Exploring Assistive Technology Solutions and Universal Design

by

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Submitted to the Department of Mechanical Engineering
in Partial Fulfillment of the Requirements for the Degree of

Bachelor of Science in Mechanical Engineering

at the

Massachusetts Institute of Technology

June 2017

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ABSTRACT

Creating devices that take those with limited physical abilities into account can make everyday tasks easier for everyone to perform. During this project, a user with restricted fine finger dexterity was considered in the design of a product that assists people with opening sealed packages. The primary user was first interviewed about his needs and limitations. After initial research was performed, the team ideated and completed basic sketches of products concepts. The user was again consulted for impressions and feedback about the variety of ideas, and the team continued by focusing on one broad concept and fleshing out the details. Once several different mock-ups of the chosen concept were made, they were presented to the user. His feedback then informed the design of a second round of prototypes. User testing will be completed before settling on a final design. The final product will be presented at the Design for America Spring Critique on May 18th, 2017.

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Acknowledgments

The author would like to thank the members of MIT's Design for America for their support; Kelly Chen, Rachel Adenekan, Carly Silvernale, and Ananya Nandy for their participation in this project; Dr. Burton Pusch for his input, advice, and participation; and Associate Professor Maria Yang for her guidance.

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Chapter 1
Introduction

Universal design is the development of an environment that can be accessed and utilized by all people regardless of age, size, or ability, whereas assistive technology refers to devices that help people with disabilities adapt to the current environment [1]. Rather than serve only the average members of the community, universal design intends to benefit the entire population. By considering the diverse needs of humanity throughout the design process, universal design results in products and services that meet everyone's requirements. In the meantime, assistive devices serve to bridge the gap in environments that were not designed universally.

As a Project Lead for MIT's Design for America, I have spent the past year managing a team of students whose goal is to find solutions in these categories in order to improve the quality of life of people with disabilities. From the beginning, we planned to follow a user-centered design approach in this project. After contacting several rehabilitation hospitals, research labs, course representatives, and peers, my team and I found a user, retired professor Dr. Burton "Burt" Pusch, who was willing to test and provide feedback for hardware products aimed at making life easier for people with his or similar disabilities. Our end goal for the project is to develop a device that works not only for Burt, but can be expanded to help anyone open packages, thus following the principles of universal design.

Burt was born with congenital disabilities, which, in his case, means that he has three fingers a shortened leg. For the purposes of this project, we will be focusing on his limited fine finger dexterity. Burt cannot grasp or manipulate objects with his fingers due to a lack of grip strength and an inability to perform the finger coordination necessary to pinch an object between two fingers. Additionally, since he has fewer than five fingers on each hand, he cannot use products that rely on the use of multiple fingers at a time. In general, he cannot lift anything that weighs more than two pounds. This thesis describes a case study of the design project for Burt: My team and I have ideated, designed, and prototyped devices that will help Burt open packages, such as potato chip bags or other sealed plastic food containers, independently. In the process, we considered the principles of universal design and aimed to bridge the gap between Burt's current environment and his ideal one.

Chapter 2
Background (or Theory)
2.1 Universal Design

The design researcher Ronald Mace of North Carolina State University led a multidisciplinary group to develop the seven principles of universal design [1]. These principles guide and educate designers about ways to make products more widely usable. The first principle urges designers to provide identical or at least equivalent means of use for all users and to avoid segregation. Choice and flexibility in methods of use are advocated in the second principle [1]. The third principle of universal design guides designers in eliminating complexity and embracing consistency in user expectations and simplicity. Principle Four outlines ways to effectively communicate essential information to the user regardless of their sensory abilities. The fifth principle advocates for designers to minimize and provide warnings for hazards and errors [1]. Low physical effort and the maintenance of neutral body positions during operation are explained in Principle Six. Finally, the seventh principle advises analysis of appropriate size [1]. These seven principles were used to guide the team's design process as well as evaluate the successes and shortcomings of the final product.

2.2 Fine Finger Dexterity

Fine motor coordination is defined as the ability to complete delicate manipulations with the fingers. This coordination often requires steady hands, muscle control, and simultaneous distinct finger movements. Dexterity refers to skill in using one's hands [2]. It generally requires both fine and overall motor coordination.

The University of Cambridge has created an Inclusive Design Toolkit that explains the uses of fine finger dexterity in daily life [3]. Many existing products require the physical manipulation of controls or switches. Hands are often needed to grasp, move, and exert forces for the operation of even simple products. The idea that the hand is made up of four fingers and an opposable thumb is central to many tasks that take advantage of dexterity. While many products aimed at helping people with limited dexterity focus on ailments like arthritis, the user for this project, in contrast, was born with approximately one finger and thumb on each hand. Therefore, he cannot utilize clamping force between fingers or exert pulling and pushing forces as readily as people with all ten fingers. This project intended to result in a product that can comfortably be used by people with various amounts of fingers. In addition, the product could be useful in situations where able-bodied people have experienced temporary bruising or breakages. The product should minimize frustration by eliminating a need for high levels of strength or two-handed coordination.

2.3 Dexterity Functions

Dexterity functions, as outlined in the Inclusive Design Toolkit, can be divided into four categories: Pushing, pinch gripping, power gripping, and two-handed tasks [3]. Pushing is the simplest function and involves using the fingers or palm to exert forces in the same direction as the movement without grasping. There are three directions in which a force can be applied: using the body weight, such as when opening a door; pushing up and down, such as when depressing buttons; and pushing left and right, such as when moving sliders. It is most comfortable to push down rather than up and toward the body rather than away from it [3].

Pinch gripping involves creating opposing forces between the thumb and fingers. This function is usually only used for activities that require minimal forces, such as manipulating sliders and knobs. In order to make users more comfortable, the surface and texture of sliders and knobs should allow the user to operate them with a loose grip and their preferred combination of thumb and fingers. The optimal shape for an object that a user turns with a pinch grip is a long strip that provides room for the thumb and fingers to grab either side of it. A spherical shape like a doorknob, on the other hand, is the hardest to grip because fingers can slip on the surface [3].

Power gripping involves using the thumb, fingers, and palm to generate large forces with comparatively little effort. In comparison to a pinch grip, many more muscles are used; however, the precision is reduced. Examples of activities that require this grip include grasping handles and picking up mugs. To provide comfort for the users, the objects should be shaped so that the hand can be wrapped completely around the object and contact area can be maximized. The optimal shape for providing rotational motion with a power grip is a handle or lever because it is easy to grip and does not rely on frictional contact. Alternatively, circular knobs and surfaces that do not allow the whole hand to be used are the most difficult shapes. For maximum inclusion, products should be designed so that they can be used with one or two hands. This information regarding dexterity functions was used during the team's design process to direct our ideas and refine design concepts by ensuring the team selected the most comfortable option for the user [3].

2.4 Environmental Context

The environmental context affects one's ability to perform dexterity tasks, especially those that rely on friction. For instance, more strength is needed if the user's hands or fingers are sweaty, wet or lubricated via substances that are from workshops or kitchen environments [3]. Hand function and sensitivity of the fingers is decreased with decreasing temperature; however, wearing gloves or protective clothing can also make it more difficult to operate controls. The ability to make precise movements or grip objects can also be impaired by vibration, motion, and lack of visibility [3]. In addition, it is difficult to maintain finger dexterity in the cold. Tasks that someone would be able to perform in warm weather might not be possible if they went outside in the cold or if they were wearing gloves [3]. Designers should consider when or where users would need to use the product and ensure that it works with even further limited dexterity from cold weather.

2.5 Population Statistics

According to the 2010 United States Census Bureau, roughly nineteen percent of the population, or 56.7 million people, has some type of disability [4]. More specifically, about 19.9 million Americans have difficulty lifting or grasping objects such as a bag of groceries, a glass, or a pencil [4]. These statistics indicate that Burt's daily problems permeate throughout the United States, and our solution could likely improve the quality of life of approximately one in twenty Americans.

2.6 Existing Solutions

While conducting our background research, we found two products that closely resemble the device we are attempting to create. One of them is called the Snippit Bag Opener, which is a small, plastic, hook-shaped product fitted with a sharp cutting blade, as shown in Figure 1 [5]. It also includes a magnet so that it can be attached to a refrigerator. The Snippit is intended to open plastic bags, bacon packages, lunch meats, and candies [5].

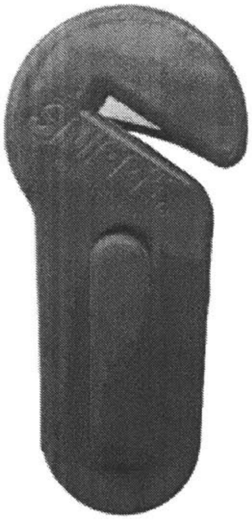

Figure 1: Picture of the Snippit Bag Opener.

The second device we researched was the Easy Glide Bag Opener, as shown in Figure 2. This product cuts plastic as well as potato chip bags [6]. It is used by placing it around the top of a bag, squeezing the device gently, and sliding it across the bag. In addition, the Easy Glide Bag Opener is dishwasher safe and claims to be safer to use than scissors or knives [6].

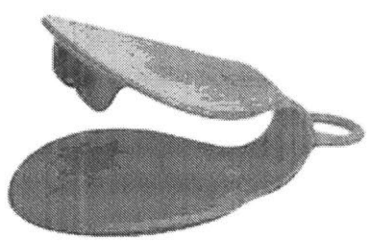

Figure 2: Picture of the Easy Glide Bag Opener.

While both devices serve the purpose of opening bags, neither of them caters to people with Burt's abilities. The Snippit Bag Opener requires uncomfortable wrist movements and has a handle that is difficult to grip without all five fingers. The Easy Glide Bag Opener, while it is designed as an enabling device, still requires a small pinching movement between the fingers.

2.7 Analogous Products

Before designing our device, we looked to existing products for inspiration. One product we drew inspiration from was the Swiss Army Knife. The Swiss Army Knife is constructed like a sandwich, with several compartments out of with tools can emerge [7]. A floating spring mechanism is used for extruding and stowing the tools from and into their respective compartments. Swiss Army Knives are made of stainless steel because it is durable, not highly corrosive, and it is easy to clean [7].

Folding pocketknives were also a source of inspiration for us. There are several different types of locking mechanisms for everyday carry knives, including the lockback, liner lock, frame lock, and the slip joint and friction folder [8]. A lockback mechanism is essentially a spine that locks into a notch on the back of the blade when opened. In order to close the knife, users push down on the middle of the spine to release the part of the spine in contact with the blade [8]. The benefits of a lockback mechanism include reliability and minimized risk of cutting yourself. Unfortunately, it requires two hands and some dexterity to operate. The liner lock is a common mechanism with a spring bar beside the sharp edge of the blade and inside the handle. The spring bar is held under tension when the knife is closed but releases to make contact with the blade when opened to prevent it from closing [8]. The spring bar must be pushed out of the way to disengage the lock. While liner locks can be operated with just one hand, they are not well suited for heavy-duty tasks and certainly require fine finger movements. The frame lock is similar to the liner lock; however, the spring bar is part of the handle rather than internal [8]. Frame locks are better than liner locks for performing heavy-duty tasks, but they again require small finger manipulations. Slip joints are the mechanisms typically seen in Swiss Army Knives and, technically, do not have a true lock. The user just pulls on the blade, which snaps into place once the user overcomes the force of the spring [8]. Friction folders also lack a true lock. Instead of a spring or spring bar, they utilize the friction between the blade and knife scales to hold the blade in place. Although slip joints and friction folders do not have a real locking mechanism and cannot withstand heavy-duty tasks, they are legal, easy to carry, and simple to use [8].

We also looked into switchblades, which are spring-loaded knives that deploy at the touch of a button, but after further investigation we discovered that these devices are illegal to carry in Massachusetts and would therefore be of no use to our user [9].

Chapter 3
Methods

3.1 User Research

Once we determined that our primary user would be Burt, we conducted some background research to determine what kind of products would be most beneficial to him. During an initial meeting, Burt described the types of challenges he faces in his everyday life. He detailed his problems using phone chargers and light switches, preparing drinks, and opening packages. These activities had one overarching theme: they require fine finger dexterity. Because many people face issues with fine finger dexterity, whether it be fewer fingers, arthritis, or simply a sprain, the team determined that a device that solves one of Burt's problems could be an exercise in universal design. We then settled on creating a product that helps Burt open packages independently.

After narrowing the scope of the project, we prepared follow-up questions for our user. We asked questions about his range of motion, the model and dimensions of his power wheelchair, preferences for controlling a device, and the biggest flaws in his current solutions. We discovered that Burt has the capability of reaching roughly a one-foot diameter around his body and can lift object of up to two pounds. We also determined some of Burt's functional requirements. Burt requested that the device be portable so that he could access food in sealed packages when he is outside of his home. He specified that aesthetically, he would like the device to be sleek rather than to call attention to itself. Ideally, the device could be used for re-sealable packages.

3.2 Ideation

The following phase in our design process was ideation. As a group, we brainstormed ideas about how we could help Burt open packages. We first considered the different ways Burt could potentially hold the device. We thought of a finger attachment similar to a ring, which would be fitted to Burt's finger and would therefore prevent him from having to use any pinch or grip strength. We also conceived of a cell phone attachment, which takes advantage of the fact that we know Burt already uses and can hold a cell phone. Another idea was to have the device connect via Burt's wrist, which has similar advantages to the ring, but could offer a wider range of motion. A wall or table attachment removes the need for Burt to hold anything; however, it does not offer portability.

Next, we considered the use of technologies such as sensors that could assist Burt in activating his device. We thought it might be useful to incorporate pressure sensors that active the device only when a downward force is exerted. We also thought we could use sensors to determine when the bag is closed or opened.

3.3 Sketching

After noting some general ideas regarding what the device could look like or how it could function, we created sketches of these ideas to better conceptualize and communicate our thoughts. Each team member contributed sketches, which we then discussed with each other and our user, Burt.

One team member explored the idea of a fixed device that could attach to a table or wall, as shown in Figure 3. This device would open a bag via a blade that could puncture the packaging, and it would attach to a surface using a suction force. The device could also include some kind of rubber casing to make it easier for the user to grip. The main drawback of this device is that it lacks portability.

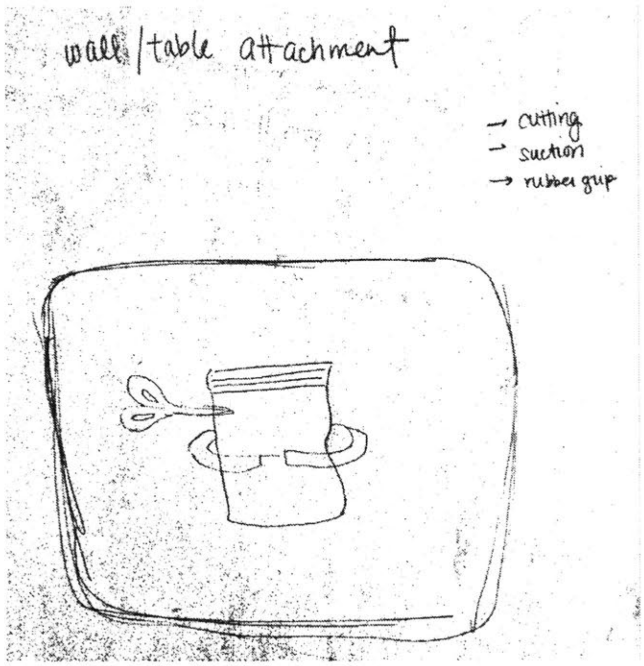

Figure 3: Sketch of wall or table attachment idea. This concept would include some kind of suction to keep it attached to a flat surface, a blade for cutting the package, and a rubber grip for one's hands.

The same team member also illustrated an idea for a device that eliminates the user's need to hold the physical object by including a wrist attachment, as shown in Figure 4. The device could be worn around the user's wrist during operation, and two "fingers" extending from the device could open and close to pinch and manipulate a plastic package. These "fingers" would operate similarly to the way the assistive technology devices often referred to as "Pick Up Tools" or "Reachers" operate. The challenge of creating this device would likely be deciding how the user would operate the "fingers".

Figure 4: Sketch of wrist attachment idea. This concept would include extensions from a bracelet-like wrist attachment that could pinch or grab objects.

Another team member sketched an idea that was inspired by the Easy Glide Bag Opener, as shown in Figure 5. This device would be shaped and function similarly to a stapler, and works by pressing one's own body weight onto the device in order to deploy the blade and puncture the bag. One concern about creating this device would be its weight. It would have to be well under two pounds in order for it to be useful to Burt.

Figure 5: Sketch of stapler-shaped bag clamp idea. Similar to the Easy Glide Bag Opener, this concept would include a blade that would slit a bag open when the clamp is pressed together. This design, however, would be larger so that the clamp could be pressed together simply by exerting one's body weight on it.

This team member also sketched an idea for a device that operates with the use of pressure sensors, as shown in Figure 6. The user would exert a force on the device and bag using their entire hand, and once a certain threshold of pressure was reached, the device would deploy a blade to cut open the package. In order to determine if this device should come to fruition, we would need further information on whether or not it is comfortable or plausible for Burt to exert his entire body weight on an object.

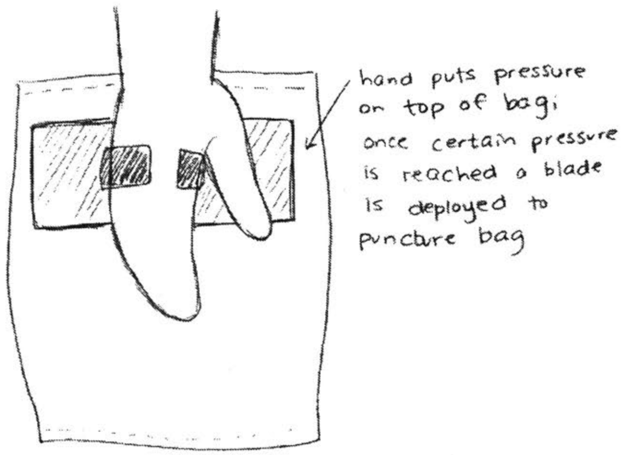

Figure 6: Sketch of pressure sensor idea. This concept would include a blade that would deploy to open the bag or package only when a certain amount of pressure was exerted on the device.

Another concept that the team decided to sketch was a blade that attaches to a finger like a ring, as shown in Figure 7. This device would be lightweight, portable, and provides a simple solution for how the user would grasp it. We would, however, have to determine how the blade could be safely stowed so that it is not dangerous to carry around.

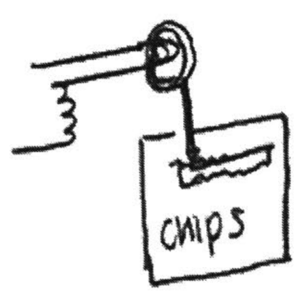

Figure 7: Sketch of finger attachment idea. This concept would include a blade that extends from a ring worn on the user's finger. The blade would pierce the packaging to open the bag.

We also sketched a device that functions similarly to a chip bag clamp, in that it would fasten around the top of the bag, as shown in Figure 8. In order to open the bag, the user would pull a loop that slides the blade across the top of the bag. The primary benefit of this solution is that it safely secures the bag and points the blade away from the user. On the other hand, someone with limited fine finger dexterity may have difficulty fastening the device around the bag in the first place.

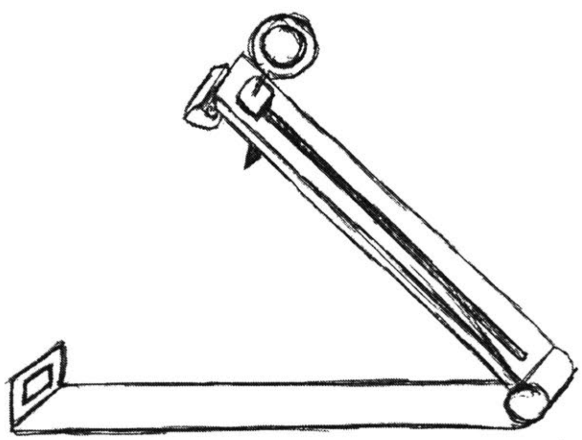

Figure 8: Sketch of chip bag clamp idea. This concept would include a hinged clamp that would sandwich and secure the top of the bag or package. The blade would then be slid across the bag to open it cleanly.

A second fixed table attachment concept was sketched, as shown in Figure 9. The main differences between this concept and the device in Figure 3 is that the concept shown below is attached to the corner of the table, secures the bag by weighing it down, and includes a loop to slide a blade across the top of the bag. Again, this idea does not offer portability.

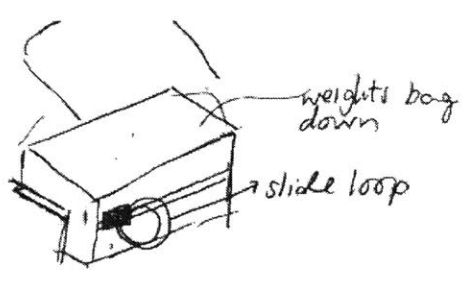

Figure 9: Sketch of fixed table attachment idea. This concept would include a blade that when pulled via a loop across the device would slit the bag or package cleanly. The device would be shaped to fit on the edge of a table and would hold the bag in place.

Finally, we sketched an idea for a device that connects to the user's cell phone, as shown in Figure 10. This concept utilizes that fact that we know most people with limited fine finger dexterity carry around and are somewhat comfortable with a mobile phone. The device would therefore be small, lightweight, portable, and would include a manually deployable blade. The biggest concern for this concept would be how to safely and easily stow the blade.

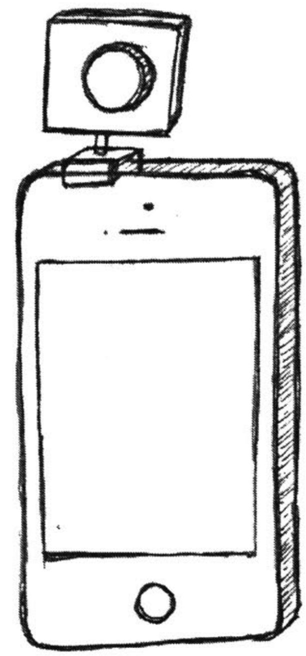

Figure 10: Sketch of phone attachment idea. This concept would be a small, square-shaped device with a deployable blade to puncture the bag or package. It would attach to the phone to ensure that it can always be taken with the user wherever they go.

After completing these sketches, we brought them to our user, Burt, for feedback and discussion.

3.4 User Feedback

When we met with Burt to review our sketches, we gained several new insights into his needs. After looking at the drawings, Burt immediately saw potential in the finger attachment and phone attachment ideas. Because he currently uses key rings to perform tasks such as pulling zippers, he liked the idea of a device he could grasp by threading his finger through a hole. He specified that the hole should be at least three centimeters in diameter. Burt appreciated the square shape of the phone attachment because it would allow him to easily rest the device of any flat surface; however, he did not think the ability to attach the device to his cell phone would be a large benefit for him. He then proposed a device that would be a combination of the two concepts. Ideally, he wanted a square-shaped device with a hole in it and a manually deployable blade, as shown in Figure 11.

Burt also discussed a few areas of importance to him that he did not see in any of our sketches. One thing Burt emphasized was safety. He explained that a blade needs to be easily deployable, so that he could use the device independently, yet it cannot be so easy to deploy that it deploys without a human to trigger it. Burt also reiterated that portability was a priority for him, and that he would likely carry this type of device in the bag he always keeps attached to the arm of his power wheelchair. He showed us some Xacto knives that he currently owns and demonstrated how the switch that slides that blade out is difficult for him to use. He additionally mentioned that curved blades tend to be easier for him to use than straight ones. Burt finally requested that the device be black or silver in color. These explanations helped us better understand Burt's desires and requirements and informed our next iteration of design.

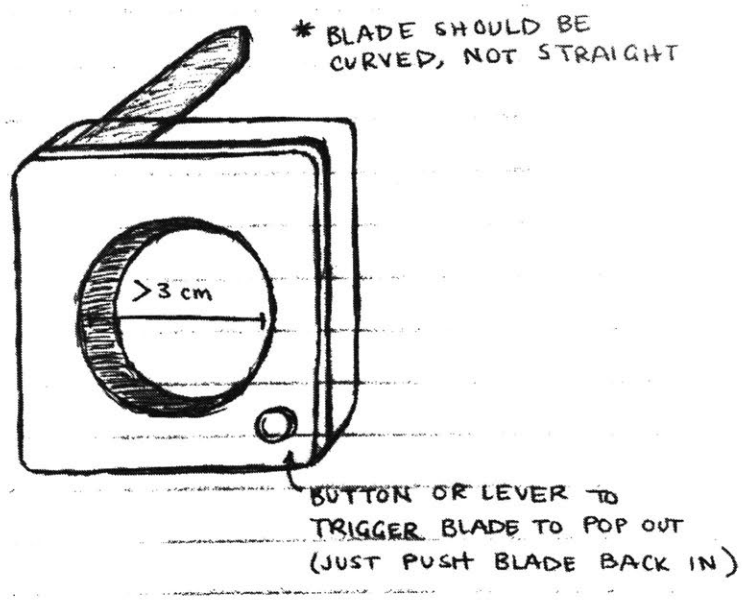

Figure 11: Sketch of the concept that came out of our user feedback meeting. It is a square device with rounded corners for safety, a hole that is three centimeters in diameter for easy grasping, and a button or lever to manually deploy a curved blade that is stowed within the form of the device.

3.5 Prototyping

Once we settled on a concept that would fulfill all or most of Burt's wishes, team members designed devices to prototype. Each of the three devices includes a hole or opening that is easy for Burt to grasp and a unique mechanism for deploying the blade. The prototypes were built by creating SolidWorks drawings of the form factor, laser cutting these form factors in dark gray acrylic, and using duct tape, gaff tape, bolts, and nuts to secure the parts together.

The first design, as shown in Figure 12a, is a compact device with a three-centimeter wide hole and curved shape for ease of grasping. It has flat edges so that it is easy to place on surfaces, and has a curved, manually deployable blade. The blade it released by pulling outward on the wire loop so that the blade rotates outward. There is a stop on the inside of the blade to prevent it from rotating inward toward the hand or finger.

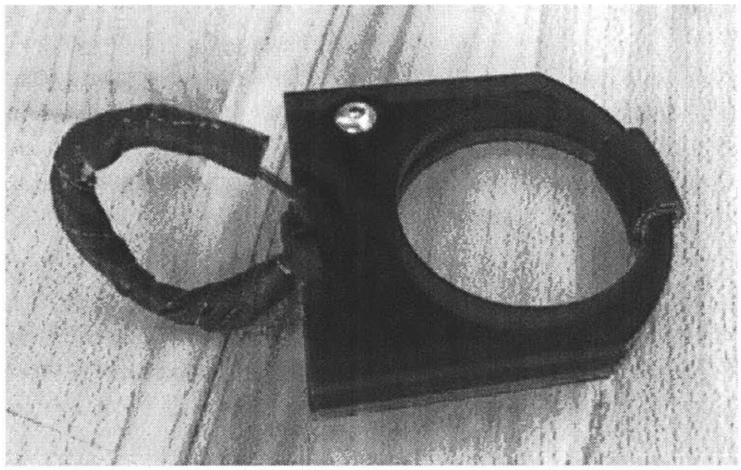

Figure 12a: Prototype of a device that can be grasped by hooking a finger through it, has a flat top and bottom so it can rest easily on a surface, and has a curved blade that rotates outward by pulling on the loop.

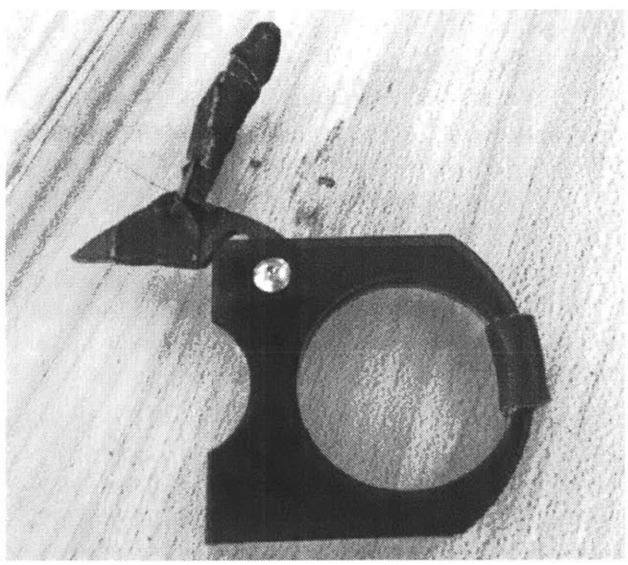

Figure 12b: Image of same prototype as above with the blade released.

Our second design, as shown in Figure 13a, is a device that, similarly, has a three-centimeter hole for grasping, a simple square shape with rounded corners for sleekness, and a sliding blade mechanism. This mechanism is operated by pulling the loop upward, sliding it across a track, and dropping it into a second notch, which holds the blade in place.

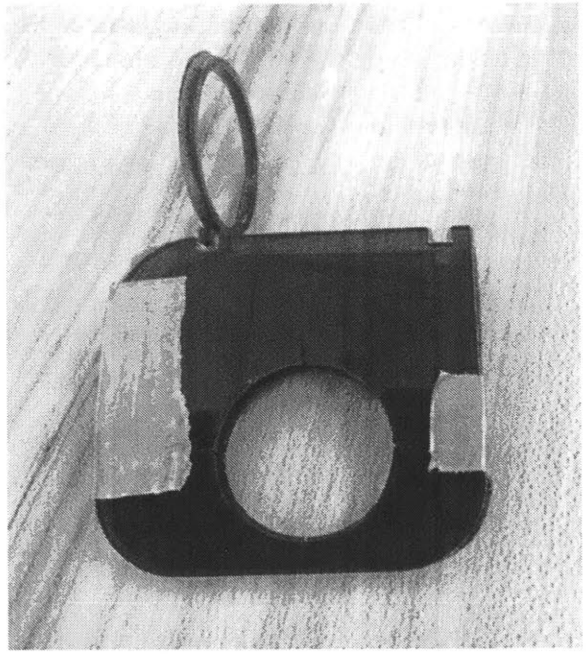

Figure 13a: Prototype of a device that can be grasped by hooking a finger through it, has a flat top and bottom so it can rest on surface, and has a curved blade that slides outward by pulling a loop across a track.

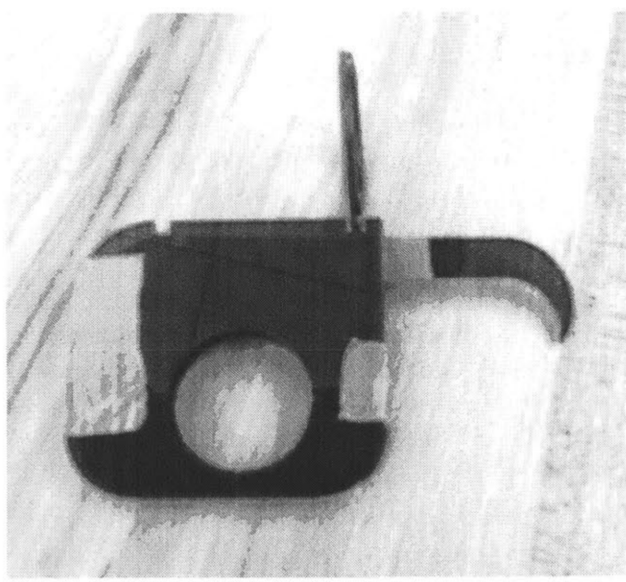

Figure 13b: Image of same prototype as above with the blade exposed.

The third design we prototyped, as shown in Figure 13b, is a four-bar linkage with a rotating blade. The device can be grasped by hooking a finger around a linkage and can rest on surfaces because of its flat edges. The curved blade rotates outward by manipulating the linkages.

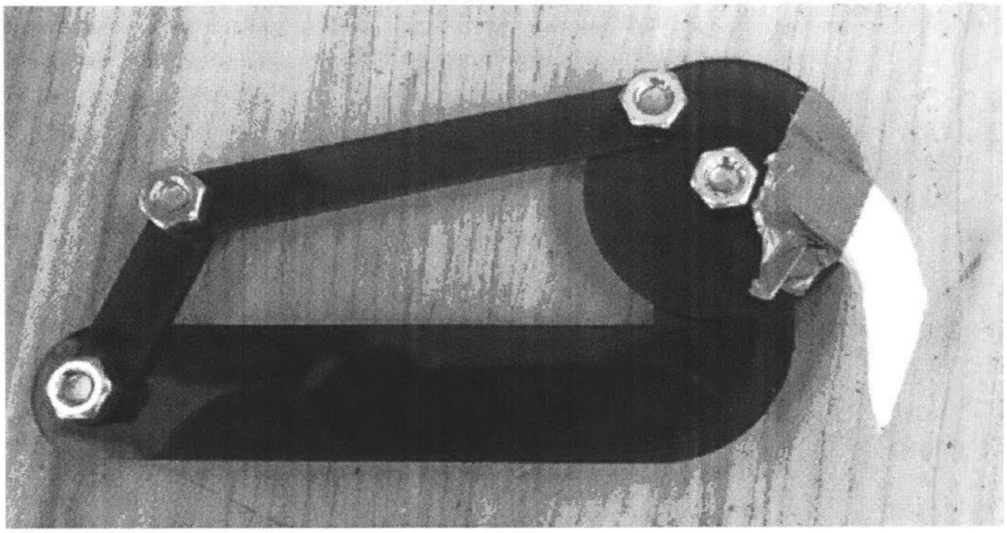

Figure 14: Prototype of a device that can be grasped by hooking a finger around a linkage, has a flat bottom so it can rest on surface, and has a curved blade that rotates outward by controlling the linkages.

After prototyping these three devices, we sent pictures of them to our user, Burt, in order to get his feedback on our designs.

Chapter 4
Results and Discussion

Once we sent pictures of our prototypes to Burt, we were able to gain insights into the benefits and drawbacks of each design. For instance, the first design is extremely size-efficient and lightweight. While the wire loop does make the blade mechanism slightly easier to use, it still requires some dexterous movements to operate. The second design is aesthetically sleek and offers a simple and straightforward mechanism. Burt prefers this design because it is visually streamlined and has a more intuitive actuator for the blade. With some refinement, the sliding mechanism could provide genuine ease of use for people with limited fine finger dexterity since it does not require any rotation of the wrist or small finger movements. The third design is easy to operate with two hands but is significantly more difficult to grasp than the other two designs.

Because Burt favors the second design, we plan to iterate on this concept and create a new set of prototypes. Each member of the team will come up with a new design for a streamlined device with a sliding blade mechanism. Again, we will create the designs in SolidWorks and laser cut the prototypes. We will then bring these physical prototypes to Burt so that he can test them and provide feedback in person. We plan to conduct user testing by asking Burt how he would use each device without providing him any explicit instructions, and then observing his behaviors and taking note of his comments. That way, we are not influencing his opinions. After we receive his feedback, we will decide on and flesh out one final design of which we will create a higher quality prototype for the Design for America Spring Critique on May 18th, 2017 and to give to our user, Burt.

Aside from getting feedback from Burt, our testing for our next iteration of prototypes will likely consist of asking people to try our devices with simulated limited fine finger dexterity, as well as evaluating the universality of the design via the seven principles mentioned previously

[1]. For our final design, we will put greater consideration into the materials used to create the prototype in order to ensure a durable product. In the future, we would like to test with a variety of other potential users with limited fine finger dexterity.

Chapter 5
Conclusion

Through our interactions with Burt, it became clear that each of our prototypes could be improved to better cater to his abilities. Because he liked the ease of the sliding mechanism in the second design and the size of the first design, we will base our final design on these two concepts. On May 18th, 2017, we aim to present a robust prototype that combines portability and simplicity to serve not only Burt, but also all others with limited fine finger dexterity. Because roughly one in twenty Americans struggles with fine motor skills including opening packages, this project is a worthwhile pursuit to improve the quality of everyday life of many. By making the details of our research public, we hope that others interested in this topic can expand on our work and further assist those with inhibited dexterity.

Chapter 6
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