Hands-on Part I: create your montage and build your cap

Dalila Burin, Franziska Keller
Scientific Consultants – NIRx

6.5.2025 SYNCC lectures and workshops - Warsaw

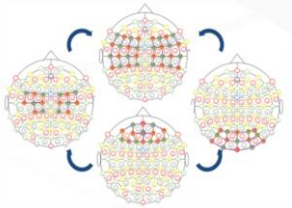
Montage Design Flow

NIRx

Decide on regions and check literature

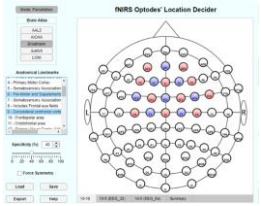
Download premade montage

support.nirx.de/software > Montages



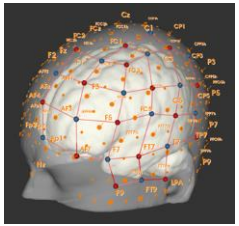
Use software tool to suggest targeting

github.com/nirx/fOLD-public
github.com/DOT-HUB/ArrayDesigner



Edit/Create Montage in NIRSite

support.nirx.de/software > NIRSite

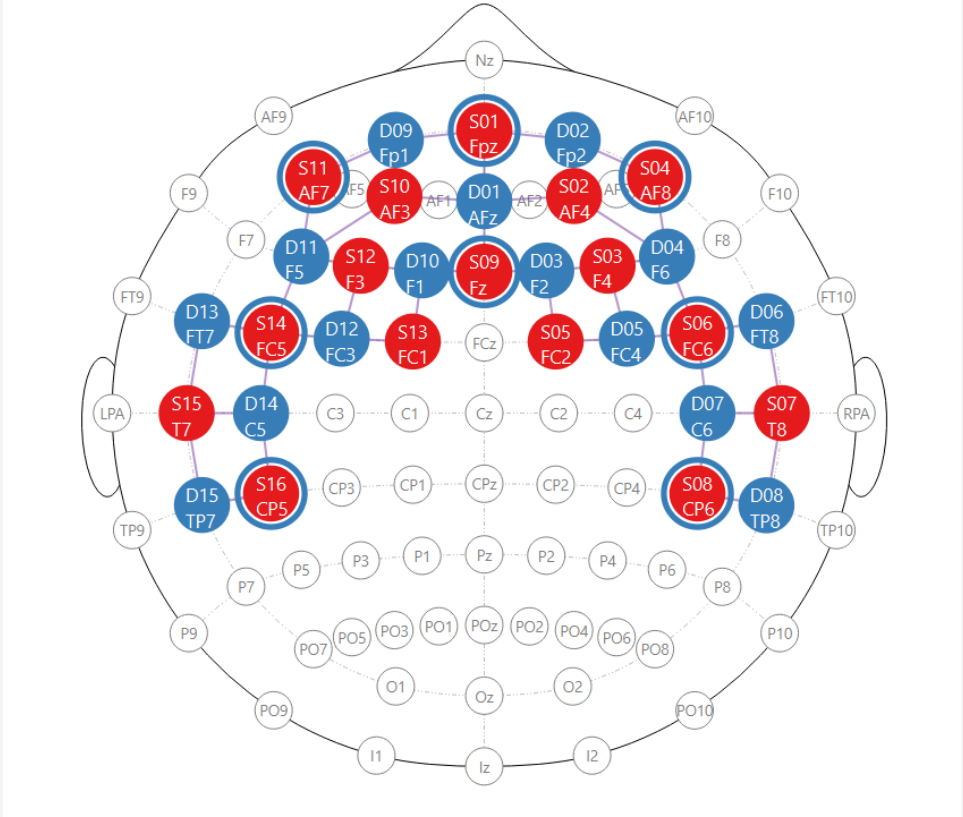


Export Montage for Data Acquisition

https://github.com/nirx/fOLD-public

Optode locations reference sheet

NIRx



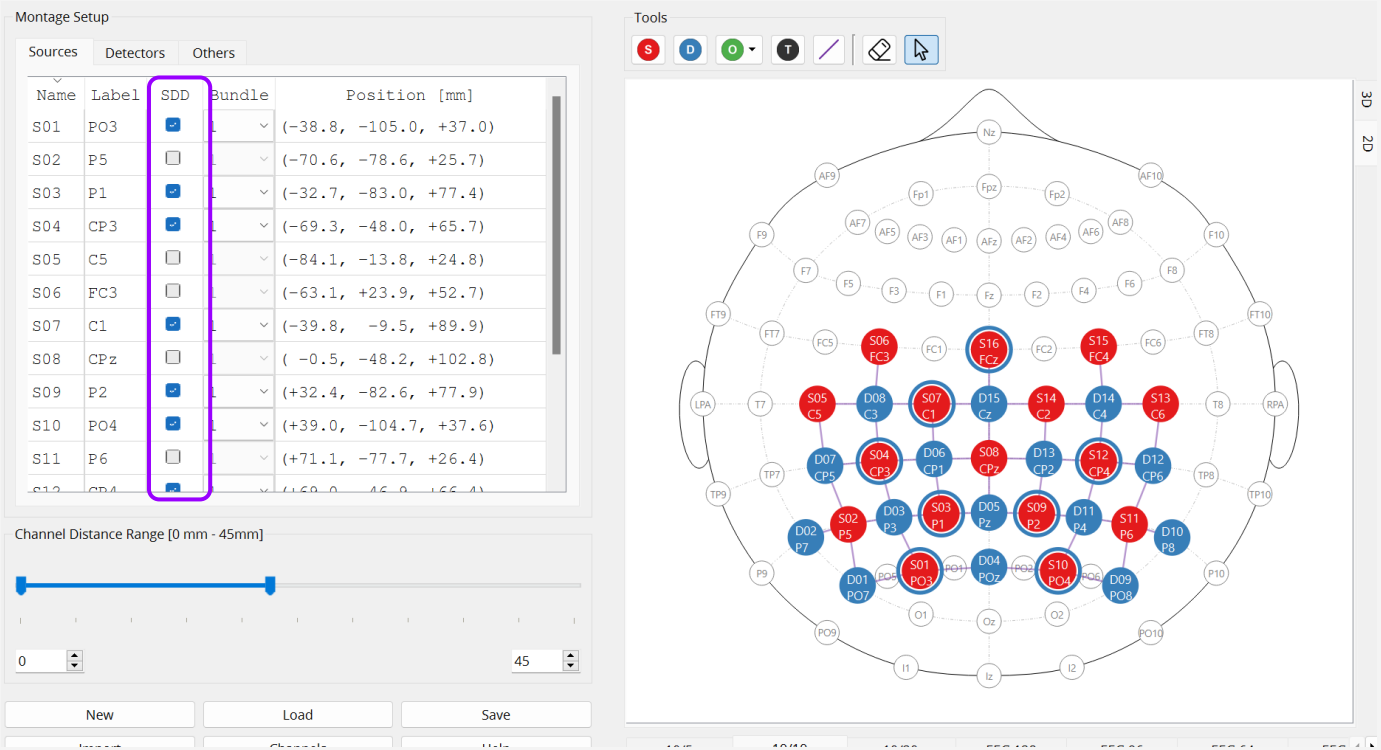
See NIRSite 2025.2!

Source-detector distances [mm]

Automatic channels

	D01	D02	D03	D04	D05	D06	D07	D08	D09	D10	D11	D12	D13	D14	D15
S01	39.9	29.9	76.8	77.3	108.2	108.5	135.3	158.7	30.4	77.2	78.4	109.3	110.0	137.1	159.8
S02	38.7	31.4	45.4	41.2	70.6	84.4	103.3	136.5	71.7	78.8	104.7	118.4	136.2	151.4	175.6
S03	58.2	62.8	30.3	30.4	36.8	74.0	76.5	117.8	99.8	83.2	119.5	119.8	148.0	152.9	177.2
S04	74.5	29.8	79.6	35.5	83.7	59.4	96.3	118.3	84.9	112.5	123.8	143.9	144.3	166.6	180.1
S05	80.1	108.1	38.9	76.5	37.0	105.8	81.9	126.3	126.0	75.1	122.8	101.6	150.1	137.2	167.5
S06	100.3	87.1	73.4	33.7	37.0	37.3	33.4	73.1	128.9	119.9	145.3	144.0	160.8	164.8	177.4
S07	137.6	113.8	118.6	72.6	82.1	30.0	41.1	31.0	151.1	154.6	164.7	167.1	166.2	173.5	171.8
S08	153.6	147.9	123.0	99.7	77.8	76.6	34.3	40.9	177.7	157.4	176.9	163.6	178.9	170.0	172.0
S09	39.8	87.6	30.2	85.5	74.0	124.0	119.0	157.5	87.8	30.4	86.1	74.9	125.0	120.5	158.2
S10	39.1	71.6	78.7	104.1	117.7	135.2	150.1	174.9	31.6	45.6	41.9	71.5	85.5	104.9	137.4
S11	75.3	85.4	112.9	123.8	143.7	143.8	165.9	179.8	30.4	80.1	36.0	84.4	60.3	97.8	119.1
S12	59.0	100.1	83.3	119.3	119.3	147.4	151.9	176.6	63.4	30.5	30.6	37.2	74.7	77.7	118.3
S13	80.8	126.3	75.6	122.8	101.4	149.8	136.4	167.1	108.7	39.2	76.7	37.2	106.2	82.8	126.6
S14	101.5	129.7	120.5	145.5	144.0	160.6	164.2	176.9	88.3	74.1	34.1	37.0	37.5	34.0	73.1
S15	139.4	152.6	155.9	165.6	167.8	166.8	173.7	171.8	115.7	119.9	73.7	82.7	30.6	41.1	30.4
S16	154.6	178.2	158.0	177.2	163.9	179.0	170.0	171.8	148.9	123.7	100.0	77.9	76.5	33.6	40.8

Short Channel Considerations



*** Always use highest numbered detectors:** For instance, if using two short channel bundles, they must be connected to detectors 15 and 16

Montage Resources

Montages

- support.nirx.de/software > Montages

Guides

- NIRx NIRSCap User Guide
- **NIRx Montage Design for fNIRS Experiments

Videos

- NIRSite Refresher Course
- fNIRS Montage Design using fOLD toolbox

Automated fNIRS Montage Design Tools

- github.com/nirx/fOLD-public
- github.com/DOT-HUB/ArrayDesigner

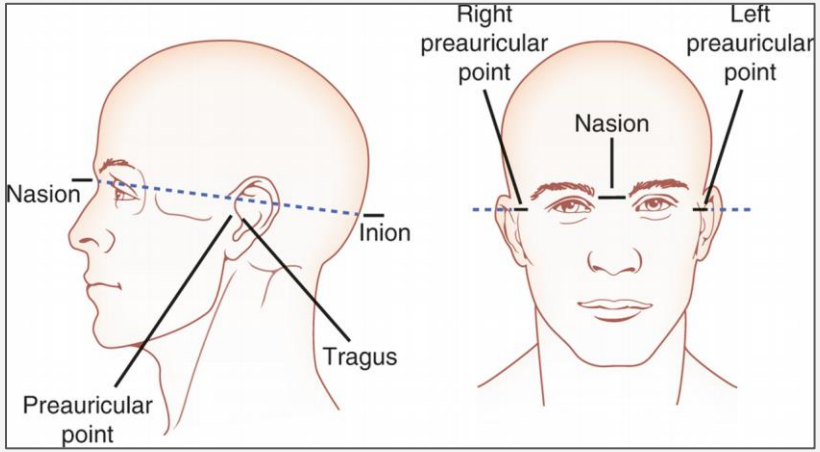
Manual fNIRS Design Software

- support.nirx.de/software > NIRSite
  - NIRSite User Manual

Other Tools

- Montage powerpoint template

Sizing the Cap



Cap Size/Head Circumference (cm	Men	Women	Children/Teens	Toddler	Infants	Slit #
20					Pre-term week 22	32 slits
22					Pre-term week 24	32 slits
24					Pre-term week 26	32 slits
26					Pre-term week 28	32 slits
28					Pre-term week 30	32 slits
30					Pre-term week 32	32 slits
32					Pre-term week 34	32 slits
34					Pre-term week 37	32 slits
36					Newborn	32 slits
38					1-month	32 slits
40					3-months	32 slits
42					5-months	64 slits
44					7-months	64 slits
46				1 year		64 slits
48				2 years		64 slits
50				3-4 years		128 slits
52			5-10 years			128 slits
54		Small Female	11-14 years			128 slits
56	Small Male	Medium Female	15-17 years			128 slits
58	Medium Male	Large Female				128 slits
60	Large Male	Extra Large Female				128 slits
62	Extra Large Male					128 slits

Populating the Cap

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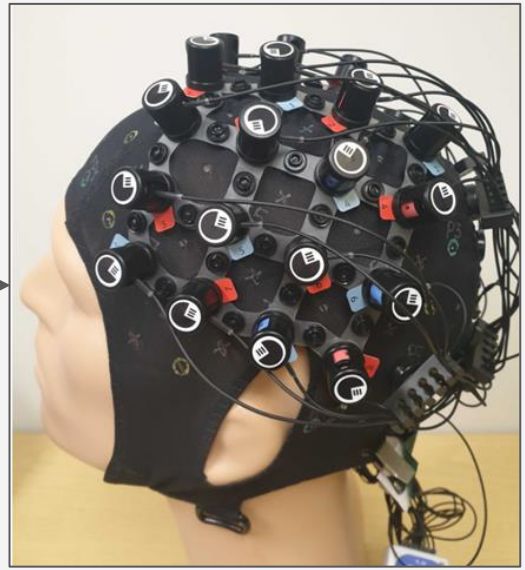
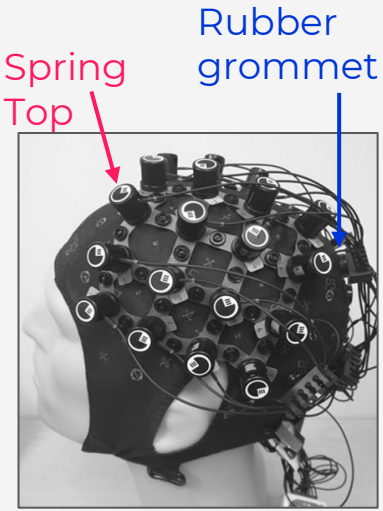
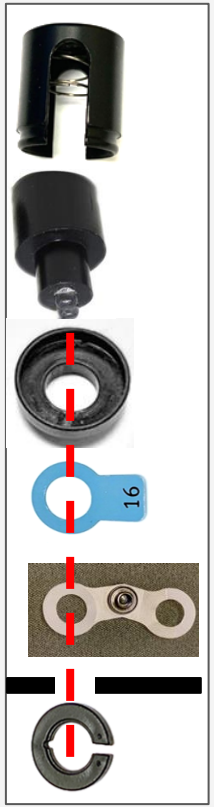


Cap preparation

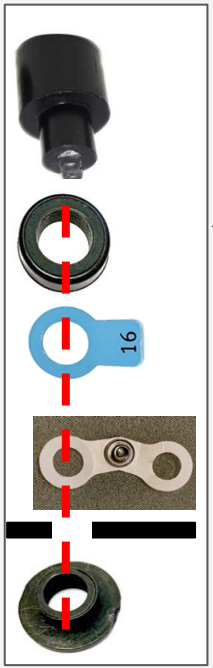
Optode Installation

Spring Top
(Pressure Fit)

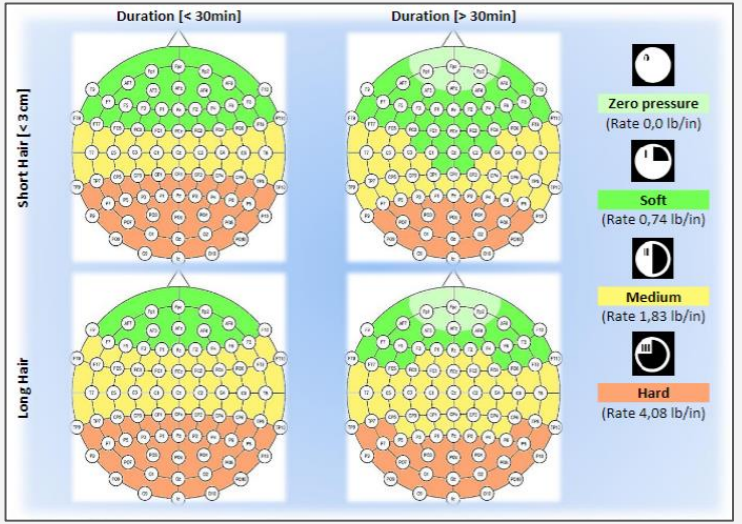




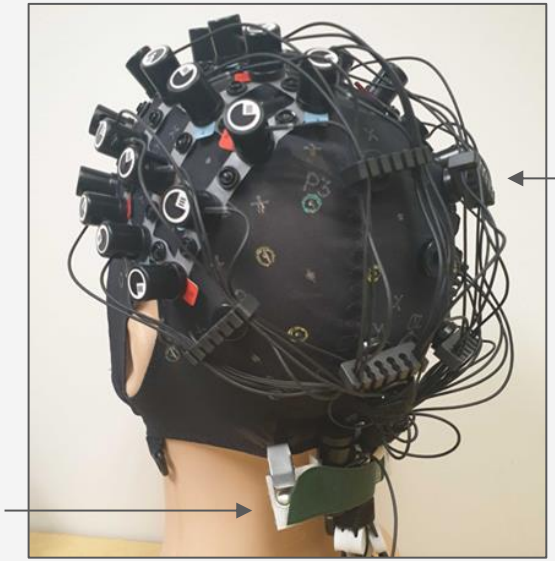
AC/Standard
(Friction Fit)



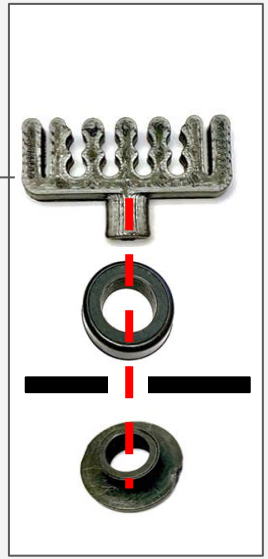
Spring Top Pressure Levels



Cable Management



Velcro Clip

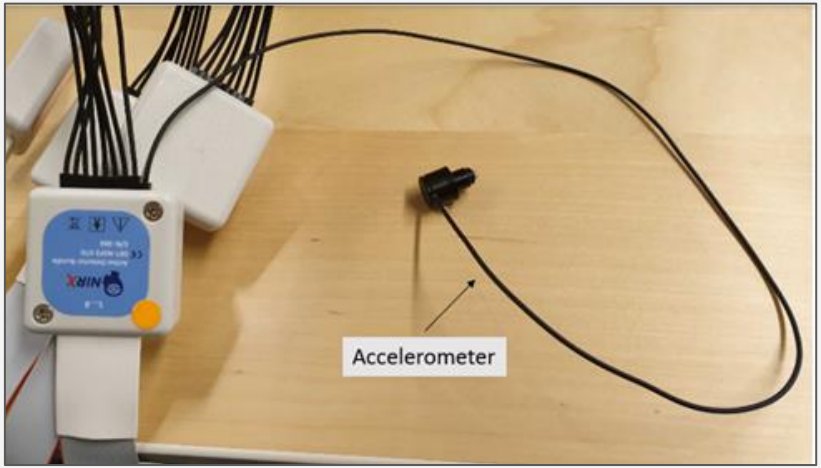


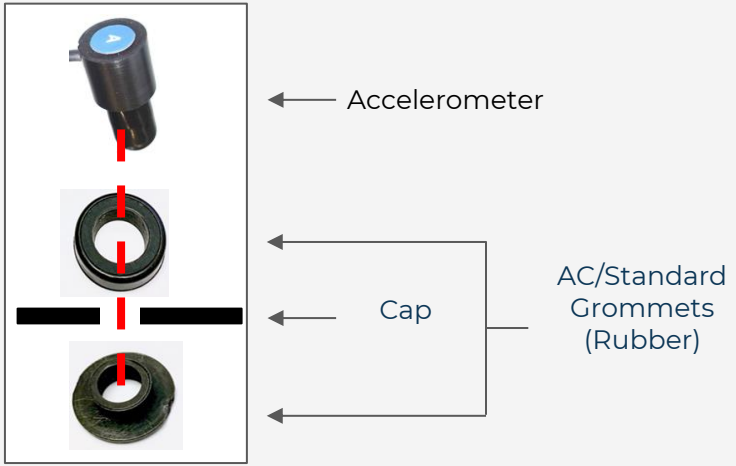
Cable Organizer “Tree”

Cap

AC/Standard Grommets (Rubber)

Accelerometer





Cable relief is also important for Accelerometers to avoid damage!

Short Channels

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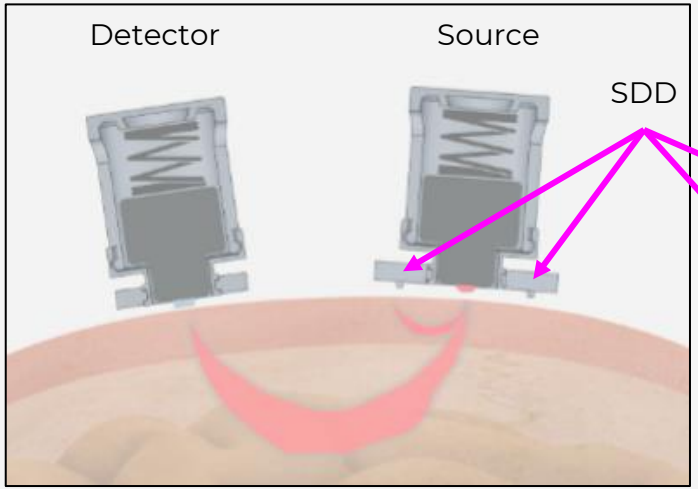
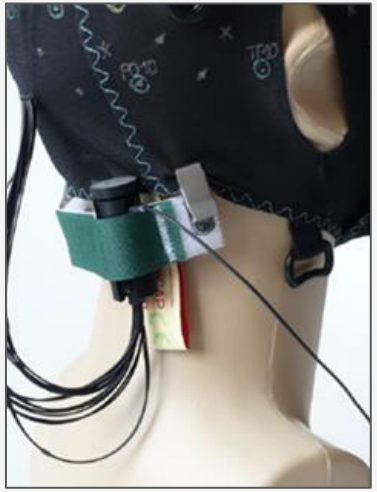
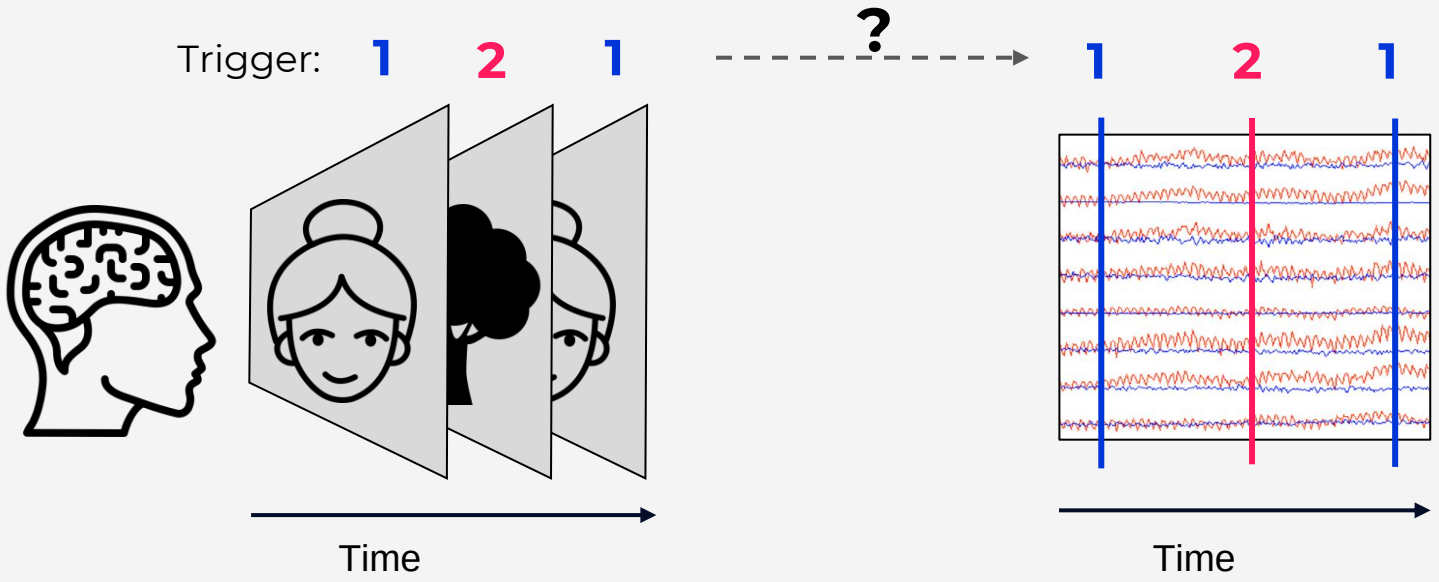
Connecting the clips



Connecting bundle to highest numbered detector

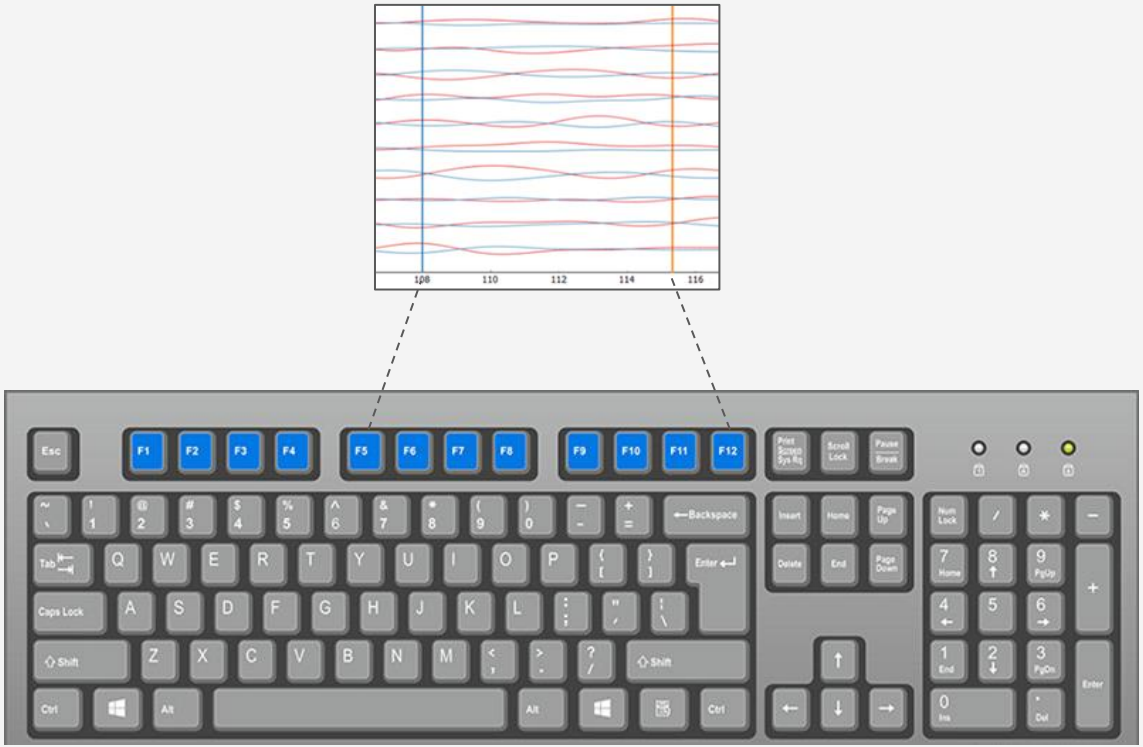


What is a Trigger?



Manual Triggers (F1…F12)

Data Acquisition Computer



Wireless Triggering with LSL

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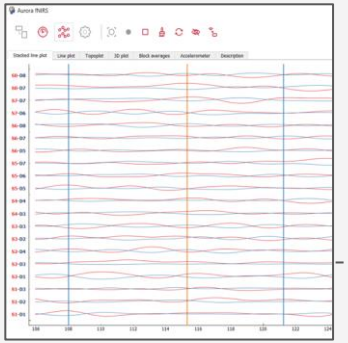
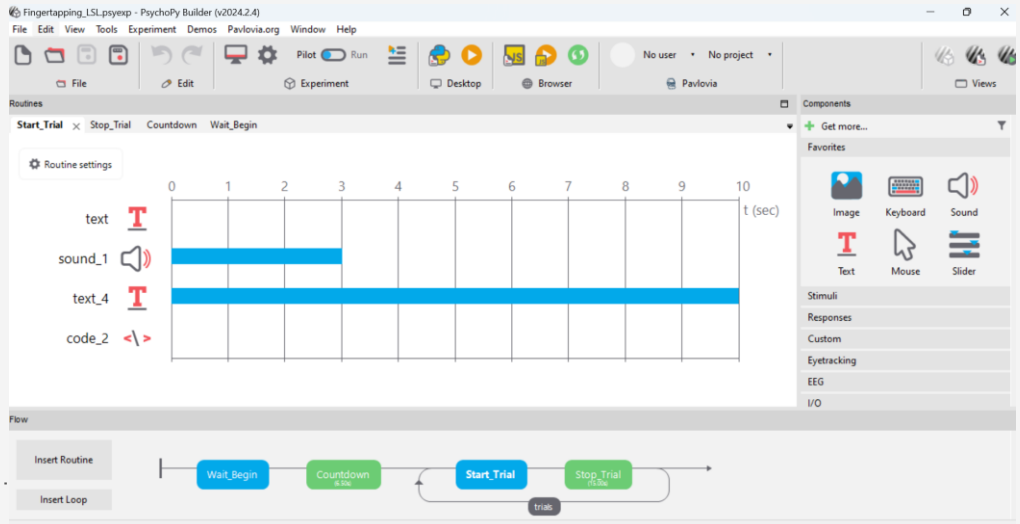
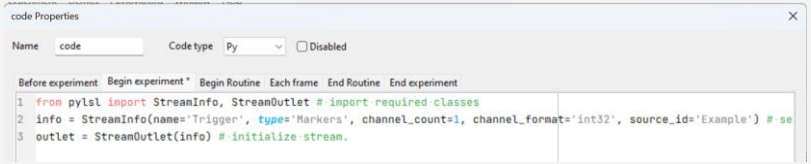
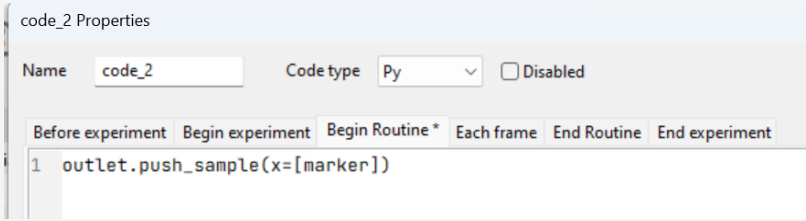
Data Acquisition Computer



Access Point

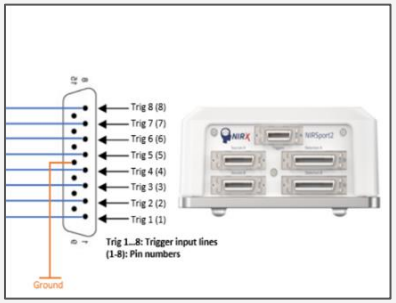




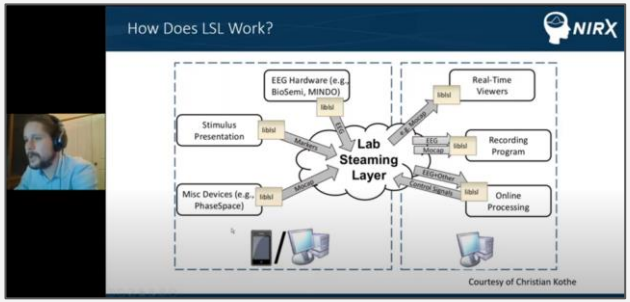


Triggering Resources

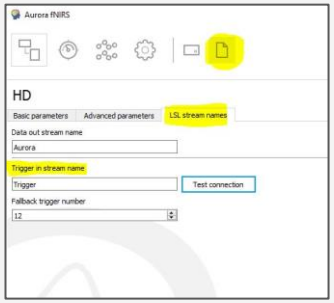
[NIRx Trigger Guide]



[Intro to LSL NIRx Webinar]



[Common LSL Triggering Issues]



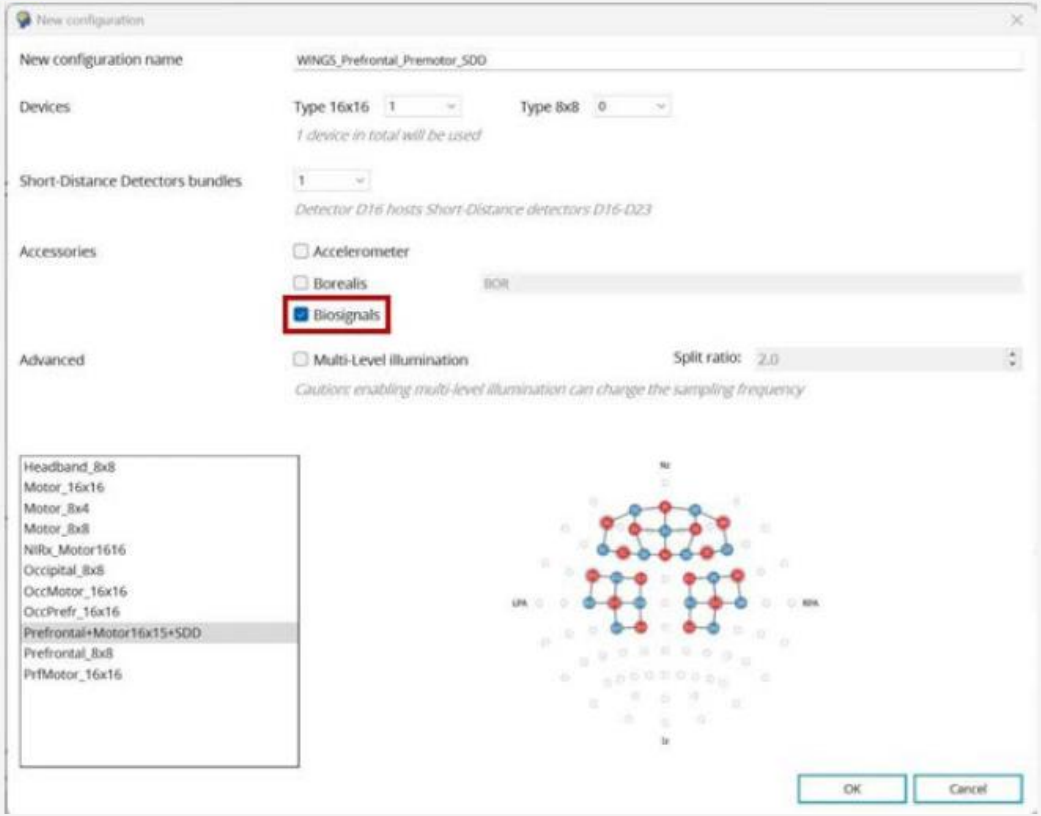
Physiological measures

NIRx

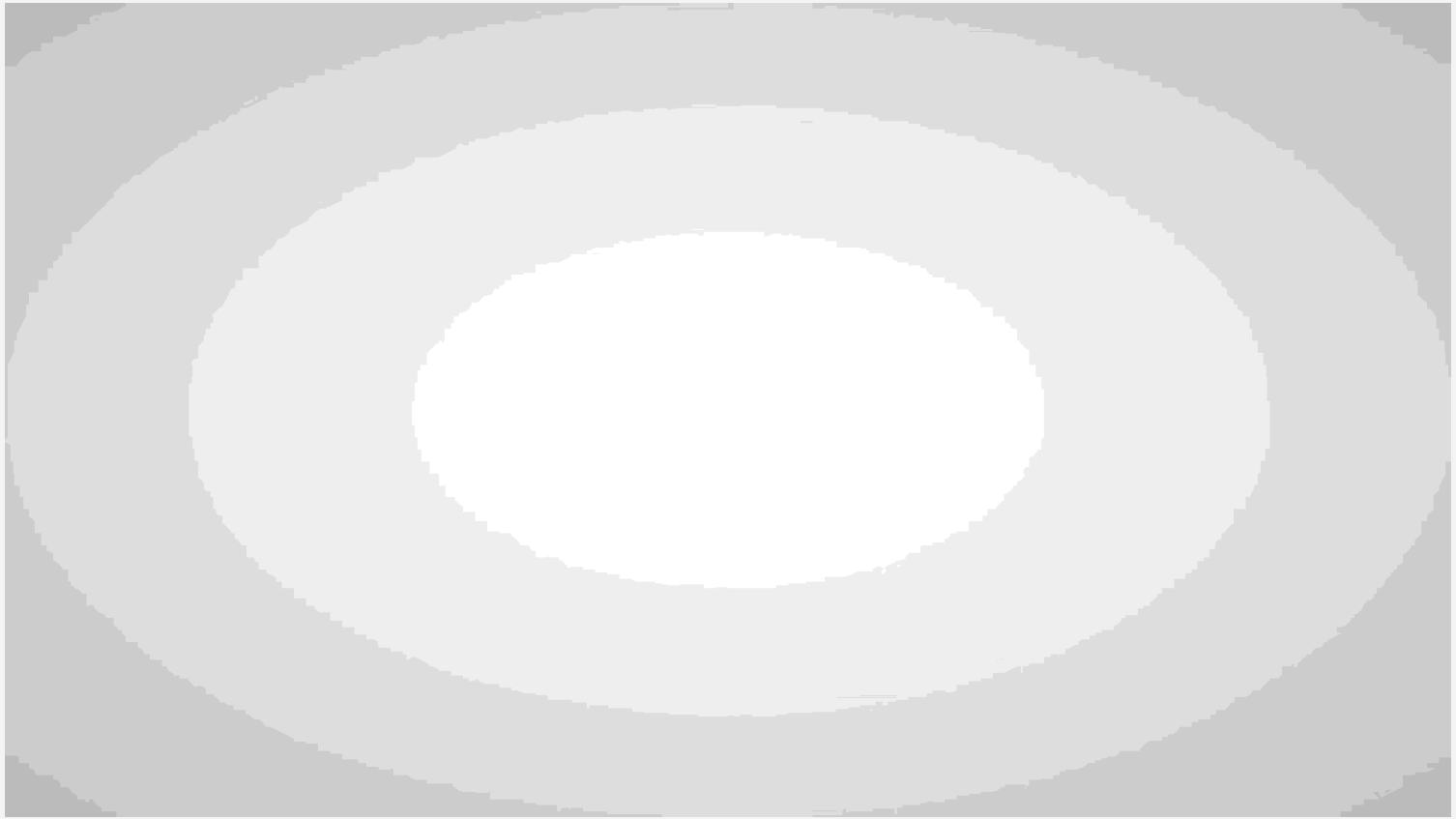
WINGS2

1. Respiration belt with breakout box affixed to belt via hook-and-loop fastener.
2. ExG positive/negative leads (not visible) with distant ground (2a), configured for effector EMG.
3. EDA sensors, here affixed to the palmar surface of the intermediate phalanx of the index and ring fingers with medical tape.
4. Temperature probe (not visible), here affixed to the dorsal surface of the middle finger with the finger strap.
5. PPG clip, here clipped to the participant's ear.
6. NIRxWINGS2 main unit in its pouch with hip belt.
7. Example cable management with surgical tape.

Physiological measures



Populate the cap!



NIRx
ENLIGHTENING INNOVATION

Hands-on Part II: record hyperscanning data

Dalila Burin, Franziska Keller
Scientific Consultants – NIRx

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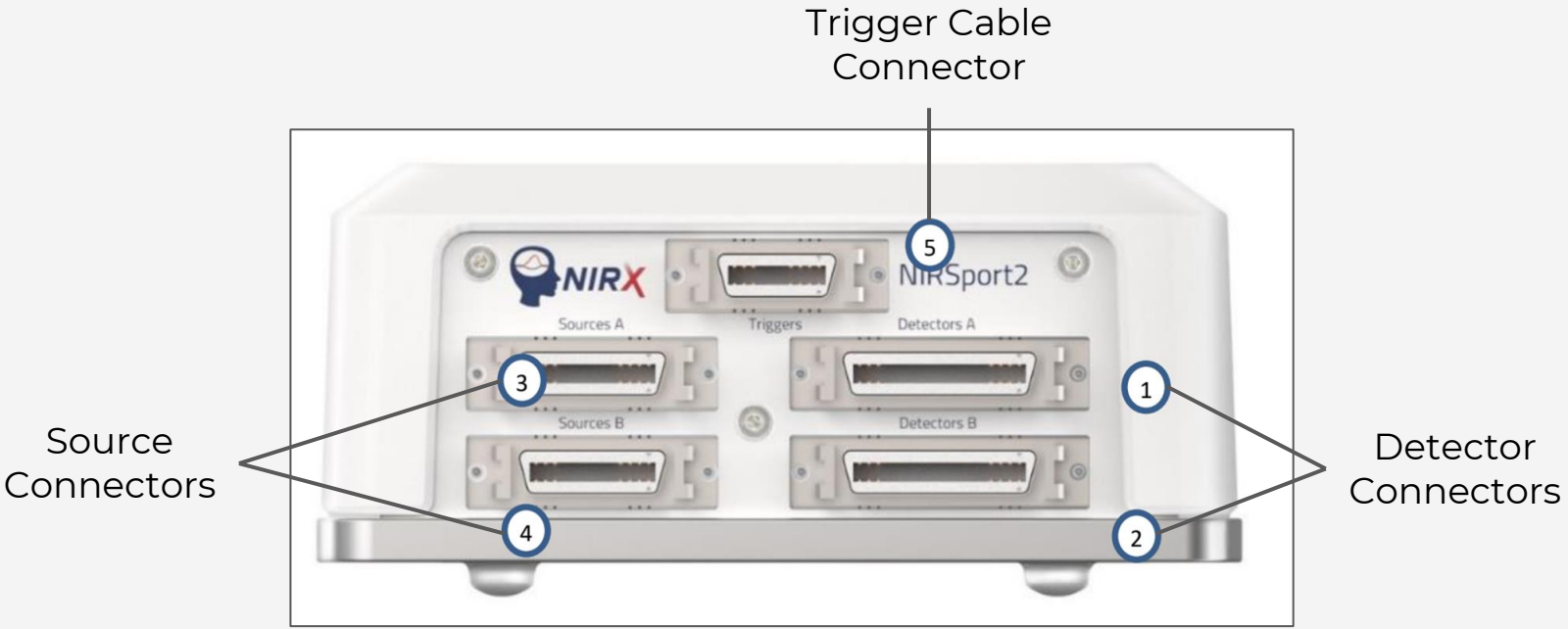
NIRSport 2 Front Panel



NIRSport 2 Back Panel

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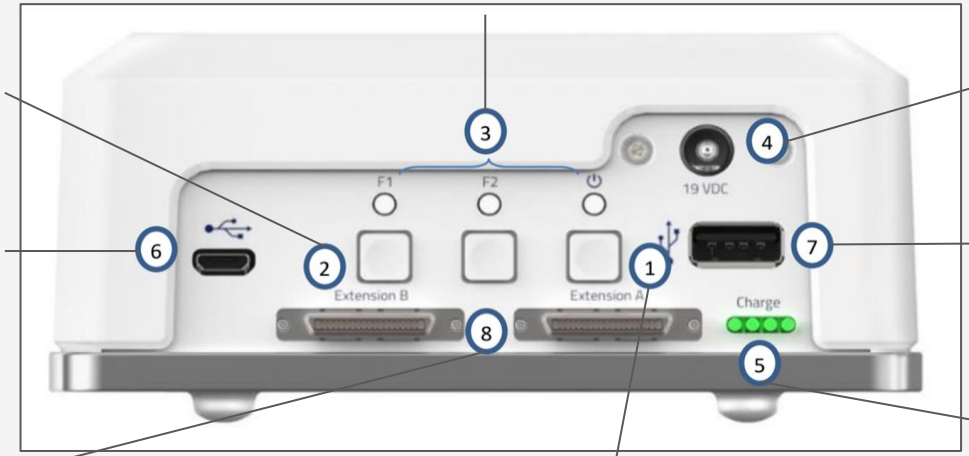
F1	F2	⏻	System Status
🔵	🔵	🔵	System starting up
🔵	🔵	🟢	System CPU booting
🔵	🟢	🟢	System idle
🟢	🟢	🟢	System running (data acquisition)
🔴	🟢	🟢	Error

Status LEDs

Charger supply input

Multi-purpose buttons



micro USB data connection to host PC

USB port

Connectors for daisy chain cable for multi-device mode

Power

Battery charge indicator

Connecting to the NIRSport 2

NIRx

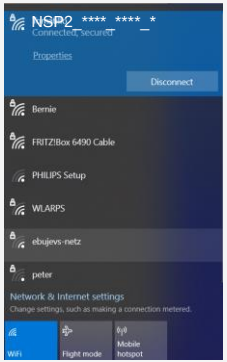
Hardwire Connection

Data Acquisition PC
(Aurora Software)

Connecting to the NIRSport 2

Wireless Connection

Data Acquisition PC
(Aurora Software)



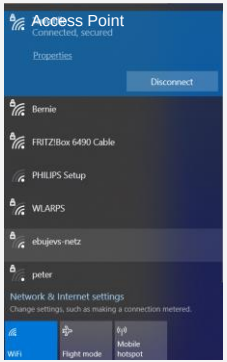
NIRSport2
WiFi

Connecting to the NIRSport 2

NIRx

Wireless Connection
(Hyperscanning)

Data Acquisition PC
(Hyperscanning app
and Aurora Software)



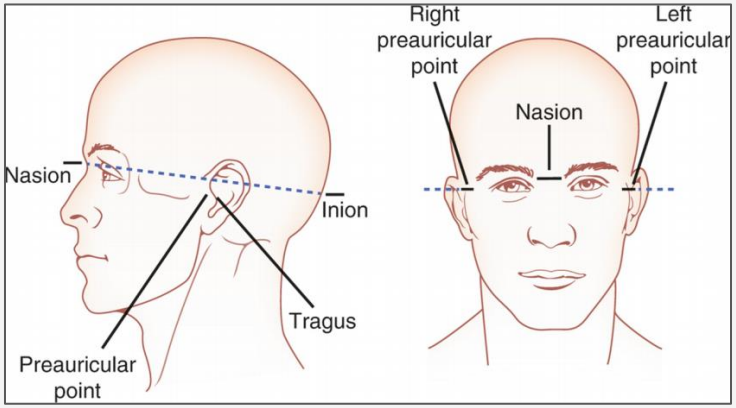
Access
Point WiFi

Recommended Model:
TP-Link TL-WR902AC

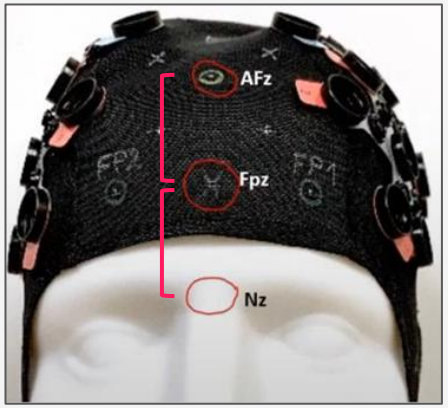
NIRSport2
WiFi

NIRSport2
WiFi

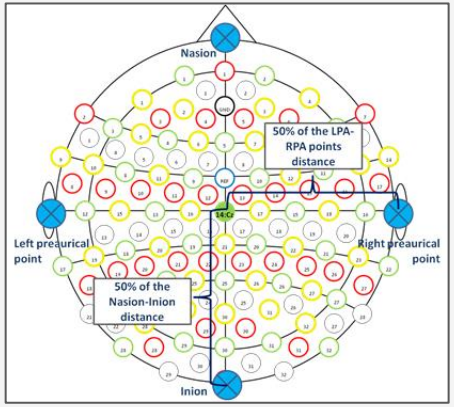
Installing the Cap



Fpz should be equidistant to AFz, Nz



Cz should be equidistant to Nz, Iz



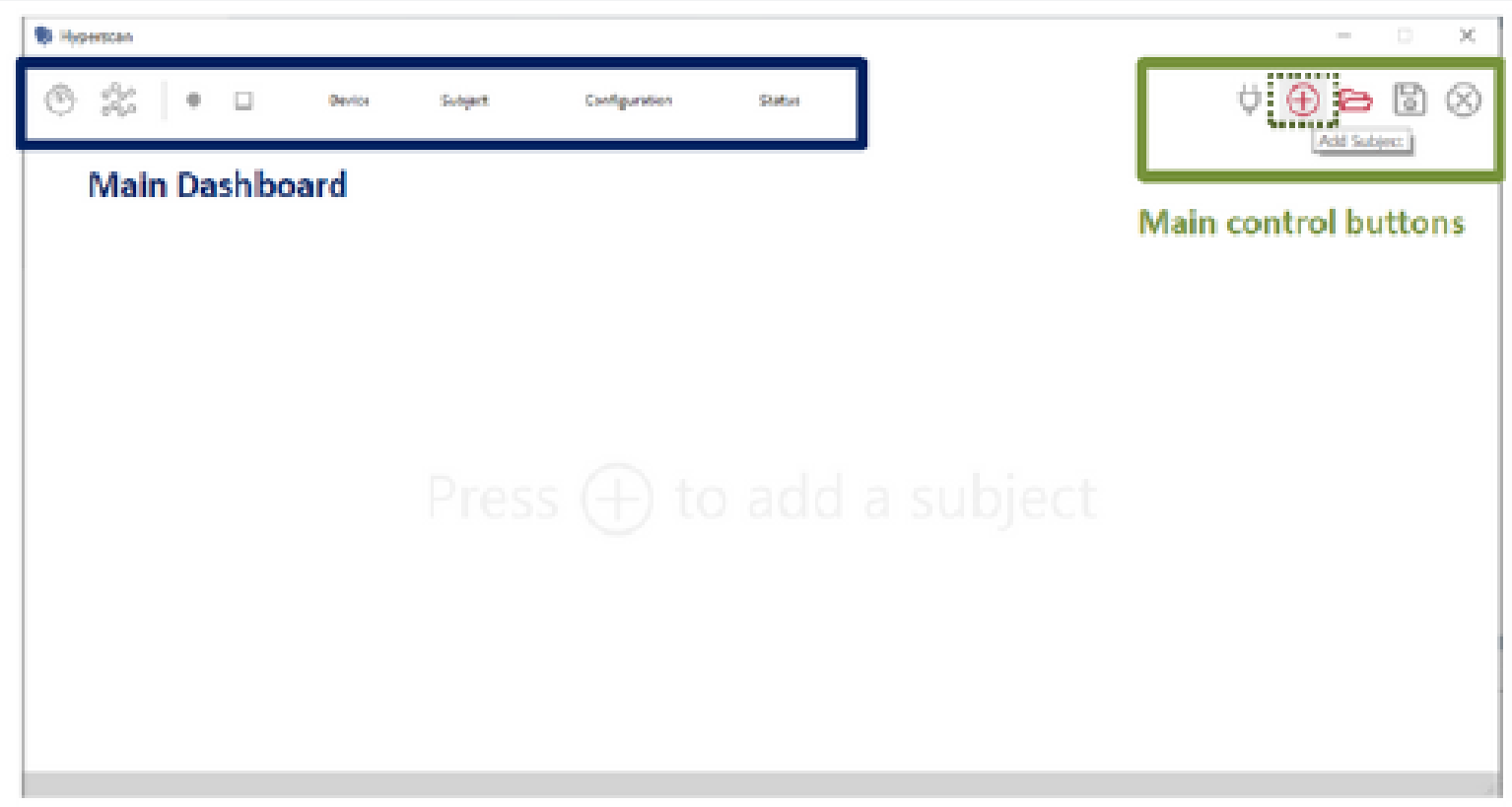
Reduce Ambient Interference

Opaque Shower Cap

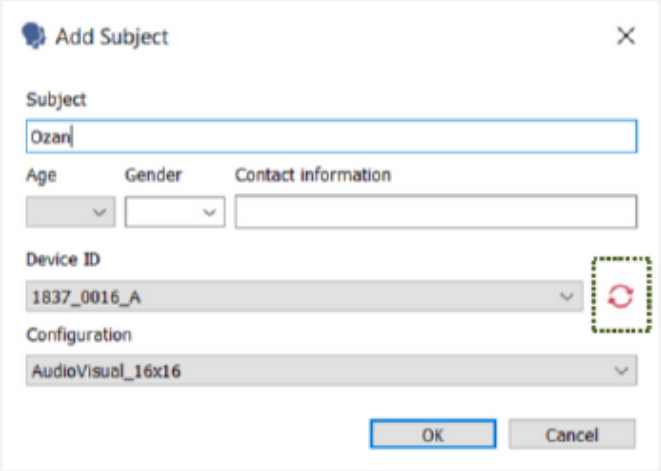
See **dark noise** discussion during signal optimization.

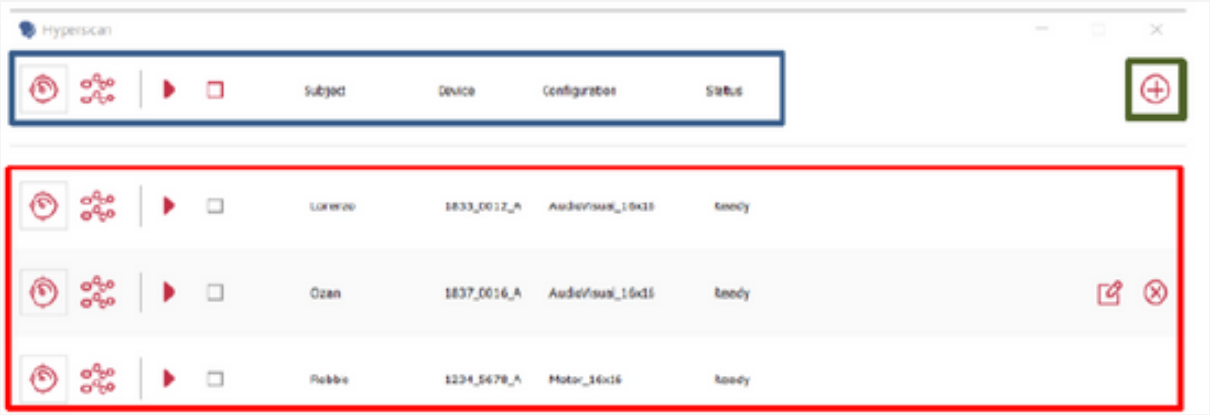
* optional

Hyperscanning app

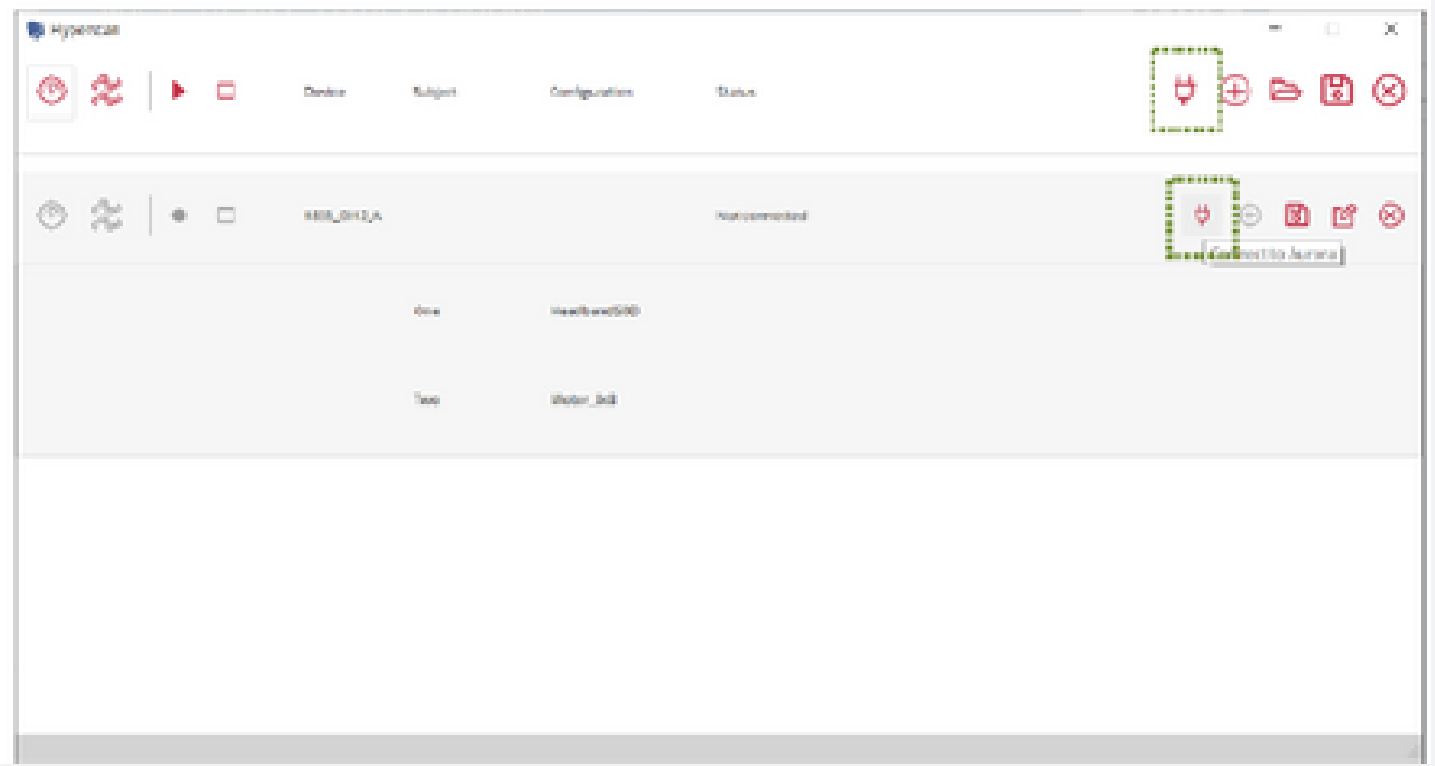


Hyperscanning app





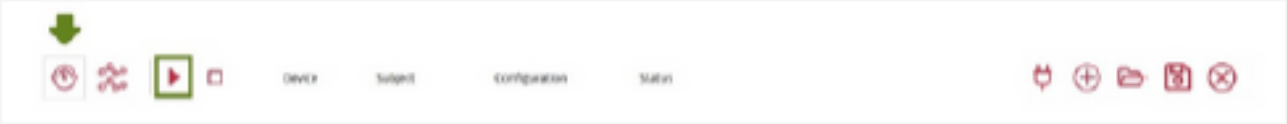
Hyperscanning app



Hyperscanning app

NIRx

Signal Optimization



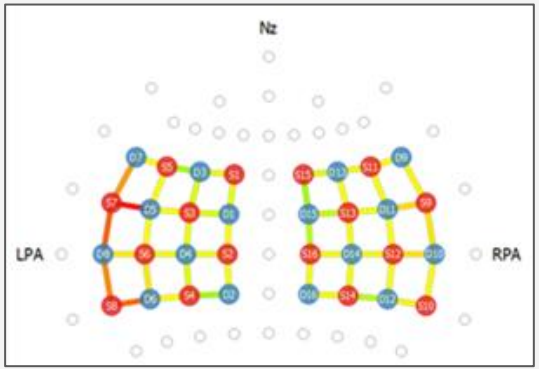
Record data

Stop recording

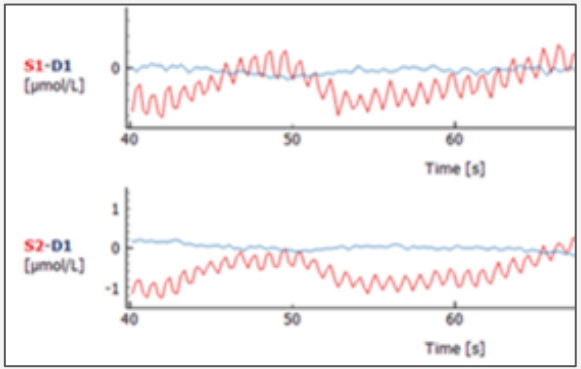
Aurora recording software

NIRx

Optimization



Recording

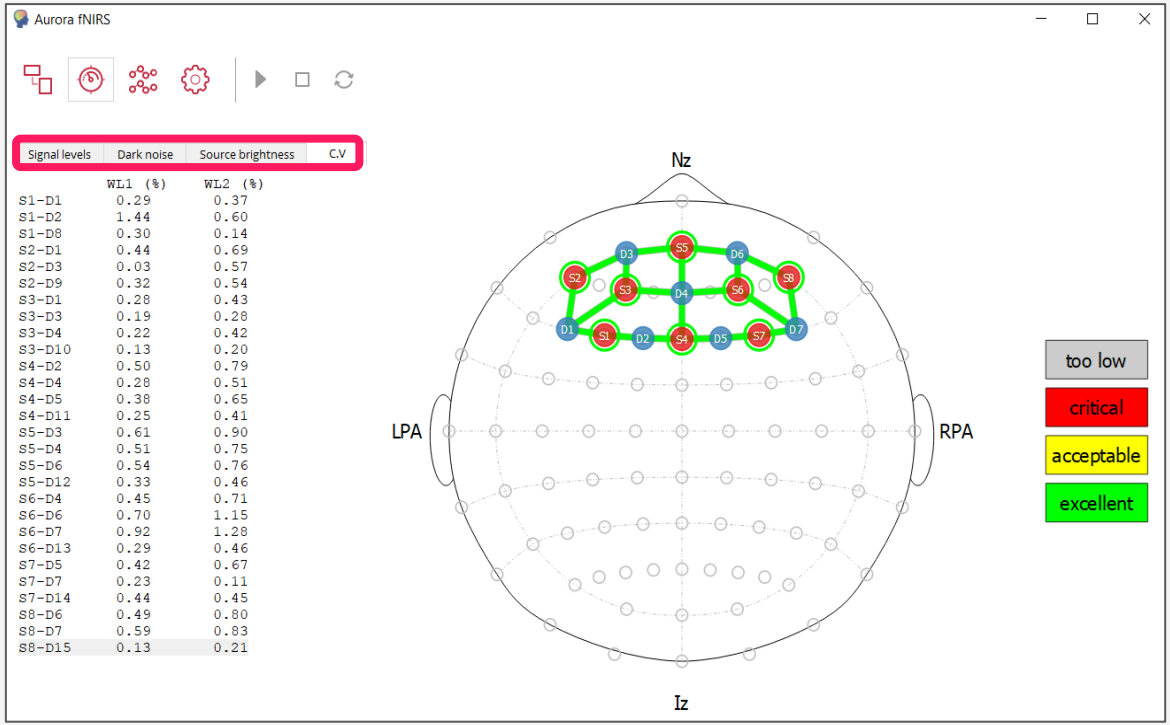


Installer, Documentation: https://support.nirx.de/aurora/

Quantitatively Assessing Signal Quality

NIRx

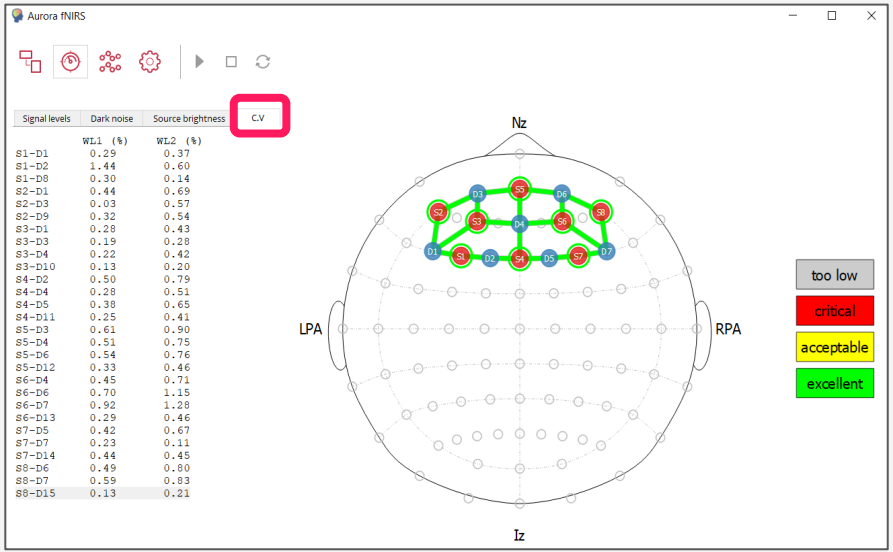
- Coefficient of Variation (CV)
- Signal Levels
- Dark Noise
- (Source Brightness)



Coefficient of Variation (CV)

NIRx

CV = standard deviation / mean



too low

critical > 7.5

acceptable > 2.5 and < 7.5

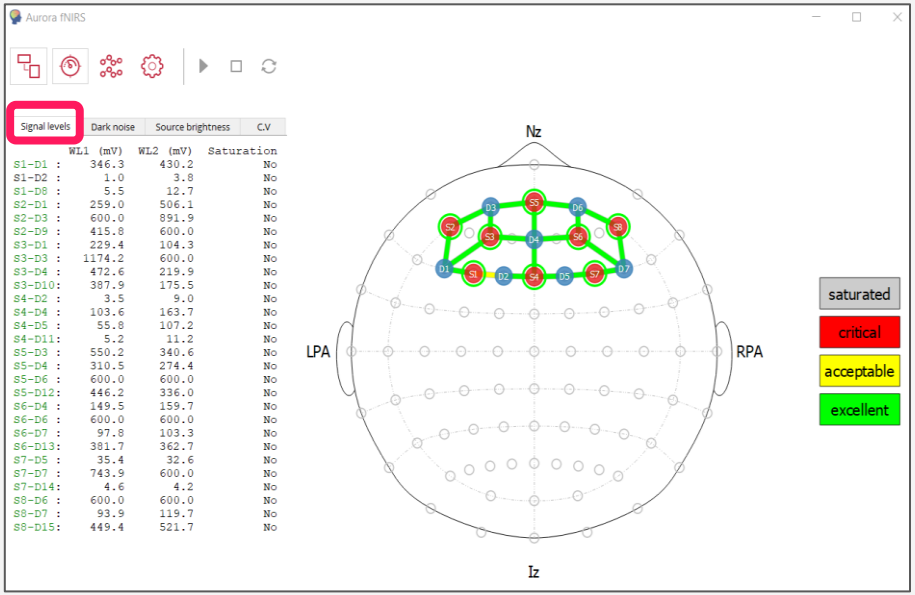
excellent < 2.5

Unit = %

Signal Levels

NIRx

Detected intensity with Sources ON

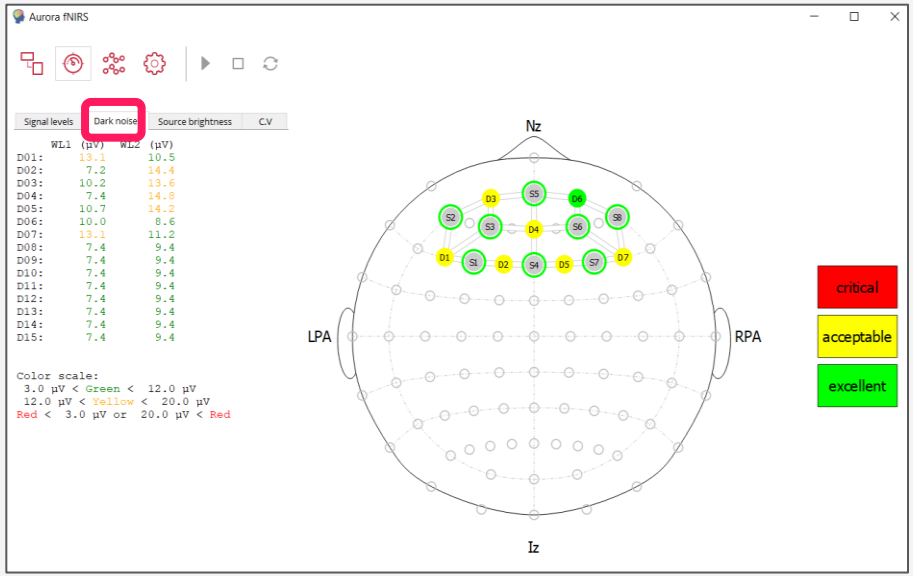


saturated	
critical	< 0.5
acceptable	> 0.5 and < 3
excellent	> 3

Unit = mV

Dark Noise

Detected intensity with Sources OFF

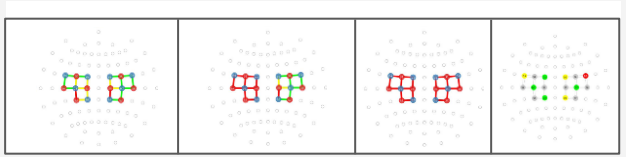


critical	< 3.0 or > 20.0
acceptable	> 12.0 and < 20.0
excellent	> 3.0 and < 12.0

Unit = µV

Troubleshooting Rank Chart

NIRx



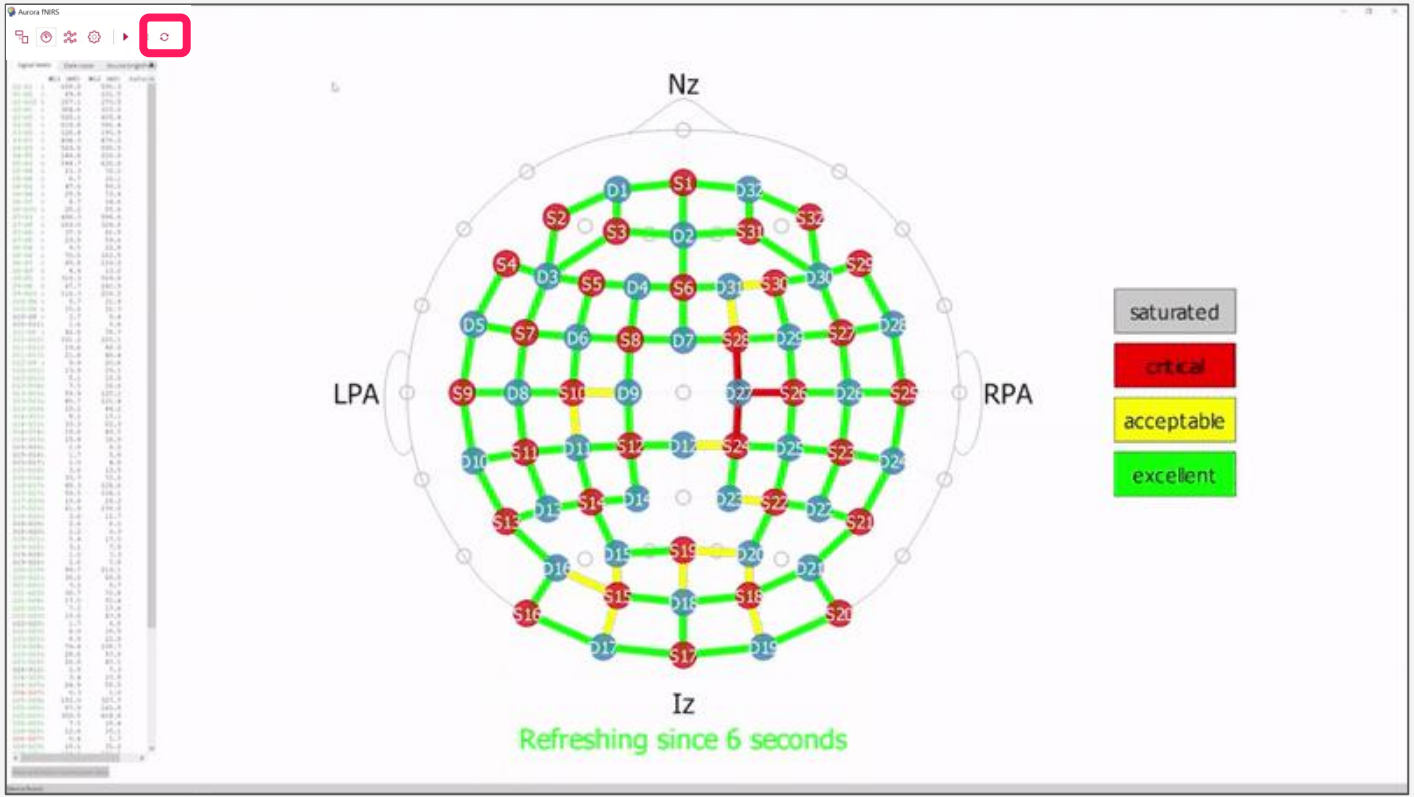
NIRx Signal Quality Guide

Assessment & Troubleshooting

Click here

	Source of Error *NIRScout Only	Ref.	Signal Optimization Results A. A few red or lost channels across montage	B. Red or lost in channels formed by optodes in the same bundle	C. Red or lost in all channels	D. Critical dark noise values
NIRScap	Hair prevents good optical contact	4.a	1	4	7	1
	NIRSCap setup sub-optimal	4.b	2	5	7	2
	Probes incorrectly placed according to montage	4.d	3	6	7	
	Interoptode distance too long	4.c	4	8	7	
	Environmental light interference	4.f	5	8	7	4
	Skull Thickness	4.e	6	7	7	
Optodes	Optode bundle(s) not fully secured to system	5.a		2	3	
	Optode bundles plugged in device in wrong order	5.b		1	4	
	Optode(s) broken	5.c	7	3	6	5
Device	**Device not turned on***	6.a			2	
	Hardware specification improperly declared*	6.b			1	
	Detector type not declared properly	6.c				3
	USB connection	6.d			4	

‘Refresh’ while troubleshooting



Hair prevents good optical contact

Source of Error *NIRScout Only	
NIRScap	Hair prevents good optical contact
	NIRSCap setup sub-optimal
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	Skull Thickness
Optodes	Optode bundle(s) not fully secured to system
	Optode bundles plugged in device in wrong order
	Optode(s) broken
Device	**Device not turned on***
	Hardware specification improperly declared*
	Detector type not declared properly
	USB connection

Gently move head relative to cap
so that the optodes comb through

Hair prevents good optical contact

Source of Error *NIRScout Only	
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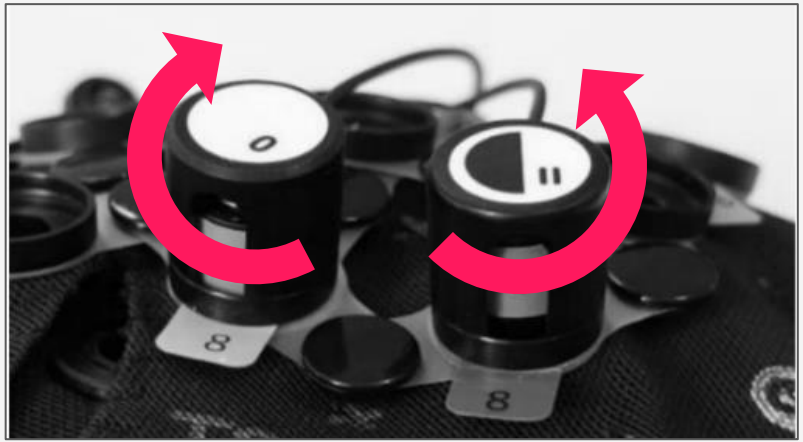
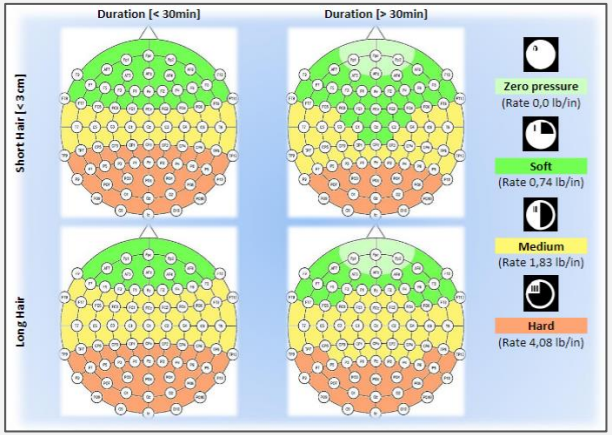
	USB connection

Half-Turn Spring Tops on Dual-Tip Optodes





Hair prevents good optical contact

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	USB connection

Move hair away from underneath grommet

Cap setup sub-optimal

NIRx

Source of Error *NIRScout Only	
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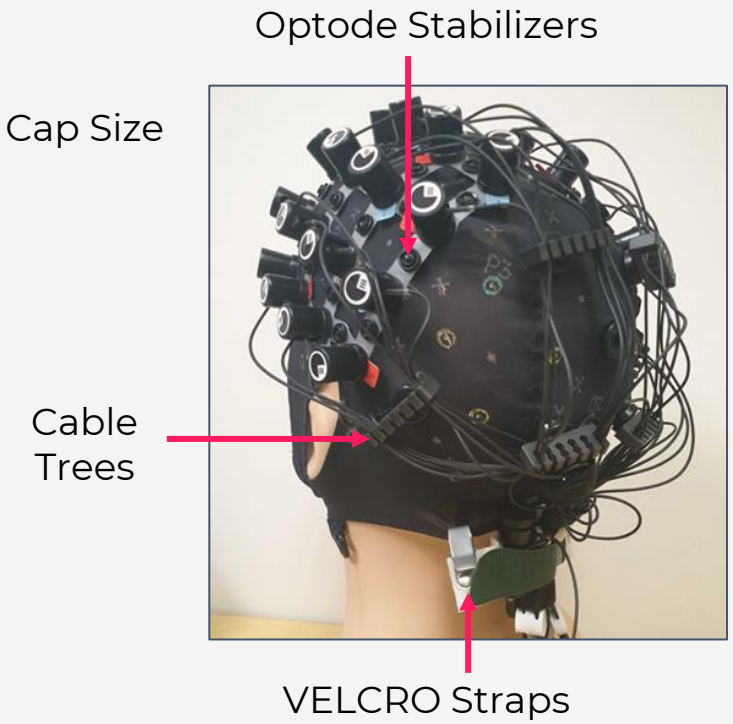
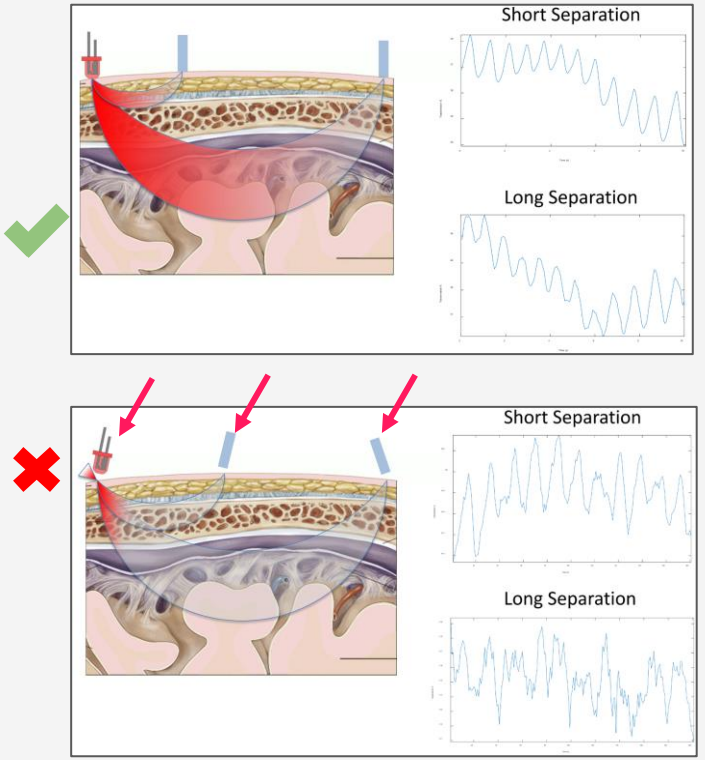
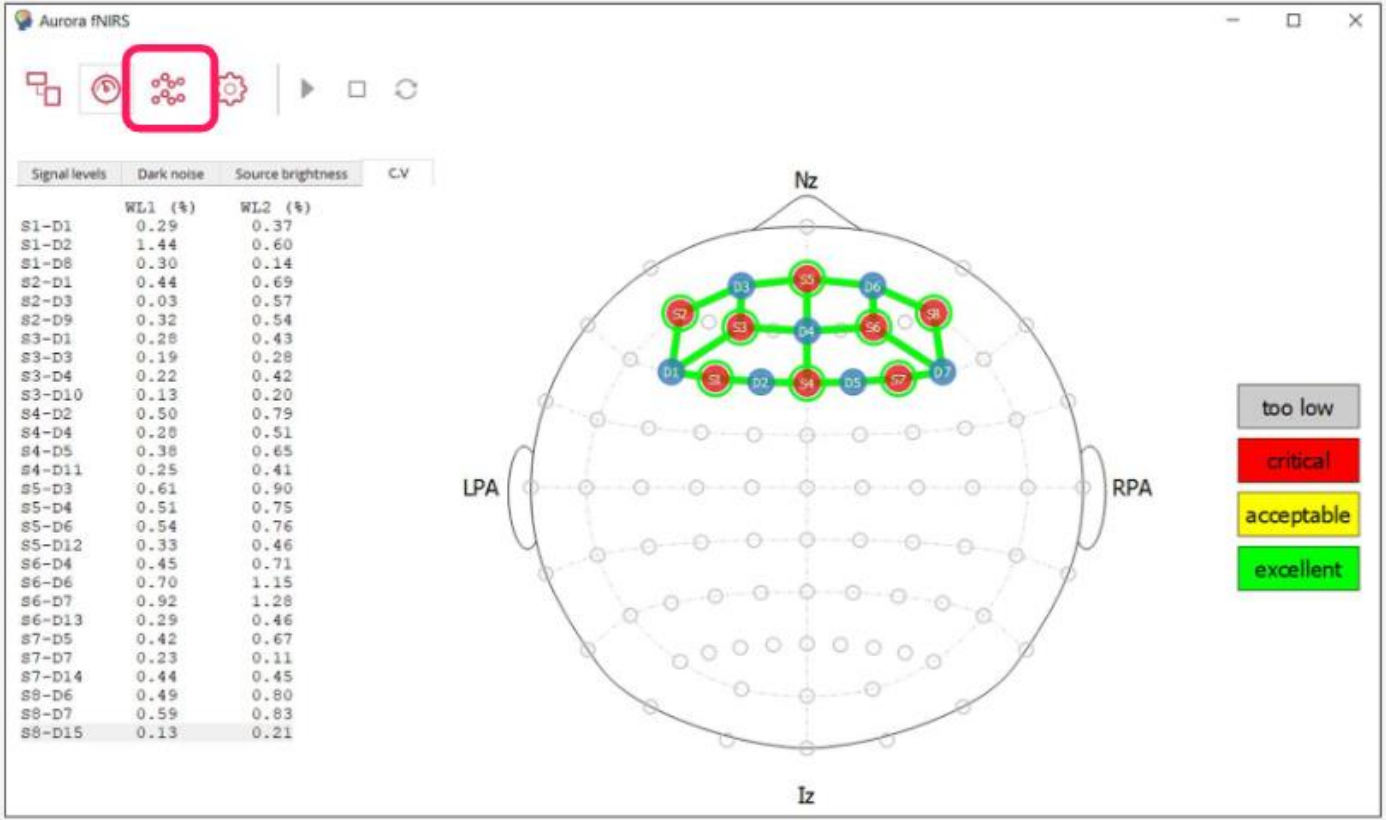
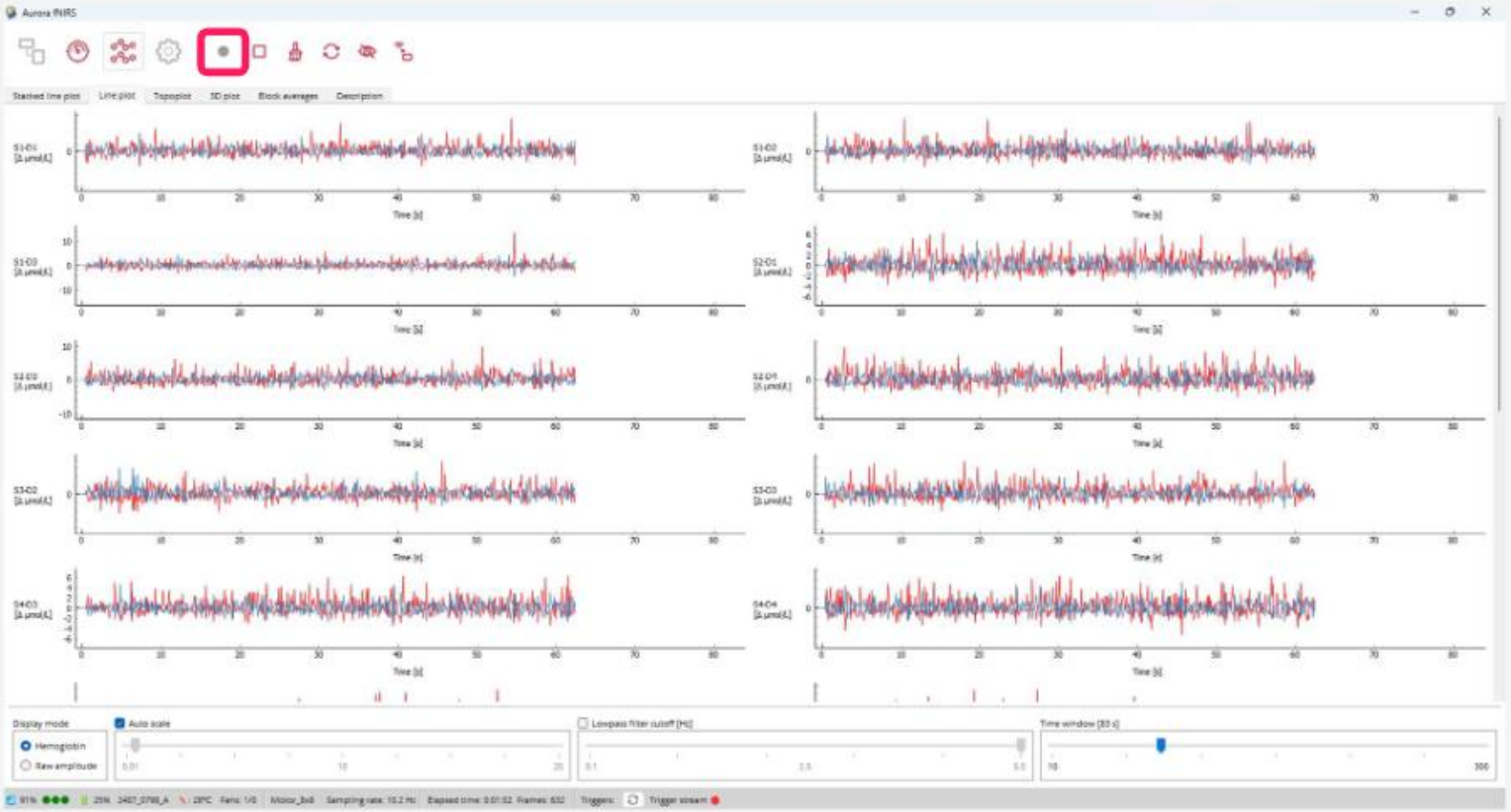




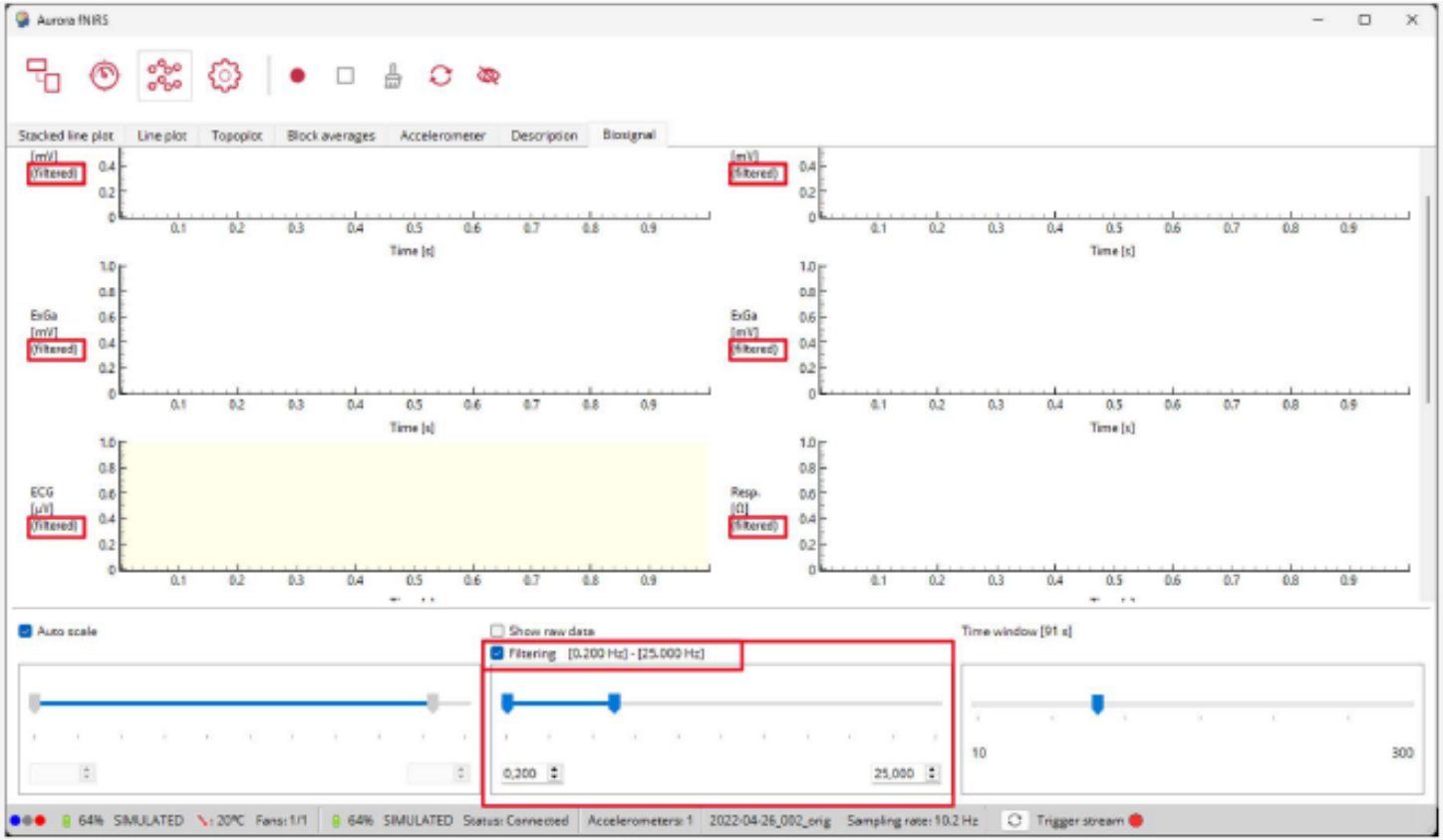
Recording


Aurora fNIRS
Signal levels
Dark noise
Source brightness
C.V
WL1 (%) WL2 (%)
S1-D1 0.29 0.37
S1-D2 1.44 0.60
S1-D8 0.30 0.14
S2-D1 0.44 0.69
S2-D3 0.03 0.57
S2-D9 0.32 0.54
S3-D1 0.28 0.43
S3-D3 0.19 0.28
S3-D4 0.22 0.42
S3-D10 0.13 0.20
S4-D2 0.50 0.79
S4-D4 0.28 0.51
S4-D5 0.38 0.65
S4-D11 0.25 0.41
S5-D3 0.61 0.90
S5-D4 0.51 0.75
S5-D6 0.54 0.76
S5-D12 0.33 0.46
S6-D4 0.45 0.71
S6-D6 0.70 1.15
S6-D7 0.92 1.28
S6-D13 0.29 0.46
S7-D5 0.42 0.67
S7-D7 0.23 0.11
S7-D14 0.44 0.45
S8-D6 0.49 0.80
S8-D7 0.59 0.83
S8-D15 0.13 0.21
Nz
LPA
RPA
Iz
too low
critical
acceptable
excellent

Recording


Aurora fNIRS
Stacked line plot
Line plot
Topoplot
3D plot
Block averages
Description
Display mode
Hemoglobin
Raw amplitude
Auto scale
Lowpass filter cutoff [Hz]
Time window [30 s]

Recording

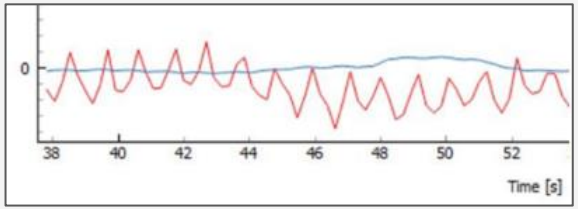

Aurora fNIRS
Stacked line plot
Line plot
Topoplot
Block averages
Accelerometer
Description
Biosignal
[mV] (Filtered)
Time [s]
ExGa [mV] (Filtered)
ECG [µV] (Filtered)
Resp. [Ω] (Filtered)
Auto scale
Show raw data
Filtering [0.200 Hz] - [25.000 Hz]
Time window [91 s]
0.200
25.000
10
300
64% SIMULATED 20°C Fans: 1/1
64% SIMULATED Status: Connected
Accelerometers: 1
2022-04-26_002_orig
Sampling rate: 10.2 Hz
Trigger stream

Visually Assessing Signal Quality

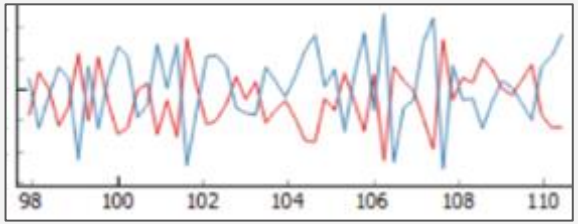
NIRx

Check for Cardiac (~1 Hz)
and Respiration (~0.25 Hz)

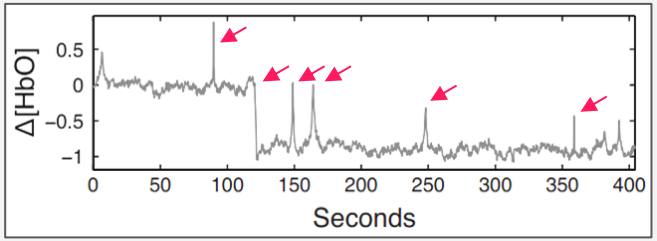
Good



Bad

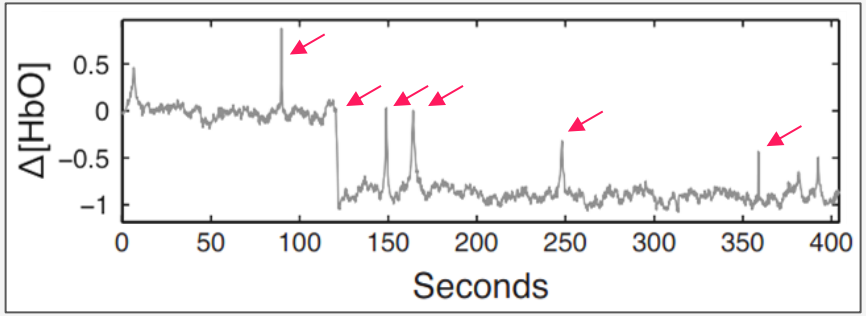


Check for Rapid, Large
Amplitude Motion Artifacts

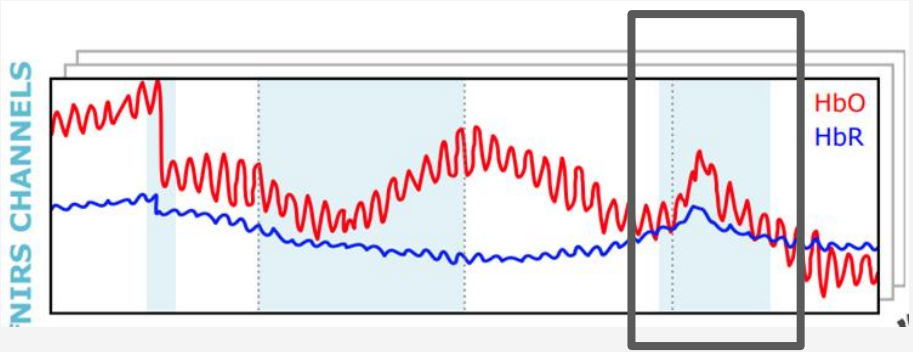


Movement Artefacts

Direct Motion Artefacts



Indirect motion artefacts



Data Acquisition and Signal Quality Resources

Videos

- **Optimizing Signal Quality
- Signal Quality Presentation by Dr. Pollonini

Guides

- NIRSport2 User Guide
- NIRSport2 Static Phantom Testing
- Aurora User Guides
- NIRx Signal Quality Assessment Guide

Signal Quality Assessment Tools

- https://github.com/lpollonini/qt-nirs
- https://github.com/lpollonini/phoebe

NIRx
ENLIGHTENING INNOVATION

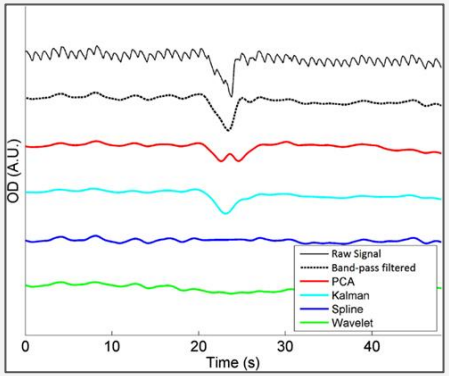
Extra/Optional Slides and Notes

Movement Artefact Removal

NIRx

Two Paths

Preprocessing



Cooper et al., 2012

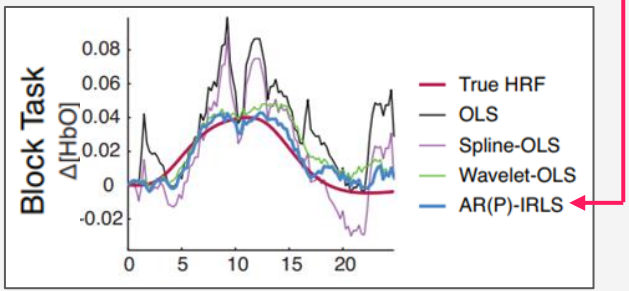
- TDDR
- PCA
- spline
- wavelet
- Kalman
- TARA
- ...

Partially Compared in

- Cooper et al., 2012
- Brigadoi et al. 2014

Analysis

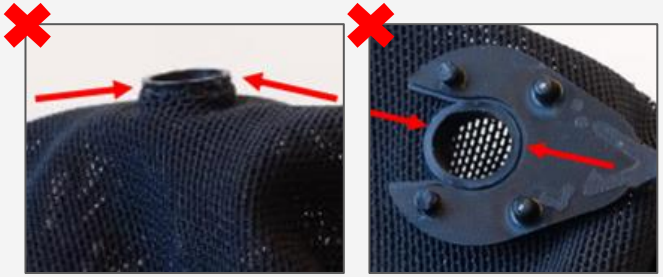
Robust Regression

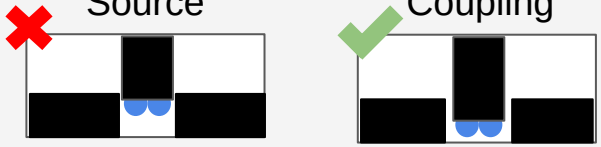


Barker, et al. 2013

Short Distance Detector Checks

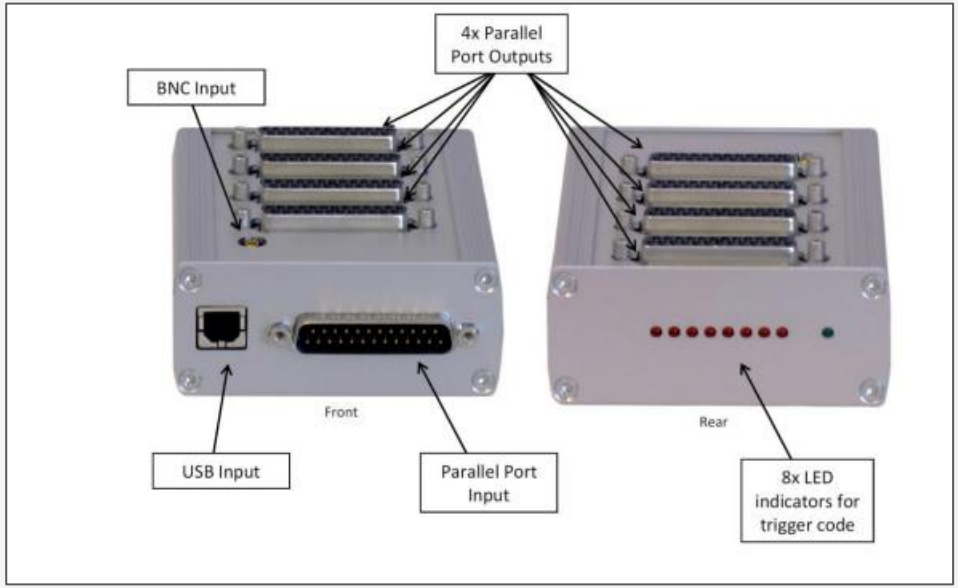
Prevent fabric from getting caught to avoid grommet distortion

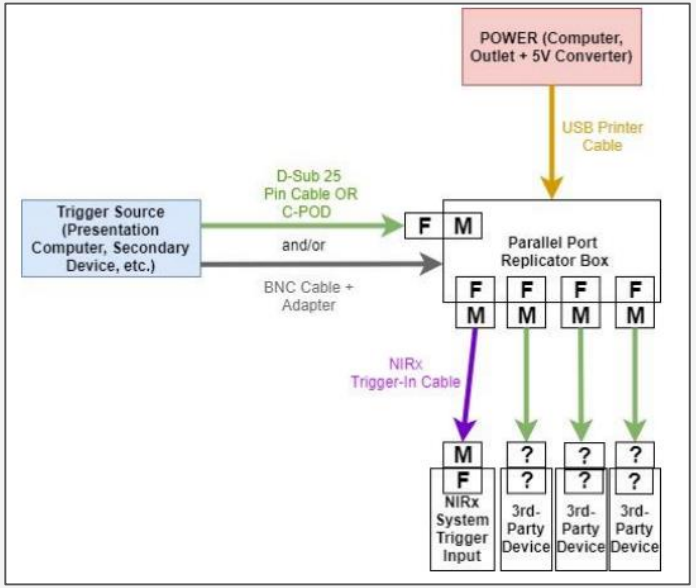




Route the fiber cables to avoid decoupling optodes from the scalp

Sending Wired Triggers to multiple devices





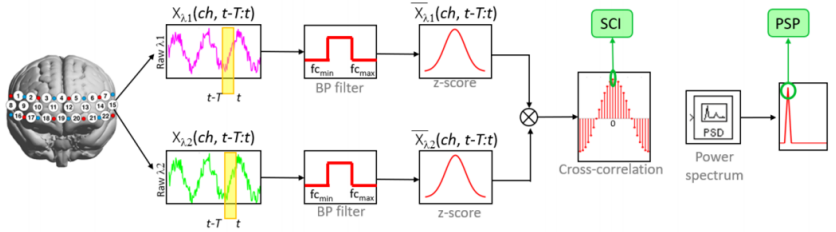
Additional Signal Quality Metrics

NIRx

Metric	Formula	Rationale	Goal	Category
SNR	$10\log_{10}\left(\frac{\sigma^2_{signal}}{\sigma^2_{after}}\right) - 10\log_{10}\left(\frac{\sigma^2_{signal}}{\sigma^2_{before}}\right)$	Quantification of the difference before and after the artifact removal (Siddiqui et al., 2018)	Motion artifact correction algorithm	Pre-GLM analysis
	$\frac{\sigma^2_{Task} - \sigma^2_{Rest}}{\sigma^2_{Rest}}$	Analytical determination of SNR bounds (Aqil & Jeong, 2018)	Real time estimation of brain activity	
CNR	$\frac{mean(dur) - mean(pre)}{\sqrt[2]{std(dur)^2 + std(pre)^2 + \lambda}}$	To quantify the effects of spatial eigenfiltering (Zheng, Brooks, et al. 2005)	Physiological interference reduction	
	$\frac{mean(Task) - mean(Baseline)}{\sqrt{var(Task) + var(Baseline)}}$	Difference in amplitude between task and immediate previous baseline (Cui, Bray, & Reiss, 2010)	Signal improvement	
CV	$\frac{sd(signal)}{mean(signal)} \times 100$	Metric for signal quality control (Hocke et al., 2018; Zimeo Morais et al., 2017)	Signal processing pipelines assessment	
QI	% of time where NIRS and EKG signals reach statistically significant coherence	To quantify periods of high quality in fNIRS signals during continuous long-term monitoring (Govindan, Massaro, & du Plessis, 2018)	Improvement on fNIRS-based cerebral pressure autoregulation in newborns	Pre-GLM analysis, cardiac information
CSNR	$log\left(\frac{Power(Cardiac_{[0.8,1.67]})}{Power(Noise_{[5,20]})}\right)$	Ratio of the power in cardiac pulsation band (0.8-1.67 Hz) over the power in the high freq. band (5-20 Hz) (Yücel, Selb, Boas, Cash, & Cooper, 2014)	Optical fiber tips design and coupling	
MSE	$MSE(HRF_{true}, HRF_{corrected})$	Targeted PCA based correction (Yücel, Selb, Cooper, & Boas, 2014)	Motion artifact correction algorithm	Post-GLM analysis
SNR	$\frac{\beta}{\sigma_{rest}}$	The beta value after GLM analysis divided by the standard deviation of optical densities during rest (Chiarelli, Maclin, Fabiani, & Gratton, 2015)	Motion artifact correction algorithm	

SNR: Signal-to-noise ratio, **CNR**: contrast-to-noise ratio, **CV**: Coefficient of variation, **QI**: Quality index, **CSNR**: Cardiac signal-to-noise ratio, **MSE**: mean-squared error

- **Scalp Coupling Index (SCI) and Peak Spectral Power (PSP)** have fixed ranges that are independent of sampling frequency of the signal



Luca Pollonini - SfNIRS Educational Tutorial - June 28th, 2021

https://fnirs.org/events/educational-tutorials/

Hair prevents good optical contact

Source of Error *NIRScout Only	
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	NIRSCap setup sub-optimal
	Probes incorrectly placed according to montage
	Interoptode distance too long
	Environmental light interference
	Skull Thickness
Optodes	Optode bundle(s) not fully secured to system
	Optode bundles plugged in device in wrong order
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	Hardware specification improperly declared*
	Detector type not declared properly
	USB connection

APD detectors