Car Key Aid

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ENG 1P03: Engineering Profession and Practice

Fall 2014

1.0 INTRODUCTION

1.1 Background Information

Brad Langmead is a client with hypertonia, caused by a stroke. Hypertonia is “the reduced ability of muscles to stretch due to increased muscle tension” [1]. Brad’s right hand is most severely affected by this, as it is stiffly clenched in a fist. Brad’s hand is always in a power grasp, a static hand position the body uses to apply a large force to grip something tightly. This holds the wrist firmly in place, restricting movements of the wrist in the dorsal and palmar directions [2]; however, Brad finds movements in the dorsal direction especially difficult. Often, Brad’s problem is that he cannot open his hand, as his grip is too firm, and he has to concentrate to let go. He is unable to move his index finger, thumb, and little finger, although his middle and ring fingers are functional. Brad experiences greater difficulty when extending his joints than he does when flexing them. Additionally, the stroke has caused some loss of feeling in his hand; Brad does not feel pain in the same way that he used to, and can often bend his fingers back past the point where it should be painful. Furthermore, Brad has some difficulty with the movement of his arm, especially when these motions are going against gravity (in the dorsal direction). Lastly, upper limb spasticity makes it difficult to grasp and hold things, as there is actually very little control in the muscles, especially the flexors within the fingers and wrist; they may release without warning [3] [4]. These complications cause many disruptions in Brad’s everyday life.

The problems chosen for this project are all daily tasks with which Brad struggles due to his affected right hand. Turning a car key in the ignition, buttoning his shirt, tying his shoes, and wearing a jacket are all tasks with which Brad has difficulty. When wearing a jacket, Brad cannot move his right arm and must keep it stiff as he uses his left arm to do all necessary work. When buttoning a shirt, Brad cannot use his right hand to hold the buttons or move them around; he experiences a similar problem with the “bottom stop” [5] of a zipper when zipping up a jacket. Whether cutting food or buttering bread, Brad’s main difficulty when using a knife is that his hand is too stiff and he cannot manipulate the knife easily. The necessity of using only his left hand to accomplish the majority of tasks in his daily life is inconvenient, frustrating, and time consuming for Brad.

1.2 Refined Problem Statement

Design an assistive device to help Brad Langmead hold and turn a car key easily using his right hand, which is affected by hypertonia due to a stroke.

1.3 Objectives and Constraints

As illustrated by the objective tree in Appendix D (Figure 1) there were three principle objectives for the project design: useful, user-friendly, and inexpensive. Firstly, and most importantly, it was imperative that the device be useful. It was of great importance to Brad and the design team that the device worked with his disability; if Brad wanted to avoid using his right hand entirely, an assistive device for this issue would be unnecessary. A rehabilitative device is one that uses and trains the existing impairments, thus “re-training” the affected body part. Moreover, the goal of a rehabilitative device is to improve the functionality of this part over time [2]. Physical rehabilitation also has other advantages: as Brad gains strength and functionality in his right hand, he will become more independent. Additionally, the durability of the device was important. In order for Brad to be able to use the device regularly, it would have to be strong and able to withstand everyday stresses.

Secondly, the design team determined that it was important to make the device user-friendly. In order for Brad to use the device with ease, it is imperative that the design be both portable and comfortable to use. This meant carefully considering factors such as weight, size, and the materials used for building.

Lastly, the design team also deemed cost to be an objective. Minimizing the cost of the device ensured that the client would be able to easily replace parts if necessary.

The two constraints for this project were safety and that the device needed to work around the client’s disability. Any design that was unsafe for use would not be acceptable; this includes anything with sharp edges, is unstable, or has reactive materials that are not rust or water proof. Furthermore, if the device did not work around Brad’s disability, it would be useless, as it would be pointless in giving Brad something that he cannot operate due to his body’s restrictions.

1.4 Prior Art

1.4.1 Commercial Products

There are several existing commercial products that help stroke victims accomplish tasks, such as independent eating, getting dressed, and turning on cars, in their daily lives.

Devices that address independent eating include the “Universal Cuff,” [6] an adjustable Velcro band attached to an eating utensil and circling the affected hand, allowing for a steadier hold. Although this may help avoid any problems caused by spasticity, it is not the best solution; Brad’s main problems lie in releasing objects, and in the case of holding utensils, rotating his wrist to manipulate food. The “Rocking T-Knife” [6] is a knife whose blade is shaped like the bottom of a rocking chair, and the handle is in a T-shape for easy grip. This would help Brad cut food with one hand, as it simultaneously slices and keeps the food steady. Although this does not enable or promote use of his affected hand, the one-handed approach is likely a safer alternative for Brad in these circumstances.

Other commercial products focus on the process of getting dressed; for example, there are “Button Aids” [7] that have a wired loop attached to a handle. One would insert the device into the buttonhole, loop the wire around the button, and then pull it out, taking the button through the hole [7]. The handles come in many sizes; this device could help Brad a greatly, as he has mentioned that larger handles would be significantly easier for him to use. Another product that would aid Brad is elastic shoelaces [7]; since he enjoys an active lifestyle, tie-up gym shoes are a necessity. Elastic shoelaces stretch enough to allow the foot to slip in without having to untie the shoes, and come in a variety of sizes, shapes, and colours [7]. This would also be a good solution to one of Brad’s problems.

Finally, there are devices that help users turn keys, such as the “Finger Grip Key Turning Aid” [8]. The user would slip their index and middle fingers through the two finger holes, and with the key already secured in the key holder, insert the key in the ignition and rotate their wrist to turn on the car. This product utilizes the larger hand muscles to turn a key, instead of the thumb and index finger. For this reason, Brad would find this device useful, as those are two of the fingers he is unable to use. However, in order to use the device, Brad would have to use his left hand to pry open all his fingers, put the device on, and then close his fingers; this is a time-consuming process. The “Comfort Grip Key Turner” [9] is another such device that is essentially a large handle with the user’s key secured to it. This device also uses the larger muscles of the hand to turn the user’s key. However, much like the first device, Brad would have to pry open all of his fingers, place the device in his palm, and close them in order to use the device. Unfortunately, both these devices require Brad to awkwardly contort his entire hand and wrist to guide the key into the ignition and then turn it. The “Finger Grip Key Turning Aid” [8] necessitates the rotation of the entire hand and wrist, and the “Comfort Grip Key Turner” [9] demands a forward wrist movement that is very strenuous. Moreover, Brad’s primary problem with turning on his car was that he was unable to apply the inward force and turn the key at the same time. Although these two devices solve the latter problem, they do not address the former. For these reasons, neither of these devices is truly suited to Brad’s specific needs.

1.4.2 Patents

There are several existing patents to help Brad hold different items. The “Adaptive Grip” [10] helps a person hold objects by having them push a button that causes a clasping mechanism to close. This mechanism is attached to the subject’s hand by three rings, which go around their thumb, forefinger, and middle finger. The clasping mechanism can be moved away from the hand, towards it, and along the horizontal bar that attaches the mechanism to the rings. This device provides a solution for tasks like gripping car keys, or holding a knife. However, the design would have to be adjusted for Brad, as the device uses the thumb as the finger that activates the clasp, and Brad’s thumb is not functional.

Another patent useful to people like Brad is the “Thumb-mountable protective utensil system and kit” [11]. This device serves a similar function to [10], but achieves it through different means. This device is placed over the user’s thumb, and includes a mount to which various utensil elements can be attached and detached. The device fits various thumb sizes, and holds itself firmly on the thumb due to 'shim elements,' which can also be attached or detached. Beyond the accommodation for varying thumb sizes, the design is not adjustable. A similar design could be used to solve some of the problems Brad faces in his life, even beyond what this device was designed to do. An attachment could be made for holding his car keys, a knife, or any other simple tool he needed which does not require any movement from his thumb. If necessary, the device could be changed to work with another finger.

2.0 CONCEPTUAL DESIGN

2.1 Brainstorming

A morphological chart was used as a means to brainstorm the possible functions of the device to be built. At this stage, a problem focus for the device had not been decided, so the morph chart displayed in Appendix D (Table 1) was used to determine the functions of a general-purpose gripping device. The more predominant functions for such a device include a way for the device to maintain hold with an object, and ways for the user to tighten and release their grip from the object. Between all the means generated to hold the object with the device, the most practical means were using either magnets or some sort of clamp. These ensured that the grip was powerful and the user would not need to worry about the object coming apart from the device, which is why they were used in the design alternatives. Using a clip or some sticky material as a means to hold the object are just weaker versions of the clamp and magnets. In order for the device to be rehabilitative, the tighten and release grip mechanisms of the device were to include the users right hand in a way that worked with his disability of not being able to control some of his fingers. In this sense the most beneficial means were the ones that involved his wrist, and possibly some methods with springs and/or elastics. A wind-up mechanism was also considered, but this was a little less feasible. The last important function that the device required was some way for it to be attached to the user. Most of the means listed for this function were applicable to the device, ranging from using some sort of band or glove that fit onto the user's hand, to a handle that the user would hold. Of all the means for the functions listed in the morph chart, the ones discussed here in detail were used in generating the central ideas of the preliminary design alternatives.

2.2 Design Alternatives

2.2.1 Preliminary Alternatives

After receiving feedback about the previous tutorial's brainstorming process, it was decided that the device would focus on solving the users issue with turning on his car. Figure 1 in Appendix C depicts the two design alternatives created in Week 8's tutorial to address this issue. The first design shown on the left side of Figure 1 is a contraption that holds the key and involves a handle that makes turning on the car a more painless process. A piece of plastic with a hinge acts as a foldable container for the key, with the inside covered in a rubbery material that firmly holds the key in place when the container encloses it. Velcro is used to seal the container shut and ensure the key does not fall out when the device is in operation. The shape and size of the handle is variable, because it would differ based on the available space within the car. The two components are attached with a strong enough adhesive that would allow a sufficient force to be applied to the device that would turn on the car without hindering the device's durability. In reference to the Objective Tree in Appendix D (Figure 1), this design meets both constraints of being safe and working around the user's disability. It is very durable, which means it will also satisfy the objective of requiring low maintenance. A comfortable handle makes the design user-friendly, but the size of the design prevents it from being very portable.

The second device, as shown on the right side of Figure 1, is similar to the first but uses bands instead of a handle as a means for the user to hold the device. Once again, the main component is a foldable container that securely grips the key in place. In this design, Velcro is attached to the inside of the container (hook side) as well as wrapped around the user's key (loop side). Elastic straps are adhered to the outside of the key container, which fasten to the user's forefinger and thumb. This system is a good way to separate two key functions of the device: maintaining a grip with the object, and attaching the device to the user. Having such an arrangement would allow the user to focus on just applying the forces to turn the key instead of dividing their strength between gripping the key and applying the forces. When evaluating this design with the objective tree in Appendix D, it is also meets the constraints of being safe and working around the user's disability. Similar to the first design, the second design is also comfortable and durable due to its soft yet sturdy material. Being small in size means this design is inexpensive to create, but unlike the first design this one is also much more portable. Comparing the two design alternatives, the second is superior even though they both meet the constraints and most of the objectives.

2.2.2 Secondary Alternatives

The design alternatives created in Week 9's Tutorial were more suitable to the problem that needed to be solved. The assessment of the preliminary alternatives from Week 8 developed a change in mindset when designing the secondary alternatives. Originally the central problem was thought to be with gripping the key, when in fact the main difficulty was applying the correct inward and turning forces to the key to turn on the car. Figure 2 in Appendix C illustrates the two alternatives generated in Week 9. The first design, sketched on the top half of Figure 2, is a variation of the previous designs in the sense that it is made up of two components: one piece is a container for the key and the other is a handle for the user. However, this design differs from the Week 8 designs because it separates not only two key functions of the device (gripping the object and attaching to the user) but also the function of applying the forces. The inward force is applied using the palm, and the turning force is applied using the wrist. Addressing the objective tree in Appendix D, this design goes beyond meeting the constraint of working *around* the user's disability because it works *with* the disability instead. While adjusting to the new required function of assisting the user in applying the necessary forces, the design continues to meet the primary objectives of being user-friendly (comfortable, portable), durable, and inexpensive.

The second design, on the bottom half of Figure 2, was not so much a refined version of a sketch from Week 8, even though it involved the use of a handle as one of the preliminary alternatives did. The main idea of the design is a handle that has a slot for the key, and it is angled in a way that the force applied by the user to one end of the handle will break apart into two components of inward and turning forces. The device only has one main component, which is the handle. The base of the handle is created with multiple pieces of wood, and all adjustments are made to this one handle so that the key fits securely and the force can be applied appropriately. These adjustments primarily include the necessary incisions and carvings to produce a device that looks similar to the second design alternative in Figure 2, with additional materials to ensure a secure enclosure for the key (Velcro) and a comfortable hold for the user (felt). Going back to the objective tree in Appendix D, this design meets the constraints of being safe and working around the user's disability. It meets most of the objectives excepting portability, which can be compared to the preliminary alternative that contained a handle as well.

2.3 Design Evaluation

The metrics presented in Figure 2 in Appendix D were used to evaluate the two design alternatives that were created in Week 9's Tutorial. These were the metrics that were initially used to determine how effective a design was at solving the given problem, though they were later updated when the problem focus changed. The scale used to measure how well each objective was met was a range from 1 to 5, with 1 being the least effective and 5 being the most effective. From the list shown, the most important metrics were the device's durability, how lightweight it was, and the cost of its materials. If the device survived a 2m drop test it was given a 5, but breaking at a lower height of 0.5m would be a score of 1. This metric tested if the device could withstand the force that would be applied by the user. To test how lightweight the device would be, anything weighing over 3 pounds would be given a score of 1, while around 0.5 pounds would yield a score of 5. Finally, a device costing $50 or more would not be inexpensive and would be given a score of 1. Any device costing under $10 is very cost-efficient, and would therefore be given a score of 5. The other metrics listed in Figure 2 did not apply to the designs once the objectives were updated, and so they were not considered at this stage of the design process. After applying these metrics, the first design from Figure 2 in Appendix C was chosen as the most suitable design alternative for the user.

3.0 FINAL DESIGN

3.1 Description

The function of the design was to aid people with hypertonia, like Brad, in turning a car key. This was achieved by minimizing the necessary movement and strain involved in the process. The design is made up of two primary components: the handle and the key-holder. The handle is the part that the user holds while using the device, and the key-holder is where the user puts the key. The prototype was made of a plastic 3D printed part, duct tape, Super Sculpey polymer clay, a milk pitcher, two short screws, hot-melt adhesive, and felt. These components were chosen because they gave the design the necessary durability while also being light enough that the device was not too heavy to use comfortably. The open box design that the group went with for the part that holds the key makes it easy to put the key into the device, as well as pull it out. It also keeps the key securely in place during use due to the thin slit for the key itself and the felt that provides additional friction. Figures 1 and 2 of Appendix A illustrate this description, as they are labeled with both the components of and various materials used within the design.

3.2 User

To use the device, the client would pick it up with his left hand and place the handle between the clenched fingers and palm of his right hand. The user will then use his left hand to place his key in the key-holder (Figure 1, Appendix H), with the narrow part of the key pointing away from the device (Figure 2, Appendix H). He then navigates the key into the ignition (Figure 3, Appendix H). To turn the key, the user applies the necessary inward force with his palm and rotates his wrist forward. Once the car has started, he can pull downward, parallel to the key, and the device will be separated from the key (Figure 4, Appendix H). He can then store the device wherever is most convenient within the car. When it comes time to turn off the car, he can again place the device into his right hand and align the key with the device. By raising his arm, he can reattach the key to the device, which can then be rotated backward by the user’s wrist to turn off the vehicle. The device and the key can then be pulled away from the ignition.

The small, non-strenuous wrist movement necessary to rotate the device, combined with the ease of applying any necessary force parallel to the key with the palm, makes turning on a car much easier for someone with hypertonia similar to Brad’s.

There are multiple places the device could be stored while it is not being used. Most cars have storage compartments along the driver's side door, which would be the user’s best option because it would allow the easiest access for the user's left hand. The device could also be stored in the compartment that most cars have between the driver and passenger seats. This compartment could still be accessed by the user’s left hand, though it may be uncomfortable to do so. Some cars also offer additional storage below the dashboard, which could be used to house the device if it is more convenient for the user.

The device does not lend itself to being carried in a pocket. If the user had a bag of some kind that he was carrying, the device could most likely fit. Assuming that the user does not have a bag with him most of the time, he would have to carry the device in his hand while transporting it. This lack of portability is a shortcoming of the design. However, it should be noted that the device was designed for use in a car, and is easily stored within a car, and that there is no frequent reason to move it out from the car anyway.

3.3 Construction

Table 1 in Appendix A describes all the items required for building the device. The required tools are an oven, a drill, a glue gun, a computer, sandpaper, scissors, a knife, and a pan. The required expertise is the knowledge of how to use a drill and a glue gun.
The key-holder must first be printed using a 3D printer before the construction steps can be followed. The file that needs to be printed can be downloaded in the link located in Appendix G. It can be printed by many online businesses such as Shapeways and 3dphacktory. A link to these companies' websites can also be found in Appendix G.

After the key-holder is printed (Figure 1, Appendix I), follow these steps to create the device:

1. Taking the milk-pitcher, cut downward on the jug itself, parallel to the handle and 2.5 centimeters from the point where the left side of the handle touches the pitcher. The cut should be roughly the same length as the handle itself. Do this with the scissors.
2. Do the same cut on the other side of where the handle meets the pitcher.
3. Cut perpendicularly to the handle at end of the first cut until the end of the second cut is reached. Detach the cut piece from the pitcher (Figure 2, Appendix I).
4. Using the polymer clay, fill in the entire half-circle curve formed by the part of the pitcher that was cut from the main body. Make sure the clay is flat and flush with the top of both sides of the curve.
5. Place the key-holder's base against the clay, one inch from the top of the device and centered about the width. Outline the base with a pencil.
6. Along this outline, cut entirely through the clay with the knife and remove the clay from the handle. Put the cut square piece aside. Bake the remaining clay in the oven for 15 minutes on the pan. For additional instructions, see the clay's packaging
7. Once the clay is done baking, take it out of the oven and allow it to cool. After, fit the base of the key-holder half a centimeter down the hole in the clay on the flat side. With the glue gun, fill in the hole at the back of the piece with the hot-melt adhesive.
8. Cover the rest of the back of the clay with the adhesive as well and then put the clay back into the plastic handle. Allow the adhesive to harden (Figure 3, Appendix I).
9. Fill in the hole in the clay on either side of the key-holder at the top with the adhesive.
10. Begin wrapping the entire device, except for the key-holder, in the duct-tape (Figure 4, Appendix I).
11. Using the drill, drive a screw through the area directly above and below the key-holder, through the key-holder's base and into the clay (Figure 6, Appendix I).

12. Cut a piece of felt to the appropriate size (approximately 10 centimeters by 10 centimeters) and stick it along the length of where the user holds the device (Figure 5, Appendix I).
13. Cut two pieces of felt that are 2 cm by 2 cm and two more that are 1 cm by 1 cm. Stick one of each of these to the sides of the inside of the plastic key-holder at the bottom. The two pieces on either side should layer on top of each other.
14. Sand off any sharp edges at the end of the key-holder.

3.4 Safety

The plastic key-holder originally had sharp edges, which posed a cutting hazard to the user. If he was to pick up the object by the key-holder or drop it in such a way that the object touched exposed skin, there was the possibility that the user could have scratched himself. To deal with this, the edges of the holder were smoothed using sandpaper.

Another hazard that the device poses is parts breaking off. The holder undergoes a torque when the key is turned, and a small amount of force when the key is put into or pulled from the ignition. After many uses the key holder could succumb to these forces and break off. The handle could also break off after much use. Both of these cases would force the client to use his left hand to remove the broken device from the ignition or to turn the car on or off. This leads to an additional scratching hazard since the broken device could have sharp or jagged edges. To deal with this hazard, the key-holder was attached using screws and a strong adhesive so that it would hold very tightly to the handle, which was made of a thin, but strong plastic as well as clay. These elements combine to make the device very durable.

Hand strain was a smaller, but still important hazard that was considered. The milk-jug handle was not very comfortable to hold initially, and if the user was clenching hard on it then it could have caused pain or discomfort. To deal with this, the handle was wrapped in duct tape and then covered in a soft material, which makes the device more comfortable to use.

3.5 Description of Prototype

The general design decided upon early in the term was very similar to the prototype, but a number of small changes were made to optimize the device. In the final design alternative sketch in Appendix B, Figure 1, two pieces of soft Velcro were going to be used on the inside of the key-holder to increase friction on the key. Felt was used instead because it was thinner. This allowed the felt to be secured with the desired orientation without having to make the holder in two pieces. The handle was also going to just be made of polymer clay, but that was too brittle (Figure 4, Appendix F). Instead, a milk-pitcher handle was used and the clay was just added where the key-holder was going to go, making a custom fit for the key-holder into the handle. Originally the key-holder was going to be secured by contact cement, but after finding out that the cement could shatter and may be too weak, the design was changed. In the final design, the key holder is embedded in the clay and attached by screws, which hold it in place very strongly. Additionally, Figures 2 and 3 in Appendix B illustrate a small change made in the design of the key holder, although ultimately the first design (Figure 2) was used.

Another small change was that felt was originally going to only be used on the inside of the handle, but the design was uncomfortable to use without padding where the palm touches the handle so felt was placed on both sides. A final change was with the shape of the bridge, which connects the handle to the key-holder. It was originally going to be u-shaped, but because of the milk-jug that was used in the construction, the bridge ended up being more of a square shape. Some of the differences between the final design alternative sketch and the prototype are illustrated in Figures 3-6 in Appendix A.

The small changes that happened to the initial design did not come about all at once; they happened across multiple team meetings, and through many different drawings. Every time that the group came up with new design ideas, they followed the same process of brainstorming, sketching, and consultation between members. Every time this was done, positive changes to the design happened, which taught the group the value of iteration in the design process. Going through the different design phases also taught the group that even if a design does not change drastically (though it certainly can), there are always improvements that can be made in all areas. For instance, Figures 2 and 3 in Appendix F illustrate the small change made from Prototype 2 to Prototype 3, which was the design of the key holder. All objectives must be considered at each phase of the design process, even if it means making a whole new prototype for the sake of a slightly stronger key holder.

3.6 Discussion of Feedback from Design Reviews

The design review feedback that the group received can be seen in Appendix E and the prototype used to demonstrate the initial design is Figure 1 in Appendix F.

The feedback the group received significantly affected what ended up being the final design. Originally the key-holder was going to be attached to the handle by contact cement, or a silicone based adhesive. The occupational therapist students made us reconsider this because they did not believe that would hold up over time, and that if the key-holder broke off that it could cause a safety hazard. The group agreed with them, and so the key-holder was attached by both an adhesive and by screws so that the hold between it and the handle is very strong.

The feedback from both the biology students and the occupational therapists that the handle needed to be durable also caused a change in the design. After being told the clay would likely be too brittle, using a milk pitcher was proposed, but some of the group thought that would also be too weak. After some testing, the group decided to use part of a pitcher in combination with the clay to optimize the benefits of both.

The Biology Students' feedback that Brad may have to use the device with gloves on also caused the group to modify the design such that there is now significant distance between the handle and the key-holder to accommodate for those circumstances.

Some of the group's initial ideas also involved using various types of metal in the structure of the design, but peer feedback that said the group needed to make sure that the design was not too heavy caused only plastics and other light materials (other than the screws) to be used in the final design.

4.0 CONCLUSIONS

The Car Key Aid design is very useful for people like Brad who do not have full control of their right hand, which is necessary for turning a car key in an ignition. Brad was able to guide the key into the ignition with no problem previously, which meant that that was not the problem that needed to be addressed. Brad could not provide the necessary inward force along with the force needed to turn the key at the same time with his fingers. Through the design process, a list of objectives and constraints were created which provided the basis for the design.

During the beginning of the design process, the objectives and constraints that were to be met were generated through the use of an objective tree. The method in which how well each of the objectives were met would be measured using a scale, which designates a number from 1 – 5.

The first objective that was to be addressed was durability. As the device should be able to resist the forces needed to turn the key in the ignition, as well as any additional forces affecting it (for instance, if it were dropped), durability was a key objective. This affected the choices of adhesives and materials that were used for the prototype. The chosen metric for this objective was a drop test of 2 metres, which would be the maximum height the device would most likely fall if the user dropped it from a standing or sitting position. If the device broke at a height of 0.5m or less, it would achieve a score of 1, and if it resisted 2 metres or more, it would achieve a score of 5. In the case of our device, it was able to resist falling more than 2 metres, which gave it a score of 5.

The next objective was comfort. This was a bit more difficult to measure, as comfort is always subjective to the client. However as the client would be using the device often, it was essential that a level of comfort be reached. The comfort of the device was measured by the designers by emulating the natural position of the user’s right hand and testing the device on our own, with 1 being very uncomfortable and 5 being very comfortable. In this case, as all the designers tested the design, it comfortable for the most part as the handle was wrapped in a soft felt. However, the shape of the milk pitcher handle was not ideal, as the curve of it did not work with the natural position of the user’s thumb. For that reason, the comfort of the device was given a 3.

Being inexpensive was another objective for the device. It was important to choose a design that would be both economically feasible and appealing to the client. Choosing materials that would be just as effective but at a lower cost was the best way to approach this. If the design was under $10 it would receive a score of 5, whereas if it was over $50, it would receive a 1. In the case of our design, though the cost of all the materials reached $23.44 in total, the cost for the device itself came to be $14.25. This cost includes the hypothetical cost for the 3D printed part, which the team received for free from the University. However, in terms of manufacturing, it could cost about $10. Thus, the device meets the objective of being fairly inexpensive, receiving a score of 4.

Another objective for the device was portability. As the user would have to carry it around for convenience and be able to store it somewhere as they were driving, it would make sense that the design was small. If the design would be something that could fit in a pocket, a flat shape and 125 cm^2, it would earn a 5, and a design greater than

125 000 cm^3 would receive a 1. As the device was approximately 8 x 8 x 12 cm or 768 cm^3, it received a score of 4.

Being rehabilitative was yet another objective for the device. As a device made to help someone who has lost functionality of his hand, the device should be able to enable the affected limb. This objective is difficult to measure, as one cannot necessarily measure how helpful something is. However, the metrics for how rehabilitative it was can be measured by how much of the device requires aid from the left hand, 5 being no aid at all from the abled hand and 1 being the device not using the disabled hand at all. In terms of the device, it required some aid from the left hand, earning a score of 3.

The final objective for the device was for it to be lightweight, which was tied closely with the objective of being portable. The amount of strain the device has on the user should be minimal, it is crucial that the device is light. If the device weighed less than 0.5 lbs, the device would achieve a score of 5 whereas if it were over 2 lbs, then it would achieve a score of 1. The device weighed roughly 0.44 lbs, which means that it would receive a score of 5.

In terms of meeting objectives, the device designed met them very well and proved to be a very adequate design for the user.

The constraints that were also brainstormed at the start of the design process were all met, allowing for the device to be practical. The constraints had to be met in order for the design to be approved as a design alternative. The constraints for the design were safety and working around the user's disability.

A device that is safe for the user is very important because the device should not be causing further injury to the body. When the handle was cut, the edges were very sharp and were hazardous. This was handled by wrapping duct tape around the entire device to mask the sharp edges as well as provide the extra support that the device needed. Felt was wrapped around the handle part of the device to provide an extra layer of support while also providing cushion for comfort.

The device worked around the user's disability in the sense that it did not require the fine motor skills needed to turn a car key. Instead of relying on these fine movements, the device required an inward force by the palm and a forward rotational movement of the wrist: motions that can both be performed by the user without discomfort. It is not strenuous on the user's muscles and requires little aid from their functional left hand to use.

The device was created so that it could meet all constraints and as many objectives as it could to make it the best design for the user. Further work that would be needed to improve the design would be the design of thicker walls for the portion of the device that holds the key. Thickening the walls of that part would provide extra assurance of the device being able to resist the torque needed to turn the key in the ignition. In an earlier prototype, that proved to be a problem, as the 3D printed plastic could not stand the force, so it snapped. Other work that would need to be implemented would be moulding the handle so that it fits the natural form that that the user (Brad's) hand takes so that it is more comfortable to use.

Overall, the device that was created was simple and required no strenuous motions from the user. As a rehabilitative device, it did not work *around* Brad's disability, it worked *with* it. It is portable, inexpensive and comfortable for the user to use in his day-to-day life. It was easy to slip on around the natural position of Brad’s hand and allowed for him to be able to start his car nearly as quickly as someone who had full function of their hand, which allowed for Brad to be able to get to places in his car in a timely fashion. It can be easily stored either in his pocket or in the compartment of his car, making it easily accessible. The car key aid is a very effective design for an assistive rehabilitative device for users experiencing hypertonia similar to Brad’s.

5.0 REFERENCES

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[10] G. Starr, “Adaptive grip,” U.S. Patent 8 146 968, April 3, 2012.

[11] G. Stacy, “Thumb-mountable protective utensil system and kit” U.S. Patent 8 844 080, September 30, 2014

APPENDIX A

Materials Required

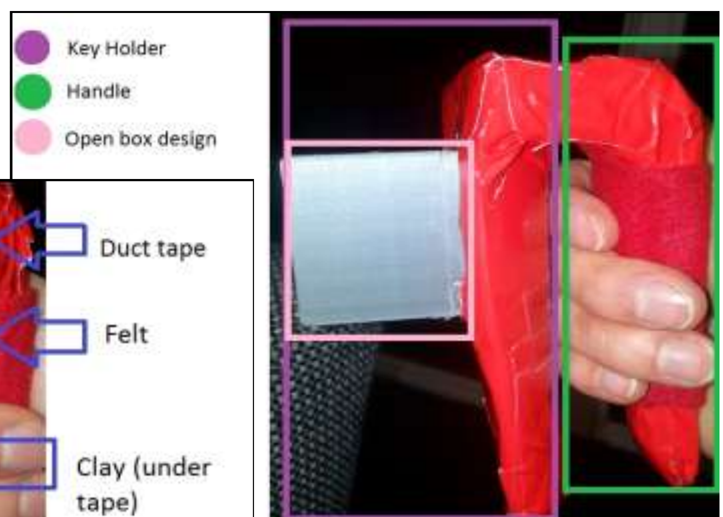
Table 1: Bill of Materials

Item	Cost ($)	Location
Duct Tape	1.00	Dollarama
Milk Pitcher	1.25	Dollarama
Steel Wood Screws	2.00 (for 4)	Home Depot
Hot-melt Adhesive	3.00 (12 pack)	Home Depot
Felt	1.69	Michaels
Super Sculpy Clay	12.50	Michaels
Foam	2.00	Dollarama
3-D Printed Piece	Free for us, (ideally $10)	Mills Library, McMaster University

Our total for all supplies: $23.44

Total for a buyer (supplies we used + $10 estimate for 3-D printed piece): **$14.25**

Figure 1 (right): Parts of Prototype



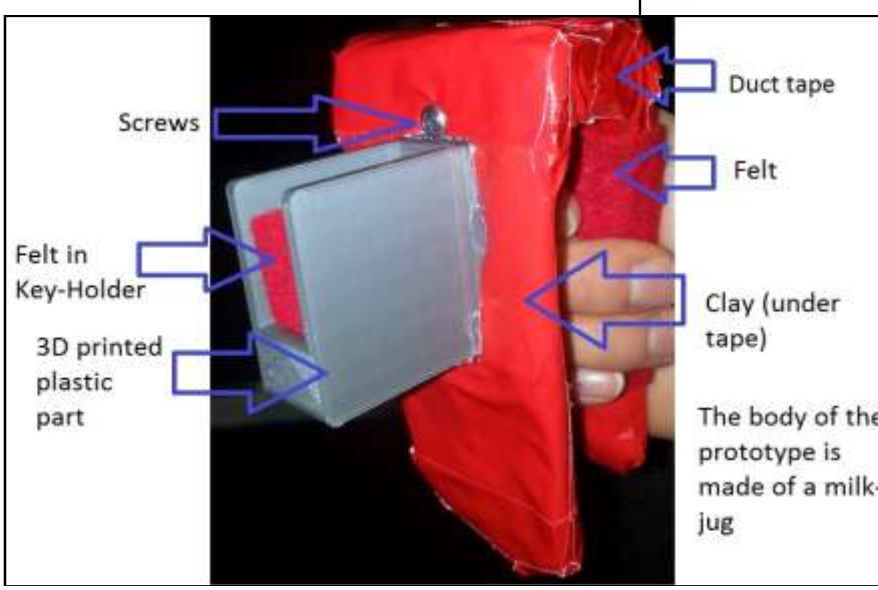


Figure 2 (left): Materials on Prototypes

Figures 3-5→ Material Changes made from Final Design to Final Prototype:

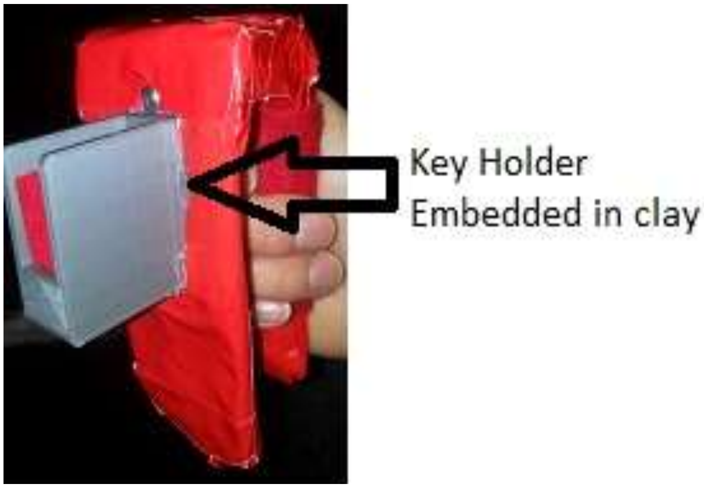
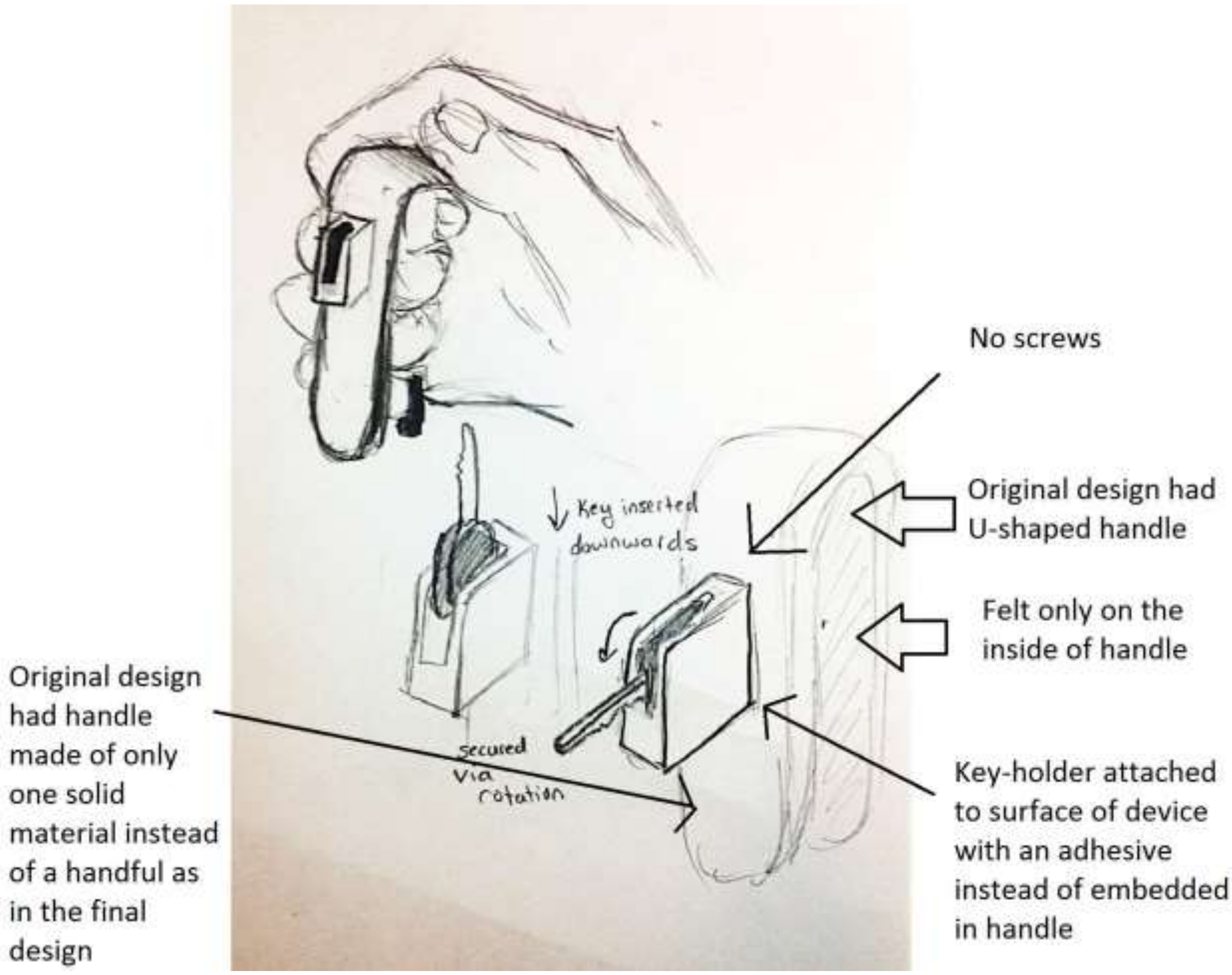


Figure 3 (left)

Figure 4 (left)

Figure 5 (left)

Figure 6: Material Differences in Prototype from Final Design Sketch



APPENDIX B

Final Design Alternative Sketching and Modeling

Figure 1: Design Sketches

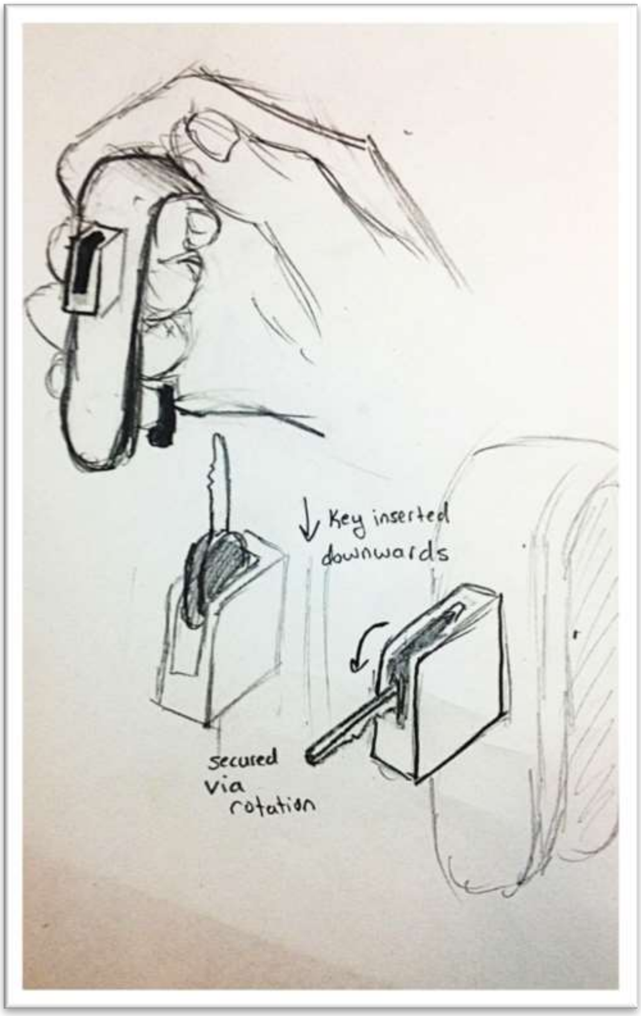


Figure 2: CAD Model 1 (Inventor Sketch)

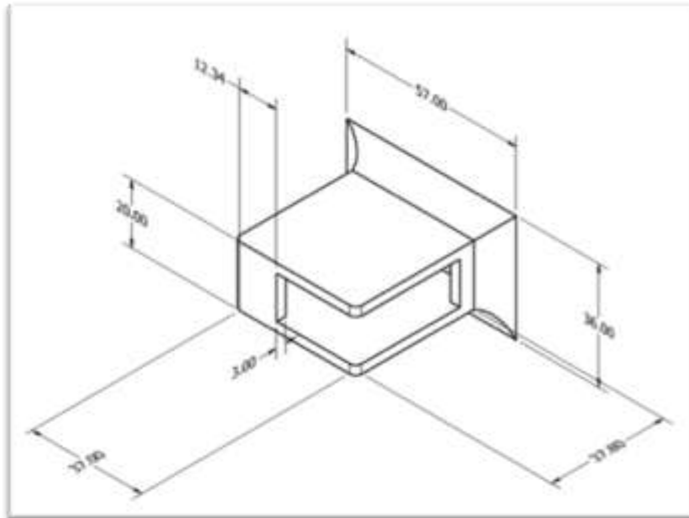
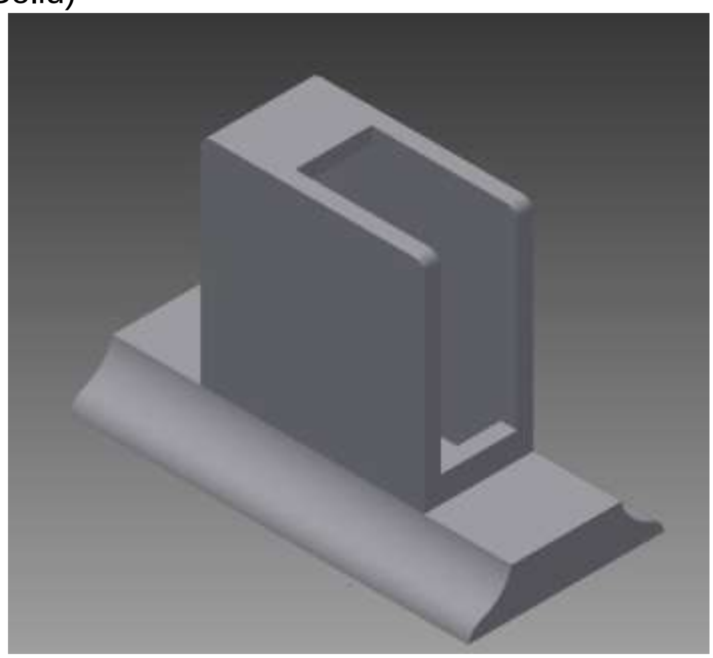


Figure 3: CAD Model 2 (Inventor Solid)



APPENDIX C

Conceptual Designs: Tutorials 8 and 9

Figure 1: Week 8 Designs

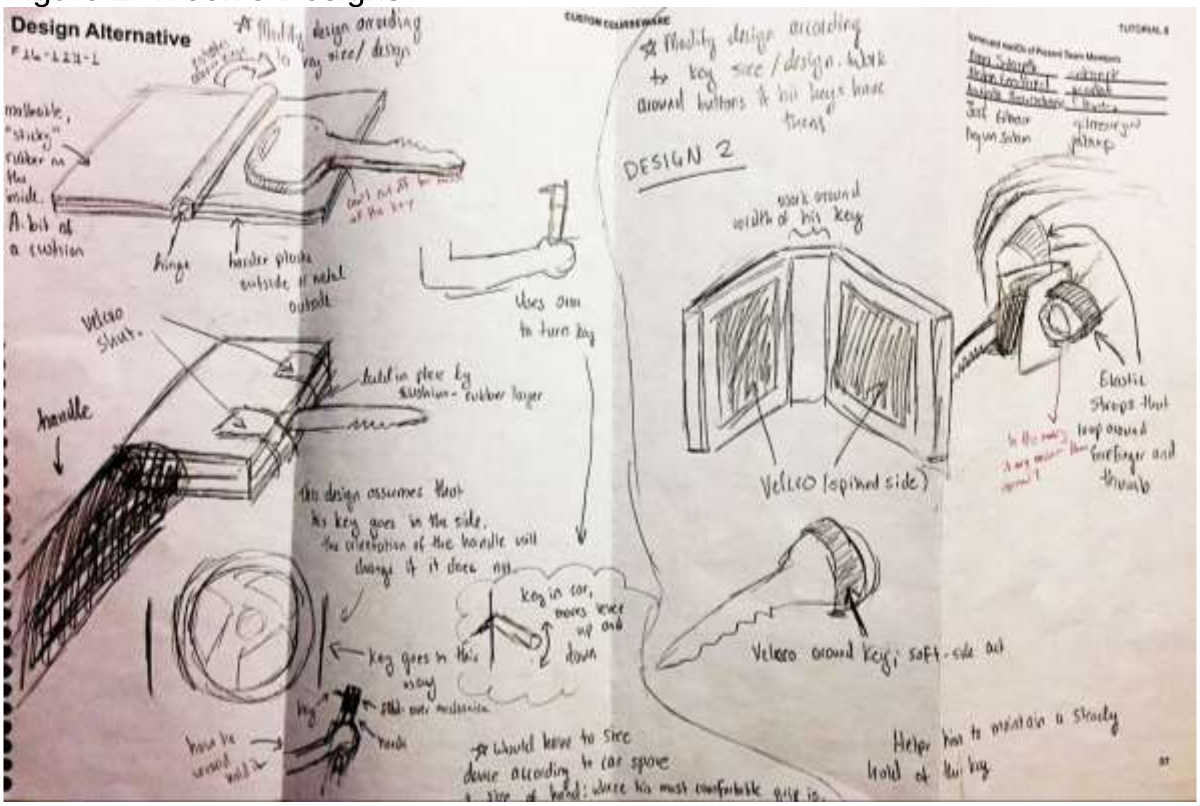
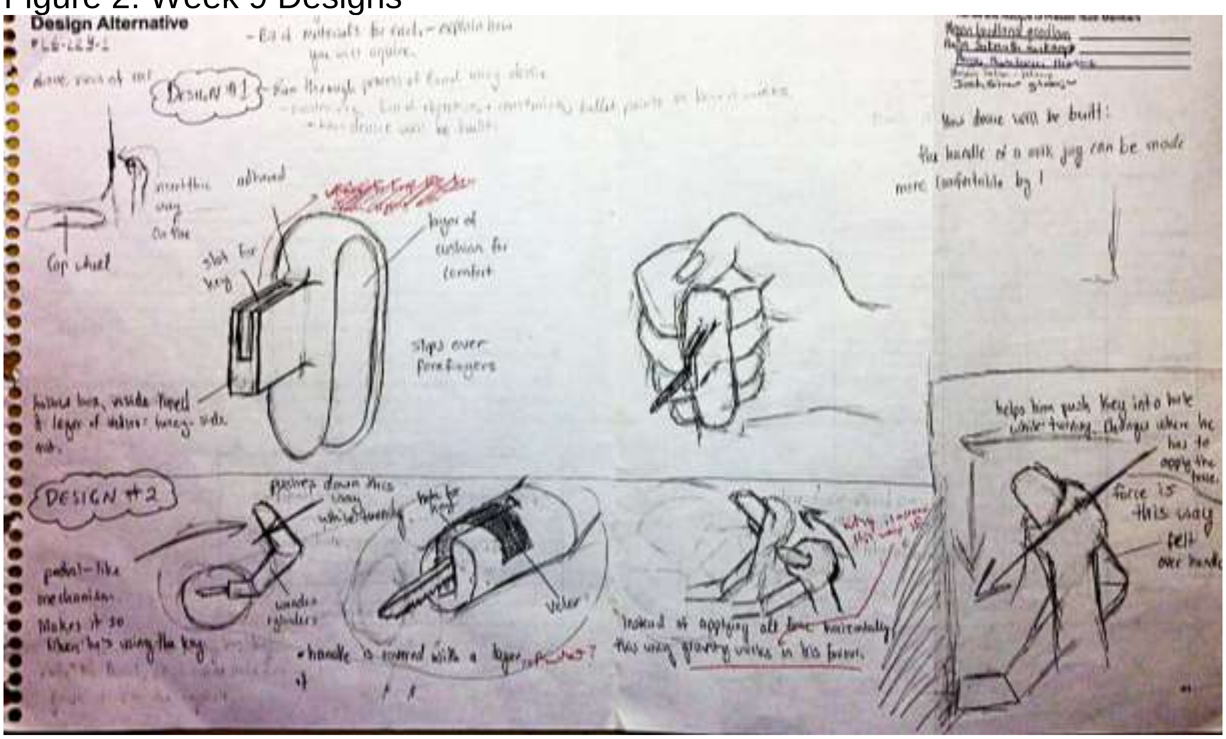


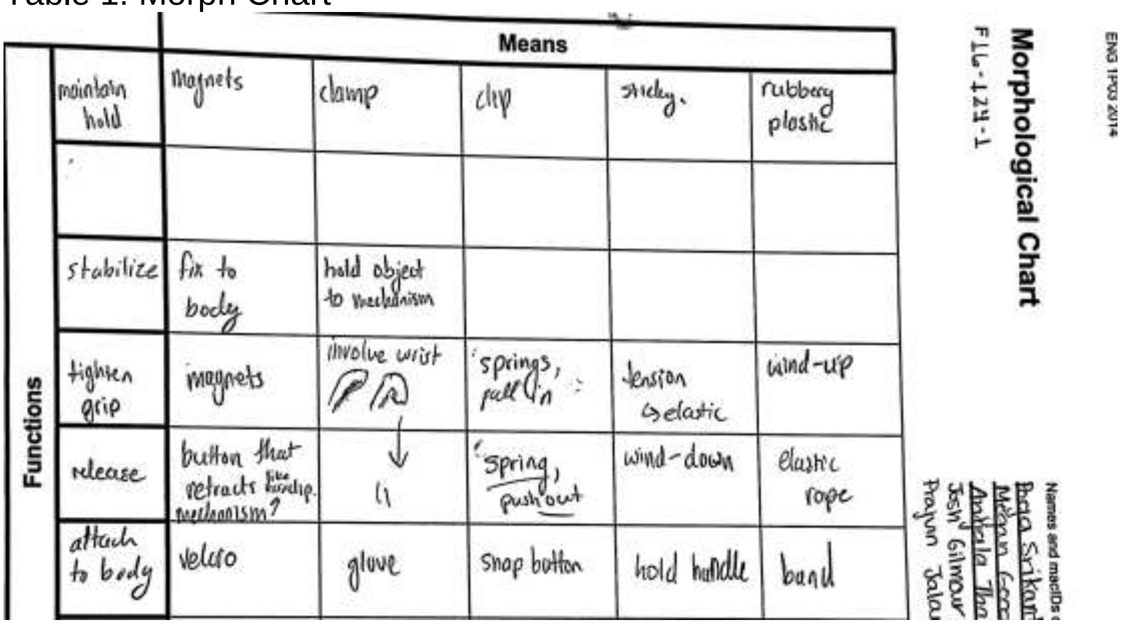
Figure 2: Week 9 Designs



APPENDIX D

Morph Chart, Objective Tree, and Metrics

Table 1: Morph Chart



Functions	Means				
maintain hold	magnets	clamp	clip	sticky.	rubbery plastic
stabilize	fix to body	hold object to mechanism			
tighten grip	magnets	involve wrist	springs, pull in	tension elastic	wind-up
release	button that retracts mechanism?		spring, push out	wind-down	elastic rope
attach to body	velcro	glove	snap button	hold handle	band

Figure 1: Objective Tree

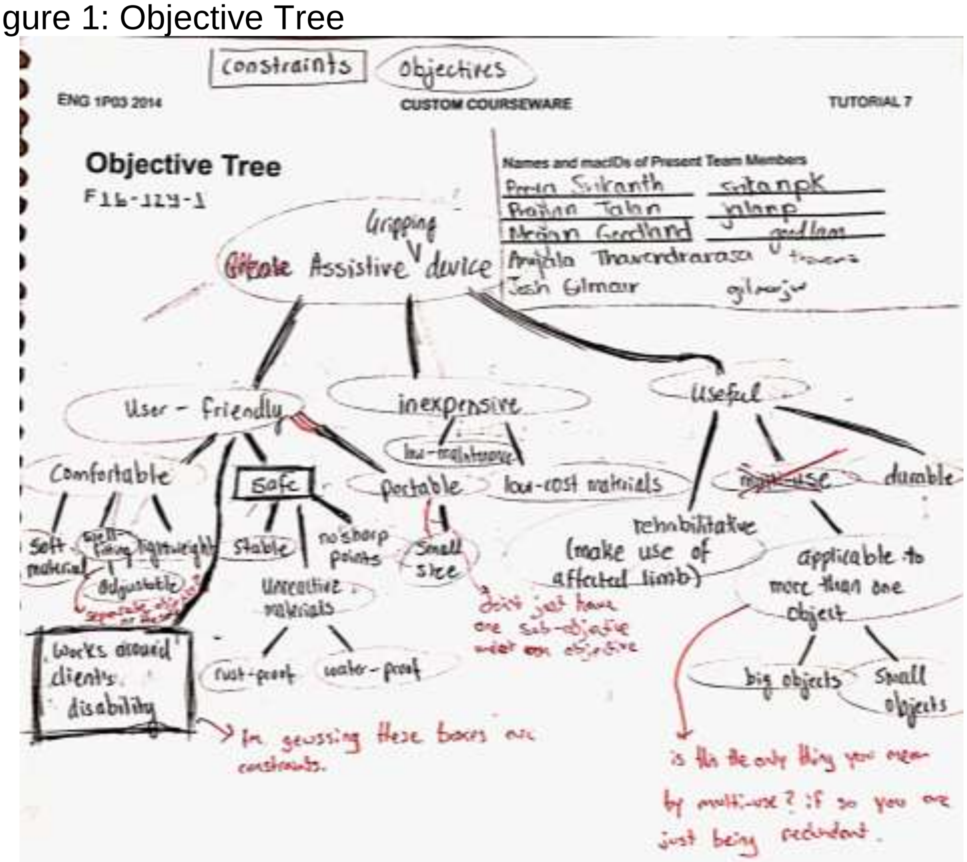


Figure 2: Metrics

Metrics

F16-123-1

Names and macIDs of Present Team Members

Pria Srikanth srikanpk
Archana Jalan jalanp
Megan Goodland goodlam
Angala Tharendrarasa tharenra
Josh Gilmour gilmoujw

Objective: Durability

Metric: Drop test from height (2m)

Objective: lightweight

Metric: grams (g)

Objective: rust/water proof

Metric: surface area that could be affected by rust/water (cm^2).

Objective: applicable to small objects

Metric: cm^3

Objective: applicable to larger objects

Metric: cm^3

Objective: low-cost materials

Metric: Canadian dollars $

You have ~~how you meet~~ the units you will measure. But how will you use these units to assess how well the objectives are met?

APPENDIX E

Design Review with Expert

Reviewer(s): Occupational Therapists

- If the key holder breaks off with the key in ignition, will it fall off and create a safety hazard?
- Even though he showed he could do the motion, he may have to try the device to make sure it would work
- Concern about strength of choice of material for the handle
- Concern about whether he can maintain the strength required in his wrist
- Unsure if the adhesive will be strong enough to resist the torque required to turn the key

Reviewer(s): Biology Students

- Don't make the handle too small. Might need to use with gloves
- Is the 3d printed part breakable since it isn't replaceable
- Consider using PVC, or some other plastic for handle
- Design is overall very practical and easy to use, no large changes necessary

Make sure handle is strong enough to resist forces

Design Review with Peer Team

Reviewers: F 1 6 - 1 2 4 - 8

- Can Brad turn the device enough for it to start the car?
- Don't make the device too bulky or heavy

APPENDIX F

Figure 1: First Prototype

Figure 2: Second Prototype

Figure 3: Third Prototype

Figure 4: All-Clay Handle Trial

APPENDIX G

Download link for key-holder file:

http://en.file-upload.net/download-9919378/BradDevice--2-.ipt.html

Companies for 3D Printing:

- http://3dphacktory.com/
- http://www.shapeways.com/

APPENDIX H

How Device Works

Figure 1

Figure 2

Figure 3

Figure 4

APPENDIX I

How to Make

Figure 1: 3-D Print

Figure 2: Cut-Out Milk Jug Handle

Figure 3: Clay Added In

Figure 4: Duct Tape Covering

Figure 5: Felt Added to Handle

Figure 6: Screws Put In