

Standard Operating Procedures for WACARDIA MATLAB program to use Shimmer sensors and Heartbeat Detection tasks



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2020/01/24	First version
2024/09/20	Update with Bluetooth Lag Detection and more troubleshooting from IK and JC
2025/04/18	Update with ECG to pin connectors, add MATLAB Arduino installation

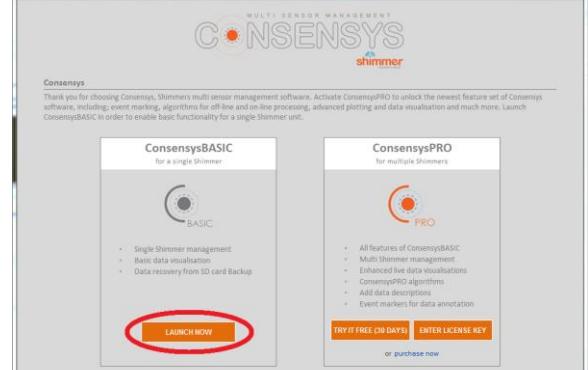
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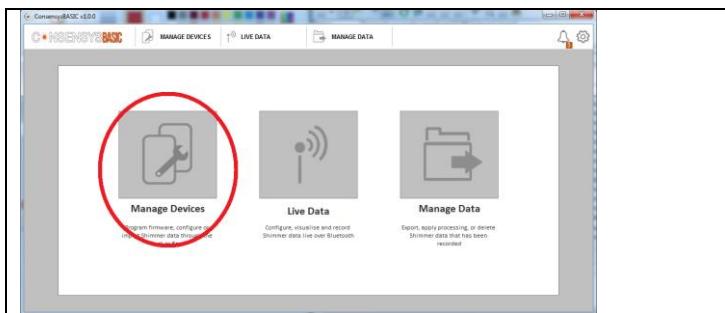
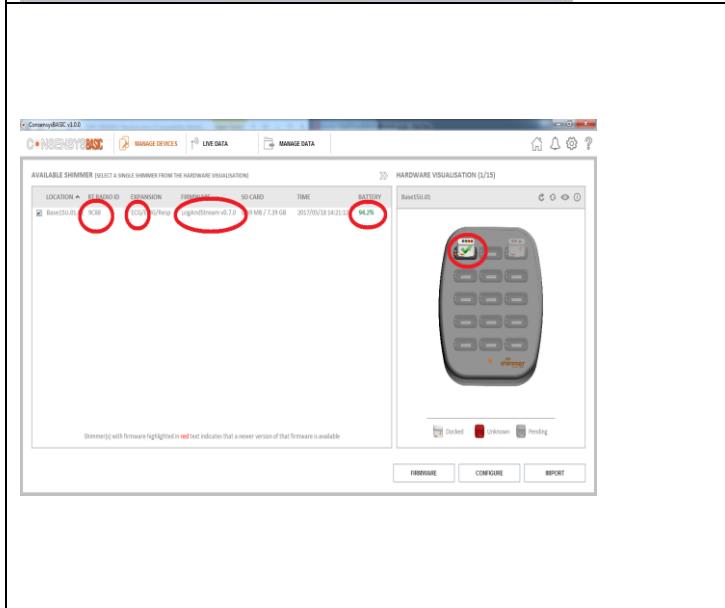
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PREPARING THE SHIMMER MOBILE SENSORS

THE RED TEXT MEANS: DO THIS ONLY ONCE PER SHIMMER SENSOR, NOT EVERY TIME BEFORE THE SUBJECT COMES TO THE LAB (UNLESS THE SENSOR DOES NOT WORK PROPERLY)

To save time, keep a single set of sensors for in-lab use only so you don't have to do this often.

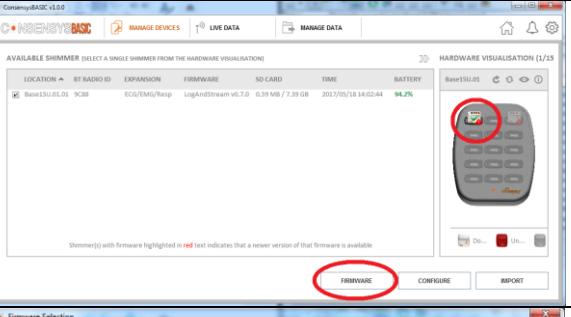
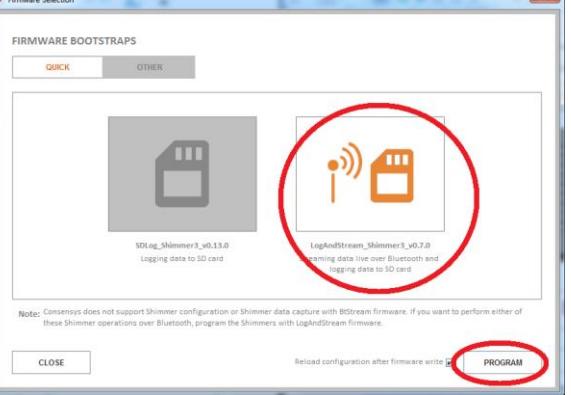
	<ol style="list-style-type: none">1. Plug Shimmer dock into the surge protector (if not already plugged in)2. Plug Shimmer dock USB into the computer
	<ol style="list-style-type: none">3. Plug Shimmer sensors into dock (use one ECG and one EDA/GSR)
	<ol style="list-style-type: none">4. Turn the devices on by flipping the orange switch up. You'll know it is on because the lights on the front will illuminate
	<ol style="list-style-type: none">5. Open Consensys (Start menu...type Consensys, press Enter)6. Choose ConsensysBASIC and click LAUNCH NOW at the bottom left

	<p>7. Click on "Manage Devices"</p>
	<p>8. If you get this message requesting that the Shimmer Mobile Sensor be encrypted, choose <u>Continue without Encryption</u></p>
	<ol style="list-style-type: none"> 1. For each of the two sensors, write down the following on the data sheet <ol style="list-style-type: none"> a. Bluetooth (BT) radio ID, e.g., 91E0 b. FYI the BT ID is also on the back of the sensor itself in a black rectangle c. Expansion (e.g., ECG or EDA/GSR+) d. COM port from Bluetooth settings (instructions in the next section with black text) 2. Check that the following are valid <ol style="list-style-type: none"> a. Firmware should be LogAndStream. If not then repeat prior instructions using the FIRMWARE button b. Battery should be at least 20% before the participant wears the device 3. Close the Consensys program by clicking the X in the top right corner of the window <ol style="list-style-type: none"> a. Click <u>Yes</u> to exit

On the computer, set up the FIRMWARE for the in-lab devices

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To save time, keep a single set of sensors for in-lab use only so you don't have to do this often.

	<ol style="list-style-type: none">1. Open the Consensys program (see above) if not already open2. Click on the Shimmer device (or both if possible) and click FIRMWARE3. FYI, at this window you can check the Firmware version and see whether it needs to be changed or not
	<ol style="list-style-type: none">4. Choose LogAndStream_Shimmer to ensure that the device can stream data via Bluetooth5. Click PROGRAM6. Wait until process is complete7. Click DONE8. Do NOT encrypt the device, if asked by Windows

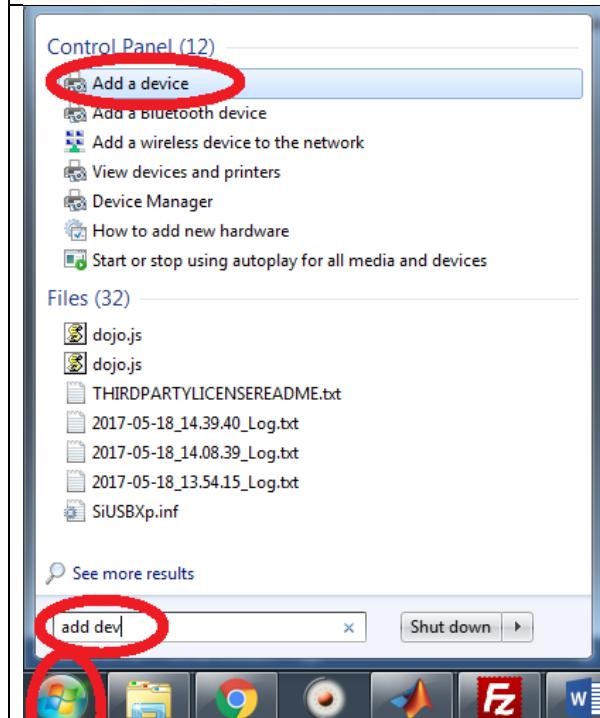
Windows 7 and older: Set up devices for Bluetooth connection with computer

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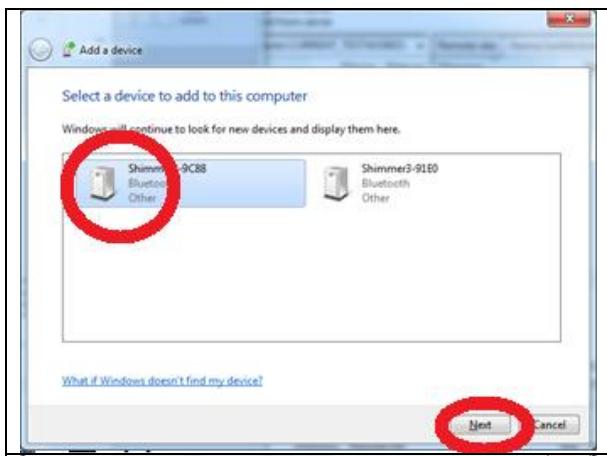
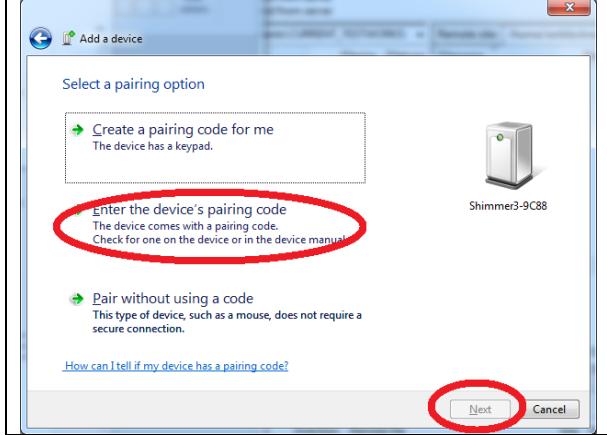
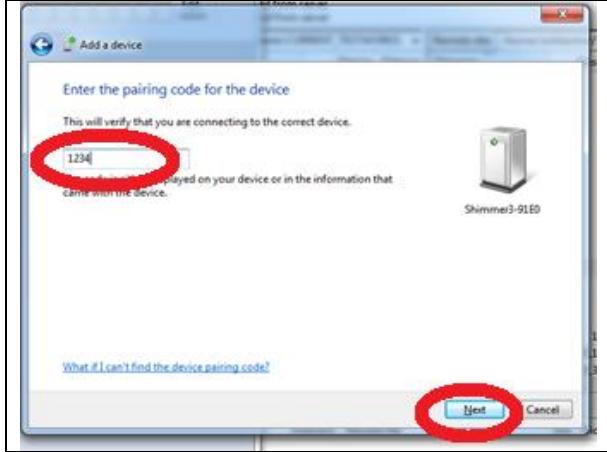
To save time, keep a single set of sensors for in-lab use only so you don't have to do this often.



If you are using a USB Bluetooth Dongle (probably yes) then make sure that is inserted as it will affect the COM ports that each Shimmer is assigned to



1. Click the Start button (or press the Windows button on the keyboard)
2. Type add device
3. Click the Add a device option that appears

	<ol style="list-style-type: none"> 1. The nearby Shimmer Sensors that are ON should appear here <ol style="list-style-type: none"> a. If they do not appear here, you must ensure your computer has Bluetooth capabilities (e.g., using a USB dongle), and perhaps you need to enable Bluetooth b. One setup in the lab uses a Bluetooth USB dongle and once it is pugged in then Bluetooth is enabled
	<ol style="list-style-type: none"> 2. Click enter the device's pairing code 3. Click Next
	<ol style="list-style-type: none"> 4. Enter the pairing code: 1234 5. This pairing code is the same for all Shimmer Sensors 6. Click Next
	<ol style="list-style-type: none"> 7. Repeat this process for any other Shimmer Sensors that need to be streamed to the computer <ol style="list-style-type: none"> a. FYI, the sensors that are given to participants to take home do NOT need to use Bluetooth

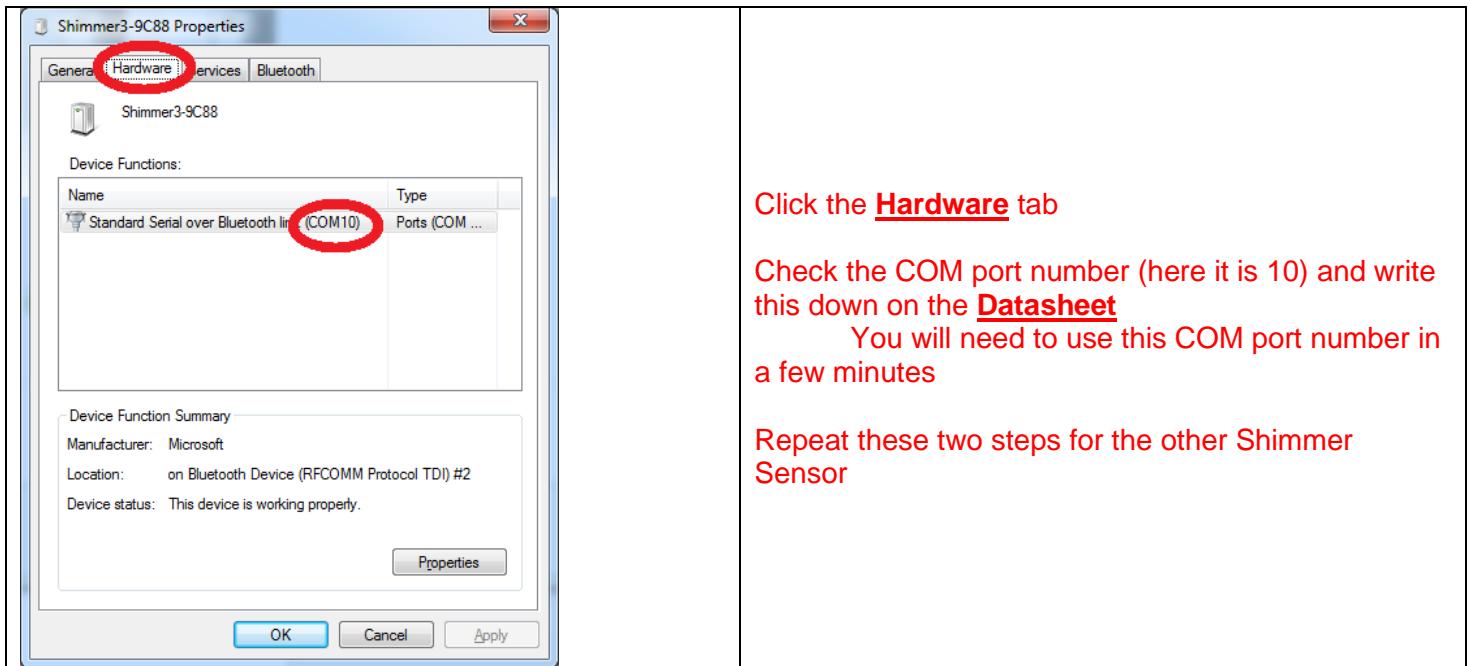
Check COM port for Shimmer sensors

You only need to do this once per computer + Bluetooth dongle + Shimmer sensor combination

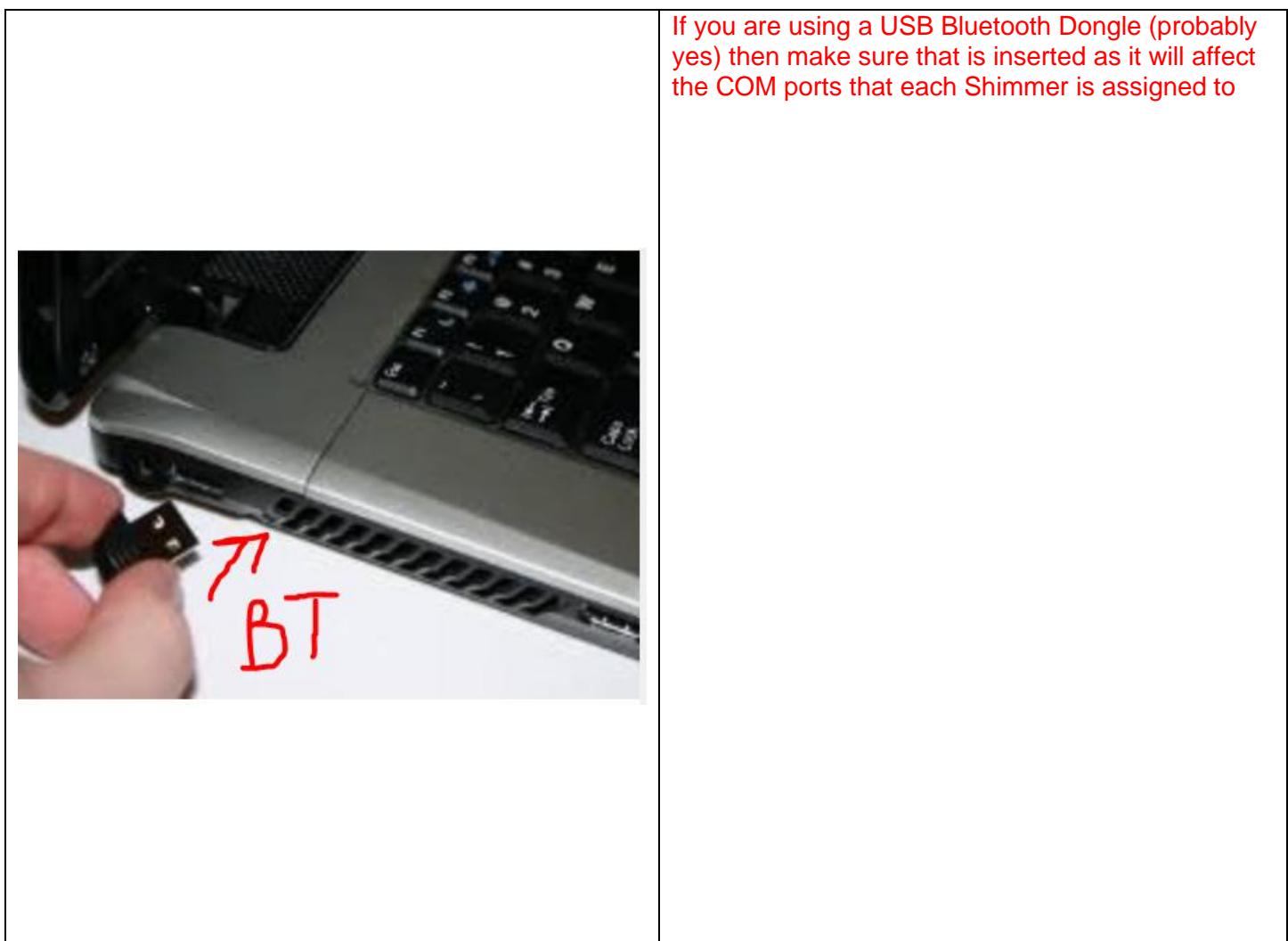


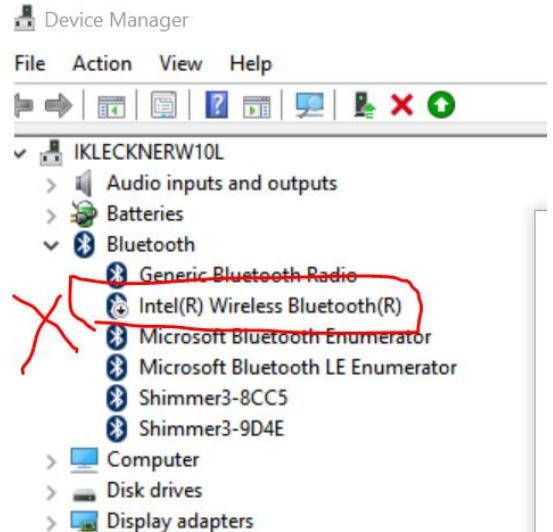
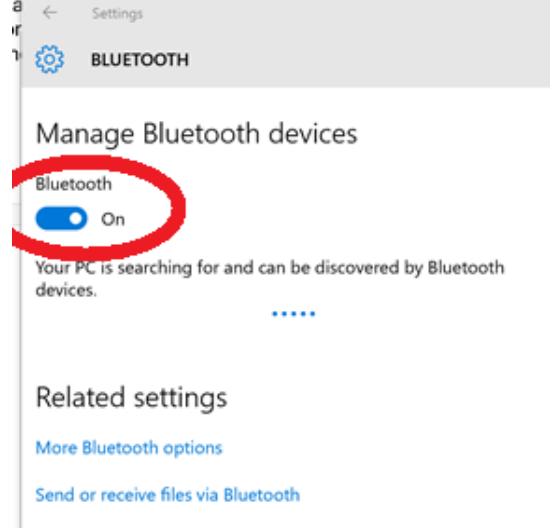
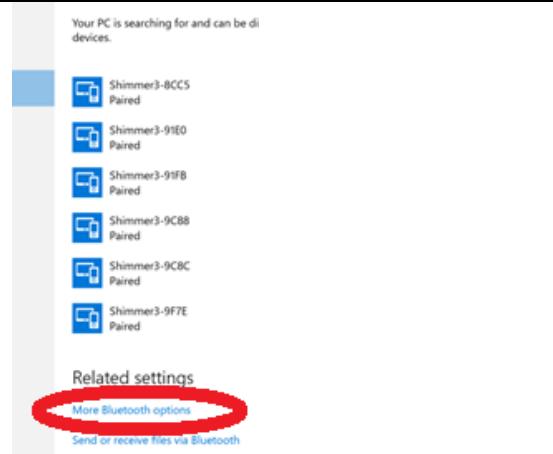
Windows 7

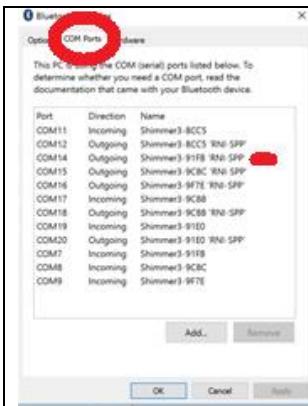
<p>The screenshot shows the Windows 7 Control Panel interface. The 'Devices and Printers' option is circled in red at the top of the list. Below it is a search bar containing the word 'devices'. A red circle highlights the search bar.</p>	<p>Click the Start button (or press the Windows button on the keyboard) Type <u>devices</u> Click the <u>Devices and Printers</u> option that appears</p>	
<p>The screenshot shows the 'Devices and Printers' window in Windows 7. It displays a list of paired devices under the 'Devices' category. Two Shimmer sensors, 'Shimmer3-9C8B' and 'Shimmer3-9LED', are circled in red. Other listed devices include a Dell M3116 USB Optical Mouse, a KLECKNER1WLT, and a CSR8510 A0.</p>	<p>Double click on each of the Shimmer Devices that you just paired</p>	



Windows 10



	<p>If there is integrated AND external Bluetooth then disable the integrated Bluetooth using the device manager (Windows button...type device manager)</p> <p>Right click on the integrated Bluetooth and click Disable</p>
	<p>Press the Windows button on the keyboard or click the Windows icon in the lower left hand corner</p> <p>Type Bluetooth into search</p> <p>Hit enter to open Bluetooth settings</p>
	<p>Click to turn on Bluetooth</p>
	<p>Devices should be paired</p> <p>Click More Bluetooth Settings near the bottom</p>



Click on COM Ports tab to see list of devices

The COM we want has RNI-SPP in the name

Ex: EDA Shimmer is 91E0, COM16

Ex: ECG Shimmer is 9C88, COM18

Check the COM port number (here it is 14) and write this down on the [Datasheet](#)

You will need to use this COM port number in a few minutes

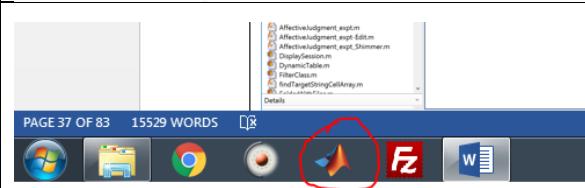
Windows 11

	<p>If you are using a USB Bluetooth Dongle (probably yes, then follow the steps above for Windows 10 to disable integrated Bluetooth.</p> <ol style="list-style-type: none"> 1. Open Settings > Bluetooth and devices 2. Press “View more devices” 3. Scroll down until “Bluetooth devices discovery” under Device settings 4. Switch it from Default to Advanced
	<ol style="list-style-type: none"> 5. Return to “Bluetooth and devices” and select “Add device” 6. Choose Bluetooth, the top option 7. Select your Shimmer sensor when it appears and connect! (The PIN default is 1234) <p>After this, follow the steps above to determine the COM port number for the Shimmer</p>

Test connection with Shimmer Sensors

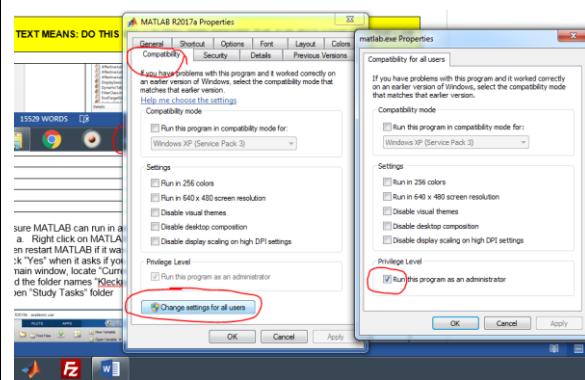


If you are using a USB Bluetooth Dongle (probably yes) then make sure that is inserted as it will affect the COM ports that each Shimmer is assigned to



Open MATLAB

- Use the shortcut on the computer desktop or taskbar
- Or click Start...type **matlab** then hit **Enter**

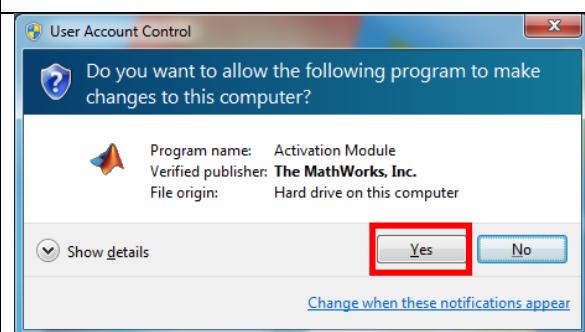


Only do this once per computer

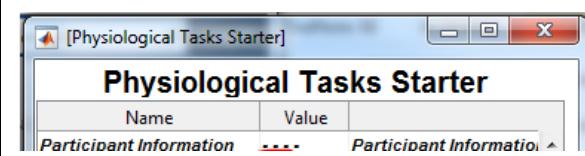
Ensure MATLAB can run in administrator mode (only needs to be done once per computer)

Right click on MATLAB shortcut...Properties...Compatibility...Run as administrator

Then restart MATLAB if it was already running

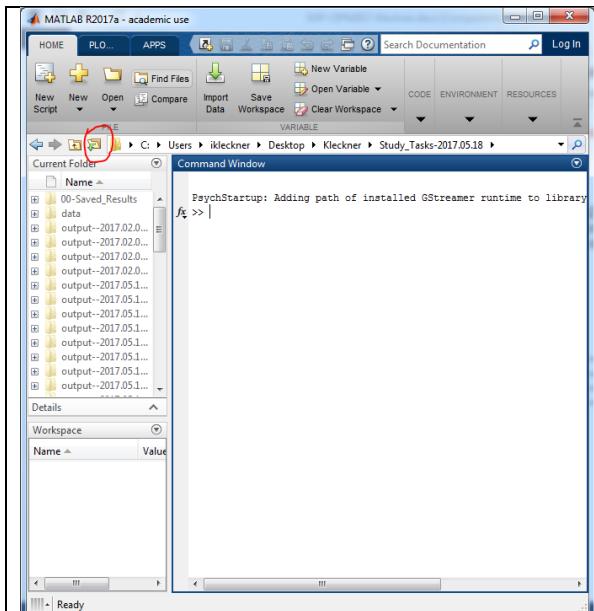


Click "Yes" when it asks if you want MATLAB to make changes to the computer

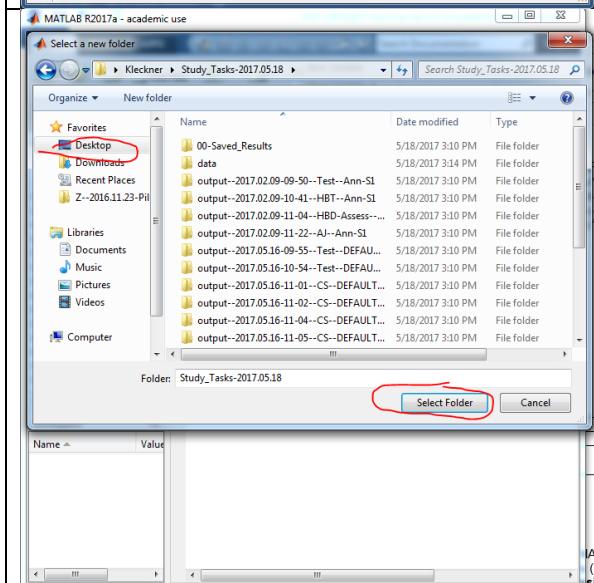


MATLAB may be set up with the proper directory and to automatically open the **Task_Starter** program

If a window like this does NOT open, then complete the following 3 steps in red to open it.



In main window, click **Current Folder** on left side of screen

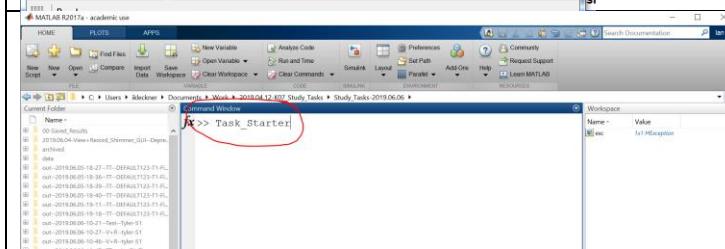


Go to **Desktop**

Kleckner

Study_Tasks-2019.06.12 (or most recent folder of a similar name)

Click **Select Folder**



In the command window, type **Task** and hit **tab**, it will complete the command for you to **Task Starter**

Hit **Enter**

	<p>Type in subject number (1, 2, ...)</p> <p>Type in timepoint (1, 2, or 3)</p> <p>Type in COM port for Shimmer ECG (e.g., 10) obtained from Windows Bluetooth settings (steps above)</p> <p>Type in COM port for Shimmer EDA (e.g., 8) obtained from Windows Bluetooth settings (steps above)</p> <p>At bottom left, set Task to run to Test Shimmer Sensors</p> <p>Click Go! at bottom right</p>
--	--

Command Window

```
fx >> edit Task_Starter.m
```

Task_Starter.m

```

120
121
122 - specsTable.addRow('HEADING', 'Shimmer Connection', NaN, '', NaN,
123 - specsTable.addRow('BOOLEAN', 'Use_ECG', true, '** Acquire ECG'
124 - specsTable.addRow('NUMERIC', 'COM_ECG', [11], 'COM port for Shi
125 - specsTable.addRow('NUMERIC', 'Sampling_rate_ECG_Hz', 512, 'Sa
126
127 - specsTable.addRow('BOOLEAN', 'Use_EDA', true, '** Acquire EDA'
128 - specsTable.addRow('NUMERIC', 'COM_EDA', [9], 'COM port for Shi
129 - specsTable.addRow('NUMERIC', 'Sampling_rate_EDA_Hz', 64, 'Sam
130

```

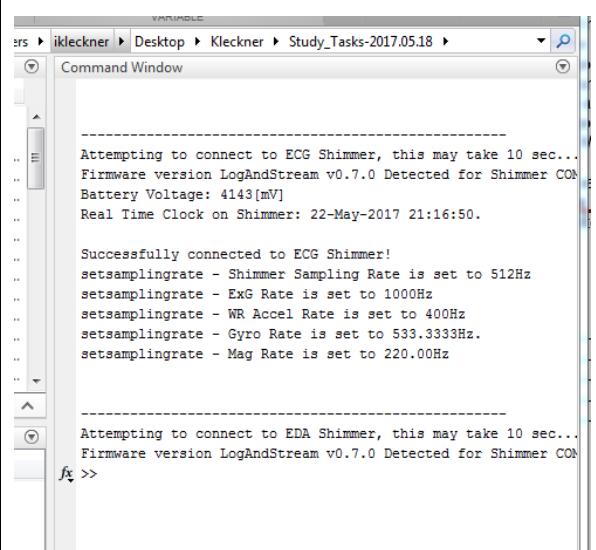
If you want to edit the DEFAULT values in the Task Starter, edit the file Task_Starter.m

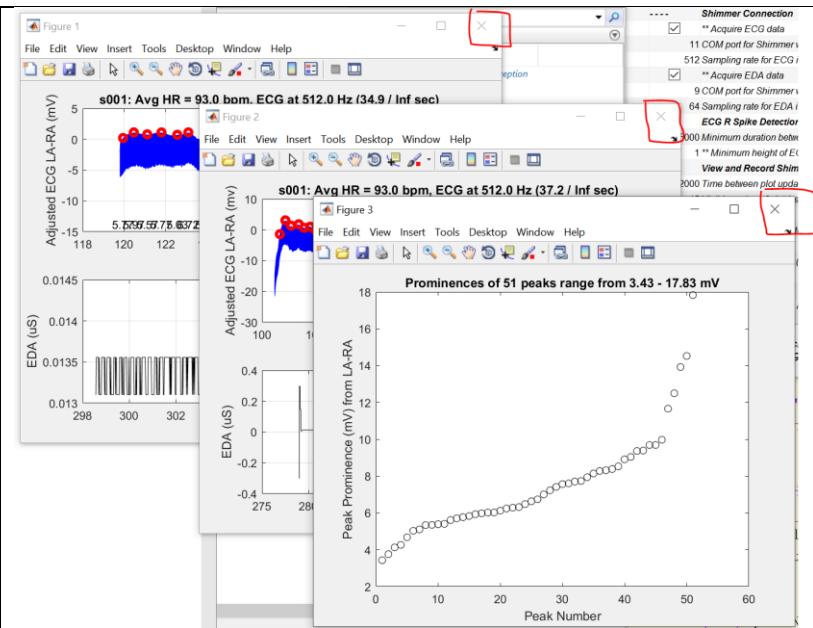
In the command window, type **edit Task_Starter.m**

In the window that opens, edit the values shown in the picture to the left. E.g., to change the default COM port for the Shimmer ECG, you would edit this code around line 123 (might differ by code version). You would change 11 to a different value.

```
specsTable.addRow('NUMERIC', 'COM_ECG', 11, 'COM port for Shimmer with ECG', 0, Inf);
```

Then Save the file (**Ctrl+S**), exit the Task_Starter (click the x in the top right), and start it again by typing **Task_Starter** then hitting **Enter** in the MATLAB command window.

	<p>Watch the MATLAB command window for progress for how the computer is connecting to the Shimmer devices</p> <p>This takes approximately 20 sec</p> <p>If there are any issues here (red text in MATLAB window) then check the following</p> <ul style="list-style-type: none"> • Computer's Bluetooth is on (press the Windows button, type Bluetooth, hit enter, and turn it on) • MATLAB has administrator access • Shimmer devices are on • RealTerm software installed on computer • Shimmer source code is in MATLAB directory where Kleckner/Study_Tasks files are • Try turning the Shimmer devices OFF...waiting 5 sec...then turning them ON again • Try restarting MATLAB (type exit at the command window then hit enter) • Call Ian or email him
	<p>Click START</p> <p>A new windows opens up and shows data from the sensors. If anything appears, that is a success</p> <p>You can watch the number of seconds in the recording until it reaches the goal or you can hold Shift+Esc for a couple seconds to exit</p>



Now you know that MATLAB can successfully connect to both Shimmer ECG and Shimmer EDA devices! Of course, these data are just noise because the electrodes are not connected to anything.

When the program is complete, **close all three figures** showing data, or click **Close Figs** in the Task Starter

```
documents > Work > 2019.04.12-KD>Study_Tasks > Study_Tasks-2019.06.06 >
Command Window
setsamplingrate - Mag Rate is set to 220.00Hz
-----
Attempting to connect to EDA Shimmer, this may take 10 sec..
Firmware version LogAndStream v0.11.0 Detected for Shimmer C
Battery Voltage: 3912[mV]
Real Time Clock on Shimmer: 12-Jun-2019 13:34:38.

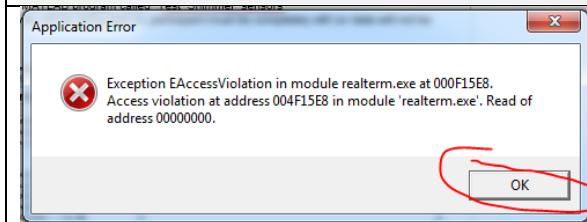
Successfully connected to Shimmer device!
setsamplingrate - Shimmer Sampling Rate is set to 64Hz
setsamplingrate - EXG Rate is set to 125Hz
setsamplingrate - WR Accel Rate is set to 100Hz
setsamplingrate - Gyro Rate is set to 64Hz.
setsamplingrate - Mag Rate is set to 75.00Hz
Warning: Default character vector does not match any button
character vector name.

Starting continuous signal monitoring for Inf sec
** To stop recording early press Ctrl + Esc **
User stopped recording via keyboard.

fx All done!>> close all
```

If you ever see this message, just click **OK**

It is **no big deal**, and you don't need to document it. It's just a side-effect of exiting the MATLAB programs early, so it's bound to happen sometimes.



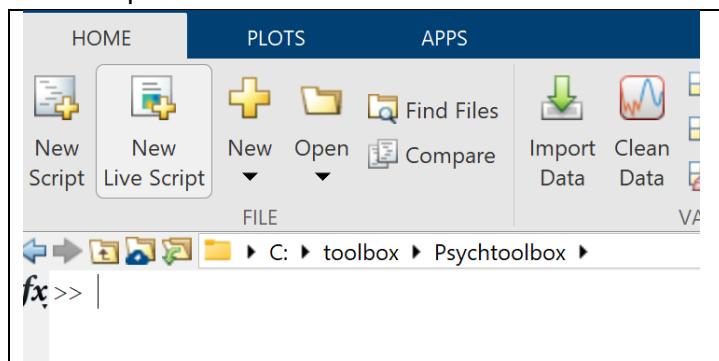
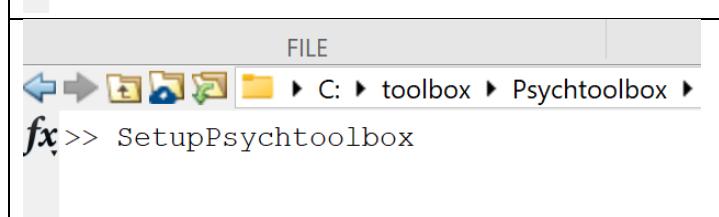
TROUBLESHOOTING

Error: Invalid MEX-file

'C:\toolbox\Psychtoolbox\PsychBasic\MatlabWindowsFilesR2007a\Screen.mexw64':

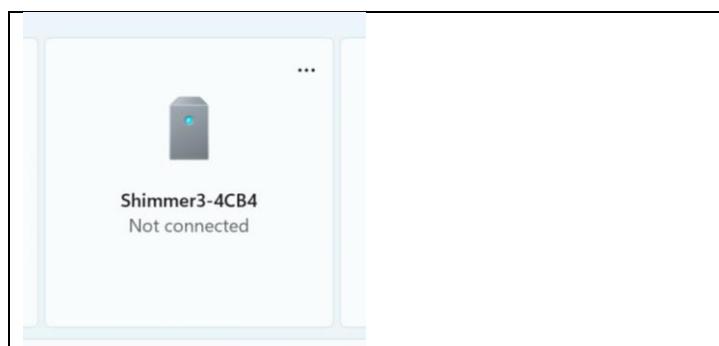
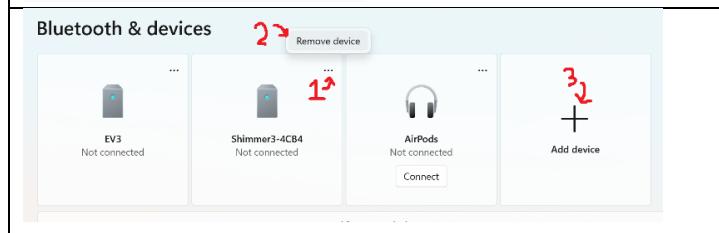
The specified module could not be found.

If you receive this error message in the MATLAB command window, please reinstall Psychtoolbox by following these steps:

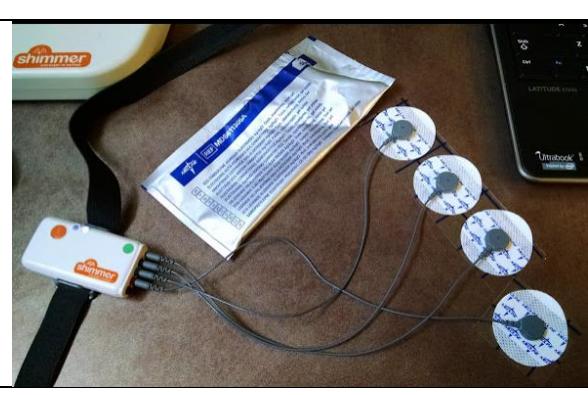
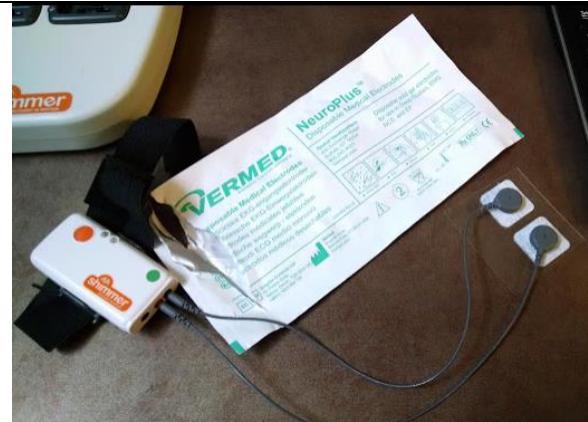
	<p>Open MATLAB using 'Run as administrator'</p> <p>In the MATLAB command window, navigate to Psychtoolbox (probably inside C:/toolbox)</p>
	<p>Run the command 'SetupPsychtoolbox'</p>

Psychtoolbox will automatically re-install, and the program should work from there.

Error: Shimmer device will not connect to the computer via Bluetooth

	<p>There is a bug in Windows 11 where Settings might show that the Shimmer is not connected when it actually is.</p> <p>If your screen looks like this even after following the steps to connect to the device, do this to check whether or not the Shimmer is actually connected.</p>
	<ol style="list-style-type: none"> 1. Click the 3-dot menu on the Shimmer 2. Select 'Remove device' 3. Press the box labeled 'Add device' 4. Add a Bluetooth device (the first option) 5. Select the Shimmer when it pops up (PIN: 1234)
	<p>The display will probably show the Shimmer Connected for a few seconds, but then revert back to Not connected.</p> <p>If so, start MATLAB (as administrator) and run the View and Record Shimmer program. The program will hopefully run successfully, and you can move on to running trials.</p>

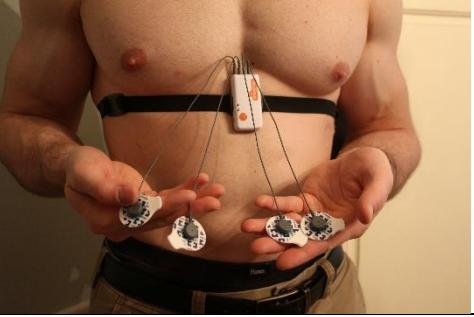
PREPARE SHIMMER SENSORS, ELECTRODES, AND STRAPS

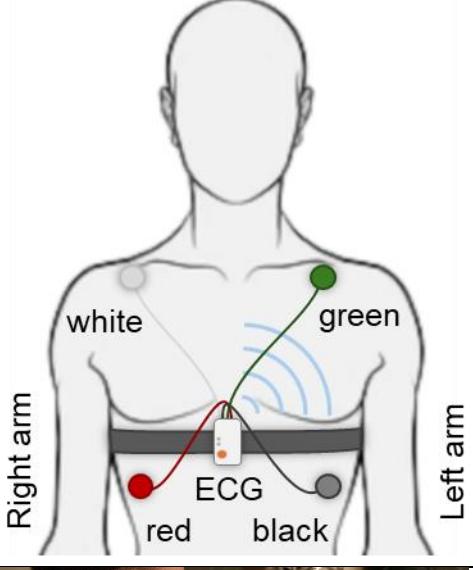
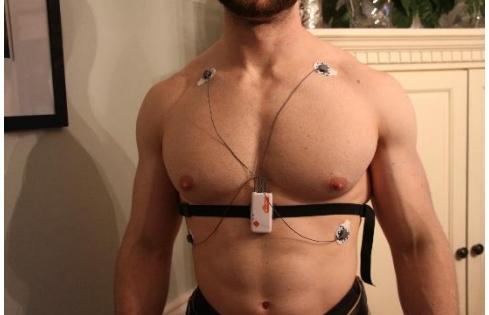
	<p>The Shimmer ECG has four wires: red, green, black, and white The brown lead receptacle (on the left) is not used here</p>
	<p>Plug the Shimmer ECG leads into each of four round Medline ECG electrodes Attach a long chest strap to the Shimmer ECG</p>
	<p>Plug the Shimmer EDA leads into each of two square Vermed ECG electrodes(here, used for EDA) Attach a short arm strap to the Shimmer EDA</p>
	<p>Plug the Shimmer sensors back into the dock so their battery will remain charged</p>

SUBJECT ARRIVES

- Offer them a drink of water (also helps improve signal quality)
- Offer them a bathroom break
- Ask them to wash their hands lightly with little / no soap

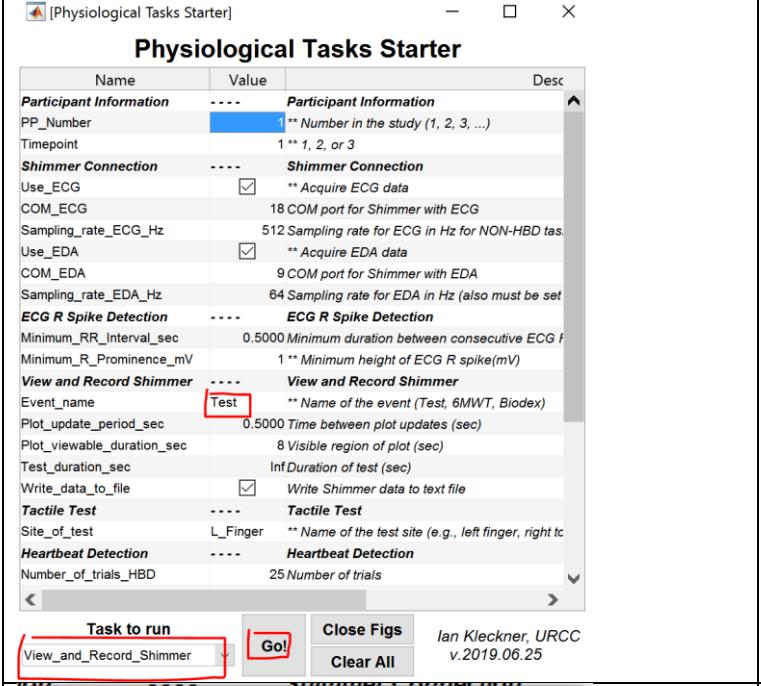
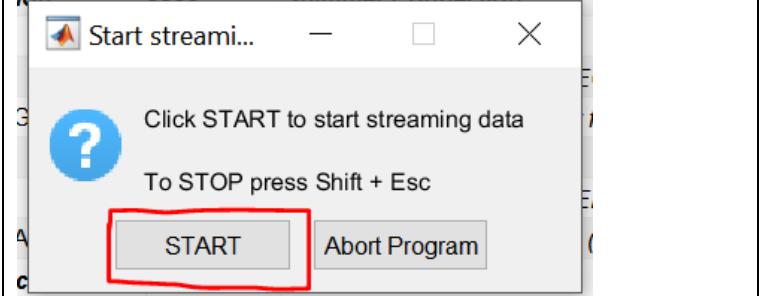
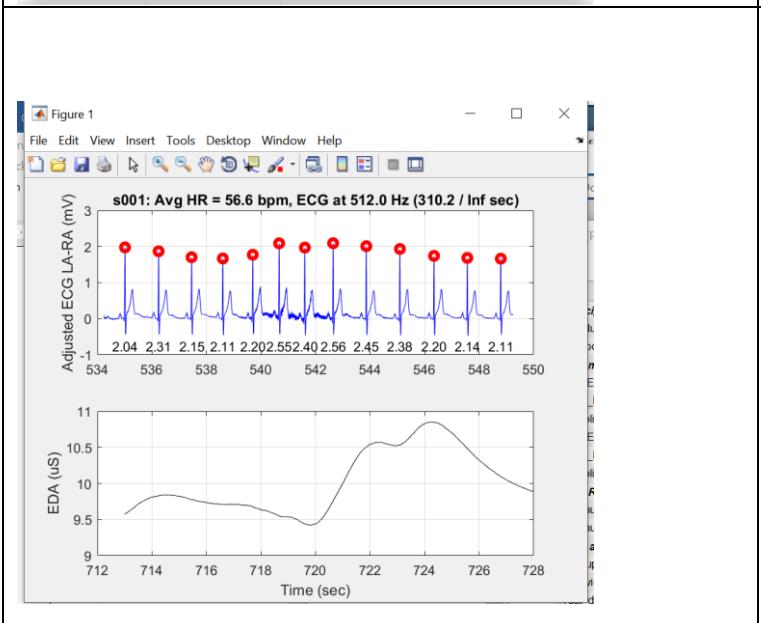
Place Shmmer ECG (chest)

	Thread belt through clasp
	Secure belt around waist
	Move belt up to below the chest (above the chest is fine too, just make sure the ECG leads aren't under tension)
	Snap the heart rate monitor into plastic harness
	Snap each of four sensors into the head of the wires

	<p>The locations of the four sensors should follow the colors: red, green, black, and white. The locations may be moved slightly to fit the body and clothing</p> <ul style="list-style-type: none"> • White on right collarbone • Green on left collarbone • Red on right rib • Black on left rib
	<p>Ensure your skin is clean by rubbing with an alcohol pad and gauze pad (if needed) and letting the skin dry</p>
	<p>All four sensors in place, you may add medical tape on the wires to keep them in place Make sure the wires are not under tension because that will introduce noise</p>

TEST SHIMMER ECG AND EDA DATA QUALITY

1. Signal quality is best when the participant is still (either standing, seated, or lying down)
2. If the task involves movement (e.g., walking), this step should involve the participant standing still
3. High quality data can still be obtained during ambulatory tasks such as walking as long as appropriate measures are taken (e.g., taping ECG leads to the skin so they do not tug on the electrodes or Shimmer device while moving).

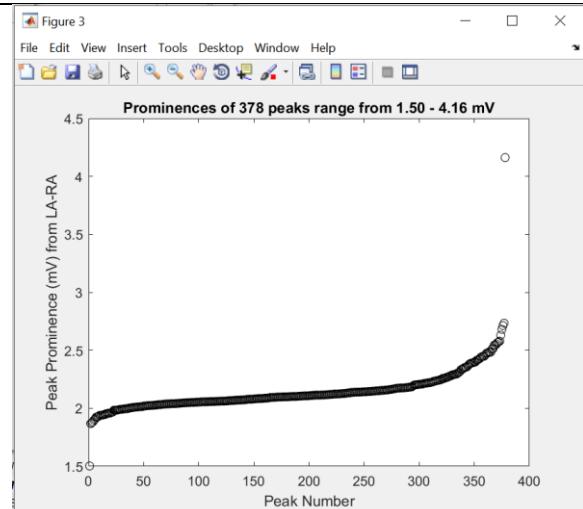
	<p>Make sure the Event Name is still Test</p> <p>Click Go! in the MATLAB Physiological Tasks Starter to run the View_and_Record_Shimmer program</p>
	<p>Click Start</p>
	<p>Watch the signals from the ECG at the top</p> <ul style="list-style-type: none"> • There should be one red circle per R spike (heartbeat) • Read the prominence values under each R spike to get a sense of its minimum value • You can also see the T wave after each R spike • This signal here looks good in terms of signal to noise ratio • If there is excessive noise or artifacts, then try the following: <ul style="list-style-type: none"> • Ask the subject to sit still and upright with feet on the floor • Consider replacing or repositioning the electrodes after another rougher alcohol and gauze wipe • If the electrodes are on a region with a lot of subcutaneous fat then move them

closer to a near-superficial bone (ribs or clavicle)

- Re-initialize the Shimmer sensor (new firmware, new settings. See above instructions in red text)

Watch the EDA signal at the bottom

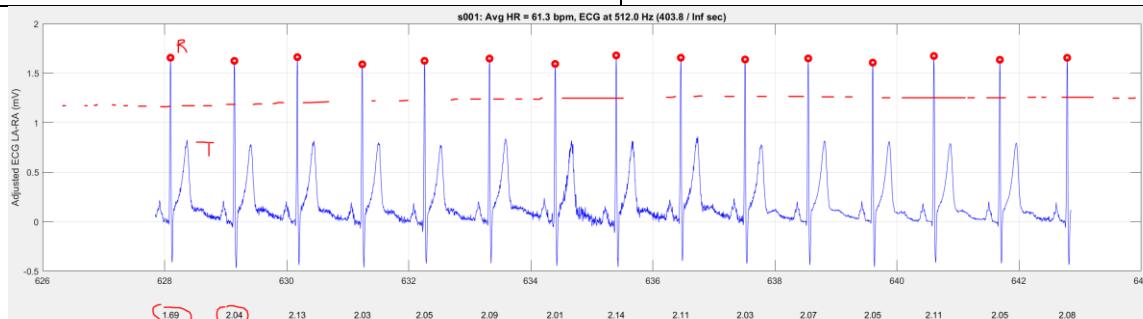
- Should look smooth and decreasing over time
- There will be some transient “responses” that increase the signal substantially over the course of a few seconds
- Ask the participant to take a big breath and hold it for a couple seconds, you should see a rise in EDA over the next few seconds after the breath hold
- If the signal does not look something like this
 - Reposition the electrodes
 - Re-initialize the Shimmer sensor (new firmware, new settings. See above instructions in red text)



Find the best prominence value that would have captured nearly all of these R spikes and go slightly smaller

- From this plot it would be 1.5
- But this is only if the subject is sitting in this position

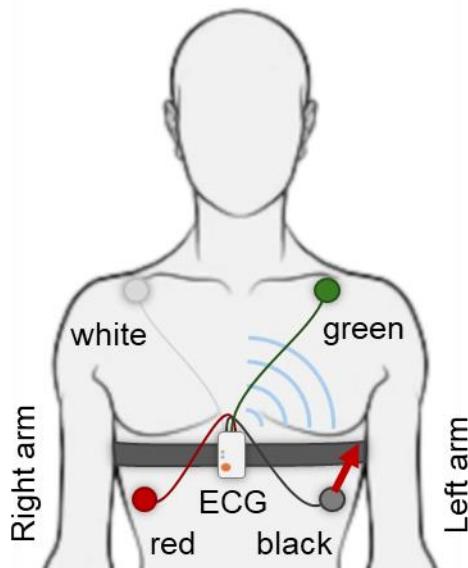
This should be small enough to catch **EVERY** ECG R spike, but large enough to **NOT** catch noise spikes



To determine the best prominence value you should **think of drawing a horizontal line through the ECG data that is between the tops of the R spikes and tops of the T waves**. Specifically, so that spikes ABOVE the line are R spikes and T waves never cross the line

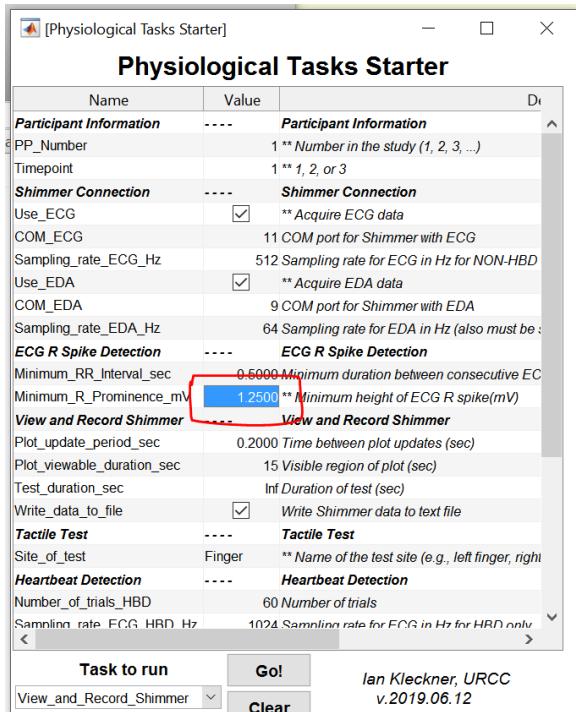
These data are high quality in that the horizontal line at approximately 1.25 mV is much lower than every R spike and much higher than every T wave

The prominence values are shown at the bottom of this plot (first two are circled)



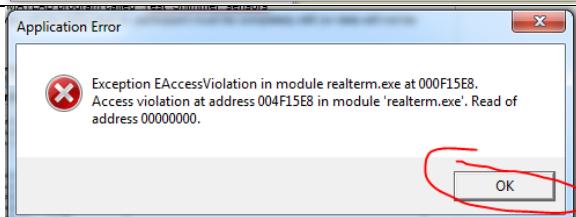
If the T-wave is very large then it might interfere with detection of R spikes.

If needed: to reduce the T-wave, try moving the lower left (black) electrode up



If needed, update the Prominence value in the Task Starter

The default value is 1 mV and this **default value can be changed** by editing Task_Starter.m, if desired (see instructions above in red)



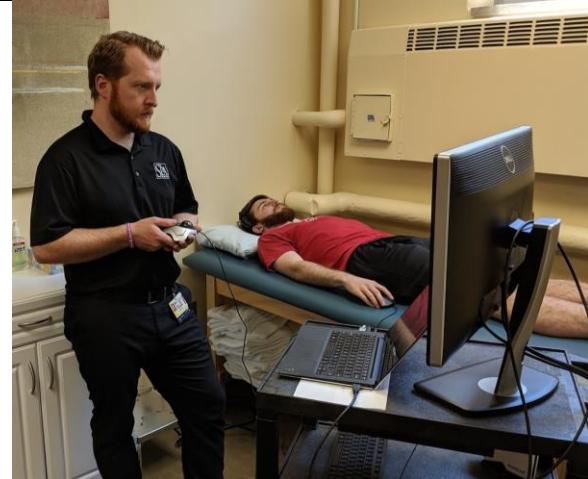
If you ever see this message, just click **OK**

It is **no big deal**, and you don't need to document it. It's just a side-effect of exiting the MATLAB programs early, so it's bound to happen.

HEARTBEAT TRACKING TASK



WARNING: If you are completing BOTH HBD and HBT tasks, complete HBT first to prevent participants from obtaining knowledge of heart rate by hearing the beeping from HBD



Have the participant lay down on the table and make them comfortable with pillows or towels (e.g., under their neck, knees, etc.)

The participant can start the trial when they are ready by clicking the mouse button

They do not have to view the monitor during the test, but they may like to view the monitor during instructions

[Physiological Tasks Starter]

Physiological Tasks Starter

Name	Value	Desc
Participant Information	-----	Participant Information
PP_Number	1	** Number in the study (1, 2, 3, ...)
Timepoint	1 ** 1, 2, or 3	
Shimmer Connection	-----	Shimmer Connection
Use_ECG	<input checked="" type="checkbox"/>	** Acquire ECG data
COM_ECG	18	COM port for Shimmer with ECG
Sampling_rate_ECG_Hz	512	Sampling rate for ECG in Hz for NON-HBD task
Use_EDA	<input checked="" type="checkbox"/>	** Acquire EDA data
COM_EDA	9	COM port for Shimmer with EDA
Sampling_rate_EDA_Hz	64	Sampling rate for EDA in Hz (also must be set in Shimmer)
ECG R Spike Detection	-----	ECG R Spike Detection
Minimum_RR_Interval_sec	0.5000	Minimum duration between consecutive ECG R spikes (sec)
Minimum_R_Prominence_mV	1	** Minimum height of ECG R spike(mV)
View and Record Shimmer	-----	View and Record Shimmer
Event_name	Test_Laying	* Name of the event (Test, 6MWBT, Biodesix)
Plot_update_period_sec	1	Time between plot updates (sec)
Plot_viewable_duration_sec	8	Visible region of plot (sec)
Test_duration_sec	Inf	Duration of test (sec)
Write_data_to_file	<input checked="" type="checkbox"/>	Write Shimmer data to text file
Tactile Test	-----	Tactile Test
Site_of_test	L_Finger	** Name of the test site (e.g., left finger, right toe)
Heartbeat Detection	-----	Heartbeat Detection
Number_of_trials_HBD	50	Number of trials

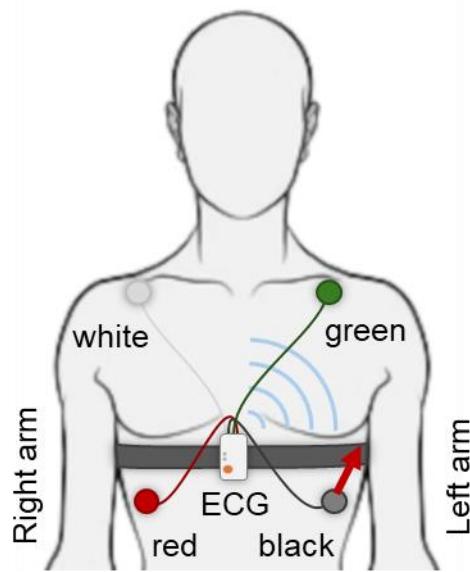
Task to run: View_and_Record_Shimmer

Go! Close Figs Ian Kleckner, URCC v.2019.06.25 Clear All

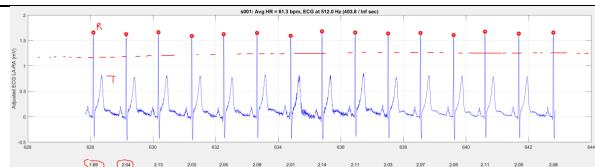
Because the ECG signal can change when they are lying down, check the signal again

Set sampling rate back to 512 Hz

Set the Event Name to **Test_Laying**

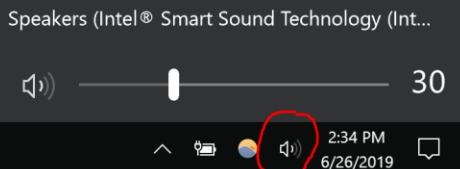


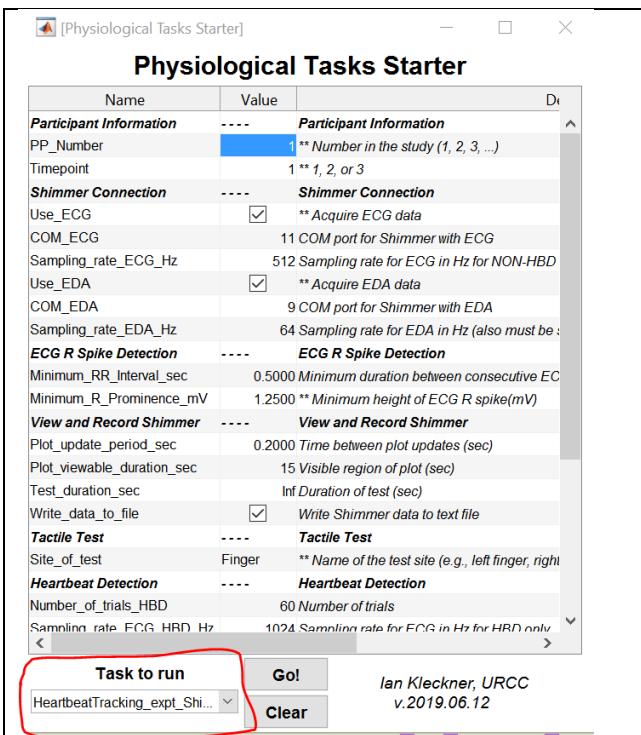
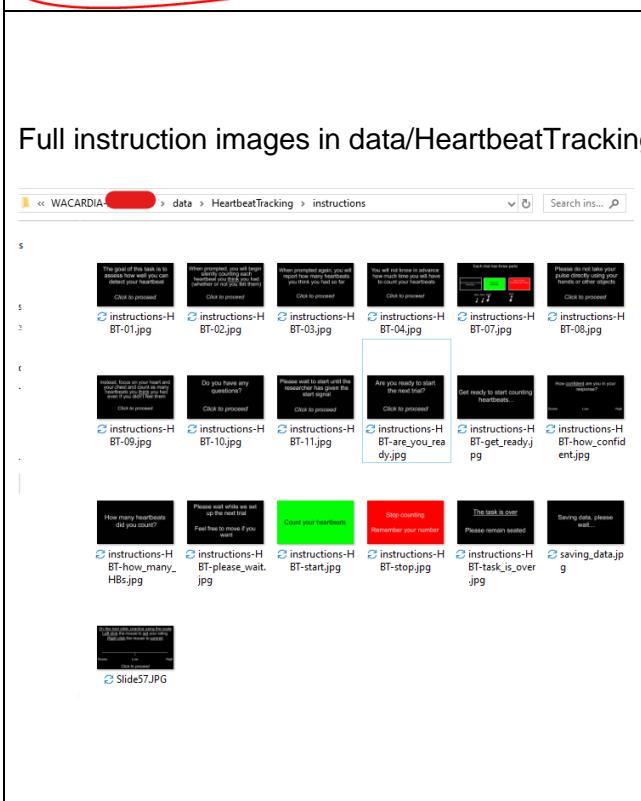
Adjust electrode position if needed to reduce T wave, etc.

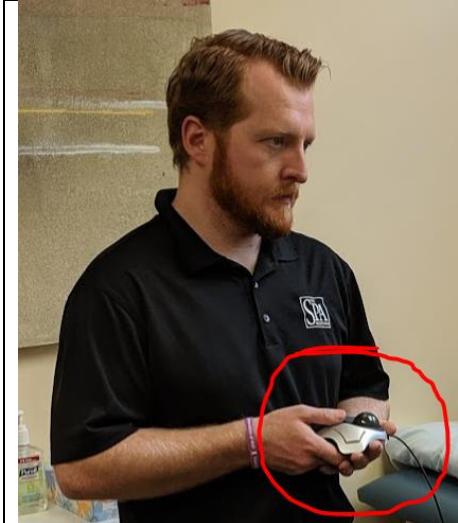


Adjust the prominence if needed

Make sure the computer volume is on and audible to the participant (try Volume=30 to start)



<p>Physiological Tasks Starter</p>  <p>The screenshot shows the 'Physiological Tasks Starter' application window. In the main pane, there's a table with various parameters like 'Participant Information', 'Shimmer Connection', 'ECG R Spike Detection', etc. A red box highlights the 'Task to run' section, which contains a dropdown menu set to 'HeartbeatTracking_expt_Shi...' and a 'Go!' button. To the right of the table, it says 'Ian Kleckner, URCC v.2019.06.12'.</p>	<p>In the task starter program, choose the Heartbeat_Tracking_Shimmer task</p> <p>Then click Go!</p> <p>Follow on-screen instructions (see full instructions below)</p>
<p>Full instruction images in data/HeartbeatTracking</p>  <p>The image shows a grid of 25 small thumbnail images, each labeled with a file name like 'instructions-H BT-01.jpg'. These thumbnails represent the visual instructions provided to the participant during the task. Some thumbnails have a red box drawn around them, specifically highlighting the first few images which likely correspond to the initial setup and counting instructions.</p>	



The researcher should explain the task instructions by reading from the screen

The researcher will make all responses for the subject

HEARTBEAT DETECTION TASK



[Physiological Tasks Starter]

Physiological Tasks Starter

Name	Value	Desc
Participant Information	-----	Participant Information
PP_Number	1	** Number in the study (1, 2, 3, ...)
Timepoint	1	** 1, 2, or 3
Shimmer Connection	-----	Shimmer Connection
Use_ECG	<input checked="" type="checkbox"/>	** Acquire ECG data
COM_ECG	18	COM port for Shimmer with ECG
Sampling_rate_ECG_Hz	512	Sampling rate for ECG in Hz for NON-HBD tasks
Use_EDA	<input checked="" type="checkbox"/>	** Acquire EDA data
COM_EDA	9	COM port for Shimmer with EDA
Sampling_rate_EDA_Hz	64	Sampling rate for EDA in Hz (also must be set)
ECG R Spike Detection	-----	ECG R Spike Detection
Minimum_RR_Interval_sec	0.5000	Minimum duration between consecutive ECG R spikes
Minimum_R_Prominence_mV	1	** Minimum height of ECG R spike(mV)
View and Record Shimmer	-----	View and Record Shimmer
Event_name	Test_Laying	** Name of the event (Test, 6MWT, Biodesix)
Plot_update_period_sec	1	Time between plot updates (sec)
Plot_viewable_duration_sec	8	Visible region of plot (sec)
Test_duration_sec	Inf	Duration of test (sec)
Write_data_to_file	<input checked="" type="checkbox"/>	Write Shimmer data to text file
Tactile Test	-----	Tactile Test
Site_of_test	L_Finger	** Name of the test site (e.g., left finger, right toe)
Heartbeat Detection	-----	Heartbeat Detection
Number_of_trials_HBD	25	Number of trials

Task to run: HeartbeatDetection_expt_Shi... | Go! | Close Figs | Ian Kleckner, URCC v.2019.06.25 | Clear All

Have the participant lie down on the table and make them comfortable with pillows or towels (e.g., under their neck, knees, etc.)

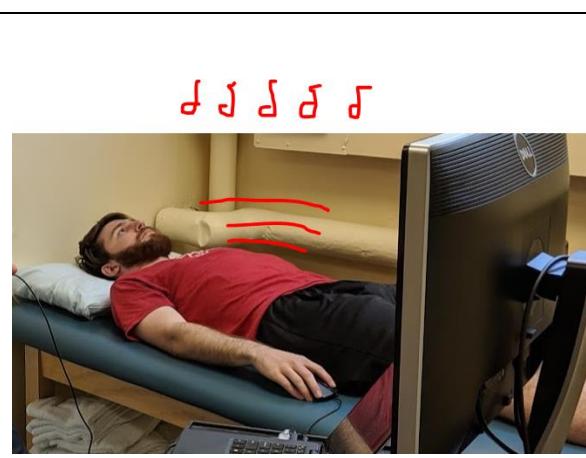
The participant can start the trial when they are ready by clicking the mouse button

In the task starter program, choose the **Heartbeat_Detection_Shimmer** task

Then click **Go!**

Follow on-screen instructions

- The goal of this task is to assess how well you can detect your heartbeat.
- You will hear a series of 10 beeps, each of which is triggered by your heartbeat.
- Sometimes, the 10 beeps occur during your heartbeats.
- Other times, the 10 beeps occur in between your heartbeats.
- For each series of 10 beeps, indicate whether you heard the beeps during or between your heartbeats.
- You will also be asked how confident you are in your response.
- Please do not take your pulse directly using your hands or other objects. Instead, focus on your heart and chest.
- Finally, please remain still during each trial (the beeping).
- Do you have any questions?



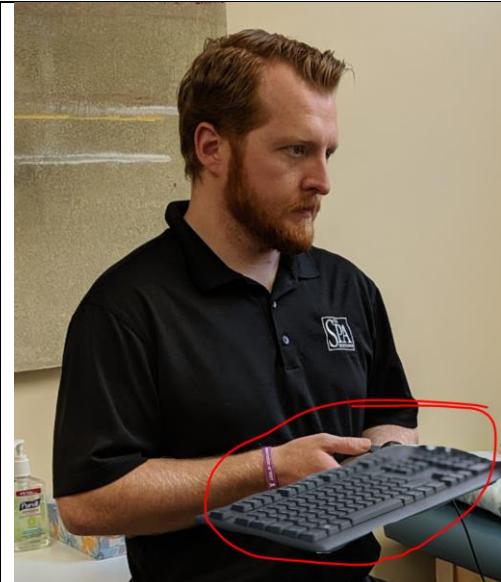
Perform a practice trial with beeps DURING heartbeats (this starts automatically before the first trial of the task)

Participants **may take their pulse** to hear beeps and feel heartbeats

Provide guidance that they can **breathe deeply, hold their breath, and exhale slowly** to increase pressure in the chest and feel their beating heart

Have them try this for a minute or two

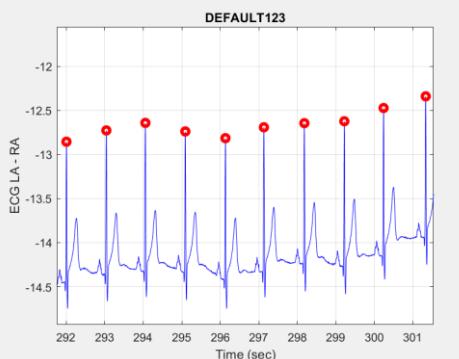
After the practice, they may not touch their bodies during the beeping



The participant will only make verbal responses for this task to make it easier and faster for them

The researcher will have their own **keyboard** to enter responses for the participant

You can exit the practice by holding Shift + Esc



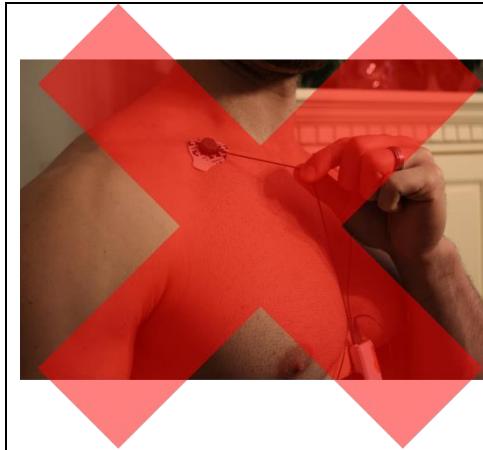
If there is a beeping mistake during the trial (too fast, too slow, missed beat), the **researcher should hold Shift + Esc** to restart the trial

This task can also be done without the participant having to view anything. The researcher can enter responses for the participant while verbally asking the participant after each trial.

REMOVE THE PHYSIOLOGICAL SENSORS

General care and removal of sensors

- Please be careful, as these devices are very sophisticated and sensitive, as well as fragile and expensive



Never pull the wires, they might break



To remove the wires use one finger to push down on the electrode and the other fingernail to pry the sensor head off the electrode



Gently prying the sensor head away should make it pop off

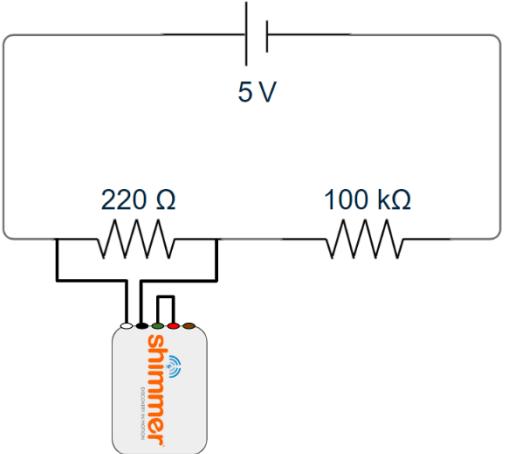
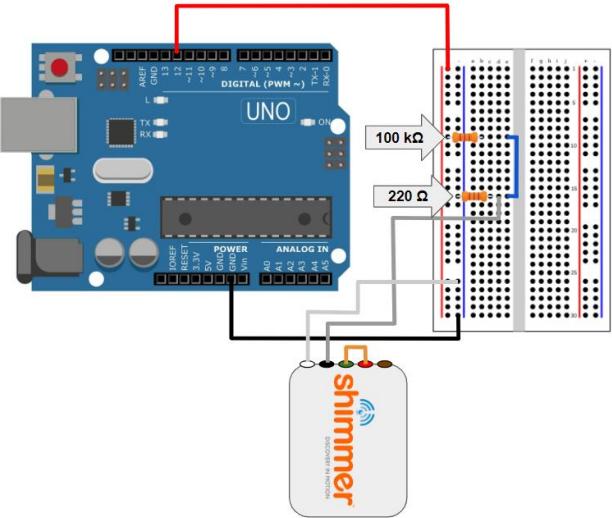
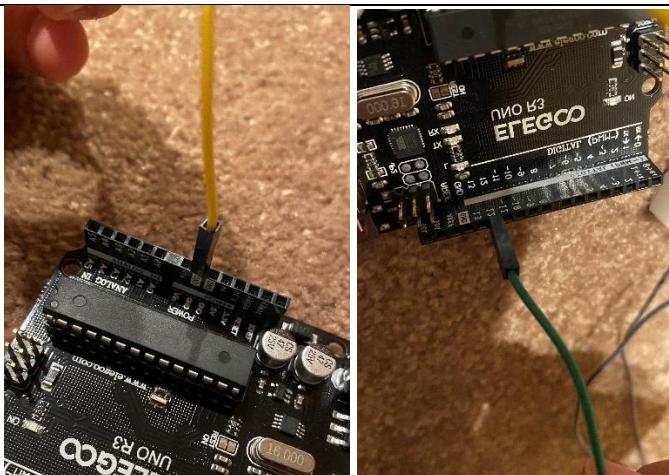
BLUETOOTH LAG DETECTION: SHOPPING LIST

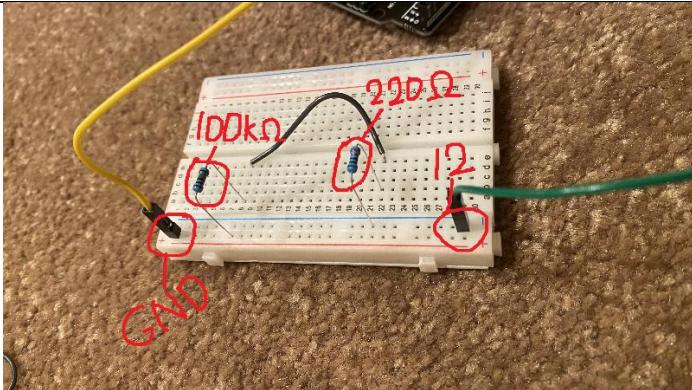
Item	Price	Picture	Example Vendor Link
Arduino UNO (and USB cable):	\$15		https://a.co/d/hVkJWBm
Resistor kit	\$6		https://a.co/d/2HRYN8K
Breadboard	\$7		https://a.co/d/hliAigO
ECG male leads to pin connectors	\$9		https://a.co/d/0EKkqOY
Wires with pins	\$8		https://a.co/d/fS564xB
Electrical tape	\$2		https://a.co/d/gunv23S

OPTIONAL More Shimmer Leads	\$52		https://shimmersensing.com/product/9in-biophysical-lead-pack/
OPTIONAL Short Wires	\$8		https://a.co/d/0VzUSP3

BLUETOOTH LAG DETECTION: ARDUINO-SHIMMER CIRCUIT SETUP

These instructions assume access to the contents of the WACARDIA Shopping List (see above)

	<p>Note: The goal of these setup instructions is to create the circuit shown on the left with the Arduino as the power source. Feel free to build this circuit in another way, as long as the resistors have the correct strengths, and the Shimmer electrodes are configured correctly.</p>
	<p>Note: These instructions are meant to construct the circuit shown in more detail on the left. We now provide step-by-step instructions to get to this point.</p>
	<p>First, insert two wires into the Arduino: one (pictured as yellow) in a pin labeled “GND”, and the other (pictured as green) in the pin labeled “12.”</p>



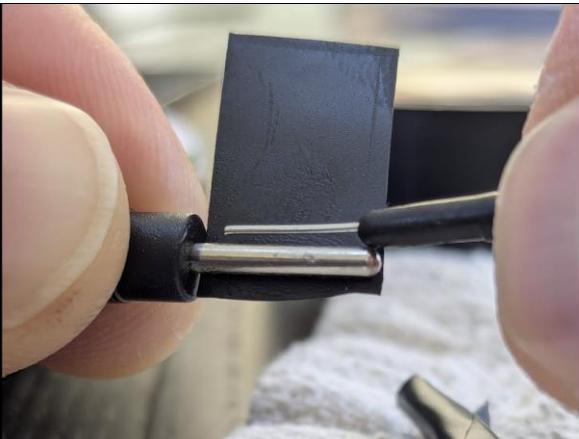
Insert wires and resistors onto the breadboard as shown in the picture.

You should also refer to the diagram above.
The yellow and green wires correspond to the yellow and green wires connected to the Arduino.

Setup if you DO have the ECG snap to pin connectors (preferred)



If you can get these, it will make the setup much cleaner and easier, but they may be out of stock on Amazon



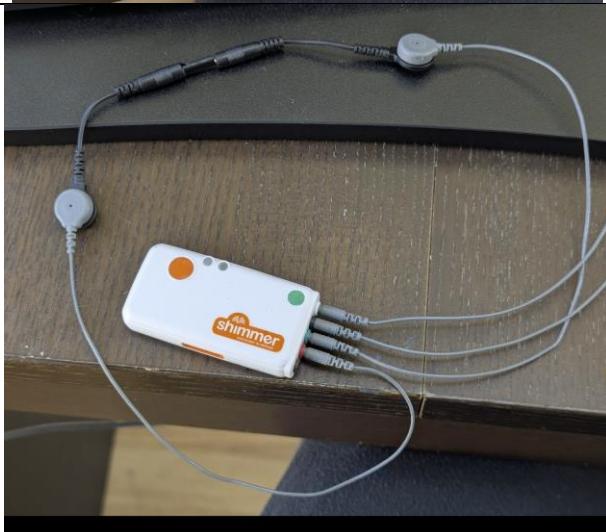
Cut a thin piece of electrical tape to connect the 2 breadboard wires to 2 ECG snap electrodes to Shimmer White and Shimmer Black per the above cartoon diagram



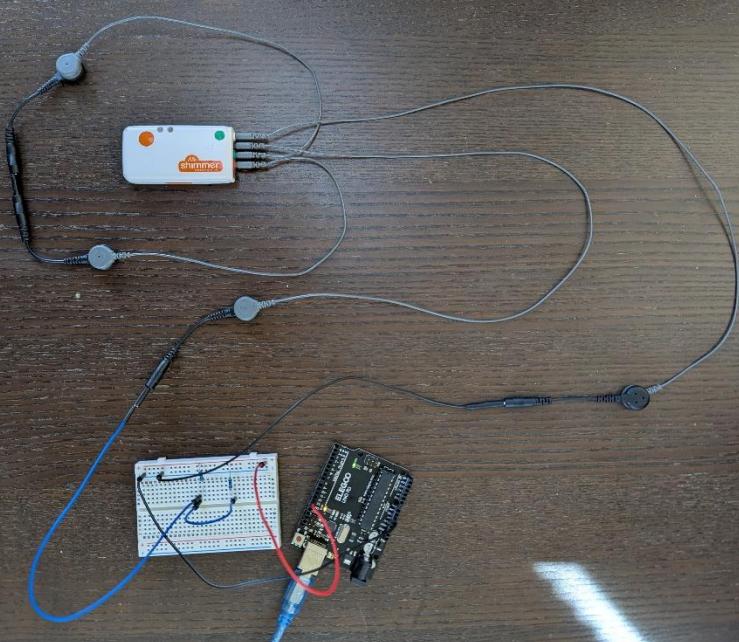
Wrap it around to make a tight seal



Connect the snap leads to the Shimmer wire



Use the snap to pin to connect the Shimmer RED and GREEN leads together using the same method (except these are two pin connectors)



If you have the ECG to pin connectors then your final setup will look like this.

The ones in this example are black whereas the ones in the shopping list are white

Setup if you do NOT have ECG snap to pin connector (less preferred)



Use the electrical tape to tape the ends of the red and green electrode leads together, so that the two metal parts are securely touching.



Remove the electrode leads from the white and black ports on the Shimmer sensor.

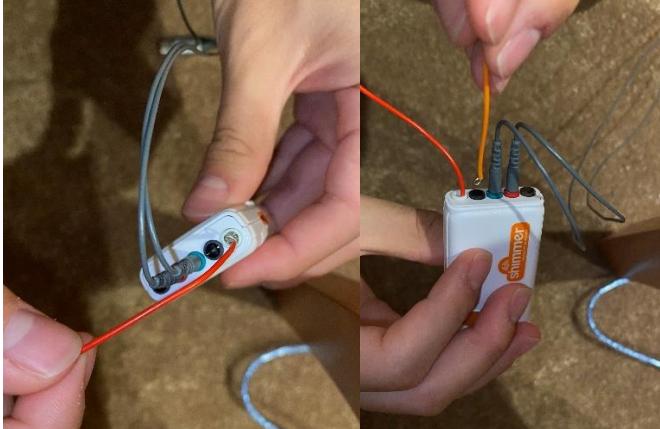
Notice that inside the ports, there is a thin metal piece which connects to the electrode lead.



This step requires finesse:

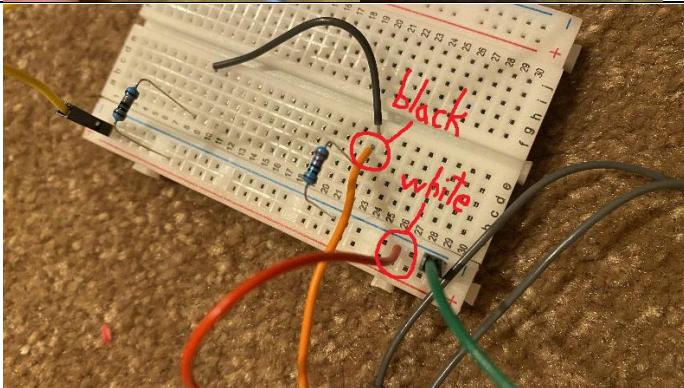
Twist the end of one of the wires into a small loop, just wide enough to fit around the electrode leads. **This might take multiple tries to perfect.**

Create two of these looped wires.



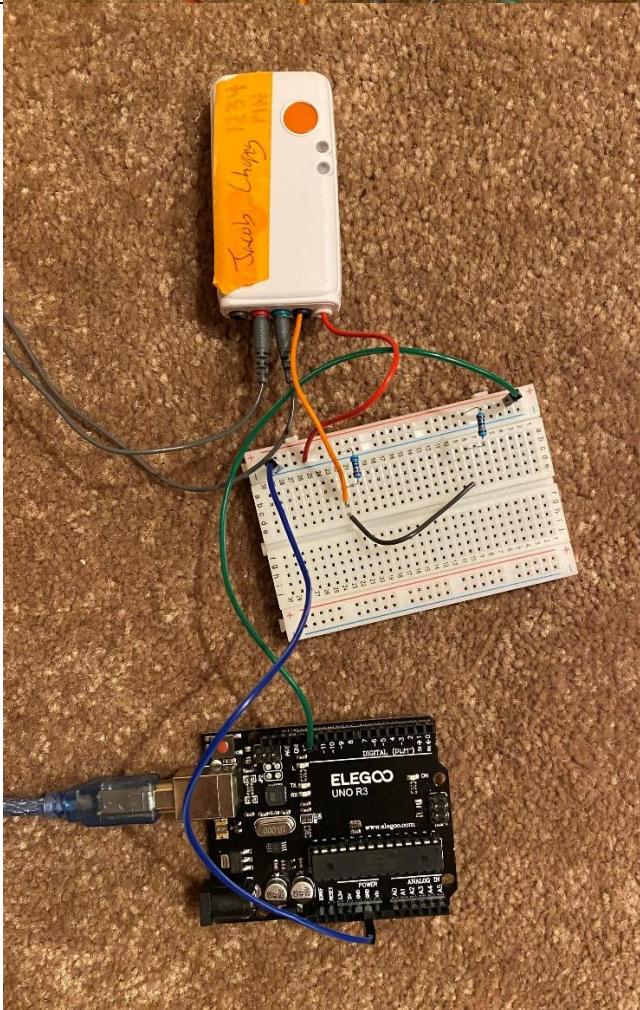
Carefully, insert the loop of a wire into the white and black ports. If your loop is the right size, you should be able to feel when the wire is securely fastened.

Be gentle when dealing with these wires, since they can easily become dislodged.



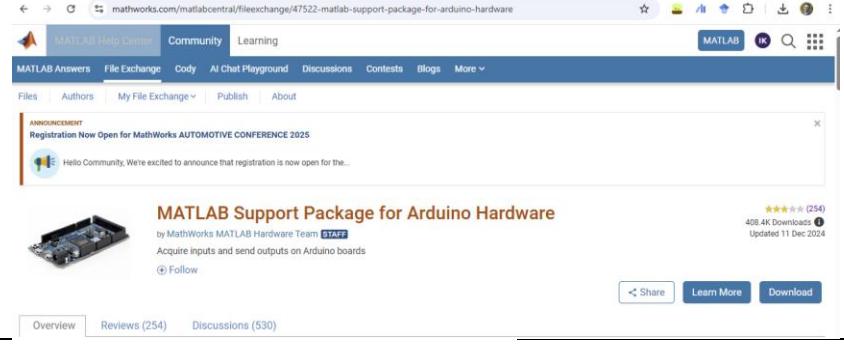
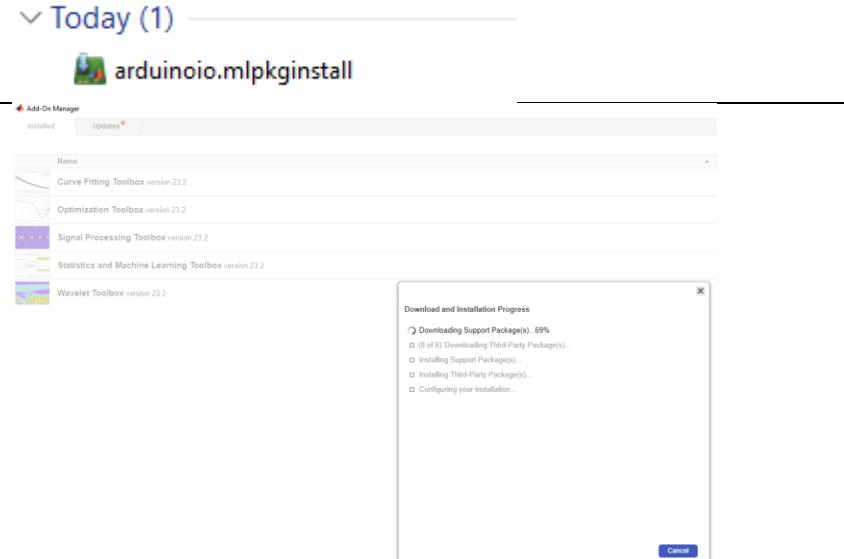
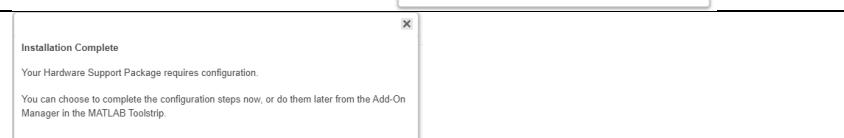
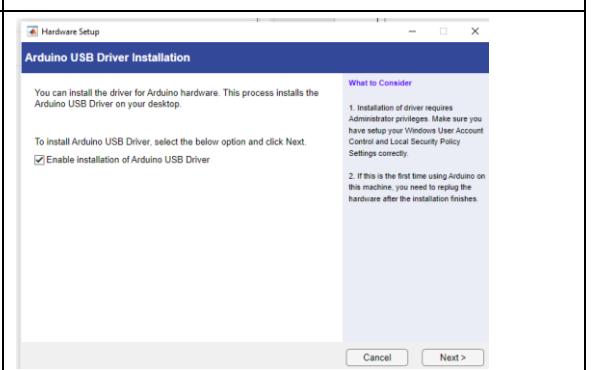
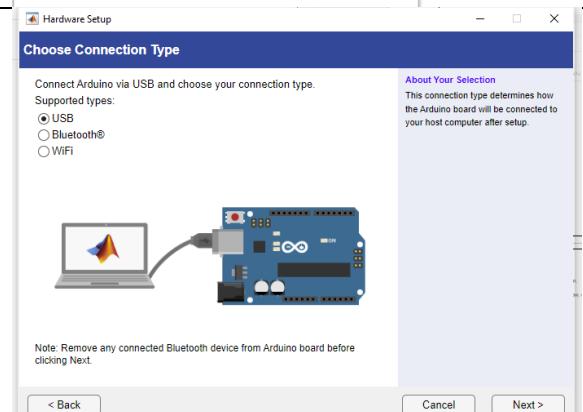
Insert the ends of the wires connected to the Shimmer ports into the breadboard, as shown in the picture.

You should also refer to the diagram above.
The orange wire connects to the black Shimmer port, and the red wire connects to the white Shimmer.



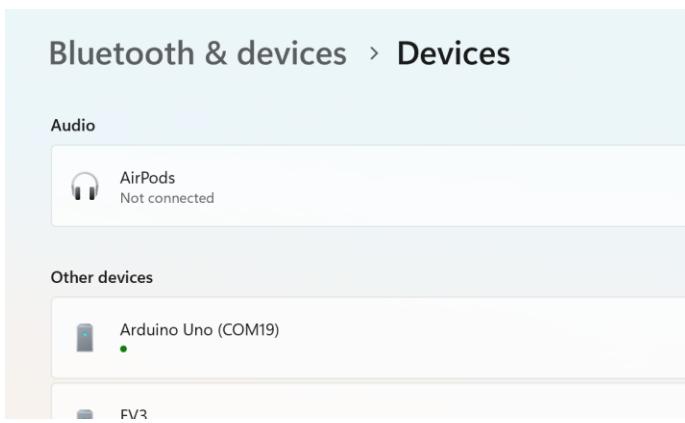
In the end, your setup should look like this.

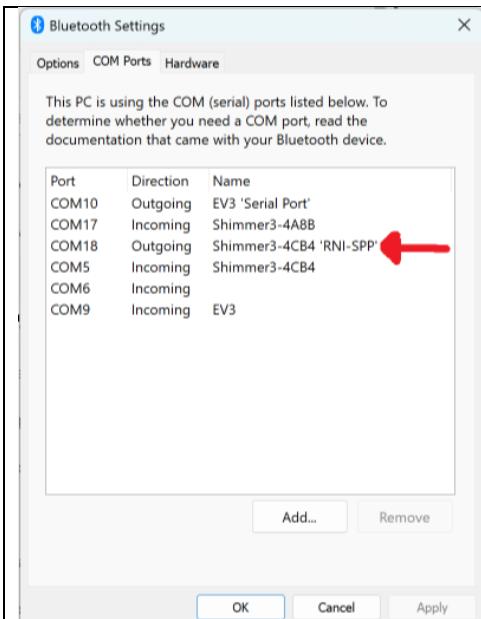
BLUETOOTH LAG DETECTION: INSTALL MATLAB ARDUINO PACKAGE

	Go to the Mathworks website, log in, and click Download for the Arduino package
	Download the file and open it
	Let MATLAB run the installer to get the packages installed This will take several minutes
	
	

	<p>Just choose the default packages</p>
	<p>Test the connection</p>

BLUETOOTH LAG DETECTION: RUNNING THE PROGRAM

	Setup hardware <ul style="list-style-type: none">Follow the steps above to set up the Arduino-Shimmer circuitTurn on the Shimmer device and connect to it via Bluetooth (follow previous instructions)Connect the Arduino to the computer via USB portEnsure that the Bluetooth dongle is inserted if it is being used (probably yes)
	Check Arduino COM port <p>Navigate to Settings > Bluetooth & devices > View more devices</p> <p>Scroll down to the 'Other devices' section until you see the 'Arduino Uno' device</p> <p>Record the number of the COM port</p>
	Check Shimmer COM port <p>If you're still in 'View more devices,' scroll down further to the 'Related settings' section</p> <p>Select 'More Bluetooth settings'</p>



Check Shimmer COM port (cont.)

In the window that pops up, go to the 'COM Ports' tab. Record the COM port number of the Shimmer sensor that is 'Outgoing' and labeled 'RNI-SPP'

Follow the instructions on the first two pages of the **Test connection with Shimmer sensors** section (pages 11 and 12 of this document) to open the Task Starter program.

Adjust relevant variables in Task Starter

After changing a value, press Enter to confirm the change.

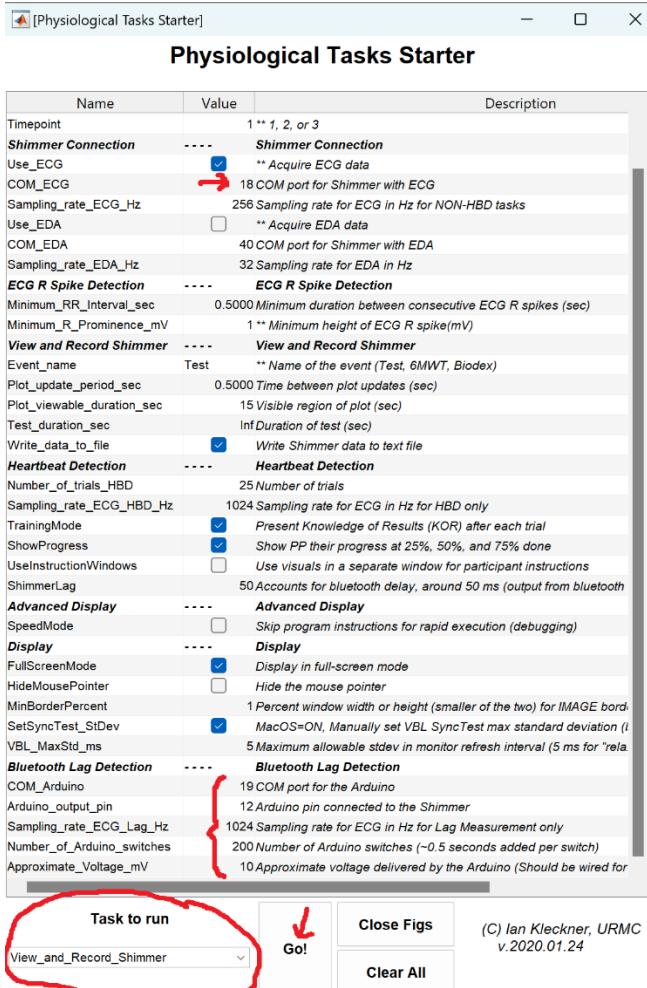
Under Shimmer Connection:

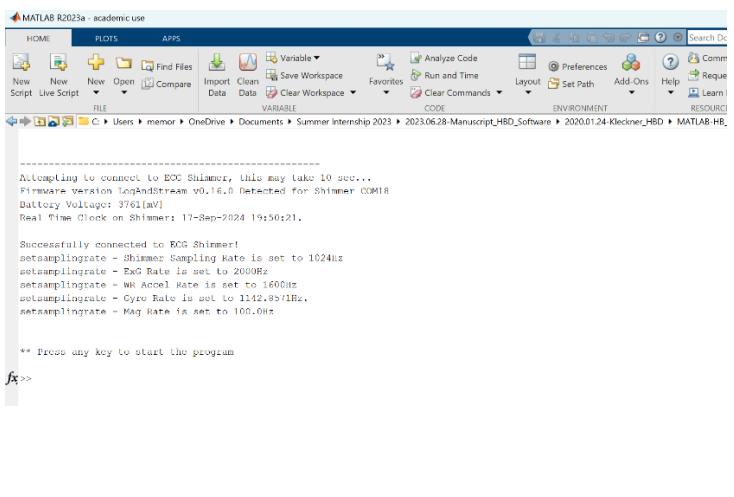
- Change **COM_ECG** to match the COM port for the Shimmer found above

Under Bluetooth Lag Detection:

- Change **COM_Arduino** to match the COM port for the Arduino found above
- Change **Arduino_output_pin** to the number of the digital pin that your circuit is wired to (probably 12)
- **Sampling_rate_ECG_Iag_Hz** should stay at 1024
- Change **Number_of_Arduino_Switches** to the desired number of data points (i.e., number of times the Arduino signal turns on or off). We recommend 200 for a standard trial
- **Approximate_Voltage_mV** should stay at 10 mV with the resistors we recommend in this SOP. If different resistors are used, change this value to approximately $5000 * R2 / (R1 + R2)$, where R1 and R2 are the resistances of the resistors used in the circuit (right now R1 = 100,000 and R2 = 220)

At the bottom, change the 'Task to run' from **View and Record Shimmer** to **Bluetooth Lag Detection**.



	When everything is ready, press Go!
<pre>arduino requires MATLAB Support Package for Arduino Hardware. Error in <u>Bluetooth_Lag_Detection</u> (line 39) a = arduino(comPort_Arduino, 'Uno'); Error in <u>Task_Starter>button_Go_Callback</u> (line 324) eval(sprintf('%s(table_dataStructure)', taskName)) Error in <u>gui_mainfcn</u> (line 95) feval(varargin{:}); Error in <u>Task_Starter</u> (line 70) gui_mainfcn(gui_State, varargin{:}); Error in <u>matlab.graphics.internal.figfile.FigFile/read>@(hObject</u> Error while evaluating UIControl Callback.</pre>	If you get this error, you need to download MATLAB Arduino support (see above, Bluetooth Lag Detection: Install MATLAB Arduino package)
	<p>Shimmer information will be output.</p> <p>IF there is an error stating that the Shimmer cannot be found...</p> <ul style="list-style-type: none"> • Delete any Realterm tabs you have open • Wait a short period and run the program again • Check again to ensure that you have the correct COM port • Disconnect and reconnect to the Shimmer in Bluetooth settings <p>Press a key to start the program when prompted</p>
	<p>If you get this error about MATLAB connection to Uno at COM exists then close any other MATLAB connections to the Arduino board</p>
 <pre>Attempting to connect to ECG Shimmer, this may take 10 sec... Firmware version TopAndStream v0.16.0 Detected for Shimmer (COM18 Battery Voltage: 3761mV) Real Time Clock on Shimmer: 17-Sep-2024 19:50:21. Successfully connected to ECG Shimmer! setsamplingrate - Shimmer Sampling Rate is set to 1024Hz setsamplingrate - Ecg Rate is set to 2000Hz setsamplingrate - Wk Accel Rate is set to 1600Hz setsamplingrate - Cyro Rate is set to 1142.8571Hz. setsamplingrate - Mag Rate is set to 100.0Hz ** Press any key to start the program fx>></pre>	<p>The live graph of Arduino signals and ECG data should appear (press Ctrl + F if it doesn't appear immediately)</p> <p>While the program is running, monitor the graph to watch for abnormalities, like unusually high levels of noise or signal magnitudes significantly higher than 10-15 mV.</p>

Movement artifacts



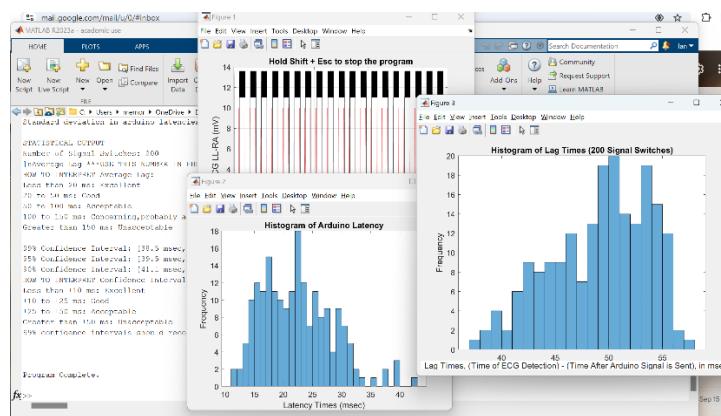
If the signal looks very noisy just check all the electrical connections, you may need to squeeze them together, for example if your electrical tape got in the way

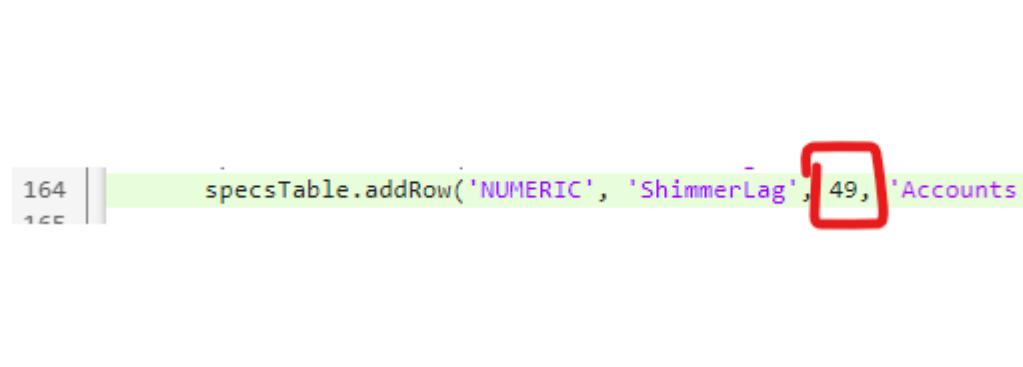
Make sure you do not touch or move the equipment as it is being tested to avoid **movement artifacts**

After the program terminates, the statistical output and two histograms will appear.

The **Histogram of Lag Times** displays all the lag time data points measured by the program. These should all be clustered roughly around 50 ms. If there is significant deviation or major outliers, you should run the program again.

The **Histogram of Arduino Latency** displays the average amount of time it takes for the computer to send an Arduino command (for debugging)



<pre> STATISTICAL OUTPUT Number of Signal Switches: 200 InAverage Lag ***USE THIS NUMBER IN HBD PROGRAM***: 49.2 msec HOW TO INTERPRET Average Lag: Less than 20 ms: Excellent 20 to 50 ms: Good 50 to 100 ms: Acceptable 100 to 150 ms: Concerning, probably acceptable Greater than 150 ms: Unacceptable 99% Confidence Interval: [38.5 msec, 56.5 msec], Range: ±9.0 95% Confidence Interval: [39.5 msec, 55.7 msec], Range: ±8.1 90% Confidence Interval: [41.1 msec, 55.3 msec], Range: ±7.1 HOW TO INTERPRET Confidence Interval: Less than ±10 ms: Excellent ±10 to ±25 ms: Good ±25 to ±50 ms: Acceptable Greater than ±50 ms: Unacceptable 99% confidence intervals should be recorded in publications Program Complete. fx>> </pre>	<p>The command window will display statistics from the trial.</p> <p>The Average Lag is clearly marked. This value should be input into Task Starter as ShimmerLag under the Heartbeat Detection section.</p> <p>We also provide 90%, 95%, and 99% confidence intervals, along with ranges.</p> <p>Information about how to interpret these values is included in the output.</p> <p>If any of these statistics are absurdly outside of reasonable ranges, check the ECG graph and Lag Times histogram for possible errors.</p>
	<p>Go to MATLAB Task_Starter and fill in ShimmerLag under the Heartbeat Detection section</p>
<pre>>> edit Task_Starter.m</pre>	<p>You can also edit the default value in the Task_Starter.m code</p> <p>Go to the MATLAB command window and type</p> <p>edit Task_Starter.m</p>
	<p>Look for 'ShimmerLag' and enter the value</p> <p>Save the program (Ctrl + s)</p> <p>Now whenever you open Task_Starter it will have your correct lag value for your computer + Bluetooth + experimental configuration</p>