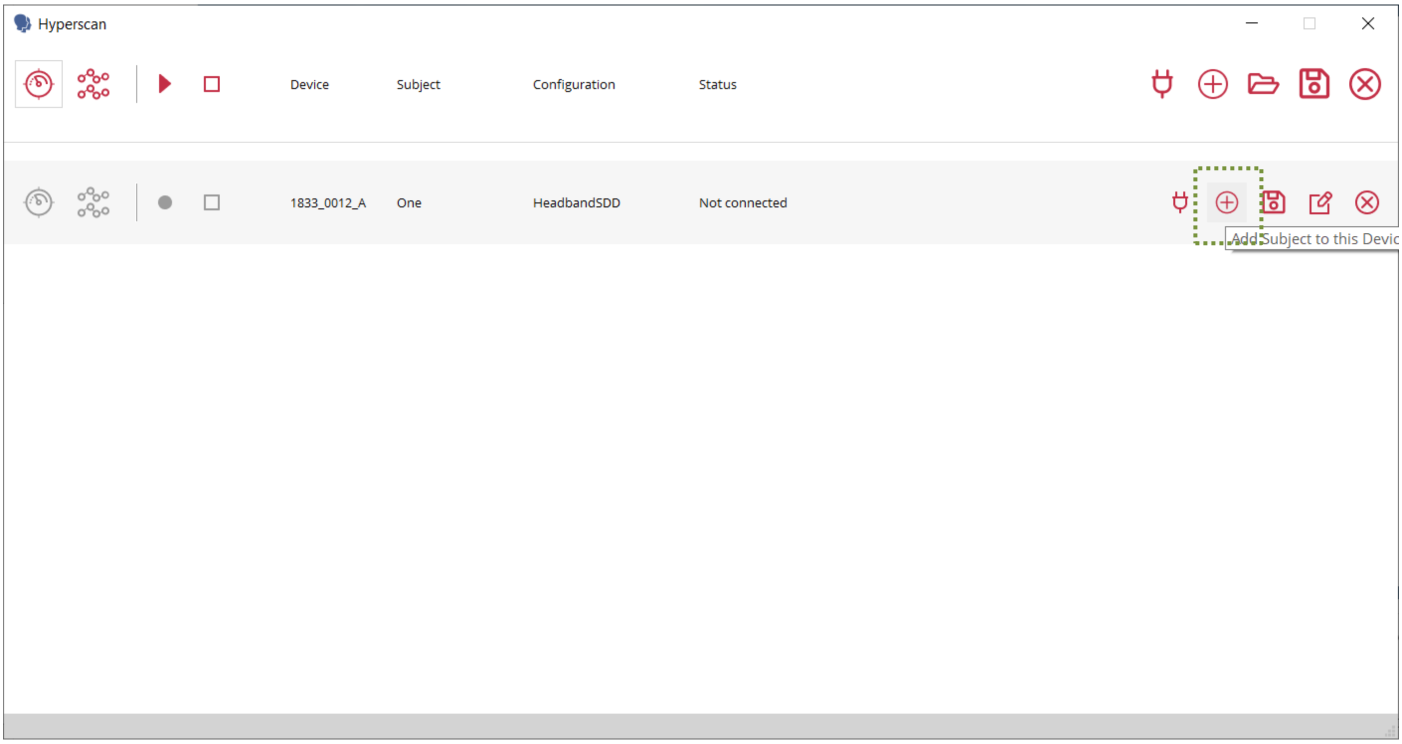



*Figure 9.7: Adding a second subject to the same device.*

The same NIRSport2 may be shared between two participants by pressing the button *Add subject to this Device*, to be found in the subject modifier buttons. This will prompt out the window shown in Figure 9.6 with the Device ID field greyed out, as the serial number of the shared NIRSport2 is the same. The configuration field, however, allows the use of different setups for each participant.

## 9. 4. 5. Connect subjects to Aurora

When the subject information has been added to the Hypercan App, the user must hit the *Connect to Aurora* button, either in the main control dashboard or in the individual subject modifiers.

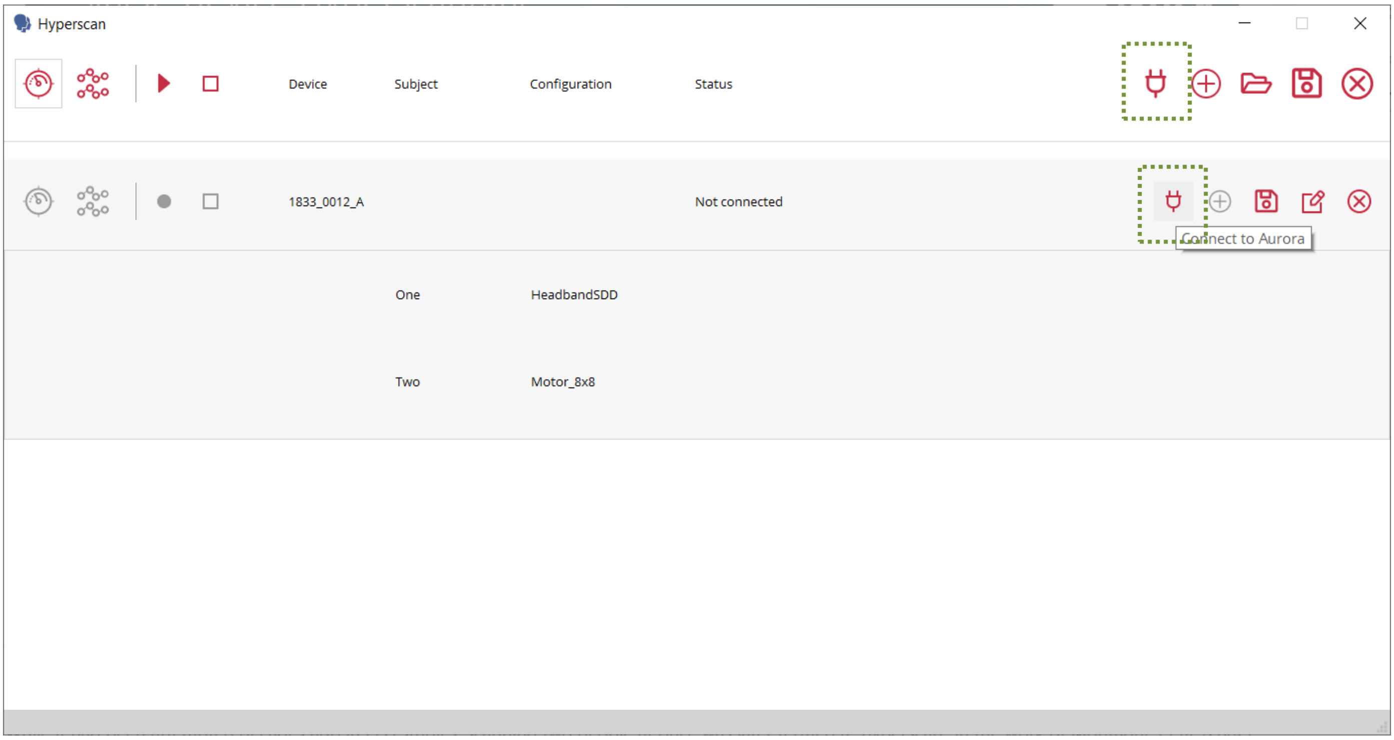



*Figure 9.8: Hit the button with the socket icon to connect the chosen setup to Aurora.*


This will initialize in a subject toolbar the main page of Hyperscan, as above. Here, the subject toolbar is greyed out, and the status of the subject is marked as *Initializing…*

While initializing, the Hyperscan app will run Aurora in the background, following every single step one would do if the recording session was to be performed on a single subject in Aurora alone. These steps are:

A. Launch Aurora.
B. Relate the subject information.
C. Connect to the selected device.
D. Select the desired configuration.

When the process is done, one Aurora screen will be steady in the background and the status of the subject in its Hyperscan subject toolbar will become *Ready*. As more subjects are added, there will be as many Auroras opened as described subjects in the Hyperscan app. See 9.8 on the next page, which shows 3 subjects added, their *Ready* status, and the three instances of Aurora created, as seen in the application preview in the Windows toolbar.

*Figure 9.9: Main navigation bar in an individual Aurora instance through Hyperscan. Setup and settings are greyed out.*

Note that each Aurora version is limited to signal optimization and data recording, as seen in Figure 9.9. This is because the device and configuration will have already been chosen through the Hyperscan app, and the application settings cannot be modified here; they can only be modified through Aurora itself.

A subject may be edited by hovering the mouse over its subject toolbar and clicking the *Edit Subject* ( ) button on the far right of the screen. This will prompt an *Edit Subject* window to pop-up, which has the same layout as the *Add Subject* window. A subject may also be deleted using the *Delete Subject* ( ) button.

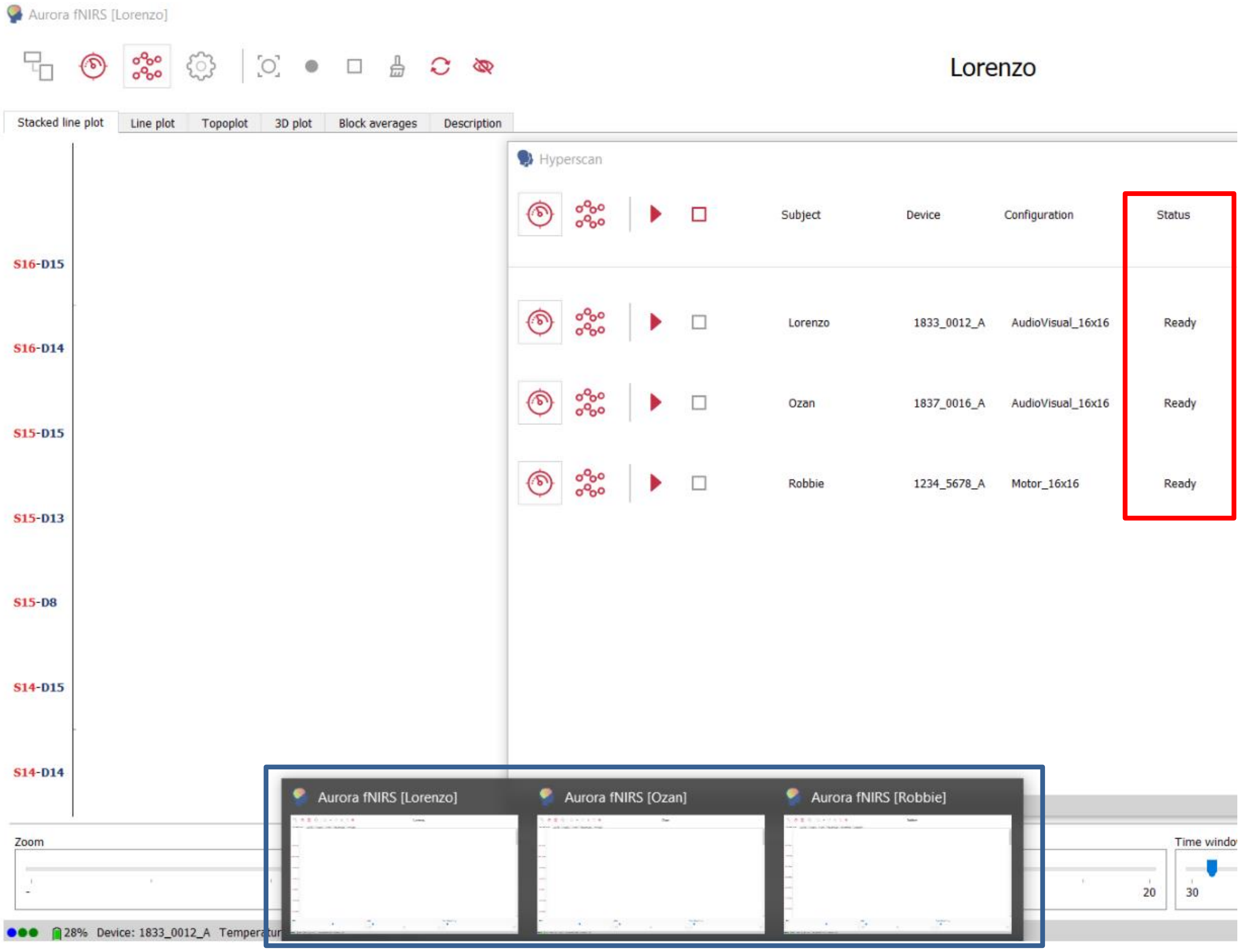



*Figure 9.10: Hyperscan with three subject added and ready for signal optimization/recording. The addition of each subject creates a new instance of Aurora, as seen in the application previews on the bottom of the screen.*

## 9. 4. 6. Signal Optimization

When the status of all subjects is *Ready* and all equipment is correctly configured, the user may advance to the signal optimization routine by clicking the *Start* ( ) button. It can be pressed in the main dashboard to start optimization for all subjects at the same time, or in the individual subject toolbars, to start the process for an individual subject.

During this procedure, and the subject status will change to *Calibrating* and a status bar will appear, as seen in Figure 9.11. To see the results of each procedure, you may go to the specific Aurora window of each subject.

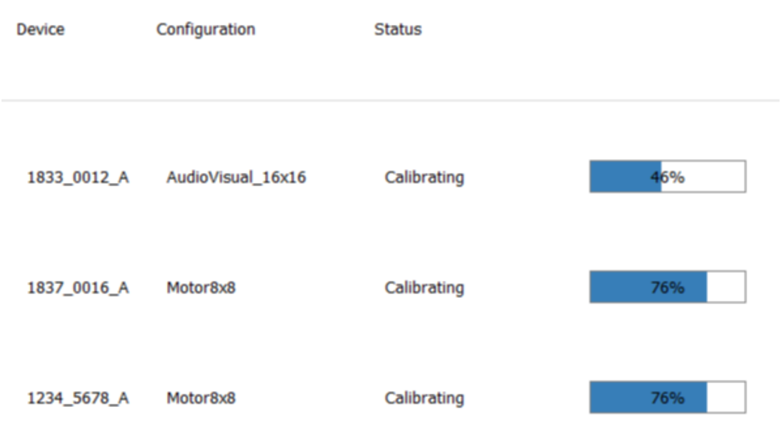



*Figure 9.11: The status bar for three subjects during signal optimization, which was started using the main dashboard start button; the first subject lags because it has a bigger montage.*

### 9. 4. 7. Data Recording

Once the signal optimization routine is successfully completed, the user may proceed to the recording step by clicking the *Data Recording* ( ) button. The user may start the acquisition by clicking the *Record* ( ) button. As with signal optimization, this is possible for either all subjects at once using the main dashboard button or one at a time using the individual subject toolbar buttons. When recording, the status of each subject will change to Recording on the main dashboard, as seen in Figure 9.12. Start of recording is also indicated by the F1 LED of the device of the corresponding subject, which will turn from blue to green.

| Subject | Device | Configuration | Status |
|---|---|---|---|
| Lorenzo | 1833_0012_A | AudioVisual_16x16 | Recording |
| Ozan | 1837_0016_A | Motor8x8 | Recording |
| Robbie | 1234_5678_A | Motor8x8 | Recording |

*Figure 9.12: The status of each participant changes to Recording when the record button is pressed in the main dashboard.*

Recording may begin at slightly different times for each subject, due to network and computer lags. Therefore, the data must be ultimately synchronized via triggers rather than start times.

All data viewing tabs may be seen by going to the Aurora interface of each subject, which will be running in the background. All features of data viewing with Aurora are available, as they are using Aurora alone.

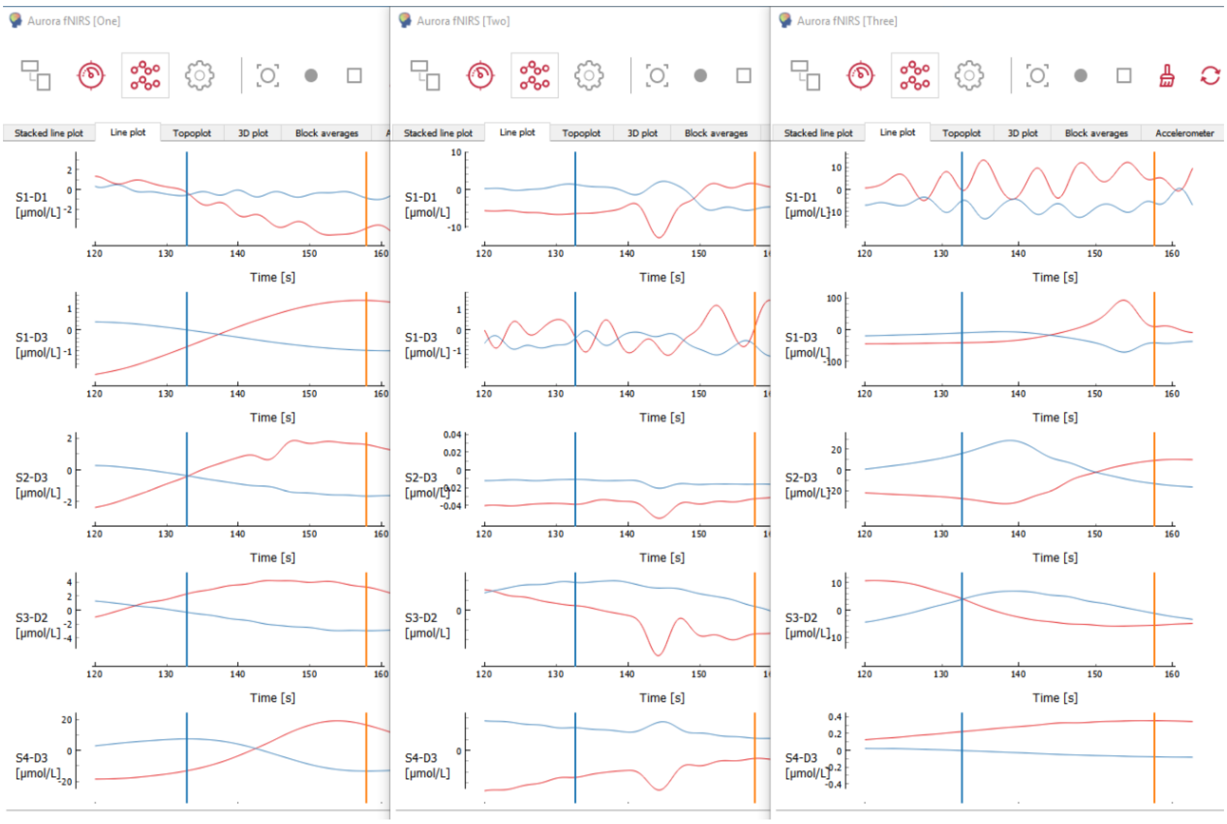



*Figure 9.13: The Aurora Line plot windows for 3 subjects. Triggers appear in each window.*

Data Recording can be stopped by pressing the desired ( ) button.

To finish the session after stopping a recording, simply close the Hyperscan application and it will remotely turn off all Aurora activity.

### 9. 4. 8. Triggering with Hyperscan

Hardware triggers sent via TTL pulse must be sent to each subject's primary device to be recorded with each subject's data. This is possible with a NIRx parallel port replicator. However, this adds considerable hardware/cables to the experimental setup, and limits participant mobility. Thus, it is recommended to use LSL triggers with the Hyperscan application.

Manual triggers will only appear in the data set corresponding to the Aurora screen that is selected at the time that the manual trigger is recorded.

Please note that manual triggers are not available in single-device Hyperscan.

### 9. 4. 9. Hyperscan Data Format

Data recorded via Hyperscan is saved in the Documents>NIRx>Hyperscan folder. A folder is saved with the date of the recording; each individual data set is saved within this folder, with an '_00#' in the folder name to distinguish subjects. The recording from the first subject corresponds to the first file '_001', the second to the second file '_002', and so on. Note that if there are multiple recording sessions within a day, the numbering scheme will increase sequentially. In a case that multiple files are recorded from with Hyperscan each day, it is recommended to add notes in the Aurora description tab to further distinguish subjects/runs.

### 9. 4. 10. Reconnecting a Lost Device

When a device is turned off for some reason (i.e. running out of battery, losing connection to the computer) the status of its corresponding subject will become "Absent". At this point, the Aurora screen belonging to it must be manually closed.

If the user wants to reconnect the device because the issue that disconnected it is solved, they may press the *Reconnect* () button that will appear on the right side of the subject toolbar. It will refresh the available devices and try to reconnect into the previous one, if detected. Importantly, this feature will only be available if the status is *disconnected*.


***Figure 9.14: Subject dashboard when the device disconnects.***

If a device loses connection, its data stream will no longer be synchronized with the other devices. To resynchronize the streams, all data recording must stop and begin again, or a trigger to line up the data later in analysis must be sent.

## 9. 5. Cascading Devices (Multi-Device Mode)

The NIRSport2 may be 'cascaded' to connect multiple devices together to create higher-density montages. All data and event trigger information are fully synchronized between NIRSport 2 devices.

Currently, Aurora 2021.9 supports up to five devices cascaded together., meaning that up to 80 sources and 80 detectors can be configured to measure a single participant at the same time.

### 9. 5. 1. Hardware Setup

The first pre-requisite to connect multiple devices is to have NIRSport2 cascading cable. The cable attaches at the *Extension A* or *Extension B* port on the rear panel of the device. The cable attached to the same port on each device. Thus, if the cable is attached to the *Extension A* port on one device, it must be connected to *Extension A* on the other device; if connected to *Extension B* on one device, it must be connected to *Extension B* on the other.

Figure 9.15: The cascading cable attached to the Extension B port on two devices.

The device which connects to the acquisition PC takes the role of the primary device and connects to other devices. For example, in case of a 3-device system, *Extension A* & *B* of the primary device connects to *Extension A* of the secondary device and *Extension B* of tertiary device, respectively. See Figure 9.16 for illustration.


Figure 9.16: Three cascaded NIRSport2s. The device attached to the two other devices is the primary device.

It is important to note that Aurora numbers the optode according to the order in which the devices are cascaded. The optodes are numbered as shown below.

| | Optodes A | Optodes B |
|---|---|---|
| **Primary Device** | 1-8 | 9-16 |

| | | |
|---|---|---|
| **Secondary Device** | 17-24 | 25-32 |
| **Tertiary Device** | 33-40 | 41-48 |

*Table 9.1: Optode labeling for up to 3 devices in cascade.*

Please ensure to clearly identify the optode numbering according to device assignment. This numbering may or may not match up with the stickered red and blue labels on the optodes. Please contact [support@nirx.net](mailto:support@nirx.net) if in need of more optode labels.

Once the physical connections have been established, the primary NIRSport2 can be connected to the acquisition PC via USB or Wi-Fi. Please note that other devices are not visible under Devices page at this stage. The devices appear after selecting a configuration.

### 9. 5. 2. Montage Design

The process of creating a configuration for multi-device mode begins with designing an appropriate montage in NIRSite. The montage design process remains exactly the same as for standard single device mode; the only difference being the increased number of optodes due to cascading of devices.

It is advisable to create a montage in such a way that optodes from different devices are well separated. For example, when two devices are cascaded together, the optodes from the primary device could be placed on one side of the head and the optodes from the other device on the other side. This will not only a ensure a neater arrangement of cables but would also be beneficial in terms of comfort and ease of troubleshooting.
Note that there are several NIRSite montages for download at the NIRx help center at the following location: [www.support.nirx.de/software](http://www.support.nirx.de/software)

### 9. 5. 3. Configurations in Aurora

To create a multi-device mode configuration, choose *New Configuration* in the bottom left corner in the Aurora configuration selection page.

In the pop-up window, select the *Device Type* from the drop-down menu and a relevant montage. In figure 9.15, a high-density montage with 40 sources and 40 detectors is selected. This will require three 16x16 NSP2s, or two 16x16 NSP2s plus one 8x8 NSP2.

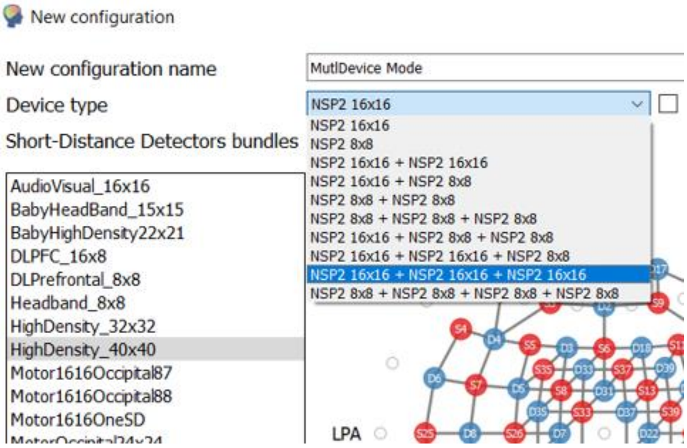



*Figure 9.17: Device selection in the new configuration window*

### 9. 5. 4. Short Distance Detectors

Similar to standard single device mode, short-distance detectors are connected to the last standard detector of the montage. For example, if multiple short-detector bundles are used in a two-device, 32x32 configuration with two short distance detector bundles, the first bundle will be connected to detector 31 - hosting short-distance detectors D31-D38 - and the second bundle will be connected to detector 32 - hosting short detectors D39-D46. In this manner, short channel bundles will always be connected to the final device in the cascade.

As always when creating a new configuration with short channel measurements, be sure to choose a montage with short channels included, and to declare the number of bundles used under the *Short-Distance Detectors bundle* drop down menu. Note that a maximum of two short channel bundles per participant are allowed for.

#### 9. 5. 5. Accelerometers

The NIRSport2 allows one accelerometer per detector bundle. If multiple accelerometers are connected, the one attached to the primary device will be labelled '*Accelerometer 1*', secondary as '*Accelerometer 2',* and so on.

#### 9. 5. 6. Sampling Frequency

The default way to illuminate sources in multi-device mode is standard time-multiplexed switching of sources in a sequential way. This standard mode allows for only one source to be activated at a particular instant of time, effectively decreasing the sampling frequency. If the need arises for higher sampling rate, the user may choose to increase the sampling rate under modulation settings. Alternatively, a bilateral or custom illumination pattern may also be chosen to increase the sampling frequency. When choosing such an illumination pattern, it is important to place the simultaneously switched source further apart in the montage in order to avoid any crosstalk. Increasing the sampling rate decreases the signal to noise ratio, and users are advised to be considerate of this fact. See section 6.2.3.2 of this manual for more information.

#### 9. 5. 7. Trigger Reception

When sending triggers via hardware (parallel port, C-pod etc), the trigger cable only needs to be connected to the primary device for trigger information to be saved for all data streams. Wireless triggers through lab streaming later (LSL) are sent directly to Aurora, and no additional setup is required.

#### 9. 5. 8. Data Visualization

Once a multi-device configuration is created, the rest of the functionality is exactly the same to single device mode. The user may choose to edit the channel names under *Edit configuration > Basic parameters* in order to better recognize channels from different devices.

### 9. 6. Standalone Recording

Once the configuration has been setup and signal optimization has been successfully completed, the NIRSport2 can be completely disconnected from Aurora to allow for data recording on the device itself. This allows the subject to move completely freely and independently of an acquisition PC. Data will be stored on the internal memory of the device itself, or a USB drive, if this is placed into the NIRSport2 before starting the recording.

To allow for operation in standalone mode, the NIRSport2 needs first to be connected to an acquisition PC running Aurora. As usual, the NIRSport2 can be connected to an acquisition PC via provided USB cable or Wi-Fi. Note that starting the experiment from Wi-Fi has different considerations that from USB, as detailed in the following sections.

### 9. 6. 1. Wi-Fi to Standalone Mode

Connect the NIRSport2 via Wi-Fi as usual, as noted in section 4. 2. Wi-Fi connection can be either direct, or through a dedicated access point, as noted in section 6. 3. 1. 1. Proceed with configuration selection, subject setup and signal optimization as usual. Once excellent signal quality is achieved, it is advisable to run a preview recording to make sure data quality is as expected.

#### 9. 6. 1. 1. Disconnect the NSP2 from Aurora

Next, the device may either be disconnected before starting a recording (see next section) or during one. For the latter, click the *Disconnect device* button, as seen in 9.18

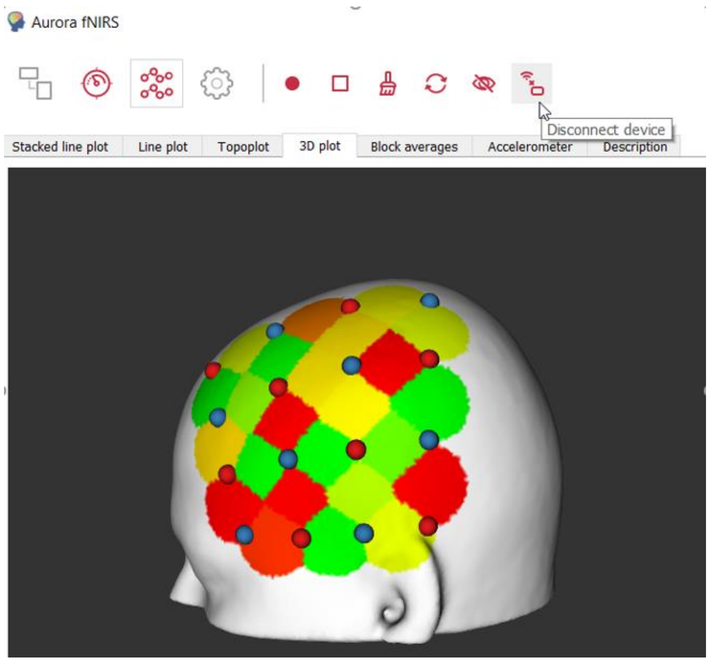



*Figure 9.18: The Disconnect device button on the data recording supporting navigation pane*

Aurora will disconnect the device and return to the main page for device selection, as in Figure 9.19. In the right information panel, there will be a notification that the *Device is taking data!* meaning that it is recording in standalone mode.

Aurora may be now be closed. The NIRSport2 is taking data independently, in standalone mode.

### 9. 6. 1. 2. Starting a Recording in Standalone Mode

If the NIRSport2 was disconnected from Aurora before starting a recording, the recording will need to be started by operating the NIRSport2 rear panel.

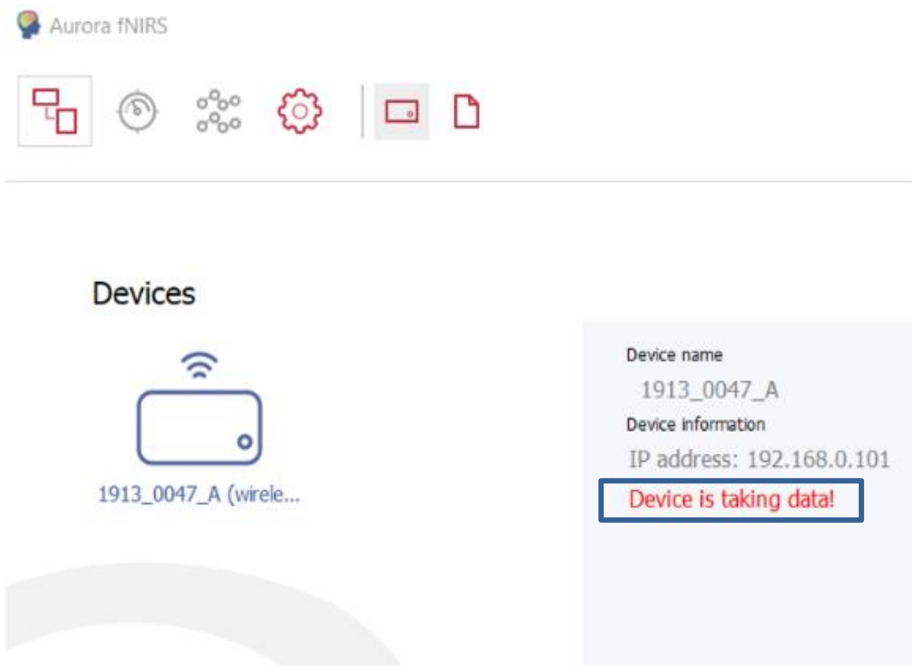



*Figure 9.19: Device selection page, indicating that the device selected is recording in standalone mode.*

Start recording by pressing the F1 button on the device rear panel for 3-4 seconds. If the device started recording successfully, the status of the LED indicators should change accordingly (all three LED indicators turn green, as shown in the table below).


*Figure 9.20: (Bottom) Table of LED Colors and their Meaning, (Top) The Rear Panel of the NIRSport2*

| F1 | F2 | ⏻ | System Status |
|---|---|---|---|
| 🔵 | 🟢 | 🟢 | System idle |
| 🟢 | 🟢 | 🟢 | System running (data acquisition) |
| 🔴 | 🟢 | 🟢 | Error |

**Please note that if data recording started via Wi-Fi before disconnecting, it does NOT need to be started through the device rear panel** – the status of the LED indicators should immediately show that the device is taking data recording is started via Wi-Fi connection.

#### 9. 6. 1. 3. Stopping a Recording in Standalone Mode

Recording may be stopped either directly through the device rear panel, or through Aurora (if the experiment was originally started via Wi-Fi).

1. To stop a recording from the device rear panel, simply press the F1 button for 3-4 seconds. The corresponding LED indicator should turn to blue from green, as shown below.

| F1 | F2 | ⏻ | System Status |
|---|---|---|---|
| ● (blue) | ● (green) | ● (green) | System idle |

2. To stop a recording from Aurora, the NIRSport must be reconnected to Aurora.
   a. Launch Aurora as usual. Your acquisition PC should be connected via Wi-Fi to either the NIRSport 2 directly, or the hotspot, if you are using one.
   b. Your device should appear in the list, with the indication “Device is taking data!” as shown in Figure 9.19. Select the device and proceed.
   **c.** Aurora will reconnect and display incoming data. Click Stop recording, as usual**. If standalone mode is enabled, data is stored on the NIRSport2 device, and not the data acquisition PC.**

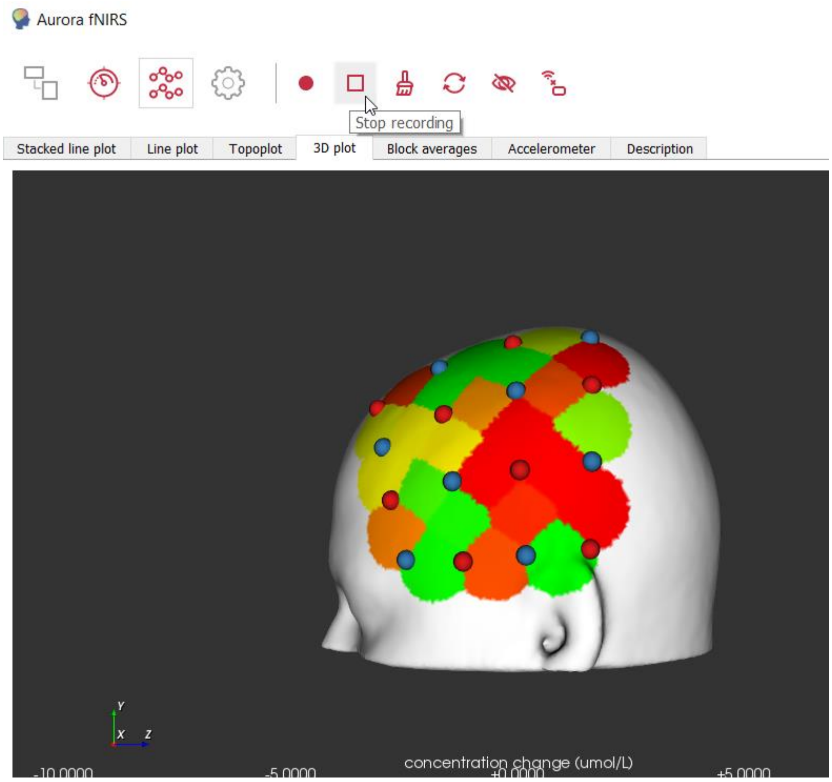



*Figure 9.21: If the experiment was originally configured via Wi-Fi, the data recording may be stopped by reconnecting to Aurora and selecting the Stop recording button*

IMPORTANT: If Aurora is running and connected to your NIRSport 2 device, do NOT stop the recording through the device rear panel, by pressing the F1 button. This is to be used only when Aurora is disconnected or closed.

### 9. 6. 2. USB to Standalone Mode

Connect your NIRSport 2 via USB as usual, as noted in section 4. 1. Proceed with configuration selection, subject setup and signal optimization as usual. Once excellent signal quality is achieved, you may want to run a preview recording to make sure data quality is as expected.

#### 9. 6. 2. 1. Disconnecting the NIRSport 2 from Aurora

Simply unplug the USB cable from the computer running Aurora and from the NIRSport 2. You may also close Aurora now. Do NOT start a recording via Aurora when connected via USB.

#### 9. 6. 2. 2. Starting and stopping a recording

A. As described in *Starting a Recording in Standalone Mode (*section 9. 6. 1. 1), start recording by pressing the F1 button on the device rear panel.
B. As described *Stopping a Recording in Standalone Mode* (section 9. 6. 2. 2), stop recording by pressing the F1 button on the device rear panel.
C. If one wishes to start another recording on the same subject (with the same signal optimization results), simply press the F1 button again to start another recording.
D. Retrieve the data from the NIRSport2 device as described in section 9. 2 of this manual.

When working in USB mode, the NIRSport 2 device needs to be disconnected before the recording, and not during, as possible in Wi-FI mode. You are also not able to reconnect to the device from Aurora, while the device is taking data. Do not attempt to connect the device to Aurora via USB while the device is taking data – this will stop data recording.

### 9. 6. 3. Where is Data Stored in Standalone Mode?

The NIRSport2 device has an internal storage of 4GB, 2.7GB of which can be allocated for data storage. When running the device in standalone mode, the data will be always stored on the device itself.

Before starting a new recording, the NIRSport2 will make sure that at least 1.5GB are available for data storage. Existing data will be deleted if not enough storage is available**.** Before proceeding with a new recording, make sure to retrieve all data from the device; see steps for doing so in section 9. 2 of this manual.

With 16 sources and 16 detectors and at highest sampling rate, the minimum storage space needed of 1.5GB is enough for 8 hours of continuous recording. With 8 sources and 8 detectors or at lower sampling rate, more than 8 hours of data can be recorded. If the user plans on running a multi-hour experiment, it is recommended to pilot data collection with the configuration that will be used, for about as long as the experiment will run (plus some added time, for cushioning) to ensure that there is enough storage for the experiment onboard the device.

If this capacity is not enough, you may use an additional USB drive (recommended >4GB). Please insert the USB drive into the NIRSport 2 USB port before starting a recording.

If a USB drive is available and recognized by Aurora before starting a recording, data will be stored both on the NIRSport 2 device itself and the USB drive. If the device internal memory runs out of storage space, data will be securely still stored on the USB drive.


### 9. 6. 4. Triggering in Standalone Mode

It is possible for a device recording in standalone mode to receive hardware TTL triggers via the trigger-in cable. LSL triggers in standalone mode are not supported, nor are manual F triggers in Aurora.

## 9. 7. NIRxWINGS

The NIRxWINGS module for peripheral physiology measurements extends the NIRSport2 possibilities allowing the user to collect pulse oximetry (PPG), heart-rate, heart-rate variability (HRV), oxygen saturation (SpO2), respiration, temperature, galvanic skin response (GSR), and bipolar signals such as EMG and ECG. All signals fully synchronized and in one data stream.

Wireless data transfer allows the participant to move freely while real-time data is stored on the device, but also streamed, and displayed in real-time.

### 9. 7. 1. Hardware setup

For detailed information about how to connect the NIRSport2 with the NIRxWINGS please refer to the *NIRxWINGS Hardware Manual* or the *Getting Started Guide* on NIRxWINGS.

After connecting the NIRxWINGS dongle to the NIRSport2 and turning both devices on, Aurora should be able to detect the combined setup and label it with an icon in the shape of wings, as seen in the red box in Figure 9.22.

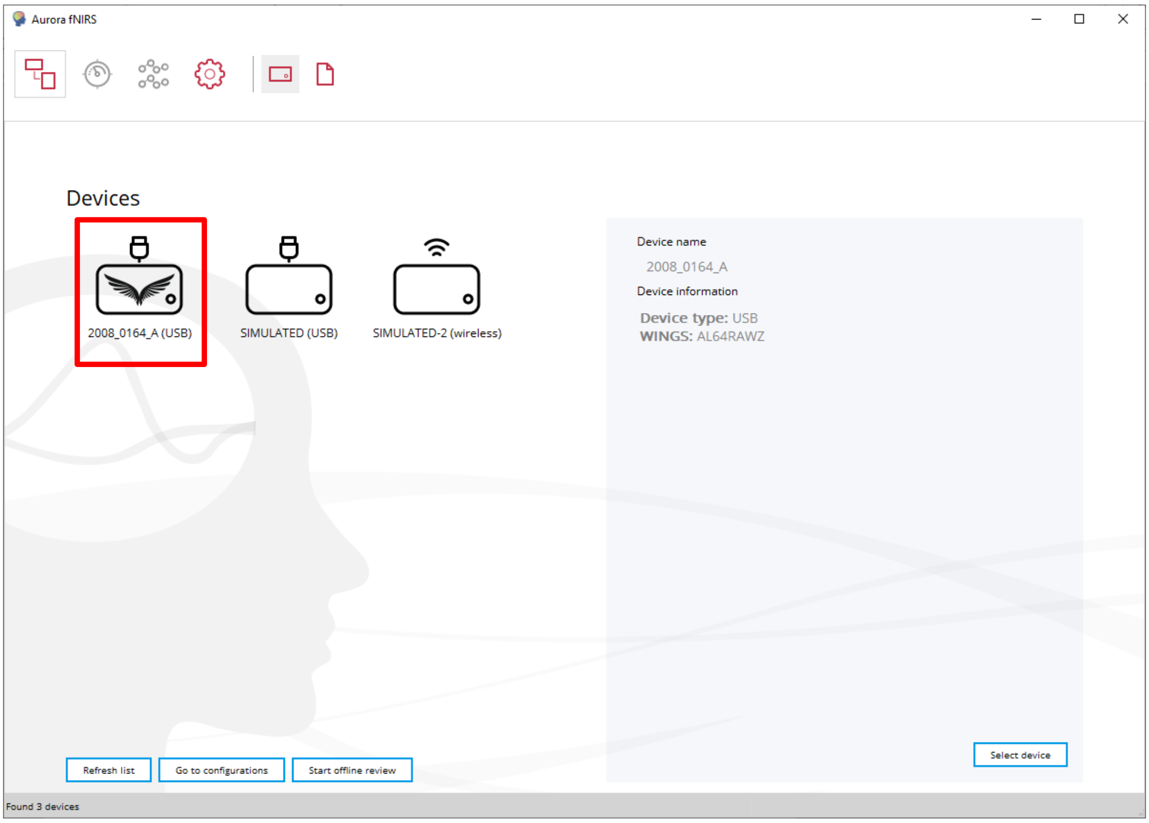



*Figure 9.22*

## 9. 7. 2. Creating a new Configuration

A new configuration with NIRxWINGS may be created by using the *New Configuration* button and checking the Biosignals checkbox (Figure 9.23, red box). It is not necessary to edit the montage file to accommodate them; the cap setup can be configured as usual (i.e., with short-distance detectors, accelerometer…).

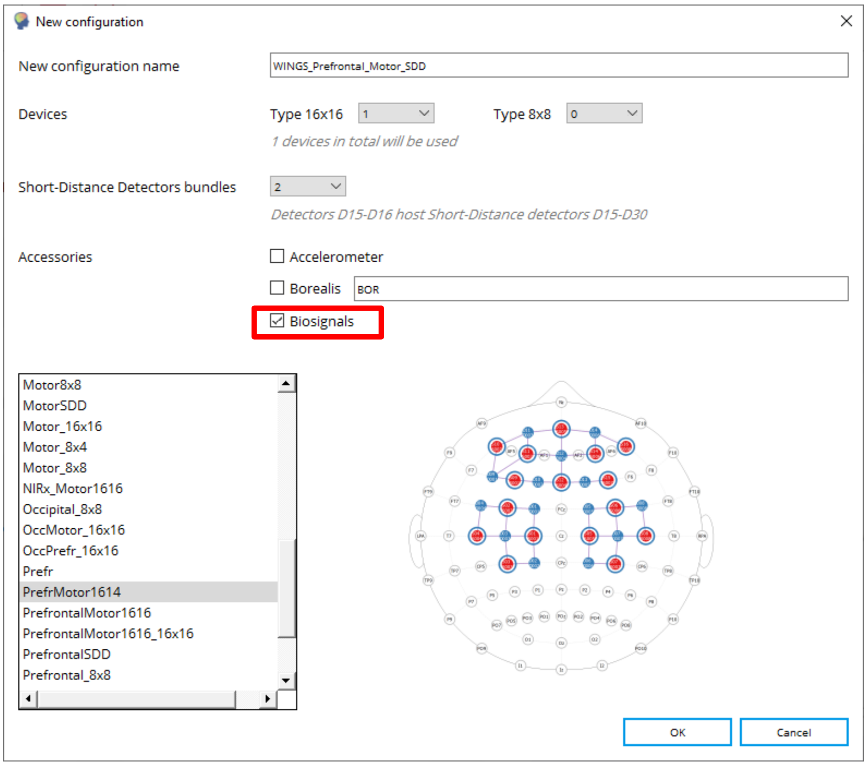



*Figure 9.23*

To add NIRxWINGS to a pre-existent configuration, the user should go to *Edit Configuration* and under the *Basic Parameters* tab there will be a Biosignals checkbox to be enabled.

After enabling the Biosignals option one way or another, the Configuration details should look as depicted in Figure 9.24.

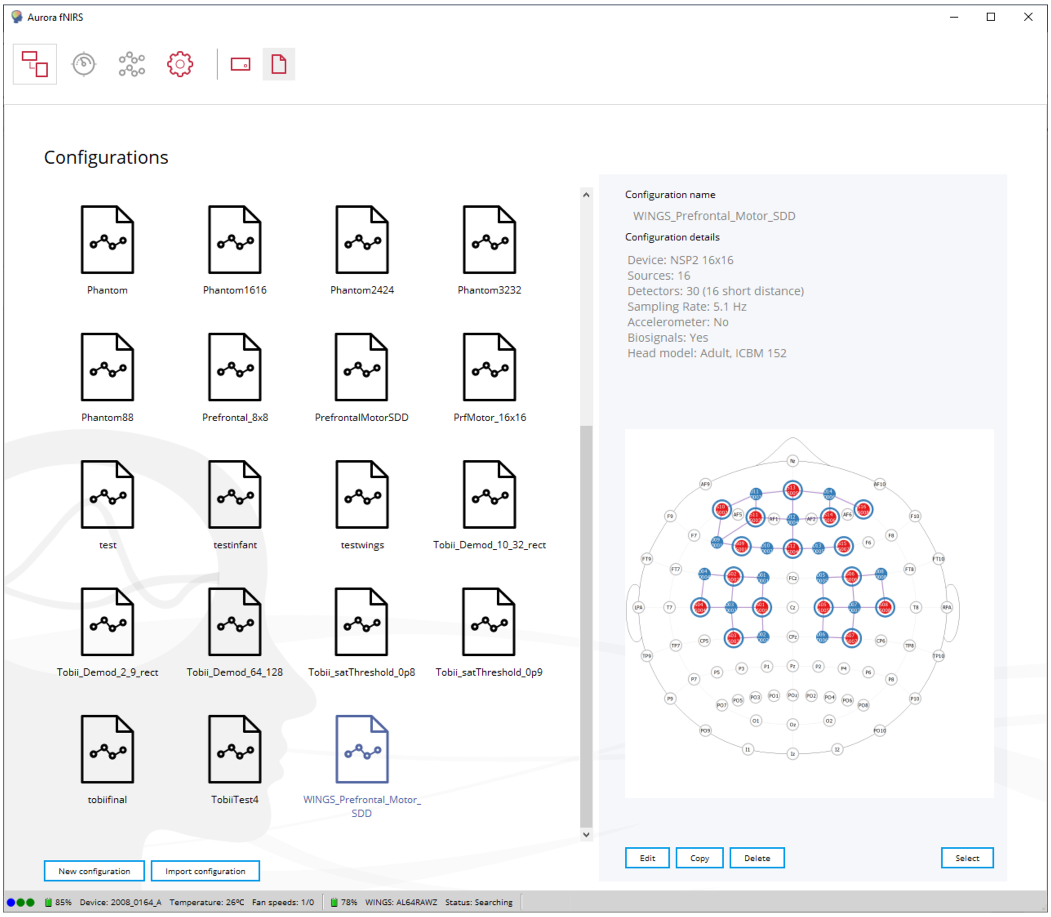



*Figure 9.24*

The information bar at the bottom of the Aurora window shows the details about the selected NIRSport2 device and the NIRxWINGS, whose Status will be *Searching* until the data recording is started.

### 9. 7. 3. Data Recording

Enabling the biosignals option generates an additional tab called Biosignal, which contains all the possible sensor connections, also called Biosignal channels (See Figure 9.25). These are ExGa1 to ExGa4, ECG, Resp, PPG, SpO2, HR, GSR and Temperature.

These signals may be individually modified to improve the visuals by single clicking over the chosen channel, which will turn its background pale yellow, as shown for ExGa4 in Figure 9.25. The scale and filtering options will then be enabled. The recorded data is stored independently from the options chosen within these panels, scale and filtering parameters only apply to visualization.

Double clicking on a signal will hide it on the display.

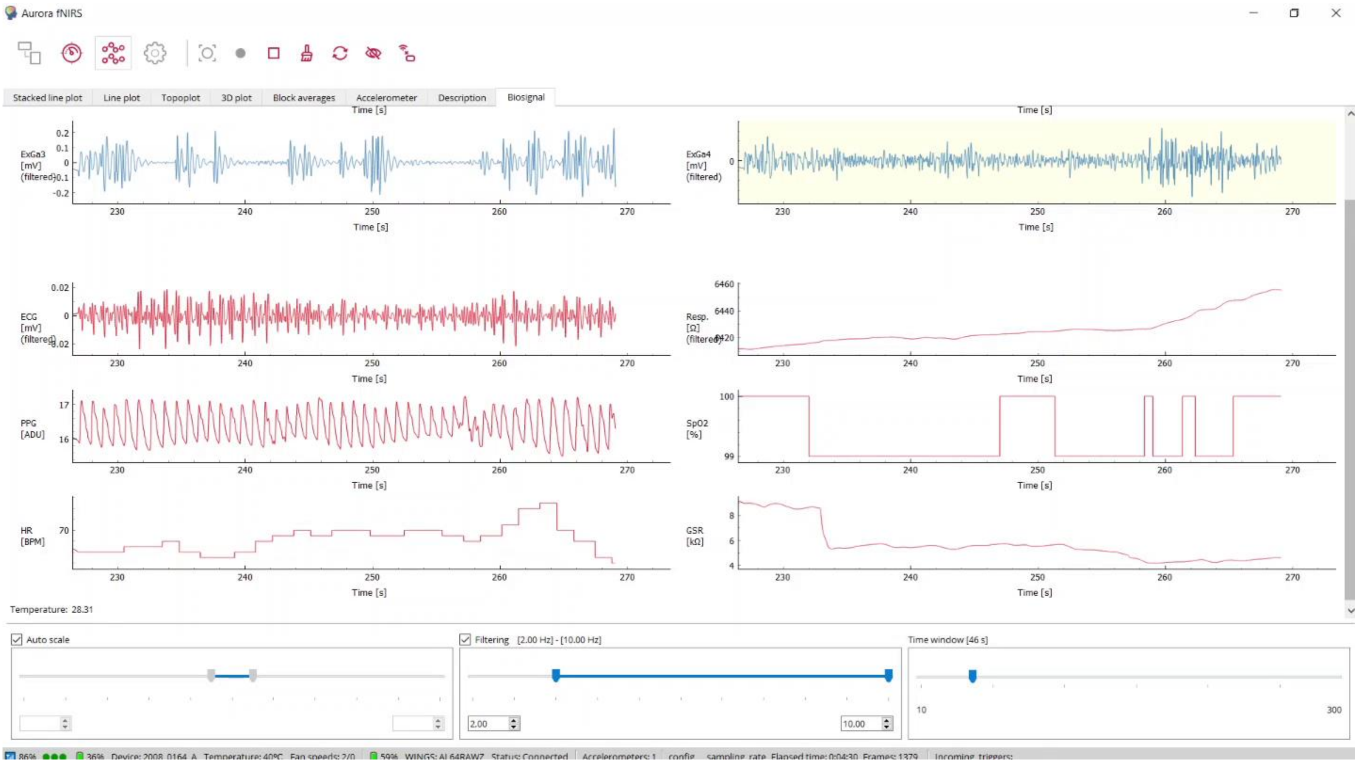



*Figure 9. 25*

For a more comfortable view of the experiment, one can double click on the Biosignal tab to extract it from Aurora. This will create two separate Windows of the software, allowing to observe the fNIRS and the physiological signals at the same time (See Figure 2.26).

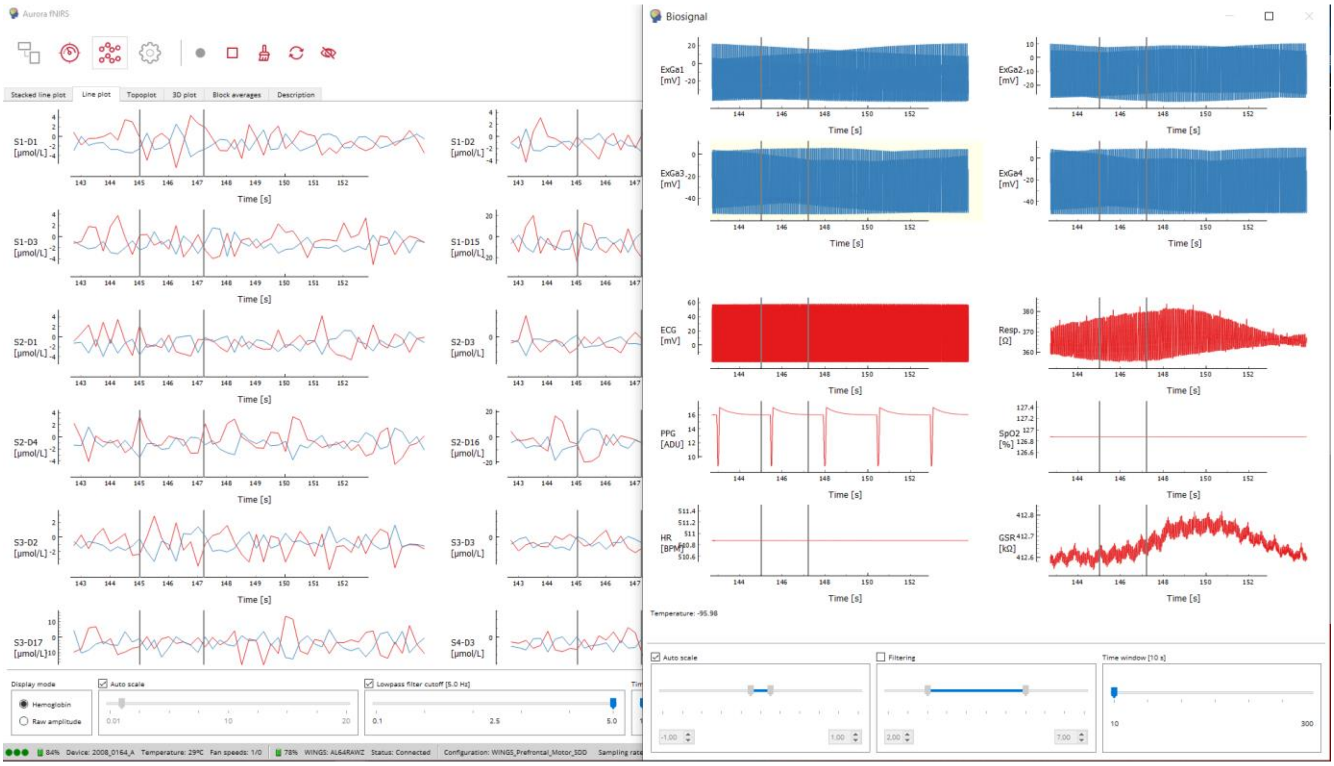



*Figure 9.26*

The recorded data is automatically stored in the following files: *.snirf (as Aux variables) and in *.wings (see more information under section *8. Data Formats*).