Assistive Context-Aware Toolkit (ACAT)

BCI User Guide

Table of Contents

Installation

Getting Started

- Download ACAT 3.x that includes BCI, from the link below
  https://github.com/intel/acat/releases
- For step-by-step installation instructions, please refer to the ACAT User Guide
- If you have already installed ACAT, you can find the user guide on your computer in the folder *C:\Program Files (x86)\ACAT\Docs\en*

1. Hardware

Disclaimer

BCI Hardware – Cyton Board

The Cyton Board is not a medical device, nor is it intended for medical diagnosis and provided to you "as is," and we make no express or implied warranties whatsoever with respect to its functionality, operability, or use, including, without limitation, any implied warranties, fitness for a particular purpose, or infringement. We expressly disclaim any liability whatsoever for any direct, indirect, consequential, incidental or special damages, including, without limitation, lost revenues, lost profits, losses resulting from business interruption or loss of data, regardless of the form of action or legal theory under which the liability may be asserted, even if advised of the possibility of such damages.

BCI Hardware - Evaluation Board

Evaluation Board/Kit Important Notice: OpenBCI, Inc. provides the enclosed product(s) under the following conditions: This evaluation board/kit is intended for use for ENGINEERING DEVELOPMENT, DEMONSTRATION, OR EVALUATION PURPOSES ONLY and is not considered by OpenBCI, Inc. to be a finished end-product fit for general consumer use. Persons handling the product(s) must have electronics training and observe good engineering practice standards. As such, the goods being provided are not intended to be complete in terms of required design-, marketing-, and/or manufacturing-related protective considerations, including product safety and environmental measures typically found in end products that incorporate such semiconductor components or circuit boards. This evaluation board/kit does not fall within the scope of the European Union directives regarding electromagnetic compatibility, restricted substances (RoHS), recycling (WEEE), FCC, CE or UL, and therefore may not meet the technical requirements of these directives or other related directives.

BCI Hardware - Electrode Cap

The OpenBCI Electrode Cap is not a medical device, nor is it intended for medical diagnosis and provided to you "as is," and we make no express or implied warranties whatsoever with respect to its functionality, operability, or use, including, without limitation, any implied warranties, fitness for a particular purpose, or infringement. We expressly disclaim any liability whatsoever for any direct, indirect, consequential, incidental or special damages, including, without limitation, lost revenues, lost profits, losses resulting from business interruption or loss of data, regardless of the form of action or legal theory under which the liability may be asserted, even if advised of the possibility of such damages.</value>

1.1 Hardware Requirements (#1 of 2)

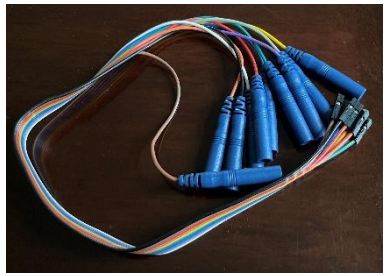
OpenBCI

To purchase click on the embedded links

[OpenBCI Cyton Biosensing Board 8 channels]

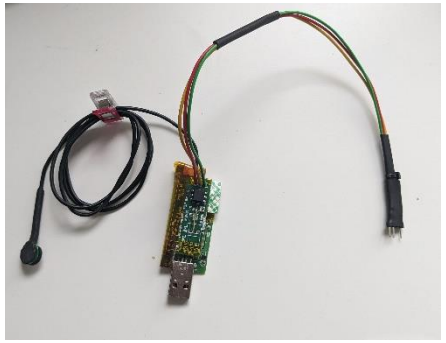
[OpenBCI EEG Electrode Cap Kit]

[OpenBCI Header Pin To Touch Proof Electrode Adapter]



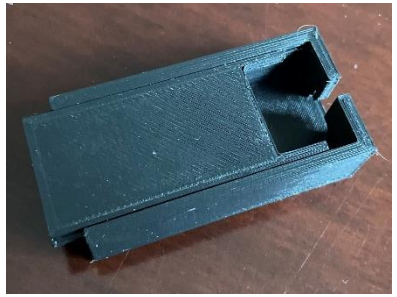
Custom hardware (ACAT):

Contact acat@intel.com to get this hardware

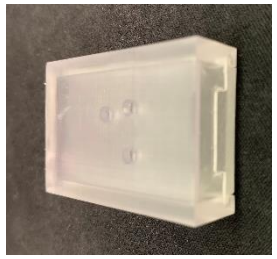


Trigger (optical) Sensor

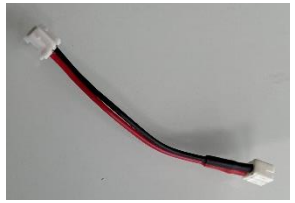
ACAT uses this sensor readings for timestamping the EEG data in order synchronize the recorded brain signals with the highlighted UI elements



Enclosure for Trigger Sensor Board
3D printed



Enclosure for OpenBCI USB Dongle



Extension cable for easy connection of the battery to the Cyton board

1.2 Hardware Requirements (#2 of 2)

To purchase click on the embedded links

Electro conductive Gel

Grounding wrist-strap or equivalent grounding strategy

Copper Tape for OPENBCI USB Dongle Enclosure for reducing interference

Clips to attach sensor to display

Isopropyl alcohol swab

Laptop or desktop
Intel Core i7 or higher or equivalent CPU
16GB RAM

Recommended, but optional

Additional Battery

Is handy, as backup battery in case your main battery runs out of charge

USB 3.0 Hub, 4 or more ports

Will be needed if your system does not have at least 2 free USB port

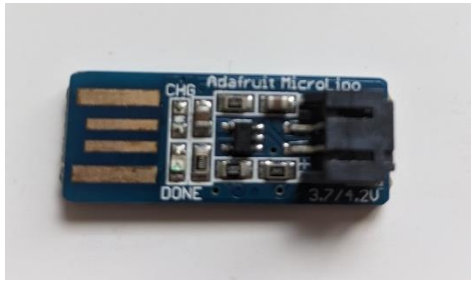
2. One-time Setup

This includes hardware setup

2.1 Step #1: Charge battery for the Cyton board

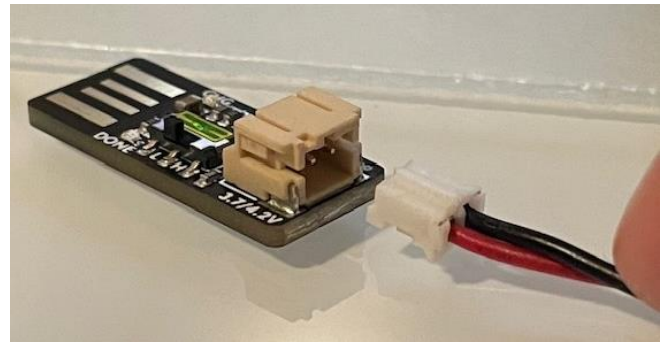
Components needed

Battery

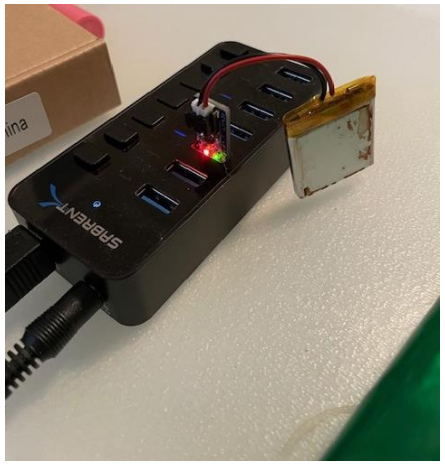


Charger

a) Plug battery in the charger – make sure to align the notch on the connector with the battery plug



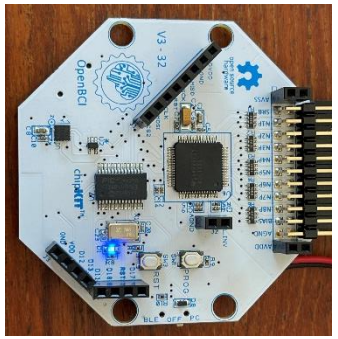
b) Plug in the charger into a USB port for charging



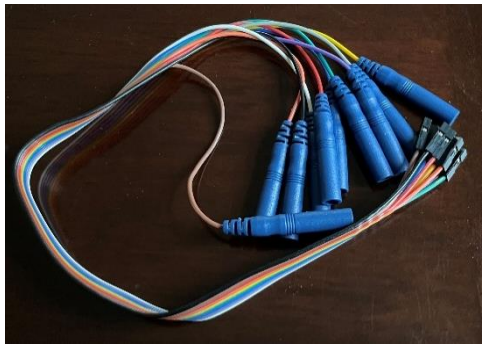
c) Charging the battery fully can take a couple of hours. Hence the recommendation is to have 2 batteries so that you always have a spare fully charged battery

2.2 Step #2: Connect the adapter cable to the Cyton board

Components needed

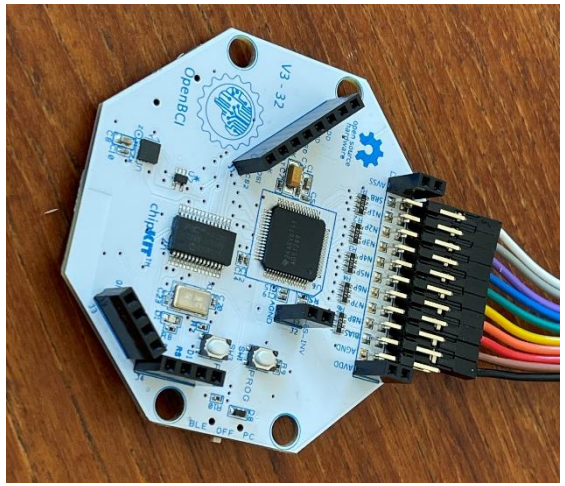


Cyton board

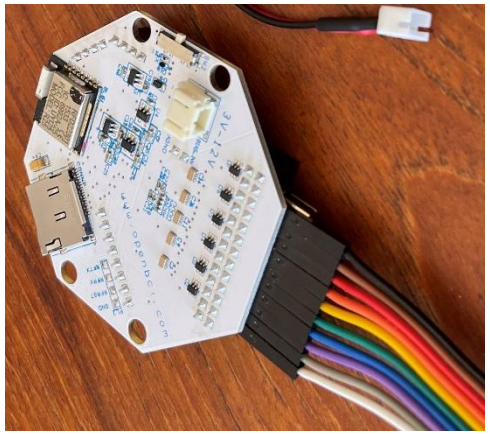


Touch proof electrode adapter cable

Connect each colored wire on the adapter cable to the bottom set of pins on the Cyton board as shown in the table

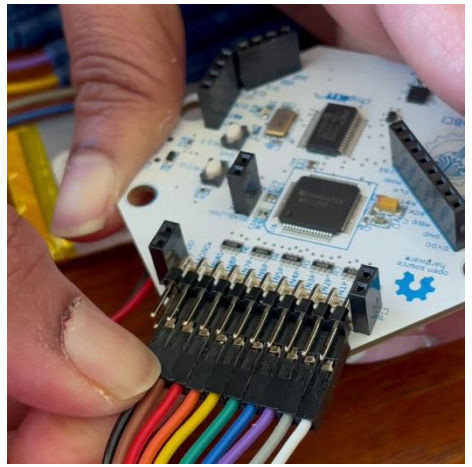


front-side



bottom-side

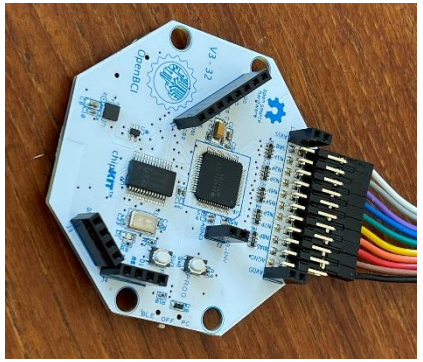
Make sure each individual connector is pushed all the way into the pin



#	Cyton Board pin	Adapter cable color
1	SRB	White
2	N1P	Gray
3	N2P	Purple
4	N3P	Blue
5	N4P	Green
6	N5P	Yellow
7	N6P	Orange
8	N7P	Red
9	N8P	Brown
10	BIAS	Black

2.3 Step #3: Connect the adapter cable to the EEG Electrode Cables from the Cap

Components needed



Cyton board connected to the adapter cable

EEG Electrode Cap

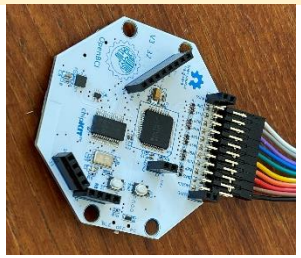
a) Find the Cap electrode connectors labeled with the electrode names in column 4 of the table below
b) Connect the Cap electrode connectors to the corresponding colored electrode cables on the adapter

Make sure the individual connectors are pushed all the way into the corresponding cap electrode

#	Cyton Board pin	Adapter cable color	Cap Electrode
1	SRB	White	**T4**
2	N1P	Gray	**Cz**
3	N2P	Purple	**C3**
4	N3P	Blue	**C4**
5	N4P	Green	**Pz**
6	N5P	Yellow	**P3**
7	N6P	Orange	**P4**
8	N7P	Red	**T5**
9	N8P	Brown	**FZ**
10	BIAS	Black	**GND**

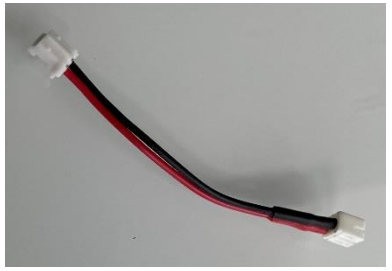
2.4 Step #4: Assemble the Cyton board

Components needed



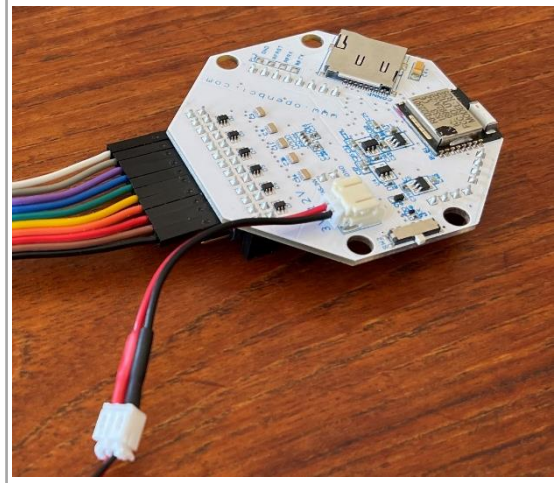
Cyton board connected to the adapter cable

Cyton board enclosure from the kit



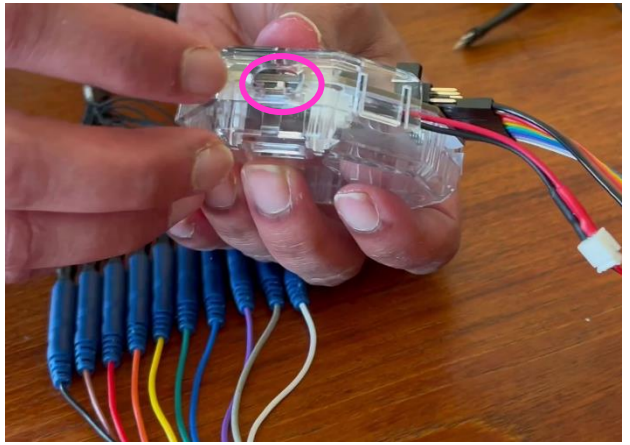
Extension cable for easy connection of the battery to the Cyton board

a) Insert the male-end of the custom pigtail connector into the battery connector on the Cyton board



b) Enclose the Cyton board in the enclosure

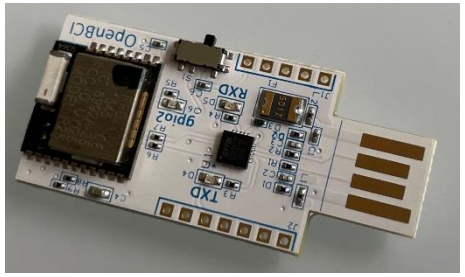
c) Make sure the Cyton board button is accessible



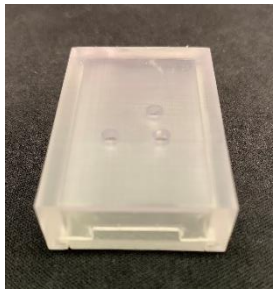
2.5 Step 5: Setting up the USB Dongle (#1 of 4)

2.5.1 Step 5a: Prepare USB Dongle

Components needed



USB Bluetooth Dongle

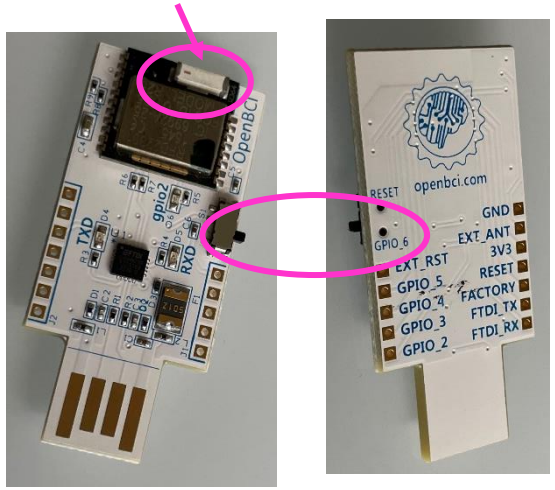


Enclosure for USB Bluetooth Dongle

Copper tape

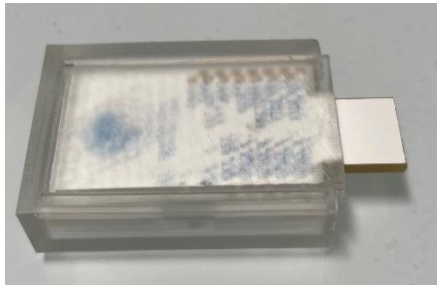
i. Make sure the USB dongle switch is on the GPIO6 position

Bluetooth antenna



ii. Place the dongle in the enclosure

iii. Slide on the cover



iv. Wrap the copper tape around the enclosure making sure the Bluetooth antenna is not covered by the tape

ii. Refer to this video on how to put the dongle in the enclosure and shield it.

Step 5: Setting up the USB Dongle (#2 of 4)

2.5.2 Step 5b: Get the Dongle Driver

Components needed

Laptop

a) Download the driver from: [Cyton USB Dongle drive].
   i. The driver typically gets downloaded in folder *This PC > Downloads* on your system
   ii. Open the folder in Windows Explorer.
   iii. The driver is in compressed format. Right–click on the name of the file and select *Extract All to* uncompress

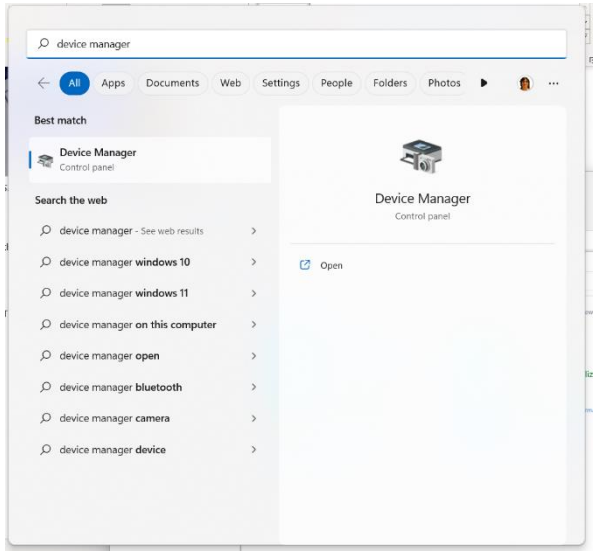
Step 5: Setting up the USB Dongle (#3 of 4)

2.5.3 Step 5c: Connecting the USB Dongle

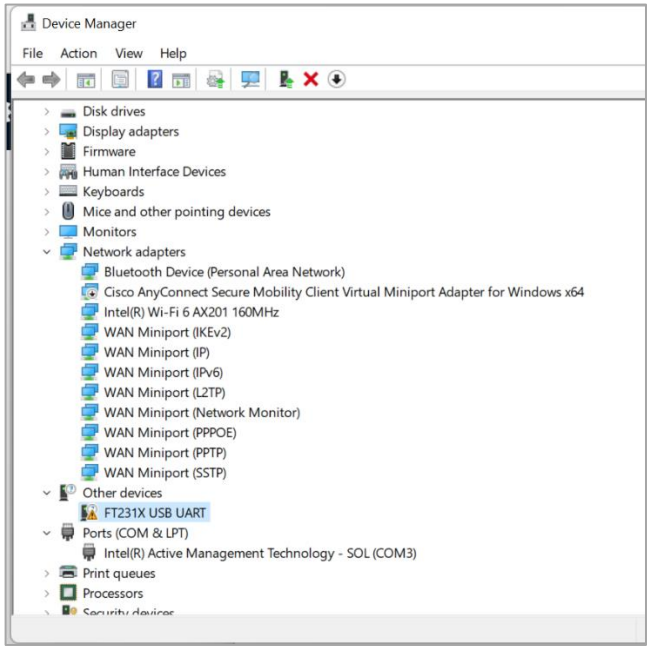
a) Connect the USB dongle to the computer
- Option 1 : Plug Dongle directly into the USB port on your laptop

  OR
- Option 2: Plug the USB Dongle into a USB port on the USB hub. Turn on the USB port

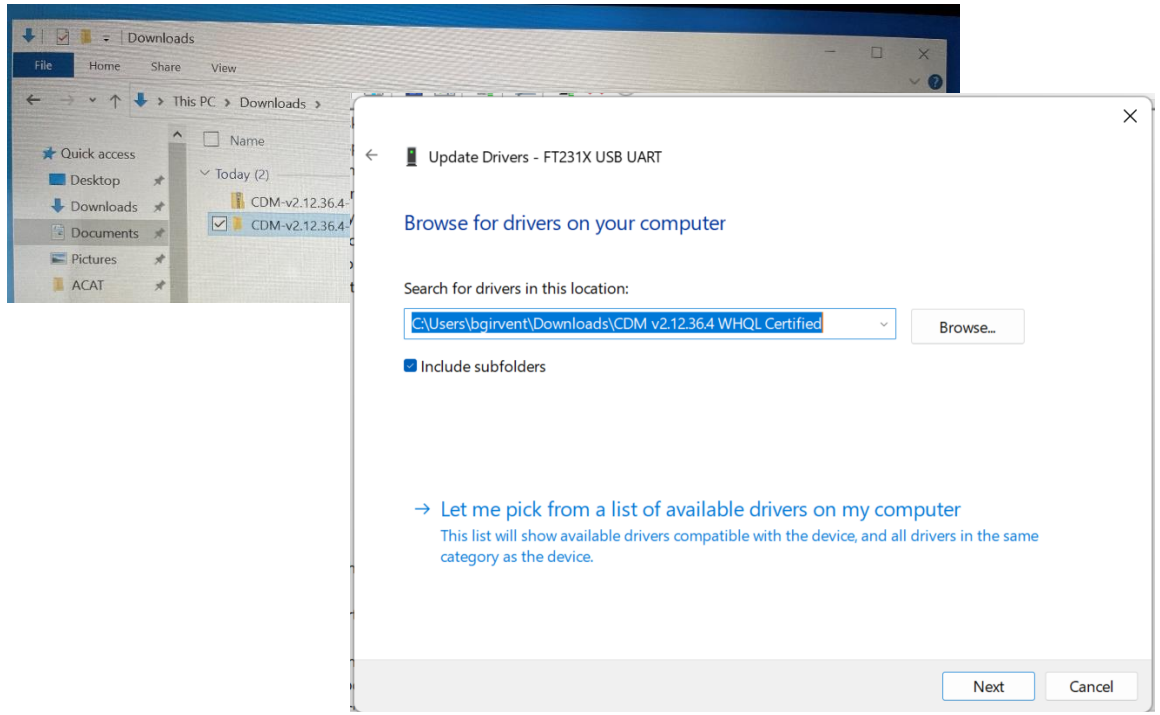
b) Open Device Manager by typing Device Manager in Windows Search window



c) Find FT23X USB, right click and select install driver



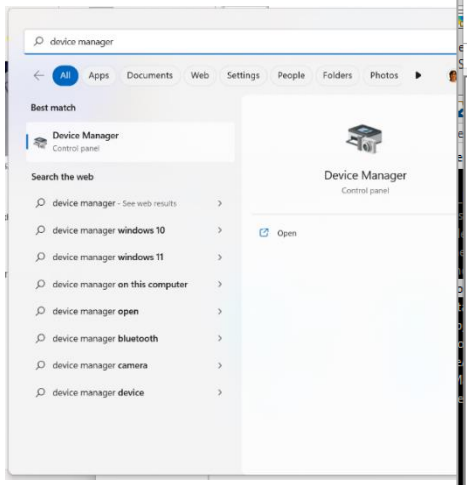
c) Click “Browse” to the location of the uncompressed driver folder from Step 2.5.2. Select it and click Next



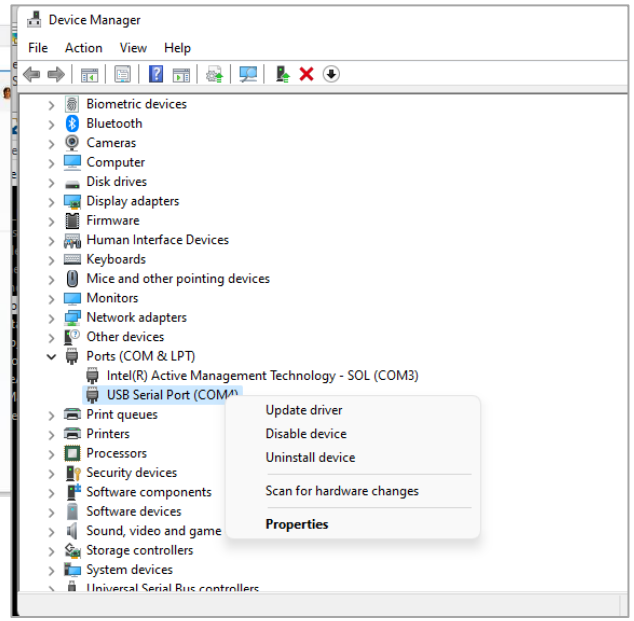
Step 5: Setting up the USB Dongle (#4 of 4)

2.5.4 Step 5d: Changing the latency settings on the port

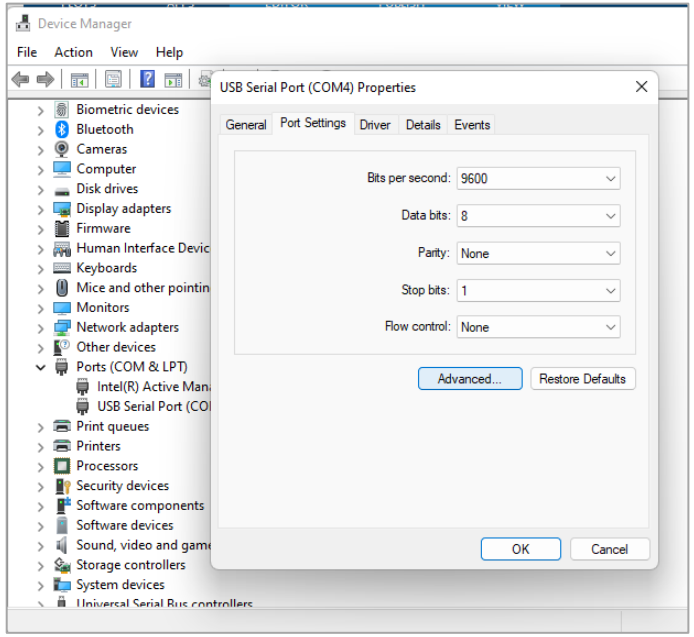
a) Open Device Manager by typing Device Manager in Windows Search window



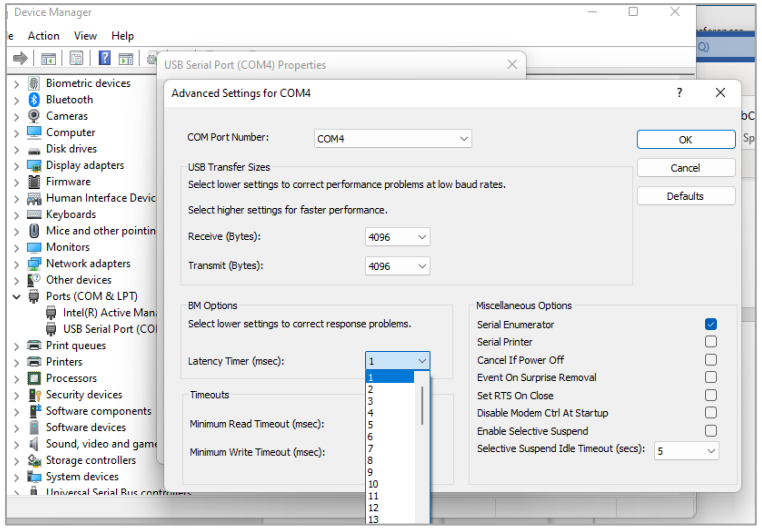
b) Under Ports (COM & LPT), find the USB Serial Port (COMx). Right click on the USB Serial Port (COMx) and select Properties



c) Go to the Port Settings tab, and click on Advanced...



d) Change Latency timer (msec) to **1ms** and click OK

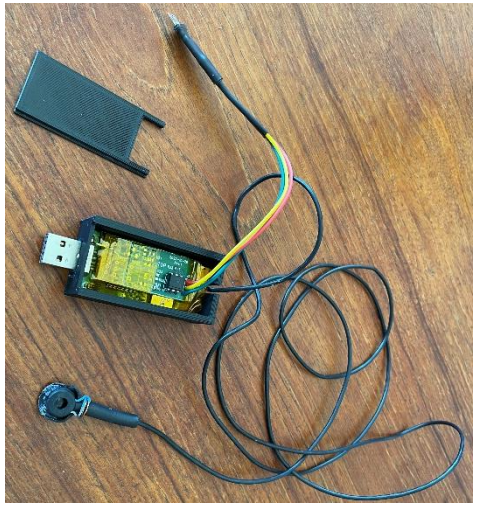


2.6 Step 6: Set up the Trigger Sensor

Components needed

Trigger sensor board + enclosure

Place the trigger sensor in the enclosure, if it is not already enclosed.

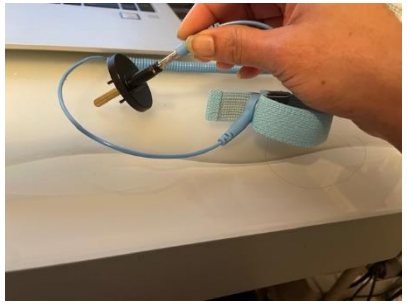


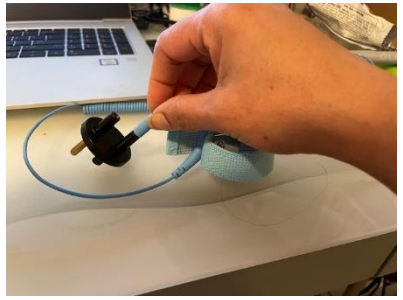
2.7 Step 7: Set up the Grounding ESD Strap

Components needed

ESD anti-static wrist strap

a) Plug in the ESD wrist strap into the grounding plug





b. Plug the grounding plug to a wall socket or power strip

3. First-time Use for the Day

If you have disconnected the hardware for battery charging, cleaning cap, etc.

3.1 User Readiness Checklist

1. Preparing the Scalp for Good Signals

ACAT uses non-invasive EEG electrodes for record brain signals. These neural signals are of extremely low magnitude (100-500 microvolts) being generated from within the skull. When using non-invasive electrodes, noise is introduced due to the bones, skin and hair that lie between the source of EEG and the electrodes on the scalp surface. Hence the scalp needs proper preparation to reduce this noise.

Some guidelines for users to help get clear EEG signals (similar to those used in a standard sleep study)**

- **Wash your hair** and refrain from applying oil or other hair styling products on the day or night before using ACAT
- As scalp oils and dead skin cells act as barriers for conducting signals, it is recommended to **clean the scalp**, especially the area right below the electrode locations, **with isopropyl alcohol** (~70%)
- **User's hair** is a source of impedance (noise) and needs to be **pushed aside** to expose the scalp to the electrode. It is best to hair not tied in a ponytail, but let loose, so it is easy to reposition and stay in place with gel application

2. Grounding the user

The static electric build up in users can introduce noise in the low magnitude brain signals. It is essential to dissipate this static charge buildup in users to record clean EEG signals.

In our experiments, we have used an ESD wrist strap (mentioned in the Hardrware requirements) with a grounding plug to help with static discharge. **This is a pre-requisite for getting consistent clean EEG signals**

Put the ESD wrist strap on the user's wrist

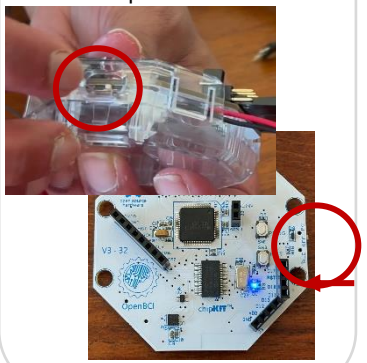
**References:

- Degabriele R, Lagopoulos J. **Techniques for effective EEG subject preparation**. *Acta Neuropsychiatrica*. 2008;20(4):218-219. doi:10.1111/j.1601-5215.2008.00318.x
- Campbell IG. **EEG recording and analysis for sleep research**. Curr Protoc Neurosci. 2009 Oct;Chapter 10:Unit10.2. doi: 10.1002/0471142301.ns1002s49. PMID: 19802813; PMCID: PMC2824445.

3.2 Hardware Checklist (#1 of 3)

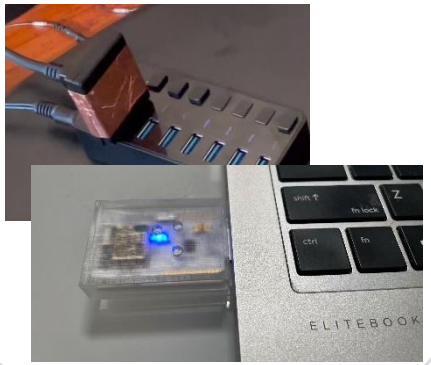
a) Make sure that you have a charged Cyton battery

b) Make sure the Cyton board switch in the OFF position

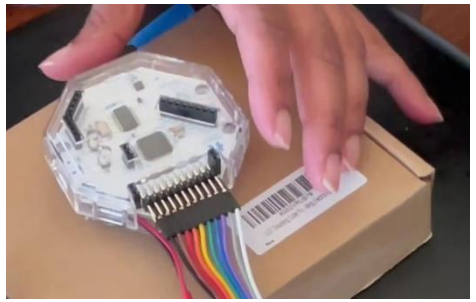


c) Plug in the charged battery into the female connector of the pigtail on the board

d) Plug in the USB dongle in one of the USB ports of your laptop or USB Hub and turn on the power



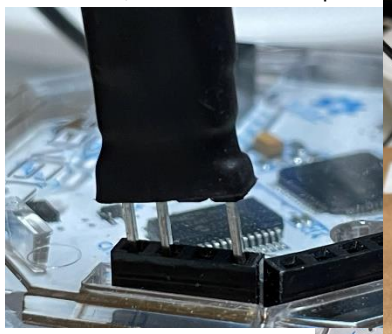
e) Place the Cyton board on a box, any cardboard box will do, e.g., the box from the OpenBCI kit. **<u>This is essential to reduce noise in the signals due to other components</u>**

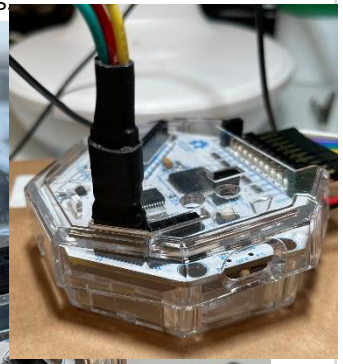


f) Plug in the optical sensor in one of the USB ports of the Hub or laptop.

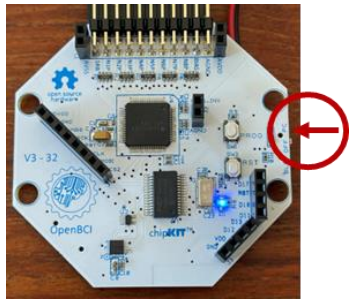
Note: if it is already plugged in, it is recommended to reset it by unplugging and plugging it back in or turning the power off/on the USB HUB.

g) Connect the Trigger sensor connector to the Cyton board making sure the the green, red and yellow cables are in the GND, VCC and D13 pins.

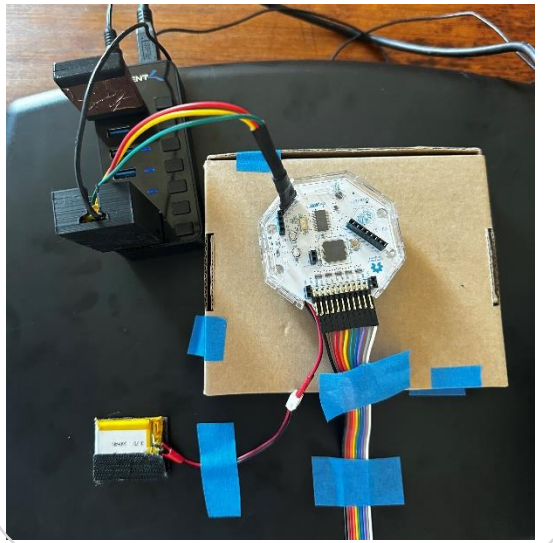




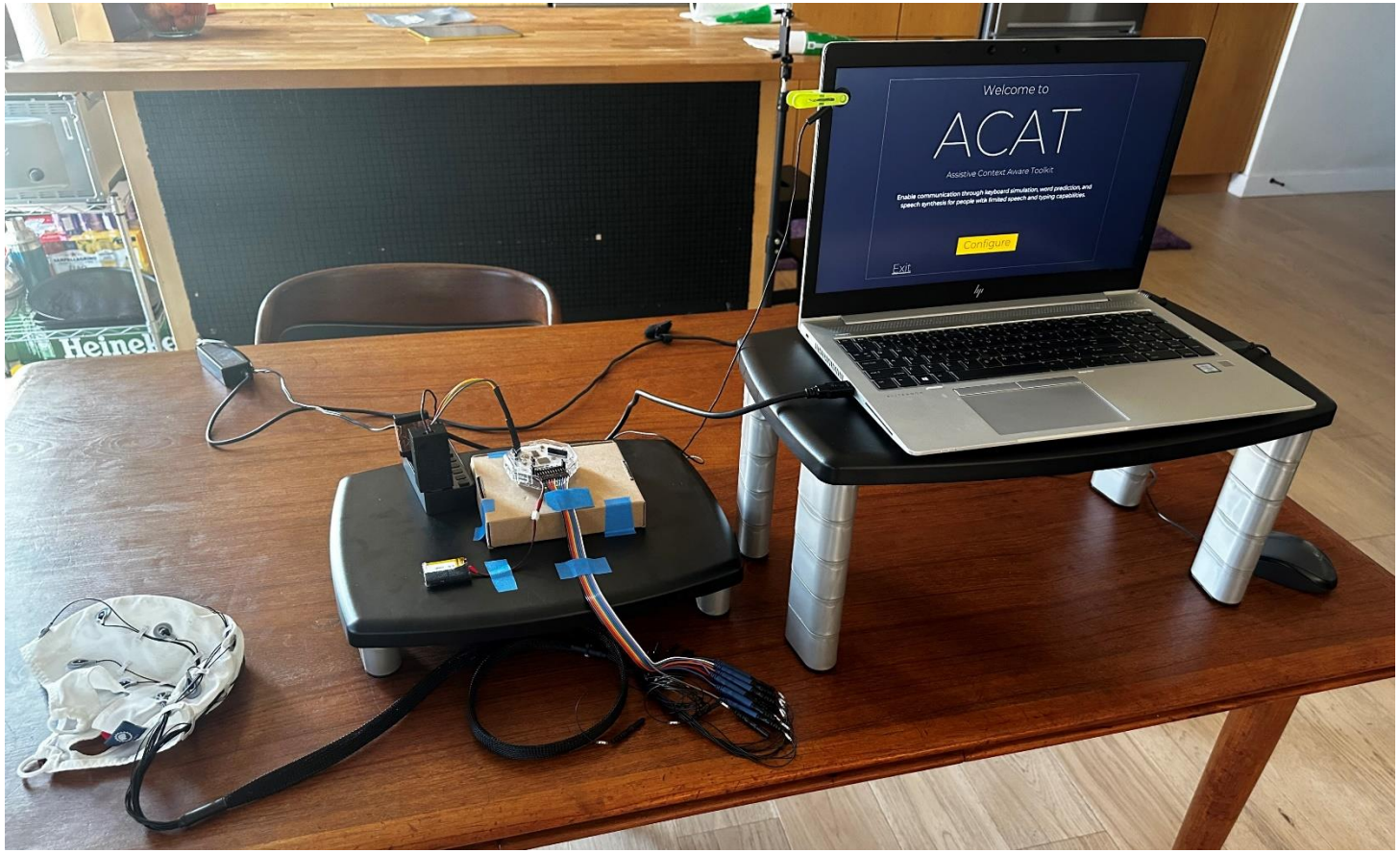
h) Move the Cyton board switch to the PC position



i) Lightly secure the components by a masking tape or similar



3.2 Hardware Checklist (#2 of 3) : Setup

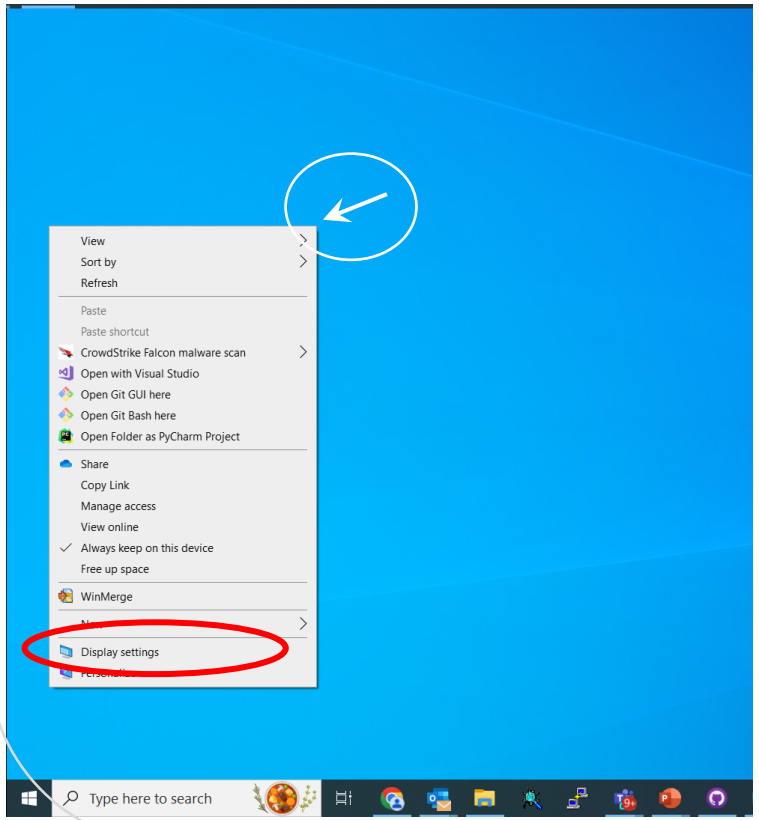


3.2 Checklist (#2 of 3)

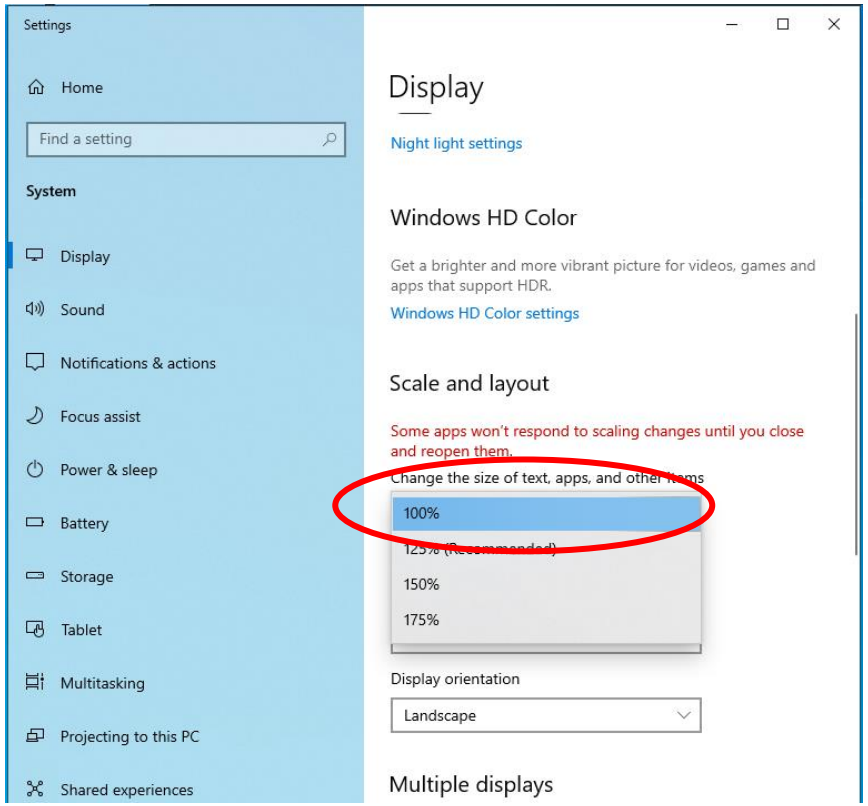
1. Make sure laptop is plugged into a power outlet
2. Adjust your display brightness to maximum

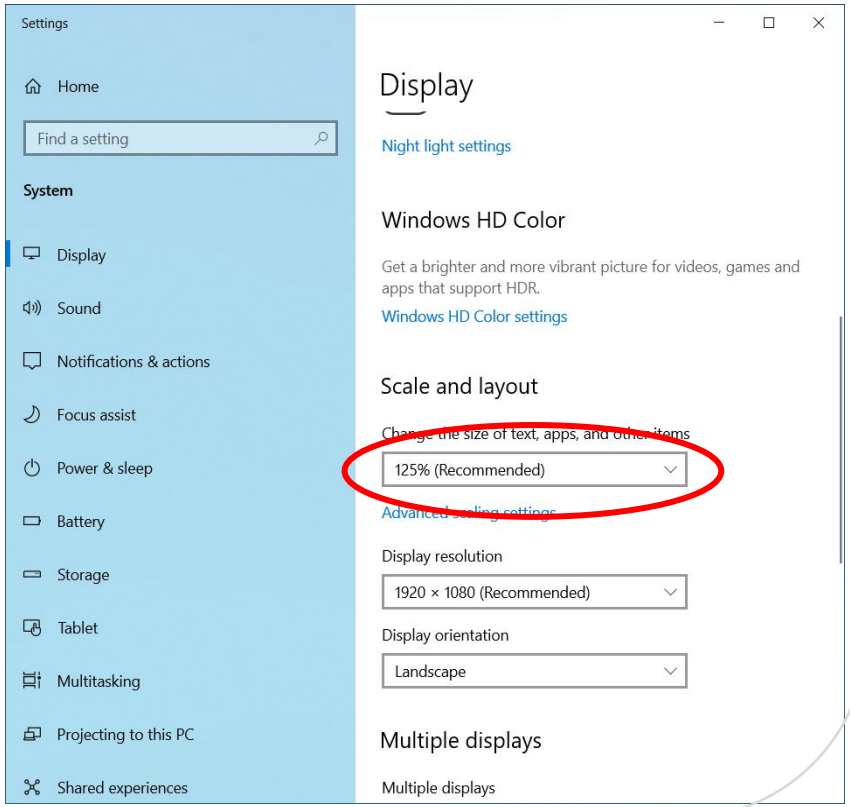
3. Check the Display scaling is set to 100% or 125%

a) Right-click anywhere on the display. A menu will pop-up,
b) Select Display Settings



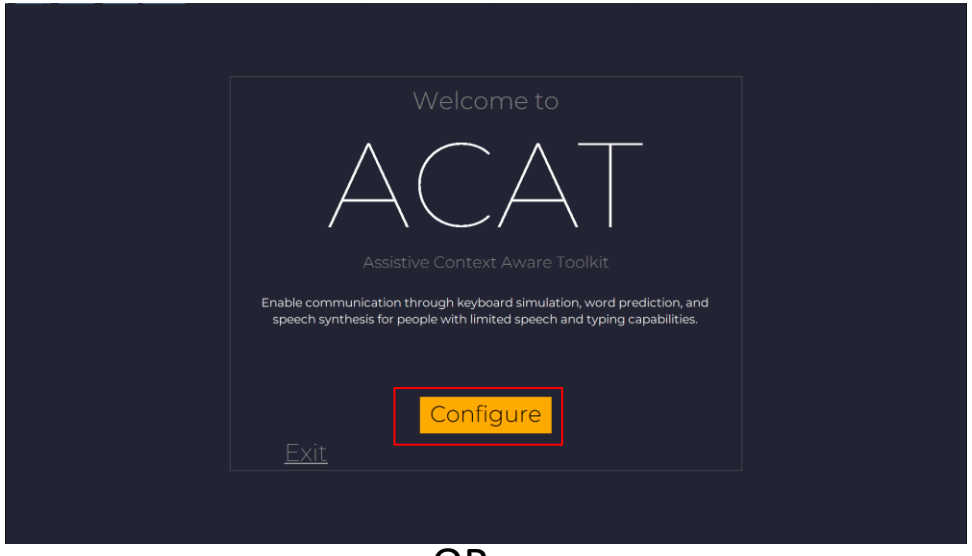
c) Scroll down to the "Scale and Layout section
d) Change the Scaling to 100% or 125%, if it is not already one of these





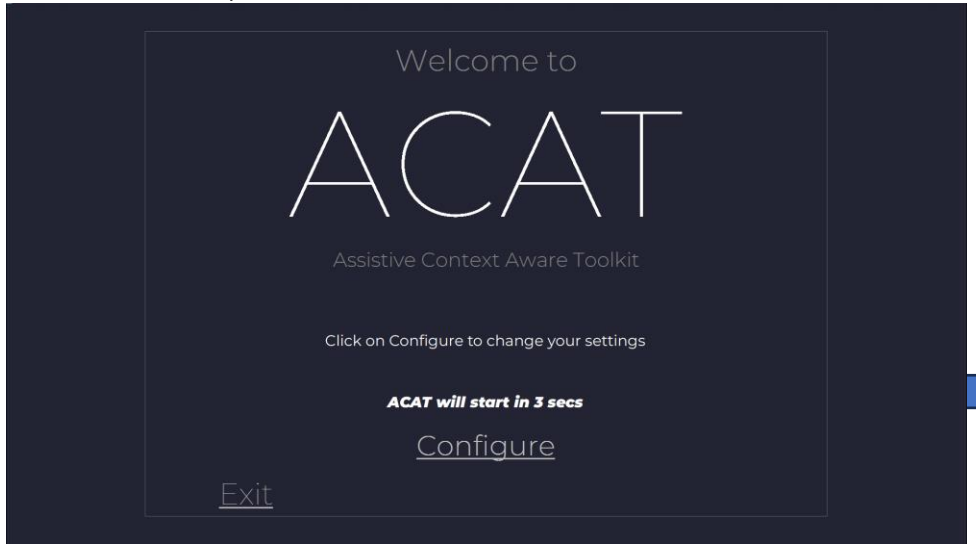
3.3 Step – Run ACATTalk with BCI switch

a) Click ***Configure***, if this is your first time launching ACATTalk with the BCI switch

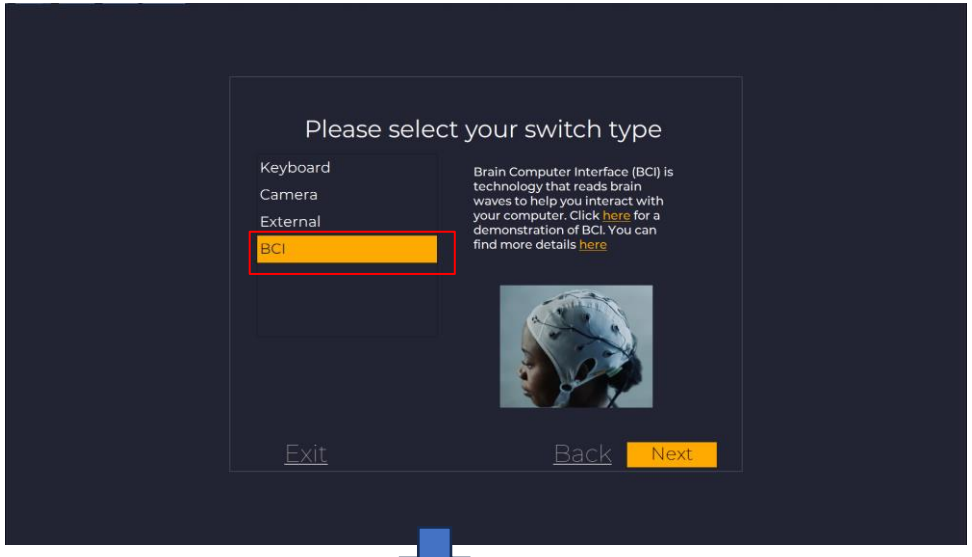


OR

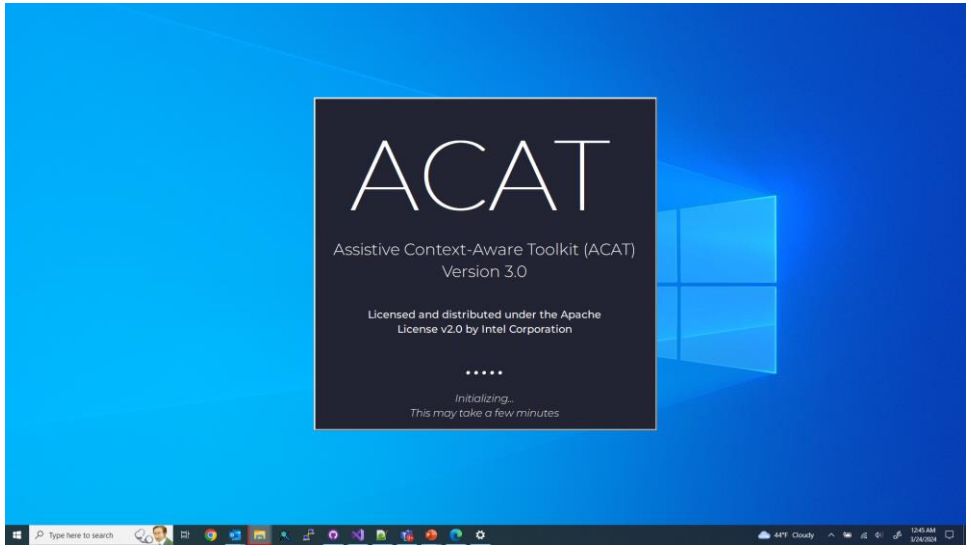
For subsequent runs, ACAT will auto-start with the last



b) Click ***BCI*** switch



ACAT does startup initializations, including loading the language models. This step can take several minutes. It is usually much longer when you launch ACAT for the first time or after rebooting your system.



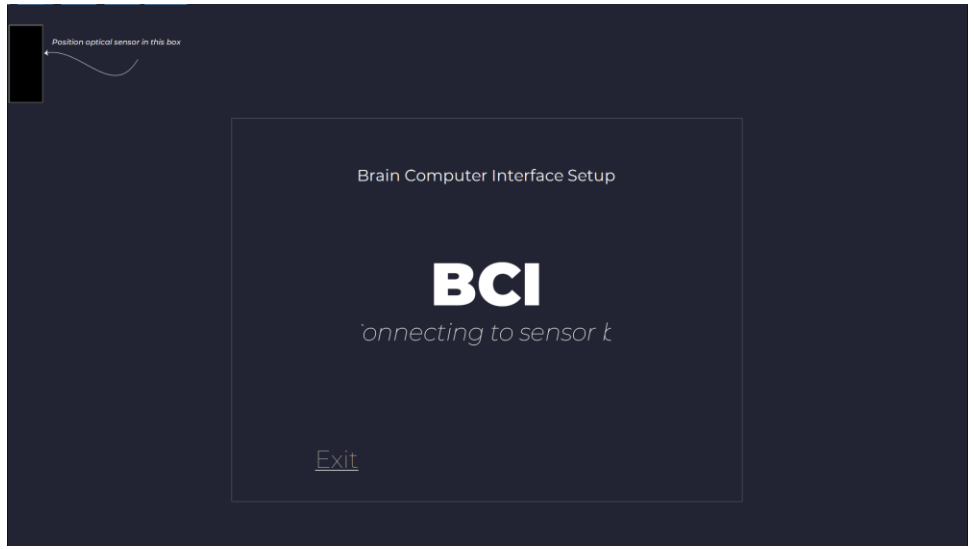
3.4 BCI Onboarding

Connecting to Cyton Board and Optical Trigger Sensor

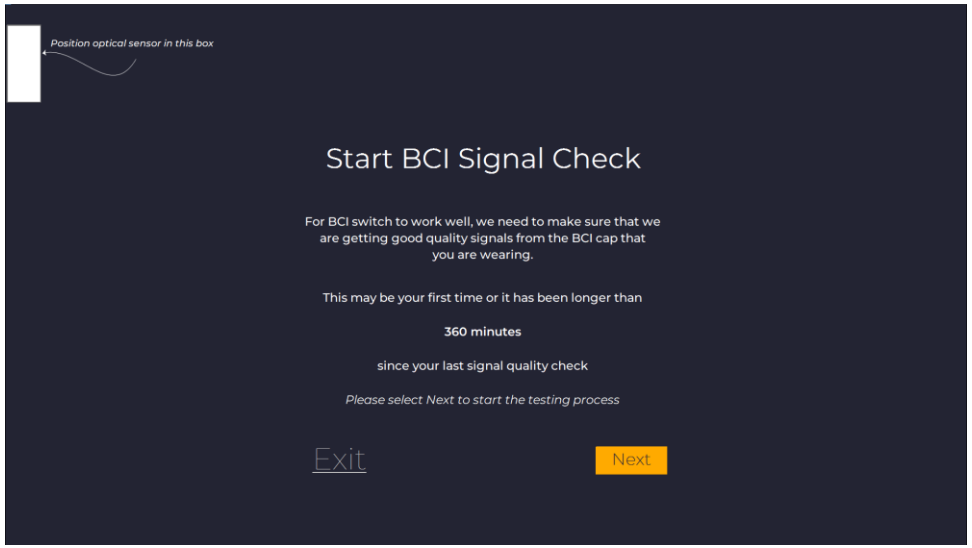
3.4.1 ACAT Initialization : Success

After ACAT initializations are complete, ACAT continues with initializing the BCI hardware. This includes

a) establishing connection with the BCI (OPENBCI Cyton) board
b) establishing connection with the Trigger sensor board
c) checking if the trigger sensor is set up correctly on the display



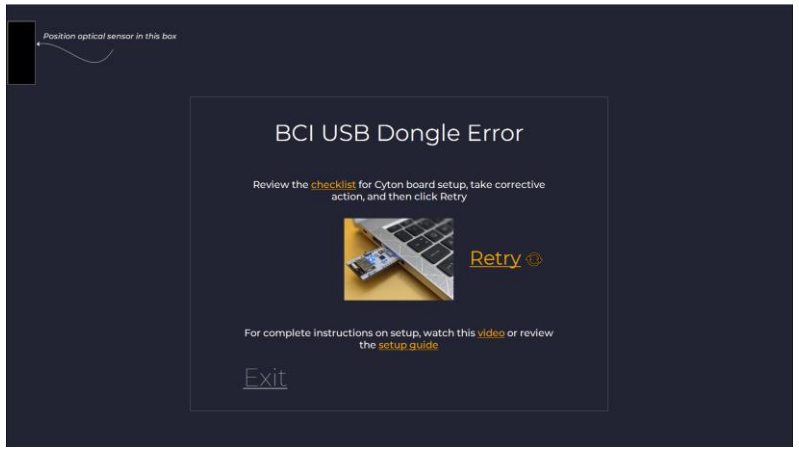
If Initializations Succeed, ACAT will auto advance to the Signal Quality Check



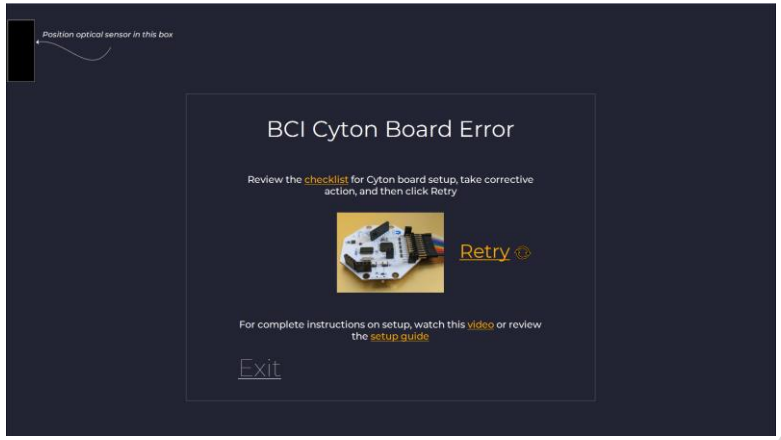
3.4.2 ACAT Failure connecting to the Cyton Board

Troubleshoot!

If you see one of these error screens



OR

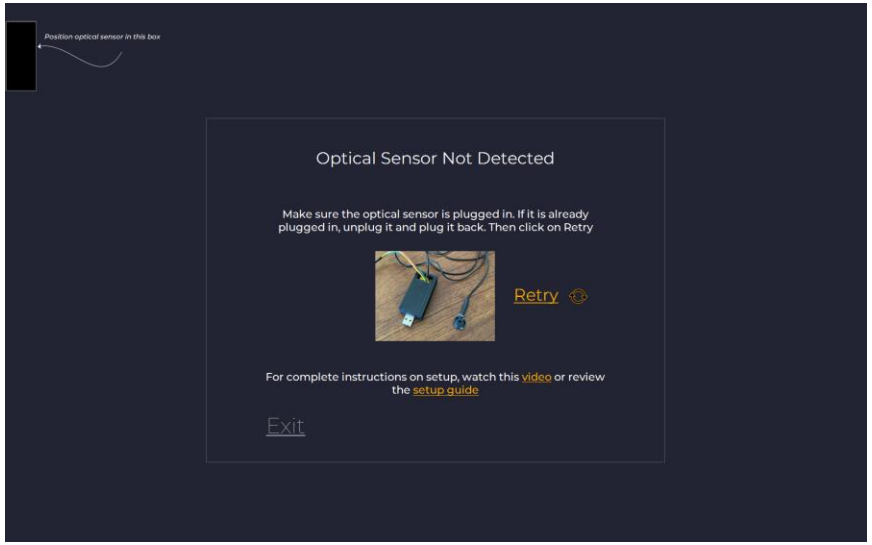


a) Check if the USB Dongle is plugged in and powered on
b) Check that you have installed the Cyton driver (refer to Section 2.5.3)
c) Check if the Cyton board switch is in the "***PC***" position
d) In case you identified (a) or (b) as an issue and fixed it, click ***Retry***. ACAT tries to connect to the Cyton board again.
e) If it still does not work,
   - put the Cyton board switch to the off position.
   - Unplug/plug-back the USB dongle
   - power on the Cyton board (put the switch on the PC position)
   - click "***Retry***"
e) If it still does not work, it could be that the battery is low on charge. If you have a charged backup battery, replace the battery.
   - put the Cyton board switch on the off position.
   - replace the battery
   - power on the Cyton board (put the switch on the PC position)
   - click "***Retry***"

3.4.3 ACAT Failure connecting to the Trigger (optical) Sensor

Troubleshoot!

If you see this error screen



a) Check if the Optical sensor is properly set up. Refer to Section 3.1 d-e

b) If not, set it up and, click ***Retry***. ACAT tries to connect to the optical sensor board again

c) If it still does not work,

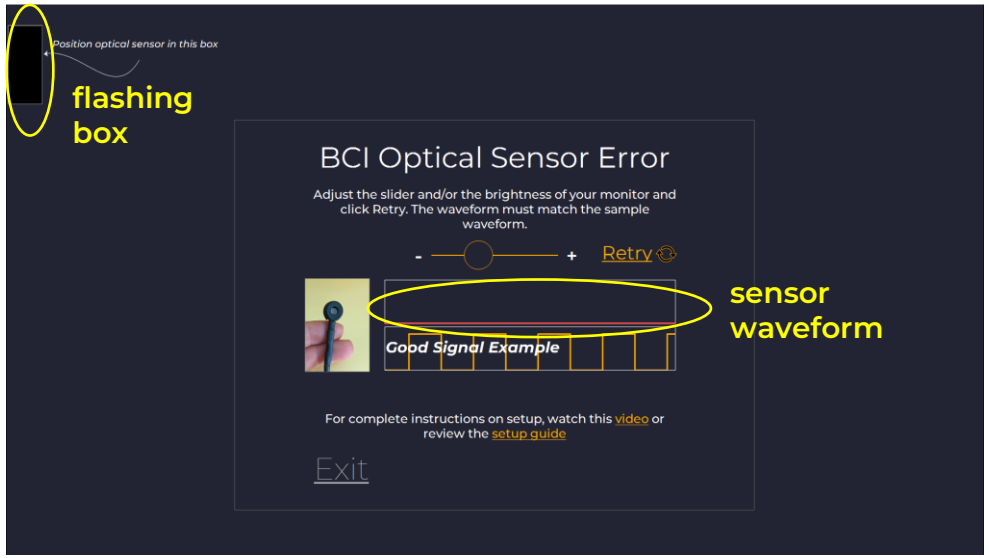
- put the Cyton board switch to the OFF position.
- Unplug the optical sensor board (or power it off if connected to a hub)
- Plug-back/power-on the sensor board
- power on the Cyton board (put the switch on the PC position)
- click "***Retry***"

Note: *This error can also occur if your system has been in sleep state or been inactive for some time. On some systems, the USB port goes into suspend state. Hence the USB device needs to be reset to make the USB port active again*

3.4.3 ACAT Failure: Optical Sensor not triggering correctly

Troubleshoot!

If you see this error screen



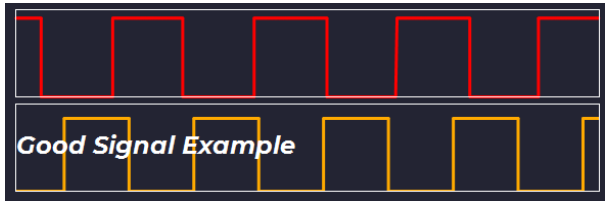
a) Check that the rectangular box in the top left corner is flashing. If it is not, it implies that there is an issue with the sensor board connection, and it needs to be reset

- Exit ACAT
- Plug out the sensor board and plug it back in
- Restart ACAT

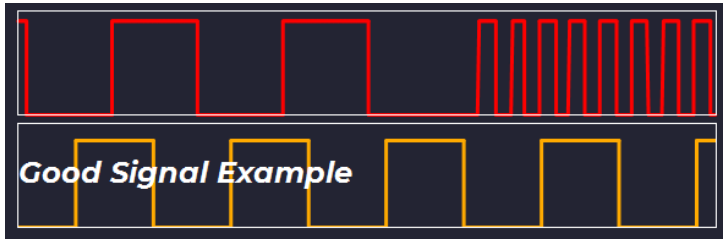
b) Check the ***sensor waveform*** in the box above the *Good Signal Example*. If it is a flat red line as shown below

- If the rectangular box in the top left is flashing, then, check if the sensor is placed correctly on top of the flashing box. Refer to Section 3.4.4 for instructions on how to position the sensor correctly on the display
- Once you see a waveform that's similar to the *Good Signal Example, go to 3.4.3.c*
- If the rectangular box is not flashing, follow the steps in (a)

c) If the waveform is similar to the *Good Signal Example*

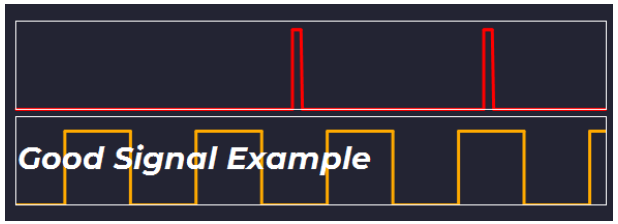


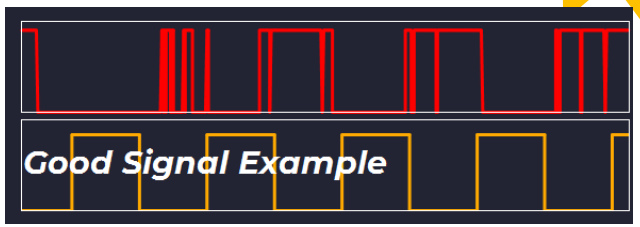
- Click the ***Retry*** button to run the trigger test. You will pulses as shown below and if the test succeeds, ACAT will advance to the Signal Check Screen



Troubleshoot!

d) If the waveform is different than the square *Good Signal Example* (see some examples below)





i. Make sure that the sensor is positioned correctly on the flashing box on the top left area of the display (Refer to Section 3.2.1). Adjust the position if needed and follow Step c)

ii. If the sensor position is correct, then make sure that your display is set to the maximum brightness. Adjust the brightness, if needed and follow (c)

iii. If (i) and (ii) are not the issue, you will need to change the sensitivity of the optical sensor. This can be done using the slider control on the screen

iv. Move the slider slightly either down and up and Click *Retry*

v. If the adjustment worked, it will go to the Signal Check Screen (Refer to Section 3.3)

vi. Continue making small increments/decrements and Click *Retry, until trigger test succeeds and screen advances to Signal Check (Section 3.3)*

3.4.4 Position the optical sensor on the trigger box area of the UI

Components needed

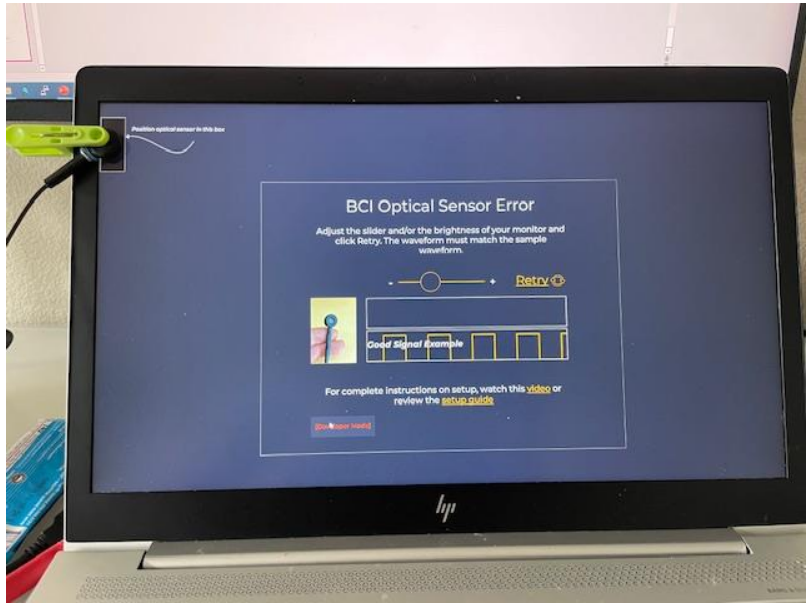
Sensor

Clip

Front side

Back side

a) Run ACAT. The BCI initialization will pause on this screen



b) Clip the optical sensor on the box in the top left as shown, making sure the front side is face down on the display

Note: Make sure the sensor is completely inside the box and it is snugly attached to the display, such that no additional light (besides the box color) is triggering the sensor

3.4.5 Optical Sensor Functionality

ACAT uses the optical sensor to timestamp the EEG data. These timestamps help ACAT synchronizing the recorded brain signals with the highlighted UI elements on ACAT's interface. In our BCI, accurate timing is crucial for detecting changes in brain patterns, known as event-related potentials (ERPs), generated by visual stimuli like highlighted UI elements.

You will see a rectangular box close to the top left corner of the UI. This box flashes, alternating between black and white colors. When ACAT is in the switch scanning interface, the flashing is synchronized with the scanning speed. The function of the optical sensor is to detect the change in color from black to white. Hence, the optical sensor needs to be positioned on top of this rectangular box on your display.

The optical sensor is also connected to the auxiliary pins on the Cyton board (https://docs.openbci.com/Cyton/CytonExternal/) – Refer to Section 3.1.g - to timestamp the EEG data.

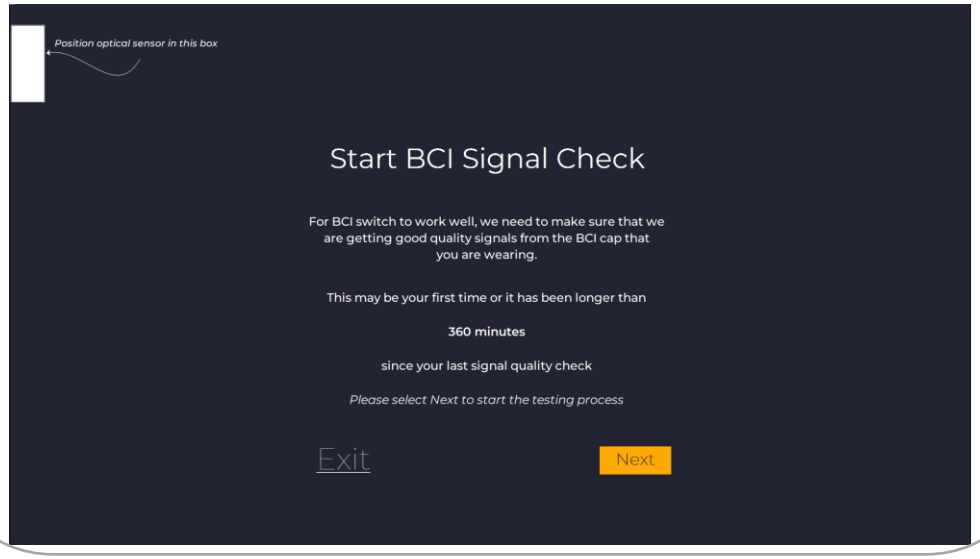
3.5 BCI Onboarding: Signal Check

It is essential to get good, clean brain signals for the BCI input to work. The signal check screens will guide you through

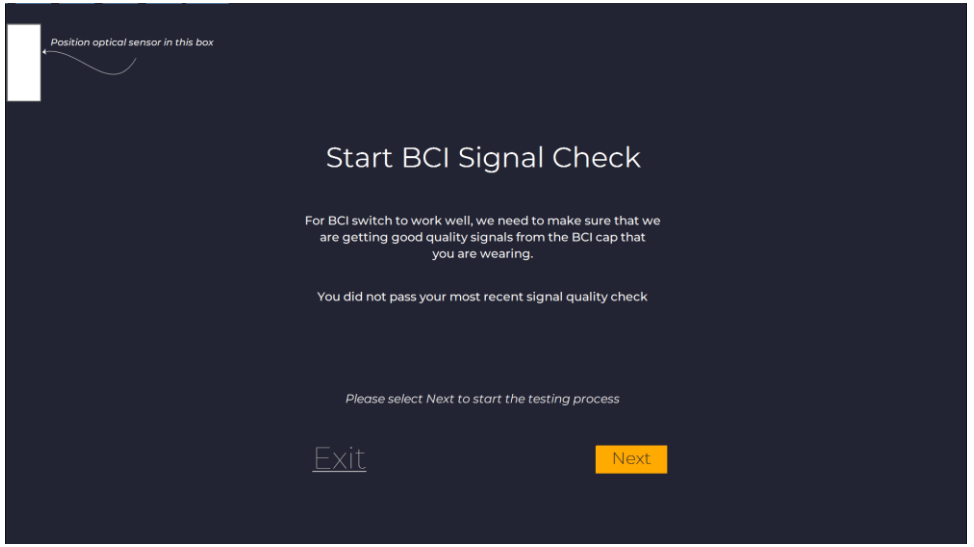
- Setting up the EEG cap, adding gel, if this is the first time you are putting on the cap for the day
- Showing the brain signals being captured by the sensors
- Providing metrics for the signal quality
- Ensuring that the quality is adequate for proceeding further with typing

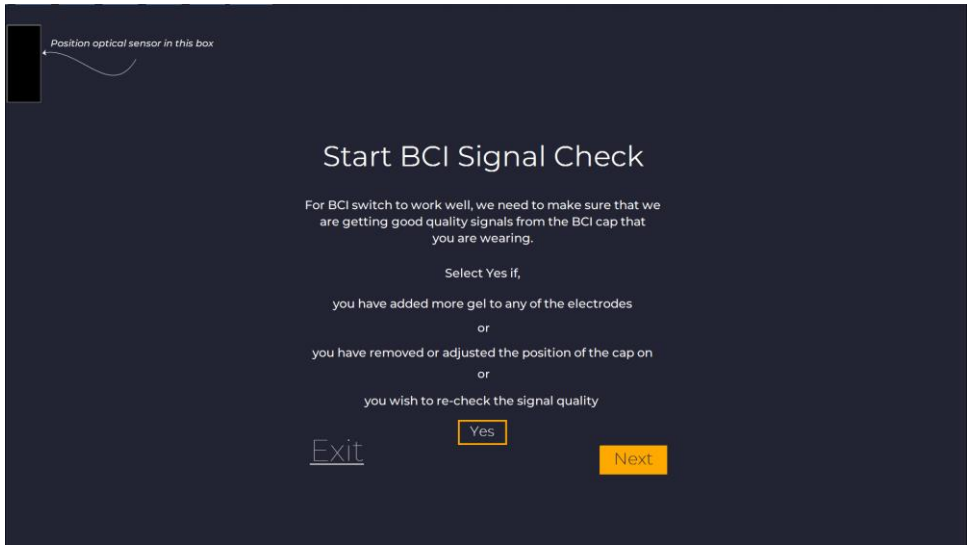
3.5.1 Signal Check – 3 Different Start Sequences

i. If this is your first time running ACAT or it has been more than 6 hours since you used ACAT, you must run the Signal Check



ii. If your Signal Check had failed the last time you ran ACAT, you must run Signal Check





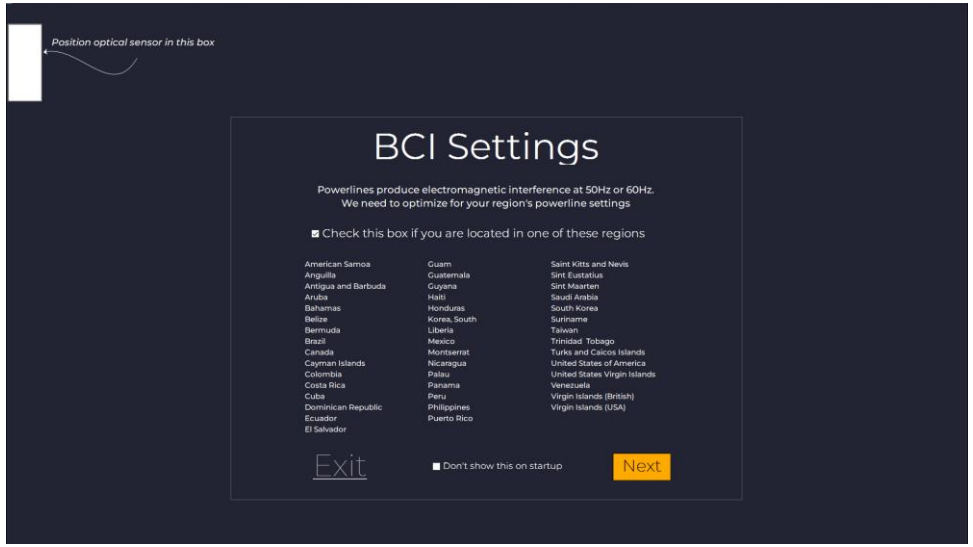
iii. If you had a successful Signal Check the last time and it has been less than 6 hours since, you can choose to skip *Signal Check. However, i*t is recommended to redo the check, if

- you have adjusted the cap since your last run **OR**
- you are having difficulties triggering the interface and you want to check whether your Signal Quality is still good.

Note: BCI Signal quality depends on good electrical connection between the scalp and the electrodes on the cap. The quality can vary significantly even if the cap has to be adjusted or if the cap is removed and placed back on the scalp and extra gel added. Hence it is advised to run signal check if any cap adjustments have been made between sessions

The signal quality checks are executed on the 8 electrodes connected to the main Cyton board. Any additional electrodes connected with the optional Daisy board, are not checked.

3.5.2 Signal Check: Set your Geographical Location



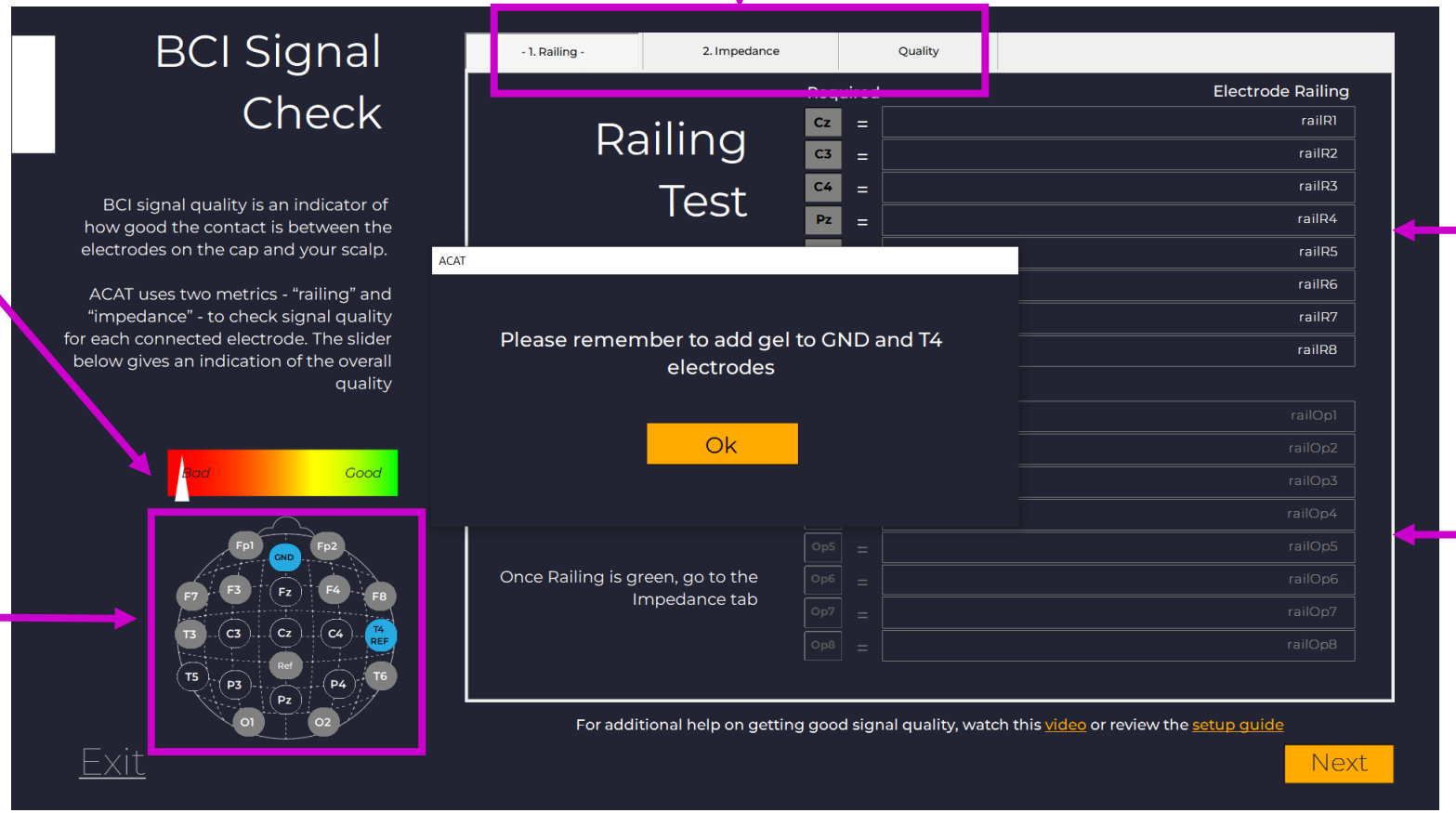
ACAT uses non-invasive EEG electrodes to record brain signals. These neural signals are of extremely low magnitude (100-500 microvolts) and generated from within the skull. The signals represent electrical recording of brain activity. Powerline interference is one of the most common source of interference for EEG signals and is caused by electromagnetic coupling from powerlines. This interference needs to be suppressed.

The powerline frequency is either 50Hz or 60Hz and is dependent on the geographical region/country. This screen asks you to identify your geographical region, in order to filter out the appropriate interference signal

This needs to be set only once. Check the '*Do the do not show this on startup*' checkbox to not have to set it everytime you start ACAT.

3.5.3 Signal Check: UI Overview

Three clickable tabs : 1. Railing 2. Impedance 3. Overall Quality



Color bar which indicates the overall Signal quality from all the electrodes

Signal quality checks are executed on the top 8 electrodes connected via the main Cyton board

Bottom 8 channels connected via the optional Daisy board are not tested for signal quality

Schematic of the EEG cap and electrode locations

- **Gel needs to be absolutely applied to these electrodes first**
- **Gel needs to be applied to these electrodes after the blue electrodes. The color of these electrodes will change after you apply gel and run the tests to indicate signal quality**
- **Gel does not need to added to these electrodes. ACAT does not use these electrodes by default**

3.5.4 Putting the cap on the user

a) Put the cap on the user's head

b) Secure with the strap around the chin. It should be snug but still comfortable for the user

c) Adjust the cap such that there are no wrinkles by pulling at the edges. Make sure the electrodes lie flat on the scalp

Correct Cap placement

EEG electrode cap correctly placed with the green tag on the back and the wires on the outside

EEG electrode cap correctly placed with the two frontal electrodes aligned to the eyes

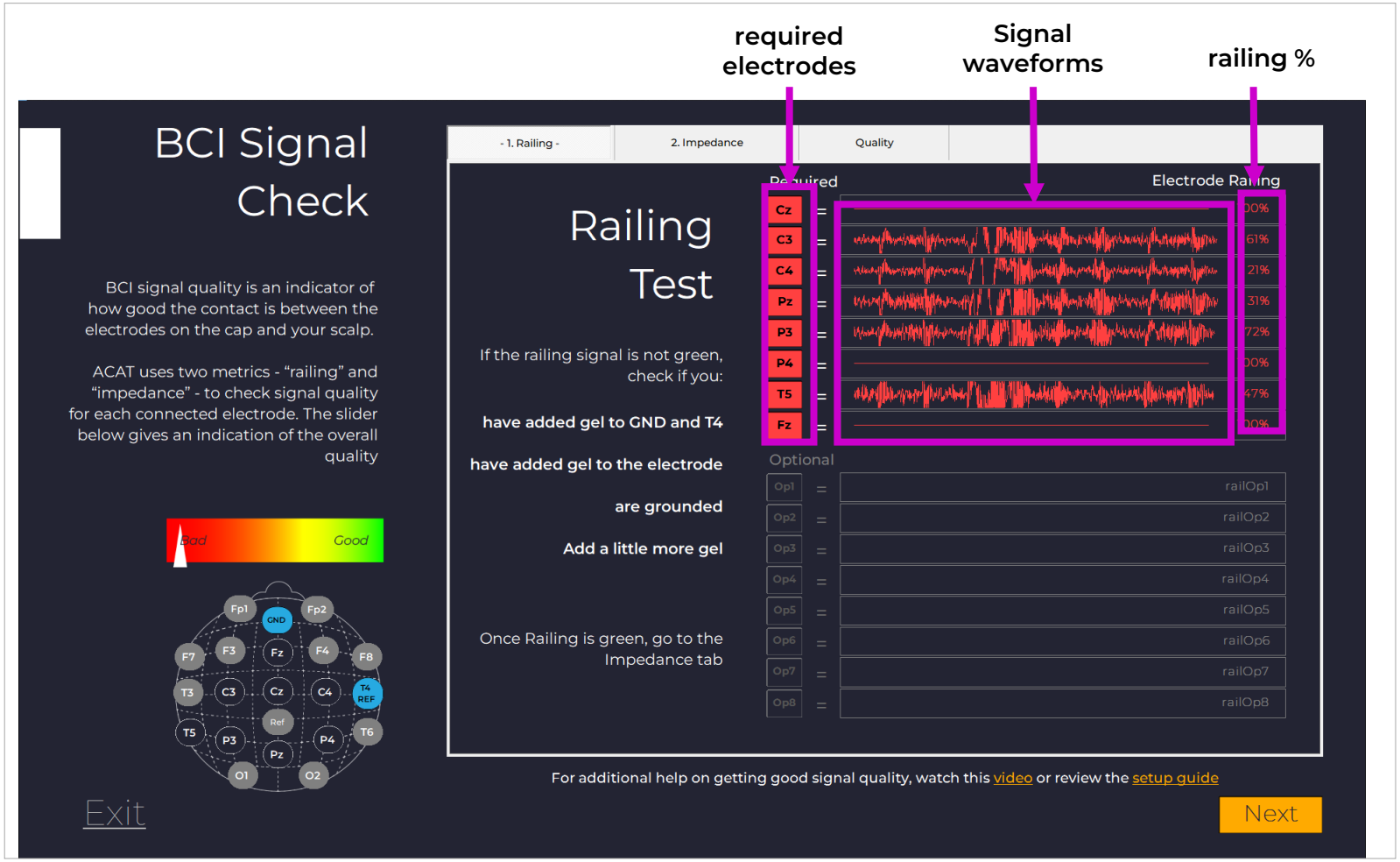
3.5.5 Fill the syringe with gel

Gel & syringe

3.5.6 Signal Check: Guide to Applying Gel to the Cap

- As soon as you land on this screen, you should start seeing signals in the *signal waveform* region of the UI
- If you have not yet applied gel, all the required electrodes will show red indicating bad signal quality.

Note: The goal is to get all the required electrodes to 'green' railing status. The railing % should be ideally less than 10% and as close to 0% as possible



Guide to applying gel to the electrode cap

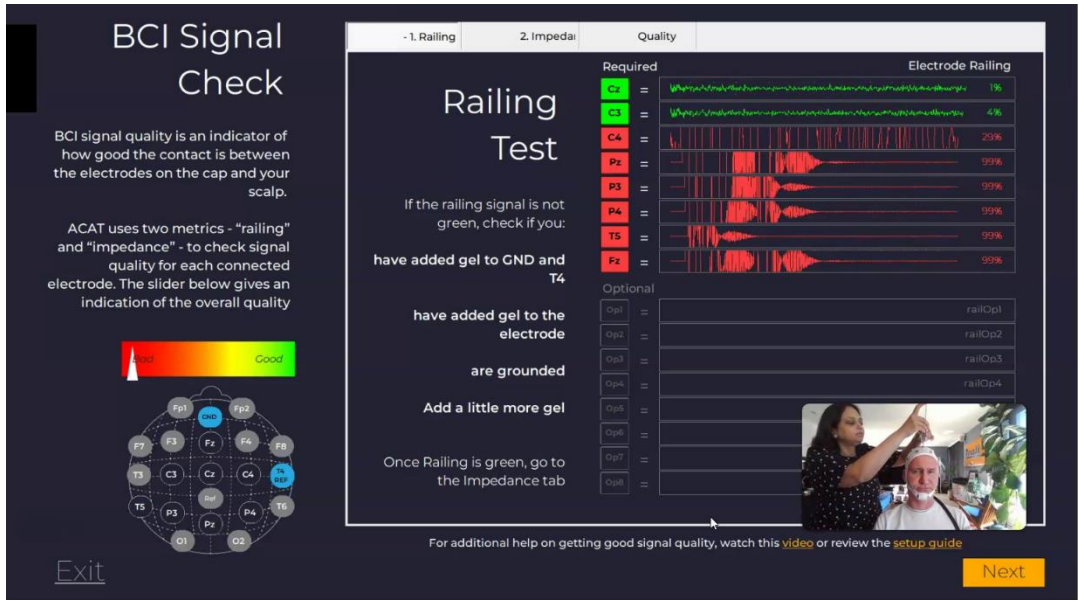
1) With no gel applied the Start by adding gel to the GND electrode location
2) Next add gel to the T4 electrode location. ACAT uses this as reference electrode

Note: There will be no visible change in the UI after you apply gel to GND and T4.

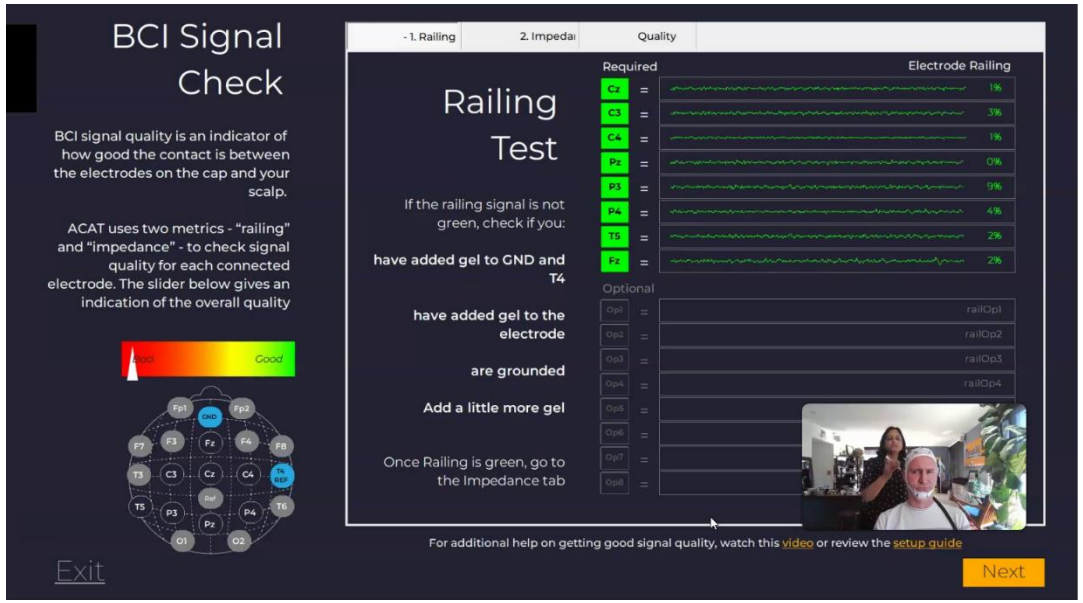
3) Starting with the first electrode in the list, add gel to that electrode. ***Note: too much or too little gel impact signal quality.*** So just add enough until user feels the gel on their scalp.
4) Give it a few seconds, you should start seeing the corresponding waveform turn green and the railing % change
5) If the railing % does not drop to below 10%, tap down the corresponding electrode location to help electrode make better contact with the scalp
6) Add a tiny bit more gel until the railing drops down to ideally below 105

Examples of applying gel to the electrodes

Signals after adding gel to GND, T4, Cz and C3



Signals after adding gel to GND, T4 and all the 8 required electrodes.



Note: the electrodes on the cap do not show the status, since the impedance test has not been completed

3.5.7 Signal Check: Troubleshooting: Railing (#1 of 2)

Problem: all electrodes are still 'red' and close to 100% railing even after adding gel to all of them

Solution:

i. Double-check that you have added gel to electrodes labeled GND and T4. Unless these have adequate gel, the signals are just noise

ii. If GND and T4 have gel, and the signals are still red, tap the location of one of the electrodes, say Cz, see if there is any change in the signals

iii. Add a little gel to one of the electrodes and observe for any change in signal and railing %

iv. If there is no signal change, there is a possibility that the battery on the Cyton does not enough charge and might need recharging.

- Exit ACAT - click 'Exit'
- Restart ACAT
- If you get the Cyton board error during BCI initialization (refer to Section 3.4.2), it implies that the battery is discharged and needs recharging
- Exit ACAT
- Put the battery for charging
- If you have a charged backup battery, replace battery on the Cyton board (refer to Section 3.2.c)
- Restart ACAT

Problem: a few electrodes are green and there are some yellow and some red

Solution:

i. Check that you have applied gel to corresponding electrodes

ii. Check that you have grounded the user using the ESD wrist strap or some equivalent mechanism

iii. Tap down the electrode location to help make better scalp contact

iv. Add a little bit more gel to that electrode location

v. Wait a few seconds and observe change in railing %. It should turn yellow or green

Problem: the above 2 does not help

Solution:

i. If most electrodes are green and only a couple are yellow, click the Impedance tab

ii. Run impedance test

3.5.7 Signal Check: Troubleshooting: Railing (#2 of 2)

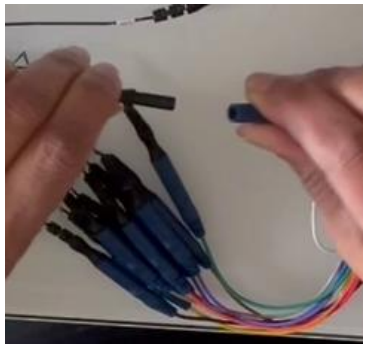
Problem: all electrodes are still ‘red’ even after adding gel to all of them, but the railing % is 20-40% range

Solution: change reference – try T3 as reference

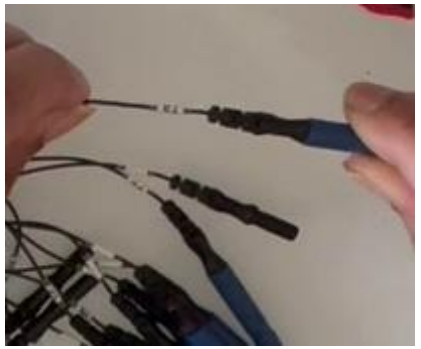
a) Find the cap electrode T4 which is connected to the white wire on the cable.

b) Find the cap electrode T3. This is an unconnected cable

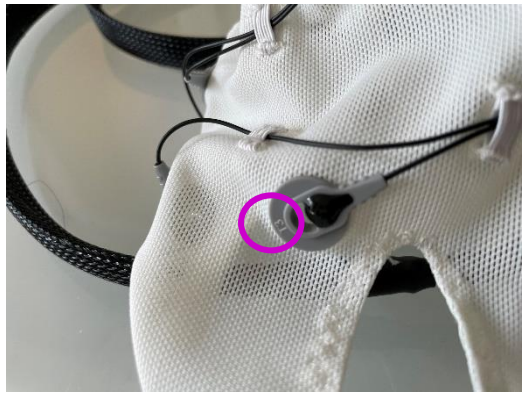
c) Disconnect T4 from the connector of the white wire



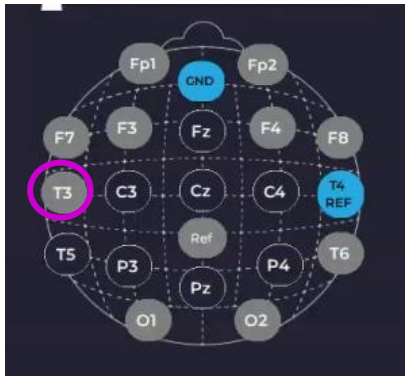
d) Connect T3 to the connector of the white wire. ***Now T3 is the REF electrode***



e) Add gel to T3. It is positioned close to the user’s left ear



Note: The T3 electrode on the cap UI, will show grey. But it will still be used as reference because of the hardware connection change made in steps a-d above

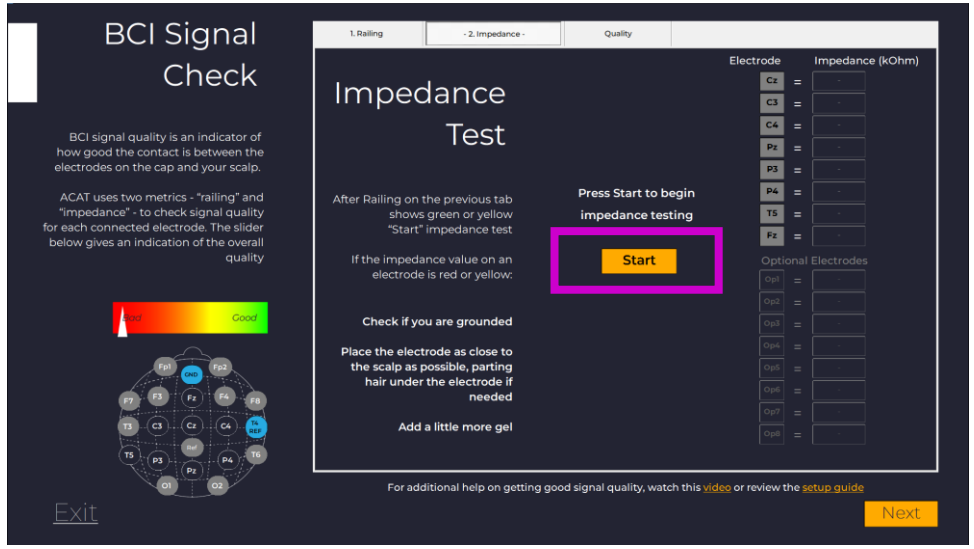


f) Now check to see if the railing % values go down on all electrodes

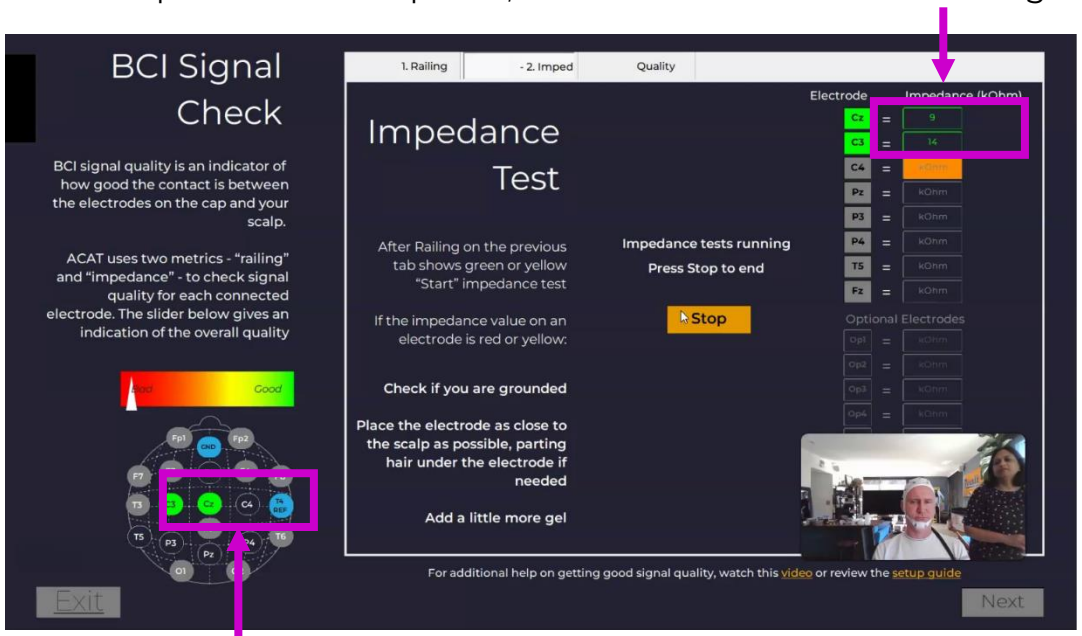
3.5.8 Signal Check: Impedance Test

- After the railing test shows most electrodes as green, Click on the ‘Impedance’ tab. Click ‘Start’ to start the test
- The impedance test will automatically stop after completing one cycle through all electrodes. There’s no need to press Stop button.
- This test measures the impedance at every electrode one at a time.
- During this test, the board sends a small current through the highlighted electrode to obtain the impedance value

Note: The goal is to get all the required electrodes to ‘green’ status. The impedance value should be ideally less than 100 kOhm and as close to 0 kOhm as possible



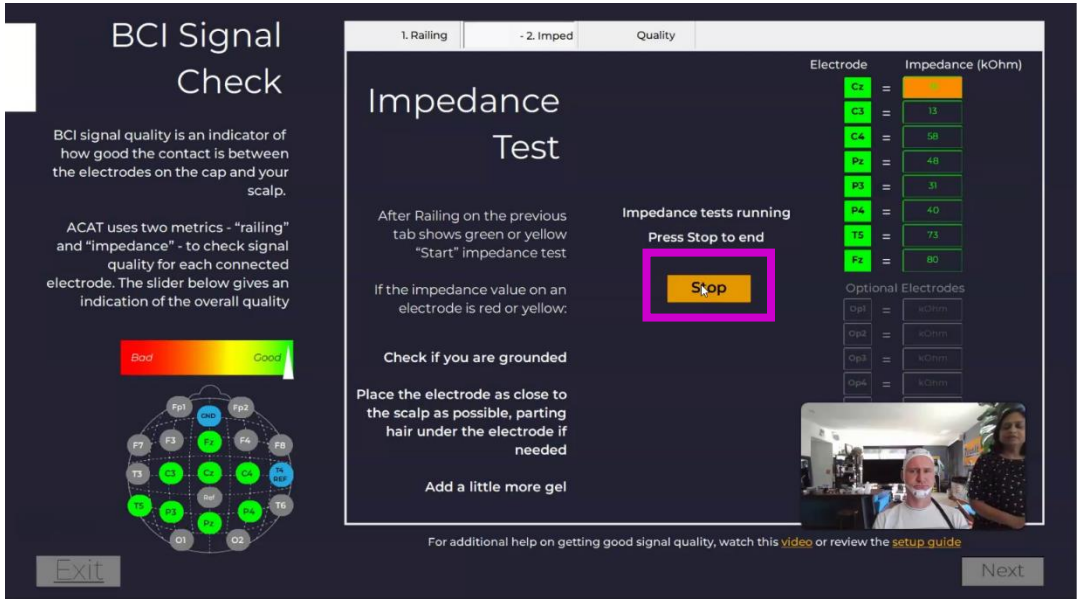
As the impedance is computed, the color on the electrode changes.



Note : the color of the corresponding electrode on the cap image changes to reflect the overall signal quality of that electrode

Note : Only use the Stop button if you need to stop impedance testing prematurely. It is recommended to wait for the test to automatically stop on its own as each electrode needs their impedance tested to pass signal check.

Stopping impedance testing takes a little while (~8-10 sec) as the board resets .



3.5.9 Signal Check: Troubleshooting: Impedance Test

Problem: Some electrodes are yellow or red (Assuming you have already completed the “Railing” test and have observed “green” or “yellow” railing status on all required electrodes)

Solution:

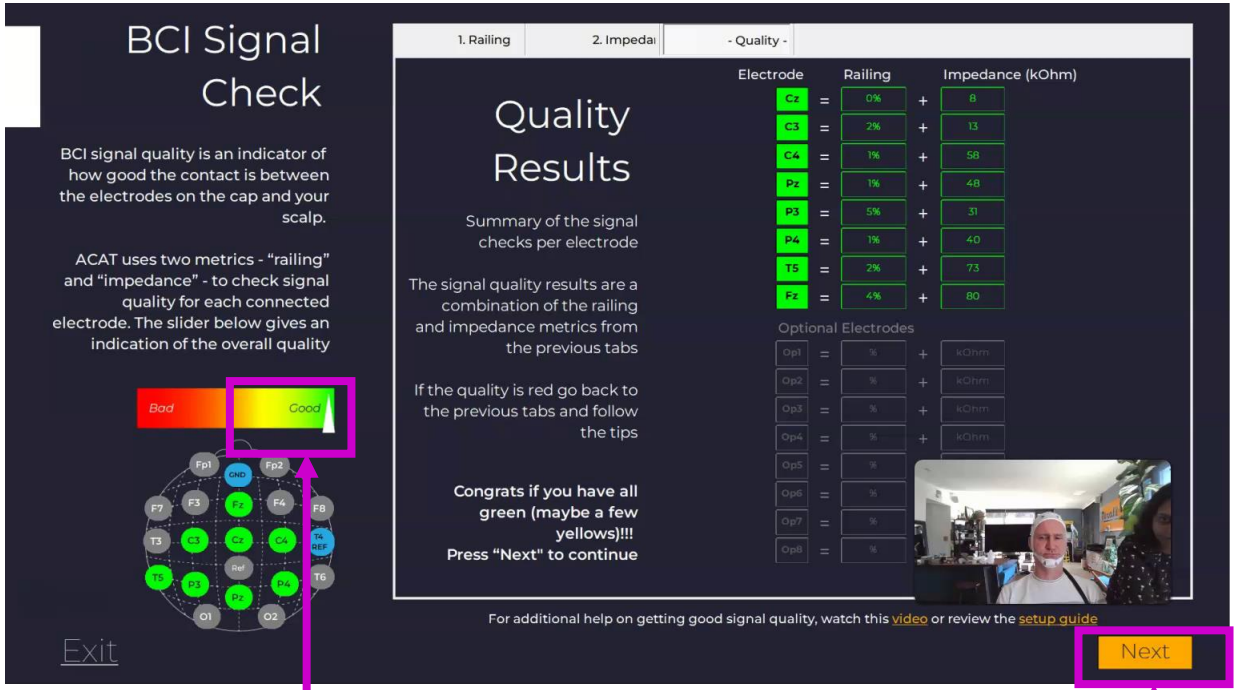
i. Add a little gel to the yellow/red status electrodes and rerun the impedance test by clicking “Start” if you have “Stop”ed it.

ii. Check to ensure that the user has been grounded using am ESD wrist strap or an equivalent mechanism

3.5.10 Signal Check: Quality

Click on the *Quality* tab to get a summary of the both the Railing and the Impedance tests

Note: This is screen is for informational purposes



If the slider is on ***Good***, it implies that we have overall good signal quality and we can now proceed to the ***Next*** step.

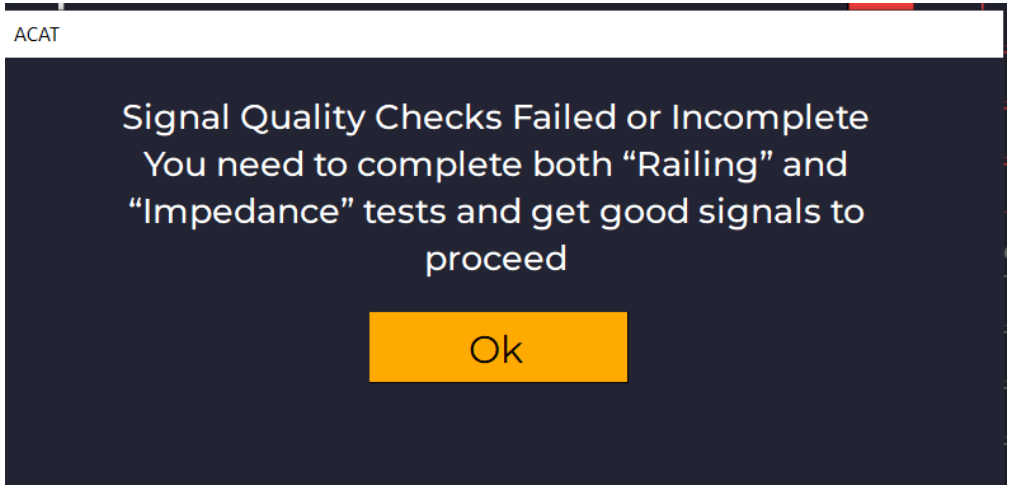
3.5.11 Signal Check: Unable To Pass Signal Check

Problem: You cannot get past this check when you click 'Next' *and*

- 1 or 2 (max) electrodes remain red for both railing and impedance tests while the remaining 6 (or 7) have green status
- The troubleshooting guide (Section 3.5.2, 3.5.4) do not help

This can happen if any of the below are true for the top 8 electrodes

- The locations of the problematic electrodes on the scalp make them hard to add gel to, possibly because of occlusion due to other equipment the user is using, e.g., a ventilator or
- The electrodes on the cap are malfunctioning / broken or
- Leads / pins on the Cyton board have been damaged



Solution: (Step 1) Determine if the problem is due to faulty electrodes on the cap by swapping them with alternative electrodes. (Step 2) If the problem persists, disable the malfunctioning channels so invalid data isn't processed and you can pass signal check.

Step 1: Replace the bad electrodes in the required list (top 8) with electrodes from the optional list (bottom 8). This requires changing the hardware configuration and ACAT application settings

Step 2: Disable broken channels which were found by following the process outlined in Step 1. These are likely broken / malfunctioning channels since multiple electrodes failed to provide good signals when connected to them. This requires changing the ACAT application settings

3.5.11.1 Step 1: Replace Bad Electrodes

Troubleshoot!

Refer to the process outlined in section 3.5.7 to replace bad electrodes in the required list (top 8), with alternative ones in the optional list (bottom 8).

Swap the names of the electrodes in ACATConfig so they appear correctly in Signal Check

- Run ACATConfig application (refer to Appendix on how to navigate to the BCI settings in the config application.
- In ACATConfig, switch the names of the electrodes with which you've swapped physical connections.
- Save ACATConfig changes and restart ACAT

Example : When you've swapped the wiring for required electrode C4 with the optional electrode T6

3.5.11.2 Step 2: Disable Bad Channels

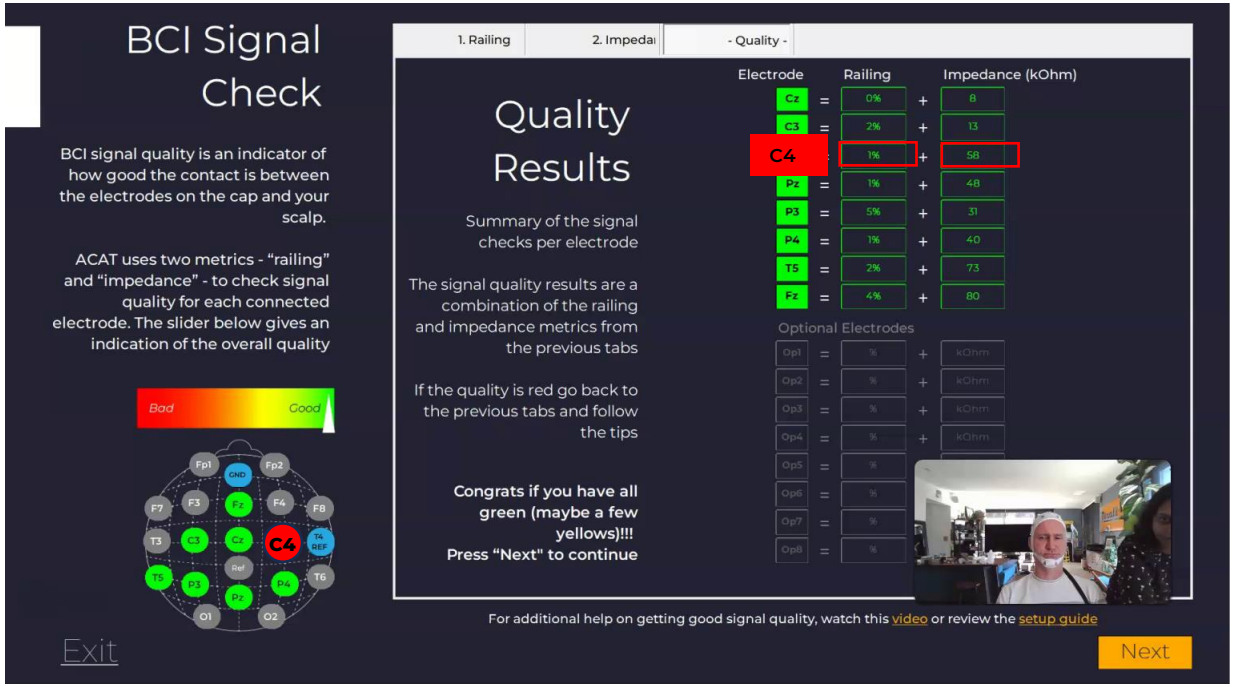
Troubleshoot!

ACAT uses 8 electrode configuration by default. However, in our tests, we have found it to be usable with **at least 6 electrodes** providing **Good** signal equality

To disable the electrodes with **Bad** signal quality, you need to

- Run ACATConfig application (refer to Appendix on how to navigate to the BCI settings in the config application.
- In ACATConfig, disable the corresponding electrode (channel), and reduce the parameter controlling the maximum number of electrodes allowed with ok (yellow) signal quality.
- Save ACATConfig changes and restart ACAT

Example : when C4 Electrode has Bad signal quality



1. Note the channel number corresponding to bad electrode. **Channel3** in this example

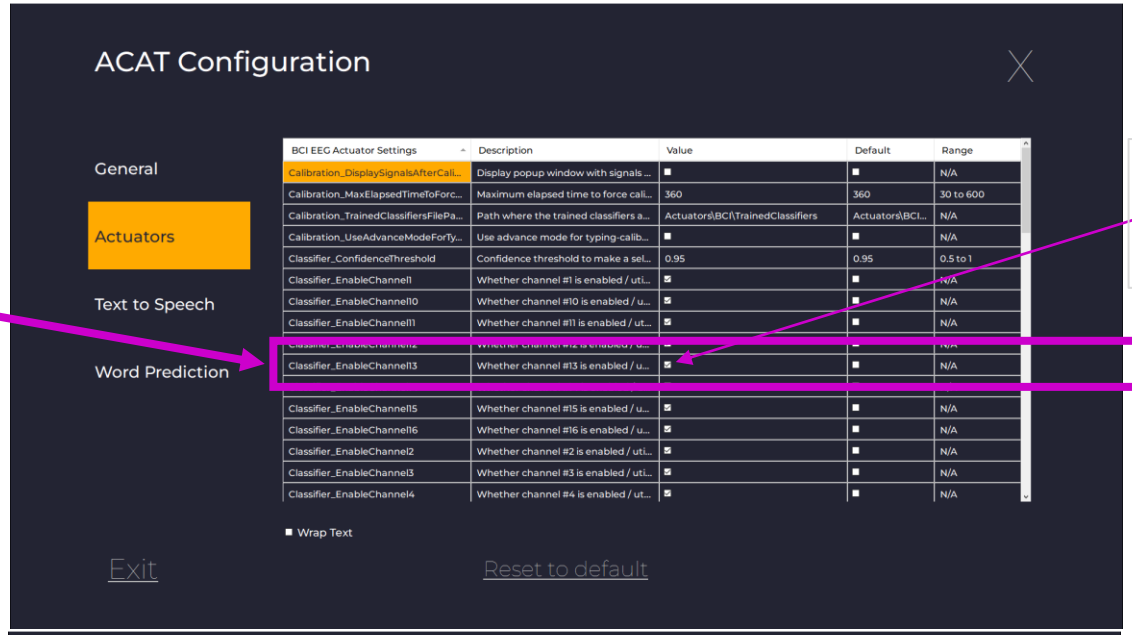
Electrode name	ACAT Internal Mapping to Channel numbers
Cz	Channel1
C3	Channel2
C4	**Channel3**
Pz	Channel4
P3	Channel5
P4	Channel6
T5	Channel7
Fz	Channel8

3.5.11.3 Step 2: Disable Bad Channels :

Example : when C4 Electrode has Bad signal quality

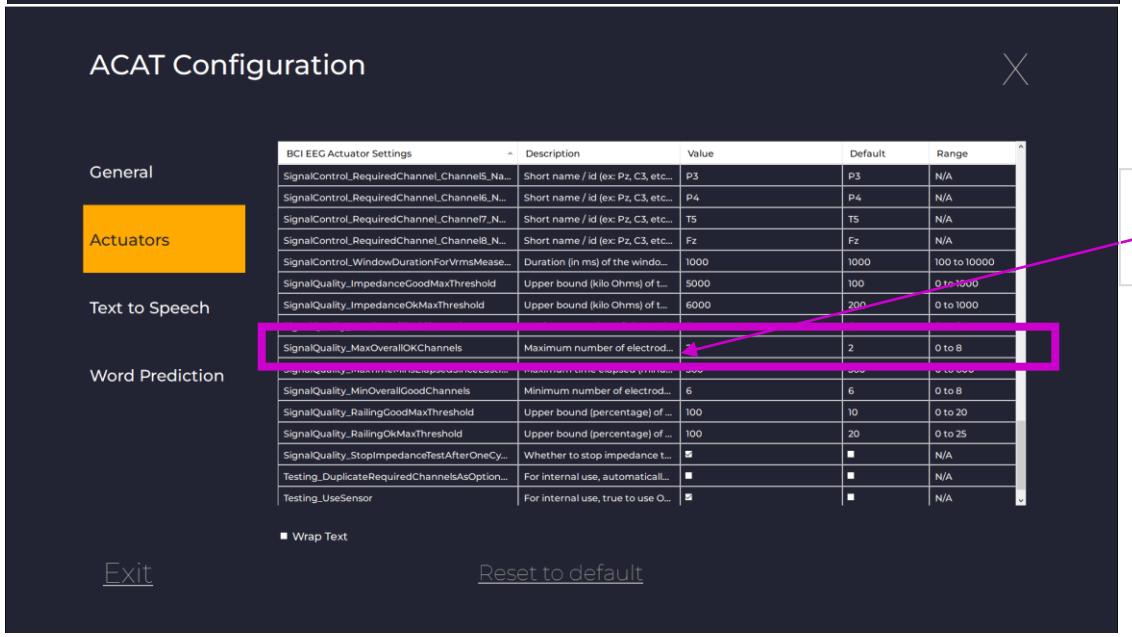
Troubleshoot!

Electrode name	ACAT Internal Mapping to Channel numbers
Cz	Channel1
C3	Channel2
C4	**Channel3**
Pz	Channel4
P3	Channel5
P4	Channel6
T5	Channel7
Fz	Channel8



Run ACATConfig

2. Uncheck the corresponding channel ***Classiifer_EnableChannelX*** *(In this example,* ***Classiifer_EnableChannel3****)*



3. Change the value of the parameter ***SignalQuality_MaxOverallOkChannels*** from 2 to 1

3.5.12 Advanced Users: Adjusting Status Parameters

Advanced, experienced users/care-givers can adjust the signal check parameters using the ACATConfig application. The tables below list the parameters that are configurable

Railing Test Configurable Parameters	Default	Status and Decision Logic
SignalQuality_RailingGoodMaxThreshold	10	green railing% <= SignalQuality_RailingGoodMaxThreshold
SignalQuality_RailingOkMaxThreshold	20	yellow railing% <= SignalQuality_RailingOkMaxThreshold
		red railing% > SignalQuality_RailingOkMaxThreshold

Impedance Test Configurable Parameters	Default	Status and Decision Logic
SignalQuality_ImpedanceGoodMaxThreshold	100	green impedance <= SignalQuality_ImpedanceGoodMaxThreshold
SignalQuality_ImpedanceOkMaxThreshold	200	yellow impedance <= SignalQuality_ImpedanceOkMaxThreshold
		red impedance > SignalQuality_ImpedanceOkMaxThreshold

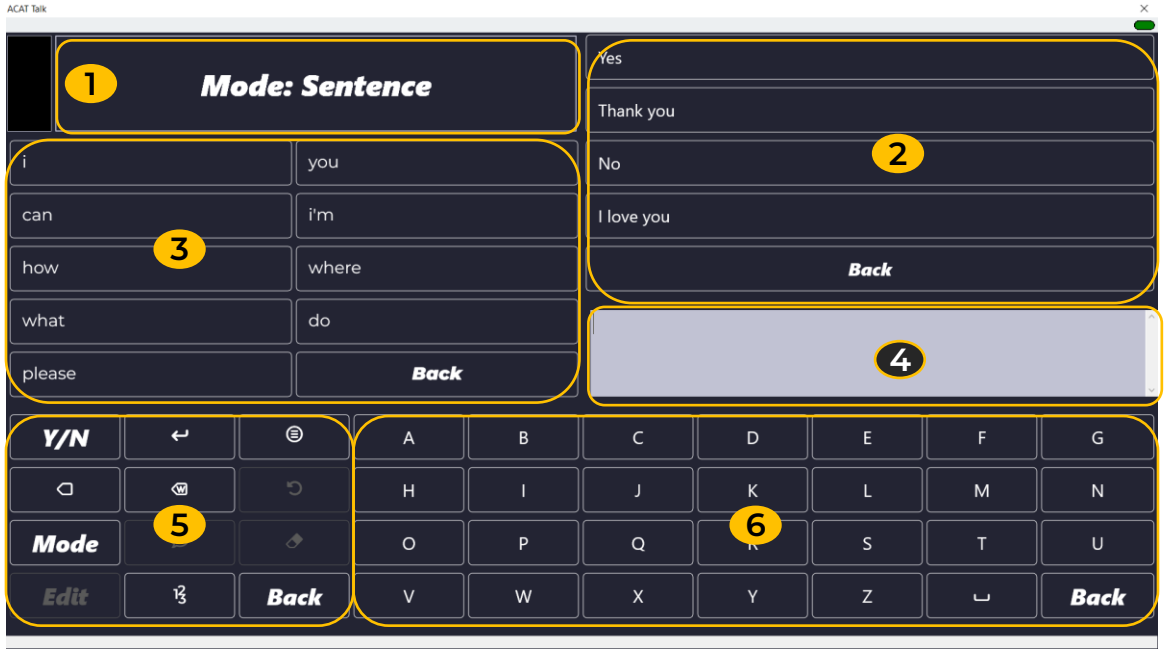
Electrode Overall Signal Quality Status		Status and Decision Logic
green		railing==green **AND** impedance==green
yellow		railing==yellow **OR** impedance==yellow
red		railing==red **OR** impedance==red

Overall Quality Success Parameter	Default	Status and Decision Logic
SignalQuality_MinOverallGoodChannels	6	Ok-to-proceed: #green electrodes >= SignalQuality_MinOverallGoodChannels **AND** #yellow electrodes <= SignalQuality_MaxOverallOKChannels
SignalQuality_MaxOverallOKChannels	2	

4. Typing: BCI Main Screen

4.1 UI Regions

To understand ACAT's BCI calibration requirements, let's look at ACAT's Main Screen. The ACAT main screen is the primary interface that lets you communicate by typing text and converting it to speech so others can hear what you want to say. The Screen is split into different regions.



Note: Only the Sentence (#2) , Word (#3), Keyboard-Left (#5), Keyboard-Right (#6) are selectable by switch scanning.

Regions

1. Current Mode

   This region displays the current typing mode.

   - Sentence
   - Canned Phrase
   - Shorthand

2. Phrases (Sentences)

   This region has suggestions on possible ways you can complete the sentence you are currently typing based on the words you have entered so far.

3. Predicted Words

   Displays a list of the top ten suggested words to either complete the word you are typing or the probable word that would likely follow the word you just typed.

4. Talk Window

   This is a text box which displays the text you enter by using the keyboard, the Word Prediction block, or the Phrases region.

5. Keyboard – Left

   This region has function keys

6. Keyboard – Right

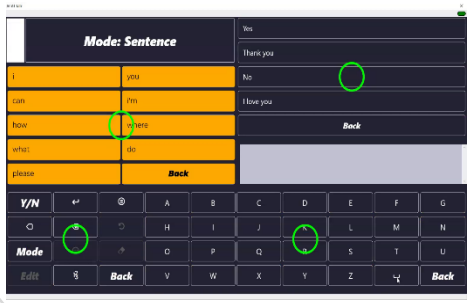
   This region has alphabetic keyboard

4.2 BCI Scanning Modes

The main screen for BCI uses different styles of scanning for selecting items in different scannable regions.

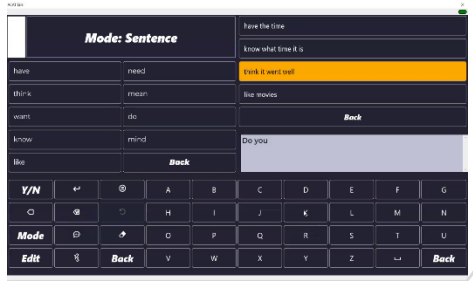
1. Box Scanning

To Select Regions
Each region scanned
4 regions scanned per iteration



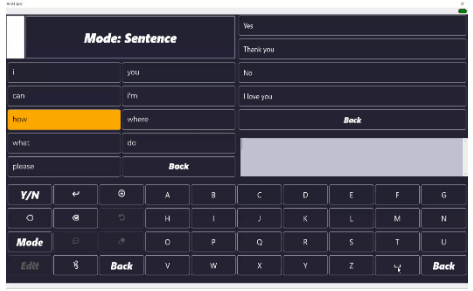
2. Sentence Scanning

To Select Sentences (phrases)
Each sentence scanned
4 sentences + special '***Back***' scanned per iteration



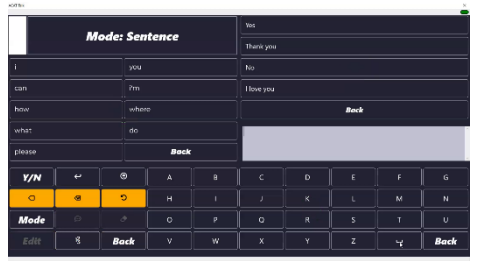
3. Word Scanning

To Select Words
Each word scanned
9 words + special '***Back***' scanned per iteration



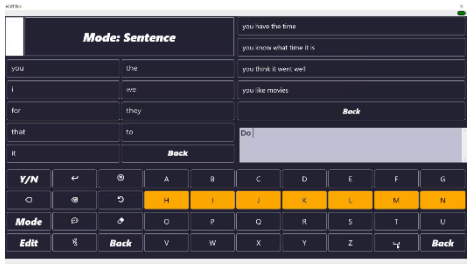
4. Keyboard-Left Scanning

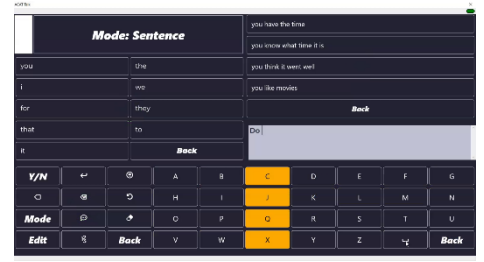
To Select keys from Keyboard-Left
Rows and columns are sequentially scanned
4 rows and 3 columns scanned per iterations



5. Keyboard-Right Scanning

To Select keys from Keyboard Right
Rows and columns are sequentially scanned
4 rows and 7 columns scanned per iteration





4.2 How to Select

ACAT uses a two-step process to select an item on the main screen

- Step 1: Select the region that has the item you want to select
- Step 2: Select the item from the selected region

To Select

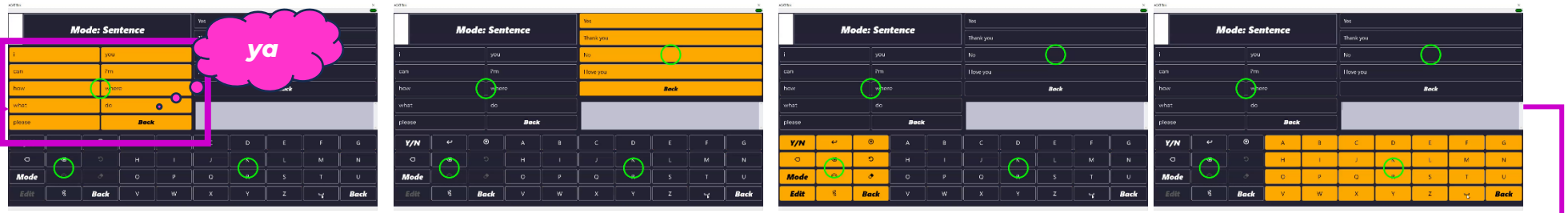
- Switch scanning sequentially highlights the items on the main screen
- When the highlight is on the region/item of interest, mentally think "***yes***", "***yeah***" or "***ya***" at the instant when that item gets highlighted
- After a max of 10 iterations an item gets selected based on the internal aggregated probabilities ACAT computes based on the brain signal patterns it detects. After every iteration ACAT uses the classifiers trained during calibration to estimate probability of selection for every item in that scanning. It keeps accumulating the probabilities over several iterations and when it has enough confidence, the item with highest accumulated probability is selected.

4.2 Examples (#1 of 2) Select a word from the Word Region

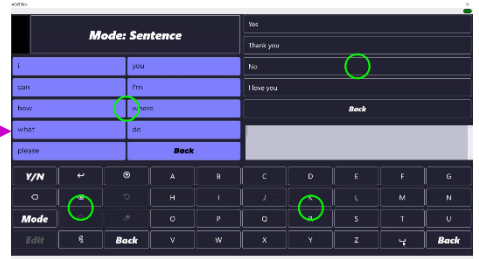
Step 1: Select the ***Word*** region – ***focus on the circle in the center of the word box***

think *'YA'* <u>only</u> when the word region is highlighted in each iteration

1 iteration of Box scanning for region selection



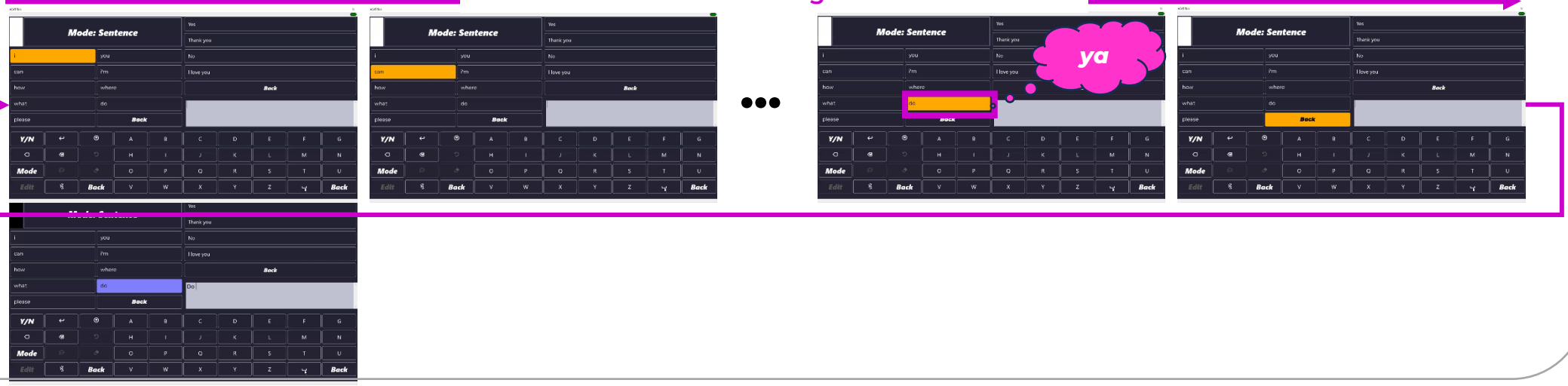
After a few iterations, the ***Word region*** gets selected and Word scanning begins



Step 2: Select the ***word*** – ***focus on the word you want to select***

think *'YA'* <u>only</u> when the word is highlighted in each iteration

1 iteration of Word scanning for word selection



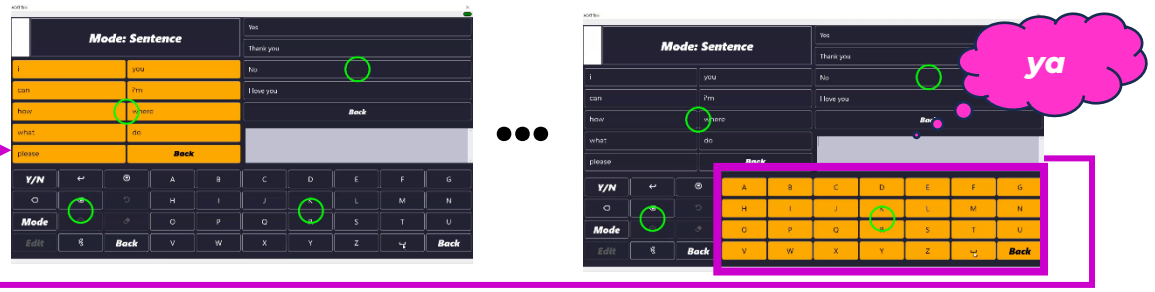
After a few iterations, the ***<u>word</u>*** gets selected

4.2 Examples (#2 of 2) Select a letter from the Keyboard-Right Region

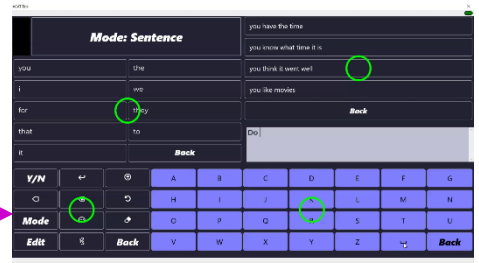
Step 1: Select the ***Keyboard-Right*** region – ***focus on the circle in the center of the keyboard-right box***

think *'YA'* <u>only</u> when the keyboard-right region is highlighted in each iteration

1 iteration of Box scanning for region selection



After a few iterations the ***keyboard-right region*** gets selected and Word scanning begins

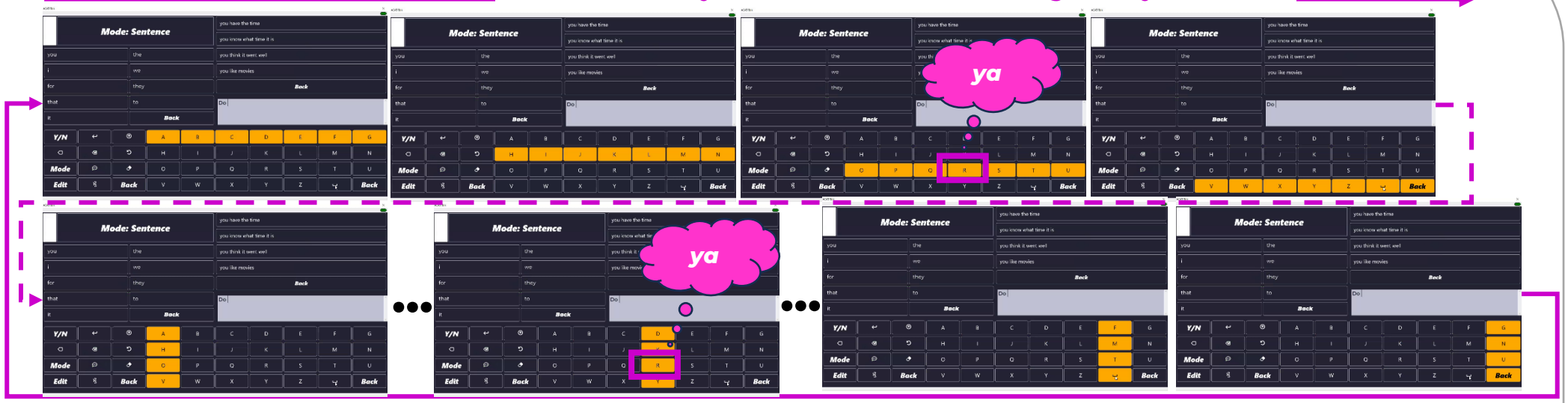


Step 2: Select the ***letter*** – ***focus on the letter you want to select***

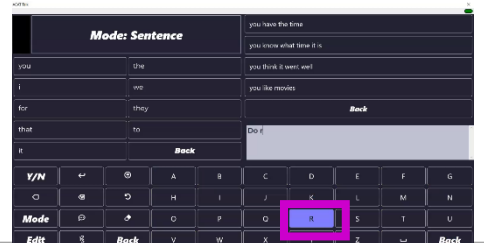
think *'YA'* <u>2 times per iteration:</u>

- **<u>first</u> when the row with the letter is highlighted**
- **second when the column with that letter is highlighted**

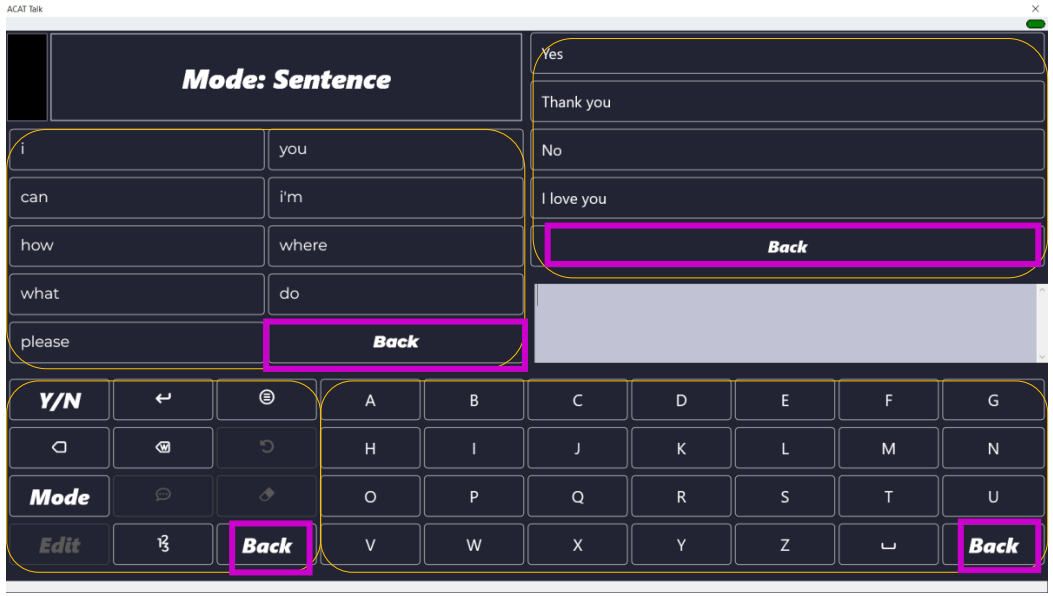
1 iteration of Keyboard row/column scanning for key selection



After a few iterations, the letter gets selected



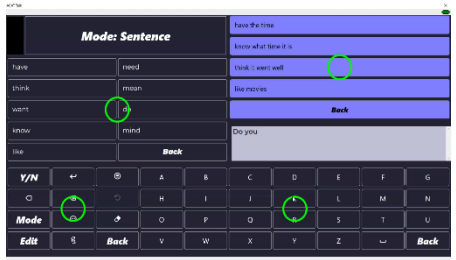
4.2 Special "***Back***" Item In Each Region



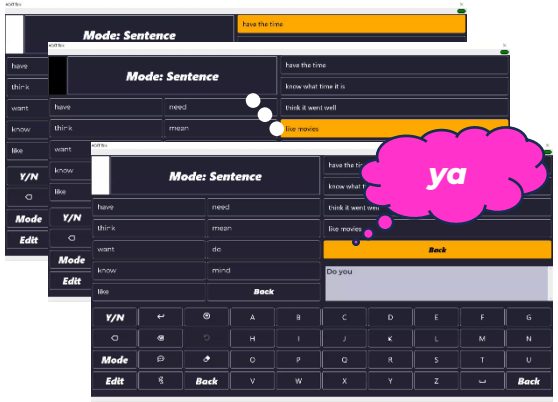
Incorrect Selection by ACAT

If a wrong region gets selected, try selecting the ***Back*** item from the selected region. For example, if you were trying to select the ***Word*** region but instead the ***Sentence*** region got selected, you can try selecting the ***Back*** item from the ***Sentence*** region. This is equivalent to going back to region scanning, without selecting any other item from the ***Sentence*** region.

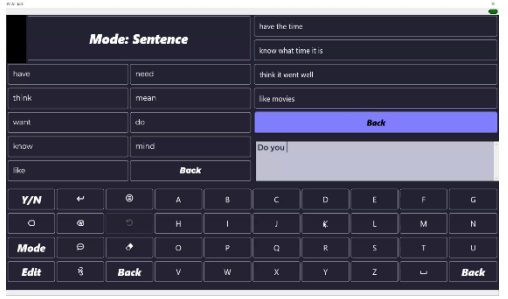
For example:



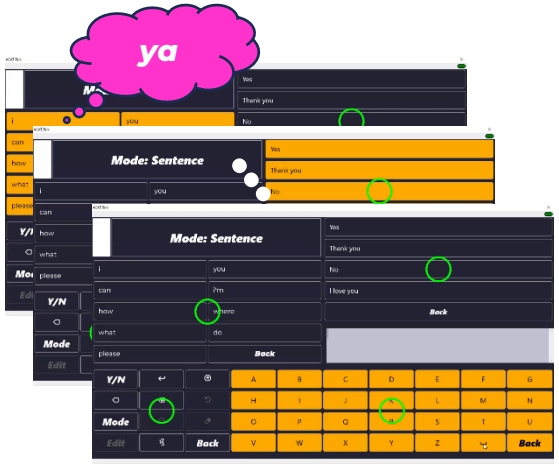
You were intending to select the Word region but ACAT incorrectly selected another region (the Sentence region in this example)



The Sentence region will start highlighting. Select the Back Item by focusing on it and thinking "***Ya***" when it's highlighted, as explained in section 4.2 step 2.



After a few iterations, the ***Back*** Item should get selected



ACAT will now start highlighting the different regions, select the Word region as you intended

5. Calibration

5.1 Why and When To Calibrate

To make a selection ACAT's UI, you need to mentally think 'yes' ('ya') when the item you are interested in is highlighted by the scanning interface (refer to Section 4 for details).

This kind of selection on visual presentation is called Event Related Potentials (ERP). ACAT needs to be trained to understand ERPs in your brain signals. This is done through the ***Calibration*** process

ACAT has 5 different scanning modes (refer to Section 4.2)

1. Box scanning mode to select among the 4 regions on the UI
2. Word scanning mode to select the words
3. Sentence scanning mode to select sentences
4. Keyboard-Left scanning mode to select the function keys
5. Keyboard-Right scanning mode to select the letters

Each scanning mode is slightly different

- The type of scanning differs: per item scanning versus row/column canning
- The size of item to be selected varies
- The number of elements in the scanning also varies in each mode

In our testing, we have noticed that these variations can affect the accuracy of selection. Ideally, calibrating for each scanning mode is recommended. However, calibration is time consuming. Considering the similarities between word and sentence scanning modes, as well as between the two keyboard scanning modes, calibrating for three modes is sufficient. By default, ACAT requires calibration for ***at least 3 of these modes:*** **1)** ***Box mode 2) Sentence Mode and 3) Keyboard –Left mode***

When to Calibrate (Recalibrate)

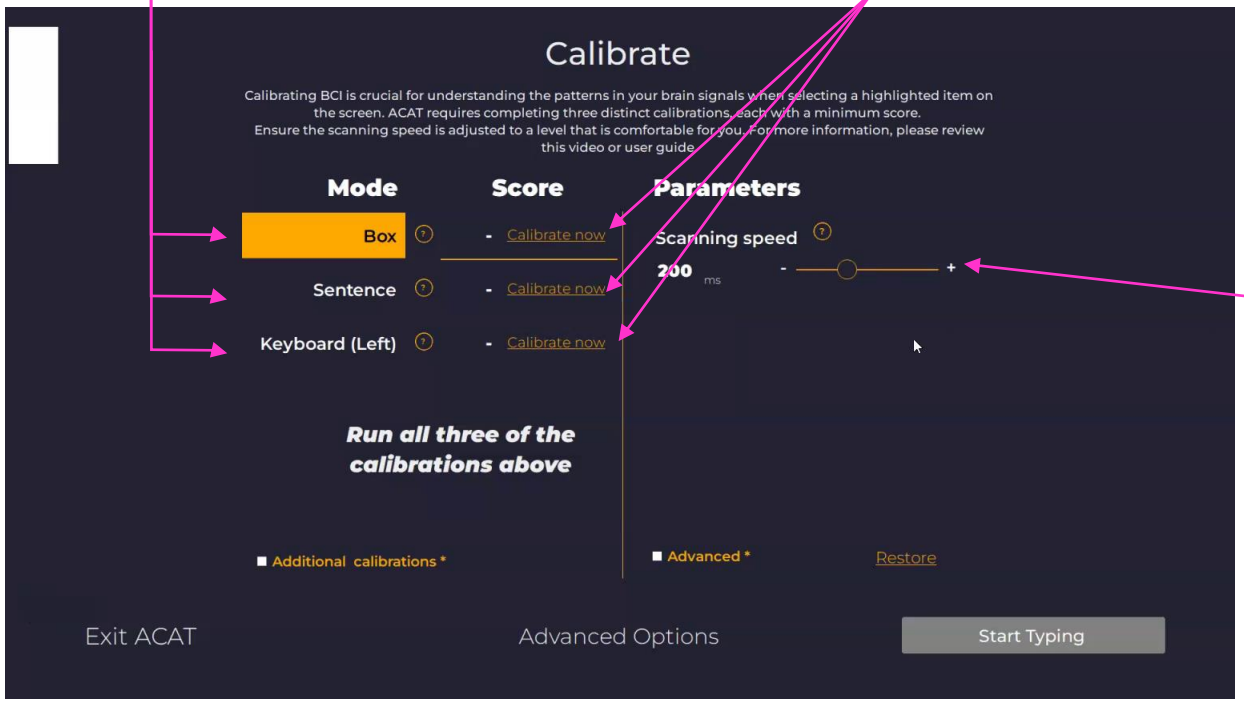
The brain signal patterns captured by the sensor can significantly differ based on the placement of the cap (and consequently, the electrodes), the amount of gel applied, and the quality of electrode contact with the scalp, all of which affect signal reliability. Given these variations, ACAT needs to be recalibrated under the following conditions (even if you have successfully calibrated before):

- Every time the cap is removed/adjusted and repositioned on the user's head
- Every time gel is applied to the electrodes
- If more than 6 hours have passed since the last calibration
- Or when selection accuracy has degraded, resulting in difficulties in accurately making selections

5.2 Calibration UI

1. Start by selecting one of the modes for calibrating

3. Click on Calibrate now (or Recalibrate) to start calibration



2. [optional] adjust the scanning speed if you find that the default scanning speed is too fast or too slow for you to respond.

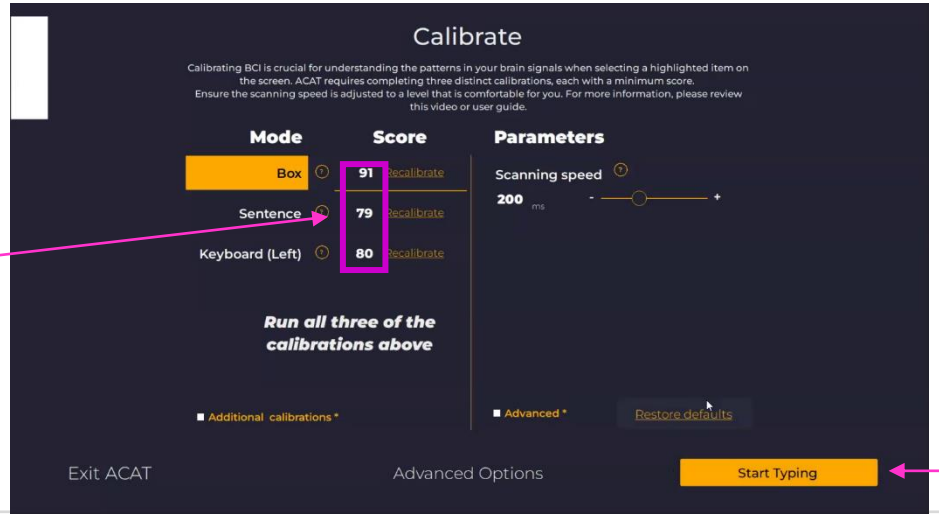
Note: you can set different scanning speeds for different modes. You can adjust based on what works best for you

As you successfully complete calibrating, your calibration score will show on the UI

Note: If a mode does not show a score, it implies that either

- ***this is first time you are calibrating or***
- ***the calibration failed or***
- ***a previous calibration has expired.***

In either case, you will need to run calibration for that mode

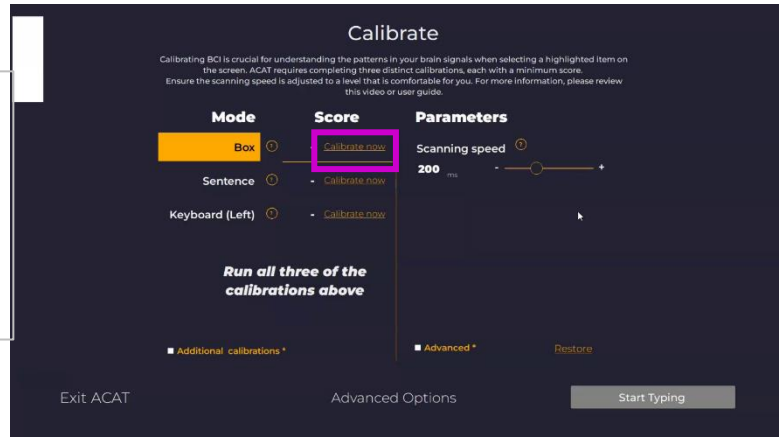


Only after you complete calibrating for all the 3 required modes, **Start Typing** will be enabled that takes you to the Main UI

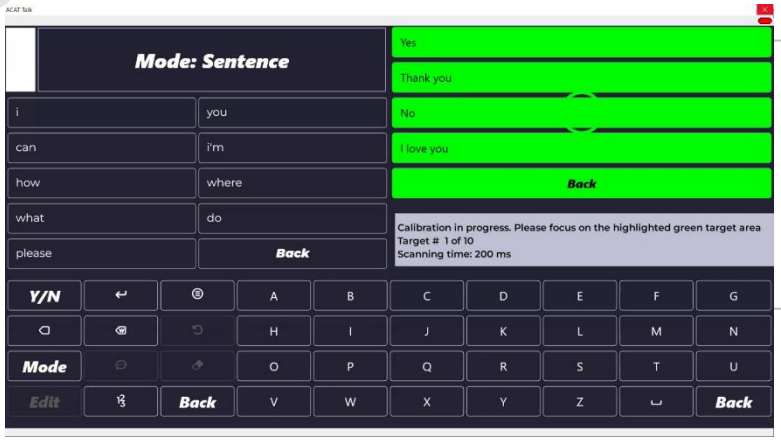
5.2 Example: Box Mode Calibration

1

- Select ***Box*** mode
- Click '***Calibrate now***' to start Box Mode Calibration.



2

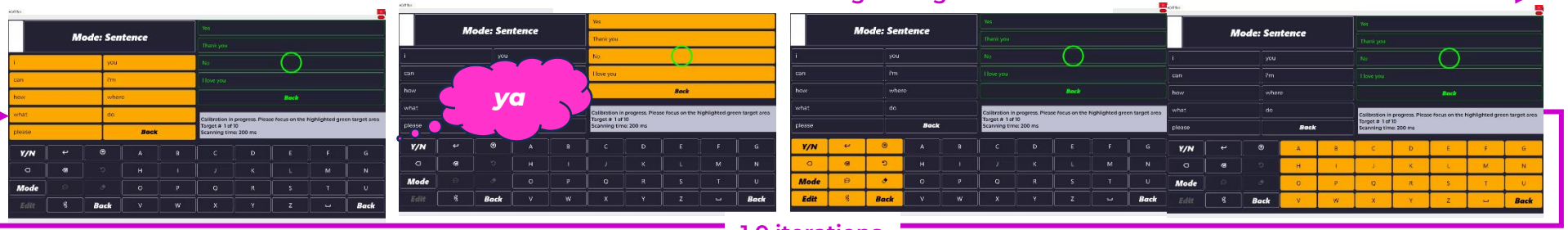


A 'box' target a shown on the UI in green. Focus on the circle in the shown target region

3

Box scanning begins. Think ***Ya***, every time the scanner highlights the target region. This continues for a default of 10 iterations the process repeats.

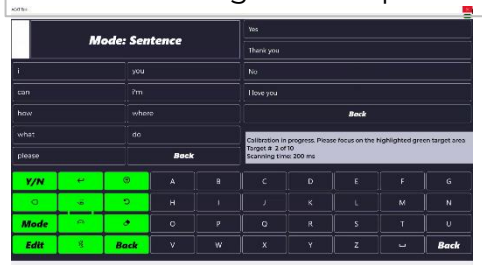
1 iteration of Box scanning for region selection



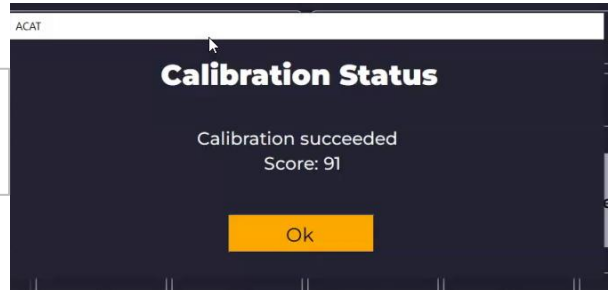
1 0 iterations

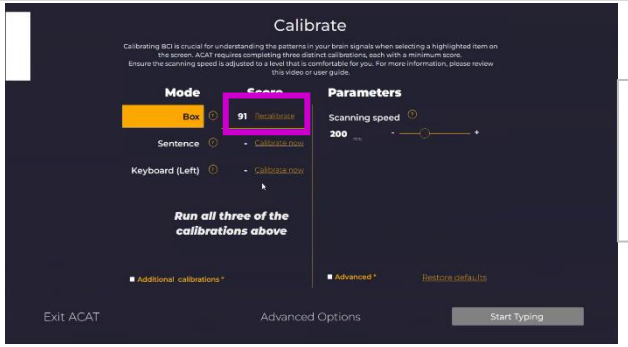
4

Once 10 iterations of scanning are complete, ACAT presents a new target. Focus on the circle in the new target and repeat



At the end of calibration a success (or failure) status is displayed





If calibration is successful, the score is displayed on the Calibration UI next to the corresponding mode

5.2 Advanced User : Calibration Parameter Options

1. ***Scanning speed***: is the most important parameter because the appropriate scanning speed is user dependent. ACAT allows the user to adjust the scanning speed independently for each scanning mode. You need to (re)calibrate that mode after changing the scanning speed

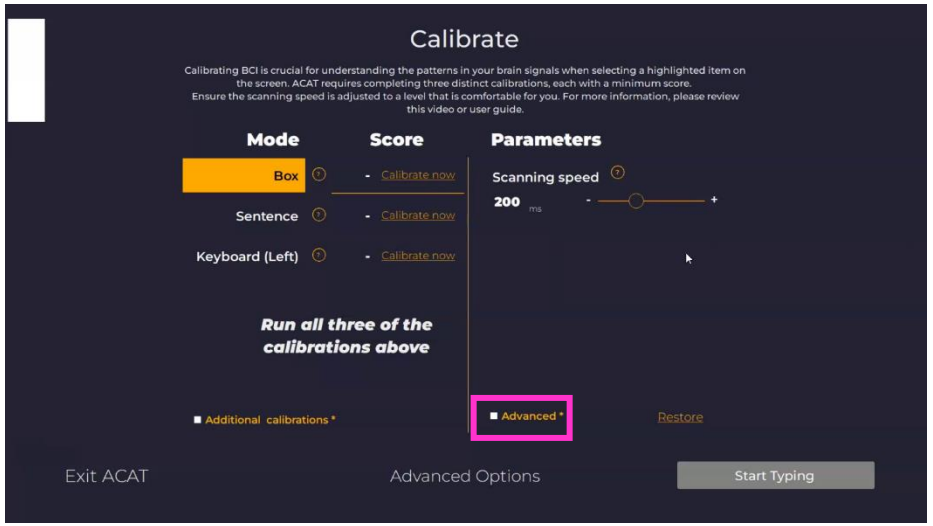
There are other parameters that can be adjusted to help improve calibration. Click on the ***Advanced*** check box under ***Parameters*** to see these options

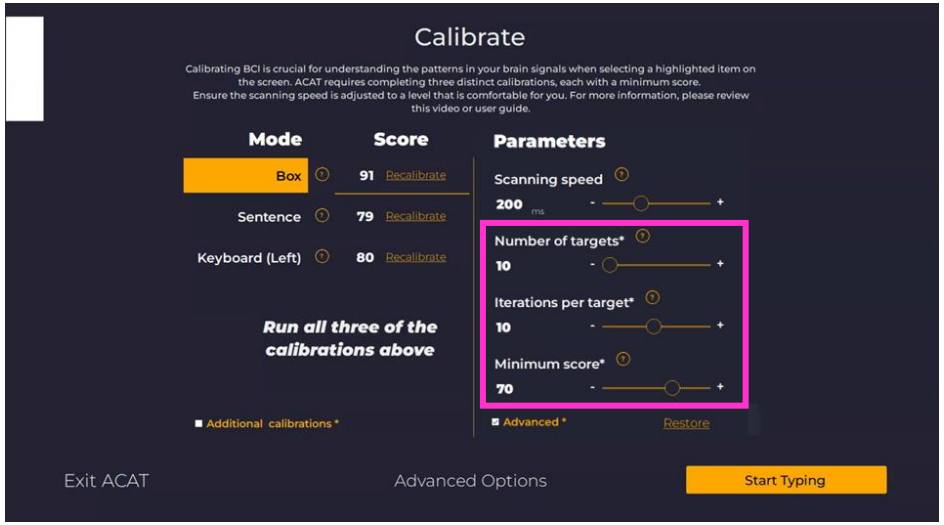
During Calibration (refer to the calibration example),

- A ***target*** is highlighted in green on the UI
- Scanning begins in the mode under calibration
- The user is expected to focus on the green target and think ***Ya*** whenever the scanning highlights the target area
- The target stays green for a fixed number of iterations ***(iterations per target)***
- After the fixed number of iterations, a new target is highlighted, and the calibration process repeats
- The ***number of targets*** parameters controls how many targets are presented for a complete calibration
- ACAT creates a classifier at the completion of all scanning iterations for all targets and computes a score that indicates how accurately the trained classifier is able to detect a selection (user thinking ***Ya***).
- The calibration is successful if the computed score is greater than the ***minimum score*** parameter setting

In our experiments, we have found that calibrating with ***Number of targets=10***, ***Iterations per target=10*** and calibrating with a ***minimum score=70***, results in a good calibration. For best results the score should be as close to 100 as possible. Increasing the number of targets and iterations per target to have more for the classifier to learn from, can help improve calibration score. However, there is a trade off with the increased calibration time it can take and subsequently the difficulty in maintaining focus of that amount of calibration time.

Note: It is recommended to not change the Advanced settings.

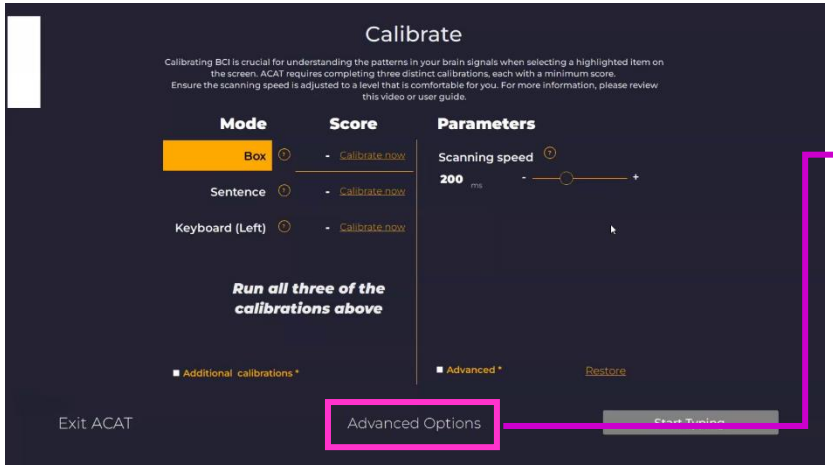


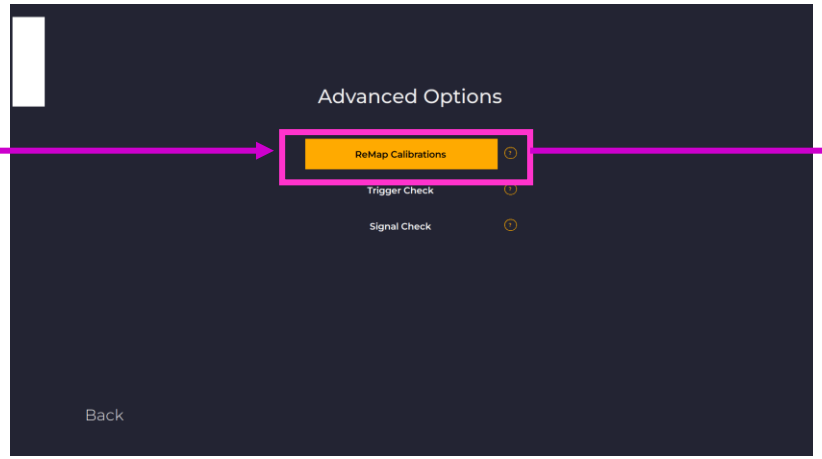


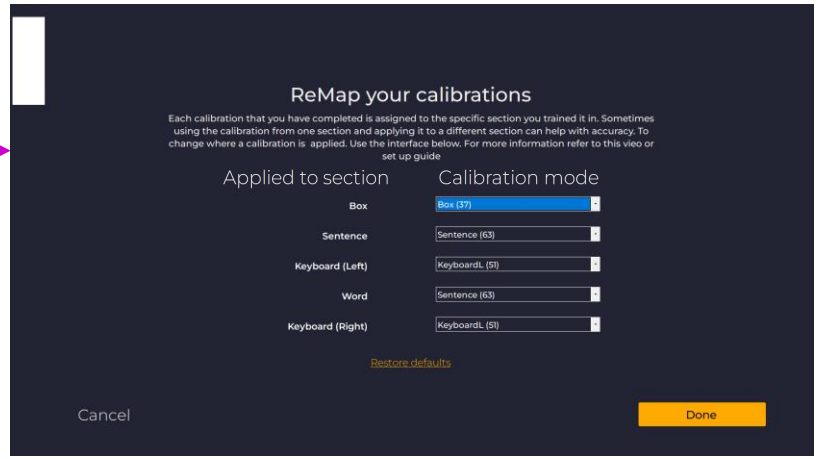
5.2 Advanced User : Mapping Calibrations

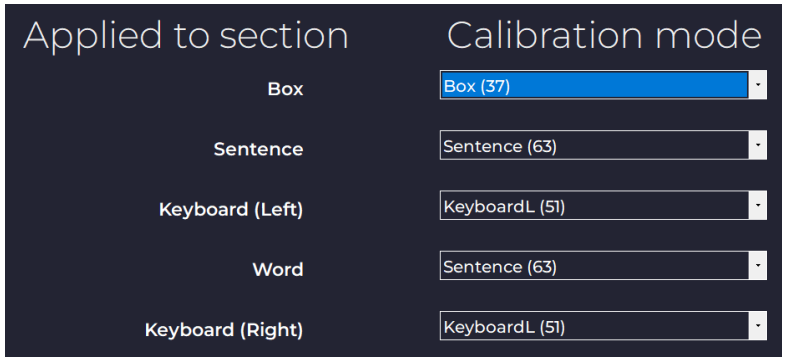
ACAT requires a minimum of 3 calibration modes to be successfully completed to use the interface: 1) Box 2) Sentence 3) KeyboardL (left).

ACAT uses one of these calibrations depending on the active scanning region. The default mapping of calibrations to scanning sections can be accessed by clicking through the following ACAT screens :









As seen in the screenshot, by default,

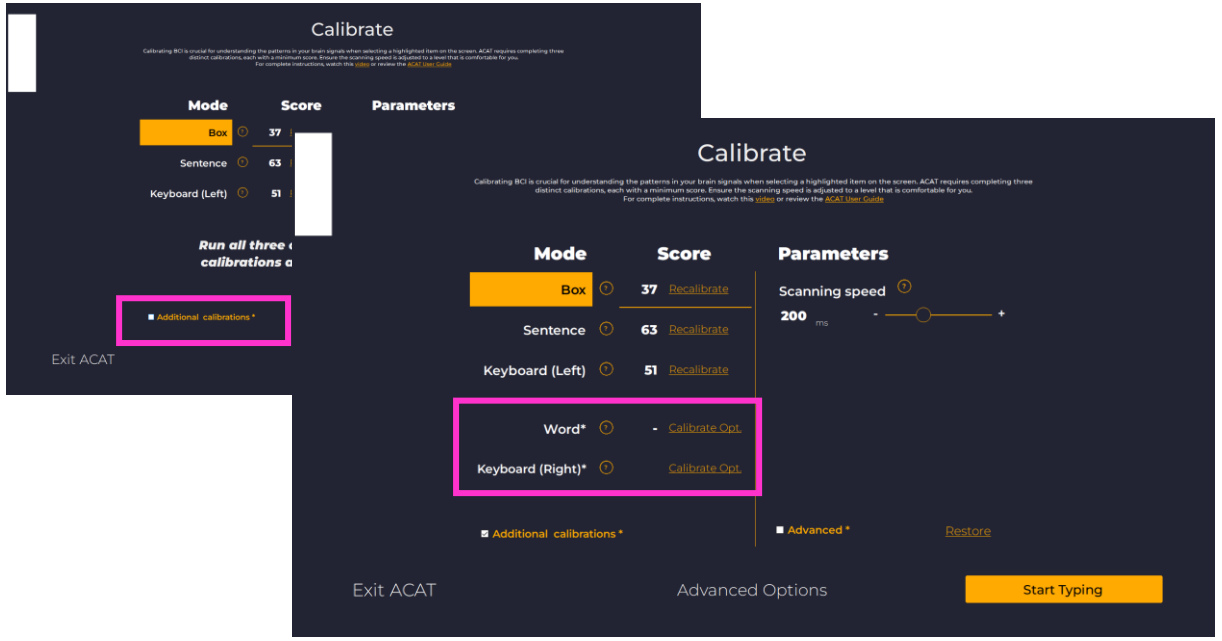
- Calibration computed in the Box calibration mode is used for Box (region) selection
- Calibration computed in the Sentence calibration mode is used for selecting sentences selecting words from their respective regions
- Calibration computed in the KeyboardL (left) calibration mode is used for selecting keys from both Keyboard (Left) and Keyboard (Right) regions

5.2 Advanced User : Additional Calibration Modes and Remapping

While the default calibrations work in general, in our usage, we have found that sometimes using additional calibrations improves the selection accuracy.

For example, by default ACAT applies the calibrations from the keyboard left mode to both keyboard left and right selections. However, if we additionally calibrate specifically for keyboard right, it could improve the experience of selecting a key from keyboard right.

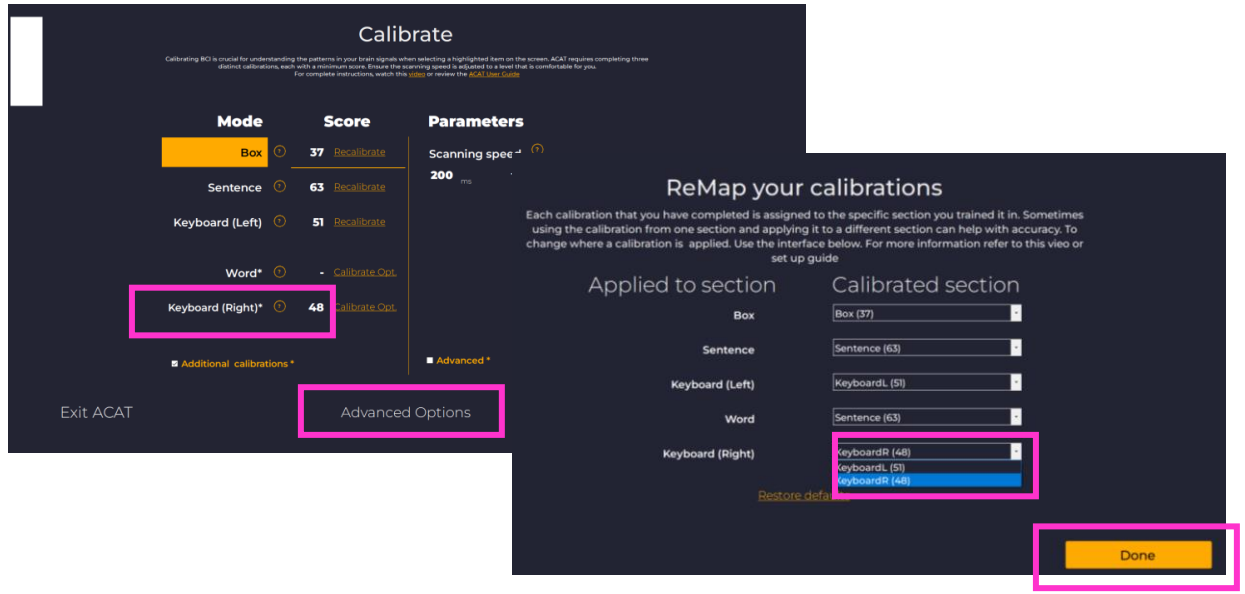
These additional calibrations can be accessed by clicking on the Additional calibrations check box as shown. Either one, or both additional calibrations can be done.



If you do the additional calibrations, you also need to specify which scanning section, should this additional calibration be applied to.

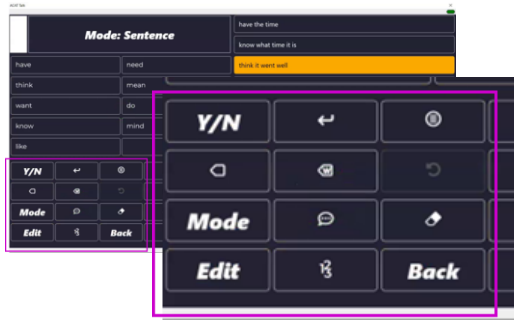
For example, say you did the keyboard (right) additional calibration. To use this specifically during selection of a key in keyboard right -

- Click Advanced Options → then click Remap Calibrations
- You can now map the keyboard right calibration to the keyboard right section as shown in the figure.



6. Other Keyboards

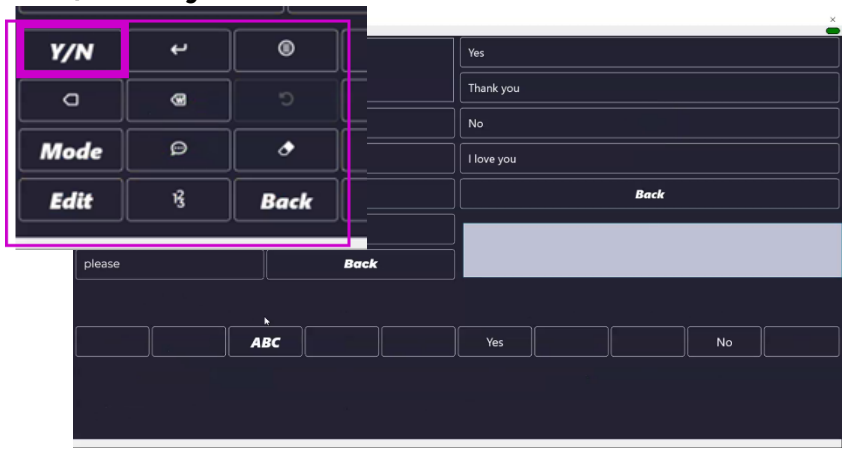
6.1 BCI Supported Keyboards



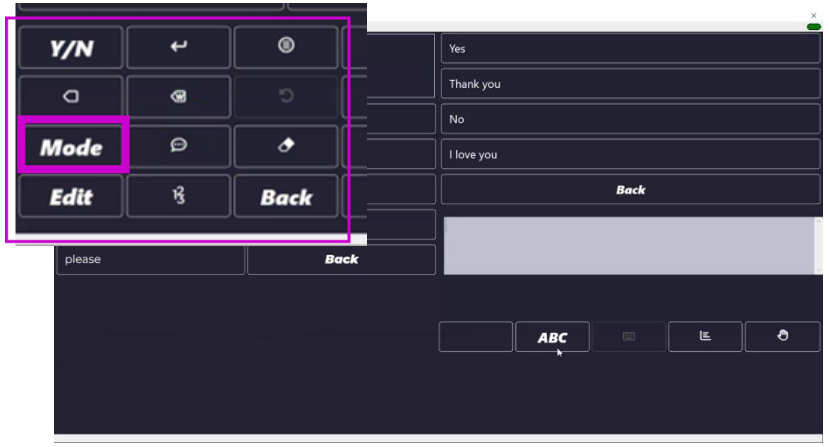
The BCI Keyboards support all the functionality as the Keyboards of other ACAT switches. However, the look-and-feel of the keyboards is different. This is to enable the type of scanning and the timing precision needed by BCI.

For details on the functionality, refer to the ACAT User Guide.

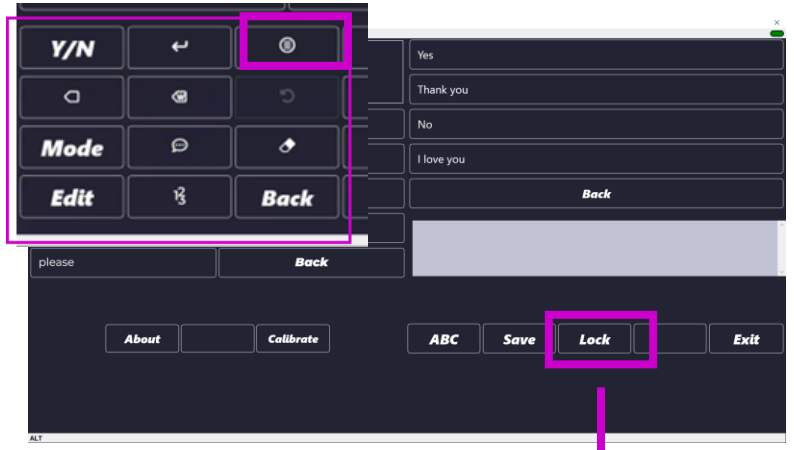
Yes/No Keyboard



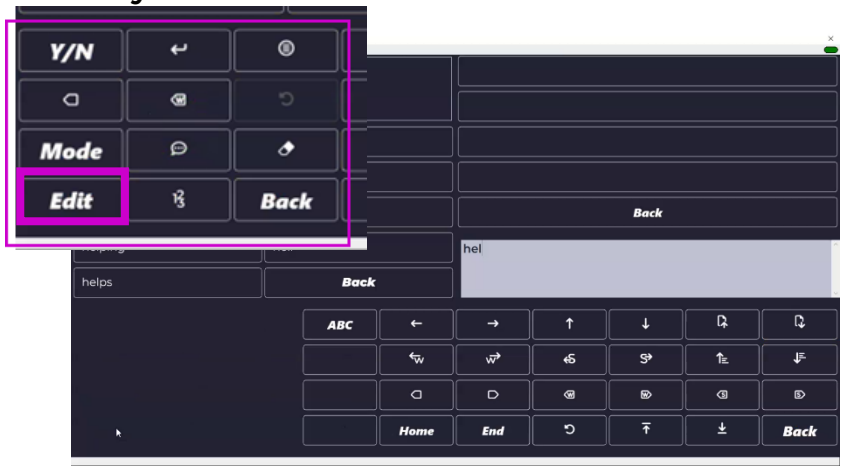
Mode Keyboard



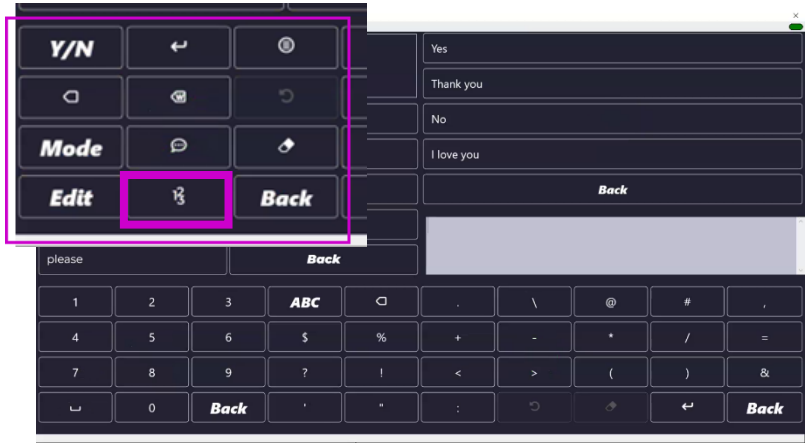
Main Menu Keyboard



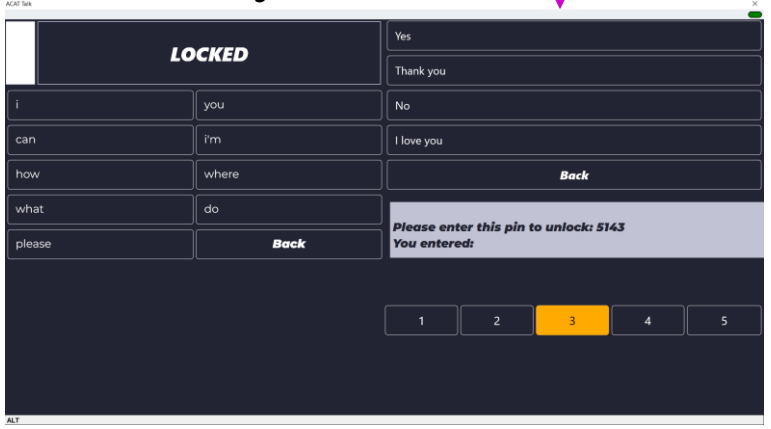
Edit Keyboard



Numeric Keyboard



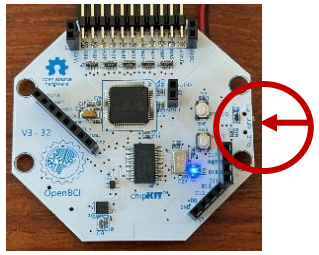
Lock Screen Keyboard



7. End-of-Day Clean Up

7.1 Clean Up The EEG Cap

a) Make sure the Cyton board switch is in the OFF position



b) Unplug the optical sensor wire connector from the Cyton board

c) Place the Cyton board and the connecting electrodes inside a Ziplock bag. The cap should be outside the bag for cleaning

Cleaning swab

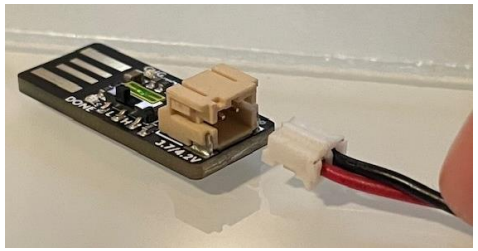
Cleaning of the EEG electrode cap

d) To clean the cap, submerge only the cap in water. Clean the gel from the electrode mounts with the included swab (you can use a cotton swab too). Rinse the cap thoroughly and let it air dry for a few hours

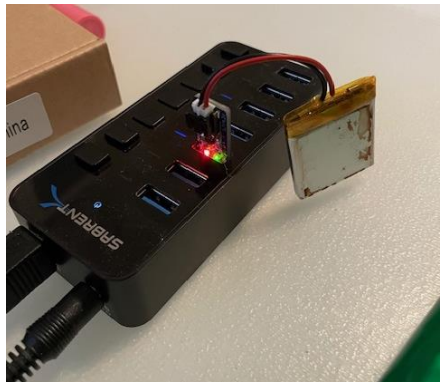
7.2 Charge the Cyton Board Battery

a) Disconnect the battery from the pigtail connector

b) Connect the battery to the charger



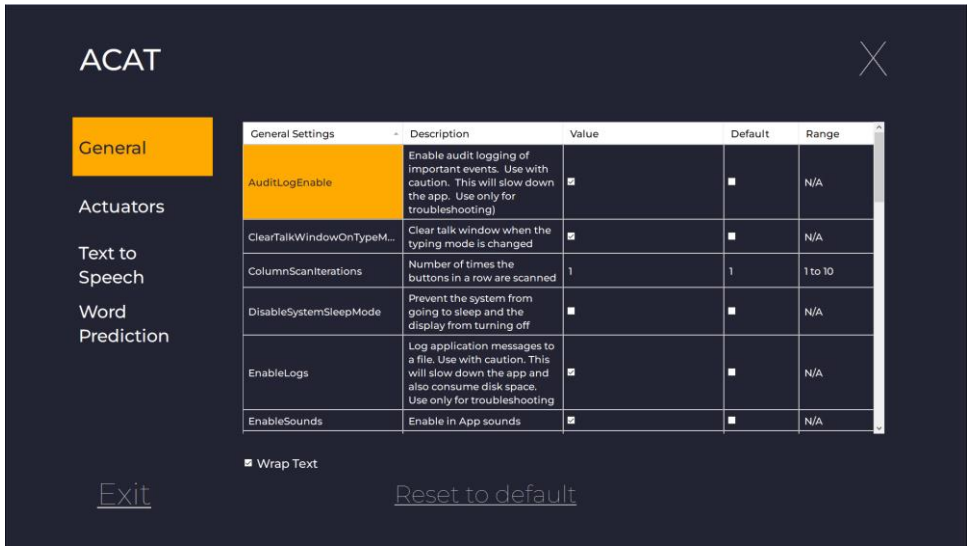
c) Charge the battery



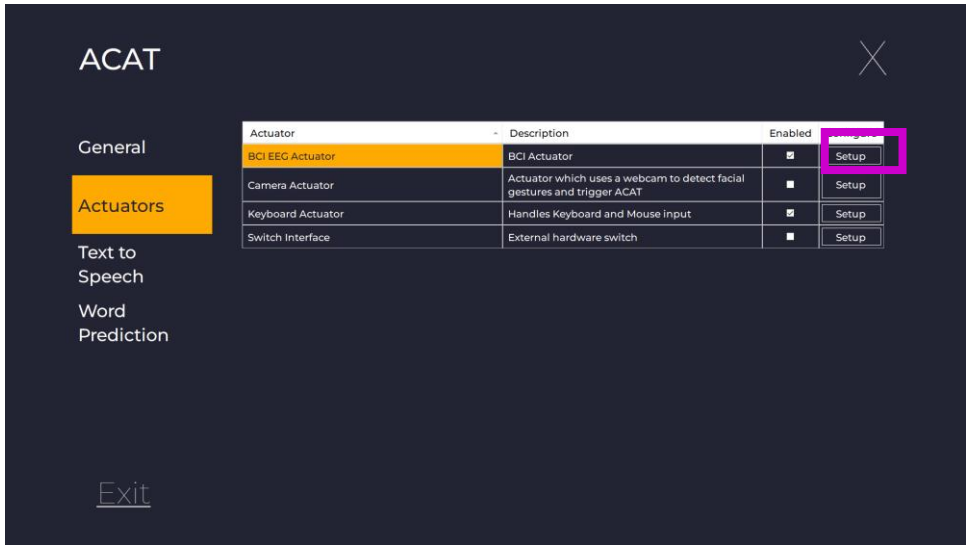
Appendix

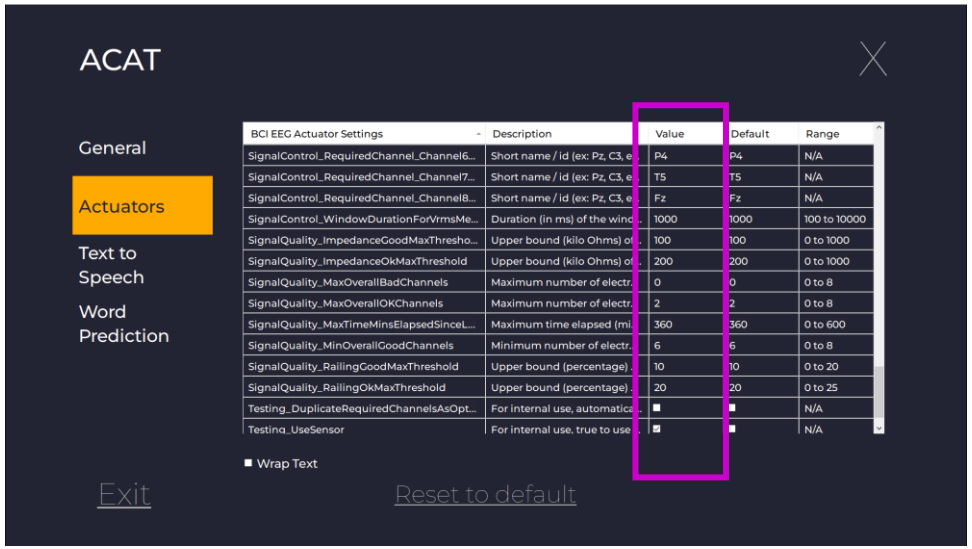
ACATConfig

i. Run *ACATConfig* application



ii. Select *Actuators*
iii. Then Select *BCI EEG Actuator*
iv. Click *Setup*



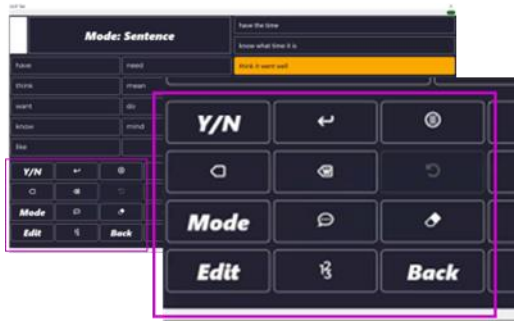


v. Click on the *Value* of the parameter and type in the new value
vi. Click *Save* and *Exit* the applications

Troubleshooting: Known Issues

Problem: ACAT exits prematurely sometimes when a mouse is used to select/trigger keys on the left or right keyboards of the BCI Talk UI

Description: This can happen when a mouse is used to click on the action–buttons of the left keyboard and when using the mouse on the additional BCI supported keyboards shown in Section 6.1. The action buttons are the ones that change the keyboard layout to support additional functionality, for e.g., Yes/No, Mode, Edit, Main Menu, Lock, Numeric Keyboards – all of which results in a keyboard change.



Left Keyboard

Workaround:

- The Talk interface is continuously scanning
- However, you will observe that once an item is selected, there is a brief period when the scanning is paused. This brief pause in scanning is by design to give the user the time to notice the selection and plan on what they would like to select next.
- If the mouse is clicked during this pause period, the underlying software implementation is currently unable to process this and causes ACAT to exit
- To avoid this, it is recommended to use the mouse only when the scanning animation is active