Total Control: Accessible Gaming Controllers

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Abstract

Gaming can improve cognitive function, reduce brain fog, and slow the neurodegeneration rate, presenting a promising avenue for enhancing mental well-being. This potential holds particular significance for disabled individuals, as video games offer a means to mitigate the heightened prevalence of mental health issues within this population. The interactive and engaging nature of gaming has been shown to foster a sense of accomplishment and social connection, thereby addressing the isolation often experienced by disabled individuals. Furthermore, the immersive environments of video games can serve as therapeutic outlets, aiding in pain distraction and stress reduction.

Despite the widespread popularity of gaming across diverse age groups, the journey remains arduous for disabled gamers who continue to confront substantial accessibility challenges. The existing disparities are multifaceted, encompassing factors such as the high costs associated with acquiring specialized gaming devices and peripherals tailored to specific disabilities. The lack of standardized accessibility features across games further compounds the issue, hindering many disabled individuals from fully participating in the gaming experience, resulting in further financial repercussions. It is imperative that strides be made to address these challenges and promote inclusivity within the gaming industry, ensuring that the potential therapeutic benefits of gaming are accessible to everyone, regardless of their physical or cognitive abilities.

Background

Multiple Sclerosis (MS) is a neurodegenerative disease where the body's immune system attacks the myelin sheath of the nerves. Attacking the myelin sheath means that the efficiency of nerve signaling is decreased (Cleveland Clinic), causing weakness in the limbs, a lack of coordination, and cognitive problems (Mayo Clinic). This disability, along with many others, limits an individual's ability to play and enjoy video games.

Despite being a common leisure activity across multiple age groups (Malone et al. 1), 66% of disabled gamers report that they struggle with accessibility barriers that limit their ability to game (Scope) with 30% referencing affordability as the barrier and another 22% reported a limited availability. Due to this barrier, two in five disabled gamers have purchased games they are unable to play with approximately 14% unable to return the game (Scope). This means that disabled people are losing money resulting from a lack of accessibility.

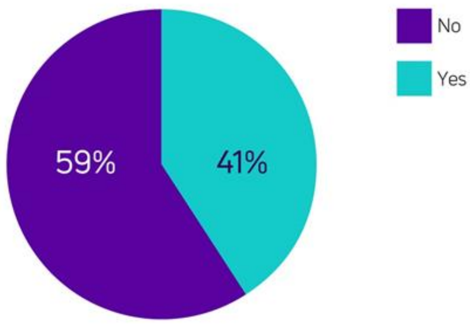

Figure 1: Graphed results of a question, "In the last 12 months, have you purchased a game you haven't been able to play due to poor accessibility?" Sourced from Scope.

Gaming itself may not seem incredibly important to disabled individuals, but according to the CDC, with disabilities report experiencing frequent mental distress almost 5 times as often as adults without disabilities. With a survey from Scope indicating that disabled gamers are more engaged than able-bodied individuals, a key consumer group is being left behind as technology progresses.

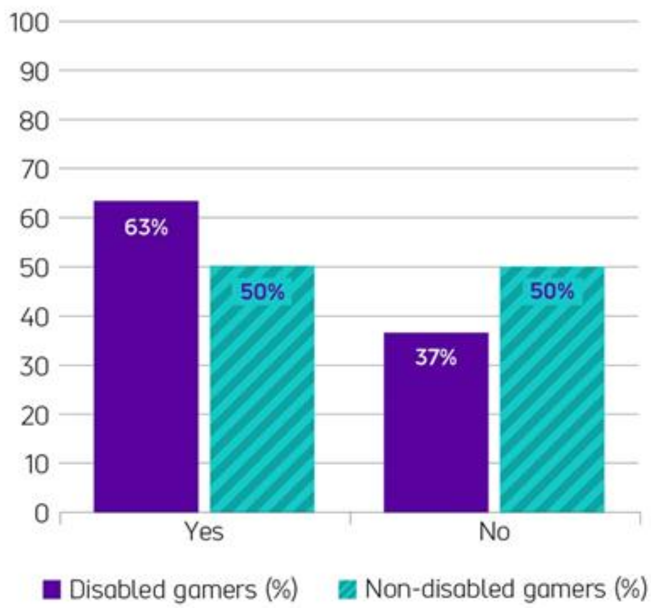

Figure 2: "In the last 12 months have you purchased any in-game add-ons or subscriptions?" Sourced from Scope.

Video games can alleviate symptoms of neurodegeneration (Sokolov et al. 1) and improve mental well-being (WebMD). The goal of this project is to increase the accessibility of gaming to disabled individuals by decreasing the cost of adaptable controllers while providing a highly customizable experience. With this controller, gamers with disabilities will be able to access the benefits that video games bring.

Design Objectives

The first design objective of the accessible gaming controller is to make the inputs/buttons on the controller modular. The modular design is a key aspect of the controller because the user group can largely vary in abilities and preferences. The modular buttons of the controller will allow each individual to place components in their preferred location. Current accessible controllers have some modular ability, but Total Control's Design will allow every button to be moved in an easy and quick manner. Many video games have a button layout option where you can customize what action each button performs. Our design will take this idea a step further by also allowing for button and joystick movement in 3D space. This will allow disabled gamers to play a wider variety of video games where the button layouts were an obstacle to effectively completing a game.

The second design objective of Total Control is to increase the overall scale of the gaming controller. For individuals with physical limitations, such as limited dexterity or mobility, smaller buttons on a controller can be difficult to press accurately or quickly. This can make gaming frustrating and sometimes impossible. Larger buttons on a controller can be immensely important for those with disabilities as they provide greater accessibility and ease of use. These larger buttons provide more surface area and a wider target for users to press, making it easier for them to interact with the controller and effectively play the game. Furthermore, the scale of the controller casing will be much larger than a typical controller. This will help with the modular design of the controller and allow the user to place the controller on their lap, instead of having to hold the controller while simultaneously pressing buttons. The increased accessibility can greatly enhance the gaming experience for those with disabilities and allow them to fully participate in the gaming community.

The third design objective is to make the controller more affordable than what is currently on the market. Similar products available to similar demographics can easily cost over a hundred dollars excluding additional parts necessary for individual cases. This is over double the price of a normal gaming controller and is unaffordable to most of the targeted demographic and can make the purchase of a product like this difficult for someone who needs it. This increase in price is generally the result of a variety of materials that are used to make the casing, advanced manufacturing techniques, and custom circuitry. Using cheap materials like aluminum and plastic will allow for a decrease in the product's price significantly. The use of Arduino programming and circuitry will also allow for the cost to be lowered as opposed to the customized programming and circuitry that is typically used for these kinds of products. The use of 3D printing to manufacture the casing will also allow for a significantly less expensive manufacturing process to be implemented than other products on the market. By using these methods to decrease pricing, gaming will become more accessible to Total Control's target demographic.

Materials & Methods

- **Identifying Potential User/Customer Needs**

Identifying user needs is a crucial aspect of the design process. The purpose of any design is to create a solution that meets the needs of the users it serves, whether it be a product, a service, or an experience. Failing to consider the needs of users can result in a design that is ineffective and is difficult to use. Identifying customer needs allows designers to create products that are tailored to the specific needs and preferences of their users. This can lead to increased satisfaction and engagement, as users feel that the design is truly meeting their needs.

User needs will be identified to create a satisfactory design using surveys and interviews. Total Control has created a google form survey that was distributed at a Multiple Sclerosis clinic. The results of this form will influence the design and allow the interface to be more intuitive for the user. Total Control has also completed and will continue to perform zoom interviews will applicable users. One interview, completed with a professional disabled video game player, gave the group crucial insight on necessary design changes. Total Control will continue to interview and use the form to collect data as well as possible test subjects to improve the design.

- **Generating Design Concepts**

When generating design concepts, the perspectives of our demographic were taken into consideration. Gamers who suffer from muscular dysfunction were interviewed and asked what design choices they would benefit more from. There were a variety of design ideas brought up by those surveyed. From these ideas, four new concepts were generated by the producers. The first is to make the layout of the controller bigger than normal. The second is implementing inputs so they reach higher than usual from the gamepad surface. The third is slanting the surface of the gamepad.

A bigger controller layout was found to be more effective because there is less precise muscle activation required for necessary inputs than what would be required in a normal controller layout. Other disability accessible gaming controllers currently on the market have also implemented this concept.

Inputs that have a high reach from the controller surface allow for less muscle exertion which lowers the physical demand for gaming. Some gaming controllers on the market currently do implement this concept. However, the extent to which they do is insufficient compared to the concept's demands for those who were surveyed.

A slanted surface allows for inputs at a higher altitude at the back of the controller, making those inputs easier to reach, and inputs at a lower altitude closer to the controller. This choice was made after many of those surveyed complained about difficulty reaching inputs closer to the gamepad surface. Therefore, it was determined that input difficulty also increased with distance of the input from the consumer.

- **Selecting Design Concept**

As previously mentioned, a bigger controller layout will allow for more accurate inputs to be registered with less precise muscle contractions required. However, if the layout is too big, this will make reaching the necessary inputs more difficult. The concept of high input altitude has similar pros and cons. Although a high input altitude will also result in easier accessibility of the inputs, an input altitude too high off the gamepad will also result in an input that is difficult to reach. A controller surface slanted towards the consumer would result in easier accessibility to inputs that are further away from the consumer. However, this benefit comes at the cost of less accessibility to the inputs closer to the consumer. Ranking these design methods and selecting a final design will entail determining which design is believed to allow for the most ease of accessibility for our target demographic. Once the product with the desired concept is designed, it will be tested using a small representative portion of our target demographic.

Project Management/Results

The below Gantt chart describes the Spring 2023 and Summer 2023 semester deliverables. Many of the big milestones are spit into smaller goals to track progress.

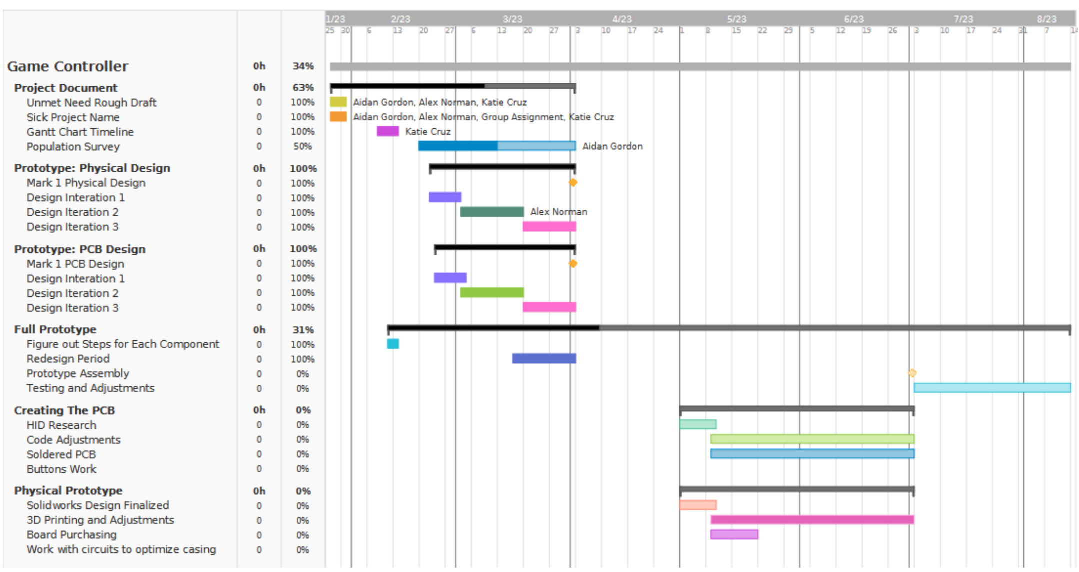

Figure 3: The Gantt chart for the Total Control project.

Deliverables

The final product consisted of four different components, a modified peg board, a case, 3D printed button pegs, and electrical wiring. Below is the SOLIDWORKS drawing of the first prototype for the casing. The original case had a slanted design based off feedback from representatives of our demographic. 3D printing was decided on for design accuracy.

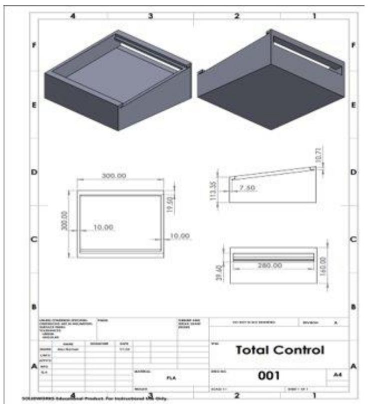

Figure 4: SOLIDWORKS drawing showing the design of the first prototype of total control and its dimensions from a top-down, left-side, and right-side view. Prototype designed with PLA material.

Below is a SOLIDWORKS drawing of the second prototype which involves a more flattened surface over the first prototype and similar dimensions. The material was also altered from 3D printed PLA to wood to cut costs.

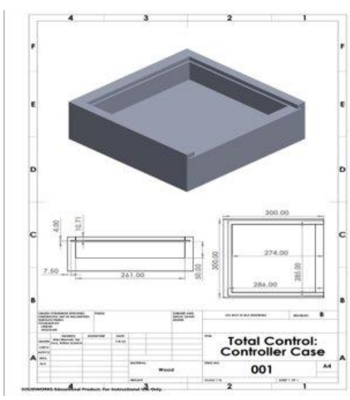

Figure 5: SOLIDWORKS drawing showing the design of the second prototype of total control and its dimensions from a top-down and left-side view. Prototype designed with wood.

Below (right) is a SOLIDWORKS drawing of the final prototype which involves a rectangular shape over the second prototype as well as an indent in the bottom to allow for a lap rest (left) to easily be inserted and taken out at will for maximum comfort.

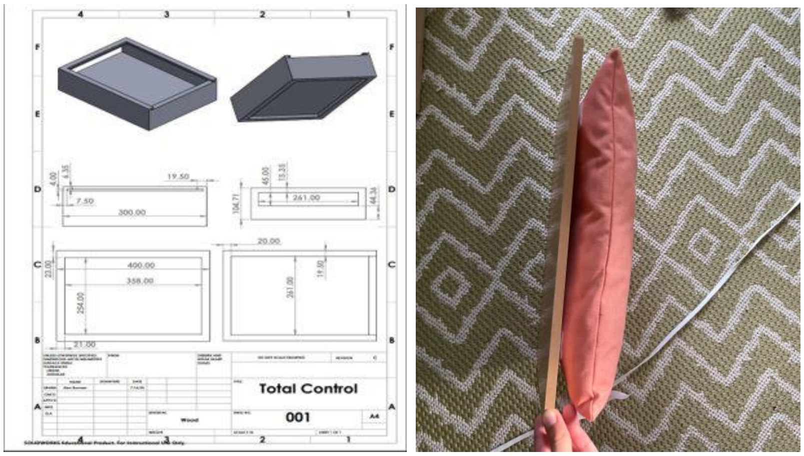

Figure 6: SOLIDWORKS drawing (left) showing the design of the final prototype of the total control case and its dimensions from four different views including top-down, left-side, right-side, and bottom-up view. Prototype manufactured using wood. Picture of the lap rest (right) used to fit into the bottom of the case.

The images below show the joysticks and buttons that were used for the controller. The buttons are pulled directly from an arcade machine to allow for less precise movements from the consumer to push. Xbox joysticks were used due to programming resembling an Xbox controller.

Figure 7: Images of the Joysticks (left) and the buttons (right) used for the product.

Figure 8: SOLIDWORKS drawing (left) and final completed model (right) of the Xbox one joystick extenders.

Figure 9: SOLIDWORKS drawing (left) and final completed model (right) of the joystick button pegs.

The images below show the original model drawing and outcome for the 3D printed button pegs using SOLIDWORKS.

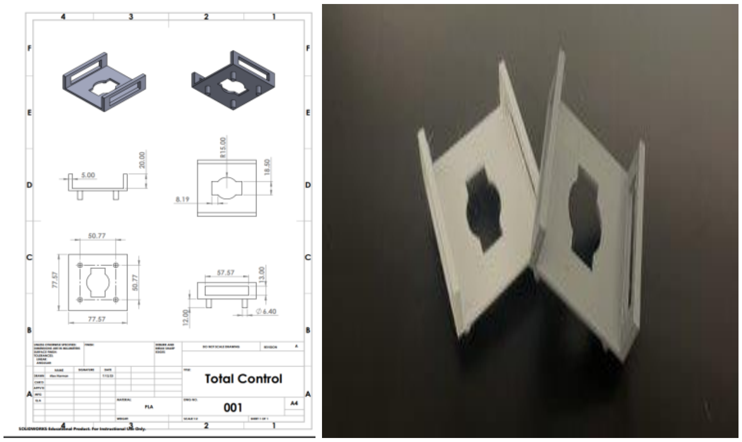

Figure 10: Drawing showing the original button peg design (left) PRUSA printed designs of the original button peg model (right).

The images below show the final SOLIDWORKS drawing and outcome for the 3D printed button pegs.

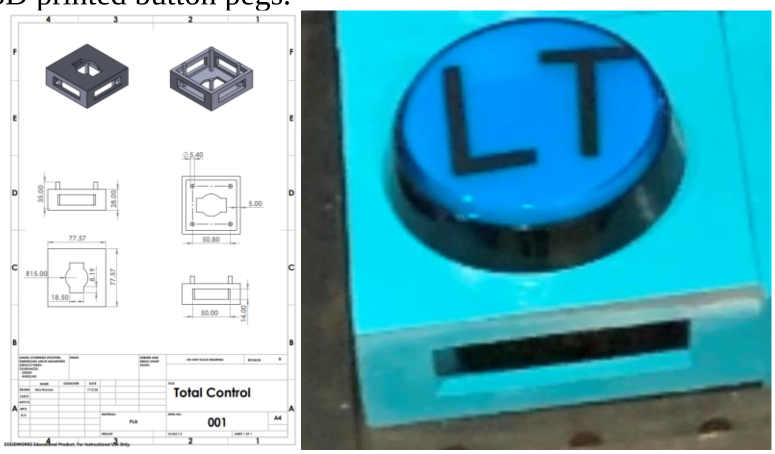

Figure 11: SOLIDWORKS drawing (left) and final PRUSA printed product (right) of the final version of the button pegs. Spray paint used on the pegs for decoration.

The image below shows the initial peg board bought (left) and the modified component (right).

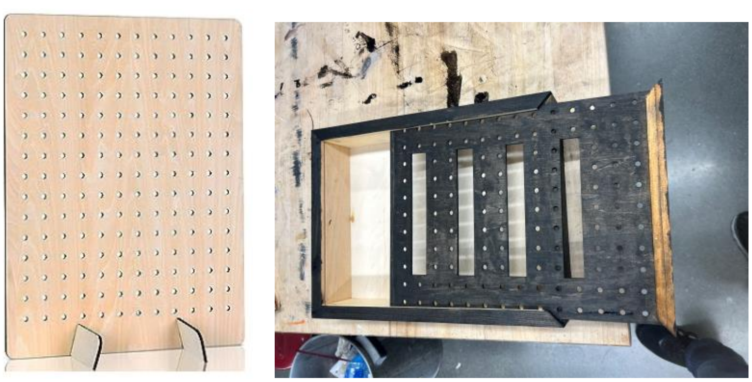

Figure 12: Amazon listing image of the peg board purchased (left) and the final product attached to the case. Wood staining was used for decoration. Woodshop

was used to cut the board to fit the case and a laser cutter was used to make the holes in the peg board. Yellow handle was attached to the peg board using wood glue

The following Arduino code was used to operate the controller, the code resembles that of the Xbox controller due to easy accessibility:

```
#include <XInput.h>

//2 and 3 are R3 and L3
boolean b_R3_state = digitalRead(2);
boolean b_L3_state = digitalRead(3);
boolean b_A_state = digitalRead(4);
boolean b_B_state = digitalRead(5);
boolean b_X_state = digitalRead(6);
boolean b_Y_state = digitalRead(7);
boolean b_dPad_Up_state = digitalRead(8);
boolean b_dPad_Down_state = digitalRead(9);
boolean b_dPad_Right_state = digitalRead(10);
boolean b_dPad_Left_state = digitalRead(11);
boolean b_RB_state = digitalRead(12);
boolean b_LB_state = digitalRead(13);
boolean b_RT_state = digitalRead(A4);
boolean b_LT_state = digitalRead(A5);


int joy_R[] = {analogRead(A0),analogRead(A1)};
int joy_L[] = {analogRead(A2),analogRead(A3)};

int scaledRX;
int scaledRY;
int scaledLX;
int scaledLY;

void setup() {
  // put your setup code here, to run once:

  XInput.begin();
}

void loop() {
 // put your main code here, to run repeatedly:
 // Update control surfaces here

joy_R[0] = analogRead(A0);
joy_R[1] = analogRead(A1);
joy_L[0] = analogRead(A2);
joy_L[1] = analogRead(A3);

scaledRX = int((joy_R[0]-(512)) * (32767/(1023/2)));
scaledRY = int((joy_R[1]-(512)) * (32767/(1023/2)));
scaledLX = int((joy_L[0]-(512)) * (32767/(1023/2)));
```

```
scaledLY = int((joy_L[1]-(512)) * (32767/(1023/2)));


b_R3_state = digitalRead(2);
b_L3_state = digitalRead(3);
b_A_state = digitalRead(4);
b_B_state = digitalRead(5);
b_X_state = digitalRead(6);
b_Y_state = digitalRead(7);
b_dPad_Up_state = digitalRead(8);
b_dPad_Down_state = digitalRead(9);
b_dPad_Right_state = digitalRead(10);
b_dPad_Left_state = digitalRead(11);
b_RB_state = digitalRead(12);
b_LB_state = digitalRead(13);

XInput.setButton(BUTTON_R3, !b_R3_state);
XInput.setButton(BUTTON_L3, !b_L3_state);
XInput.setButton(BUTTON_A, !b_A_state);
XInput.setButton(BUTTON_B, !b_B_state);
XInput.setButton(BUTTON_Y, !b_Y_state);
XInput.setButton(BUTTON_X, !b_X_state);
XInput.setButton(DPAD_UP, !b_dPad_Up_state);
XInput.setButton(DPAD_DOWN, !b_dPad_Down_state);
XInput.setButton(DPAD_RIGHT, !b_dPad_Right_state);
XInput.setButton(DPAD_LEFT, !b_dPad_Left_state);
XInput.setButton(BUTTON_RB, !b_RB_state);
XInput.setButton(BUTTON_LB, !b_LB_state);

if (b_LT_state == HIGH){
  XInput.press(TRIGGER_LEFT);
}
else {
  XInput.release(TRIGGER_LEFT);
}

if (b_RT_state == HIGH){
  XInput.press(TRIGGER_RIGHT);
}
else {
  XInput.release(TRIGGER_RIGHT);
}

XInput.setJoystickX(JOY_LEFT, scaledLX);
XInput.setJoystickY(JOY_LEFT, scaledLY);

XInput.setJoystickX(JOY_RIGHT, scaledRX);
XInput.setJoystickY(JOY_RIGHT, scaledRY);

XInput.send();  // send data over USB
delay(10);
}
```

After being uploaded into the Arduino, buttons and wiring were appropriately placed onto two connected breadboards to ensure the buttons worked as desired.

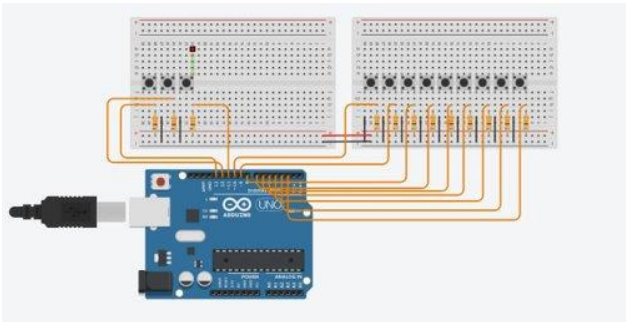

Figure 13: Tinkercad breadboard model simulation the circuitry used to allow the buttons and joysticks for total control to function properly.

After the buttons were confirmed to work as desired on the breadboard, the wiring and buttons were then placed and soldered onto a circuit board.

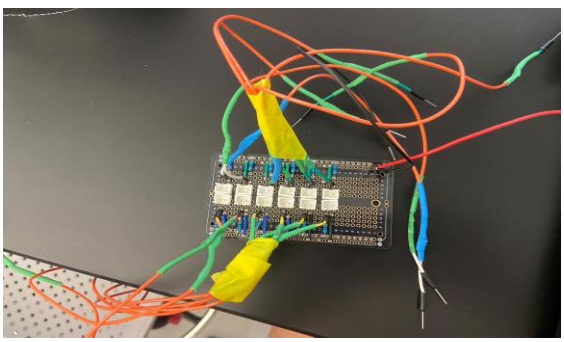

Figure 14: Circuit board used to operate the buttons and joysticks once all parts were confirmed to work. All parts were soldered on. All wires received necessary tubing for cable management.

The image below shows the final product for the prototype.

Figure 15: Image of the final prototype product with all previously mentioned parts assembled connected to a PC.

To ensure that the controls worked properly on the breadboard, the controller was testd with minimal gameplay via Elden Ring on PC. After being converted to the circuit board and set up with the necessary button pegs, casing, and peg board, the controller's efficacy was tested by playing the full tutorial of overcooked and then some additional levels in the game.

ANSI, ASME, and NIST are all standards of engineering that were significantly considered when designing and manufacturing our product.

Our primary ethical concerns for the project involved easy accessibility to the product and socioeconomic benefits received from it.

This product will have a socioeconomic impact as it will make an important industry more accessible to a wider demographic by making it more affordable for certain demographics.

Spring 2023

(1) Final Design
(2) Project Presentation
(3) Application for Funding
(4) 15 Page Project Proposal

The deliverables for the Spring 2023 semester are a finalized complete design, the unmet need document, a project presentation, and a fifteen-page project proposal. The final design was broken into two subsections with smaller milestones. The two subsections are physical design and electrical design. The physical design deliverable had three redesigned iterations to accommodate changes and team discussions. The electrical design component had the same timeline as it had to work in conjunction with the design of the casing. This design period was met by the deadline.

The project presentation was due April 7th, 2023, and consisted of an exploration of the unmet need, current solutions, our solutions, and our design. Each of these were completed on time by the due date. The application for funding was due April 10th, 2023, and has not yet been completed.

The final deliverable is the project proposal due April 11th, 2023. There are several sections to this deliverable. Katie Cruz is responsible for the Abstract, Background, and Deliverables sections. Alex Norman is responsible for Design Objectives and Materials and Methods.

Summer 2023

(1) Physical Prototype Completion
(2) Complete PCB
(3) Complete Prototype
(4) Continuous Update on Paperwork

Physical Prototype completion requires a finalized SolidWorks design to enable simultaneous prototyping with PCB design. This is due to the space beneath the peg board needing to be adjusted for wiring. Additional physical prototyping milestones include 3D printing of the board to test the size and comfort of the casing and the purchasing of the pegboard for the design of the button casings.

The completed PCB design requires a redesign of the joystick algorithm. This is due to the need for the updated microcontroller for the use of HID. This is why there is a section for the HID research week to garner an understanding of the system. In addition, a soldered PCB prototype is another goal for the Summer 2023 semester. Finally, the buttons of the controller need to be confirmed to work.

Budget

Below is a table of the proposed budget needed to complete the controller design.

Item	Number	Cost	Purchased?	Total
Thumbstick Board	8	$5.98	Y	$47.84
Arduino Leonardo	1	$24.99	Y	$24.99
60mm Arcade Buttons	12	$5.95	Y	$71.40
Arcade Button Wires	1	$4.85	Y	$4.85
Peg Board	1	$11.98		$11.98
Solderable Breadboard	1	14.99	Y	14.99
Resin Cartridge, Gray V4	1	$149.99		$149.99
Total				$326.04

Figure 16: The proposed budget as of April 8th, 2023

Currently, Total Control does not have a sponsor and the group members will have to pay out of pocket for this project. The team needs to complete the Senior Capstone Industry Partner Program (SCIPP) funding application to be awarded money to complete this project. Total Control does not have the necessary design drawings for this application but is currently working towards this goal. The group will be in contact will the project mentor to assess options moving forward.

Team Qualifications

Alexander (Alex) Norman has history in mechanically related concepts having taken multiple manufacturing classes at Wentworth and worked as a Research assistant for professor Seredinski from May 2022 to April 2023, designing a station that can be used to manipulate and observe van der Waal's materials under varying environments and wavelengths that is more affordable and accessible than what is currently on the market. Alex presented his research findings to an APS convention held at Amherst college and to the Dean of sciences at Wentworth. Alex is also currently working at the Wyss institute for his first co-op where he handles the mechanical aspects of various projects.

Katie Cruz has done quality assurance electrical engineering work at Formlabs Inc. and worked as a repair technician at Zyno Medical Solutions. Her role at Formlabs included major projects such as the Form 3L mixer check failures project, the characterization of the mixer subsystem behavior, and the diagnosis of the solvent monitor failures for the Wash L. Her work at Zyno Medical Solutions included the diagnosis and fixing electromechanical systems. Additional experience is in

Aidan Gordon has worked as a Testing Technician at Zyno Medical Solutions d as a Biomedical Intern at TriMedx. At Zyno Solutions, Aidan evaluated and performed rework on the electromechanical systems of infusion pumps returned for preventative and corrective maintenance resulting in the delivery of properly functioning customer pumps. He also optimized and completed testing procedures of infusion pumps to ensure accurate administration of medication to patients across the U.S. TriMedx is a third-party clinical engineering company that works in many hospitals across the U.S. In Aidan's position at Tufts Medical Center, the clinical engineering team was responsible for managing the medical equipment lifecycle for over 14,000 devices. In this role, Aidan conducted risk assessments and developed preventative maintenance plans for medical equipment to ensure compliance with regulatory agencies, such as Joint Commission

References

1. Bierre, Kevin et al., Game Not Over: Accessibility Issues in Video Games, Games Accessibility Special Interest Group, HCI International 2005: 11th International Conference on Human-Computer Interaction, 2005, https://www.researchgate.net/profile/Kevin-Bierre-2/publication/267403944
2. Brilliant, T.D., R. Nouchi, and R. Kawashima, *Does Video Gaming Have Impacts on the Brain: Evidence from a Systematic Review.* Brain Sci, 2019. **9**(10).
3. Control, C.f.D. *The Mental Health of People with Disabilities*. 2020 [cited 2023 April 6]; Available from: https://www.cdc.gov/ncbddd/disabilityandhealth/features/mental-health-for-all.html.
4. Granic, I., Lobel, A., & Engels, R. C. M. E. (2014). The benefits of playing video games. American Psychologist, 69(1), 66–78. https://doi.org/10.1037/a0034857
5. Junttila, K., et al., *Gaming enhances learning-induced plastic changes in the brain.* Brain Lang, 2022. **230**: p. 105124.

6. Malone, L.A., et al., *Active Video Gaming Using an Adapted Gaming Mat in Youth and Adults With Physical Disabilities: Observational Study*. JMIR Serious Games, 2021. **9**(3): p. e30672.
7. Patrick M. Markey, C.J.F., Lauren I. Hopkins, Video Game Play: Myths and Benefits. American Journal of Play, 2020. 13(1): p. 87-106.
8. SCOPE. Accessibility in gaming report. [cited 2023 April 6]; Available from: https://www.scope.org.uk/campaigns/research-policy/accessibility-in-gaming/#Barriers-faced-by-disabled-gamers.
9. Sokolov, A.A., A. Collignon, and M. Bieler-Aeschlimann, Serious video games and virtual reality for prevention and neurorehabilitation of cognitive decline because of aging and neurodegeneration. Curr Opin Neurol, 2020. 33(2): p. 239-248.
10. Staff, M.C. Multiple sclerosis. [cited 2023 6 April]; Available from: https://www.mayoclinic.org/diseases-conditions/multiple-sclerosis/symptoms-causes/syc-203502\