ZipQuik

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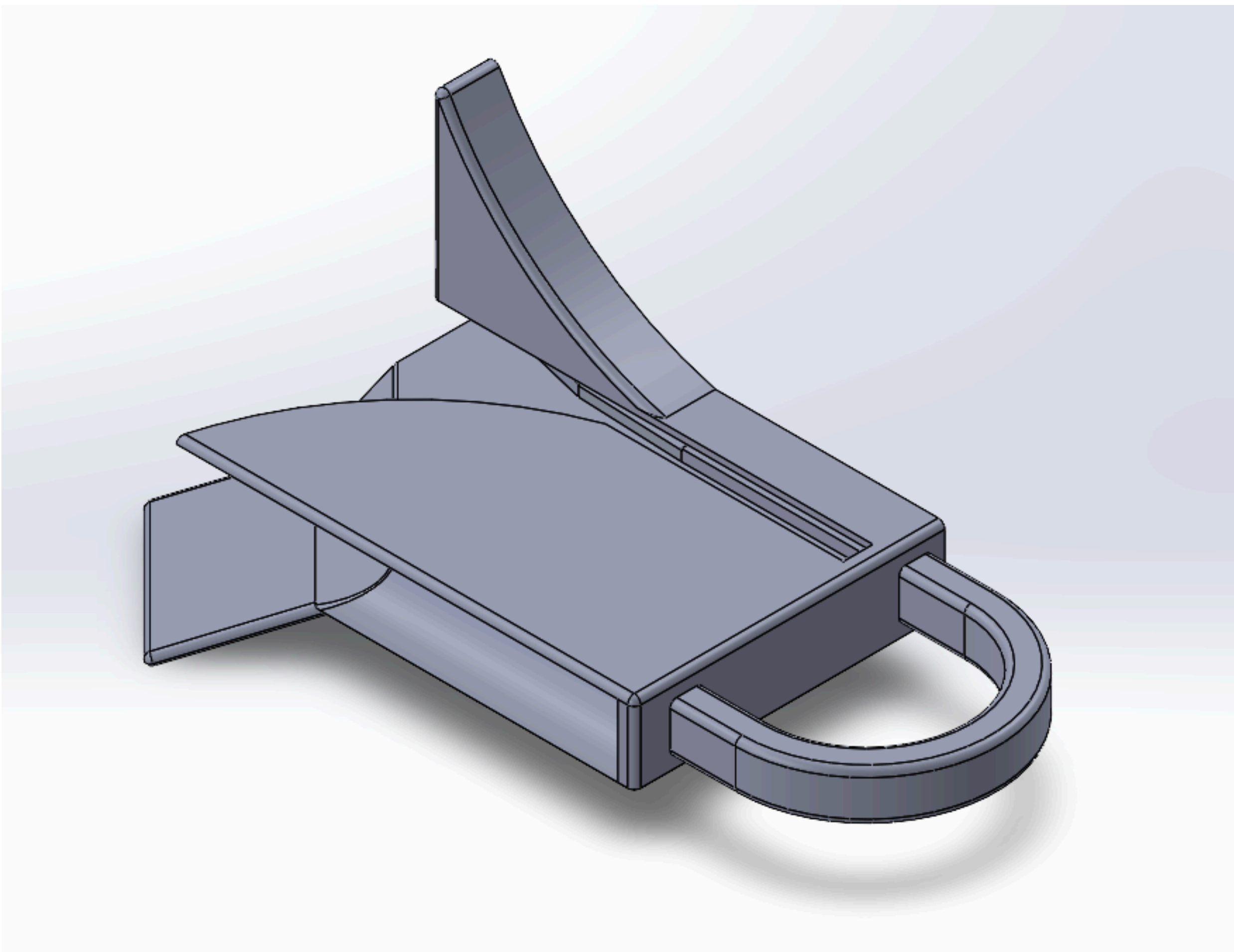
May 21st, 2024



Introduction

Millions of people around the globe are afflicted with medical conditions that cause them to have shaky or impaired motor function, including grip strength and fine motor skills. An individual with impaired motor function came to a member of the team and described their struggles with devices like zippers, which sparked a realization: many prevalent devices are not conducive to use by the differently abled. As such, the idea for a device to aid people with using zippers was born. After doing some research online, it was found that there were no similar devices, which increased the need for a device that catalyzed zipper engagement.

The audience for this device includes individuals who have impairments that make using zippers difficult. These could be people with medical conditions, young people, elderly people, and more. As such, the device must be beneficial for people of all ages, beliefs, and knowledge levels. It must also work with various kinds of clothes to allow for various financial and material statuses while remaining effective. These factors must be tested, and the results of the tests are recorded in this document.

MARKET RESEARCH

Zippers are commonly used in a variety of clothes and have remained an efficient way to bring together two parts of an article of clothing. Prerequisite skills to operate a zipper include the ability to do a pincer and tripod grasp, use fingers independently, having bilateral and hand-eye coordination, and using both hands in the midline. These fine motor skills can be difficult for people with medical conditions (Lumiere, 2017).

Previous assistive zipper products that are currently on the market or have been patented help the user pull the zipper up once it is secured. However, the act of putting a zipper together is equally important and can be even harder to execute than pulling the zipper up for individuals who have impaired motor skills. Previously, many devices have been implemented to assist the motion of pulling the zipper up. There exists a variety of devices that use hooks that serve as extensions of the zipper, making the slider easier to pull up (Fanwer, 2018; Harris, 2015). However, not many devices have addressed the issue of connecting the two sides of a coat and starting the zipper. It is imperative that this process is executed smoothly so that the user is properly enabled to pull the zipper up. Currently, MagZip–a magnetic zipper device that redesigns the slider and insert pin–exists, is required to be sewn into the clothes to replace the old zipper if individuals want to use the zipper for articles of clothing that are not what the company offers, making the product impractical for a wide variety of coats and jackets (Active Hands, n.d.).

PRELIMINARY DESIGNS

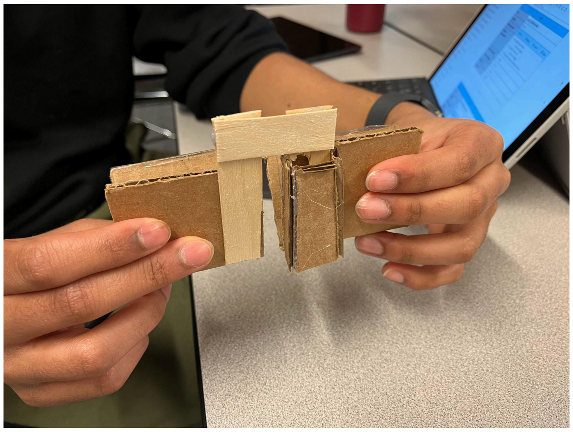


Figure 1: Design v1 (Enlarged Hole and Peg Clamping System)

The first design (Figure 1)was created with cardboard and would clamp onto each end of the zipper. By enlarging the peg and hole system, the two pieces are easy to put together, and as they engaged they brought the ends of the zipper along with them, engaging the zipper. The clamp system for this design was hard to use and required a great amount of accuracy and precise strength for the user to correctly use. It was decided to pursue a prototype that required less accuracy from the user.

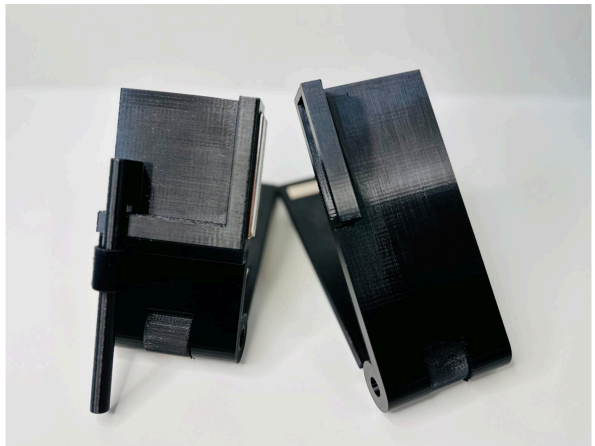


Figure 2: Design v3 (Magnet Alignment Clamping System)

Design v3 (Figure 2) was the next design found to be feasible and would clamp onto the ends of the zipper. The two pieces would magnetize together, lowering the precision needed by the user. After this, the left side of the design would break off and travel along the rail bringing the pin of the zipper down into the pull tab. This design was not usable when the pull tab was on the other side of the zipper, and was difficult to break apart to bring the bottom of the left side down.

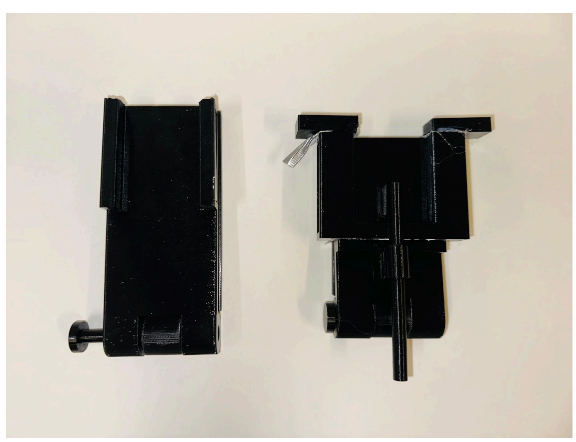


Figure 3: Design v4 (Magnet Alignment Clamping System 2)

Design v4 (Figure 3) was an improvement of the previous design. This design was mirrored to be used when the zipper was on either side. It also included a hook to make breaking the left piece apart easier. However, this design still struggled with the fundamental problems of the clamp system, namely that it required a lot of accuracy from the user when using it in order to work correctly.

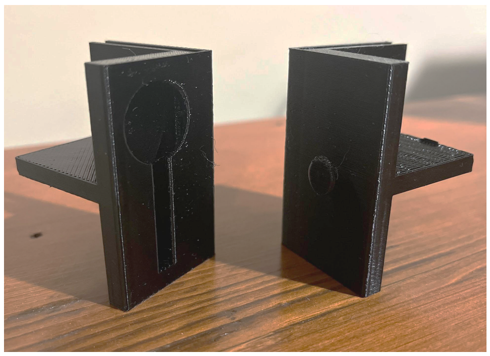


Figure 4: Design v5 (Locking Slider Mechanism)

Design v5 (Figure 4) was a completely redesigned version of ZipQuik. The previous system with magnets did not function well because it was difficult to remove the cloth after it clamped on and the usage of the zipper still required dexterity. This design aimed to solve that issue by using a keyhole-pin design. Each side of the design would hold half of the zipper, and by inserting the pin into the keyhole and sliding, the zipper ends would come together. Also, the device would slide in on the vertical edge of the fabric, allowing less precision by the user. However, because of the circular pin, the device would rotate during use. Additionally, the device still required accurate movements to use with the small openings, and the pin would often not insert properly as it was not being held in place.

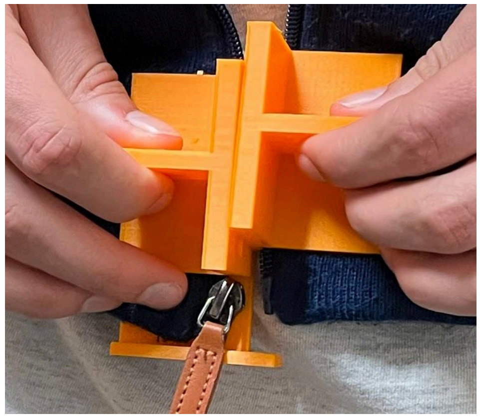


Figure 5: Design v6 (Locking Slider Mechanism 2)

Design v6 (Figure 5) was an improvement on Design v5 (Figure 4). As previously discussed, Design v5 had an issue where the pin would rotate in the system because of its circular nature. Design v6 fixed this issue by using a cubical pin and slot system instead. Additionally, a support was added to stop the pull tab end of the zipper from being too flimsy. However, because of the required thickness of the walls, it was difficult to bring together the two ends. Furthermore, it was difficult to put the ends together with some fabrics.

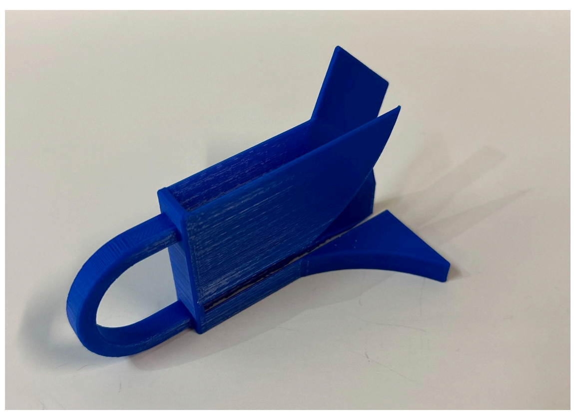


Figure 6: Design v7 (Final) (Pull Tab Holder and Funnel System)

Design v7, as shown in Figure 6, is the current final design of ZipQuik. This design works to solve some of the major flaws in Design v6 (Figure 5) including the difficulty of inserting the cloth and the challenges of making the ends of the zipper meet. The pull tab side of the zipper goes in the main open space through a funnel system. There is then a funnel system to guide the pin end of the zipper into the other side. The device can then be removed using the handle. By only using one piece for the whole design, the device requires less hand function to use. This design capitalizes on Design v6, fixing many of its flaws, but the funnel system is also somewhat fragile. It was decided that if a future iteration was to be made, the funnel system would have to be strengthened.

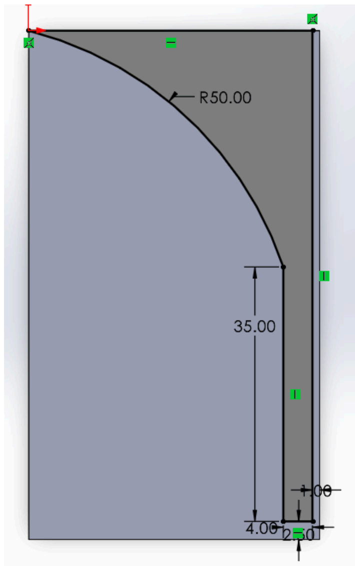
Build and Testing

FINAL DESIGN

To replicate the model, the only materials required are a 3D printer and 3D printing filament. In order to make the design as accessible as possible for clients around the world, it was important that the final design was easy and cost effective to make. First, download the 3D model of the final design from Sketchfab at the following link:

https://sketchfab.com/3d-models/zipquik-29a81a31433d478f9a96e3d6067485c6

This stl file can then be exported to a slicing platform (such as Ultimaker Cura) to be converted into a g-code file with support. Finally, the g-code file can be sent to the printer. After removing the supports with one's hands or a tweezer, the user will have the finished product ready to use.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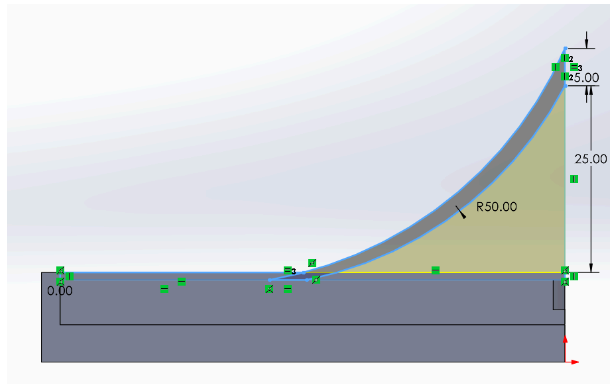
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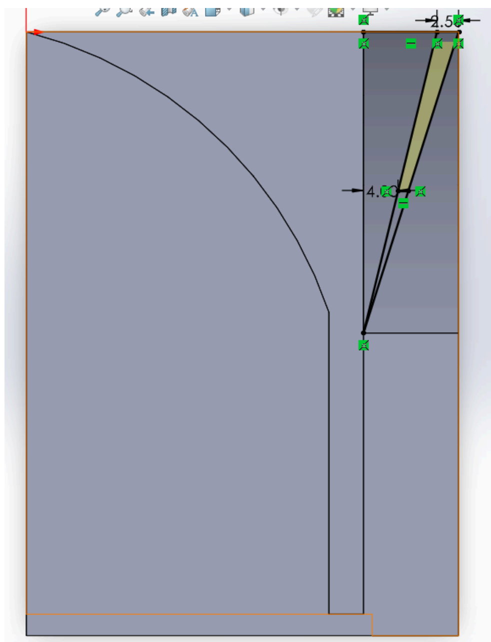
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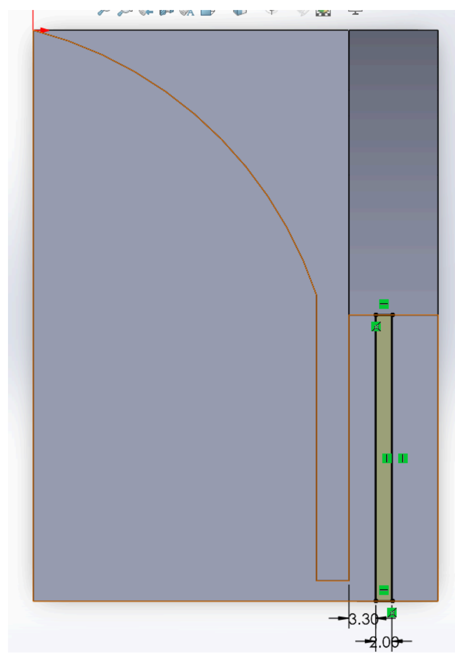
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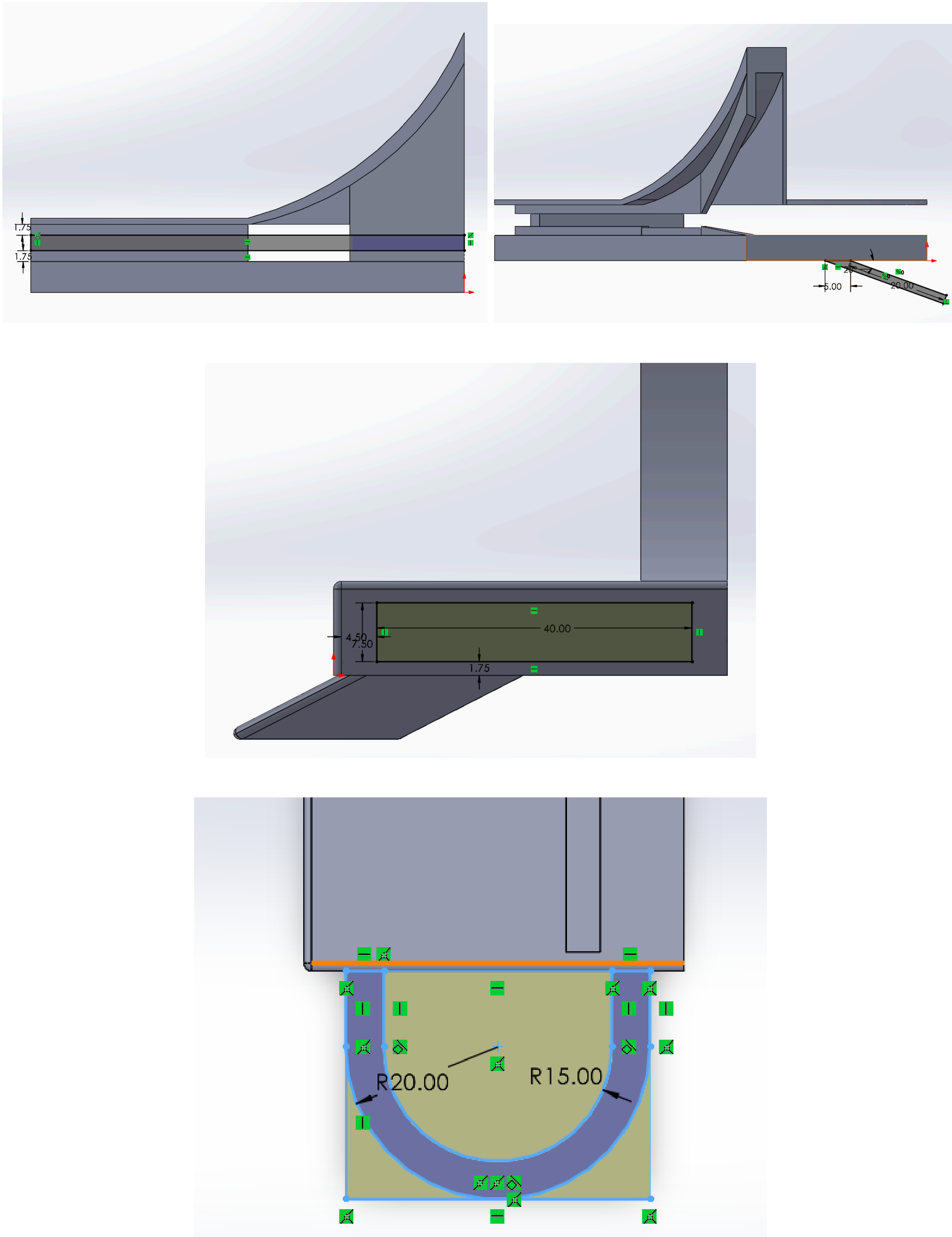

Figures 7-14: Dimensioned Solidworks Diagrams of the Final Design

Design Studies

Prototype Testing

May 9th 2024

Purpose:

The goal of this design study was to determine which prototype is most successful in engaging the zipper. The group has developed multiple different approaches to the problem. It was necessary to find which prototype would yield the fastest engagement of the zipper to determine which design would move forward to the next stage in the design process.

Independent Variables:

The independent variable of this experiment was which design was used. These included Design 1 with the enlarged hole and peg clamping system, Design 4 with the mirrored magnet alignment clamping system, Design 6 with the improved locking slider mechanism, and Design 7 with the funnel alignment system.

Dependent Variables:

The dependent variable was the time the participant took to engage the zipper. This time was recorded with a stopwatch, which started once the participant was instructed to start their attempt and ended once the two ends of the jacket were fully connected together with the engaged zipper.

Materials:

- Stopwatch
- Design 1
- Design 4
- Design 6
- Design 7
- Blue Polyester Jacket

Hypothesis:

Design 7 will yield the fastest times to engage the zipper as compared to the other designs.

Methodology:

1. The participant put on the jacket with the zipper undone.
2. The subject was instructed to begin attempting to engage the zipper using Design 1. A stopwatch was started from the moment they were instructed to start engaging the zipper and it was stopped once the ends of the zipper were fully connected.

Figure 15: Testing with Design 1

3. When the zipper pin was fully inserted into the pull tab, the testing assistant stopped the timer and recorded the time under trial 1.
4. Repeat steps 2 and 3 for trials 2 and 3.
5. Repeat steps 2 through 4 for each design that was tested.

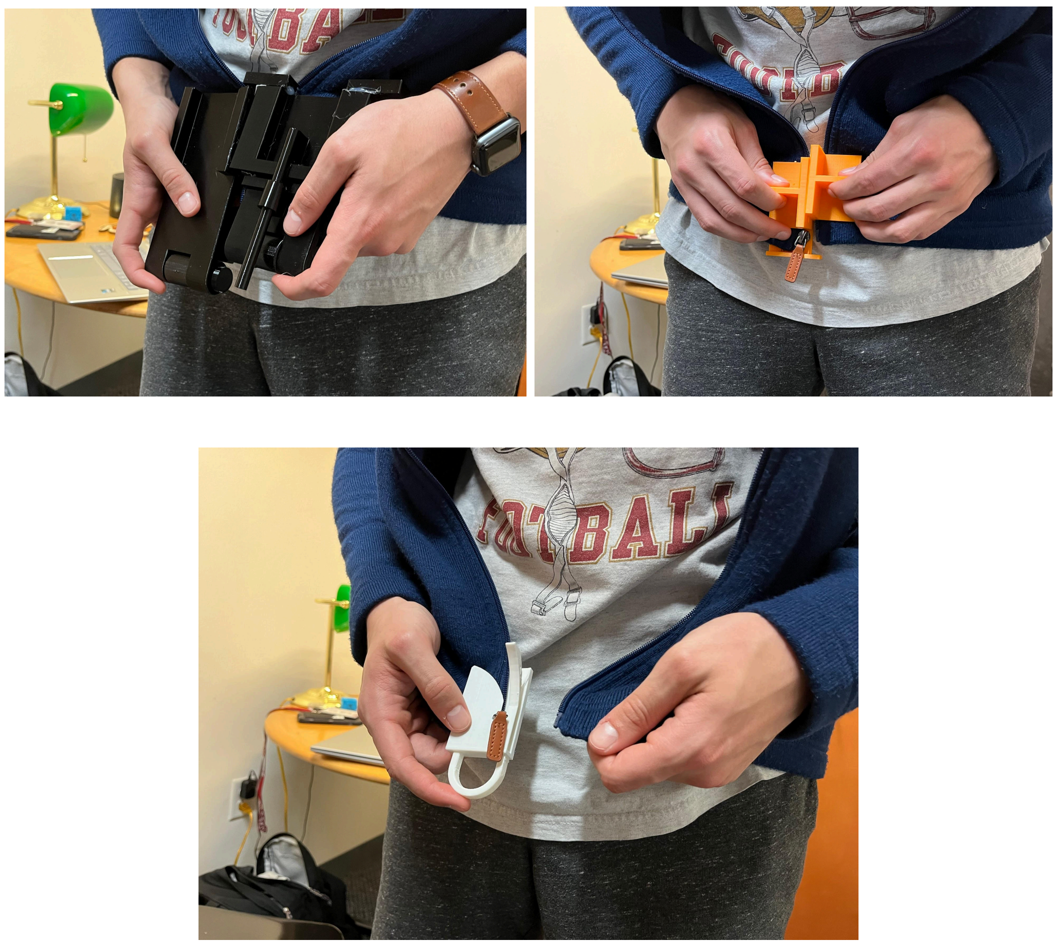

Figure 16-18: Testing with Designs v4, v5 and v7 respectively

<u>Results and Analysis:</u>

Prototype #	Trial 1 (s)	Trial 2 (s)	Trial 3 (s)
1	100	100	100

2 (4)	100	100	57
3 (6)	40	24	23
4 (7)	14	5	5

Table 1: Raw Data from Prototype Testing

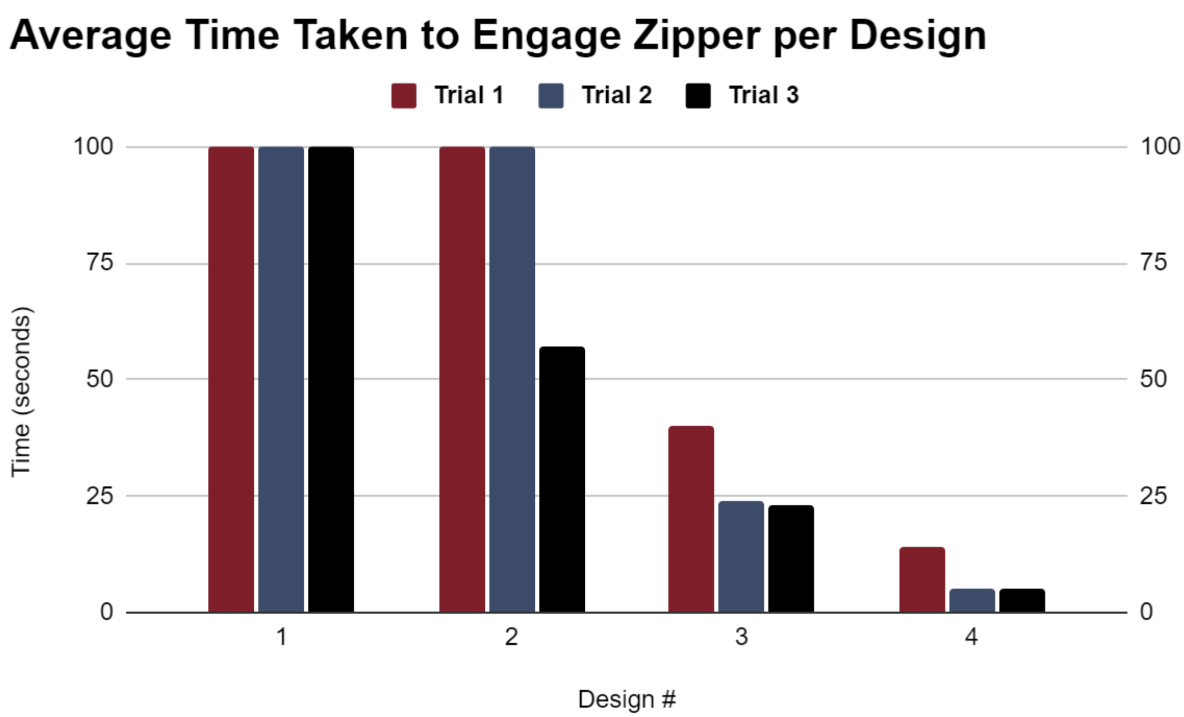

Figure 19: Graph of time taken to engage a zipper for each design tested

When tested, the different designs yielded very different times to engage the zipper. There was a downward trend in time taken to engage the zipper for each design in chronological order of creation. This is to be expected when taking into account that each subsequent design identified the shortcomings of the previous design and improved upon them. When looking at the time it took to engage the zipper in Figure 1, the data shows that the first two designs yielded very similar results, reaching the maximum time limit to engage the zipper. However, the third trial of the second design was able to engage the zipper in under the time limit, showing a slight improvement from the previous design. Design 3 showed a significant decrease in time taken averaging 29 seconds to engage. However, design 4 proved to be the fastest out of the prototypes, with a significantly lower time than the other three prototypes at an average of 8 seconds to engage.

One other trend noticed in the data was the decrease in time taken to engage the zipper between trials of individual prototypes, with the exception of design 1 which failed all three trials. Design 2 failed the first two attempts but succeeded on the third attempt. Design 3's first trial took almost double the amount of time it took for the second or third trial. Finally, design 4 took almost 3 times as long as the first trial as compared to the second and third. One possible explanation for this trend would be the overcoming of a learning curve by the testing individual. When the user is first presented with the device, they have a lack of experience and knowledge about its usage. However, after using it one time during the first trial, the user has a better understanding of how to use the device. Because of this, they are more skilled and faster during subsequent trials. Design 1 being an outlier can be explained by a lack of functionality of the design.

<u>Future Work:</u> The design with the lowest average usage time must continue to be isolated and evaluated. Some reasonable modifications to decrease usage time may include increased adaptability, more areas for the clients to grip onto, and an improved alignment system. In

addition, an instruction manual or video can be created to assist the user in overcoming the initial learning curve of using the device as seen in the data.

Material Testing

May 9th 2024

Purpose:

This test will determine whether the type of material will affect the effectiveness of ZipQuik. The reason for this study is to determine if the type of material affects the functionality of ZipQuik. In most of the assistive devices in the market, there is no indication of whether the device works for all types of materials or even if the effectiveness of the device varies from material to material. We tested a cotton jacket, a polyester jacket, and a jacket with 50% of each material. We picked these materials since they are the most common material used in jackets.

Independent Variables:

The independent variable was the material of the jacket. All the Jackets were the same size with the zipper being a similar shape and on the same side. The three different materials used are cotton, polyester, and 50% of each.

Dependent Variables:

The dependent variable was the time, in seconds, required to engage the zipper, with ZipQuik not initially attached to the jacket. This was observed with a stopwatch.

<u>Materials:</u>

- 3 different jackets with similar thicknesses
    - Polyester jacket
    - Cotton jacket
    - 50% polyester and 50% cotton
- ZipQuik Final Design
- Stopwatch

<u>Hypothesis:</u>

The type of fabric will not have an effect on the amount of time it takes for the zippers to be engaged when using ZipQuik.

<u>Methodology:</u>

1. The participant put on the cotton jacket with the zipper undone.
2. The subject was instructed to begin attempting to engage the zipper using ZipQuik. A stopwatch was started from the moment they were instructed to start engaging the zipper and it was stopped once the ends of the zipper were fully connected.

Figure 20: Testing Individual using the Cotton Jacket with Device

3. When the zipper pin was fully inserted into the pull tab, the testing assistant stopped the timer and recorded the time under trial 1.
4. Repeat steps 2 and 3 for trials 2 and 3.
5. Repeat steps 1 through 4 for the cotton and polyester blend jacket and the polyester jacket.

Figure 21: Testing Individual using the Half Polyester Half Cotton Jacket with Device

<u>Results and Analysis:</u>

Jacket material	Trial 1 (s)	Trial 2 (s)	Trial 3 (s)	Average (s)
cotton	6.3	8.8	9.9	8.333333333
50% cotton, 50% polyester	6.8	5.2	4.2	5.4
Polyester	3.3	3.1	3.2	3.2

Table 2: Raw Data from Jacket Material Testing

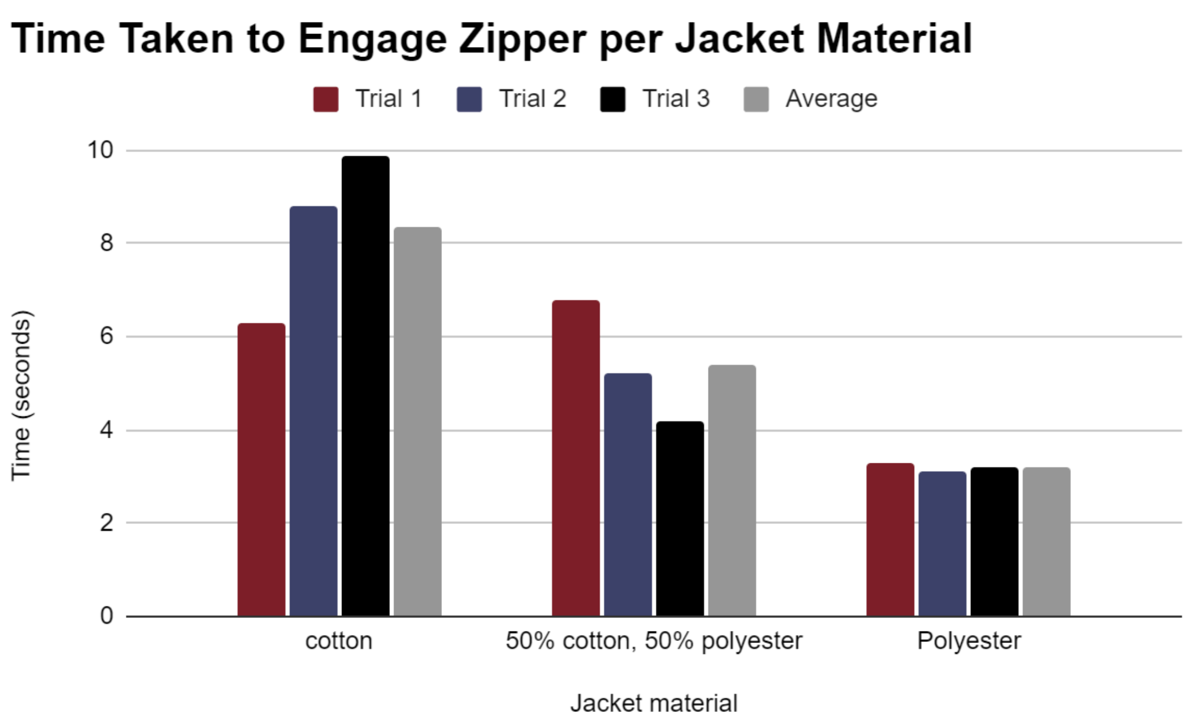

Figure 22: Graph of time taken to engage a zipper for each jacket material tested

The graph of the data shows a slight difference in time taken to engage the zipper between the different jacket materials. On average, the jackets containing a higher cotton percentage take longer to engage the zipper using the device. The jackets contain a higher polyester percentage and take less time to engage the zipper. When looking at the averages of the trials, the cotton jacket yielded the greatest amount of time with 8.33 seconds, the polyester yielded the least amount of time with 3.2 seconds, and the half cotton and half polyester blend yielded a result in the middle of the two with 5.4 seconds. This trend indicates that cotton percentage has an inverse correlation with time to engage the zipper with the device and polyester percentage has a direct correlation with time to engage the zipper with the device. One possible explanation for the difference in times between these two materials is how the material is structured. Polyester is a synthetic fiber and is denser and heavier than cotton. Because of this, polyester might have held its shape better when in the device, making it easier for the user to engage as the materials were not moving around as much.

While the material the jacket was made out of did seem to have an affect on the time it took to use the device to engage the zipper, this difference was very small. There was a 5 second difference between the two jackets of completely different material. As well, all times measured were under 10 seconds which is within an acceptable range to engage a zipper. This demonstrates Zipquick's versatility and usability across a wide range of jackets.

<u>Future Work:</u>

In the future, the divide between times of the two materials can be lessened by adapting the design to work as well for both materials. A potential way this can be done is by making the device narrower to provide a stronger grip on the material, holding it in place regardless of its structure. As well, more jacket materials such as fleece, cotton, and French Terry can be tested to further investigate how well ZipQuik works when placed in different scenarios.

Client Testing

May 13th 2024

Purpose:

The goal of this design study was to determine if ZipQuik makes the zipper engagement process faster for those with physical impairments that affect their ability to do so. This is a vital design study as the main goal of our project was to make it easier for those with limited motor function to be able to engage a zipper.

Independent Variables: The independent variable in this study was whether the device was used by the participant for zipper engagement.

Dependent Variables: The dependent variable was the time the participant took to engage the zipper. This was measured by a stopwatch.

Materials:

- Blue polyester jacket
- ZipQuik Final Design
- Stopwatch

Hypothesis: The time it takes for the participants to engage the zipper with ZipQuik will be less than the time it takes for the participants to engage the zipper without the device.

Methodology:

1. The participants were first asked for verbal consent before they were tested on and they were told that they were allowed to stop testing at any time.
2. Participants were then asked to engage the zipper without using the device. Each attempt was considered a trial and trials were either repeated three times or until the client did not wish to resume further testing.
3. The time the participant took to engage the zipper was recorded with a stopwatch, which started once the participant was instructed to start their attempt and ended once the two ends of the jacket were fully connected together with the engaged zipper.
4. Steps 1 through 3 were repeated for each available client.

Results and Analysis:

Client	Without	With
1	39.605	14.345
2	50.8	20.4

Table 3: Average Data from Client Testing

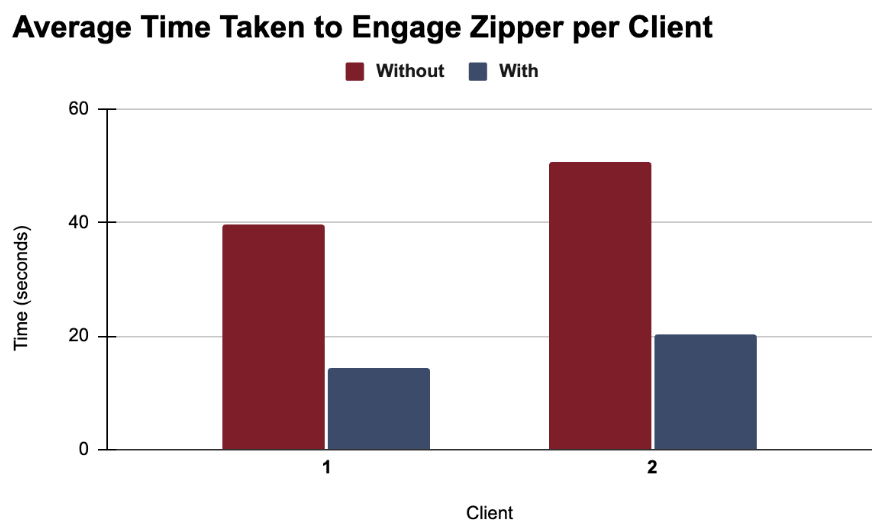

Figure 23: Graphical Representation of Average Time Taken per Client

ANALYSIS

As demonstrated in the graphs above, both of the participants from Seven Hills took significantly less time to engage with zippers with ZipQuik compared to without the device. Participant 1 finished the zipper engaging process about 65% faster when using ZipQuik, and participant 2 finished the process 60% faster when using ZipQuik. Overall, although there are few data points in this study, it is evident that using ZipQuik decreases the time required to engage zippers for those with motor impairments.

Future Work:

Future work can incorporate more participants in testing so that more data points can be obtained. This would result in more prevalent trends and enable statistical testing. In addition, the device can be altered so that it works for zippers on both the left and right side, instead of needing a mirrored version of the device for a specific side. Altering the device in this manner will also help with the portability and generalizability of the device, relieving the need for possibly two separate devices. Furthermore, the durability of the device can be increased by adding more supports and areas of connection to the model.

Users without Motor Impairment Testing

May 21st 2024

Purpose:

The goal of this design study was to determine if ZipQuik makes the zipper engagement process faster for those without physical impairments. This is an important design study because we want to determine if ZipQuik makes the zipper engagement process easier for all individuals no matter their physical condition.

Independent Variables: The independent variables are the method of engaging the zipper, which are with ZipQuik and without ZipQuik.

Dependent Variables: The dependent variable was the time the participant took to engage the zipper for each method.

Materials:

- Blue polyester jacket
- ZipQuik Final Design
- Stopwatch
- Random participants

Hypothesis:

Null Hypothesis: There is no significant difference in the times taken to complete the task with and without the device

Alternative hypothesis: There is a significant difference in the times taken to complete the task with and without the device.

Methodology:

1. The participants were asked for verbal consent to ensure that they felt comfortable with helping us test ZipQuik.

2. Participants were then asked to use a zipper without the device twice to establish a baseline time for their zipper usage.
3. Participants were then asked to use a zipper multiple times with the device to find the change in their times using Zipquik over time.
4. The data was collected and a paired t-test was performed to check for a difference in means.

Results and Analysis:

Client #	Time Without ZipQuik (sec)	Time With ZipQuik (sec)
1	2.55	3.92
2	2.7	3.11
3	2.28	3.1
4	3.38	3.58
5	2.55	5.68
6	2.7	5.67
7	3.25	2.8
8	3.58	2.56
9	2.7	2.25
10	2.89	2.37

Table 4: Raw Data from Users without Motor Impairment

Analysis:

With the data above, we decided to do a paired t test to determine if there is a significant enough time difference to verify whether ZipQuik hinders or amplifies the time taken to engage a zipper. Our null hypothesis was that there is no significant difference in the times taken to complete the task with and without the device. In other words, the mean difference between the times taken with and without the device is zero. The alternate hypothesis is that there is a significant difference in the times taken to complete the task with and without the device. In other words, the mean difference between the times taken with and without the device is not zero. After performing a paired t-test on the data above, the p-value came out to be 0.199. Since the p-value (0.199) is greater than the significance level of 0.05, we fail to reject the null hypothesis. This means there is not enough evidence to suggest that there is a significant difference in times between using the device and not using the device. Because this study was done with people without motor impairments, and we can see that we cannot say that there is a significant difference in the time taken, ZipQuik is not detrimental to the use of a zipper. As such, because many motor-impaired individuals cannot use a zipper, we can safely say that ZipQuik will help them.

Future Work:

In the future, it would be helpful to do more statistical testing with as many more clients as possible. Because of availability constraints, it was difficult to find clients. Doing these tests with more clients would increase the accuracy.

Decision matrix:

#	Requirement type	Requirement Statement	Level	Importance Multiplier	Design v1(Enlarged Hole and Peg Clamping System)	Score	Design v4 (Magnet Alignment Clamping System 2)	Score	Design v6 (Locking Slider Mechanism 2)	Score	**Design v7 (Final)**	**Score**	**Pass/Fail (final design)**
1	Functional	The device shall enable users to start the zipper more easily.	1	x3	Maybe - 0.5 points	1.5	Yes - 1 point	3	Yes - 1 point	3	**Yes - 1 point**	**3**	**Pass**
2	Functional	The device shall be usable by those with limited dexterity, decreased grip strength, and other physical impairments.	1	x3	Maybe - 0.5 points	1.5	Yes - 1 point	3	Yes - 1 point	3	**Maybe - 0.5 points**	**1.5**	**Pass**
3	Functional	The device shall enable other medical devices (like pacemakers) of the user.	1	x3	Yes - 1 point	3	Maybe - 0.5 points	1.5	Yes - 1 point	1.5	**Yes - 1 point**	**3**	**Pass**
4	User	The user shall be able to lift at least 1 pound at hip level.	1	x3	Yes - 1 point	3	Yes - 1 point	3	Yes - 1 point	3	**Yes - 1 point**	**3**	**Pass**
5	Physical	The device must weigh less than 300 grams.	1	x3	Yes - 1 point	3	Maybe - 0.5 points	1.5	Maybe - 0.5 points	1.5	**Yes - 1 point**	**3**	**Pass (15.1 g)**
6	User	The user must be able to exert a force of at least 4 Newtons of force to pinch the device	1	x3	Yes - 1 point	3	Yes - 1 point	3	Yes - 1 point	3	**Yes - 1 point**	**3**	**Pass**
7	Physical	The device should be within eight inches in any dimensions.	2	x2	Maybe - 0.5 points	1	Maybe - 0.5 points	1	Yes - 1 point	2	**Yes - 1 point**	**2**	**Pass (82mmx53.8mmx62mm)**
8	Documentation	The device should include design documentation.	2	x2	Yes - 1 point	2	Yes - 1 point	2	Yes - 1 point	2	**Yes - 1 point**	**2**	
9	Cost	The cost of the materials for the device should be less than $40 USD.	2	x2	Yes - 1 point	2	Maybe - 0.5 points	1	Yes - 1 point	2	**Yes - 1 point**	**2**	**Pass (~25 cents)**
10	Functional	The device should preserve the integrity of the clothes worn.	2	x2	Yes - 1 point	2	Yes - 1 point	2	Yes - 1 point	2	**Yes - 1 point**	**2**	**Pass**
11	Functional	Starting the zipper with the device should take less time than without the device.	2	x2	Yes - 1 point	2	Yes - 1 point	2	Maybe - 0.5 points	1	**Yes - 1 point**	**2**	**Pass**
12	Physical	The device should function without an electrical outlet.	2	x2	Maybe - 0.5 points	1	Yes - 1 point	2	Yes - 1 point	2	**Yes - 1 point**	**2**	**Pass**
13	Functional	The the device should take less than 10 seconds to put on	2	x2	Yes - 1 point	2	Yes - 1 point	2	Yes - 1 point	2	**Yes - 1 point**	**2**	**Pass**
14	Documentation	The device may include a user manual.	3	x1	Maybe - 0.5 points	0.5	Maybe - 0.5 points	0.5	Maybe - 0.5 points	0.5	**Maybe - 0.5 points**	**0.5**	
15	Documentation	The device may come with an instructional video showing the user how to use the device.	3	x1	Yes - 1 point	1	Yes - 1 point	1	Yes - 1 point	1	**Maybe - 0.5 points**	**0.5**	
16	Physical	All materials used for the device may be easily accessible and commercially available.	3	x1	Maybe - 0.5 points	0.5	No - 0 points	0	Maybe - 0.5 points	0.5	**Yes - 1 point**	**1**	**Pass**
17	Physical	The device may be available in different colors.	3	x1	Maybe - 0.5 points	0.5	Maybe - 0.5 points	0.5	Maybe - 0.5 points	0.5	**Yes - 1 point**	**1**	**Pass**
			Total Score			**29.5**		**29**		**30.5**		**33.5**	

Figure 24: Decision matrix for deciding v7 as the final prototype

As seen above, the design that scored the highest in the decision matrix of all the requirements is Design v7, which is the final design. Although the other prototypes were also fairly successful, Design v7 satisfied almost all of the level 1 requirements and satisfied all of the level 2 requirements. The decision matrix was made to take level 1 requirements at a higher weight than the others as well, which further increases their importance and makes it more important to fulfill them.

According to the design studies above, Design v7 is about 60% more efficient in engaging zippers compared to without the device for people who struggle with fine motor skills. Additionally, there is no significant difference between using and not using Design v7 to engage the zipper for people without physical impairments.

The final design (v7) successfully enables individuals to be able to engage the zippers. This also includes those with only one functioning hand. The device also works very efficiently with polyester but takes more time with cotton. Additionally, sometimes the zipper gets stuck in the slit the zipper slides through, which will need to be fixed in the later designs.

Appendix:

Table 5: Bill of Materials/Tools

Purchased		
Item	Price	Purpose of Purchase
MIKEDE Strong Rare Earth Neodymium Magnets, Heavy Duty Bar Magnets with Double-Sided Adhesive, Powerful Pull Force, Perfect for Fridge, Garage, Kitchen, Science, Craft, Office, DIY 60x10x3mm 10pack	$8.99	Integrating magnets into proof of concept
3D Printing Filament	None	Creating the framework and printing the design