Getting Started

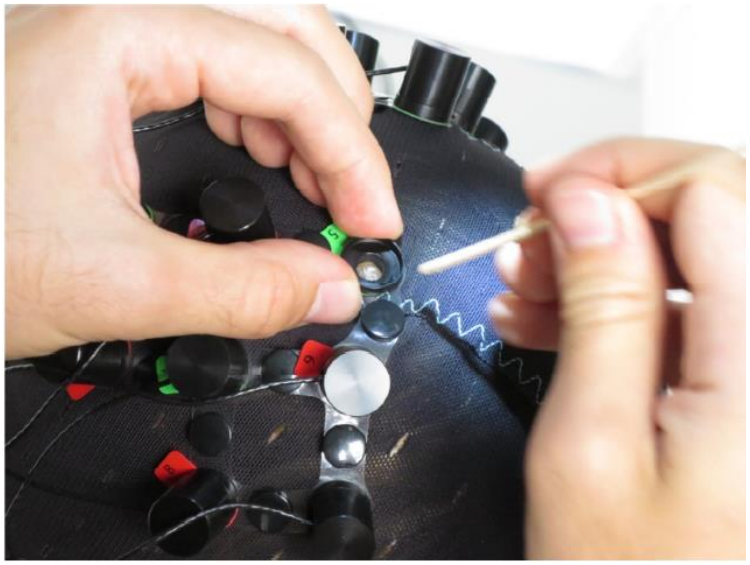
SIGNAL QUALITY

IMPROVING SIGNAL QUALITY

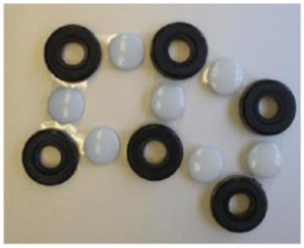
HOW TO IMPROVE THE SIGNAL QUALITY?

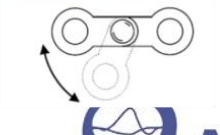
In order to obtain good signal quality, please make sure to always follow these guidelines:

- **It is very important to ensure low-loss optical contact between the skin and the optical interface**. When placing both sources and detectors, please take care to properly part the hair in such a way that, when looking through the retaining ring, a clear view of the scalp can be achieved. **NIRX suggests to use wooden applicators, like for example one-sided cotton swabs to part the hair.** The applicator should be used to displace the hair and sweep it underneath the optode holder. It may help to gently lift the holder and reseat it once the hair is parted. **NIRX recommends the use of preparation gel** (non conductive clear gel), especially in subjects with particularly dense hair. The gel improves the optical contact and makes it easier to part the hair**. When preparing the hair, it might be very useful to help yourself with a light source** that can be directed to well illuminate the optode holders, like for example a head lamp.



- **It is very important to stabilize the probes on the skin to prevent signal variations and artifacts due to motion**. NIRX has developed several tools that will help you stabilize the optodes on the skin and minimize motion artifacts:
    - **Stiffening joints should be used to increase the mechanical rigidity of the optode holder arrangement** and to facilitate a more equidistant probe arrangement. These stabilizers are also well suited to restrict the holder distance to exactly 30 mm in cases where the neighboring holders are farther apart.





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- **To avoid undue torque and tipping of the probe tips, fiber optic cable and wire organizers should be used**. These facilitate the routing of the fiber optic cables and relieve mechanical strain. Each of them can hold up to eight fiber optic cables and eight wires. Cable organizers are designed to fit into the optode holders, and should be placed in the same way optodes are. Depending on the region of interest, you should place the cable organizers in a way that optimizes the spatial arrangement of the fiber optic cables and wires. One cable organizer should be dedicated to each group of optodes. The central slots are dedicated to the fiber optic cables while the lateral thinner slots are dedicated to the wires of the sources. If the cable organizers have been placed correctly, any movement of the fiber optic cables or wires under the organizers themselves should not translate to the optodes, which should have constantly good and stable contact with the skin.

- **In order to exert an even pressure onto the probes and stabilize the setup against motion, overcaps (retaining caps) should be used**. Since the overcaps are made of stretchy fabric and zip fasteners, they exert even pressure over the optodes, improving in this way the optical contact. The zip fasteners should be used to tighten the overcaps and control in this way the pressure the overcaps impose to the underlying optodes. Ideally, optodes in every region of the head should have an equally good optical contact with the underlying skin. Due to the shape of head, this is generally hard to achieve. The overcap, thanks to its strategically positioned zip fasteners, should help you achieve good optical contact even in regions where, due to the shape of the head, it is more difficult to stabilize the optodes.

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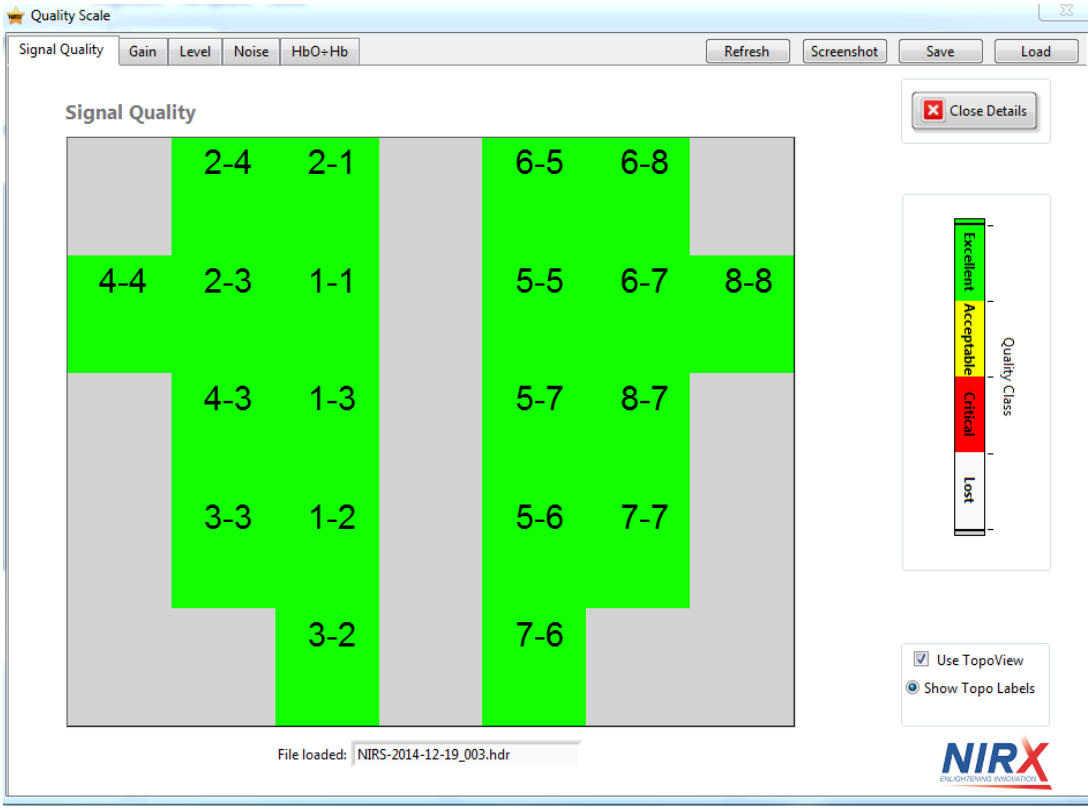
- **It is very important to keep the interoptode distances below a threshold value.** The recommended distance between each source and detector is about 30mm. Slight deviations are permitted, especially in the frontal area, where the penetration depth of light is higher. As mentioned earlier, the NIRX stiffening joints have been designed to limit the distance between each source and detector pair to about 30mm.

How to check signal quality?

Check the signal quality before recording



- **Always analyze carefully the results of the calibration.** Please make sure to run the "Quality Scale" tool that you will find in the NIRStar "System setup" tab, after you perform the calibration. The quality scale is a complex indicator composed of several parameters that affect the signal quality: the gains, the signal level, the noise level and a hemodynamic index, based on the computation of the standard deviations of the extrapolated HbO and Hb values. The quality scale tool uses a simple color scale to display the quality of the signal. Before proceeding with your measurements, make sure that all channels that you have defined in your topolayout file are displayed green or considered "excellent". Yellow channels could also be accepted. Each of the parameters that compose the "Signal quality" index, can also be viewed one by one: the gains, the signal level, the noise level and the hemodynamic index. If the signal quality of one or more of your channels is not acceptable, you should review all parameters, in order to have a better understanding of the problem.
    - There is an inverse relationship between gain and the intensity of the received light: the weaker the light signal, the more it must be amplified. This increases the noise level also. Channels are considered "lost" if, even when applying the maximal amplification to the detected light, the recorded signal level amplitude is not sufficient.

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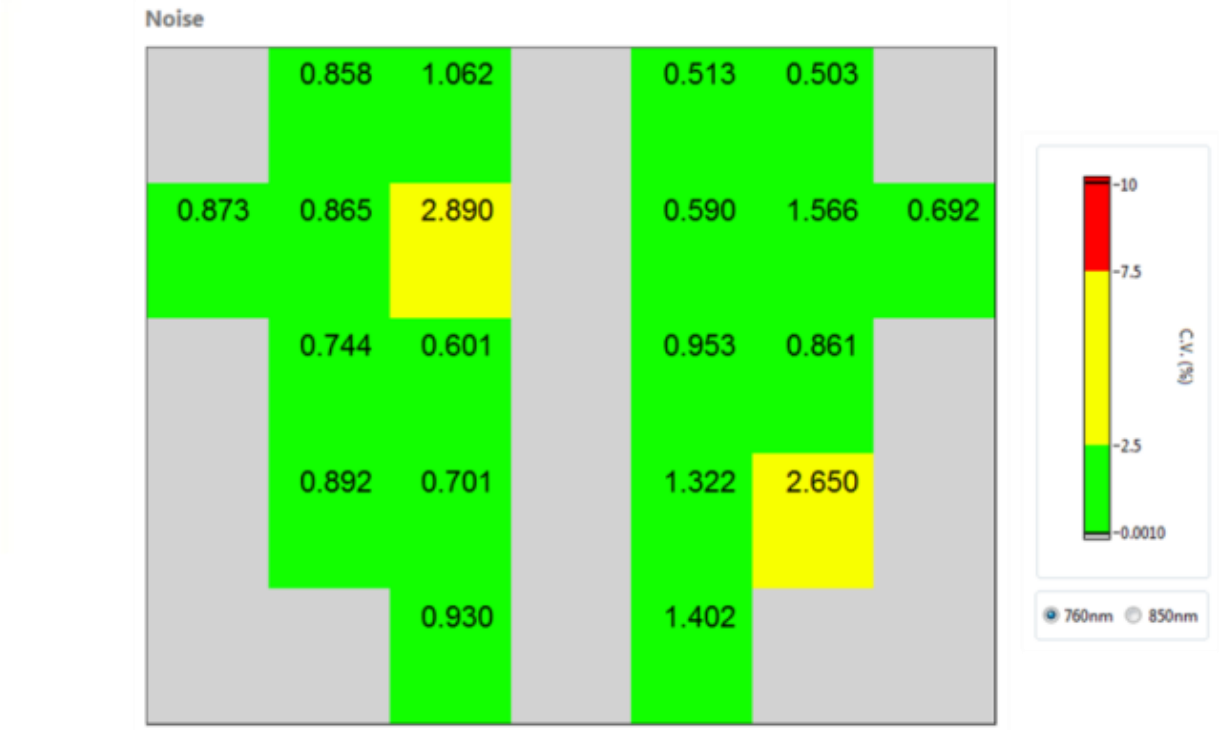
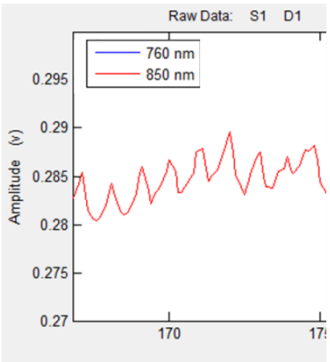
- The noise is computed as “Coefficient of Variation (CV)”. This is an indication of the variability of the signal with respect to its mean value. All channels that have a CV > 15% will most probably not yield to good signal quality.



- The computation of the hemodynamic index as the ratio of the standard deviation of the calculated HbO to that of the Hb is based on the assumption that, physiologically, the HbO signal always shows higher amplitude deviations at physiological frequencies (that of a heart rate for example). The hemodynamic index does not have the same weigh as the other above mentioned parameters when computing the overall signal quality index. If the signal level is very low and the noise level very high, the corresponding channel will be discarded by NIRStar no matter what the value of the hemodynamic index is.

If one or more of you channels do not have acceptable signal quality, please try to improve the optical contact between the optodes and the skin. Please see the “How to improve the signal quality?" section.

- **Preview the data and check for the presence of the heart beat**. Before starting a recording you should always preview the data and visually inspect it. If you can detect oscillations at a pace of approximately 1Hz on all channels, most probably the signal quality of the data is good. However, the absence of the heart rhythm does not necessarily mean that the signal quality is bad. In this case, the “Quality scale” tool of NIRStar should be give a better understanding of the signal quality.
- **Check the robustness of the signal quality to motion.** If the headgear has been setup properly, motion artifacts should not be seen in the data. If, for example, the fiber optic cables or wires are moved or if the subject moves his/her head, the quality of the signal should not deteriorate.

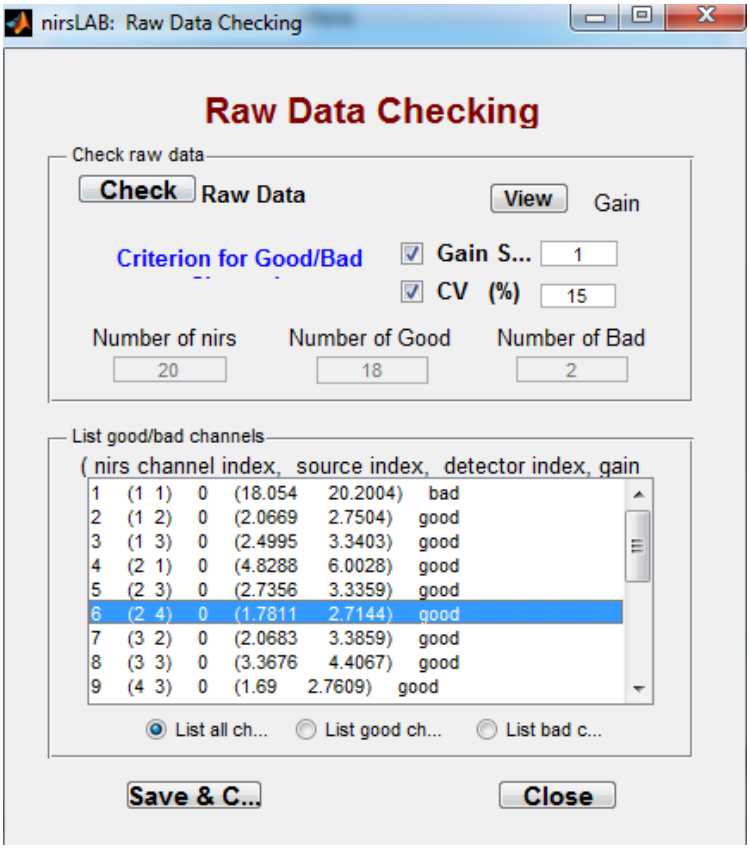


Check signal quality of recorded data

There are several ways to check the signal quality offline. Which is the most convenient for you, depends also on your analysis workflow.

- **Check the signal quality with the NIRStar “Quality scale” tool**. NIRStar allows you to load a previously recorded dataset to check the signal quality of each channel, just like right after performing calibration. In the “System setup” tab, run

the “Quality scale” tool. Through the dedicated button in the top left corner, load the recorded dataset. Check the signal quality of each channel, as described in the “Check the signal quality before recording” section.



- **Check the signal quality with the nirsLAB “Check raw data” tool**. If you plan to analyze your data in nirsLAB, we recommend to use this tool before proceeding with the analysis. In the nirsLAB main window, in the “Data preprocessing” group, launch the “Check raw data” tool, after having loaded your dataset. nirsLab allows you to choose which criteria to use when checking the signal quality: the gain settings and the coefficient of variation. As explained earlier, the signal-to-noise ratio of data decreases as the gain factor increases. Consequently, nirsLAB allows you to identify the channels that have gain factors higher than a value that you select, and exclude them from consideration in the subsequent processing and analysis steps. The default value is 8. Please remind that the possible gains depend on the system that you are using (for the NIRScout up to 9, for the NIRSport up to 5). As explained earlier, the coefficient of variation is defined as 100 times the standard deviation divided by the mean value, where the standard deviation and mean are computed from all of the raw-data values in the measurement time series. The recommended value of 15% is set as default. The two criteria can be selected independently one from another. Once you have chosen which criterion or criteria the use, proceed to “Check” the raw data. All channels will be then labeled as either good or bad, depending on the criteria you have chosen. The bad channels can be then discarded and will not be considered for further analysis. Tipp: you can double click each of the channels in the list to open the corresponding time plot.
- **Check for the presence of the heart beat.** As explained earlier, if you can detect oscillations at a pace of approximately 1Hz on all channels, most probably the signal quality of the data is good. However, the absence of the heart rhythm does not necessarily mean that the signal quality is bad.

Please remind that this short guide is intended only to address the signal quality issue. For further information on any of the above mentioned functionality please check the user guide of the NIRSport, NIRScout, NIRStar and nirsLAB.

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