GNG2101 A Introduction to Product Development and Design Management for Engineers

MY-DJ: My Digital Joystick A Specialized Joystick Mouse

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Abstract

This report goes through the process on how *MY-DJ: My Digital Joystick* came to be the final, most favourable design for the appointed client, MHK. Through means of concept generation, reiteration after receiving client feedback, and prototyping concepts at reasonable milestones, MY-DJ was created to answer the problem of "designing a durably-encased joystick ideal for a user that bears poor fine-motor skills and limited hand mobility" as the problem statement. To get to the final design made, many concepts were created, and disregarded for their lack of fidelity due to not meeting design criteria, such as high cost or low durability. The criteria fulfillment of each idea or material was done using decision matrices, fidelity analyses, and economical reports to satisfy what will be used, and what will be removed. The final project made to be MY-DJ was a successful design, which that incorporates new ideas benefiting the client, while maintaining the familiarity in which he has become so used to today, easing his transition to the new joystick. However, there is plenty or room for the product to be improved, and further the design to reach new market networks.

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Introduction

The use of joysticks date back to the early 1900s when these devices were an important feature for pilots in aviation. The pilot gained easy control of his aircraft using the simple shaft to navigate. Upon seeing the potential of maneuverability using joysticks, this device was adapted outside of flight and used in a variety of different projects. Apart from operating devices for physical movement such as automobiles, aircraft and spacecraft, the joystick was later integrated to manipulating images on a computer screen. Although the computer adapted the use of a standard computer mouse as early as the 1960s, the joystick became known as an "ergonomic mouse" starting in 1978 (Card).

The joystick mouse and its ergonomic factors were later studied by many individuals with the earliest analysis conducted by Stuart Card and his associates. From hereon, many other individuals have measured performance quality giving way to improving the joystick mouse over time. Today, the joystick mouse has grown, being modified to accommodate technological advancements and structural improvements to optimize customer satisfaction.

The joystick mouse is widely viewed to be an ergonomic and effective option when using the computer. This device is mostly enjoyed by individuals such as gamers, children and individuals with physical disabilities. However, the pre-existing design of the joystick does not accommodate to all users. Unfortunately, the extended stick that the joystick is recognized for is not optimal for those who cannot grasp the shaft. In essence, this project was initiated to resolve this problem, designing a joystick mouse that allows all users to connect with the digital world, regardless of their abilities.

MY-DJ or My Digital Joystick, is an adapted joystick mouse that eliminates the need to grasp the handle of the device. This gadget functions similar to the existing computer mouse, allowing users to navigate laptops and computers. Designing MY-DJ carefully considered a specific clientele. This mouse is best suited for individuals with limited hand mobility, poor fine-motor skills and those who have difficulty manipulating their digits.

Through its engineered durability, MY-DJ can accommodate its users and undergo rough maneuvers in its daily use. The device encompasses many features including a textured flat hand-pad, a dual analog axis, elastic-tension technology and an aesthetically-pleasing 3D-printed case. The code that the device uses is also customizable allowing for a more user-friendly experience. These features were selected to eliminate the need to grasp the joystick shaft, keeping the user's hand level and maximizing the strength and adaptability of the device.

While the principles of this design appear straightforward and true, creating the final prototype was a meticulous and disciplined process. In this report, the design process for MY-DJ will be discussed, highlighting the work that was done to achieve its current state. From primary and secondary research to the repetitive re-evaluation, this document will provide insight to the creation of MY-DJ.

Findings and Observations

Research

It is very common for newly released products to be an iteration of a pre-existing design. This occurs as many gadgets have been created over time that it is rare to unveil a novel idea. Instead, individuals are more likely to improve upon a device in order to comply with the new trends and technology. MY-DJ takes after the principles of iterative design and benchmarking it its creation. While working closely with partners at Bruyère Continuing Care such as Bocar N'Diaye and MHK, Team A4 was given an insight to the current joystick mouse implemented at the facility.

Primary research was conducted by means of personal interviews with the partners at the continuing care facility. Fortunately, Mr. N'Diaye was quite open to describing his experience with previous solutions given to this project (Appendix B.2). In essence, he put great emphasis on the durability of the device as fragility was a major factor regarding the failure of previous iterations. The team was given the opportunity to see the previous joystick mouse in action and to take note of its current specifications and features.

The current joystick mouse was comprised of a very fragile outer shell encasing the precious hardware of an Arduino Esplora microcontroller. It was connected to a desktop computer using a microUSB to USB cable and enabled by a series of open-source codes. Furthermore, the handle was of a cheap plastic tube for the shaft with a wooden cylinder affixed at 90° from the shaft as the adapted hand pad. Mr. N'Diaye notes that the current iteration is simply a "quick fix" solution (Appendix B.2) and would like to see some structural improvements.

Moreover, the client testing the device was an individual who has limited mobility. In essence, the team took inspiration from the user's adapted joystick on his motorized wheelchair. The client, MHK, discussed with the team that he enjoys the flat hand-pad of his wheelchair controller and this pushed for the group to benchmark of this design. In this same interview, the client also demonstrated how he uses his device and elaborated on the activities that he enjoys on the computer. Therefore, this direct acquisition of information provided the team with an insight to the nature of how the device will be used in the future.

Following the interview, the team initiated problem identification and idea generation. Secondary research was done to discover the best method to adapting the design to suit the user's limitations while maximizing the price and performance. In essence, the team concluded that a durable plastic must be used to ensure the durability of the external casing. Drawing inspiration from pre-existing lifeproof phone shells and bumpers, rubber or foam inserts are essential for reducing the shock on the hardware in an accidental fall. Next, to maintain the user's comfort when engaging themselves with the device, it was concluded that the hand must be kept level to reduce the torsion on the wrist. Finally, a non-absorbent textured surface would be optimal to assist the hand to stay in position while promoting blood flow while the device is in use.

Client Needs

The fundamentals of this project circled around the principles of empathetic design. Therefore, the nature of this joystick mouse was highly client-specific rather than a common founder or business approach. In essence, the project was provided to the team with the purpose of improving the user's experience when using his computer. Since society is evolving into a more digital era, it is crucial for the client to remain connected with this digital world.

Fortunately, the team had the opportunity to speak with the user, himself, during the first of three client meetings. This one-on-one interaction was a foundation to the empathetic relationship between the client and the designer. MHK shared his desire to navigate the internet to catch up on news, journals and to amuse himself with his simple computer games. Moreover, since he lives alone at Bruyère Continuing Care, the internet is also a window to keep in touch with family and friends.

Apart from the initial meeting, Team A4 also had further discussions with Bocar N'Diaye which opened the subject of the product's criteria. Since Mr. N'Diaye is an experienced technician, providing various users with adapted accessibility devices, he also had input in the physical components of the joystick mouse.

These conversations gave way to a series of client needs and wants for the future device. MHK demonstrated that his mobility is limited to the right side of his body and therefore, he wants a tool that can accomodate one hand, laying flat. Buttons however, are not ideal due to the client's poor fine motor skills, calling for a button with hypersensitive response. Moreover, he is very comfortable with the joystick on his motorized wheelchair, so, a seamless integration is crucial. Mr. N'Diaye also communicated that MHK has lots of exaggerated movements as his control is directed by his upper arm. As a result, the device must be durable and able to withstand lots of exerted force (Appendix B.2). Furthermore, during the second client meeting, the client also expressed that device must comply to plenty of constant downward force (Appendix B.3) which led to the need of a stronger joystick shaft.

Apart from the user-specific accommodations, Mr. N'Diaye informed the team that the previous iterations broke due to accidental falls which leads to the focus of the future design to be sturdy (Appendix B.2). Nonetheless, flexibility of device use and aesthetics are also equally desired for the user's preference. Therefore, a mouse that can be used at a desk or in bed would optimize the user's experience.

Despite the growing list of needs and wants for the future device, Mr. N'Diaye had several priorities (Appendix B.2). Regardless of the approach taken by the team, the joystick mouse must be strong with a "nice, rugged case". Moreover, he indicated that the team should focus on a mouse that works as it would be an upgrade from the current unit in use. Therefore, the client requires a joystick mouse that is adapted to the current situation at Bruyère Continuing Care.

Problem Identification and Justification

Upon meeting with the client and gathering information regarding what is needed, the team was able to identify the problem at hand and justify why certain attributes must be satisfied. In short, the problem was defined as "designing a durably-encased joystick ideal for a user that bears poor fine-motor skills and limited hand mobility".

From this problem statement, it can be interpreted that the joystick mouse must be durable for a specific clientele as influenced by the needs and specifications. Since this project was another iteration of a previously existing design, all needs are justified by Mr. N'Diaye who oversaw previous attempts made by students. In essence, the joystick mouse must be durable as previous iterations broke after undergoing an accidental fall or rough handling. However, the problem statement also specifies that this joystick mouse is different from any existing design as it must adapt to those who cannot grasp objects or pinch their fingers.

Design Criteria

After narrowing down the short, specific and sexy problem statement, it was easy to list the design specifications. If the team were to design a stronger joystick and case while knowing the limitations of the patient regarding precise movement, the criteria followed the translated customers needs statements. The joystick:

- Can be used with only one hand, as per the user's limitations
- Is intuitive and simple to use
- Is easy to move or, it has low resistance
- Functions properly and consistently
- Can be used from the user's bed or wheelchair
- Survives falls of s maximum of one and a half meters
- Resist consistent and rough usage
- Fits the user's hand well and prevents it from slipping off
- Optimizes weight and durability
- Stays in place while being used. In other words, it is somehow fastenable onto the surface where is it being used
- Is easy to move and carry to another location
- Manufactured with quality yet inexpensive
- Is easy to open and has parts which are easy to replace upon them breaking

In summation, the joystick had to live up to all of these design criteria. As a result, this criteria was the main reference when ideating.

To continue, the metrics were as followed while given their appropriate units:

- Length, width and height of joystick case (centimeters or inches)
- Height and radius of joystick column (centimeters or inches)
- Maximum strength applied on joystick before rupture (newtons or pound-force)
- Number of droppings before rupture (integer)
- Length of the connecting wire (meters or feet)
- Maximal distance from which the client can see the screen (meters or feet)

To sum it all up, the design criteria and metrics aforementioned were the guidelines used when the team started to ideate and create different design possibilities. Without such guidelines, Team A4 could not have created devices that were consistent with the client's needs and specifications.

Concept Generation

Concept generation was initiated by each team member through individual brainstorming and idea sketching. In this step, team members reflected on the list of design criteria before creating their list of possible solutions.

Overall, team members put heavy emphasis on an accommodating hand pad rather than durable materials as this was a conceptual approach to the problem. Preserving the physical structure of the joystick mouse previously in use was also common amongst solutions. This occurred as the team wanted to optimize the user's comfort surrounding the device which indicated that entirely new concept may not be easily accepted by the user.

Firstly, there were many approaches to the adapted hand pad. Essentially, the focus was to ensure the safety of the user by using non-abrasive materials (Appendix A.2) or to use streamlined edges (Appendix A.1). Apart from these ideas, the use of a grip pad was also introduced (Appendix A.4) to promote ergonomics and blood circulation for the user's hand.

Group members also strayed away from the traditional hand-pad design giving way to sleek designs (Appendix A.3) or more complicated ways of affixing the user to the device. Apart from the old design, team members were also keen to reinvent the concept altogether. Using the principles of benchmarking, individuals integrated the popular touch-screen in one of their proposed designs. Several members also allocated room for a bluetooth bracelet that tracks user movement for the mouse cursor. Finally, team members also branched away from the joystick itself and began thinking of ways to implement the device in the facility (Appendix A.2) including extendable desks and wheelchair adapters.

Team A4

Several methods were used in concept generation. Although benchmarking was done from the previous iterations, inspiration was also drawn from everyday objects including phone cases, video game controllers and arcade controllers. Secondary research was also done in order to clarify what is important in devices to make it user friendly for those with certain physical limitations. Finally, several ideation methods were also put to use during the basis of concept generation. These primarily circulated around the SCAMPER method. As a result, this allowed team members to easily take what they know and brainstorm possible ways to improve previously-existing objects. These brainstormed ideas were put to sketches and descriptions and then shared with the remainder of the team.

From hereon, team members discussed and selected the strongest designs from each team member and conducted a general comparison. Overlapping ideas were also considered and if one prevailed over the other, it would be selected as a potential choice. Finally, through a series of pairwise comparisons and numerical evaluations (Appendix A.6), the concepts with the strongest satisfaction rate for the proposed criteria were considered in the next steps of the the prototyping, testing and methodology.

Methodology

The first prototype concentrated on the physical and the focused aspects of the final design. Being made of cardboard, the group wanted to concentrate on the functionality of the hand pad and the joystick shaft. In this first, low fidelity, iteration, the team tested the ability to keep the handpad level by incorporating a certain accordion style design at each end of the shaft (Figure 1). This would eventually become the double analog design used in the final product.

This preliminary design also included the first solution to keeping the joystick in an upright position. An elastic stretched from the base to the top of the shaft served this purpose. In addition, the team wanted to test the dimensions of the hand pad and how comfortable it would be to the user. Therefore, drops of solidified glue were added to simulate a gripped hand pad (Figure 2).

Lastly, the initial attempt to prototyping also included comprehensive aspects in its absence of any electronic components as this was not the main focus. The first design was brought to the second client meeting where Mr. N'Diaye was the primary client. He highlighted the dimensions of the hand pad, its ability to stay level and its function of coming back to the upright position. His main concern was its inability to be secured to the surface where it was being used. He also indicated the sharp corners on the base and that it would need to withstand the users downward force. Finally he indicated that it must also withstand being dropped from the wheelchair or the hospital bed.



Figure 2. First grip structure



Figure 1. Accordion levelling feature

In total, the very first prototype's main function was to test the physical aspects of the summation of the team's ideas with special focus on the shaft and the hand pad. After bringing it to the second client meeting, Mr. N'Diaye gave critical feedback that was needed to progress and improve on this first design.

With time, resources and the feedback on the first prototype, the team was able to create a second prototype. This medium fidelity design was now more comprehensive and better represented what the team were to achieve in the final product. Between the first and second prototypes parts that were to be part of the final design were placed to order. At this point, all that was in the group's possession was an Arduino Esplora microcontroller acquired courtesy of Saint-Vincent's Hospital alongside the feedback from the first prototype.

Thus, the second prototype was built with intent of tilting towards a comprehensive model. This time, the team incorporated the software aspect and tested it to verify its working capability. The Arduino was encased within a 3D printed structure after its metrics were specified. In response to the feedback received in the second client meeting, the team made sure to round the edges on the casing. A square hole was also added to the top half of the case to accommodate the addition of the joystick shaft. The first iteration of a joystick shaft was 3D printed and secured atop the analog on the arduino board. Then, a 3D printed plastic handpad was glued onto the shaft of the joystick in absence of the second analog stick that was in transit from the team order. Team members were also waiting on the grip surface and the sticky base pad to arrive, therefore, the top pad and base were bare.

It was then time for the team to bring this prototype to the third client meeting in which MHK was present. During this meeting, team members explained what was missing and what was to be added in the final prototype. Mr. N'Diaye expressed being pleased with the appeal and durability of the base. He also noted the missing feature on the top pad of levelling and pulling to an upright position. The user, MHK, tested its functionality and said that he liked it. His main concern was the speed of the arrow on the computer screen and the need of a taller joystick. Mr. N'Diaye added that there was too much space inside the case causing freeplay of the Arduino.

Following the meeting and the reception of a new round of feedback, it was time to test the capabilities of the new casing. To do so, the Arduino was removed from the casing to avoid damaging the hardware, software or the coding of the program. Coins and small weights were then added within the case to simulate the weight of board and dropped it from one meter (hospital bed height, security constraint). The first 3D printed case, being only 2 mm in width did not survive. Therefore, the team then reprinted a case that was 5 mm thick which did not live through its drop test either. Finally, the team printed an 10 mm thick case which survived the testing sequence. The team agreed to avoid making the casing too thick as it must optimize the strength and the weight of the product.

To sum it up, the comprehensive second prototype had the task of highlighting the new case and the added software component. It had less focus on its functionality for it been had tested this in the first model. With this last set of feedback in addition to the final materials coming in the mail, the team was ready to produce the final product design.

Solution

The final solution is an excellent combination of the functionality from the first prototype and the focused improvements of the second.

First of all, the Arduino board sits comfortably padded within an 10 mm two part 3D printed case (5 mm thickness each part). The board resting in the bottom half, the top half sits on top so that the Arduino is easily accessible for repairs or replacement if needed. The lower half of the case utilizes a sticky pad on the bottom to keep the joystick in place during use. It sticks very well to hard and flat surfaces, yet, it is easily removable and carries well to other locations.

A one meter cable enters the casing through a small hole in its side. The micro-USB to USB cable can then extend to the intended device. In this case, it is MHK's computer, however, it can be plugged into and used on any electronic device with a USB port. Nevertheless, the joystick needs an external software download to add the auto-click feature. Thanks to padding on the inside of the casing, the smooth 3D case can survive falls up to one meter, and includes a circular hole in the top half large enough for a full range of motion of the joystick column itself.

The wider joystick shaft can support a great amount of force and still allows a good amount of mobility. It is bordered by analog joystick at each of its ends. The one on its bottom connects it to the Arduino and the base and the one at its other extremity links it to the hand pad. These analogs ensure that the hand pad remains level in all positions during the joysticks use. The hand pad itself kept its original dimensions from the first prototype as per the client's requests. Finally, the textured plastic grip was added to prevent the user's hand from slipping.

As all of these concepts were taken into consideration, the group believes what sets it apart from other joysticks is the truing mechanism. This feature pulls the joystick shaft back to the upright position upon release. Glued to the Arduino board is a ring including eight small loops. Threaded through these loops are eight small elastics that then extend and subsequently hook onto the base of the joystick shaft. These small elastics ensures that the joystick comes back to the zero position, therefore eliminating the cursor drifting once the user releases the joystick. In addition, it gives the right amount of resistance to the joysticks movement.

To conclude, the final design really is the best of both prototypes and includes new design concepts that were refined over time. Not only is this product ideal for MHK, being the main user, but it can also be adapted by many others that have similar conditions to him.

Constraints and Compliance

Throughout this project, the team ran into some constraints, both on "everyday life" aspects and legal or compliance aspects.

Starting with the most obvious, the main constraints that the team ran into were time, money, materials and manpower. When the project was obtained back in September, team members were convinced that with over two months to complete everything, there was plenty of time. Nonetheless, it was amazing how fast time flew. Moreover, there was a budget limit of one hundred dollars. As a group, quite a bit of time was spent finding way to optimize the materials to be used with the fixed funding. It is easy to say that it was preferred that the casing were to be built out of carbon fibre and ninjaflex rubber. However, this option was not realistic knowing that inexpensive materials could do just as good of a job. Materials also somewhat tie into money as the team ran into a lack of materials due to the spending cap. Instead of simulated weights, it would have been fantastic to use Arduinos during the drop tests to see the exact damage that may occur. The team refrained from doing so because it was too expensive to replace if it had broke. Lastly, for a group of four people with five other classes to juggle, it would have been nice to have more manpower/womanpower so that tasks could be delegated evenly amongst people rather than heavily focused on availability and willingness to work.

Dealing with compliance constraints specific to the hospital environment was not that difficult, because they were mainly common sense constraints. First, working with patients meant to preserve their anonymity and wellbeing. Those common sense rules of an health care center were not any issues on the project, despite the impossibility to communicate directly with the patient without Bocar being there. The team had also to be aware of some laws that applies to health care centers, such as the *patient's bill of right in Canada*. However, since the product has a goal of entertainment and has nothing to do with the patient's care, the team hasn't found any legal regulation that should be applied to the joystick.

Obviously, for the safety of users, the wires and all electrical components need to be properly soldered and protected, as to avoid any risks of electrocution.

About previous existing products, benchmarking showed us the existence of some patents on powered wheelchairs' joysticks, for example the two american patents US 20150033895 A1 and US 20060070477 A1. The drawings provided for the patents helped the team to understand fully how this joysticks were made. However, since the topic of this product was really specific to one patient, there did not seem to be patents on adapted computer joystick for patient with poor motor skills.

The trademark *Arduino*® will be indicated on the product, since it was the main electronic component used as the reference of the MY-DJ, and since the basis of the code was also picked on *Arduino*® official website.

Surprisingly, the team ran into another constraint near the end of the project in the form of customer rejection. This situation was not expected whatsoever as MHK expressed that he no longer needs the joystick and that he is capable of using his computer's mouse. During the final meeting, MHK also followed his statements by demonstrating that he somewhat could use a standard computer mouse, needing practice over time. Afterwards, Mr. N'Diaye explained that MHK did not understand that he was mainly the test subject because he was coherent and did not mind being bothered by curious designers. He continued to explain that there are other patients in the hospital, maybe some with more limitations than MHK that could also use this design. Therefore, MHK was there test if the generated solution would be suitable for these patients. Nevertheless, this encounter led to a realization of worry, insecurity and a slight loss of motivation for the team.

Conclusion

In conclusion, the development of MY-DJ came out a success. A plan was set out from the beginning to orchestrate the order of events that would come before the project. Constant iteration, timeline planning, feedback evaluating, and other necessary managerial tasks relating to the project are the reason MY-DJ came to completion with satisfaction. However, they did not come along with their own lessons.

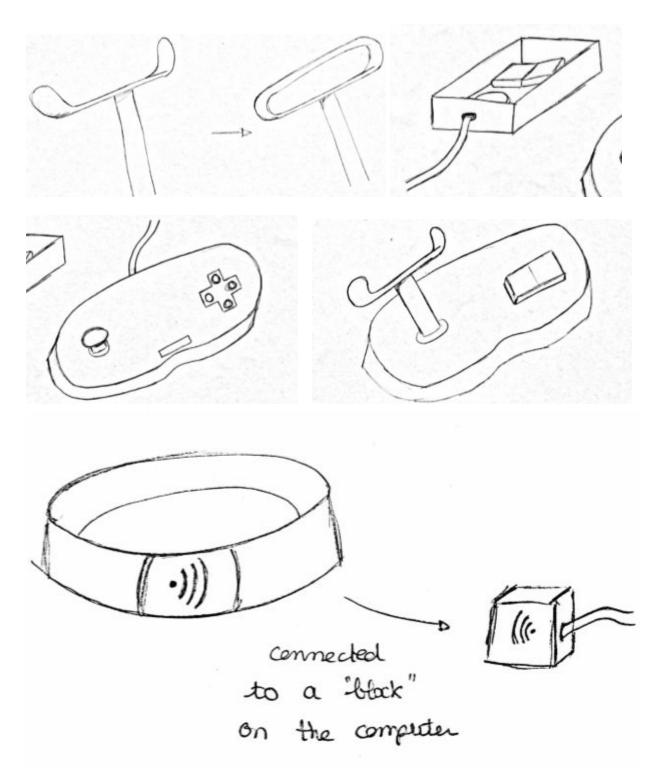
Through the trials and tribulations of this project, tasks of working in the real world were more than just a reality, but a lesson. Learning to deal with a real client, and not an imaginary criteria sheet, forced the development of real empathy and care when designing the final project. By virtue of this, team members are more willing to learn to adapt for a common goal within a group setting, through means such as conflict management. When the effort and stress put into a project is real and whole hearted, the taste of success afterwards is much warmer and satisfying, knowing someone real will get to enjoy the fruits of the labour.

Although, being that people are dynamic, so can be the product. Future development of MY-DJ starts from basic improvements, such as higher durability or stronger materials, implementing bluetooth, and making the joystick travel safe and portable. However, larger leaps can be achieved. A main goal which would like to be achieved is to have the controller function solely on its own code, without the need of additional software, thus allowing simple plug-and-play for any user. Additionally, potential sensor hardware can be added to MY-DJ to track slips and force on itself. This would be good for tracking and plotting progression of post surgery patients, from carpal tunnel syndrome for example, and assessing their progress.

As a result, the entire group is very proud of the final product and are quite excited for MHK to receive it so that he may be able to use his computer. Team A4 believes that this will make him feel happier and make his stay at Saint-Vincent's Hospital more enjoyable as he now will be able to fully access his computer. In essence, he can view interesting stories and facts thanks to the arabic newspaper he consults online, stay entertained while playing games and communicate with loved ones at all times. The team also understands that this design may be produced for other patients and end users. Here at My Digital Joystick, the goal is giving the users the key to unlocking their digital world.

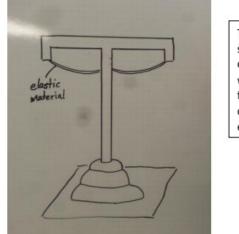
Appendix A: Supporting Documents

Appendix A.1: Idea generation by J. Vannieuwenhuyse.

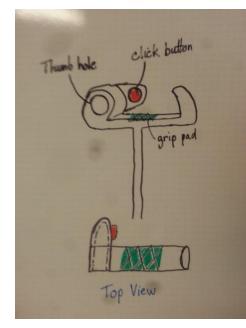


Appendix A.2: Idea generation by M. Barr.

autoria. dick butter This Joystick has This Joystick has This one uses a In this variant, a button that soft, stretchable an added rubber the click button the user can material to keep grip tape (soft is in the center press on his the user's hand and non-abrasive) of the joystick thumbside from coming out of the joystick

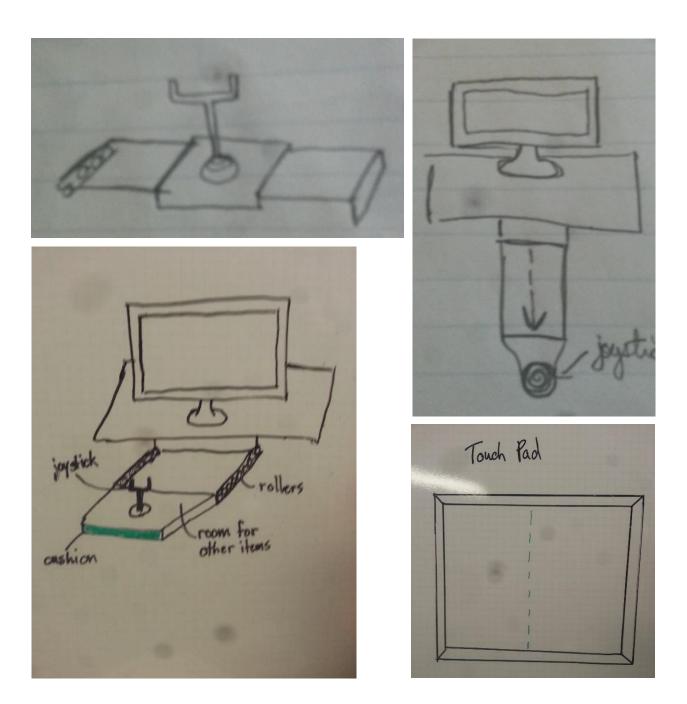


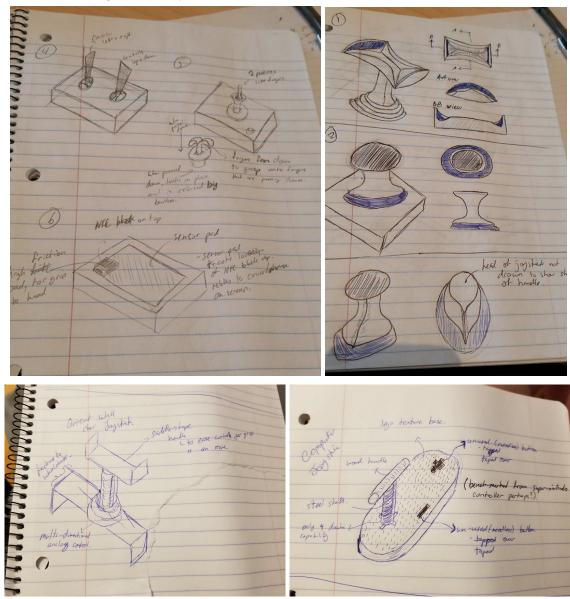
This variant of the joystick is somewhat a reversed version of a previous prototype where the user rests two fingers on each side of the center pole in a comfortable elastic material





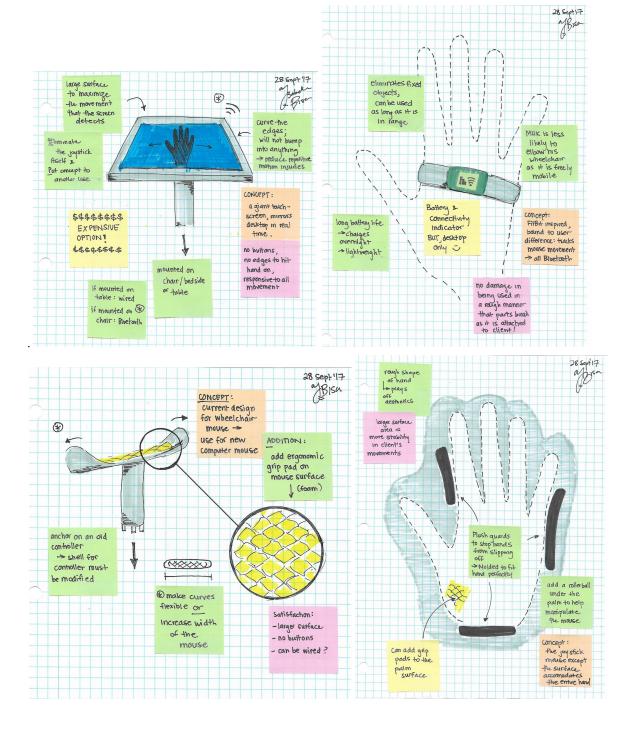


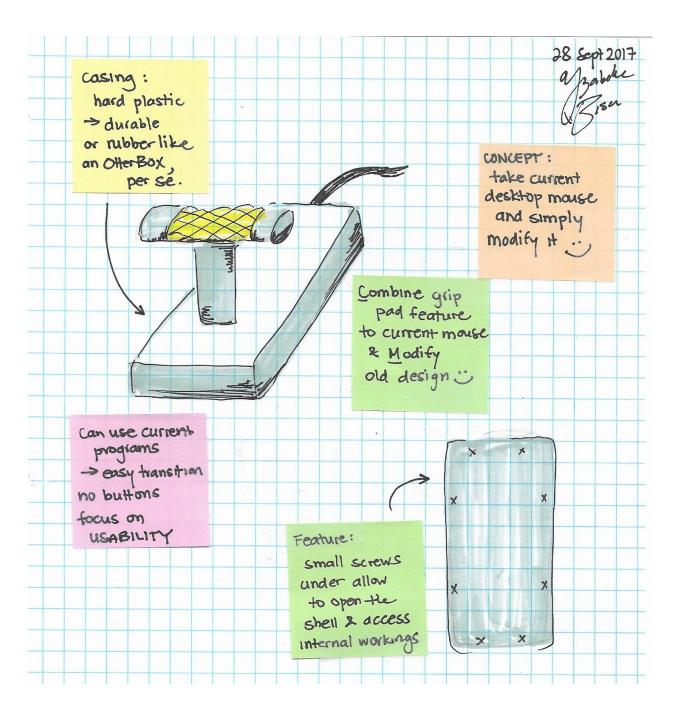




Appendix A.3: Idea generation by D. Sirianni.

Appendix A.4: Idea generation by Y. Bisa.





Appendix A.5: Initial devices.

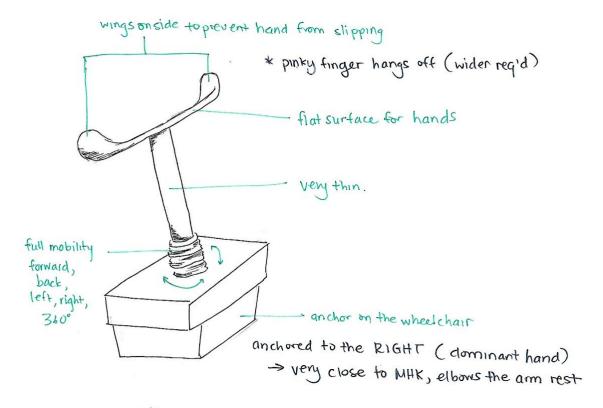
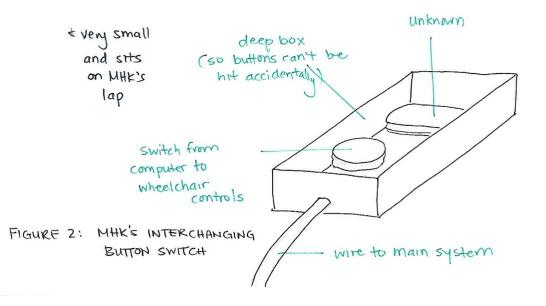
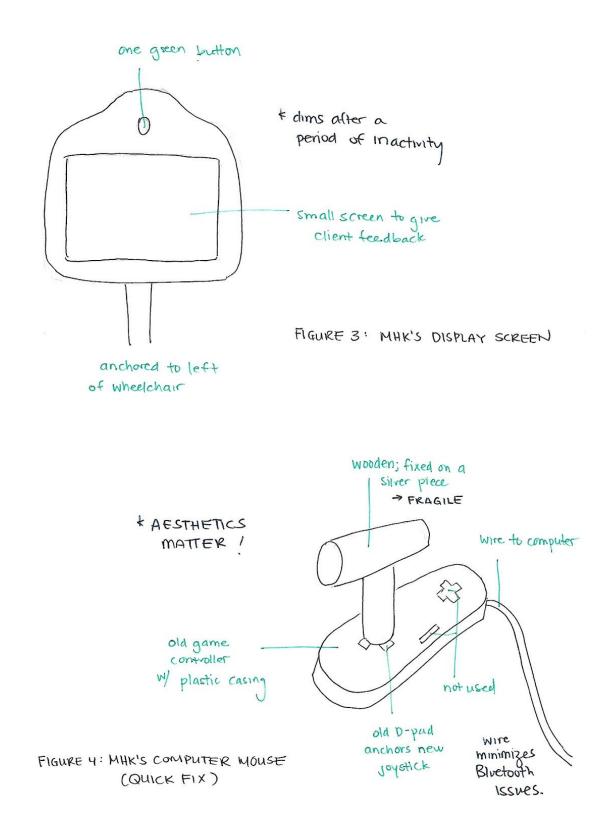


FIGURE 1 : MHK'S CURRENT JOYSTICK MOUSE





		Concepts for the joystick														
	Segment	A Original wheelchair joystick			B Wireless bracelet			C Grippad			D Horizontal handle			E "Hand blocking"		sing"
Selection Criteria	Weight	Rating	Notes	Wtd	Rating	Notes	Wtd	Rating	Notes	Wtd	Rating	Notes	Wtd	Rating	Notes	Wtd
Sensitivity	10%	3		0.30	5	1414-1-1	0.50	4		0.40	4	100	0.40	4		0.40
Durability	15%	3		0.45	1		0.15	2		0.30	3		0.45	2		0.30
Comfort	5%	3		0.15	4		0.20	4		0.20	5		0.25	4		0.20
Ease of moving	15%	3		0.45	3		0.45	4		0.60	4		0.60	1		0.15
Fitting of the hand	10%	3		0.30	4		0.40	5		0.50	5		0.50	4		0.40
Material "feeling"	5%	3		0.15	4		0.20	4		0.20	3		0.15	3		0.15
Cost	20%	3		0.60	1		0.20	2		0.40	3		0.60	3		0.60
Aesthetics	5%	3		0.15	5		0.25	4		0.20	4		0.20	3		0.15
Safety	15%	3		0.45	5		0.75	4		0.60	4		0.60	2		0.30
	Total Score Rank		3.00			3.10			3.40			3.75		2.65		
	Continue?					NO			YES			YES			NO	

Appendix A.6: Pairwise comparison of designs.

		Concepts for the case														
		A Previous try, actual but not working			B Silicon			C Wood			D Solid plastic			E Metal		
	Segment															
Selection Criteria	Weight	Rating	Notes	Wtd	Rating	Notes	Wtd	Rating	Notes	Wtd	Rating	Notes	Wtd	Rating	Notes	Wtd
Weight	10%	3		0.30	5		0.50	4		0.40	3		0.30	2		0.20
Durability	25%	3		0.75	4		1.00	1		0.25	4		1.00	5		1.25
Material "feeling"	15%	3		0.45	4		0.60	4		0.60	4		0.60	1		0.15
Cost	20%	3		0.60	3		0.60	2		0.40	3		0.60	1		0.20
Aesthetics	10%	3		0.30	4		0.40	4		0.40	3		0.30	2		0.20
Ease to open and change components	20%	3		0.60	3		0.60	1		0.20	4		0.80	2		0.40
	Total Score		3.00		10.0	3.70			2.25			3.60		12101	2.40	
	Rank													1		
2. 25	Continue?					YES			NO			YES			NO	

Appendix A.7: Prototype 1.



Figure 3. Low-fidelity cardboard prototype

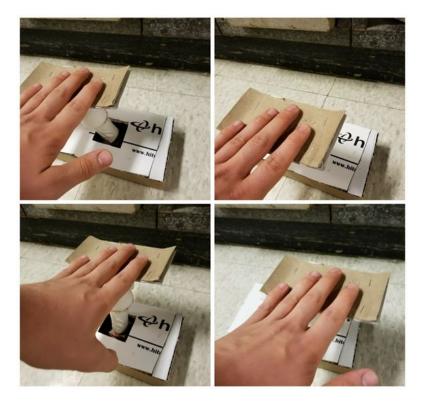


Figure 4. Joystick movement

Appendix A.8: Prototype 2.



Figure 5. Medium-fidelity components

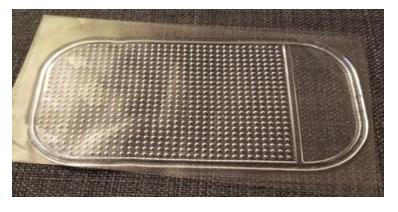
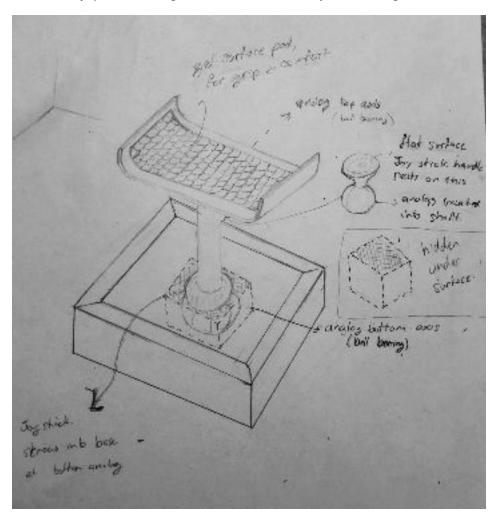


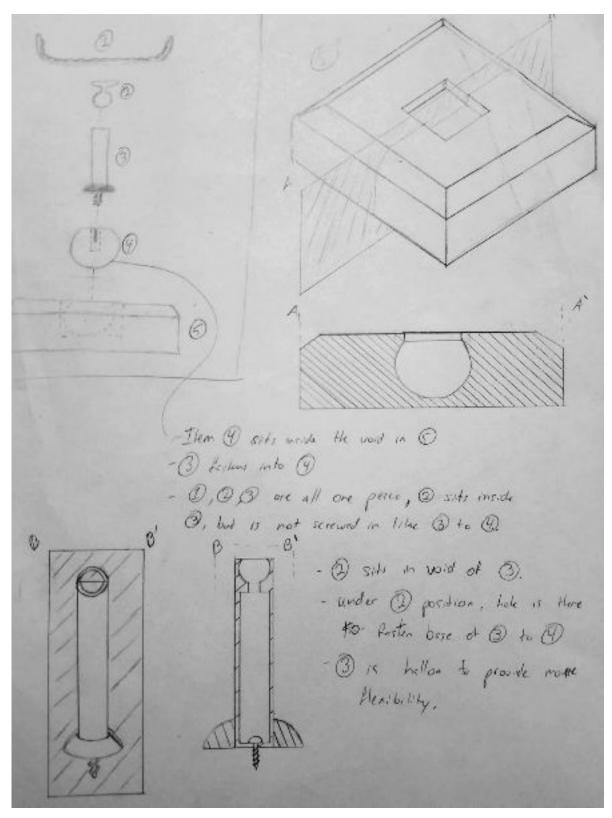
Figure 6. Silicon grip-pad



Figure 7. Initial 3D printed shaft



Appendix A.9.1: Final joystick conceptual sketches - the shaft and handpad.



Appendix A.9.2: Final joystick conceptual sketches - mechanism of the shaft.

7 = 381 (St 30") = 19mm D= 2(19) + 30 = 89mm 391 (St 25") = 16mm D= 2(16) + 30 = 62mm

Appendix A.10: Calculations for casing opening, maximizing mobility.

Appendix A.11: Final solution - the components.



Figure 8. Analog axis (1 of 2)



Figure 9. Joystick mouse hardware - Arduino Esplora

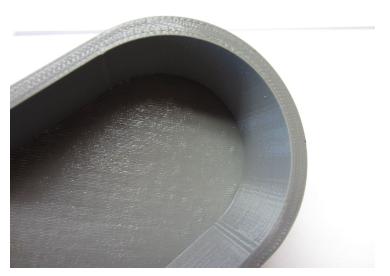


Figure 10. Durable 3D printed casing



Figure 11. Joystick shaft



Figure 12.1. Elastic-tension scheme (1 of 2)



Figure 12.2. Elastic-tension scheme (2 of 2)

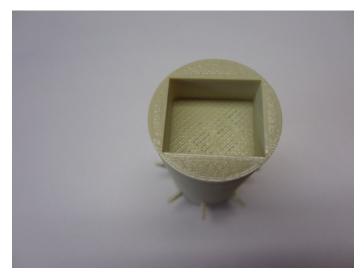


Figure 13. Upper joystick shaft

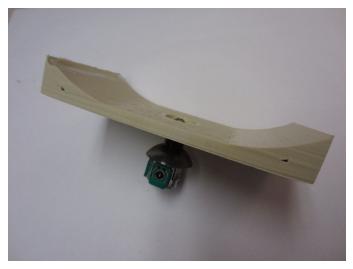
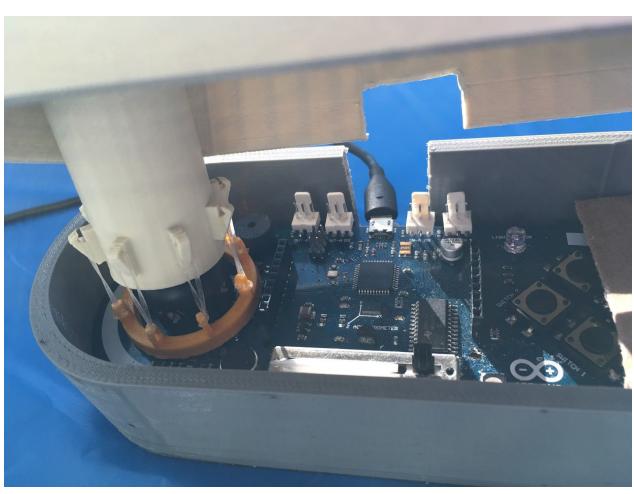


Figure 14. Adapted handpad design



Figure 15. Analog axis (2 of 2)



Appendix A.12: Final product: MY-DJ My Digital Joystick.

Figure 16. Internal organization

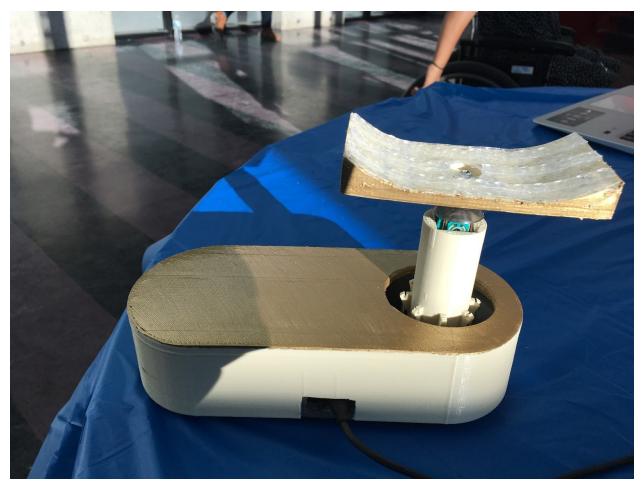


Figure 17. MY-DJ assembled with handpad

Team A4



Figure 18. Side view of MY-DJ



Figure 19. MY-DJ top view

Appendix B: Meeting Minutes

Appendix B.1: Interview Planning (19 September 2017)

Guide:

M – Matthew Barr

Y – Yzabelle Bisa

D – Dario Sirianni

J - Juliette Vannieuwenhuyse

Y: Okay, we're on air.

M: Am I, am I on the air?

Y: Yes, you're on the air. I guess this is um...alright...our schedule. These are all the guidelines and we have room for twelve questions. Alright.

[Dr. Knox audible in the back]

J: It's kind of hard to read over because we don't even have our project.

D: Yeah, it's kind of odd that we don't even have a project.

Y: That's true.

M: Okay so, are we going to pretend that we already got our topic?

D: Let's go for, let's go for joystick.

Y: Yeah, okay.

D: Um, one thing I was thinking, here...so he's in a bed a lot, where he's in a bed his portability/ how portable does the joystick have to be?

[Dr. Knox audible in the back]

J: Maybe like, what are the different things he uses the joystick for like?

D: That's another one, yeah. How many applications does his joystick need to accompany?

M: Does he also want, like, auxiliary buttons? That can do other things apart from the joystick?

J: That's true.

D: What kind of buttons do you need to have control of it?

M: Yeah, yeah, yeah.

J: Okay, the other question I was looking at was "When was the last time you used the joystick?" Do you know what I mean?

D: Yeah, when was the last time you used [the joystick]? How was the last time/ how was your last experience with the portable joystick?

M: How comfortable would you like it to be? I guess...

Y: Keep going.

M: There are no wrong questions I guess.

Y: Exactly.

D: That kind of goes along the portability. Do you want it to be handheld or do you want it to be fastened to something? So that's where the portability aspect comes in...it's uh, for basically...how do you want it/ how do you want to control the joystick? By hand or attached to like, a leverage?

M: That's what I'll let them say they'll say obviously...

D: That's right! That's what my...

J: Even if it's like made for them, what's not okay with like, the old one.

D: It did say it broke, that was a big one for durability.

J: Maybe they can list things that they don't like.

D: Right. So, we can ask them questions like, "What did you find wrong with the last?"

M: Because I was thinking of like, models that we can like, base off of something else...

D: Yeah...

M: So, you know those like old Pacman joysticks?

D: Yeah! That's exactly what I was looking at.

M: So, I was thinking we could do it more like a, uh, like the nunchucks on the Wii remote?

D: Right.

M: Like the little thing that you connect...

D: But we can't have ideas yet...we have to ask him what you...so that's where I'm asking if he wants a joystick, he can fasten it...but if he wants a nunchuck, its handheld.

J: Maybe we could have a computer and show them which is a nunchuck and which is the joystick from something else so we'll see...

D: Last time, he had a nunchuck form...so that's why it broke and that's where the durability [comes in]. I need to know like, does it need to bear weight? Does it need to bear...so that's where...he'll let us know if it CAN be nunchuck or not. Because if it needs to be fastened, cause if he can't...

J: How it broke is like [very important].

D: Exactly, how it broke...

J: Because if he's too strong...

D: Another one that I was going to ask was um...the size of the joystick.

M: Yeah, he might need a big one...

D: Because if he want's a fastened one, it can be really small beside his bed or if he wants a big pad, we can make a big, padded, joystick for his lap or something like that...because I don't know, this is more or less to him but how bed-ridden is he? Like is he not allowed to leave his bed...

Y: More so, what's the most comfortable thing for him?

D: Yeah, what's more comfortable so when you are on bed rest, how much can you move and what is most comfortable for you?

Y: Even like, his incline in his like, bed [per se]

D: Yeah, yeah.

J: Maybe we can ask the guy things that are not related to this project like, just to make it interesting like, what is a typical day for him [like]? What is he doing, like, he needs to tell us about what his normal day is...

D: Yeah! Ask about him as well as the product. Yeah.

J: Does he have, like, some activities that he [does on a daily]. How does he go for lunch? Have a lunch on his bed? Just asking things like this...

M: Another thing we can so as like a, divertissement, like to...like if we can see that he's sad about it or whatever, we can ask him like, little questions like, oh, what's your favourite colour?

D: Exactly! Little like, little up-boosters.

J: Yes, those that have nothing to do with the project, in fact that could be [helpful]

M: You know, stuff just to make him happy.

D: Yeah, that's good to have him happy because you know, we don't want to over-burden him with "this is bad" and stuff like that...

M: Um, do you want flames on it? Decals...?

J: Also, do you have, sometimes, friends or family who come to you so maybe you can have a second one...?

D: The biggest one is what is his interest? What makes him want this besides [having a joystick]? What do you want to do with this joystick?

J: I don't even know if this is for playing or like...just his bed?

D: Yes, surfing the internet. What will change dramatically, how we design it anyways, is do we want a D-pad on there? It's way different than a joystick but we can have both on there so like...

[Dr. Knox audible in the back]

[Side conversations regarding an old PS4 controller]

J: I hope the client still has the previous joystick [so he can show us] what was broken, what works, what doesn't?

Y: It can help as it indicates what he liked and didn't like so we can actually see it for ourselves.

D: Mhm.

J: Yeah so on the previous one he can point to what you did like and don't like.

[Dr. Knox audible in the back]

M: We can ask if he, he would want it like fastened...like maybe like, if it's a portable one we could do like a lanyard...

D: Yeah, so how would you want to fasten it or...do you want it completely portable or fastenable to an object?

J: ... or maybe it can be two, or like just one big on something and another one goes with him

M: ...on his arm, yeah...

D: ...or can it be corded or not corded? What is your preference of connectability?

Y: But also, like, if you think about it, [he might] need help to connect it to whatever he needs it for...

J: It should be easy to connect...or no we really don't know anything about the client.

Y: Especially if we have different nurses...

J: Even like, maybe he's just in bed but can literally do everything...

Y: Exactly.

J: We don't know so we have to ask about his ability to like...

M: We can also ask how simple he wants it because he may want it that one button does everything and depending how many times you press the button...

Y: That's true.

D: That's true, yeah. Yeah, that's a good one actually, how simple/ simplicity...

[Division of Interview Tasks: Two interviewees, physical cues and notes]

Appendix B.2: Client Meeting 1 (26 September 2017)

Client: Mohammed H. Kouis (MHK)

Bocar N'diaye : Stick to the mouse, stay on track

Previously had an all-in-one solution: Controls desktop computer, electric wheelchair and TV Bluetooth connected, this was a problem because if one broke, it restricted access to the other there is currently a simple joystick on the desktop computer, a quick fix when the desktop-feature broke potential for an all-in-one solution for wheelchair and computer like before Having one joystick mouse to use restricts his access to multiple devices, this accounts for his safety there have been lots of accidents in the hospital concerning wheelchair safety

QUICK FIX JOYSTICK MOUSE:

Downloaded a free code but the handle on the model is unideal for the client

potentially benchmark from past examples, improve them
WE CAN HAVE ACCESS TO PREVIOUS PROJECTS
2 or 3 attempts in the past but none worked

NOTE:

If the project is safe and works, it can be implemented! THE GOAL IS TO MAKE SOMETHING THAT WORKS. FOCUS ON THE COMPUTER MOUSE.

The Device: Old Device

looks similar but the mouse control is different no mouse control in the new one due to a new version (firmware and commands MIA?)

MHK has a display screen:

shows the power levels gives MHK feedback of his controls, indicates what and where to select charger connected from a corner in his room display dims after a period of inactivity

There is a box on his lap that has two simple controls:

o one button switches screens

Current features are abundant:

he can set different speeds (?)

chair control: moves seat and footrest forward and backward, up or down he can control the power, channel, volume, guide, mute button, etc. of his TV Current joystick moves in all directions, lots of mobility and can accommodate exaggerated movement. The mouse currently uses auto-click, hospital staff pre-loaded the software (if you leave the mouse on the desired option long enough, it clicks)

modified game controller with a joystick built by a carpenter gaming buttons were too hard to press for MHK

He needs a very light and sensitive button, if possible (don't get too wound up on this)
we can use the codes currently installed on the device, the simulated mouse and keyboards (ABC mode but maybe use QWERTY)
we can use open-source software and customize it

FOCUS ON A WORKING DEVICE – only one joystick is needed from us (computer use since chair is a safety risk)

UNBREAKABLE? AESTHETICALLY-PLEASING? At a minimum, the joystick needs to stay on the table WIVIK - currently used, all we need is a mouse to utilize it

Wired mouse - current, reliable, must be long so MHK can be further away

Bluetooth – desired, potential issues for connectivity and charging

Casing is a massive issue

lots of accidents and unbreakable cases would be ideal to protect the inner workings

rather than reinvent, customize a rugged and workable case

The client likes the handle, more control as it accommodates his hands

potential to add a grip pad, accommodate finger-width

round and T-shaped did not work previously

hand sometimes slides off the mouse, close to side

The Client:MHK has limited mobility, he can move his right arm left right, up, down.
The movement is not refined, very exaggerated.
Light pressure on his device.
Hand remains flat, not a lot of finger movement.

Favourite colour is white 😅

*Potential contact is a programmer of 30 years experience, email Bocar if needed. *Other group is concerned of very minor details; how can you make it larger and more doable? *Find the previous groups and ask them questions.

PLEASE DO NOT RUN OUT OF TIME PLEASE DO NOT BREAK IT DURING YOUR PRESENTATIONS PLEASE START EARLY

Appendix B.3: Client Meeting 2 (16 October 2017)

Interviewers: Matthew Barr (MB) Yzabelle Bisa (YB) Juliette Vannieuwenhuyse (JV)

Interviewee: Bocar N'Diaye (BN)

delayed recording, Matthew explaining the prototype

MB: [you can move it around] so you can do whatever you want with it or it could be bolted down to, like, a surface...

BN: Those are really good questions and options...now, I cannot give you a definite answer on [what Mr. Kouis would prefer]. I mean I like, if it is bolted, it is there [with] velcro or stapled in so it is not moving around that's a nice advantage there but at the same time he's probably gonna use it when he's close enough to [use the computer]. Depending on the table, can he go close enough and reach?

MB: Right, right.

BN: ...even if it is...

MB: ...on his lap?

BN: On his lap, he used to have to have a tray and then you would put it on that tray.

MB: If we were able to bolt it down to the tray, we were just thinking that if it was not bolted down and he does, you know, some kind of movement and then it tumbles over...

BN: yes, exactly you have to figure out a way so that it doesn't slide or you know, we use different techniques like velcro or some non-slip pad or we have this kind of material that we put on top [of the surface].

YB: So in your previous experience, did you feel that those solutions were, like, the most effective or...?

BN: Yes, they were kind of flexible and [Mr. Kouis] wants some kind of a flexibility but flexibility is not realistic right now but sometimes he wants to use it in bed, sometimes he wants

to use it on his chair but he must pick one or the other or...whatever. It's whatever you can implement that works and that will be fine.

MB: Maybe we can use velcro or something

JW: Yes.

MB: But then again, he may not be able to un-velcro it and move it so he may have to get the staff to un-velcro it.

BN: Yeah, yeah it could be part of his care plan.

JW: We have a question about the electronic part, can we take the current electronic part to do ours or should be take pictures and re-do the same one. (In reference to) the software one and the hardware one that is in the current joystick...can we take it and use it?

YB: or is there any way that you can give us a sample?

BN: It's not bad, it's Leonardo, actually it's discontinued, it's Esplora but I was able to get it on Aliexpress...I actually have a few lying around but I don't have any casing for it...if you feel like you can make a nice, rugged case

JW: That's what we want to do...

BN: Go for it!

YB: Is there any way we can have a look at it?

BN: Yes, I can even give you one, or lend you one.

JW: Yes, and we'll make the casing and joystick around it.

MB: It would also help if we have the software

BN: If I could locate the software from way back, it's a free download and I've modified a few things, you know...

Other Group: Can we assume that the computer that we are going to [connect to] for our prototype is the computer that [the client] uses as its ready to program and you are just going to navigate the joystick?

BN: Yes, that is what you'll use.

Other Group: Basically, the main idea here is to build a joystick

BN: Yes, a good joystick that works and I think that is the more realistic thing but at the same time, that is where I had an issue and that is building a nice, rugged case.

Other Group: and the materials...

MB: Now, if you don't mind, if you could test this out yourself...

BN: I would use a lot of force because the thing is, [the client's] fine motor skills are not as [refined] so he's really using his whole arm to move, so that is a big problem

MB: So one of the things we were wondering is should we make this more mobile (in terms of range)?

BN: That's actually not a bad thing because the mouse I had before, he would send it one way and the mouse would keep going (on the screen) and then he could come back so you don't REALLY need to...

MB: I see what you're saying, that's good to know. Another thing we were thinking, should we have it come up more on the edges? We were looking at the wheelchair remote and we could see that he would kind of push up against these little walls on the sides so should we bring it up or...?

BN: You can see that his hand kind of gets stuck on the edges, you know...

MB: So it's better if it's just flat?

BN: But I do like the grip pad over there so it would really help.

MB: Since this is our first prototype, we were thinking of using a silicone rubber so...

BN: Yeah, that's a really good idea!

Juliette and Matthew explaining the prototype Yzabelle adds commentary

MB: We were looking at the casing and we were wondering how we could make this sturdier s we were looking at those foam casing...we looked at the layering and we're thinking of doing the same thing.

BN: That's good!

Note: Mr. N'Diaye also mentioned that harder plastic tends to chip when it is dropped and agreed to use a rubber bumper.

Appendix B.4: Client Meeting 3: Overall Summary (14 November 2017)

*no voice transcript due to privacy reasons.

3D Printed platform was approved of by MHK and Bocar N'Diaye.

This fits the client's hands perfectly.

Possibility of buttons was suggested - Bocar reiterated that they must be extremely sensitive and easy to press.

Overall dimensions were discussed: taller joystick shaft or omission of the shaft altogether?

Client preferred a height of about 1-2 inches.

A pivoting single-analog platform may rub against each other.

Device must still be fastened onto the surface - Bocar suggested the currently used system of a non-slip pad with the device affixed onto it with Velcro.

Client wants to use the auto-click software - keep it implemented.

Side note: MHK expressed frustration, he almost didn't want this project.

> possibly done without his full consent?

> Bocar likely implementing idea to the whole facility,

*he is a responsive client to work with.

MHK is capable of using a standard computer mouse, he needs more practice.

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