Supplementary material - Linares-García, Iliakis, et al.

Part 1. Auditory-Motor discrimination task Head Fix setup assembly.

To assemble the Head-Fix setup, you will use a 3D-printed body tube (the 3D tube design can be found in Wagner et al., 2020, Supplementary Data 2) and the Janelia HHMI head post assembly (designs available at Janelia Research Campus, https://www.janelia.org/open-science/mouse-headplate-and-holder-imaging-and-electrophysiology; these components must be fabricated by a machine shop). Additionally, all 3D laser printing designs are available on the Margolis Lab GitHub in the following repository: https://github.com/margolislab/Open-Source-Joystick-Platform. Follow these detailed instructions to securely attach these components to a breadboard using pedestal posts and clamps.

1. **Breadboard Base Setup**:
    a. Use a Thorlabs breadboard (MB2020/M) as the base.
    b. Assemble three pedestal posts using TR4 optical posts and insert them into PH50/M post holders.
    c. Attach BE1/M pedestal adapters at the base of each post.
    d. Secure the posts to the breadboard using CF125C/M clamps, positioning the first clamp at C2 and the second at C7. Use M6 10mm screws at positions E2 and E7, and tighten them with a 3/16” hex key.
2. **Head Mount Bar (HHMI Head Post assembly) and Post Holder Assembly**:
    a. At the top of the optical posts, secure the head mount bar from Janelia Designs using an M4 16mm screw in the second hole, tightening it with a 7/64” hex key.
    b. Insert the bottom piece of the headpost holder into the sliding hole of the head mount bar near the end closest to the adjacent bar. Secure it using an M4 16mm screw, a 7/64” hex key, and an M4 hex nut.
    c. Attach the top part of the headpost holder to the bottom piece using an 8-32 x 1/4 cap screw. Repeat this for the opposite bar.
    d. Ensure the correct distance between the bars by fitting a head plate into the headpost holder holes.
3. **Securing the Third Post**:
    a. Position the third post using a CF038 clamp at B5, near the right-side bar.
    b. Attach the RA90/M right-angle post clamp at the top of this post and secure it with a hex key.
4. **3D-Printed Body Tube Installation**:
    a. Attach the 3D-printed body tube to the TR20/M post.
    b. Insert the body tube into the second hole of the RA90/M clamp and secure it.
    c. Adjust the height of the body tube so it sits between the two bars

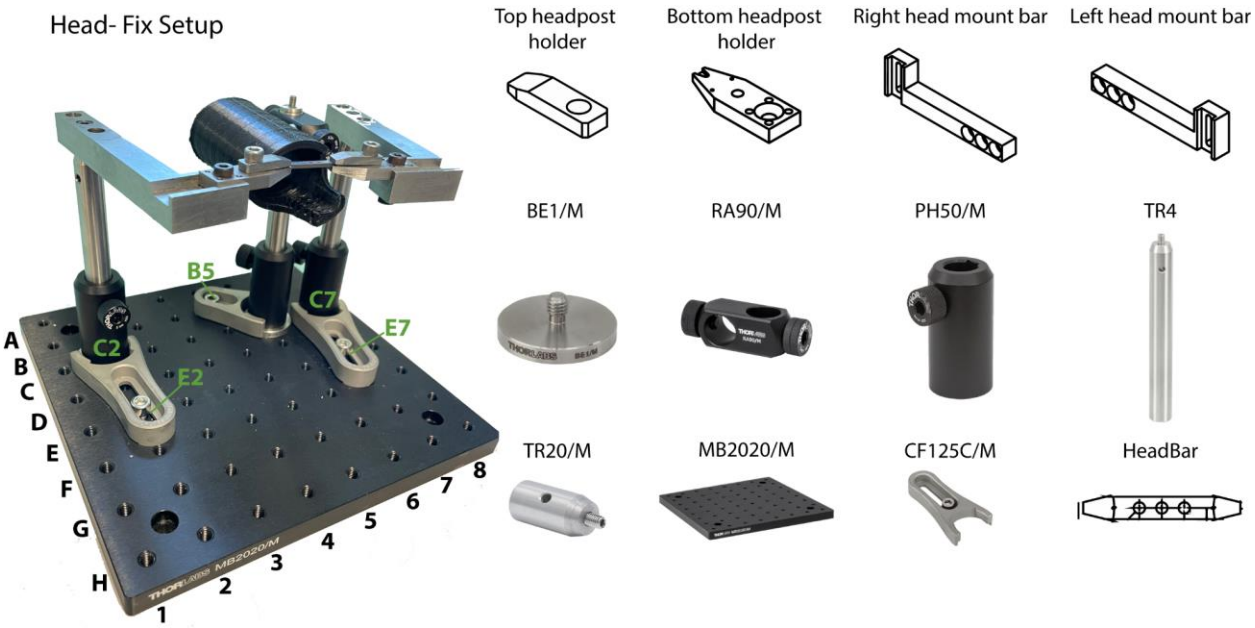

Figure 1. Auditory discrimination task Head Fix setup assembly.

Fixed Joystick setup assembly

To assemble the fixed joystick, begin by attaching the thumbstick to a 3D-printed assembly that consists of three main components: the stick lever, stick base, and joystick base holder (3D designs can be found at margolis lab repository). These parts will be mounted on a magic arm and a breadboard, allowing you to position the joystick comfortably for the mice to achieve optimal displacement.

1. **Breadboard Base Setup**:
    a. Use the Thorlabs breadboard (MB1015/M) as the base for mounting.
    b. Assemble one pedestal post using the TR4 optical post and insert it upside down into the PH50/M post holder.
    c. Secure the PH50/M post holder to the breadboard at the C1 position using an M6 x 25 mm cap screw.
2. **Magic Arm Assembly**:
    a. Attach one end of the magic arm to the port on the PH50/M post holder and secure it firmly.
    b. On the other end of the magic arm, attach a TR20/M post and secure it.
3. **Joystick Assembly**:
    a. Attach the joystick base holder to the TR20/M post using an M4 16mm screw.
    b. Insert the joystick into the base holder hole so that the joystick extends outside the hole and base.
    c. Secure the joystick with the hex nut that comes with it on the opposite side of the hole.
    d. Remove the black plastic casing surrounding the joystick.
4. **Stick Base and Lever Installation**:

a. Apply T-7000 adhesive to the inside part of the stick base, then glue it securely to the joystick.
b. Once the adhesive is set and the stick base is firmly attached, insert the stick lever into the stick base and secure it with a screw if needed.

This assembly will ensure that the joystick is stable and accurately positioned for use.

Figure 2. Fixed Joystick setup assembly

Speaker, camera and water spout setup assembly

To assemble the complete behavioral box, you will integrate the previously built joystick assembly and head-fix setup along with a speaker, camera, and water spout. These components will be installed inside a cooler that will serve as a soundproof behavioral chamber.

1. **Cooler Preparation**:
    a. Remove the plastic water leak plug from the cooler to expose a hole that will connect the inside of the box (where the behavioral setup is located) to the outside (where the microprocessors will be housed).
    b. Line the sides, front, and top of the cooler with soundproof foam. Use T-7000 glue to adhere the foam to the cooler's interior. Let the foam set and rest overnight to eliminate any lingering odors.
2. **Integrating Joystick and Head-Fix Setup**:
    a. Join the joystick and head-fix setups by aligning the breadboard bases. Secure them together using M6 10mm screws at the D2 and B2 positions.
    b. Adjust the magic arm to position the joystick close to the gap in the 3D-printed body tube, as shown in the reference image.
3. **Mounting the Speaker, Camera, and Water Spout**:
    a. Use a steel base to mount the speaker, camera, and water spout assembly.
    b. Detach the clamp from two magic arms and remove the screw at the tip. Insert the magic arms into the top two holes of the speaker and tighten the screws to secure it.
    c. For the lick port, use another magic arm to hold the needle that will be attached to the solenoid. Attach a wire to the metal part of the needle, which will be connected to a capacitor sensor to detect licks.
    d. Use an additional magic arm to mount the camera, ensuring it is positioned to record the mice during the experiment.
    e. This Infrared camera allows to record mice in the absence of light therefore no additional illumination is needed in the box to train animals.

This setup will allow you to create a functional and soundproof environment for behavioral experiments. For the electronic diagram on how to connect the hardware follow next instructions.

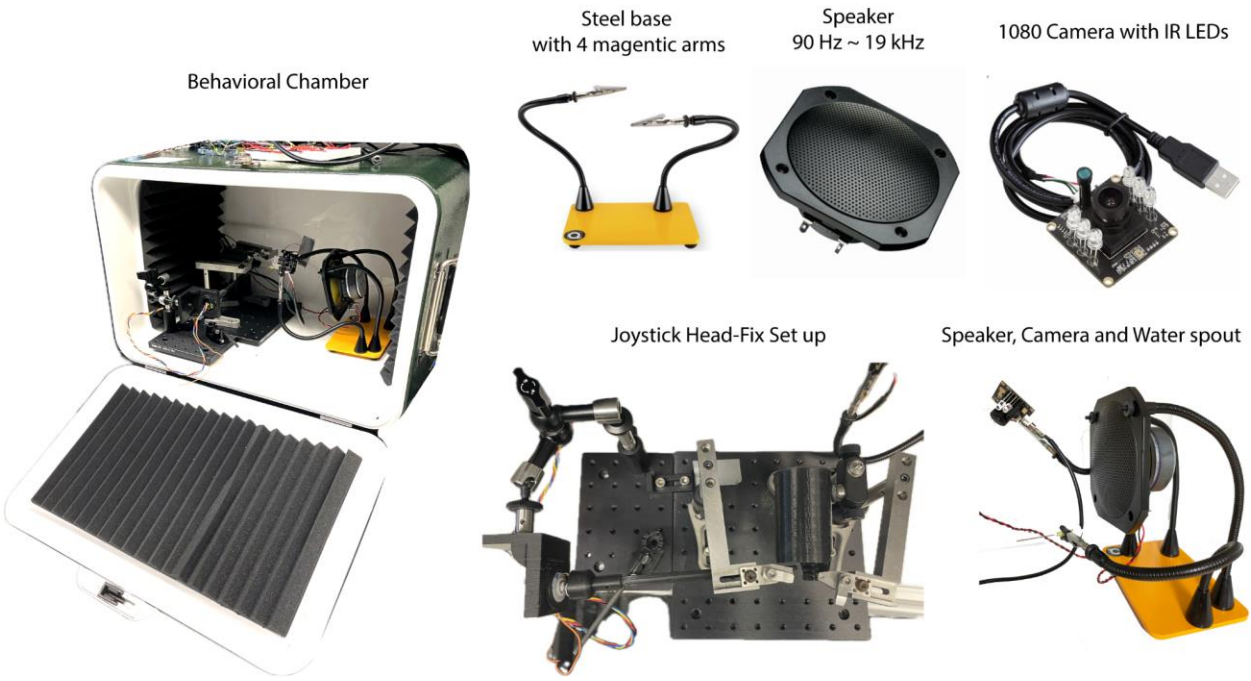

Figure 3. Speaker, camera and water spout setup assembly

Electronic Diagram

To assemble the electronic diagram for the dynamic auditory action selection paradigm, follow these steps to connect the components, including two Arduinos, the joystick, an FX Sound Board, an MPR121 capacitive sensor, and a Parker Series 3 noiseless solenoid valve.

1. **Joystick Connection to Arduino 1**:
    a. Connect the joystick wires to Arduino 1, which will handle continuous joystick displacement data collection.
    b. Wire the joystick as follows:
        i. Red voltage cable to 5V input on Arduino 1.
        ii. Black cable to ground (GND).
        iii. Blue cable to analog input 1 (A1).
        iv. Yellow cable to analog input 3.
    c. Since the joystick cables are short, extend them using additional wires and soldering, ensuring a length of at least two meters for mobility.
2. **Interfacing Arduino 1 and Arduino 2**:
    a. Maintain continuous communication between Arduino 1 and Arduino 2 by connecting the following pins:
        i. Pin 13 on Arduino 1 to A0 on Arduino 2.
        ii. Pin 12 on Arduino 1 to A1 on Arduino 2.
        iii. Pin 11 on Arduino 1 to pin 12 on Arduino 2.
        iv. Pin 8 on Arduino 1 to pin 3 on Arduino 2.

v. Pin 7 on Arduino 1 to pin 8 on Arduino 2.

3. **Arduino 2 and Breadboard Power Distribution**:
    a. Connect the 5V input from Arduino 2 to the left voltage column of the first breadboard.
    b. Connect the 3.3V input to the second left voltage column.
    c. Connect VIN to the right voltage column of the third breadboard.
    d. Ground (GND) from Arduino 2 should be connected to the left side of the first breadboard. All breadboards will share the same ground from Arduino 2.
4. **FX Sound Board Setup**:
    a. Prepare the sound card for breadboard mounting by soldering the provided pins. Position it from row one to row fourteen.
    b. Connect the following wires:
        i. Ground (GND) from Arduino 2 to sound card ground.
        ii. UG pin on the sound card to Arduino 2 GND.
        iii. RX to pin 6 on Arduino 2.
        iv. TX to pin 5 on Arduino 2.
        v. Vin to the 5V input on Arduino 2.
        vi. Voltage and ground wires from the speaker (previously soldered).
5. **MPR121 Capacitive Sensor Integration**:
    a. Solder the pins on the MPR121 touch sensor and mount it on a second breadboard next to the first one, spanning rows one to thirteen.
    b. Connect the following:
        i. 3.3V from Arduino 2 to 3Vo on the touch sensor.
        ii. GND to GND.
        iii. A5 to SCL.
        iv. A4 to SOA.
        v. Pin 11 on Arduino 2 to INT.
6. **Push Button Installation**:
    a. Place a push button between the eighteenth and twentieth rows of the second breadboard, with the middle part of the breadboard separating the rows.
    b. Connect the following:
        i. Eighteenth row (left side) to input 2 on both Arduino 1 and Arduino 2.
        ii. Eighteenth row (right side) to Arduino 2 GND using a 1kΩ resistor.
        iii. Twentieth row (right side) to Arduino 2 5V.
7. **H-Bridge and Solenoid Wiring**:
    a. Attach a third breadboard next to the second one. Place the H-bridge in the middle, spanning rows one to eight.
    b. Connect both sides of row one to the 5V input on Arduino 2.
    c. Connect pin 7 of Arduino 2 to the second row of the H-bridge.
    d. Connect the fourth row (left side) to Arduino 2 ground.
    e. Connect the eighth row (right side) to the VIN pin on Arduino 2, which will receive 15 volts from an external adapter.
    f. Connect the two wires from the solenoid to the third and sixth rows of the H-bridge, with the order of connection not being crucial.

This assembly ensures that the dynamic auditory action selection paradigm is fully operational with all components integrated and connected for precise task management and data collection.

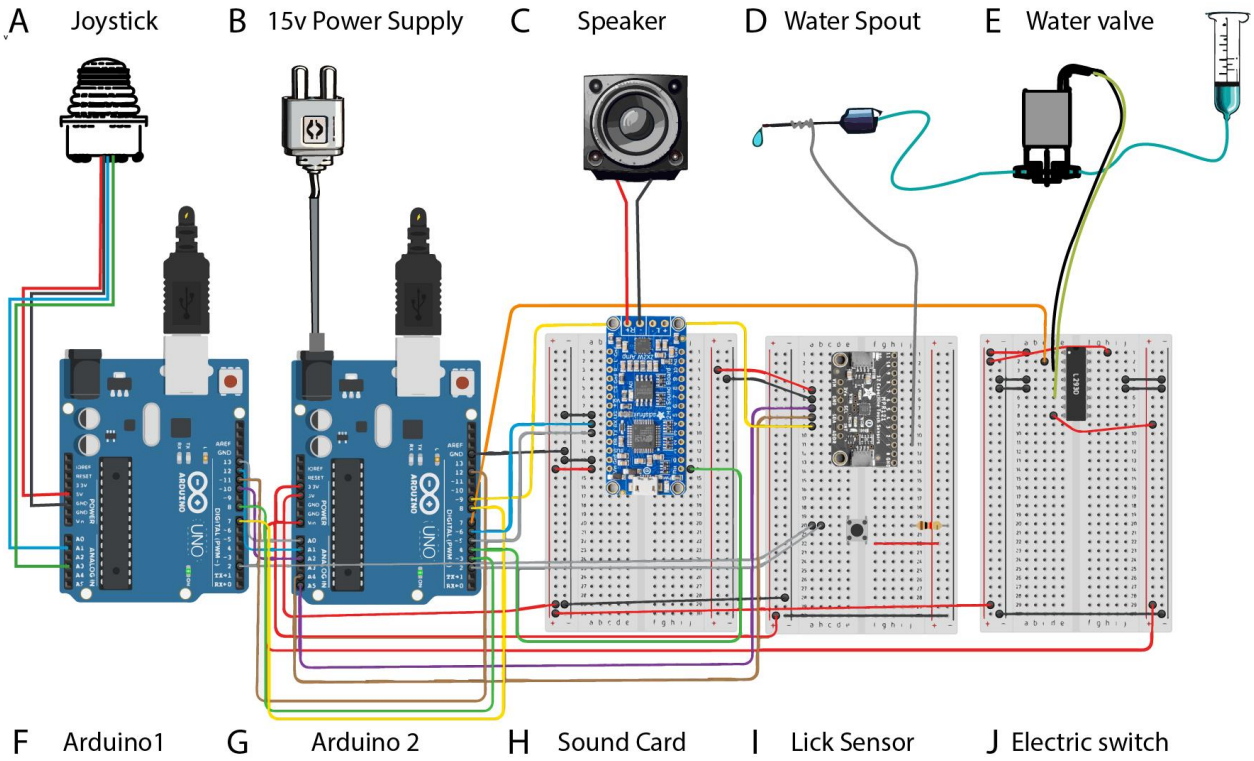

Figure 4. Auditory discrimination task electronic diagram.

Part 2 - Value-Based Decision-Making Task Rig Assembly

Note: this setup is all built on a single breadboard (Thorlabs MB1012 Aluminium Breadboard). The holes in this breadboard are arranged in a 10-by-12 configuration. In these instructions, we will refer to these holes using the following coordinate system:

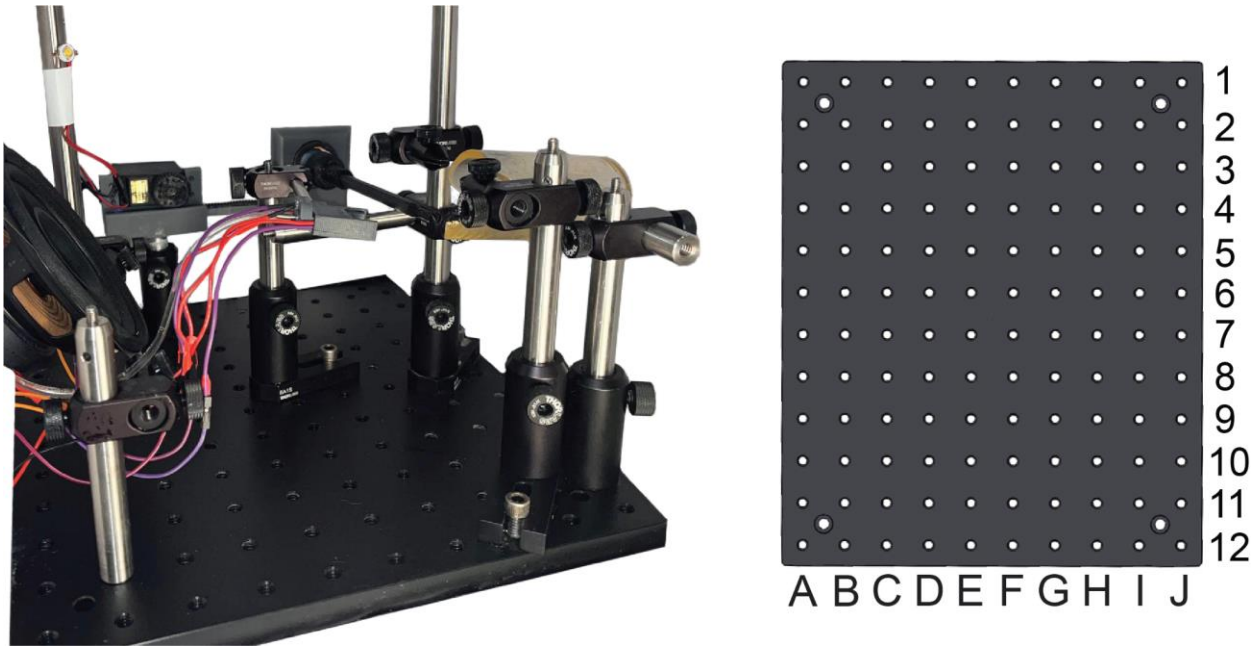

Figure 5. Value-based decision-making task rig assembly.

Gluing steps

1. Use epoxy resin to glue a 2” post (TR2) to the laser-printed motor holder. Ensure that the motor holder is as level as possible, as this step will determine the angle at which the anteroposterior movement of the joystick occurs. Let dry overnight.
2. To generate the wheel that will extend and retract the joystick, cut a piece of timing belt (GT2) long enough to loop around the wheel included in the servo motor (SG-5010, Adafruit: 155), and attach it using epoxy resin. Let dry overnight. When attaching, ensure that the timer belt overhangs in the same direction that the wheel will interface with the servo motor. If it overhangs in the opposite direction, it will not fit in the motor holder.
3. To generate the interface of the joystick reel with the servo wheel, cut a piece of timing belt (GT2) long enough to cover the entire long and thin portion of the joystick wheel. Stick to the joystick reel with epoxy resin, and let dry overnight.
4. To generate the base of the joystick, remove the plastic cover of the thumbstick (TS6T2S02A, DigiKey: 679-3658-ND) and fix the joystick holder to the exposed tip of the thumbstick (TS6T2S02A, DigiKey: 679-3658-ND) using epoxy resin, and let dry overnight. Applying epoxy resin (T60065B250) minimally and carefully to avoid disrupting the seamless mobility of the thumbstick: avoid the spring and the plastic

plates closest to the joystick base. If the cost of the epoxy resin is prohibitive, T-7000 can likely be used instead.

Assembly steps

5. Using 4 screws (SH3M10), screw the servo motor (SG-5010, Adafruit: 155) onto the motor holder glued to the 2” post (TR2).
6. Attach the wheel from the servo motor (SG-5010, Adafruit: 155) glued to the timer belt (GT2) to the servo motor (SG-5010, Adafruit: 155) at the white shaft interface. Ensure it snaps into place.
7. Insert the joystick onto the joystick base glued to the thumbstick (TS6T2S02A, DigiKey: 679-3658-ND). Some plastic might need to be scraped off the joystick to ensure a snug fit. In the case of a loose fit, some epoxy resin is recommended to stabilize the joystick.
8. Insert the rear end of the thumbstick (TS6T2S02A, DigiKey: 679-3658-ND) into the joystick reel, facing away from the long thin part of the reel, and screw tight with the hex nut included with the thumbstick (TS6T2S02A, DigiKey: 679-3658-ND). **It is critical at this juncture to ensure that the white and orange wires at the base of the thumbstick are perfectly aligned to the top/12-o’clock position of the joystick holder as shown in the image, as this will ensure the correct orientation and magnitude of the XY displacement readouts of the joystick.**
9. Guide the assembled joystick reel glued to the timer belt (GT2) into the servo motor holder at the space between the motor wheel and the bottom of the motor holder, until the tip reaches the level shown on the image above. Note that this level can and should be adjusted to ensure optimal positioning of the joystick relative to the mouse.
10. Screw a post holder (PH2) into the coordinate B4 of the breadboard (MB1012) using screw SS25S050.
11. Insert the 2” post glued to the motor holder into the post holder (PH2) and screw to tighten.

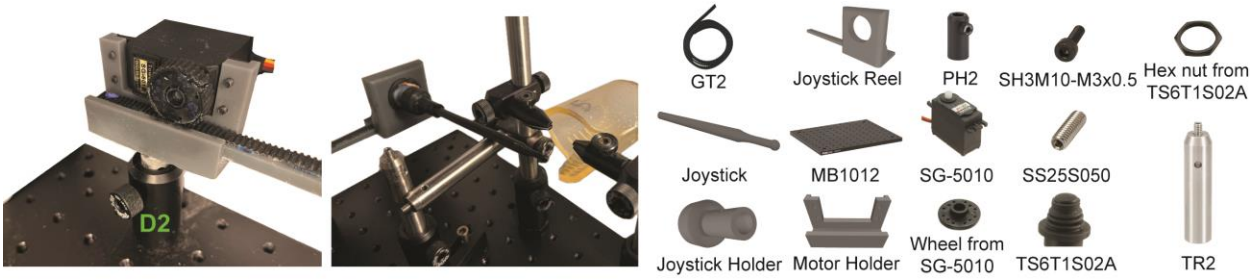

Figure 6. Retractable joystick assembly.

Head-Fix Setup and Lickometer Assembly

Set up Mouse Tube

1. Screw post holder (PH2) into breadboard at coordinate I12 using screw SS25S050.
2. Insert 4” post (TR4) into the post holder at I12. Tighten using the built-in horizontal screw on PH2.
3. Slide right-angle clamp (RA90) onto the 4” post and tighten onto post using the appropriate screw on the RA90.
4. Insert an 8-32” hex nut into its corresponding opening in the laser-printed mouse tube.
5. Tightly screw the mouse tube onto a 2” post (TR2), by screwing the small built-in screw on the post onto the 8-32” hex nut through the hole in the mouse tube.
6. Insert the TR2 post with the attached mouse tube into the horizontal hole of the RA90 clamp attached to the 4” post on I12. This tube will be used to hold the mouse as it performs the behavioral task.
7. Adjust height and position of mouse tube so that the tip of the extended joystick is at the level shown in Figure 7.

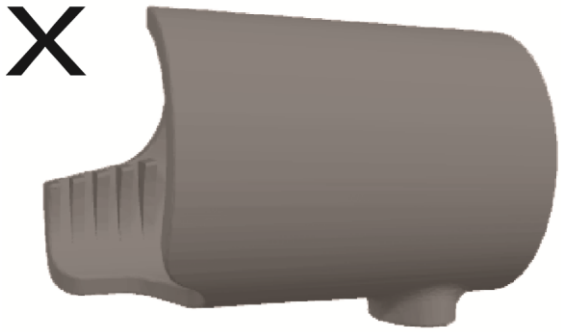

Figure 7. Recommended joystick position relative to head-fix tube.

Assemble Proximal Head Clamp

1. Screw a post holder (PH2) to mounting base (BA1S) using screw SH25S075V.
2. Insert 4” post (TR4) into this post holder (PH2), tighten using horizontal screw on post holder (PH2).
3. Slide right-angle clamp (RA90) onto the 4” post (TR4) and tighten onto post using the appropriate screw on the RA90.
4. Insert post clamp (PC2) into the horizontal hole of the right-angle clamp (RA90). Tighten the right-angle clamp (RA90) screw to fix the post clamp (PC2) in place. This clamp will

be used to hold the side of the mouse's headplate closest to the outside of the box (proximal to the experimenter).

Assemble Distal Head Clamp

1. Screw a post holder (PH2) to mounting base (BA1S) using screw SH25S075V.
2. Insert 4" post (TR4) into this post holder (PH2), tighten using horizontal screw on post holder (PH2).
3. Slide right-angle clamp (RA90) onto the 4" post (TR4) and tighten onto post using the appropriate screw on the RA90.
4. Insert 4" post (TR4) into horizontal hole of this right-angle clamp (RA90). This post will be adjusted so it sits right underneath the joystick to prevent mice from displacing the joystick downwards.
5. Slide a second right-angle clamp (RA90) onto the 4" post (TR4) and tighten onto post ~5cm above the first right-angle clamp using the appropriate screw on the RA90.
6. Insert post clamp (PC2) into the horizontal hole of this second right-angle clamp (RA90). Tighten the right-angle clamp (RA90) screw to fix the post clamp (PC2) in place. This clamp will be used to hold the side of the mouse's headplate closest to the inside of the box (distal to the experimenter).

Position Head Clamps Around Mouse Tube

It is recommended to position the head clamps around the mouse tube at the height of the top of the mouse tube, as shown in Figure 8.

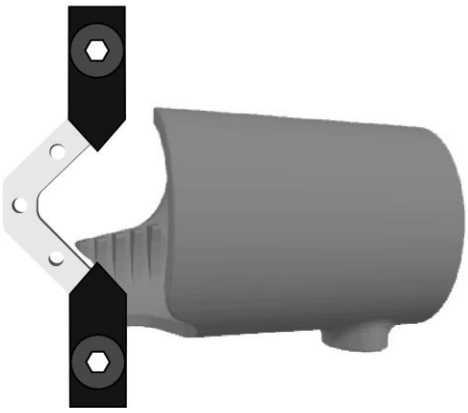

Figure 8. Recommended headplate and clamp position relative to headfix tube.

In our setup, this position is accomplished most easily by screwing in the distal clamp setup at D12 on the breadboard, and the proximal clamp setup at J10, using screws SH25S075V.

Assemble Lickometer Setup

1. Mount lickometer onto mini-series optical post (MS3R) by screwing small attached screw mini-series optical post (MS3R) into small hex nut built into the lickometer. Set aside.
2. Screw a post holder (PH2) to mounting base (BA1S) using screw SH25S075V.

3. Insert 4” post (TR4) into this post holder (PH2), tighten using horizontal screw on post holder (PH2).
4. Slide **1”-1/2"** right-angle clamp (RA90**R**) onto the 4” post (TR4) and tighten onto post using the appropriate screw on the RA90R.
5. If needed, loosen small hex screw on RA90R, then slide on MS3R attached to lickometer. Tighten the small hex screw on the RA90R to have a somewhat firm grip on the lickometer, allowing for some slack to tilt the lickometer up and down, and move it towards and away from the post, but keeping it tight enough to prevent the lickometer from tilting down on its own.
6. Position the lickometer setup in front of the mouse tube, around 2.5cm below the height of the clamps. This is best achieved by screwing the mounting base (BA1S) into hole D9 of the breadboard.

Figure 9. Head-Fix Setup Assembly and Lickometer Assembly

Speaker Assembly

1. Screw the 8” post (TR8) into hole C2 of the breadboard (MB1012), and the 4” post (TR4) into hole I2 of the breadboard (MB1012) using screw SS25S050.
2. Slide a right-angle clamp (RA90) onto each post as shown in the image.
3. Insert a post clamp (PC2) into each of the horizontal holes of the right-angle clamp (RA90) and tighten them in place using the hex screw of the right-angle clamp (RA90).
4. Insert the bottom two corners of the speaker into the post clamps (PC2) and tighten until stable.
5. Attach box LED to top of the 8” post (TR8) to serve as a box light.

Figure 10. Speaker assembly.

Circuit Assembly

A detailed circuit diagram is shown in Figure 11.

Preparation:

We recommend storing the fully-assembled Arduinos and breadboards at some distance from the behavior box to avoid consequences of spillage of reward solution, escaping mice, etc. In order to allow for easy replacement of components and far reach, we recommend the use of:

a) **Breadboard jumper wires** (e.g., https://www.adafruit.com/product/1953?gad_source=1&gclid=Cj0KCQjwzva1BhD3ARIsADQuPnX-QaDKtA02VlerAe-222DesWxESo2TQ_uBFPyQyiNimKO1F26yVKgaAhpAEALw_wcB): soldering these onto the ends of wires of all electrical components used here, e.g., lickometer, speaker, box light, joystick, servo, allows for easy replacement of these components if needed. We also recommend using these as the interface between the breadboard and the stranded wire outlined below as they provide a snug interface between the wire and the breadboard.

b) **Stranded wire** (e.g., https://www.mcmaster.com/8054T13/): allowing some slack of 2-3 meters per electrical component allows for flexibility with Arduino and breadboard placement.

Assembly:

1. **Prepare the breadboard:** to supply voltage to command and ground strips of the breadboard:
    a. connect 5V pin of Arduino 2 to a pin on the command voltage strip of the breadboard, and a ground pin of Arduino 2 to a pin on the ground strip of the breadboard.
    b. Pass this potential difference to the strips on the opposite side by connecting a command pin on one side with the command pin on the opposite side, and a

ground pin on one side with the ground pin on the opposite side. These connections are shown near the bottom of the breadboard in the figure.

2. **Servo motor:** The servo motor Tower Pro SG5010 (Adafruit: 155) comes with three wires: the brown wire is the ground, the orange wire is the 5V input, and the yellow wire is the input for the pulse-width-modulated (PWM) signal from the Arduino that determines the motor shaft angle.
    a. Connect the servo brown wire to a ground pin on Arduino 1.
    b. Connect the 5V AC-DC power supply (WSU050-1500, DigiKey: 237-1417-ND) to a barrel-to-jack port adapter (PRT-10288, DigiKey: 1568-1510-ND).
    c. Connect the ground terminal of the barrel-to-jack port adapter to a ground pin on Arduino 1
    d. Connect the servo orange wire to the positive terminal of the barrel-to-jack port adapter
    e. Connect the servo yellow wire to pin 9 on Arduino 2. Note that this pin has a curly line next to it (~) indicating that it can supply pulse-width-modulated (PWM) input to the servo motor.
3. **Joystick**: The joystick TS6T2S02A (DigiKey: 679-3658-ND) comes with five wires: red and black wires are command voltage and ground wires respectively. Yellow, orange, and blue wires track the analog position of the joystick in three dimensions: anterior-posterior, left-right, and up-down respectively. This setup only tracks anteroposterior (yellow), and up-down displacement (blue) of the joystick. The left-right readout, which is carried by the orange wire, is therefore not used.
    a. Connect joystick red wire to the 5V output pin of Arduino 1.
    b. Connect joystick black wire to ground pin of Arduino 1.
    c. Connect joystick blue wire to pin A1 on Arduino 2.
    d. Connect joystick yellow wire to pin A3 on Arduino 2.
4. **Speaker**: Arduino 1 supplies white noise input to the speaker. An arduino cannot generate real white noise, but can rapidly iterate through random tones within a certain range to create the perceptual experience of white noise. This rapid iteration is slowed by any parallel processes (e.g., reading out joystick position, licks, etc.). Therefore, a separate arduino is used for this purpose. To reduce the volume of this output, we use a 160 Ohm resistor in series with the speaker:
    a. Connect pin 2 on Arduino 1 to pin 25A on the breadboard.
    b. Connect 160 Ohm resistor (DigiKey: 13-MFR-25FRF52-160RTR-ND) to pins 25B and 22B on the breadboard.
    c. Connect pin 22A on the breadboard to the positive end of the speaker.
    d. Connect the negative end of the speaker to a ground pin on the left side of the breadboard.
    e. To control Arduino 1 via Arduino 2, connect Arduino 2 pin 31 to Arduino 1 pin 10, and Arduino 2 pin 33 to Arduino 1 pin 11.
5. **Box light**: Arduino 2 toggles the box light on and off via the breadboard.
    a. Connect Arduino 2 pin 2 to pin 16B on the breadboard.
    b. Connect pin 16A on the breadboard to the positive end of the box light.
    c. Connect the negative end of the box light to the ground strip on the breadboard.

6. **Solenoid valve ("pump")**: this is powered via a motor driver (SN754410NE, DigiKey 296-9911-5-ND). This motor driver has the capacity to power two solenoid valves or other motors, but we only use its capability for one solenoid in this setup. More details about the functions of each pin in this motor driver can be found in the following instruction manual: https://www.ti.com/lit/ds/symlink/sn754410.pdf?ts=1722601127757&ref_url=https%253A%252F%252Fwww.google.com%252F
    a. Insert the motor driver so that the left pins go into pin holes E1-8, and the right pins go into pin holes F1-8. Ensure the divet at the top of the motor driver is oriented toward the top of the breadboard.
    b. Connect heat sink (GROUND) pins on the left and right of the motor driver (D4-5 and G4-5) to ground strips on the right and left of the breadboard.
    c. Connect pin hole G2 to the command voltage strip of the breadboard on the right, in order to supply 5V power to pin VCC1 of the motor driver to power internal logic translation.
    d. Connect the 12V AC-DC power supply (SmoTecQ SA-0243-1202000US, DigiKey: 19262-ND) to a barrel-to-jack port adapter (PRT-10288, DigiKey: 1568-1510-ND).
    e. Connect the positive terminal of the barrel-to-jack port adapter to pin D8 on the breadboard (VCC2) to supply the command voltage for the solenoid(s).
    f. Connect a 100nF capacitor from pin A8 to the ground strip on the left side of the breadboard.
    g. Connect the ground terminal of the barrel-to-jack port adapter to the ground strip on the left side of the breadboard.
    h. Connect pin 13 on Arduino 2 to pin D1 on the breadboard (VEN1,2) to enable the channels that will power the solenoid.
    i. Connect pin 7 on Arduino 2 to pin D2 on the breadboard (1A). Connect pin 8 on Arduino 2 to pin D7 on the breadboard (2A). These are the driver inputs.
    j. Connect pin D3 on the breadboard (1Y) to one terminal of the solenoid, and pin D6 on the breadboard (2Y) to another terminal of the solenoid. The orientation does not matter for the solenoid we used (LHDA1231115H).
7. **Lickometer:** we use an optical lickometer (Sanworks: 1020) that detects breaks in an infrared beam that is shone perpendicularly in front of the lickspout. The setup contains an infrared photoemitter, infrared photodetector, and a built-in LED in the light of the mouse that we use as a Go cue.
    a. Photodetector:
        i. Connect the right command voltage strip to pin J9 on the breadboard.
        ii. Connect a 10 kiloOhm resistor (DigiKey: 13-MFR25SFRF52-10KTR-ND) to pins F9 and F12 on the breadboard.
        iii. Connect the positive terminal of the infrared photodetector to pin I12 on the breadboard, and the negative terminal of the infrared photodetector to the ground strip on the right side of the breadboard.
        iv. Connect Arduino 2 pin 12 to pin J12 on the breadboard. We will use this wire to track whether or not the infrared beam is interrupted by a lick.

b. Photoemitter

i. Connect the right command voltage strip to pin J10 on the breadboard.
ii. Connect a 330 Ohm resistor (DigiKey: 13-MFR-25FTF52-330RCT-ND) to pins G10 and G13 on the breadboard.
iii. Connect the positive terminal of the infrared photoemitter to pin G13 on the breadboard, and the negative terminal of the infrared photoemitter to the ground strip.

c. Lickometer LED/Go cue light

i. Connect Arduino 2 pin 10 to pin I11 on the breadboard.
ii. Connect a 1 kiloOhm resistor (DigiKey: 13-MFR-25FRF52-1KTR-ND) to pins H11 and H14 on the breadboard.
iii. Connect the positive terminal of the lickometer LED to pin I14 on the breadboard, and the negative terminal of the lickometer LED to the ground strip on the right side of the breadboard.

8. **Lick indicator LED:** To track in real time whether a mouse is licking from outside of the box, it can be helpful to install a lick indicator LED that shines whenever the infrared beam of the lickometer is broken. To do this:
    a. Connect Arduino 2 pin 11 to breadboard pin I15.
    b. Connect the positive terminal of the lick indicator LED to pin J15 on the breadboard, and the negative terminal of the lick indicator LED to the ground strip of the breadboard. Any LED will work if it can take an input voltage of 5V; otherwise resistors/different voltage input might be necessary.
9. **Compatibility with fiber photometry and optogenetics.** Our in-house codes use pins 22 and 23 as output TTLs to our photometry system to allow for synchronization of behavior clock with the photometry system clock, and pin 51 to send an output TTL to toggle the on-off state of our optogenetics light sources.

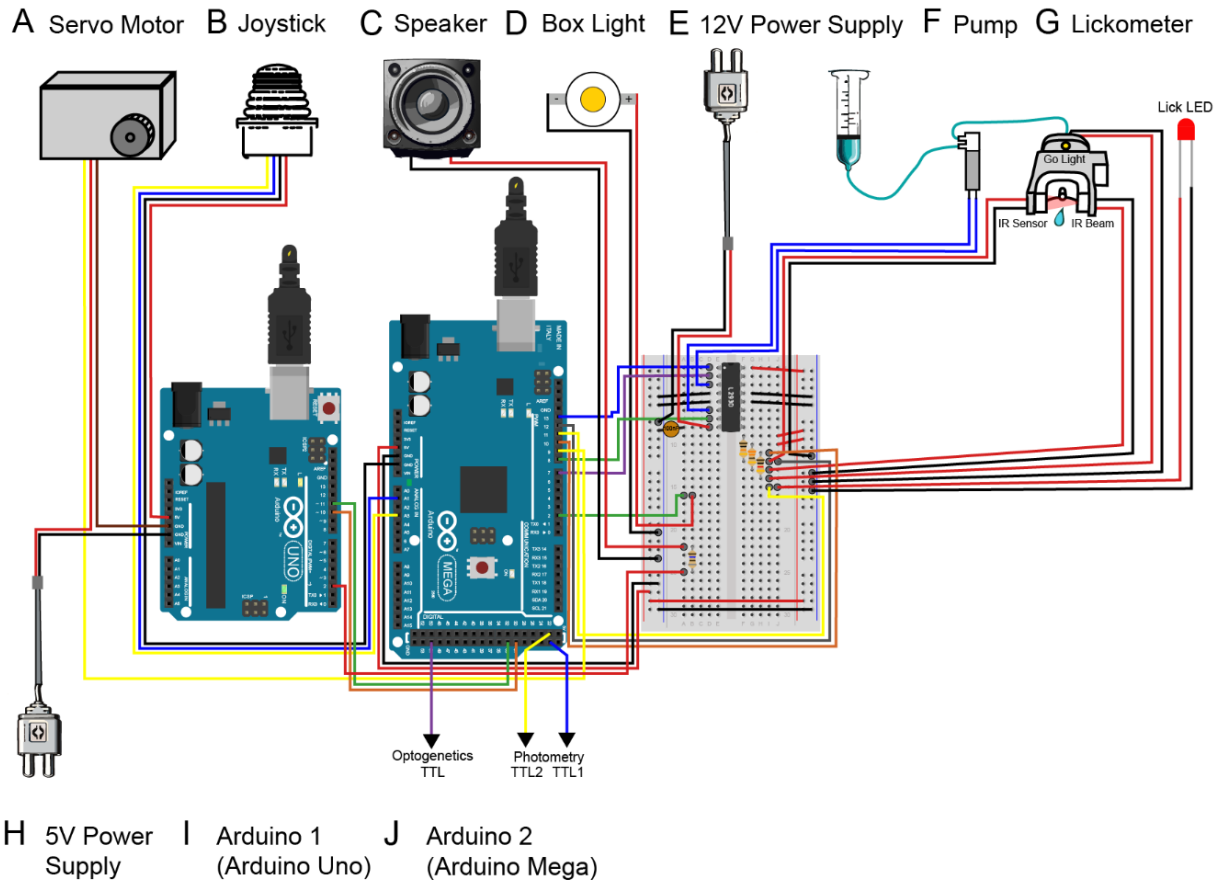

Figure 11. Value-Based Decision-Making Task electronic diagram.

Table 1

Embedded systems and development boards

Item:	Catalog Number:	Description:	Price:	System
2 Arduino Unos	DigiKey: 1050-1024-ND	Arduino Uno R3 atmega328P Board	$27.6	AD: 2 VB: 1
1 Arduino Mega	DigiKey: 1050-1018-ND	Arduino Mega 2560 atmega2560	$41.14	VB
MPR121 Touch Sensor	DigiKey: 1528-1038-ND	MPR121 Touch Sensor 12-Key	$7.95	AD
FX Sound Board	DigiKey: 1528-1209-ND	FX Sound Board 2X2W WAV/OGG 2MB	$24.95	AD
Infrared Lickometer	Sanworks: 1020	Optical Lickometer	$215.00	VB

Electronic Components:

Item:	Catalog Number:	Description:	Price:	
Speaker	DigiKey: 2806-93100TB-ND	6.5 Home/auto Mid-Woofer	$59.99	both
3 BreadBoards	DigiKey: 377-2094-ND	BreadBoard term srip 3.20X2.08"	$4.00	AD: 3 VB: 1
Wire	DigiKey: 2368-WAK-SIL18-ND	Wire Assortment Soft Silicone18A	$48.13	both
Thumbstick	DigiKey: 679-3658-ND	Switch Thumbstick Pushbutton Hall	$227.07	both
Half-H Driver	DigiKey: 296-9911-5-ND	Half-H Driver 2 Element 2 Bit per Element 3-State Output 16-PDIP	$2.94	both
Miniature Inert Liquid Valve	Parker: 003-0218-900	Series 3 - Inert Solenoid ValveModerate - PEEK Body, EPDM Diaphragm2 Way Normally Closed1/8 Barbs120.078""	$128.70	AD
Solenoid Valve	Lee Company:	Solenoid Valve - 3 port, 12V	$72.61	VB

	LHDA1231115H			
Switch Button	2223-TS02-66-70-BK-100-LCR-D-ND	SWITCH TACTILE SPST-NO 0.05A 12V	$0.10	AD
Servo Motor	Adafruit: 155	Standard servo - TowerPro SG-5010	$12.00	VB
5V AC-DC Power Supply	DigiKey: 237-1417-ND	AC/DC Wall Mount Adapter 5V 7.5W	$6.69	both
12V AC-DC Power Supply	DigiKey: 19262-ND	Adapter, 100-240VAC IN, 12VDC, 0	$19.58	VB
2x Barrel-to-Jack Port Adapter	DigiKey: 1568-1510-ND	Adapt Term BL 2Pos to 2.1mm Jack	$3.50	VB
Capacitor, 100nF	DigiKey: 399-9797-ND	Cap Cer 0.1uF 50V Z5U Radial	$0.36	VB
Resistor, 160Ω	DigiKey: 13-MFR-25FRF52-160RTR-ND	Res 160 Ohm 1% 1/4W Axial	$0.10	VB
Resistor, 330Ω	DigiKey: 13-MFR-25FTF52-330RCT-ND	Res 330 Ohm 1% 1/4W Axial	$0.10	VB
Resistor, 1kΩ	DigiKey: 13-MFR-25FRF52-1KTR-ND	Res 1k Ohm 1% 1/4W Axial	$0.10	both
Resistor, 10kΩ	DigiKey: 13-MFR25SFRF52-10KTR-ND	Res 10k Ohm 1% 1/4W Axial	$0.10	VB: 1

Thorlabs Hardware

Item:	Catalog Number:	Description:	Price:	
Aluminum Breadboard	MB2020/M	Breadboard 200 mm x 200 mm x 12.7 mm	$85.61	AD
Aluminum Breadboard	MB1015/M	Aluminum Breadboard, 100 mm x 150 mm x 12.7 mm, M6 Taps	$48.92	AD
Aluminum Breadboard	MB1012	Aluminum Breadboard, 10” x 12” x 1/2", 1/4"-20 Taps	$153.72	VB
4 x 50mm Metric Post Holder	PH50/M	50mm Metric Post Holder	$35.80	AD

Optical Post	TR4-P5	TØ1/2" Optical Post, SS, 8-32 Setscrew, 1/4"-20 Tap, L = 4", 5 Pack	$ 30.00	both
2x Optical Post	TR20/M	Post : 12.7mm Dia . 20mm Long	$10.76	AD
1x Compact clamping fork	CF038C-P5	CF038-P5 - Clamping Fork, 0.40" Counterbored Slot, Universal, 5 Pack	$44.56	AD
2x Small Clamping Fork	CF125C/M	Small Clamping Fork with M6 x 1.0 Captive Screw	$25.66	AD
3x Studded Pedestal Base Adapter	BE1/M	Ø31.8 mm Studded Pedestal Base Adapter, M6 Thread	$32.49	AD
3x Right-Angle Clamp	RA90/M	Right-Angle Clamp for Ø1/2" Posts, 5 mm Hex	$32.46	AD
5x 1/2" Post Holder	PH2	Ø1/2" Post Holder, Spring-Loaded Hex-Locking Thumbscrew, L = 2”	$8.95	VB
3x Mounting Base	BA1S	Mounting Base, 1” x 2.3” x 3/8"	$5.63	VB
2x 2” Optical Post	TR2	Ø1/2" Optical Post, SS, 8-32 Setscrew, 1/4"-20 Tap, L = 2”	$5.90	VB
2x 8” Optical Post	TR8	Ø1/2" Optical Post, SS, 8-32 Setscrew, 1/4"-20 Tap, L = 8”	$9.88	VB
2x Mini-Series Optical Post	MS3R	Mini-Series Optical Post, Ø6 mm, L = 3”	$9.27	VB
1x 5-Pack Right Angle Clamp for 1/2" Posts	RA90-P5	Right Angle Clamp for Ø1/2” Posts, 3/16” Hex	$52.76	VB
2x Right Angle Clamp for 1/2" to 6mm Posts	RA90TR	Right Angle Ø1/2” to Ø6mm Post Clamp, 3/16” Hex Thumbscrew	$18.18	VB
4x Compact Flexure Plate Clamp	PC2	Compact Flexure Plate Clamp, 1/4"-20 Tap	$24.23	VB
2x 5-Pack Vented Cap Screws	SH25S075V	1/4"-20 Vacuum-Compatible Vented Cap Screw, 316 Stainless Steel, 3/4" Long	$16.55	both

1x 50-Pack Steel Cap Screw	SH3M10	M3 x 0.5 Alloy Steel Cap Screw, 10 mm Long, 50 Pack	$9.73	both
1x 50-Pack Setscrews	SS25S050	8-32 Stainless Steel Setscrew, 1/2" Long, 50 Pack	$6.70	both
1x 25-Pack Steel Cap Screw	SH6MS10	M6 x 1.0 Stainless Steel Cap Screw, 10mm long, 25 Pack	$9.08	both
1x 50-Pack Steel Setscrew	SS4MS16	M4 x 0.7 Stainless Steel Setscrew, 16mm Long, 50 Pack	$6.97	both

Other Hardware

Item:	Catalog Number:	Description:	Price:	
Adjustable Friction Magic Arm	Amazon: B08YN2XNM5	NEEWER 5.9"/15cm Adjustable Friction Magic Arm with 1/4" Screw on Both Ends,	$16.49	AD
QuadHands Mini WorkBench	QuadHands: 13492345995315	Magnetic arms with heavy steel base	$ 29.95	AD
Magnetic Arm 200	Amazon: 39788577800	2" Flexible Metal Arm with Stainless Steel Clamp	$19.95	AD
Night Vision camera	Amazon:B0829HZ3Q7	Arducam 1080P Day & Night VisionCamera for Computer, 2MP Automatic IR-Cut Switching All-Day Image USB2.0 Webcam Board with IR LEDs for Windows, Linux, Android and Mac OS	$ 34.99	AD
Behavior box	Amazon:B0029UOYCY	Coleman Cooler	$198.89	AD
Behavior box	Ikea: 892.913.12	Hällan - Storage combination with doors, white, 45x47x67 cm	$109.00	VB
1x Timing Belt	Adafruit: GT2	Timing Belt GT2 Profile - 2mm pitch - 6mm wide 1164mm long	$9.95	VB

HeadFix Setup Hardware

Item:	Catalog Number:	Description:	Price:	
Mouse Head Plates and Holder	https://hhmi.flintbox.com/technologies/c04b8f01-f188-472a-b660-368a5f8549ad	Drawings for machine shop manufacture.	$0.00	both

3D Designs

Item:	Catalog Number:	Description:	Price:	
Body Tube	Wagner, M.J., Savall, J., Kim, T.H. et al. Skilled reaching tasks for head-fixed mice using a robotic manipulandum. Nat Protoc 15, 1237–1254 (2020)	Restraining tube	$0.00	both
Manipulandum	N/A	3D Stick	$0.00	both
Manipulandum/Holder	N/A	Holder to attach thumbstick to a base		both
Manipulandum/Holder for servo motor	N/A	Holder to attach thumbstick to a retractable base	$0.00	VB
Joystick Base Holder	N/A	Holder to attach the manipulandum to thumbstick	$0.00	both

Other Materials

T-7000 Adhesive	Amazon: B09DV18XF7	Adhesive Multi-Function Glues	$7.89	AD
Epoxy Blue Dye	Fiber Instrument Sales: T60065B250	FIS Epoxy Blue Dye 2 Grams - 50 Pack	$190.00	VB
Hex Key Set	Thorlabs: CCHK	11-Piece Color-Coded Hex Key Set	$28.68	both
Hook-up Wire	Adafruit: 1311	Set - 22AWG Solid Core - 6 x 25 ft	$15.69	both