Justine Gagnepain

Final artifact: THIS=THEN=THAT

SEMESTER PROJECT - CART 360
mystifying-hodgkin-9f12a6.netlify.app

In this semester-long project, I focused on building a home-based interactive artifact to simplify the process of building habits towards achieving desired personal goals. Noticing how hard it is for me to commit to a daily practice of a musical instrument or of body exercises, I wanted to try and ease out aspects of friction that we experience around doing activities that we would like to engage in, but sometimes find hard to get started on.

The artifact is thought out for individuals who have meaningful long-term goals that could be reachable through repetitive practice, but who struggle to commit to daily engagement in the practice.

In this document, I outline the requirements of my project, explain the design strategy that I adopted for the artifact, and retrace the process that I followed to complete a high-fidelity prototype before discussing the next steps in the conception of the final artifact.

Background

The idea originated from reading «The Power of Habit » by Charles Duhigg. The book consists of a layman's overview of recent scientific research around habit building and habit changing. It provides a bare-bones recipe applicable to each person's habit-related goals. We all make New Year resolutions, become vegetarian, or start learning instruments under two illusions: that success depends on the amount of willpower we will muster, and that w can commit to finding enough willpower to succeed. Duhigg exposes the issues with this approach and instead prescribes a somewhat science-backed approach he calls the « Habit Loop ».

For a habit to take root, three elements need to be present: a cue, a routine, and a reward. In the context of a smoking habit, for example, a cue, like seeing a cigarette, feeling anxious, or being bored, triggers the habit. The routine, smoking, is always the same. Finally, nicotine kicks in as a reward. To modify the habit, scientists interviewed by Duhigg say, one has to identify the cue and consciously notice when it is triggered, systematically replace the routine with another, and introduce a new reward.

One must also make sure to have a clear plan to follow when engaging in the activity, to remove the need for thought or decision-making. Living in a user's home, the artifact serves to provide a cue for a habit, guidance as users complete the desired routine, and a reward, for the sole purpose of helping the house's occupants to build strong habits.

Interaction design considerations

In designing the interaction, I was inspired by the work of David Rose as outlined in « Enchanted Objects ». Non-negotiable aspects of the design included having a single purpose and living naturally in an environment. It will not require that the user learns a new skill or adopts a new habit to start using it. Besides, the artifact will not convey judgment on the user about not having completed tasks or ask them for a regular commitment to using it.

I hoped to convey feelings of reassurance, autonomy, and empowerment. When users interact with the artifact, they should feel a sense of relief at being taken care of, and eventually pride at accomplishing their goals.

The essential meaning I hoped to convey with this experience is that we are harder on ourselves than we need to be and that we accomplish more when we stop trying in such hard-minded ways. It's not that we aren't capable of motivation, it's that we don't understand that that's now how our brains work; and once we do, we can stop feeling like we don't accomplish enough.

Effectively, I wanted the user to stop thinking about the list of things they need to do, to simply plug into the interface for a while, follow step by step instructions, and know that if they thoughtlessly follow what the machine asks of them for a known amount of time, they would reach their goals without it taking so much effort.

Design

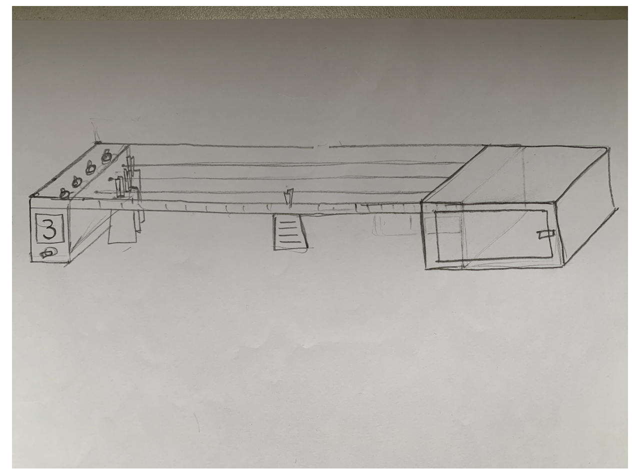
To start interacting with the device, a user had to tell it the activities that it wished to perform, and give each activity a time duration. One way to accomplish this would have been to create a mobile application where the user enters the name of an activity and selects a duration. The device would then support a screen that would display the name of the task, and a countdown. However, the screen-based solution did not meet my design requirements, as I found them obtrusive in an environment. A separate app would also go against the requirement that the device have a single, simple purpose.

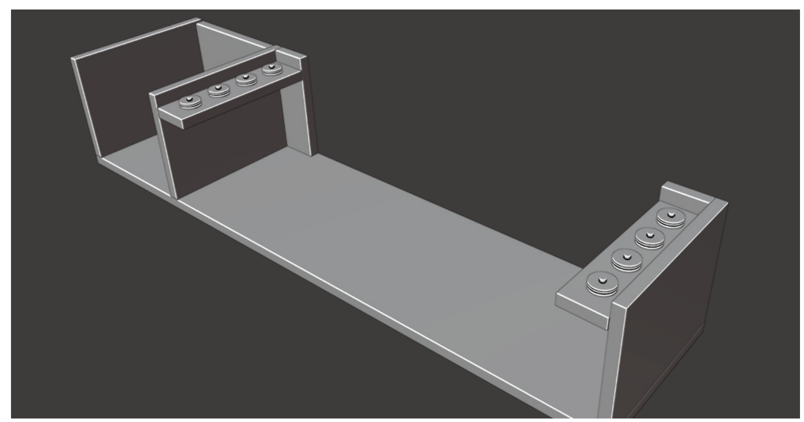
It was not difficult to come up with ways to convey the passage of time, from horizontal led strips to alarms that ring when a task is over to hourglasses. Finding a non-non-obtrusive way to communicate the name of the activity to perform proved more complicated. I initially thought of using a pico-projector but felt it would have the same issues as an LCD screen. Pico projectors also need to be placed a certain distance away from a surface and work better in dark environments, so they were deemed too limiting. I then considered a voice interface to program the device, but chatbots are cold and impersonal, and interacting with them is often cumbersome and slow. I also looked into LED matrices that could act like LCD screens but feel less like looking at a computer. However, all of these methods seemed too complicated to achieve the two affordances I needed: enter and display the names of activities.

The solution that I chose to this problem was inspired by a picture that a mother had posted of how she gets her children to perform tasks around the house: she had attached a piece of string to the refrigerator and would tie one-dollar bills to the string with clothespins along with a piece of paper with the name of the task. Whoever did the task got to keep the bill. I realized that at no point in the interaction did the artifact need to be aware of what the activity was so that I could rely on pen, paper, and clothespin to enter and display the name of the activity. From there, it was only a short jump away from noticing that the passage of time could also be represented through horizontal motion. I settled on a design with several parallel lines controlled by individual motors.

I also appreciated that requiring that the user take some time to non-digitally set up the week's practice with a pen and paper was very much in alignment with the concept of the habit loop. I posited that the process of taking a moment to focus, reflect, and interact with the physicality of the wooden artifact at the beginning of the week could help in fostering a personal relationship between the device and the user and lead to better outcomes in terms of commitment.

From then on, the design centered around horizontal motion. To select the length of time, I initially hoped I could have the user slide a finger on one of the strings from left to right to control the interface, but soldering individual captors along the string was too complicated using DIY tools. I was able to keep the intention of this design by having the user touch the side of one of the lines to indicate which line they wanted to set the timer for, and then drag a finger along the front of the shelf to increase or decrease the number of minutes spent on a task.



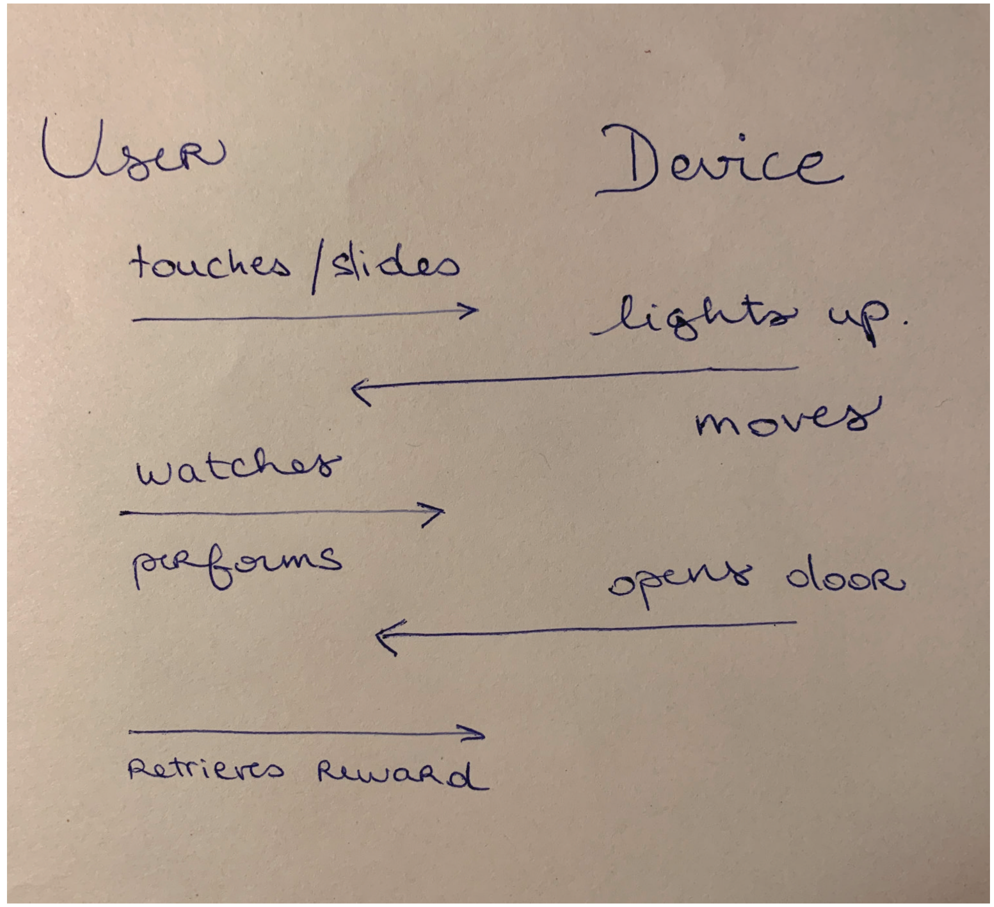


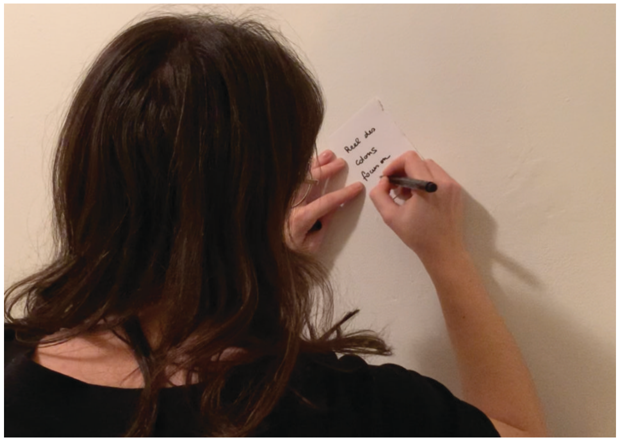
The reward box was placed on the right side of the artifact so that the experience moved from left to right in what is perceived in the Western world as the intuitive direction of time. The clothespins first travel from left to right one after the other, and then the reward box opens on the right side. This was also convenient because the numerous wires and micro-controller could be tucked away in the reward box and be hidden from view in the prototype.

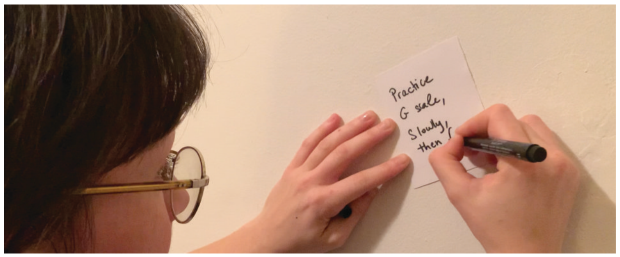
Finally, I settled on a horizontal strip of LEDs to perform all of the communication and feedback to the user. The LEDs on top of the lines are used to indicate the number of minutes set for each activity (one led per minute, except for the first LED which indicates 30 seconds). Four LEDS are dedicated as feedback (one for each line))so that the user knows which line is being configured. The two rightmost LEDs to the right indicate the current mode, either idle, setup or play. Finally, the LEDs on top of the reward box can also light up when all the activities are done as a double indication of completion. One significant advantage of using the programmable LED strips is that each LED can at different times serve different functionalities.

The linearity of the structure lent itself perfectly to double-up as an object that is common in most households: a shelf. By making sure the top surface of the wall-mounted artifact could support some weight, I achieved one of the main design requirements: that the artifact live naturally in the user's home in a way that does not distract.

Modes of interaction







The user writes down four activities using pen and paper. The activities are to be performed consecutively.

The user the presses the setup mode touch input. The device enters setup mode and the setup LED above the input turns on.

The user selects a thread line by touching one of the sensors at the right of the lines. The LED indicator for that line turns on.

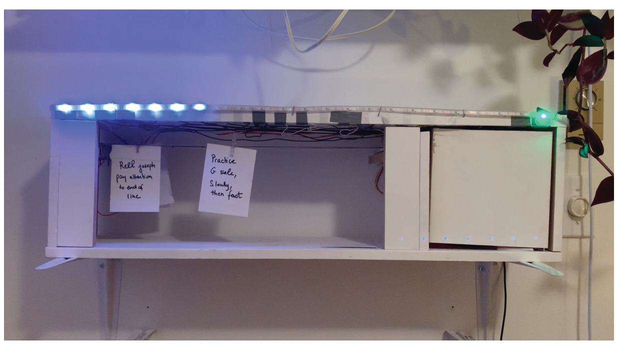
The user slides a finger over the time input touch sensors to select the number of minutes that they want to be spending on the activity that is being setup.

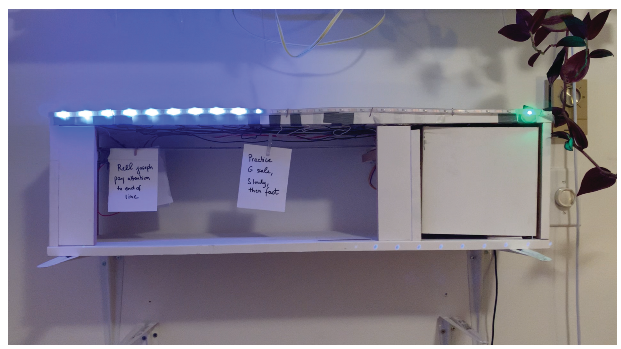
The user attaches the piece of paper to the line with the clothespins that are already hanging on the line.

The user repeats the process with each of the three remaining lines.

The user touches the play mode touch input to indicate to the device that they are ready to start.

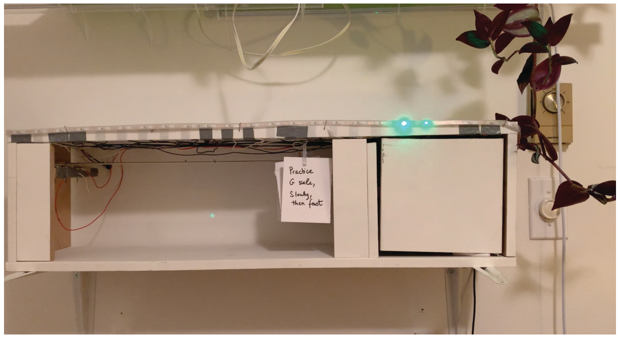
The user performs the activity as indicated by the first card.

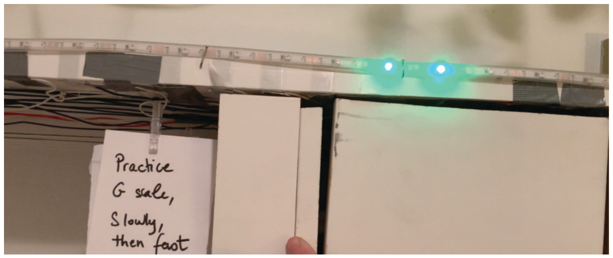




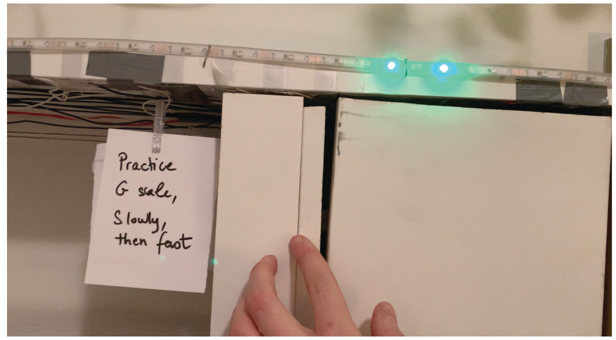
The device indicates to the user how much time is left on the activity both by moving the piece of paper to the right and by lighting up the time indication LEDs.

Each line's motor spins at a speed so that it takes the piece of paper the amount of time defined by the user to cross the length of the line.





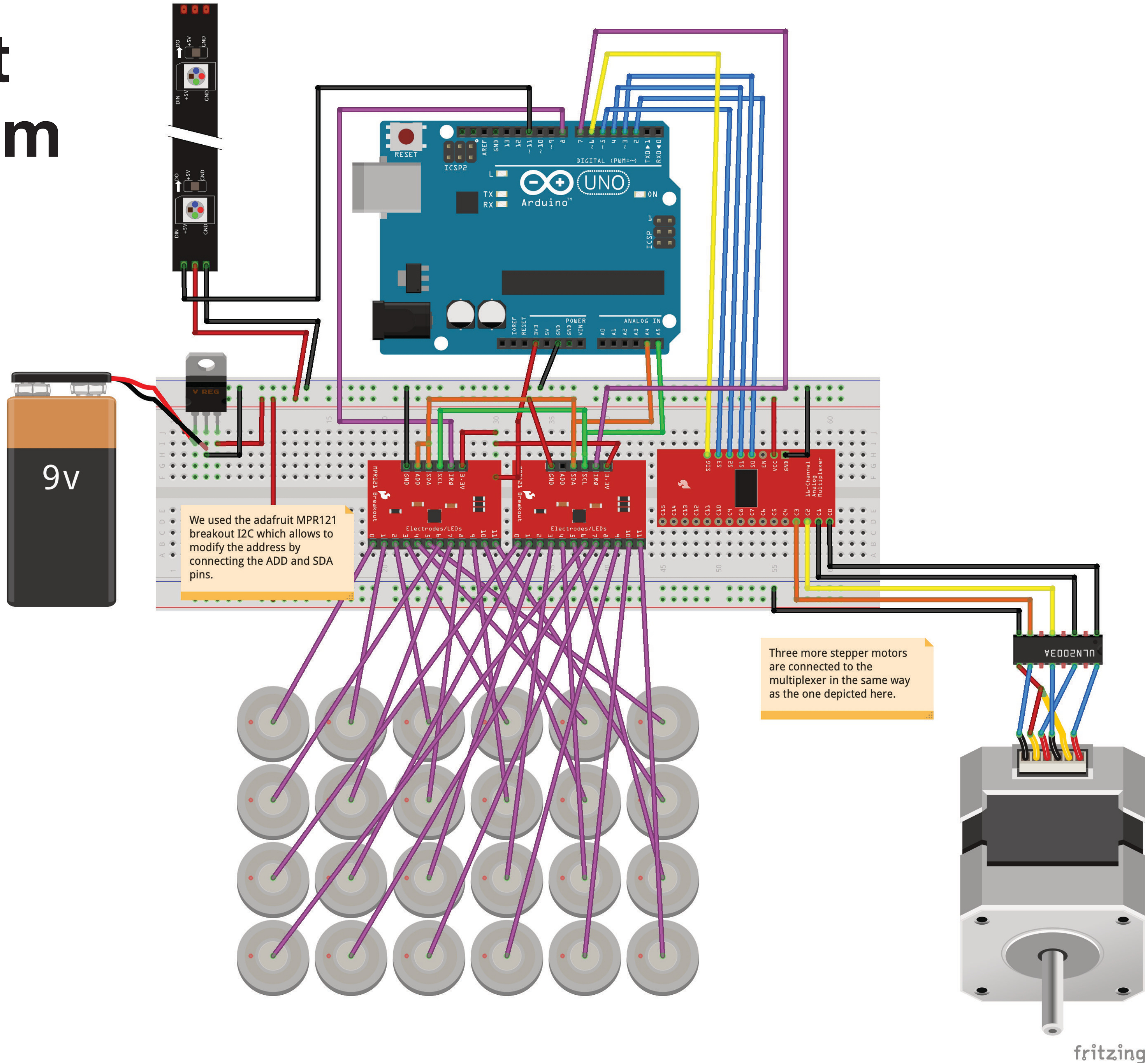
Once all four activities have been completed, the leds at the top of the reward box animate and the door opens.



The user opens the door to enjoy the reward.

As the user sees the device every day and is reminded to interact with it, they progressively automate their routine and get better at their practice.

Circuit diagram



Review of Electronics Used

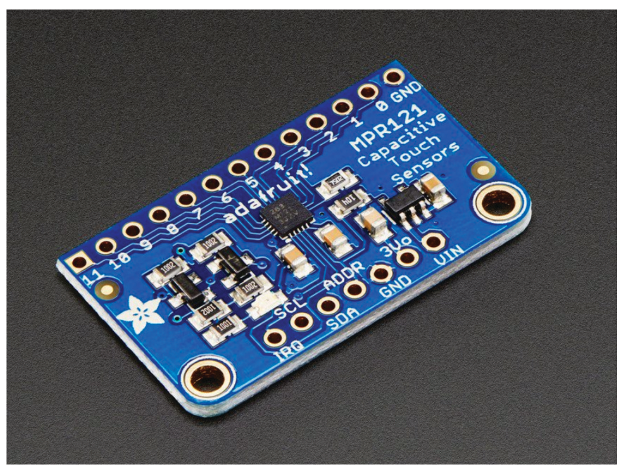
MPR121 12-Key Capacitive Touch Sensor Breakout

The user interacts with the device primarily through touch. The user touches the device to switch from idle, to set up, to play modes. The user also touches the device to select a line to set up and to control the amount of time to set each activity for. The technology of Capacitive Touch affords us the ability to detect touch without using protruding objects like buttons.

Because I wanted to accurately control a 17 point slider, I used two MPR121 capacitive touch sensor breakouts, which each allow for 12 touch inputs, which in the prototype consist of pieces of aluminum foil covered in plastic tape. The MPR121 boards communicate with the Arduino using the I2C protocol. This was ideal because IC2 uses device addresses to communicate, which allows for many devices to be connected to the same two microcontroller I/O pins. I used one breakout board manufacture by Sparkfun, and one manufactured by Adafrut. Luckily these devices worked well together, and I was able to easily change the address of the Adafruit device. I noted that these boards require a 3.5V power input and will break with 5V, and build the circuit accordingly.

28BYJ-48 unipolar stepper motor and ULN2003 Driver

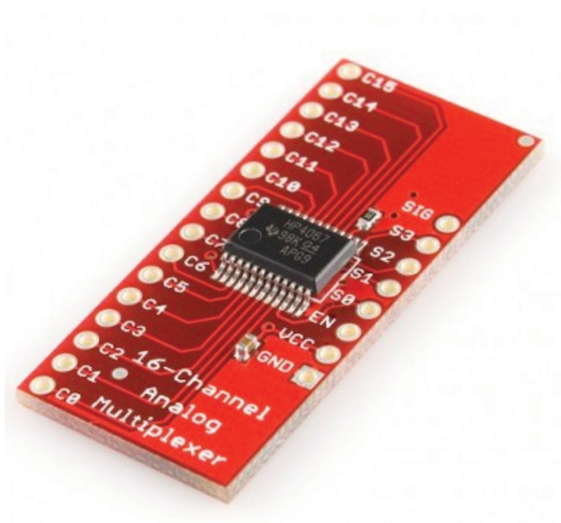
To control the rotation of the pulleys that hold the line, I needed motors. Stepper motors were the right choice because I was concerned with the precision of rotational speed and rotation amount. I chose the 28BYJ-48 stepper motors because they are cheap, they run on a standard 5V which I could easily provide using a voltage converter, and they are sold along with adapted drivers which makes running them straightforward.



16 channel Analog / Digital multiplexer

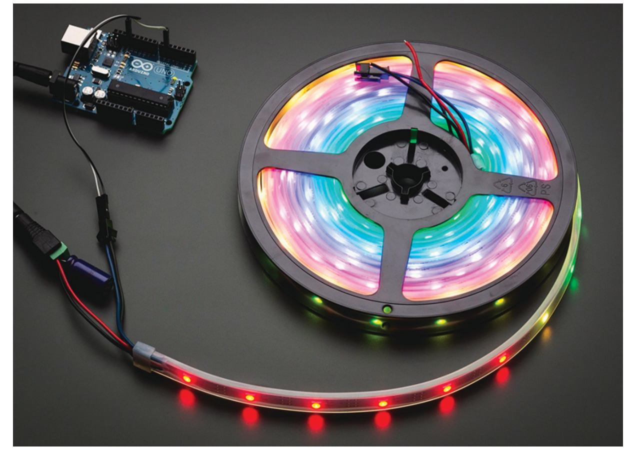
Each of the 12BYJ-48 moths requires four digital signals, as pulling up each of the outputs in a specific sequence is what makes the motor spin. I needed at least four motors, which would have meant using 16 pins on my Arduino Uno, an extravagance I could not afford. Instead, I coupled the four motors with a 16-channel multiplexer.

The multiplexer works by targeting a specific output pin using four wires to convey a binary address (0 - 15) and then sending a digital signal which is relayed to the selected pin. This means only one pin can be activated at once. This was not a problem in the case of my project because pin pins of the stepper motor are targeted sequentially, and because by design, the motors never need to spin at the same time. Had I needed simultaneous motion, I could have achieved the same result using a shift register. The logic of the multiplexer was simpler to understand so I chose the simplest option.



Adafruit NeoPixel Digital RGB LED Strip

This LED strip consists of 30 individually addressable RGB LEDs and only requires one I/O pin. It sports a clear library for targeting individual LEDs.



Solenoid motor

To create the latch for the reward box door, I obtained a 12V solenoid motor which affords linear motion without using any gears and linear rails. Solenoid motors require quite a bit more voltage than regular motors to induce motion, and I selected a 12V model because that was the voltage specification of the AC converter I had on hand and wanted to use for the project. I did not have time to implement the solenoid in this version of the project.

Process and prototype evolution

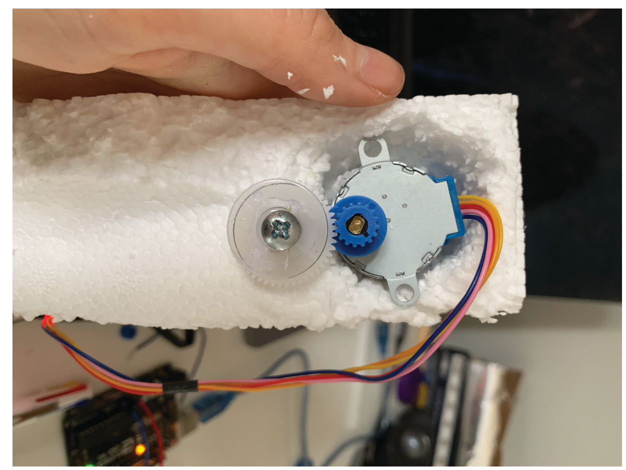
At the time of writing this document, a full-blown prototype partially or fully meeting all of the design considerations and intentions mentioned above is being finalized. It is only one in a series of many experiments with technologies, assembly methods, and materials.

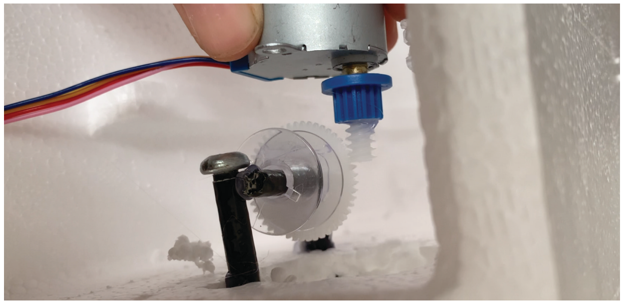
Designers prototype for multiple reasons, often as a way to showcase products to potential users and iterate based on their interactions. We are currently in a pandemic, and my access to physical persons is limited, so my prototyping focused not on testing on different users or communicating the idea, but on mitigating the risks associated with building a project with so many moving parts with a strict deadline.

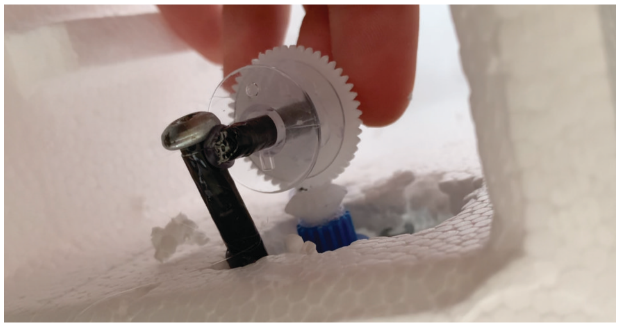
Having never worked with any of the technologies outlined above, I first needed to validate that they would individually function in providing the affordances they were selected for. I also needed to make sure I caught any missing parts ahead of time so that I had time to acquire them before the due date. Once each part had been tested and understood, I set out to build incrementally more involved versions of the prototype, treating each version as a minimum viable product, so that I would have something to show for my work by the end of the semester should any roadblocks come up. In this part, I retrace the history of the prototypes that I created and outline the difficulties that I encountered and the changes and compromises that I made to address them.

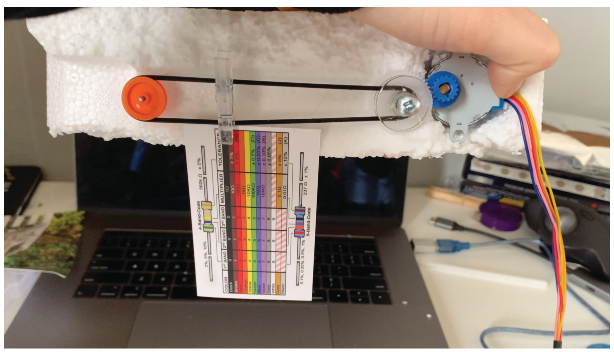
I first started with implementing a low-fidelity pulley system with a cardboard box, chopsticks, sewing bobbins, and yarn. While turning the chopstick with my hand, I visualized a piece of paper traveling along the wire.

I then built a higher fidelity prototype incorporating plastic hobby gears and a stepper motor, which I embedded in a polystyrene hold, and then another one using wood. This is when I became aware of what I felt could be the crux, or hardest difficulty, of the entire project: the plastic gears are tiny and need to match perfectly and consistently to control the line with precision. The line exerts a certain amount of force on the motor and gear combination, so the motor had to be sturdily embedded in the material holding it, which was difficult to achieve with basic home hardware tools. I tested a few gear combinations with no more success and assumed I would have to find a way of making the system more solid in later prototypes. This was a mistake, as I never was able to get the gears to align properly despite multiple attempts. This detour consumed a huge amount of time, when in fact modifying my design was a better solution. More on that later.

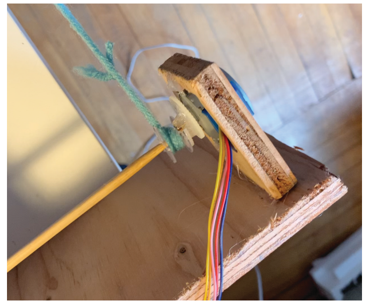


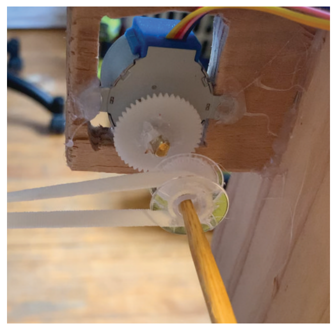




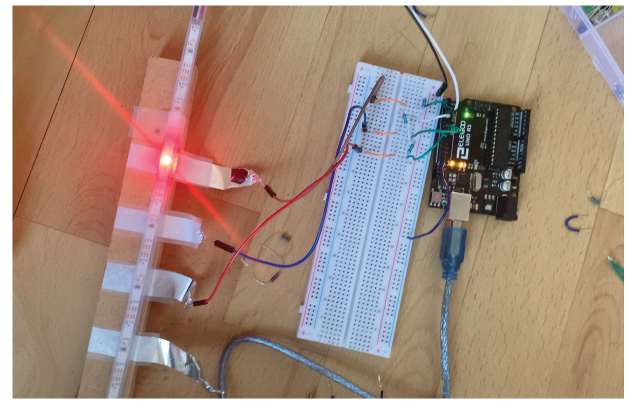


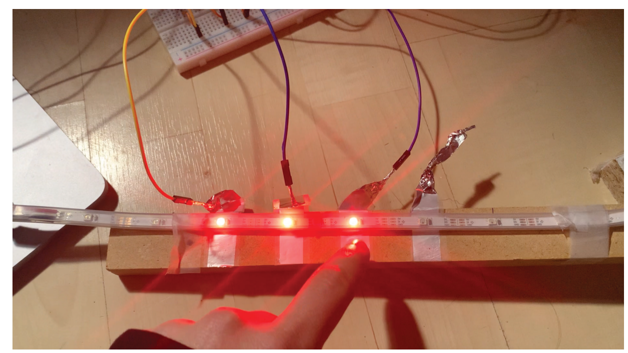
At this stage, I flagged another mechanical risk: The yarn and sewing bobbin did not have enough friction together to drive the line consistently. I tried several other materials to no avail and decided to come back to that problem later as I hadn't yet tackled any of the potential electronic difficulties.



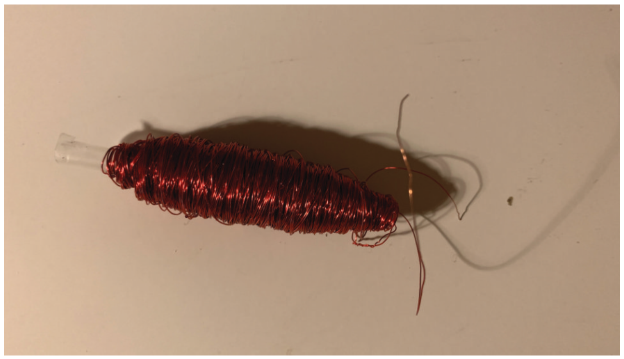


Eventually, I started focusing on the touch sensor strip, which I initially implemented with pieces of aluminum foil, large resistors, and the CapSense library. My goal for this version of the prototype was to get three touch sensors to when pressed, light up all of the LEDs on the Neopixel strip up to the index of the sensor. This proved easy enough, and it did reveal a problem that needed tackling: Each of the sensors required at least one I/O pin. I could not use a multiplexer or shift register to handle the timing logic of capacitive touch, so I asked for help from the course instructor who led me to discover the MPR121 boards.

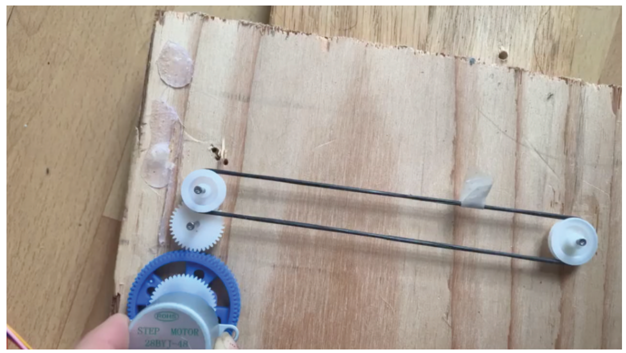




While I waited to obtain the capacitive touch devices, I attempted to prototype the door latch feature. I spent long hours painstakingly wrapping different lengths of magnet wire around tubes and straws and connecting the ends of the wire to varying voltage differences, but was never able to create enough of a force to move the metallic screws and axels I tried as latches. I eventually gave up and decided on acquiring a hobby solenoid motor.

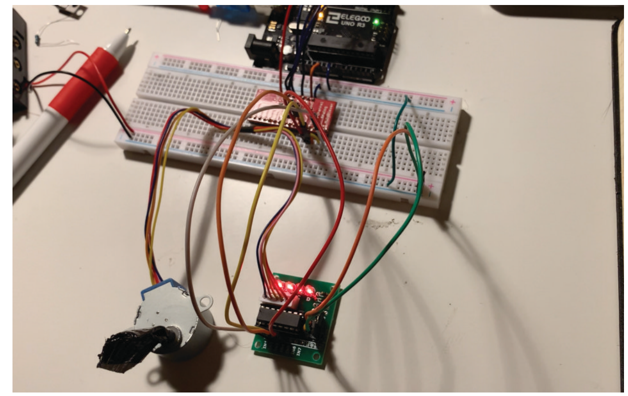


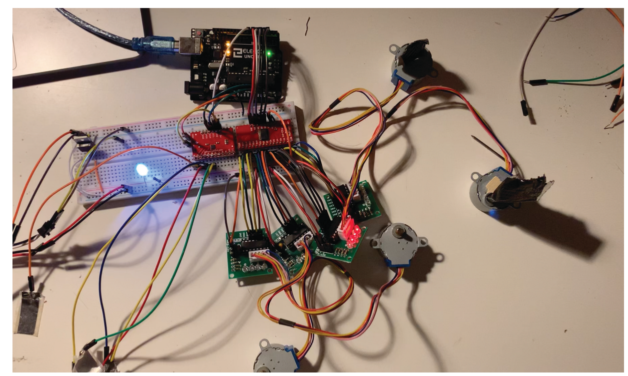
I then wanted to make progress on the logic for moving the line thread at specific speeds and for specific amounts of time. I wrote a simple program that, given the ratios of the gears involved, the pulley diameter, and the length of the line to travel, would consistently spin a stepper motor for a given duration so that the point at the start of the line would travel to the end of the line by the end of the exact imparted time. Having not yet found a sturdy way to hold the gears and motor together, this prototype consisted of me holding the motor against a teethed pulley and watching the piece of paper travel as expected.



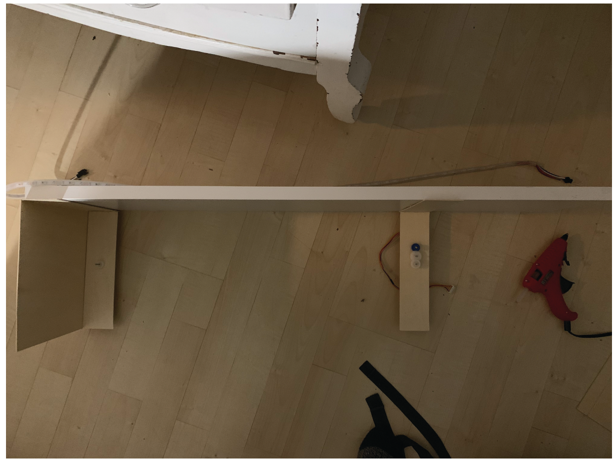
I put the functional prototypes together and was at that point able to set a duration using the capacitive touch sensors and Neopixel strip and rotate the motor accordingly.

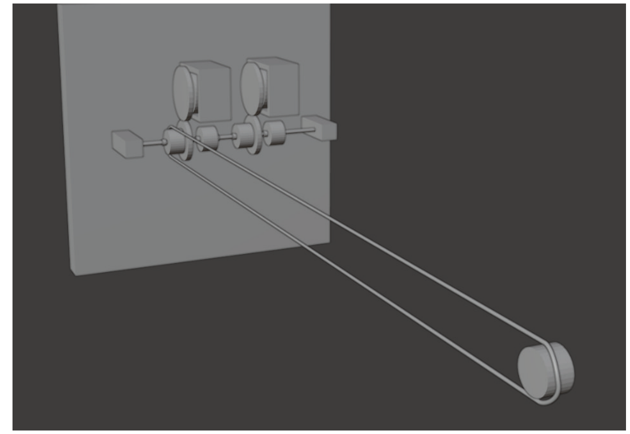
From one motor, I inquired as to how I could control four without maxing out the pins on my microcontroller and decided on using a multiplexer. I built a rapid prototype where the four steppers were controlled one after the other at a specific speed.



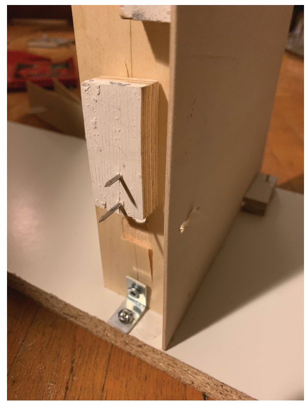


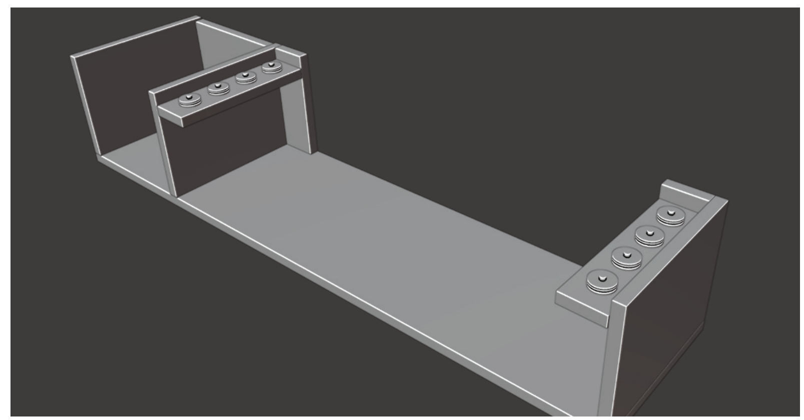
I was feeling increasingly worried about the mechanical and structural aspects of the project, so I devoted two days to building the wooden parts of the shelf. This was by far the most frustrating part of the project, as no matter what I tried, I was never able to get the moving parts positioned precisely enough for the gears to move consistently. Desperate, I asked for help from a mechanical engineer who pointed out that my design was overly complicated, and put me in a better direction. By rotating the motors so they faced up, I was not only able to use gravity to have the system hold in place, but I was also able to make do without gears entirely, which remove a lot of the uncertainty from the design. Relived, I drew up new plans and cut up pieces of wood to exact dimensions. I then secured the bottom part of the structure.



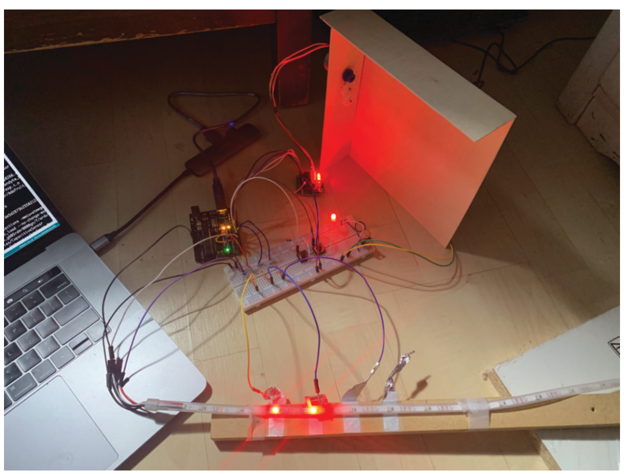


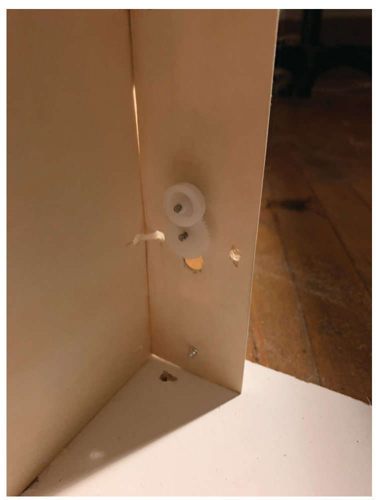
Original, non-functional design.



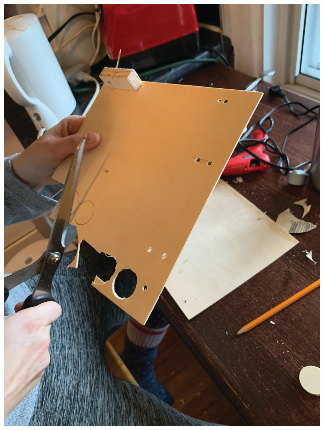


Updated design.



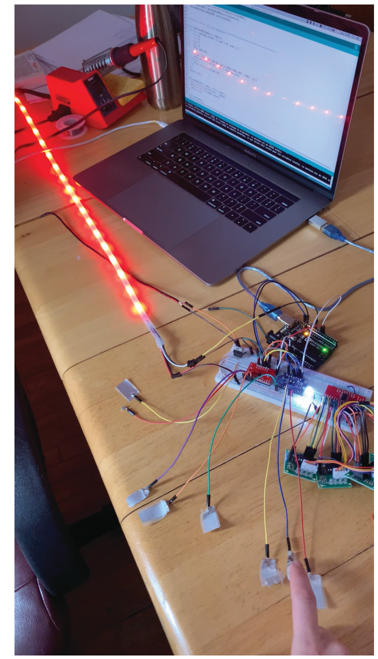
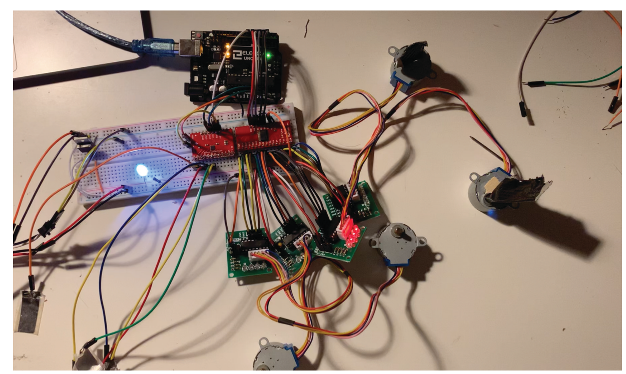


Seeing as my hobby gear set only included a few small pulleys, I decided to build custom pulleys out of thin wood sheets and hot glue. I attached one of them to the structure using a screw and forced-pushed the other on one of the stepper motors. The pulleys looked great, held onto the motor tight enough, and rotated freely around the screw, but the string kept getting caught in the grooves. To remedy this problem, I promptly filled out the inside of the pulley with silicon and waited for it to dry out.



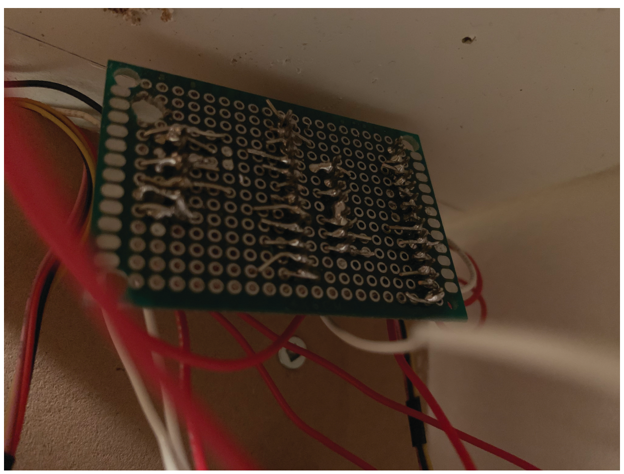


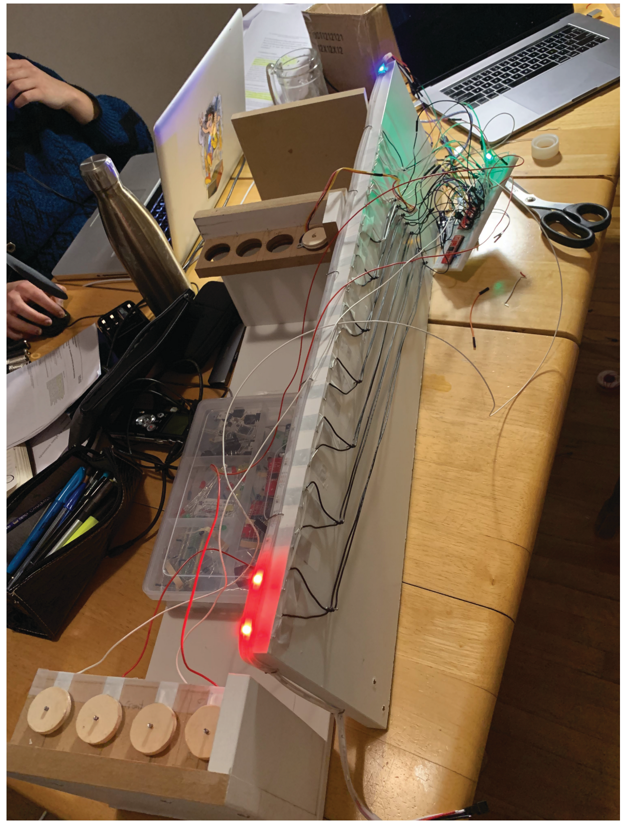

Having received the MPR121 breakouts, I then expanded the CapSense and Neopixel prototype to support 24 touch sensors. The prototype worked well when laid out on a table to I layered the front of the shelf with strips of aluminum foil which I covered with plastic tape. I then ran a wire from each strip to the breadboard and secured the wires with nails on the underside of the shelf.

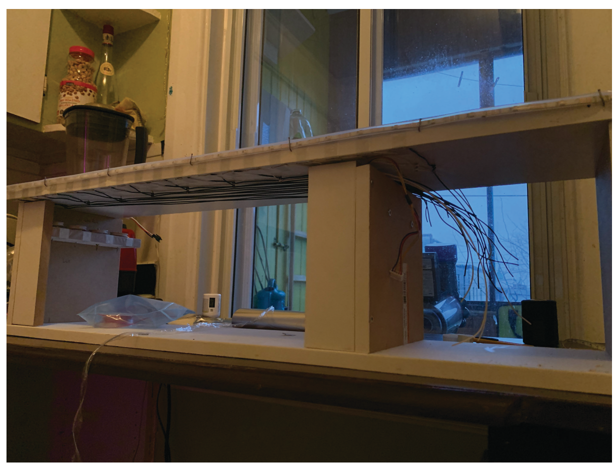



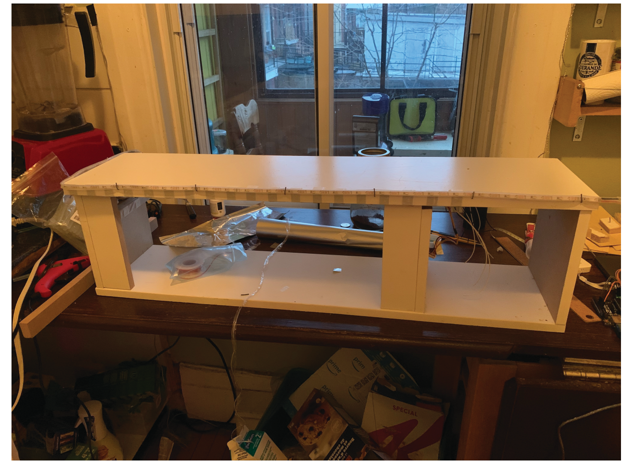
When I tried to integrate the electronic parts to the wooden structure to test this prototype, I realized that a large number of wires (24 for the touch sensor and 32 for the multiplexer and motors), and the awkward placement of wires on the underside of the shelf made it nearly impossible to do without disconnecting a few wires from the breadboard. When they disconnected, I was not able to re-connect them without taking the whole system apart. After a few disheartening attempts, I resolved to solder all of my electronic components solidly on a perf board.

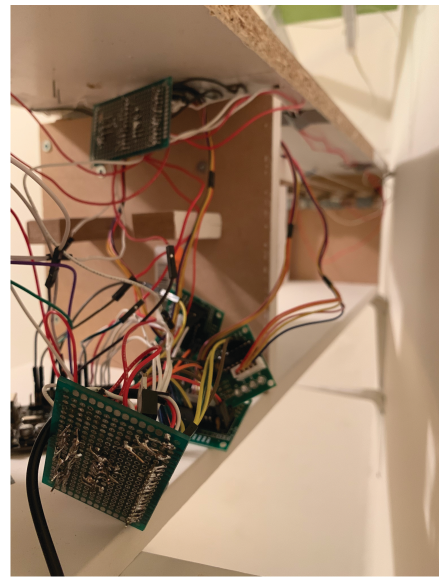
I am not sure this was the right decision because soldering everything together was extremely time-consuming and came with its own sets of issues: The solid-core wire I was using to connect the components turned out to be very fragile so that when I bent a part to solder one connection, a few other connectors would rupture and I had to unsolder them to solder them again.











Takeaways and looking to the future

While the current prototype satisfies the majority of my initial requirements, it is far from being a finished product. One of the betterments I would consider bringing to the artifact in the future is reducing the number of wires and replacing as many as possible with conductive paint or custom printable circuit boards. Currently, they are not only disgraceful, but they also risk often disconnecting, making the artifact unreliable for a user and frustrating for the designer who has to check each connection to identify the origin of bugs.

One necessary improvement to this iteration would be to support EEPROM storage of configurations so that the device could be turned off in between uses.

Using the artifact, also come to see that it could have been streamlined further to only use one modality, either light or movement. The pixels and the motor lines are inelegantly redundant and my goal was to convey as much information as possible with as little modalities of communication as possible. Not only is the redundancy unnecessary, but it also adds a huge amount of breakage risk and debugging difficulty, which caused me a lot of trouble. In future iterations, I would consider implementing only one of the modes at a time.

For the prototype only relying on motion, the line itself could be moved to indicate time and the clothespin could serve as a vertical marker on a horizontal scale. In the same concept, the line could spin so that the clothespin follows the finger of the user when they are using the Capacitive touch sensor.

For the prototype relying only on light, I would indicate progress with the rightward motion of the light emitted but the LEDs. To indicate the name of the activity, four cards of paper could be alternatively illuminated. This would remove a lot of the complexity of the project without reducing its value to the user. The artifact would be less prone to breaking and would take less space.

Most importantly, now that the prototype is realistic enough to meet the initial goals of the project, I would like to use it over time to see whether it does create a habit loop and serve its primary function of helping people form long-lasting habits.

This exercise demonstrated to me how easy it is to get carried away with making something work at the cost of testing the user-friendliness of a functionality. While we learn about how important it is to prototype and test iteratively, I only realized at the end of the process that the interaction for the user is jumpy and confusing. Setting up requires the user to look alternatively left and right, turning the head a lot, and inserting their hand in an uncomfortable place to select the lines. Had I not been so worried about getting the functionality to work, I would have spent more time making non-electronic prototypes and focusing on the form. This would have saved me a lot of trouble because I would not have had to implement some of the difficult features that turned out to be unpleasant to use.

Overall, the process was at times rewarding and at times excruciating. I learned one important lesson from creating this series of prototypes: the physical world is a lot less friendly than the digital world. Most of the time on a project is spent dealing with the impracticalities of the physical world, which dwarf the hazards of coding when it comes to complexity. In the future, I will consider this in my designs and simplify things from the beginning. My attachment to simple products that can with minimal modes of interaction support complex features has never been stronger.