Game Controller For Impaired Individuals Technical Documentation

1st Matthew Hunsaker
College of Engineering
University of Utah
Salt Lake City, U.S

2nd Khang Lieu
College of Engineering
University of Utah
Salt Lake City, U.S

3rd Brian Burton
College of Engineering
University of Utah
Salt Lake City, U.S

4th Kashish Singh
College of Engineering
University of Utah
Salt Lake City, U.S

***Abstract*—Disabled individuals have difficulty using conventional game controllers which are designed for those with fingers that are fully capable of simultaneous pressing and rotating. They ignore the fact that not everyone has the luxury of finger mobility for one reason or another. This work develops a solution that allows controller buttons and a joystick to be placed on the ground or even on a table. These components are enlarged enabling a person to use their whole hand, wrists, feet or other body parts to manipulate the joystick and buttons. These components are connected to a device that will convert their data to a format that is be read by a PC in a format that mimics a conventional game controller.**

I. Introduction

Video games have become a very prevalent form of media and entertainment over the past several decades with the games increasing in complexity over that time. However, the standard method for playing these games, using a keyboard and mouse or a controller, requires significant use of and dexterity with the user's fingers. This excludes a portion of the population that, for whatever reason, can no longer use their fingers effectively enough to utilize these devices.

There are more than one billion people in the world living with some form of disability and nearly 200 million experiencing substantial difficulties in functionality [1]. This is not projected to decrease since its prevalence is on the rise due to ageing populations and increases in chronic health conditions such as diabetes, cardiovascular disease, cancer and mental health disorders [1]. Diseases and disorders that have an effect on the hand, hand muscles, joint muscles, and the feeling or lack of feeling in the fingers and hands are numerous. These conditions should not be reasons to exclude individuals from interacting with others through gaming. People around the world use video games to connect with others. Infirmities and different conditions should never stop anyone from doing something that they want to do.

While disabled players have long used video games in order to expand their world by creating a sense of community and opportunity, hundreds of thousands of games require extensive dexterity in the players fingers and hands. This makes it hard or even impossible for some to play certain games with the controls that are available. This simple fact has caused many people with disabilities or chronic illnesses to feel isolated, largely because many have trouble physically leaving their homes to meet up with their friends [2]. The fear of social interaction has also pushed individuals to live a more isolated life style. Gaming provides comfort to those by giving them the opportunity to socialize and play together in the comfort of their own homes.

Video games are a means in which people with disabilities can enhance their mental, social, and physical wellness. They also can inspire us to rethink how video games can be much more than simple entertainment. When we recognize the health benefits that video games can bring to the disabled, maybe then we will more carefully consider the role that video games can play in our own self-care habits [2].

By having controllers that require small finger movements, we are leaving out an enormous part of the worlds population. Many popular games remain inaccessible due to conventional controllers. That said, there is no excuse for not developing accessible games. Game accessibility should be an industry standard, not an after thought. Research from Muscular Dystrophy in the UK found that one out of every three gamers has been forced to stop playing due to their disability [3]. No one wants to be told they can't do something. Having games that can adapt to the needs of the user is how we can close the gap.

If the video gaming industry were to design more accessible video games, players with and players without disabilities would have a better experience overall [2]. This is why we are developing a controller that can be used by such an individual to play video games on a PC using other body parts like their feet or wrists while still providing the full functionality of a conventional video game controller. Every disabled gamer has different game controller access needs which is why we aim that our controller will allow the user to position its buttons in whatever way suits their needs. Finally, the controller will be used with a conventional game to display all of the same functionality of a conventional game controller.

We are generating more opportunities to individuals who want to socialize and who want to participate in the gaming world but may not have the same opportunity than those who do not have a chronic illness or disability. Due to lack of accessible game controls, game producers have limited who can play their games. Creating a controller that cannot just be used by your hand but can be used in multiple ways gives others the opportunity to join in on the gaming world.

II. Background and Related Works

Since a person's disability can impact every aspect of their life most research and development into creating accessible technology for those with disabilities has focused on things that were considered a necessity. This has led to research and development of these peripherals in entertainment to fall behind [4] [5]. The few peripherals that have been developed for computers for impaired people have mainly focused on more general computer tasks that would not work well with most conventional video games, like eye tracking and speech recognition [4]. Most of the development that has been done to make video games more accessible to those that are impaired in some way has either been research, implemented completely with software, or had limited distribution or success. Most of the research concerning disabled people interacting video games has revolved around developing video games that can be used in rehabilitation or trying to combat the effects of a person's disability like trying to improve fine motor skills. For example, this creating a game that specifically exercises a person's specific disability and then using it with motion sensing peripherals to track the exercises [6].

In most cases when a peripheral like a controller was created for research or early attempts to create one for commercial release their design ultimately limited their effectiveness [4]. Since most games are fairly complex, they require several inputs usually in the form of buttons. This has resulted in most of these early attempts at a controller for disabled people to either be big and bulky mimicking an arcade style set up with fewer buttons that were larger for easy access, or a smaller peripheral that utilized another conventional controller and a second person to do half of the inputs, or requiring the user to construct the interface circuitry [4] [7]. The first of these options limits the user by limiting the games that a user can play to those that have limited inputs and can only be used by people with certain disabilities. The second option requires at least one other person to play with the user restricting those who want to play by themselves or do not have someone they can play with. Finally, the third option requires the impaired person to be able to interact with the circuitry, which is maybe difficult or impossible given that they are disabled, or have someone that has the required technical skills to construct it for them. Of these options the arcade style set up had the most success resulting in a small group of dedicated developers of games that would work with these peripherals [4].

In more recent years various companies have started creating peripherals and controllers for impaired users again. Some of these are for very specific users, for example the mouth joystick by Quadstick, found in Figure 1, is designed as a controller for quadriplegics and has certain features for their specific disability like a tube that they can breath into to change what the controller currently does [8]. Other companies have focused on a more broad design to appeal to people with less specific disabilities. The Xbox Adaptive controller developed by Microsoft, found in Figure 2, has been designed for people who cannot fully use their fingers and therefore

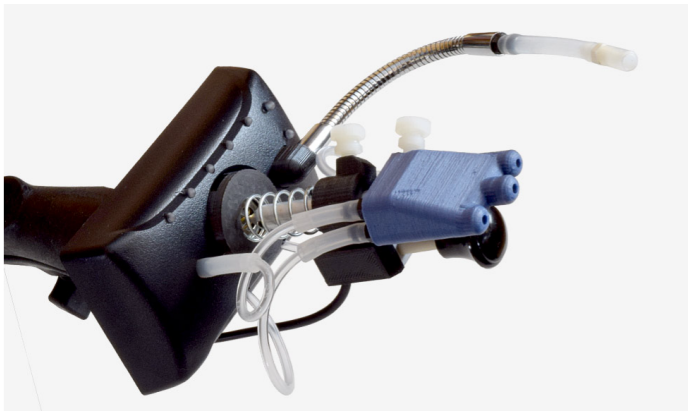

Fig. 1. Quadstick's mouth FPS controller.

Fig. 2. Xbox Adaptive Controller with additional peripherals.

cannot use a conventional controller [9]. The amazing thing about the design of the Xbox Adaptive controller that it allows numerous additional peripherals to be plugged into it to replace the existing buttons of the controller with a peripheral that is more accessible for the current user, as shown in Figure 3 [9]. This is probably the most ideal controller currently available for disabled people as these peripherals allow the user a lot of freedom in the design of their set up. However, the main controller follows the old arcade design requiring a larger space to utilize it.

III. Game Controller Design

When coming up with the concept of a different style of controller, the first question was how to make it more accessible and how. It was decided the focus would be one those who have trouble pressing small buttons and/or dealing with a controller where button placement was fixed. Inspired by the XBox controller's accessories, the conclusion was to make the buttons modular by having them be separate components that were wired to a base so the user would be able to arrange them as they pleased.

As for the buttons which are a major component of any controller, it was decided that the basic push button design would include removable caps that would allow for switching out from the smaller version to larger versions as desired

by the user. This can also lead to a design where the user would be able to press on buttons using their feet rather than fingers, hand, and/or arms. It also opens up the possibilities of different button designs that can be swapped out depending on needs and circumstances. So for someone who has fingers but possibly something like arthritis or poor motor controller, a larger button would make it easier to press and hold compared to a small key on a keyboard or controller. And once these major design aspects were agreed upon, the next part was to figure out the more logistical side of things with schedules and proposed timelines.

A. *Workflow*

To keep on track towards the December 9th, 2022 deadline, it was decided that weekly meetings will occur starting in May 2022. From there the first step would be to develop or find a way for push buttons to connect to the Raspberry Pi which could receive, interpret, and output signals that would be sent to a computer as keystrokes. Once this was functioning, joystick implementation would be done to mimic a mouse device before moving on to coding so that different buttons would represents different inputs. And when the buttons are all functioning, PCB units would be designed for each of the push buttons as well as pins to connect wires in order to allow a user custom arrangements rather than them being stuck to a single board. A different PCB would also be designed for the Raspberry device as well as 3D printed plastic bases for the buttons and system so it wasn't just exposed PCB boards. During this time, different button and joystick designs would be 3D printed to allow users to switch between them if need be with assistance. Finally leading to testing and debugging of the system before it is completed.

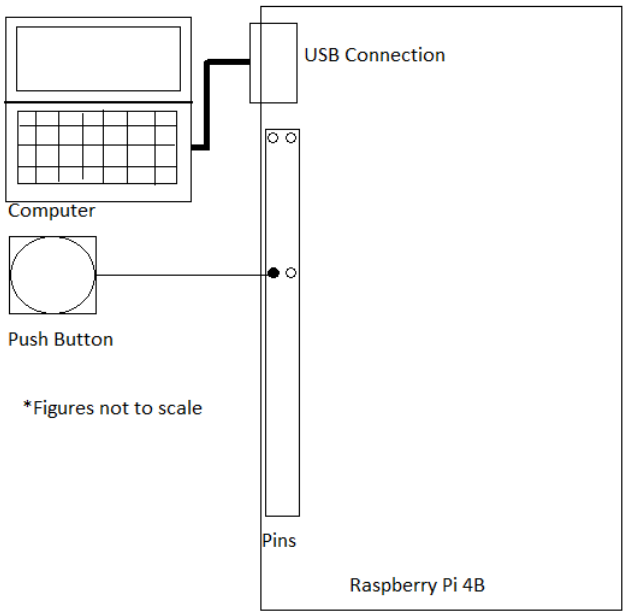

Fig. 3. Project basic concept diagram

Overall, schedule was either on track or even ahead during some portions. Although the stretch goals of possibly adding blue tooth compatibility or designing a basic video game to show off the system was not done. This is due to the fact some other goals were done instead such as rather mimicking an XBox controller, the entire standard computer keyboard was implemented as well as LED lights to indicate what "mode" the device was in for clearer visual guidance. This allows the entire project to be both a video game controller concept as well as a possible keyboard design for computers as well. Once it was all settles, the next portion would be to acquire the necessary materials and software before brainstorming and implementing the concept design in greater detail.

B. *Hardware*

When it came to the hardware design of the device, the main goal was to utilize cheaper options that could still be used for a basic controller rather than more expensive peripherals. Initially, the Raspberry Pi 4B board was used until it was discovered a cheaper option with easier software could be used in the Raspberry Pico. With the Pico being a $10 board that isn't in too high of a demand when compared to the $40 - $100 Pi 4B which is currently scarce. After getting a board, the next hardware components to be integrated were basic push buttons that could be bought in bulk as well as two joystick devices that had pin outputs that wires could connect too.

Once the basic buttons and main board was acquired, the next part of the system is the analog to digital converter (ADC) chip. This chip is necessary as the joystick device outputs an analog signal that is sent to the ADC. Then the chip converts it to a digital output that can be read by a micro-controller which is the Raspberry Pico. From there the digital input can be processed and outputted to a computer which can register that a button press represents a specific key due to the software made.

With these basic components and wiring done on a bread-board to test if it functions, the next portion was designing circuit schematics which would then become fabricated PCB boards. The purpose of this is to create a device which has modular capabilities and does not have to be connected to a single base. Instead by designing individual PCBs for the buttons and the Pico/ADC connections, it allows the user to arrange the device how they desire without having to deal with excessive wiring.

The final hardware aspect is the creation of 3D printed components such as additional button caps and bases for the components to avoid jiggling and any unwanted movement. This would not only help the user in having an easier time with using the device but also allow the open components to be more protected and secure. So in order to start production as caps would be needed for 25+ buttons, the first step was using software to design them. Autodesk Fusion 360 was the software used as it is capable of creating 3D models and exporting them in a file format that is utilized by most 3D printers. From there a few test models were created for the button components and printed with HIPS (High Impact

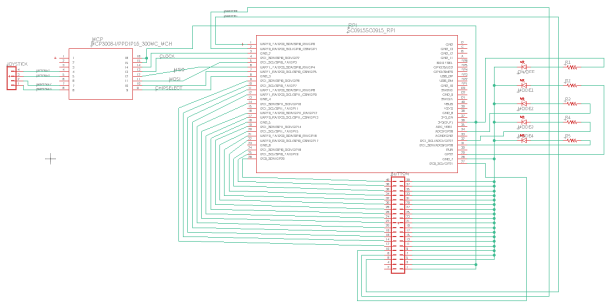

Fig. 4. Pico/ADC Circuit Schematic

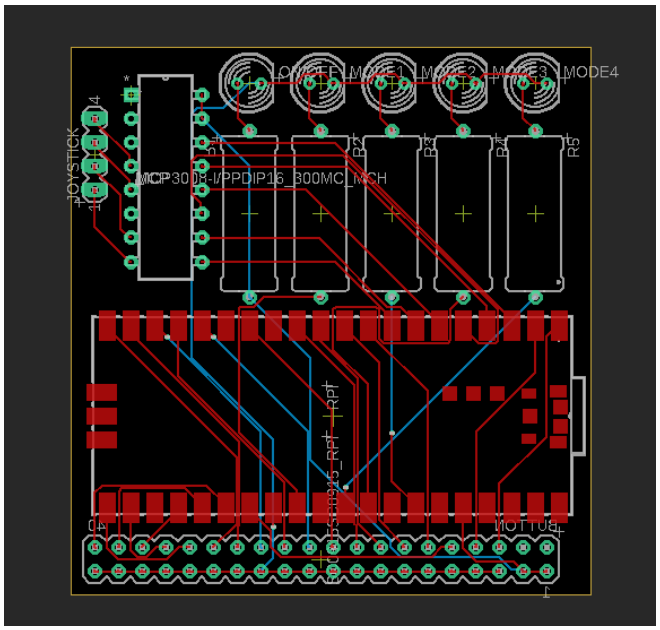

Fig. 5. Pico/ADC PCB Board Design

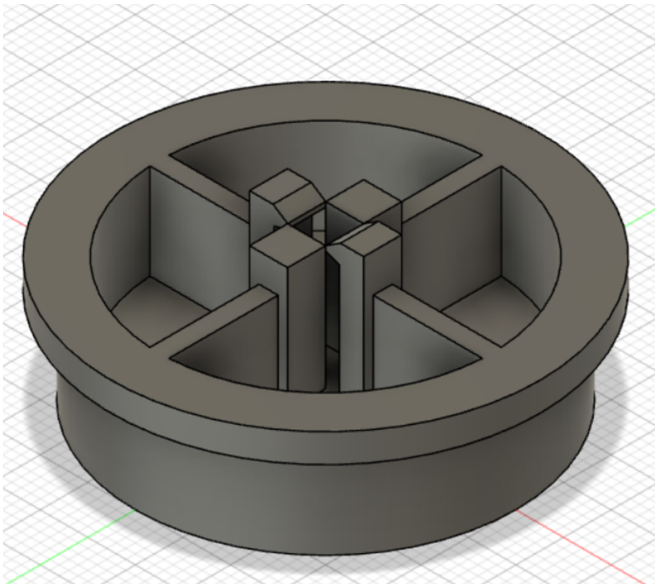

Fig. 6. 3D Model of Final Button Design

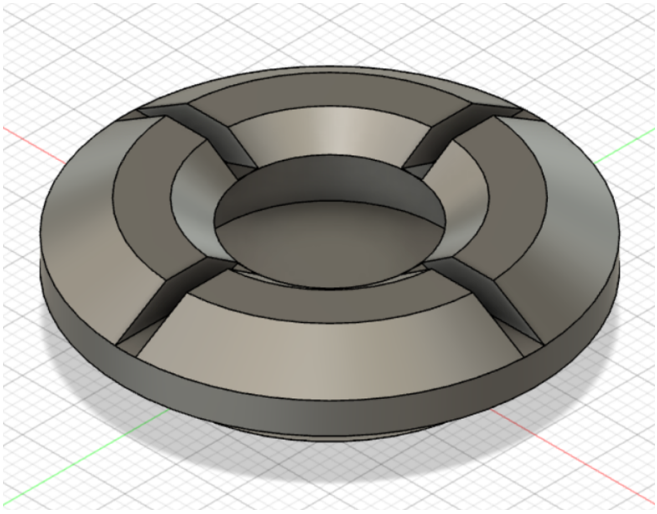

Fig. 7. 3D Model of Joystick Cap

Polystyrene) fillamint. After adjusting sizes and rations from a few failed prints, a suitable model was created then printed with PLA fillamint as it would be cheaper. The overall model is based off of the standard push button caps that was remodled, scaled up in size, then had more secure connections placed on the components that clip on to avoid breaks as in the test prints.

Once the buttons were completed, as different aspects of the project progressed like joystick implementation and PCB boards, bases and joystick caps were also created. With the final model and print being a 3-piece base that would hold the entire PCB unit with all components attached. The pieces would be able to be screwed together in order to create a shell to better protect the board rather than having electronic components exposed.

Overall, the entire cost of the project was more than it could've been. Certain components did not end up being used such as a Raspberry Pi 4B as well as PLA filament for 3D printing as we found a free source. The most costly components were the larger sized PCB board which came around $20 while other parts like the pico micro-controller were only around $10. In a more mass produced setting that cost can likely be driven down further which means we had achieved our goal on creating a design that is affordable even if it doesn't have as many options as say, the $100 XBox adaptive controller. Showing that with the proper hardware and tools, it's absolutely possible to create thing that are cost effective yet can make a difference. And once the hardware aspects were acquired or on their way to completion, the software portion was the next large aspect.

C. Software

The code for the microcontroller, stored in the file "gamepad_pico.py", utilizes the Adafruit Circuit Python libraries to access the hardware operations of the Raspberry Pi.

The two main libraries used were the Adafruit HID, 3xxx, and DigitalInandOut libraries. The HID (Human Interface Device) library is critical for the gamepad controller as it allows the Raspberry Pi to be viewed as an external USB device by whatever it is connected to and contains the keycodes and mouse codes that were essential for the operation of the gamepad. The 3xxx library contains the functions that are required for the operation and reading data from the MCP3008 Analog to Digital converter which is used to convert the analog voltages from the joysticks/mouse to to digital values that can be used by the Raspberry Pi microcontroller. Finally, the DigitalInandOut library allows access to the GPIO pins of the Raspberry Pi which is essential for the buttons of the gamepad.

The code file starts by having global variables that mainly consists of lists of the various keycodes and mouse codes for the different modes of the gamepad or the GPIO pins used on the boards. There are three functions that are used to set up the gamepad which consists of setting up the buttons as digital input pins, setup_buttons, the LEDs as digital output pins, setup_leds, and setting up the various devices of the gamepad like the mouse, keyboard, and MCP3008 devices, setup_device. The update_leds function converts the current mode of the gamepad into a binary string that is then used to set the values of the output pins for the LEDs. The reset_leds function is a helper function that is used to to turn off all of the LEDs when needed. The update_buttons function checks if a button is currently being pressed by a user and depending on which button is being pressed either updates the mode of the gamepad or outputs a keycode or mouse code to the device the gamepad is plugged into. Finally, the update_mouse_movement gets the raw voltage values from the MCP3008 device and uses the convert_voltage and get_movement_modifier helper functions to convert them to a value between -19 and 20 that can be sued by the HID library to update the movement of the mouse. This function also contains code to prevent drift in the mouse movement that came from the voltage values being decimal numbers and not whole numbers.

After the function declarations the functions to set up the gamepad device components, the buttons, LEDs, and MCP3008, are called and then the code sleeps for one(1) for a short time to give a pause before it takes in input. Then the code moves into an infinite loop that consistently checks the current mode of the gamepad and then calls the update functions to get the input from the user and output the keycodes and mouse values to the device the gamepad is plugged into.

IV. Troubleshooting and Changes

An important aspect of our project was how some of the design and intentions changed form the original design. One of the first things that was done after finalizing the concept was looking into how a device would communicate with a computer. Originally a Raspberry Pi 4B was acquired and the intention was to use a USB connection to be able to send input and output signals. However, after deeper research on the matter, it was discovered that a USB driver for this purpose was not available and needed to be developed by the team. With some experimentation and an attempt to test a basic driver using a virtual machine to host another instance of Windows, it was deemed too large of a goal in order for deadlines to be met. An alternative solution was discovered through more research on the Raspberry product line. There was an Adafruit Library that was originally considered but discarded when it wasn't initially usable with the Pi 4B model. Instead, the library could be used on a Raspberry Pico microcontroller which wasn't as powerful as a Raspberry Pi but would suit our needs regardless. Once it was decided the necessary components were ordered and the software began to take shape in Python.

Other minor challenges faced was on the 3D printing side of things. The initial button designs were prone to being the wrong sizes or having parts that connected to the main button itself being fragile and prone to snapping off. Changing the design and understanding more on how to 3D model helped alleviate these issues . Another was something as simple as not realizing that the button PCB design was off as there was no available footprint for the type of push button that was used. Creating the need to manually create a footprint to add to a schematic using the program Autodesk Eagle which was quite a learning curve but achieved in the end.

Regardless of these issues however, alternative solutions or quick fixes were achieved and allowed the project to continue to develop without any major delays. And it was through theses issues that there were various new aspects that could be considered thank to having problems. The utilization of the Adafruit library after failing with USB adaptation opened the door into implementing an entire keyboard using buttons. Something which ended up becoming a major part of the final device as now all keys from a keyboard could be mapped. Issues with 3D printing and PCB designs also allowed team members to learn more about the software and design aspects that will be useful in any and all future endeavors as well.

V. Conclusion

Of course, if the project could be redone and have changes made there could've definitely been some things altered. For example, later towards the very end it was discovered that the programming language Rust could've also been used and is more desirable than Python. Rust is based off of C and C++ but provides more safe coding capabilities to avoid the pitfalls of those languages as well as being easier to code in than Python for what was needed in the project. Another aspect would be to change the designs of the PCB boards. There were issues with connections that led to the main board not functioning as well as possible soldering issues that ended up requiring replacements. All aspects that can be improved upon with hindsight and more experience.

However, this doesn't mean that the project failed. If anything it absolutely succeeded in it's major goal of not only being a functioning game controller for a computer, but also showing that with the right design and thought, it's possible

to create affordable and viable products for those who have disabilities and difficulties in everyday pass-times such as gaming. The industry itself is also slowly recognizing this as the 2022 Game Awards even prominently had an award for video games that excelled in providing accessibility options for its players. And while it's a big step towards video game and computer accessibility, that was more of a focus on software based solutions. Hardware solutions are still very much needed both with availability and affordability. In the future, it is the hope that companies will continue to develop and research alternative options to allow more and more people be able to enjoy every day activities that is both affordable as well as useful to them.

REFERENCES

[1] WHO, "World report on disability." [Online]. Available: https://www.who.int/publications/i/item/9789241564182

[2] L. Brooks, "Disabled gamers turn video games into self-care." [Online]. Available: https://www.forbes.com/sites/lakenbrooks/2021/10/13/disabled-gamers-are-using-video-games-for-self-care/?sh=599ef8de6884

[3] C. Grace, "Disabled gamers turn video games into self-care." [Online]. Available: https://metro.co.uk/2021/10/07/as-a-disabled-person-playing-video-games-has-enhanced-my-quality-of-life-15330489/

[4] L. Fanucci, F. Iacopetti, and R. Roncella, "A console interface for game accessibility to people with motor impairments," in *2011 IEEE International Conference on Consumer Electronics -Berlin (ICCE-Berlin)*, 2011, pp. 206–210.

[5] D. McPheron, "Video gaming accessibility," in *2015 Computer Games: AI, Animation, Mobile, Multimedia, Educational and Serious Games*, 2015, pp. 107–111.

[6] M. Eckert, I. Gomez-Martinho, J. Martinez, and J. Meneses, "New Approaches to Exciting Exergame-Experiences for People with Motor Function Impairments," *Sensors*, vol. 17, no. 2, pp. 354–377, Feb 2017.

[7] D. A. Merchán-García, A. S. Enriquez-Mancheno, V. H. Uguña-Uguña, P. F. Suquilanda-Cuesta, and V. E. Robles-Bykbaev, "Development of an arcade controller for children with intellectual disabilities to improve fine motor skills through video games," in *2020 IEEE Games, Multimedia, Animation and Multiple Realities Conference (GMAX)*, 2020, pp. 1–4.

[8] Quadstick, "QuadStick FPS game controller." [Online]. Available: https://www.quadstick.com/shop/quadstick-fps-game-controller

[9] Microsoft, "Xbox Adaptive Controller." [Online]. Available: https://www.xbox.com/en-US/accessories/controllers/xbox-adaptive-controller