

## Overview

This assembly guide will instruct you in your creation of the electronic components of our custom arena behavioral apparatus. These components are made utilizing basic wires, lights, and cables, to allow for a taylor-made task to be used in the study of decision-making and disorders in rodents in a cost-effective and open-science friendly way. The customization of our system allows for on the fly changes and adaptations to the experimental environment and process, as well as animal behavior. Further, it enables the interchangeability and replacement of parts as they wear down over the course of thousands of behavioral trials. In this guide you will find the parts and materials, dimensions and measurements, along with links and assembly instructions, to our custom electronic system as well as the code and programs that we are using to manipulate it.

Directly below are links to the code used to manipulate and run our experimental setup, as well as a troubleshooting forum for its' most common problems and any new ones that might arise.

[DOI: 10.5281/zenodo.5777989](https://doi.org/10.5281/zenodo.5777989) // also, badge (think this is what other paper had): [f83c952](#)

[Batch-Files](#) (Archive of Batch files, files that Noldus will send to MCU to execute)

[EthoVision](#) (EthoVision experiment used to execute and record our task)

[Guides](#) (Archive of guides that correspond to the use and maintenance of our system)

[Microcontroller-Information](#) (Archive of Texas Instruments MCU information and code)

[Troubleshooting](#) (Archive of common issues with our system and how to resolve them)

## 0 Key Resources

### Software and Code

MATLAB R2016a	<a href="https://www.mathworks.com">https://www.mathworks.com</a>	R2016a
EthoVision XT 16	<a href="https://www.noldus.com/ethovision-xt">https://www.noldus.com/ethovision-xt</a>	Version 16
Batch files	<a href="https://github.com/glwaller/Friedman-Lab-Electronics-2021/blob/Branch-Files/README.md">https://github.com/glwaller/Friedman-Lab-Electronics-2021/blob/Branch-Files/README.md</a>	#Batch-Files
Microcontroller Programming	<a href="https://github.com/glwaller/Friedman-Lab-Electronics-2021/blob/Microcontroller-Information/README.md">https://github.com/glwaller/Friedman-Lab-Electronics-2021/blob/Microcontroller-Information/README.md</a>	#Microcontroller-Information
EthoVision Experiment	<a href="https://github.com/glwaller/Friedman-Lab-Electronics-2021/blob/EthoVision/README.md">https://github.com/glwaller/Friedman-Lab-Electronics-2021/blob/EthoVision/README.md</a>	#EthoVision

### Hardware

Noldus Modified Dell Desktop	Where did we buy?	61N4853
Noldus PhenoTyper USB-IO	<a href="https://www.noldus.com/ethovision-xt/io-box">https://www.noldus.com/ethovision-xt/io-box</a>	00955-000
Surge Protectors (brand: APC)	<a href="http://www.apc.com">www.apc.com</a>	7Z2102105928
Sabrent 13 port USB 2.0 hub w/power-adaptor	<a href="https://www.sabrent.com/product/HB-U14P/13-port-usb-2-0-hub-power-adapter/">https://www.sabrent.com/product/HB-U14P/13-port-usb-2-0-hub-power-adapter/</a>	HB-UI4P
TI LaunchPad Kit w/MSP430 MCU	<a href="https://www.ti.com/tool/MSP-EXP430FR2355">https://www.ti.com/tool/MSP-EXP430FR2355</a>	MSP-EXP430FR2355
Printed Circuit Board	<a href="https://github.com/glwaller/Friedman-Lab-Electronics-2021/tree/Printed-Circuit-Board">https://github.com/glwaller/Friedman-Lab-Electronics-2021/tree/Printed-Circuit-Board</a>	
AXTON infrared lamps 850nm, 150*	<a href="https://axtontech.com/illuminators/ir-illuminator-smart-at-11s/">https://axtontech.com/illuminators/ir-illuminator-smart-at-11s/</a>	AT-115-BC

Basler Camera	Where did we buy?	M106580-12; acA1300-60gc
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### Tools and Materials for Custom Electronics

Speaker Cable	Local Hardware Store	N/A
Blue Digi-Key LED Lights	<a href="https://www.digikey.com/en/products/detail/everlight-electronics-co-ltd/EALP05RDGBA0/11200814?s=N4lgTCBcDaIKYEMA2AHADAVgE4BMDmA RgmiALoC%2BQA">https://www.digikey.com/en/products/detail/everlight-electronics-co-ltd/EALP05RDGBA0/11200814?s=N4lgTCBcDaIKYEMA2AHADAVgE4BMDmA RgmiALoC%2BQA</a>	EALP05RDGBA0
Red Digi-Key LED Lights	<a href="https://www.digikey.com/en/products/detail/vishay-semiconductor-opto-division/VLCS5830/4073503?s=N4lgTCBcDaIGoBkDCBIArADgMwAYQF0BflA">https://www.digikey.com/en/products/detail/vishay-semiconductor-opto-division/VLCS5830/4073503?s=N4lgTCBcDaIGoBkDCBIArADgMwAYQF0BflA</a>	VLCS5830
SunFounder 5V 8 Channel Relay Shield Module for Arduino R3 2560 1280 ARM PIC AVR STM32 Raspberry Pi 3, 2 Model B & B+	<a href="https://www.amazon.com/gp/product/B00DR9SE4A/ref=ppx_yo_dt_b_asin_title_o01_s00?ie=UTF8&amp;th=1">https://www.amazon.com/gp/product/B00DR9SE4A/ref=ppx_yo_dt_b_asin_title_o01_s00?ie=UTF8&amp;th=1</a>	Relay: Songle SRD-05VDC-SL-C  Amazon ASIN: B00DR9SE4A
ASCO Solenoid Valves 24/60V	<a href="https://www.valinonline.com/products/sc8256b045v-24-60">https://www.valinonline.com/products/sc8256b045v-24-60</a>	SC8256B45V
Dupont wire	Where did we buy?	
American Beauty Silver Solder Wire (Sn96.5Ag3Cu0.5)	Where did we buy?	19YP69
Qibaok 1550 pcs dupont connector kit	<a href="https://www.amazon.com/Qibaok-Crimping-Ratcheting-Connectors-0-1-0-5mm2/dp/B07ZK5F8HP">https://www.amazon.com/Qibaok-Crimping-Ratcheting-Connectors-0-1-0-5mm2/dp/B07ZK5F8HP</a>	Qibaok536
Innhom Heat Shrink Tubing Ratio 2:1 (650pcs)	<a href="https://www.amazon.com/650-pcs-Shrink-Tubing-innhom-Approved/dp/B08W2CX5F5">https://www.amazon.com/650-pcs-Shrink-Tubing-innhom-Approved/dp/B08W2CX5F5</a>	HST-650C
Electrical Tape	Local Hardware Store	N/A
Voltage Detector	Local Hardware Store	N/A
Soldering Iron	Local Hardware Store	N/A

### **Physical Maze Components (non-3D printing)**

60 mL Syringes	Where did we buy?	
L/S® Precision Pump Tubing, Versilon™ 2001 Tubing, L/S 14; 50 ft	<a href="https://www.masterflex.com/i/masterflex-l-s-precision-pump-tubing-versilon-2001-tubing-l-s-14-50-ft/0647514">https://www.masterflex.com/i/masterflex-l-s-precision-pump-tubing-versilon-2001-tubing-l-s-14-50-ft/0647514</a>	HV-06475-14
<b><u>Stuff to add</u></b>		
<b>Need to include animals</b>		
<b>Add 3D printing files, resin, printer, autocad version, etc.</b>		
<b>David's thing</b>		

### **(Neftali) 1 Steps and basic pictures/diagrams for assembling LED Cables**

#### **Section 1:** LED Wires

The LEDs constructed will serve as a cost when associated with the reward, glucose, in the arena. Four LEDs will be placed in each corner of the arena, with the same blue light associated with a floor pattern. Each will be controlled through one signal wire and contain a black wire representing ground. After the construction of one wire, 4 LEDs rings will be ready for usage in one arena.

#### **Materials**

- 16 blue LEDs
- 8 red LEDs
- 4 Six-position female connector
- Female pin connectors
- Female House sockets
- Pitch female pin header
- Wire strippers
- Soldering iron
- Solder
- Wire cutters
- cable connector clamping tool

- Multimeter
- Speaker cable

## A. LED Ring

Each LED ring will consist of two 4cm black and blue cables including a 3 ½ cm blue and 3 cm black cable. Additionally, the usage of hot equipment will be used during assembly. Please ensure proper handling of tools and to maintain safety.

1. Strip both ends of each wire segment using the wire strippers, making sure to not cut the wire.
2. Identify the cathode and anode of blue LED (Figure 1).
3. Attach the 4-cm black wire to the cathode and 4-cm blue wire to the anode.
4. A second 4-cm blue LED will be attached on the other side of the previously attached one, resulting in two LEDs on each side of the blue and black wires (Figure 1).
5. Steps 1-4 will be repeated, creating a second LED half ring.
6. Joining of both half rings will consist of orientating each half rings with the black wires facing outwards and attaching a 3-cm black wire to each black half ring (Figure 2).
7. Similarly, the 3 ½ cm blue wire will be attached on the opposite side, creating the ring (Figure2).
8. Assembly of the 2 red LEDs will consist of attachment of a red wire to the anode and a black one to the cathode of the red LED.

*NOTE: Feeder pieces can be used for stabilization and precise fitting during soldering of the ring; however, make sure not to touch the iron as it will melt the feeder and damage the iron as well.*

Figure 1: LED Anatomy and Attachment

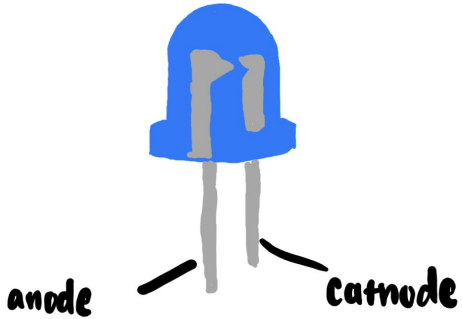
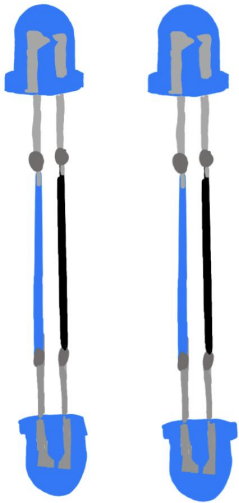
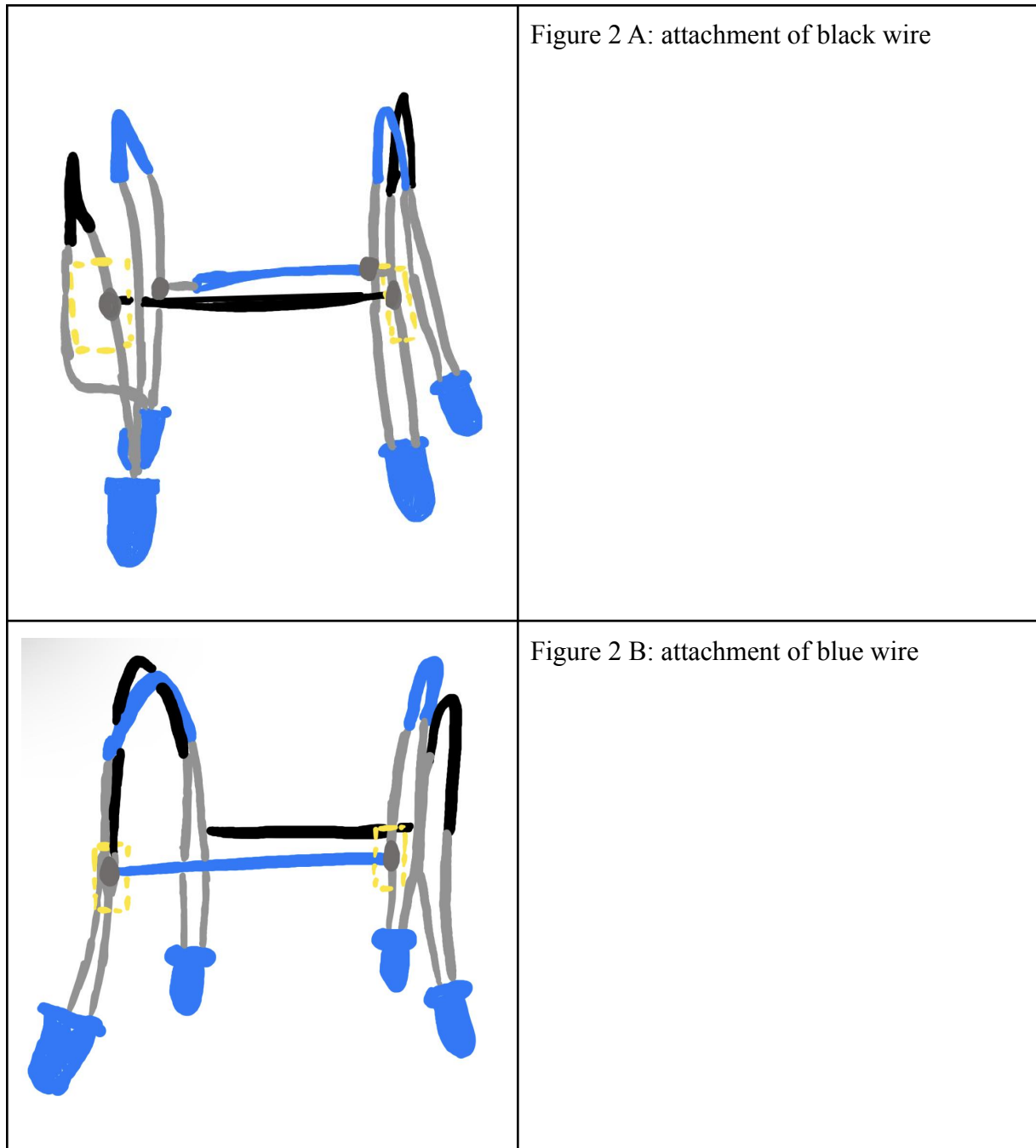
 <p>The diagram shows a single blue LED. The longer leg is labeled 'anode' and the shorter leg is labeled 'cathode'.</p>	<p>Figure 1 A: identification of the cathode and anode</p>
 <p>The diagram shows two blue LEDs connected in series. The longer legs (anodes) of both LEDs are joined at the top, and the shorter legs (cathodes) are joined at the bottom.</p>	<p>Figure 1 B: Attachment of both LEDs</p>

Figure 2: Joining of LED half rings



#### **A. LED cables**

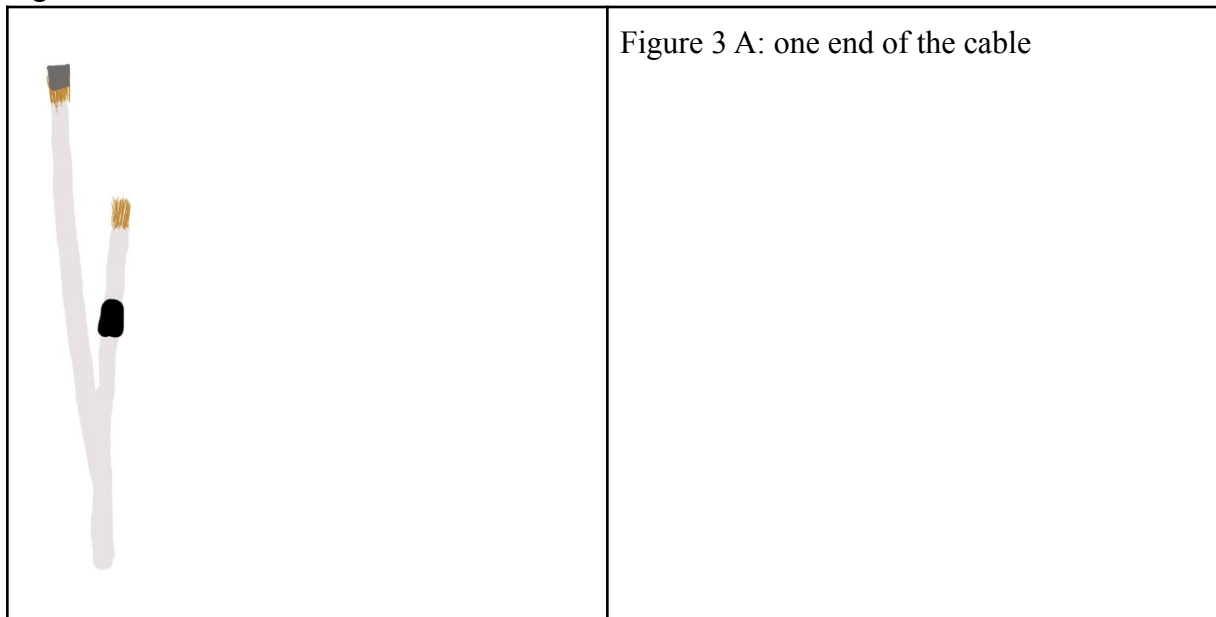
Speaker cable with two interior copper wires will be used for the attachment of LED rings and incorporation to each arena.

1. Cut the desired length of cable and peel off the PVC jacket using the wire strippers.

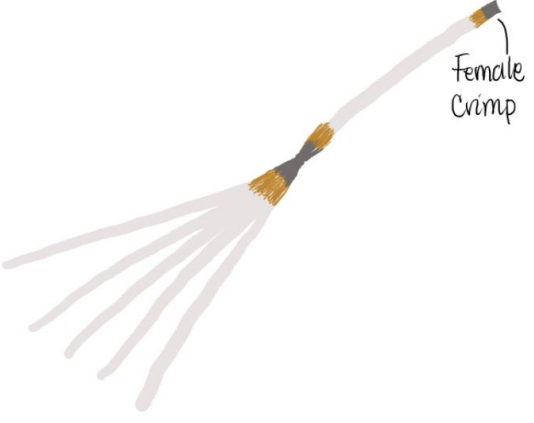

NOTE: the outer jacket may be tough to peel. Making perforations around the jacket will ensure that the inner wires are not accidentally cut.

2. On one end of the cable, roughly 1-cm of the jacket will be peeled using the wire strippers making sure not to cut the copper.
3. Opposite of the wire, peeling of the outer jacket must be done. One wire will be cut to half the length of the other. This will be marked black for complete assembly later on (Figure 3).
4. The longer wire will be stripped to 1-cm and the shorter one to 2-cm.
  - a. The wire marked black, shorter piece, will be combined with all the four cables and an additional piece of peeled cable. They will be attached together with the tip containing a female pin connector (Figure 3).
  - b. The longer piece will be attached to a female pin connector using the clamping tool.
5. As the shorter wire is marked black on one side, the same copper wire will be marked black as well (Figure 3).

Figure 3





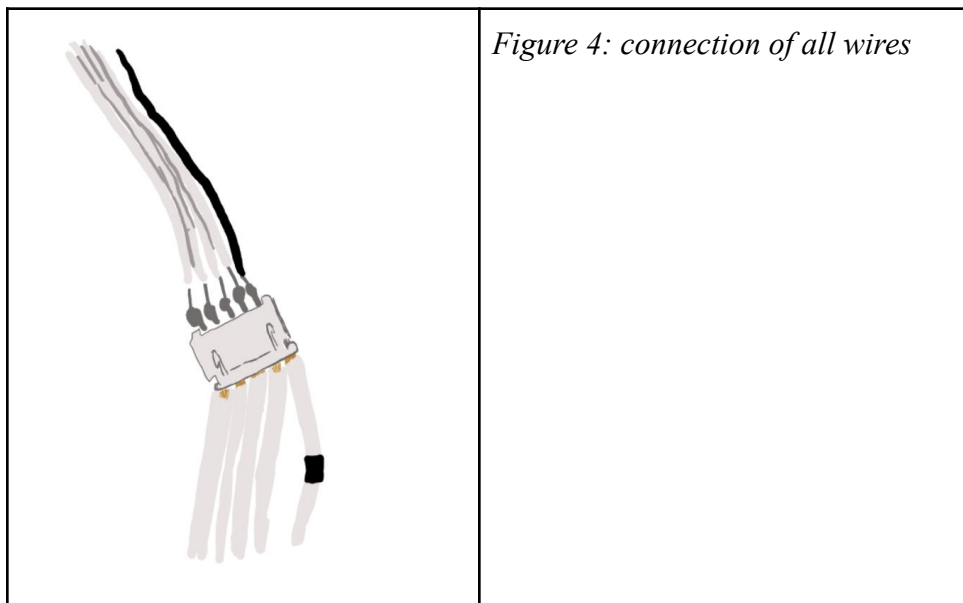
	<p>Figure 3 B: Connection of all black short cables</p>
	<p>Figure 3 C: Identification of same black marking</p>

## B. Complete assembly

1. As all 5 wires contain female pin connectors, a six-position female connector will be used.
2. The black wire will be connected in the last female socket and the red LED will be connected on the opposite end (Figure 4).
3. The remaining cables can then be connected.

4. A Pitch female pin header will then be placed on top of the six-position female connector.
5. Additional wires will be needed for attachment to the pin headers (Figure 4).
  - a. One black, red, and 4 blue wires will be needed with both ends being striped.
  - b. Attachment of the colored wires will correspond to the black and red placed wires previously done.
  - c. The top of the colored wires will contain male pin connectors, with a single dupont connector on each end

Figure 4:



## Valve Cables

### (Andrea) 2 Steps and basic pictures/diagrams for assembling Valve Cables

The valve cables will be connected with solenoid valves and together they are involved in the reward (sucrose solution) delivery to the animal arena. There will be 4 solenoid valves connected per cable. The cable will then be connected to

For the assembly of the valve cable:

- Speaker Cable
- 4 Dupont Connector Housing (2 positions)
- 8 Female Dupont Crimp Connectors
- 1 Female JST Connector Housing (5 positions)
- 1 Male JST Connector Housing (5 positions)
- 5 Female JST Crimp Connectors
- A soldering iron
- Solder
- Wire strippers
- Wire cutters
- Multimeter
- Electrical Tape

For the assembly of the solenoid valves:

- 4 Solenoid valves
- 2 Male Dupont wire halves
- Solder

To make one valve cable, measure and cut 4 pieces of speaker cable 3 meters in length. For each piece, using wire strippers, strip both ends of the speaker cable for each piece being careful to not cut the wires inside. Choose one end for each of the 4 pieces and strip the two small wires enough to fit a female JSTdupont crimp connector. Using a Cable Connector Clamp, clamp on the dupont connector for both wires on one end of all 4 cable pieces. Then attach a dupont connector house to cover the dupont crimp connector section of the wires.

For the other end of the cable, strip one of the small wires from each of the 4 pieces of cable. Once again using the Cable Connector Clamp, clamp on a female JST crimp connector. For the other wire, cut them down approximately



All valves will be sharing one ground, solder the loose ends of the black cable on every valve together. Cut another [1 meter] segment of black cable, strip the ends, and solder one end to where all four black cables meet. ***Do not solder the green cables together!***

Lastly, join the 4 valves to the female socket connector. The female socket connector has 6 pins coming out of the back and 6 holes on the front. It also has 2 “legs” coming out of the bottom, these will serve as a reference to distinguish pins 1 through 6. Connect the female housing connectors on

## Noldus Cables

(Karen) 3 Steps and basic pictures/diagrams

for assembling Noldus cables

<b>Speaker Cable</b>	 A spool of Noldus speaker cable, model 2005, with a black and orange label. Next to the spool is a short length of the same cable, showing the braided copper conductors and the black outer jacket.
<b>Wire cutters</b>	 A pair of Wiha wire cutters, model 57816, with red handles and black jaws. The handles have the Wiha logo and "USA" printed on them. The jaws have a serrated edge for cutting wire.

**Zip ties**



**Dupont Crimp Connectors Housing**



**JST Crimp Connectors Housing**



**4 Male Dupont Crimp Connectors**



**2 Female Dupont Crimp Connectors**



**6 JST crimp connector**



**Cable Connector Clamp Tool**



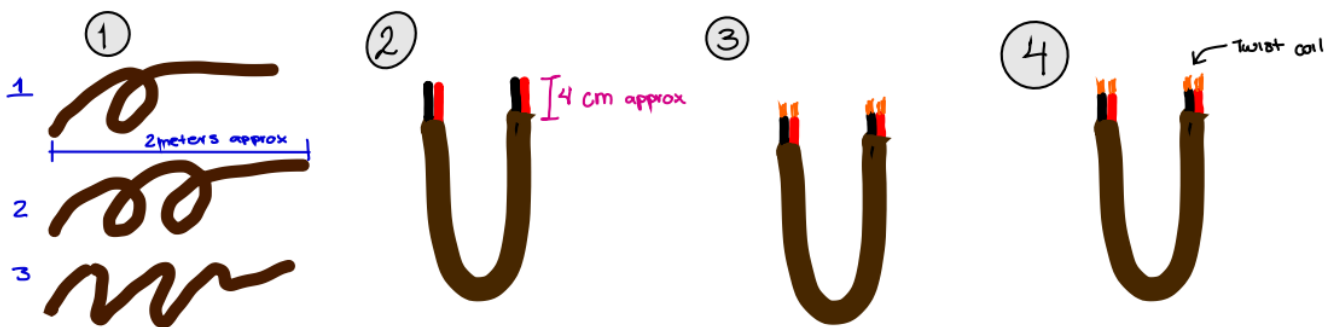
## Tweezers



### Step 1: Prepare your cables

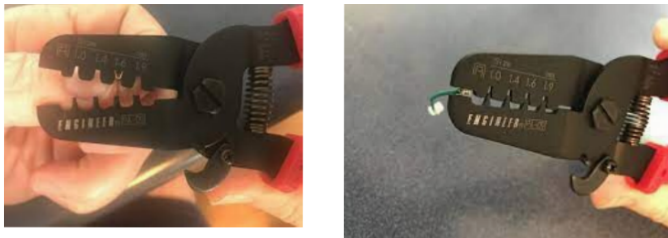
Using wire cutters, measure and cut three speaker cables of 2 meters. Continuing you would carefully cut the middle of the wires to separate them. Then with the wire cutters strip both ends of the speaker cable. After that you should be able to see two small wires from both ends. Strip both wires enough to fit one male connector on each wire from one side and one. You would apply this procedure to each of your cables.

- Cut three speaker cables with an approximation of 2 meters of length.
- Carefully cut with a wire cutter and separate the protecting cover from both ends.
- Strip from the two wires enough for the connectors to fit
- Twist the coil wire



## How to use the clamp tool

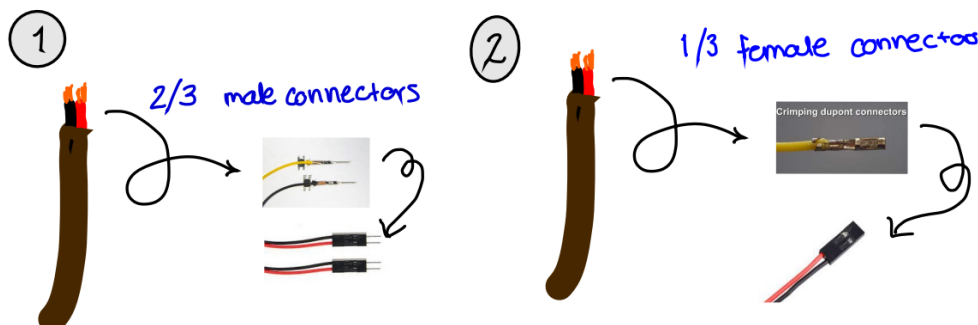
You would hear two clicks with the first click would help you to hold the connector then introduce your twisted wire and apply pressure until you hear a second click and it opens again.



## Step 2: Clamping Dupont connectors and applying housing

After you prepare your cable, it is time to clamp some connectors. The first step is to choose one stripped side. Then with the help of a clamp (cable connector clamp tool) you would clamp a male Dupont connector you would use the first hole and apply pressure for the connector to stay in the wire then repeat the same process with the other wire. Finally, when you have your two wires with Male Dupont connectors you would put a cable cover to protect both wires. After that apply a Dupont connector housing of two holes.

- From one end clamp a female Dupont connector and housing this would be your POWER cable
- Repeat the process with the two remaining cables these would be your DATA 1 & 2 cables

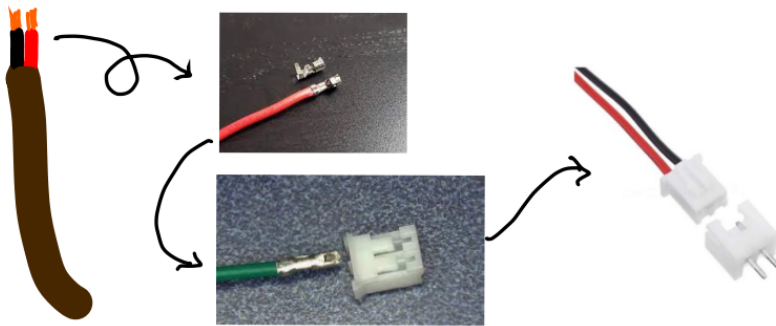




### Step 3: Clamping JST connectors and Housing

With the other side of the speaker cable, you would repeat the same process of step 2 but with the only difference being that you would be applying JST crimp connectors. If it helps you use a pair of tweezers to help you put the connector inside the clamp. Then apply JST crimp connector Housing

- With the remaining side of the cable repeat the previous procedure but changing into JST connectors



### Step 4: Put all together

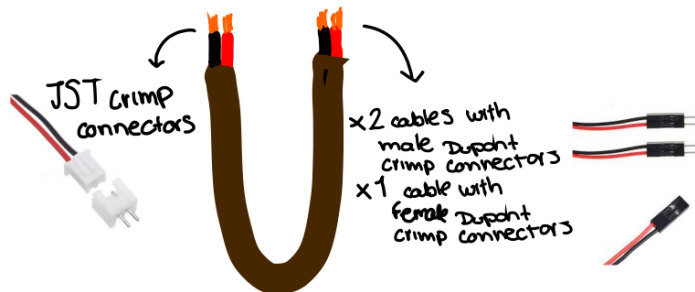
Finally, you would label two of your cables with DATA 1 and DATA 2 and the last one with POWER. Lastly put them all together with zip ties.

- Secure three speaker cables with zip ties so they could together
- Label the cables as
  - POWER ( Female Dupont Connector)
  - DATA 1 (Male Dupont Connector)
  - DATA 2 (Male Dupont Connector)



## Final Product

Noldus Cable contain 3 single cables, two of them should have Male Dupont Connectors and one Female Dupont Connector.



(Safa/ Andrea ) 4 Steps and pictures/diagrams for connecting and combining everything together in vivarium with arenas and computer system (see STAR Methods paper example: Figure 1)

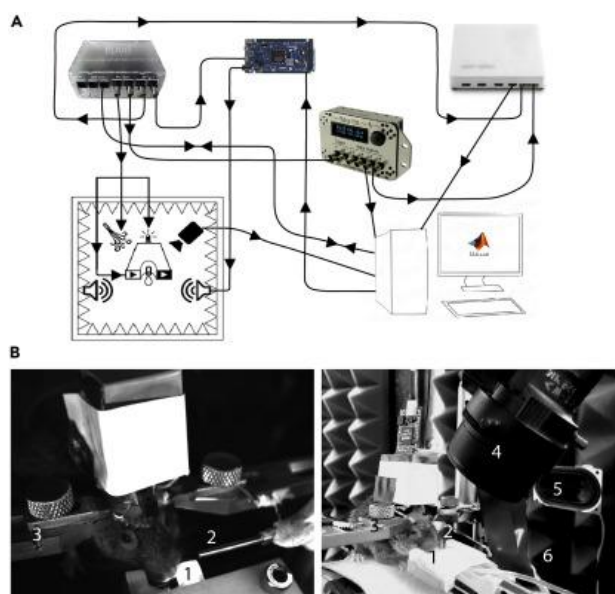
Link to paper: [10.1016/j.xpro.2021.100795](https://doi.org/10.1016/j.xpro.2021.100795)

The training setup (not done, just copied and pasted from an ex paper)

The training apparatus consists of sound-attenuated 4 training chambers, 4 valves and 4 lights for each maze,, a head-fixation platform, **an open source behavior control unit** (Bpod, Sanworks), peripheries for interacting with the animal (lick port or feeder, sucrose delivery systems or valves, speakers to provide sound stimuli), a camera, **optional open source stimulator unit** (PulsePal, Sanworks ([Sanders and Kepecs, 2014](#))) and data acquisition board (Open Ephys ([Siegle et al., 2017](#))), Noldus box and a PC connected to a CPU ([Figures 1A and 1B](#)). A lick port delivering sucrose as

reward and led light delivering light as punishment are delivered randomly. A camera is placed at the top right corner of the box and speakers for delivering auditory cues are mounted on the sidewalls of the box. The behavioral protocol is controlled via an open source closed-loop finite state machine (Bpod, Sanworks, see [Figures 1A and 1B](#)). This setup allows us to train mice on high-precision behavioral protocols with temporally controlled stimuli ([Figure 1D](#)). **Details of this open source multipurpose training platform were published in ([Solari et al., 2018](#)).**

⚠**CRITICAL:** Regularly calibrate valve opening and LED lights turning on to deliver the right amount of sucrose rewards and light as shock. It is possible to calibrate sound pressure levels of auditory stimuli as well. See ([Solari et al., 2018](#)) for details.



## **Figure 1. The experimental setup**

**(A) Schematic diagram of the setup.**

**(B) Photos of mice performing the auditory Pavlovian conditioning task. 1, lick port; 2, tubing for air puff; 3, headbar holders; 4, camera; 5, speakers;**