Design Project 2 - Dexii

Design Team 3

Cornerstone of Engineering II: GE 1501

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Problem Definition:

For this design project, our team aims to create a device that can help improve the overall function and capabilities of the hand, especially for individuals who face struggles with hand dexterity, strength, and control. We want to design this product because of our identified need for an improved way for various populations to improve coordination and usage of the hand. The use of one's hands is vital to nearly all aspects of day-to-day life, but there is a large number of individuals including the elderly, those recovering from injuries, and even small children, whose inability to complete everyday tasks can be attributed to a lack of effective hand function. Therefore, we identified the need for a device that is able to help improve this lack of ability by training one's hand to improve functions including coordination and strength.

In defining our problem, it was important to address what exactly causes these functional issues, as well as the most effective ways to improve them. This meant first researching who most often struggles with these issues and why they occur. We looked into what capabilities and muscle groups are most commonly lacking in certain populations and what conditions cause this to occur. Additionally, we researched what types of physical therapies have been proven to be effective in improving these dysfunctions.

Our initial idea to solve this problem was to create a game that helped an individual strengthen their hand(s) and improve coordination. However, through various problem-definition techniques (Figure 1 and Table 1 below) we realized that the need we are looking to address could be solved by any intuitive physical therapy device, rather than specifically a game.

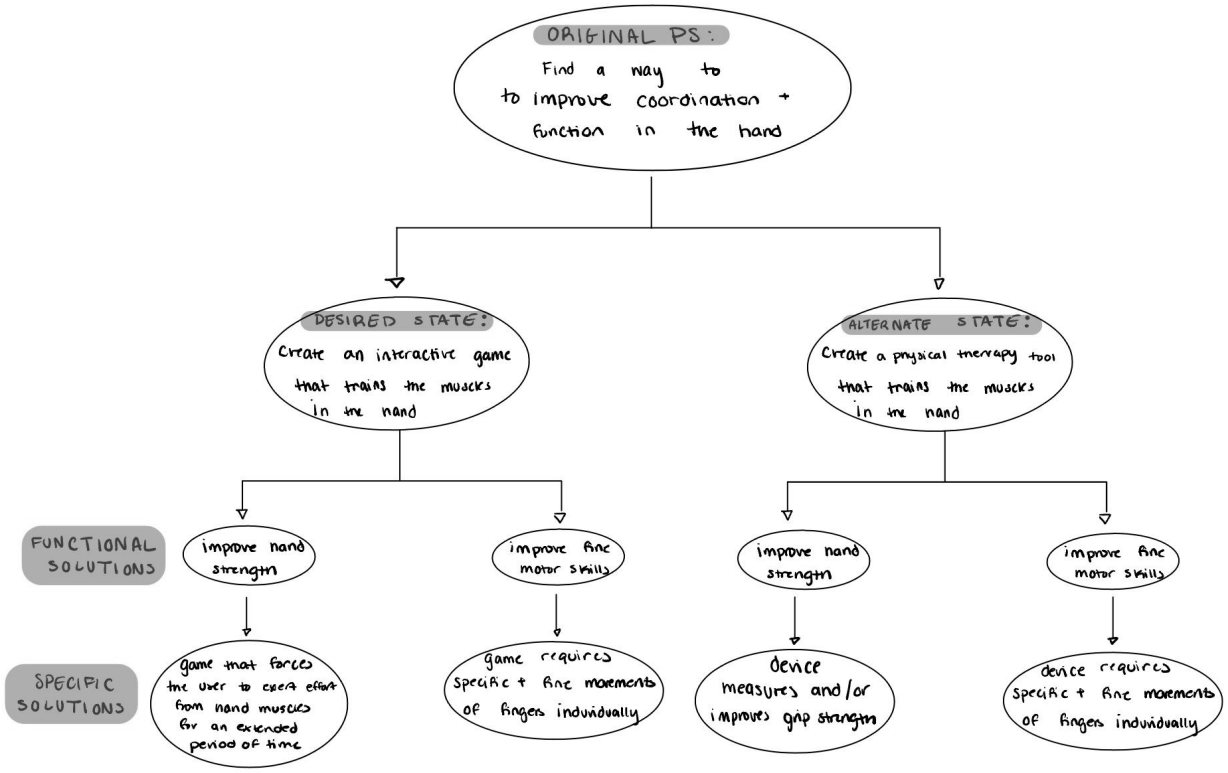


Figure 1, Duncker diagram problem definition; Diagram outlines multiple paths and creates multiple solutions, including solutions that do not satisfy the desired state. This diagram helped identify high-priority areas during the design stages of our project. (Team 3, 2024)

	Is	Is Not	Distinction	Possible Cause
What	Inefficient or under-performing hand function	Specific to one singular function of the hand	Versatility and range of needs and of applications	Dysfunction related to strength, coordination, dexterity, etc.
Where	In the hand and forearm	Specific to any one set of muscles, tendons, or joints in the hand or arm	The broadness of what anatomical areas must be addressed	The different parts of one's hand and arm work together, so dysfunction in one affects the function of all
When	Any age group or population that requires improvement in hand function; could be	Confined to one population, age group, etc.	Versatility and range of needs and of applications	Since hand function is vital to day-to-day life, 'dysfunction' can range in severity and affect many

	expanded to all people			populations
Extent	Can vary in extent based on an individual's situation (ie. injury, the general decline in function, etc.)	Specific to one type of injury or dysfunction	Versatility and range of needs and of applications	Dysfunction can be caused by a range of conditions and can thus vary in severity

Table 1, KT problem analysis matrix; Matrix was created to aid in the identifying process of potential causes of our identified need. (Team 3, 2024)

These problem-definition techniques helped confirm that while there are alternative options, an interactive game could help address our need to improve hand function. Therefore, our current team goals involve designing and creating this type of device. However, depending on the progression of prototyping and design work, it might later become clear that an alternative physical therapy device is more effective or practical.

The initial function of our design was to improve the overall function of the hand. Additionally, our original objectives included creating a device that could be used for both the left and right hand, was ergonomic and comfortable for the user, and included a game and interactive interface to incentivize use. Additionally, we wanted our design to be easy to transport and appeal to children and adults alike. Our design must also be able to be developed and prototyped for under one hundred dollars while limiting plastic use and overall environmental impact.

Background Research:

One of the audiences that experience struggles with hand function we wanted to address is the elderly. As people age they often experience a decrease in the strength, accuracy, and overall function of the hand. This is often due to metabolic and skeletal diseases commonly seen in the elderly including osteoarthritis, rheumatoid arthritis, and osteoporosis. Additionally, malnutrition, decreased physical activity and minimal exercise are commonly associated with aging and can contribute to this decline [7].

Lastly, degenerative diseases such as Parkinson's which is significantly more common in the elderly than other age groups, can contribute significantly to hand dysfunction [10].

In order to resolve these control and strength issues, there are a few key areas of the hand that are addressed with physical therapy. The first focus is an individual's prehension, which is the ability to grasp objects, which is often measured by a hand-grip strength test in order to predict functional limitations and disabilities. This ability is heavily related to the muscles in the hand as after the age of sixty, people lose a substantial amount of the muscle fibers in their hand, and subsequently a significant amount of their grip strength. Another area of decline is tensile strength, which is the maximum strength a material, in this case, tendons in the hand, can bear before breaking when stretched or pulled. In old age, the tensile strength of humans can decrease by up to fifty percent. Lastly, it has been proven that about twenty percent of motor axons in the hand are lost in old age. This part of the hand is responsible for the conduction of nerve impulses and its reduction results in less control of the hand [7].

These struggles and dysfunctions can be detrimental to an individual's life, however, it can be improved upon by simply using and exercising the muscles in one's hand regularly. People who exert a significant amount of time and effort into consciously exercising their hands generally see improvements in hand dysfunction. This is supported by the fact that musicians and people who play instruments for a majority of their lives face fewer struggles and dysfunctions in the hand [7].

Another audience that experiences struggles with hand function is individuals who are recovering from hand injuries. In injury rehabilitation, some of the main areas of focus are range of motion, sensory reeducation, and strengthening. Focusing on a patient's range of motion decreases the chances of joint contracture, which is a progressive weakness and reduced mobility in joints that is associated with inflammation or arthritis. Additionally, hand injury patients often face hypersensitivity that causes severe pain while completing normally stimulating tasks. This can be prevented by therapies that re-establish stimulation early on. Lastly, post-injury the hand is generally weaker due to lack of use. Therefore, therapies that increase muscle mass in the hand are ideal as they can help increase strength and prevent any disorders that could result from an injury. [12]

The last audience we found that struggles with hand dexterity and control is developmental-aged children. Children cannot master writing and many other essential motor skills without proper muscle development. In order to perform these tasks at a high level, children need proper muscle control, patience, judgment, and brain coordination [2]. It has been found by past studies that children excelling in attention and fine motor skills experience high achievement later in life. This same study identified a motor-cognitive dependency, indicating that both sides of the brain are active when motor and cognitive activities are performed independently. These results provide a strong basis that early motor skill development will not only lead to heightened hand skill, but also to higher rates of cognitive development [1].

There are many current activities directed toward children, which utilize developmentally appropriate experiences to improve fine motor skills. These current tasks include squeezing, matching, sifting, pressing, and other small task games [2].

Patents:

In the research stage, we found a few key patents and products that are relevant to the problem we aim to address. The most common patented design we found was a hand exercising device featuring independently activated spring buttons. These devices, such as the “Finger, Hand, and Forearm Developer” [4], the “Adjustable Grip Developer” [5], and the “Hand Development System" [6] (Fig X) are intended to improve hand strength and motor skills of the user. While this technology successfully serves its purpose, the simple design does not maximize the users use of both cognitive and motor skills. Another drawback of these designs is the fact that the device is not incentivising for the user, ultimately reducing the effectiveness as it would not be utilized as much.

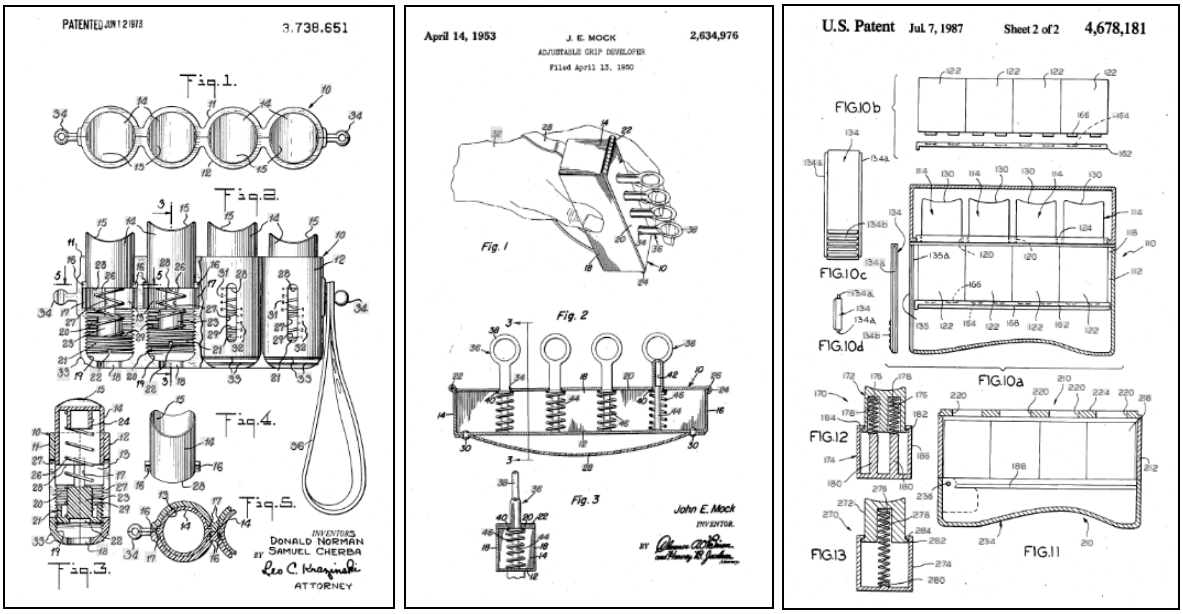


Fig 2, Motor Development Patents; Pictures of patents similar to our intended design that feature a spring-loaded button pressing feature to improve motor skills (Norman, Mock, Ditsch, 2024)

Other patents investigated include the “Game Panel Simulator” (Fig X), developed by the Department of Neuro and Pathopsychology at Moscow State University [3]. This device directs its focus towards restoring fine motor skills, visual-spatial memory, and intellectual activity in patients of a neurological clinic. This device is meant to be used in neurorehabilitation and for restoration. The device features holes with corresponding cylinders which can be used to play a variety of games that utilize motor skills. The disadvantage of this design is that it is mainly intended for group exercises and doesn’t feature many games that allow individuals to restore fine motor skills without a partner. Another drawback is the sheer size of the device, as it requires a large flat surface to be played on.

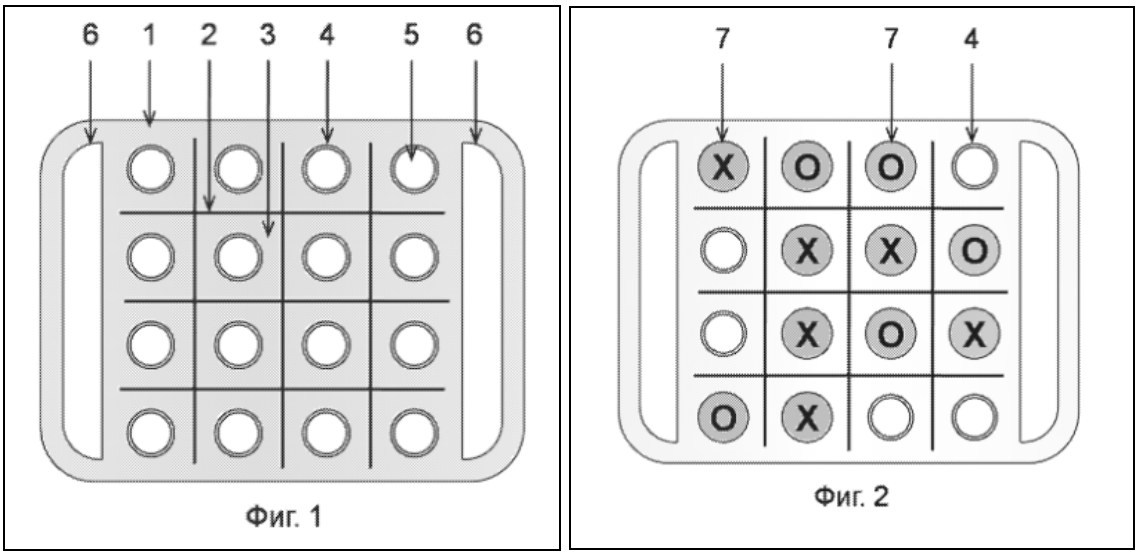


Figure 3, Neurorehabilitation Motor Restoration Device; Pictures from the patent of the game panel device which provides patients a means to play a variety of games working to restore and develop fine motor skills (Селявко, 2024)

In addition to patented products, many current physical therapy techniques use devices that aren't invented for the sole purpose of hand rehabilitation. For example, to improve strength, hand exercises are completed with stress balls and silly putty. These methods help build strength, grow muscle fibers, and focus primarily on hand dexterity. Additionally, exercises that involve stacking coins and pinching clothespins are often used to help improve coordination and fine motor skills [X]. In general, current methods emphasize the conscious use of muscles in the hand in order to improve upon or gain back control, coordination, and strength.

Value Sensitive Design:

"We are guided by our core values - Inclusivity, Accessibility, and Impact, as well as our desire to improve the lives of people spanning all capabilities and age groups"

Figure 4, Values Statement; The values our team plans to prioritize in the design and production of this device. (Team 3, 2024)

As stated in our value statement above, one of the main goals of our device is for it to be inclusive and accessible. This means being able to be used by people of all ages, from young, developmental-age children to the elderly. Additionally, being inclusive and accessible means the design should be as cost-effective as possible in order for the device to be able to be distributed at a low cost to the user. Our last value is impact, which relates to both how our device impacts the user and how it impacts the environment. We want to create a device that will positively impact the user and improve their life in some way, shape, or form. Additionally, we want to keep in mind our environmental impact with this project, which means being mindful and limiting the use of harmful and potentially non-recyclable materials.

Our project contributes to improving hand function in individuals who struggle with day-to-day tasks. This is a social problem, as it affects the lives of the users rather than the environment. By helping people train the strength and coordination of their hand(s), our device helps decrease these struggles and improves the ease of these tasks.

This problem can range in significance depending on the individual. Some individuals might have extreme difficulties using their hands that impacts every aspect of their lives. In this case, our device would be extremely impactful in improving their access to various everyday tasks and activities. On the other hand, a user might have adequate use of their hands but want to improve the control and strength of their non-dominant hand. In this case, this ‘problem’ does not heavily impact their life and everyday tasks in a significant way.

Initially, the idea behind our device was meant to address adults, specifically people with hand injuries or declining function. However, upon research, we discovered that this area of physical therapy could also address developmental issues among young children. As previously described, the accelerated development of fine motor skills among young children is associated with advantages later in life. This population is not necessarily in more need of this type of device, as there are other commonly used devices and toys that help address fine motor skills among children. However, using the resource that is our device to address this population would be beneficial as it would positively impact more people.

In terms of technical successes, ideally, we will be able to create a functioning device that is able to display and run the programmed games. On the other hand, in terms of the social issue the device is meant to address, success is slightly more ambiguous. It is hard to measure the impact of a device of this nature. However, if the design was able to be manufactured in larger quantities and distributed to the intended audiences it would be able to serve its intended purpose successfully. Additionally, if in testing, we are able to prove that our device does improve the function of the hand, it would be considered a success.

In terms of ecological issues, the main problem our device concerns is the environmental impact of the materials used. As described in our values statement, environmental impact is important to us as a team and therefore we aim to minimize the impact of our device as much as possible. Many of the materials and parts that are available to us involve various types of plastic. This specifically includes PLA from the 3D-printing material and acrylic to be used in laser cutting. These materials are more easily recyclable than other types of plastic, but the means to do so are expensive and require specialized facilities and machinery. Therefore, these materials are often not properly recycled in practice. These circumstances are out of our control as they stem from the structure of the recycling industry. Additionally, we are limited by our resources and the materials available to us. Therefore, our goal is to simply limit the amount of PLA filament and other hard-to-recycle materials in our design.

As previously discussed, in order to create the impact we intend our device to have, it must be manufactured at a larger scale and distributed to consumers. This would require a design that is efficient to the manufacturer, meaning it is made of materials that are relatively easy to source and the design is as simple as possible in order to avoid errors that might occur in a large-scale production.

The device we intend to make is more technologically sophisticated than other forms of physical therapy for the hand. Many physical therapy routines for hand rehabilitation use objects and devices that do not require power or any type of computer aid. While these methods of addressing the problem are ideal in terms of simplicity, these devices are often only able to address one aspect of hand function. This means that with traditional physical therapy devices, in order to improve upon control, coordination, and

strength, multiple devices and methods must be used. However, our design deviates from that as it is able to improve and address multiple aspects of hand function in one design.

Final Problem Definition

Problem Statement: Design and create a device that improves hand function, specifically coordination and strength. The device should be ergonomic, include a game and interactive interface, and should be able to be used with both hands. Additionally, the design should be easy to transport and appeal to users of all ages. Lastly, the device should be developed and prototyped for under one hundred dollars and should minimize the use of materials that are harmful to the environment.

Figure 5, Problem Statement; Refined problem statement for the design project (Team 3, 2024)

Methodology:

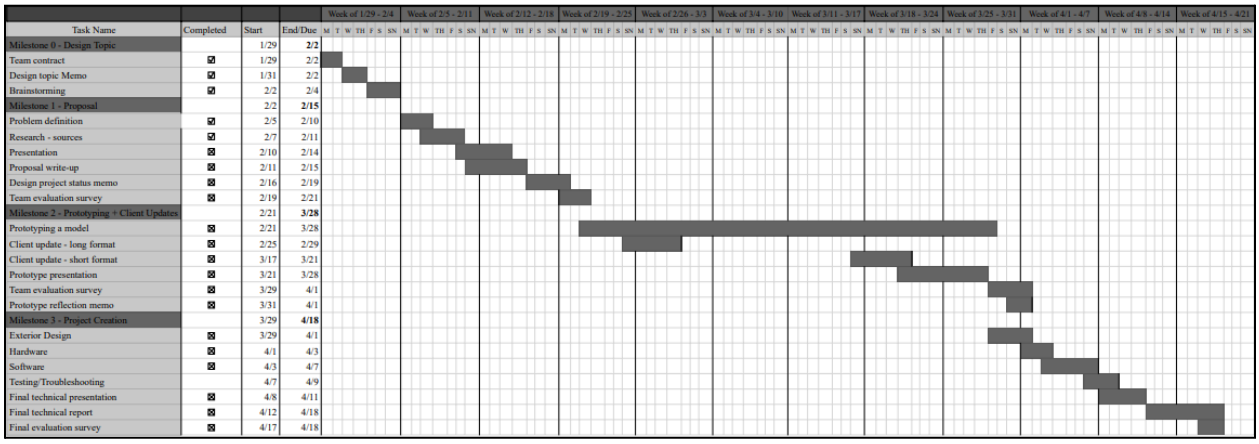
To successfully achieve all of the required tasks and desired objectives of this project it will be essential to optimally divide the workload between team members. In order to make the work more manageable, the course of the project was divided into four milestones by way of a Gantt chart (FIG X). Milestone 0 is already completed, with its main objectives being to establish the design team environment and begin brainstorming. Milestone one was directed towards the proposal section of the project, focusing on research and presentation of the proposal. Throughout this milestone, certain mental blocks arose during idea generation. The team used methods such as brainstorming and C-sketch to overcome these blocks and determine the most desired outcome. The second milestone involves developing a prototype and working with the client to ensure satisfaction and timeliness. This milestone will consist mainly of physically prototyping the device to create a rough model of what our design will look like when complete. The third and final milestone is the creation of the final product, however, this milestone requires a more thorough breakdown as it will require completion in a small amount of time.

For this final milestone, we will look to play to the individual strengths of each team member by dividing the work into four main tasks. The first task involves constructing the exterior design for the device. This will be achieved through the use of digital software such as AutoCAD and SolidWorks, in unison with laser cutters, which will be available for us to use at FYELIC for no cost. The proposed material for the exterior is acrylic, as it presents a sleek, cost-efficient, and environmentally friendly alternative to 3D-printed plastic. The exterior will be constructed so that the inner workings of the device can be easily accessed at any time throughout completion.

The second task prioritizes the internal hardware of the device. The materials used to construct the hardware will be provided by FYELIC as well as the SparkFun kit, both of which will require no cost. These hardware materials will include a redboard, breadboard(s), switch, potentiometer, RGB LED(s), buzzer(s), resistor(s), jumper wires, LCD, and an on/off switch. More materials may be required as the project goes on to ensure objectives are met and the team will construct the hardware in an organized manner in case issues arise that require the hardware to be altered.

The third task will consist of the device's software development using the Arduino IDE. This sub-task will involve constructing and coding the games for the device. The games will involve a level-based design with various games and difficulties as the levels climb higher and higher. The code will require on top of the game interface, the correct communication and output to the LCD display and buzzers for the user interface. The user interface will prioritize simplicity and entertainment, to play to the desired audiences. In the code, this will be achieved through a number of functions to ensure modularity in the programming design. This modularity will be important as the software will require the most troubleshooting, leading to the next task.

The fourth and final task of the project creation involves final troubleshooting and testing. This will require the device to be used and evaluated to see if all design objectives were met. If there turns out to be issues at this stage we will be required as a team to adapt quickly, reverting back to the beginning of the engineering design process. We will have to make adaptations and additions to the design in a timely manner to reach the final desired outcome and satisfaction of all team members, as well as the client.



Task Name	Completed	Start	End/Due
Milestone 0 - Design Topic		1/29	**2/2**
Team contract	☑	1/29	2/2
Design topic Memo	☑	1/31	2/2
Brainstorming	☑	2/2	2/4
Milestone 1 - Proposal		2/2	**2/15**
Problem definition	☑	2/5	2/10
Research - sources	☑	2/7	2/11
Presentation	☒	2/10	2/14
Proposal write-up	☒	2/11	2/15
Design project status memo	☒	2/16	2/19
Team evaluation survey	☒	2/19	2/21
Milestone 2 - Prototyping + Client Updates		2/21	**3/28**
Prototyping a model	☒	2/21	3/28
Client update - long format	☒	2/25	2/29
Client update - short format	☒	3/17	3/21
Prototype presentation	☒	3/21	3/28
Team evaluation survey	☒	3/29	4/1
Prototype reflection memo	☒	3/31	4/1
Milestone 3 - Project Creation		3/29	**4/18**
Exterior Design	☒	3/29	4/1
Hardware	☒	4/1	4/3
Software	☒	4/3	4/7
Testing/Troubleshooting		4/7	4/9
Final technical presentation	☒	4/8	4/11
Final technical report	☒	4/12	4/18
Final evaluation survey	☒	4/17	4/18

Figure 6, Gantt Chart; This chart was constructed in order to plan and timeline the work required to achieve the objectives alongside the time restrictions (Team 3, 2024)

For the prototyping and project creation sections, the group will work together to develop our combined idea of the final product. However, with each task having a specialized skill attached to it we have decided to delegate each team member to lead one section of the design. The leaders of each section can be seen in the below table (Table X), these members will work to facilitate each task in a timely and productive manner.

Task Name	Team Member (Assigned)
Exterior Design	Meg
Hardware	Anjali
Software	Dom
Testing/Troubleshooting	Chaimaa

Table 2, Task Leaders; This table assigns each member of the team a task that plays to their specialized skill set to act as the lead on (Team 3, 2024)

Initial design sketches (Fig X) were made by each member of the team and all focused on creating a device to improve the user's hand dexterity and fine motor skills. These devices all feature a common aspect of utilizing the pressing activity in combination with a trigger event to prompt the user's hand development. What differs between these devices is the focus on multiple hands in comparison to a singular hand, as well as the mechanism intended to trigger the pushing of the button from the users.

These simple design sketches helped the team avoid mental blocks during the brainstorming stage and create various designs to pick productive components from each.

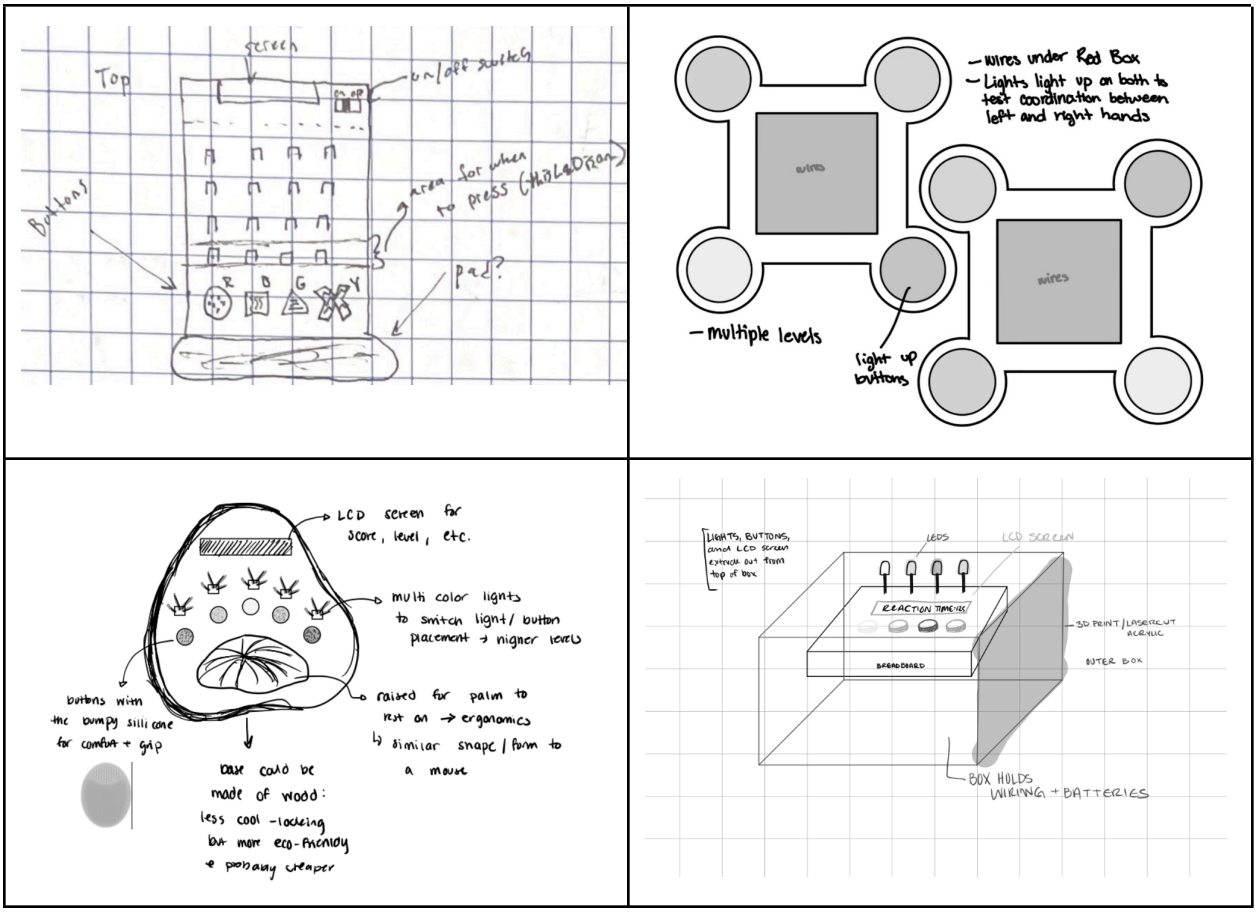


Figure 7, Initial Sketches; Each team member's initial design sketch of their design vision (Team 3, 2024)

From our initial sketches, we decided on our initial design sketch which can be seen in the following figure (Fig X), and works to successfully achieve the design objectives. Within the design, it can be seen that the intended design will feature ten buttons, for each finger, to be pressed in accordance to the game/level being played. Each button possesses a corresponding LED, placed directly above the button. Initial proposed games include a memory type game and a game to test reaction time, prompting the user to push the button within a certain time interval after the light is triggered on. The design features a fun, visually appealing exterior design as well as hidden internal hardware. On the top of the design, the

LCD screen is situated to display the information back to the user. The design features padding for the user's hand/wrist area to make the design ergonomic and comfortable for the user. The design of this device works to ensure versatility, comfortability, and satisfaction. Although this device may be changed during future stages, we believe that this initial design will provide a good foundation for the rest of the project to build and develop off of.

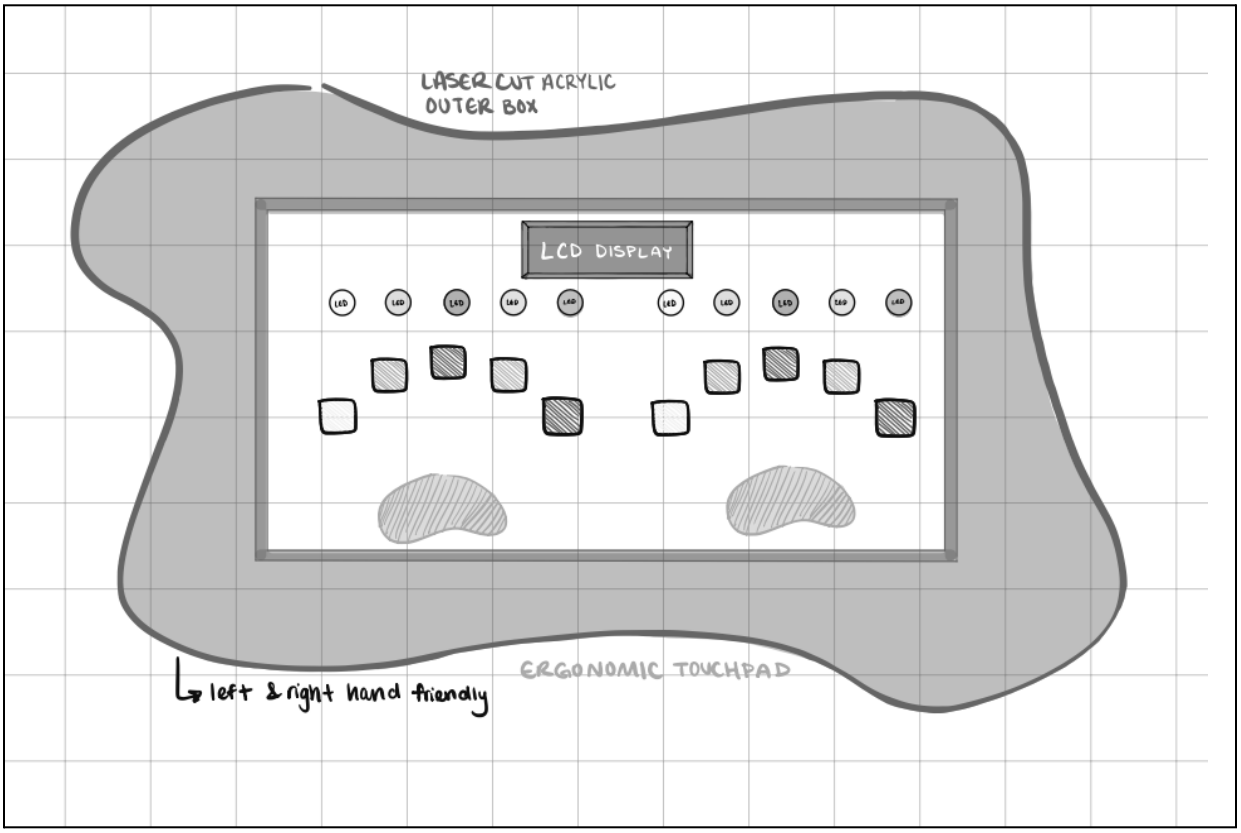


Figure 8, Combined Initial Sketch; First conceptual drawing of what the design could/will look like to build off and develop as the project progresses (Team 3, 2024)

Expected Results:

In terms of potential cost analysis, there are very few elements of our proposed design that would require money spent, as 3D printing is a free service provided by FYELIC and we already own Sparkfun kits. We do intend to use the laser cutting service at EXP which will likely cost $15-20 dollars maximum.

The main intended benefit of our device is to improve the user's hand dexterity. However, a risk of this proposed design is the impact of the plastic used in our device on the environment. We will have to be mindful of the amounts of plastic we use in our design, as we are limited with the resources we have and the finite cost-effective plastic recycling options for PLA filament and acrylic plastic.

Similarly, the major ethical implication of our proposed design is the environmental impact of our device. Our design features 3D printed components, an acrylic plastic body, and plastic sparkfun elements. While PLA filament and acrylic plastic are actually among the more sustainable plastics, they require a special industry-grade recycling center in order to effectively be recycled. This is important to consider, especially in large-scale manufacturing productions. However, we are limited by the scale of this project, so we do not have an identified method to recycle the plastic element of our design.

Our design ideas were created with the goal of offering a simple and easy-to-use method to strengthen one's hand muscles to improve their hand dexterity and hand-eye coordination. We are currently aiming to implement this device to be easy to use and highly transportable. As our design is compact and simple, the device only requires a dry, flat surface to rest on, and battery power to function. This device can be used in most indoor environments, granting the user freedom to use our product more frequently.

Our design will be implemented through the use of a small hand-sized device, which the user will interact with through the use of lights, buzzer sounds, and LCD screen, and pushing five buttons. The games will be programmed to challenge the user's hand dexterity, focus, hand-eye coordination, and patience. Ultimately, we are eager to begin designing, prototyping, and constructing each individual component of our proposed device and look forward to maneuvering our way through the engineering design process in full swing.

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