Final Design Report: Storm Strap

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Date:
March 16, 2019

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Executive Summary

Problem

Our clients Amanda Hoffman and Maggie Bulleri asked us to design a device for an umbrella for someone with hemiplegia. Their patient has little to no use of one arm and uses a cane in the opposite arm, so this solution must be usable by someone without any arms free to hold the umbrella.

Purpose & Requirements

The objective of the design is to create a compact, portable, quickly securable, and stable device to protect Abdul-Aziz (Aziz), an individual with hemiplegia, from rain while allowing him to maintain a high level of independence and mobility. This device must be created with a $100 budget.

Methodology

After observing the user attempt various tasks, we created three mockups that we brought back for user testing. By utilizing Aziz's feedback and our observed requirements, we created a final mockup. We tested the performance of this product extensively ourselves, ensuring that it complied with our specifications. After final adjustments, we built a prototype with the intent that Aziz will be able to use the device in his daily life.

Design

Our design is primarily composed of a torso and shoulder strap apparatus that attaches to the body. The umbrella is supported in a compact tube and clip on the shoulder strap to provide maximum stability in Chicago winds and rain.

Key Components	Benefits
Torso Strap & Shoulder Strap	- The straps are an appropriate width to provide stability and avoid pressing into the user's skin, allowing for a safe and comfortable experience - Buckles make the device quick to secure
Tube & Plastic Backing	- A rigid plastic tube allows for maximum compactness and portability - An elastic loop on the plastic backing secures the umbrella
Pole Clip & Velcro	- A clip and velcro on the shoulder strap secures the umbrella at the top
Umbrella	- An oversized umbrella provides maximum coverage for the user

Table 1: Key components.

Introduction

People with hemiplegia often have to modify their lives in order to perform daily tasks. They are only able to use one hand which limits the variety of activities they can do (see Appendix A - Background Research Summary). Although these people have limited use of one of their arms, some still live independently. They travel and do different tasks on their own. Our team was asked by Shirley Ryan AbilityLab to design a device that will protect patients with hemiplegia as they travel in extreme weather conditions (see Appendix B - Client Interview Summary). To maintain their independence as they face different weather conditions, we intended to create a device that will serve as a means of hands-free protection.

There are very few solutions to this problem that currently exist on the market (see Appendix C - Competitive and Model Products). The most notable design is an umbrella hat. An umbrella hat adequately covers its user from rain but it is not an attractive product. Our solution aims to provide the same amount of protection in a less distracting fashion.

Our user, Aziz is looking for a product that will cover him from rain or sun while being discreet in public. He often commutes by walking so he would like a product that provides enough coverage while also being allowing him to easily walk with a cane.

Our design, The Storm Strap will address this problem. The design effectively protects the body and can be put on with only one hand. It fits closely to the body and is very discreet. The user's mobility is not impacted by the device because the straps rest on the shoulders and they do not impact movements with a cane. It is able to be compressed and packed into a backpack so, Aziz will be able to quickly pack and store the strap in his bag. The cup and clip attached to the strap help to ensure the umbrella remains stable as Aziz travels through extreme weather.

This report defines the users, requirements, and specifications for the requested design. A detailed explanation of the design and its rationale are also included. We conclude with details for testing and ideas for future development.

Users & Requirements

Primary Users

Our primary user is Aziz, a native of Kuwait who is now living in Chicago (see Appendix D - Project Definition). Last year he had an accident that caused severe brain and nerve damage, leading to hemiplegia in his right side. He has limited use of his right leg but can still walk with some aid. He has even less control over his right arm, making it difficult for him to perform tasks requiring two hands. He would like to be able to protect himself from the elements without having his unaffected hand occupied with holding an umbrella.

Our hope is that this device can be used for other individuals with hemiplegia in the future as well, so we made the device as adaptable as possible for users of all sizes. Patients with injuries resulting in similar symptoms as individuals with hemiplegia may also be able to use our device.

Secondary Users

Maggie and Amanda are occupational therapists who work with Aziz at Shirley Ryan AbilityLab. They will help Aziz get accustomed to the device and teach him how to use it. Additionally, they may be able to use the device for other patients with similar symptoms.

Tertiary Users

Aziz's family will continue to try to help him live comfortably with his condition. They will be the ones who ensure that he implements the device in his daily life. Furthermore, they could walk with him under the protection of our device in the rain if needed.

Portability

Aziz won't need to wear the device all the time, given that it is designed to protect him from inclement weather. He'll want to have it accessible if there is a chance he could encounter such conditions. The device must be lightweight and easy to carry. Therefore, it should weigh no more than 5 pounds (see Appendix D - Project Definition).

Compactness

Because Aziz won't be wearing the device at all times, he'll want to store it away when he isn't using it. The device should be compressible so that it doesn't take up a large amount of space. The device should be able to fit into a bag such as the user's backpack. To accomplish this, the device must be able to be compressed to dimensions of 9" x 3" x 3".

Stability

The device needs to secure the umbrella in place and keep it stable while the user goes about his business. The plastic tube on the device should be wide enough to fit the handle of an umbrella. The depth of the tube should reflect the length needed to keep the umbrella stable to the device. The tube must have a diameter of at least 1.25 inches and a height of at least 3 inches.

Comfort

To feel comfortable in the device, it must be discreet so as not to draw attention. Additionally, it must not be too bulky as to limit the user's movements. The device, not including the umbrella,

shouldn’t extend further than 6 inches from the body.

Quick Deployment
The device should be able to be attached and secured quickly and easily with only one arm. It should also be simple to remove. The device must be able to be attached and secured by the user in under a minute, as well as taken off fully in under a minute.

Coverage
The device needs to cover the user’s body and bags, protecting him from weather. The device must cover 80% of the user’s body and belongings.

Mobility
The user needs to be able to utilize a cane and/or wheelchair while wearing the device (see Appendix E - User Observation Summary). Wearing the device shouldn’t limit the user’s basic body movements. The device’s weight shouldn’t impede the user’s mobility. The device needs to be used while walking or in wheelchair for at least 5 minutes. The device needs to weigh less than 5 pounds.

Design Concepts & Rationale

Overview

Throughout the design of the device, our team kept in mind four key characteristics: portability, compactness, speed of securing, and stability (see Appendix D - Project Definition). With these characteristics in mind throughout the entire process, we were able to build a device that will protect the user from rain while allowing them to function as usual. The main components of the device include a torso strap, shoulder strap, plastic tube, plastic plate, clip, and velcro strap. The torso strap uses buckles to fasten it securely and with ease, while the shoulder strap tightens with a backpack strap tightener. The plate has an elastic strap on it that coupled with the clip on the shoulder strap allow the umbrella to remain secured to the user's body in wind and other conditions. The handle of the umbrella is tightly held in a small plastic tube, chosen to be as compact as possible. A full image of the device is pictured (Figure 1), and each key feature is explored in further detail in the following sections. For detailed production instructions, see Appendix H - Instructions for Construction. Also provided for your reference are instructions for use (see Appendix I - Instructions for Use) and a list of materials (see Appendix J - Bill of Materials).

Figure 1: Overview photo of Storm Strap.

Torso Strap & Buckle

Concept

The torso strap (see Figure 2) is the main structural part of the device. It supports almost all of the weight of the umbrella. The middle of the strap is elastic fabric and in the thick part of the strap there is plastic mesh wrapped with waterproof fabric. The thick part of the strap doesn't go all the way around, the rest is extra elastic fabric that can be adjusted by pulling with the loose end on the left side of the buckle.

Rational

The elastic and plastic mesh are very good at tightly and securely wrapping around the torso while stretching enough to still be comfortable. The mesh under the fabric prevents the strap from rolling and folding on itself. The other function that it serves is to be more rigid which makes putting the the device much easier to put on than if it were made completely out of flimsy straps.

Figure 2: Torso strap buckle.

Shoulder Strap & Tightening

Concept

This ¾ inch soft cotton webbing strap connects to the torso strap in two places, one on the front and one on the back. It was looped around the torso strap and sewn to provide a secure and permanent connection (see Figure 3).

Furthermore, the strap can be adjusted with a backpack clip (see Figure 4) whose inner edge has been filed down.

Rational

The shoulder strap's main purpose is to allow the user to put the device on with only one hand. The shoulder strap is not heavy-load bearing, so a thinner strap was chosen. The ¾ inch soft cotton webbing is an ideal material for the shoulder strap because it is soft and comfortable for extended use, yet it is also light and strong for portability and durability.

The edges of this clip have been filed down in order to allow the strap to pass through with minimal force, yet it is still a secure connection. The need to file the edges was discovered in performance testing (see Appendix F - Performance Testing Results) when we were unable to pull the strap through easily. The backpack clip was chosen after user testing (see Appendix G - User Testing Results) because Aziz was unable to use our original design, two loops, with just his left hand. Thus, we implemented the backpack buckle and used it in the final prototype. The adjustability of both the torso strap and the shoulder strap will allow the user to wear the device over any type of clothing.

Figure 3: Shoulder strap sewn around torso strap.

Figure 4: Backpack buckle used to tighten shoulder strap.

Pole Clip

Concept

The shoulder strap of the design features a clip that will hold the shaft of the umbrella (see Figure 5). It is connected to the strap with a screw at the bottom of the clip and has velcro looped through its top hole and wrapped around the strap. The clip holds objects of diameters 7/16 - 9/16 inches and is 1¼ inches long. We glued a piece of soft rubber about .4 by .4 inches to the inside back of the clip.

Rational

The clip is secured only at the bottom to allow it to rotate and align with the umbrella shaft. Additionally, the velcro prevents the umbrella shaft from coming out of the clip when it is forced forward due to leaning forward, wind, etc.. Through performance testing (see Appendix F - Performance Testing Results) we found that the umbrella has room to move within the clip as the shaft is smaller than the diameter of the clip. To solve this problem, we added the rubber to create a more snug fit.

Figure 5: Clip with velcro secured to shoulder strap by a screw.

Tube

Concept

The tube is made of hard black plastic (from a vacuum attachment). The tube is 1.4 inches in diameter and 3 inches long, while the extra flat part used to secure it to the strap is 3 inches wide and ¾ inches tall (Figure 6).

Rational

The size of the tube allows just enough room for the the umbrella handle to snuggly fit in. There is no need for the tube to have a closed bottom because it is so snug that the handle does not move any further down. The tube prevents the bottom of the umbrella from moving side to side and prevents the umbrella from sliding downwards.

Elastic & Plastic Backing

Concept

Together, the tight plastic tube and plastic backing with elastic band (as seen in Figure 6) make up the main piece keeping the umbrella secured. This piece is attached to the torso strap on the right side of the users body.

The plastic backing is 6 inches tall, 1.5 inches wide, and 0.125 inches thick. A black medium sized hair elastic from the brand Scunci is pulled through a hole on the left side of the backing and a ⅜ inch projection hook of height 1⅝ inches is coming out through a drilled hole with its base taped to the back, both 0.5 inches from the top (see Figure 7).

The plastic backing is aligned with the bottom of the torso strap and secured to the torso strap using 4 rivets as shown below (Figure 8). Additionally, before riveting we slid a metal plate with four holes drilled in (aligned to the holes drilled through the torso strap) under the fabric where the backing would be riveted (Figure 9).

The cup is secured with two rivets at the bottom and a zip tie at the top part (Figure 6). The zip tie was threaded through two holes we drilled 1 inch apart, wrapped around the tube and tightened at the back (Figure 10).

Rational

We placed this piece on the same side as the shoulder strap because the shoulder strap makes that part of the torso strap stationary. Placing it there also allows the user to more easily use it with his left hand.

We attached the elastic and hook as high as possible to increase the stability of the umbrella, as we saw during performance testing (Appendix F - Performance Testing Results) that the higher up on the umbrella shaft the elastic was, the more secure the umbrella was.

We found through performance testing that a hair elastic has a good elasticity for our purposes as it is sufficiently tight to secure the umbrella, while loose enough that it can be easily stretch with one hand.

We chose this hook because that projection was the smallest that allowed the user to easily secure the elastic, making it as discreet and easy to use as possible.

The 4 rivets and aligning the plastic with the bottom of the torso strap instead of the top, allow the plastic backing to be securely fastened to the strap and not rotate forward with the weight of the umbrella (Appendix F - Performance Testing Results).

The metal plate was slid in to prevent the rivets from going through the soft material of the torso strap.

The ziptie secures the top half of the tube while the rivets secure the bottom and keep it from moving down.

Figure 6: Plastic tube and elastic band attached to plastic backing.

Figure 7: Elastic band and hook coming out of the plastic baking.

Figure 8: Four rivets securing the plastic backing.

Figure 9: Sliding the metal plate in to allow riveting.

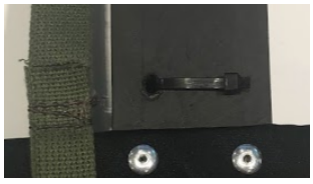


Figure 10: Zip tie threaded around plastic tube and through backing.

Umbrella

Concept

The umbrella has a button that automatically opens the umbrella when pressed and closes the canopy when pressed again. It weighs .99 lb, has a height of 25.2 inches when opened and is 41.2 inches in diameter. The umbrella is also windproof, with a double canopy design that allows air to escape. Lastly, the rim of the canopy is reflective

Rational

We chose our umbrella based on quickly securible, safety, and comfort (see Figure 11). The button allows our user to easily and quickly open and use the umbrella, then close it and put it away with only one arm. The weight also allows the user to easily wield it with one hand and puts less stress on the device when the umbrella is attached.

The umbrella's height makes it tall enough to comfortably wear without the canopy touching the user's head and tall enough that the user can easily see ahead from under it. The diameter easily protects the user's whole body from rain.

We chose a windproof umbrella because the user does not have enough balance to stand against strong winds with a large parachute-like device attached directly to his body. The double canopy improves the safety of our product and lets him use the device in reasonably windy conditions without struggle.

The reflective rim improves the user's safety at night and in low-visibility conditions, which tend to correlate with weather conditions where an umbrella is needed.

Figure 11: Umbrella chosen.

Future Development

User Testing

Our design was created to reflect the requirements we developed based on interviews, observations, and testing with one user. Both our clients and end user are affiliated with the Shirley Ryan AbilityLab, and we relied on their insights to guide our design. Additional observation and testing with our end user would be tremendously helpful in perfecting our design to accomodate all of our user's needs. Feedback from other users who are affected by hemiplegia would also be very useful to determine how the device fits on other people. Another reason to expand the pool of users for testing is that people with hemiplegia aren't all affected in the same way. Our user specifically was on the less severe side of the spectrum, so working people on the other side of the spectrum would be very informative.

Performance Testing

Overall more rigorous and extensive performance testing would be conducive to an optimal design. Due to time and weather constraints, the vast majority of our testing was done inside and focused on the basic operations of the device and walking around. To get a better sense of how our design works in inclement weather, we would need to take it outside in a variety of conditions. For example, testing the device on a day with heavy rain and/or a day with very strong winds would tell us a great deal about how it performs in the toughest conditions and what compensations we might have to make for those conditions.

Design Update - Clip

The clip that we have on the upper strap that secures the umbrella shaft could be improved. For example, we could design our own clip we would make smaller so that it could wrap fully around the shaft of the umbrella. One possible direction we could pursue would be to cut and bend different plastics or metals. We could also possibly 3D print this part.

Design Update - Torso Strap

The torso strap is very successful functionally; however, the aesthetics could be improved. For example, higher quality materials to wrap the elastic would improve both the appearance and comfort of the torso strap. Furthermore, utilizing experienced professionals to sew the strap together would ensure that stitching is less visible and the strap is more coherent overall. Additionally, with more research and testing we would hope to find a better material for the inside of the strap. Ideally this material would be lighter and slimmer but still rigid enough to support the weight of an umbrella.

Design Update - Tube

Our current prototype is designed for the specific umbrella that we purchased for it. The tube fits very tight to the umbrella handle. This tight fit adds a ton of stability to the prototype keeping the bottom from moving. To improve this feature in the future we would like to make the tube universal to all umbrellas. Making the tube larger in diameter and adding a screw to the side would allow the user to tighten the tube to different diameter handles. However, this wouldn't be

completely universal, as hook-handled umbrellas would still be incompatible. The solution to this would be to have half of the tube on a hinge so it can open and close around the straight part of the curved handle.

Conclusion

In summary, the Storm Strap will effectively meet the needs of our user Aziz and other people with hemiplegia that may use our device. The design is comprised of:

- a composition of materials that are flexible and weigh less than 5 lbs in order to be compressed and stored in a backpack
- a series of buckles and hooks that will provide stability of the device on the body and of the umbrella to the straps
- a set of two straps (shoulder and torso) that are comfortable on the body and that can be secured in under 1 minute

Our clients and user need a design that will be easy to understand and use. Having two straps provides an intuitive and simple method for putting on and taking off the device. The umbrella can be easily placed into the cup and secured into the clip. The flexible material of the straps can be compacted and store in a backpack, making the device portable.

Our user travels outdoors often and in order to ensure that he is protected as he travels our design will also provide mobility and coverage. The positioning of the cup and straps allows the umbrella to cover at least 80% of his body from the weather. Our straps do not impede his mobility and are comfortable to walk with for over 5 minutes.

The Storm Strap will allow individuals with hemiplegia to operate more independently in the future in any conditions they might experience.

References

Websites

Treating Hemiplegia and Hemiparesis After Stroke. (2018). Retrieved from https://www.saebo.com/treating-hemiplegia-hemiparesis-stroke/

Constraint-Induced Movement Therapy - upper extremity. (2016). Retrieved from https://www.strokengine.ca/en/intervention/constraint-induced-movement-therapy-upper-extremity/

What is hemiplegia? (2017). Retrieved from http://www.hemihelp.org.uk/hemiplegia/what_is_hemiplegia

Hemiplegia. (2019). Retrieved from https://www.spinalcord.com/hemiplegia

Hemiparesis. (2018). Retrieved from https://www.stroke.org/we-can-help/survivors/stroke-recovery/post-stroke-conditions/physical/hemiparesis/

Right-sided hemiparesis / Stroke CVA / Causes - Disorders. (2018). Retrieved from https://www.braininjury-explanation.com/causes-disorders/brain-injury-by-stroke/right-sided-hemiparesis

Interviews

Hoffman, Amanda. Bulleri, Maggie. Personal interview. 15 January 2019

Simpson, Scott. Personal interview. 19 February 2019

Huckabay, Heidi. Personal interview. 6 March 2019

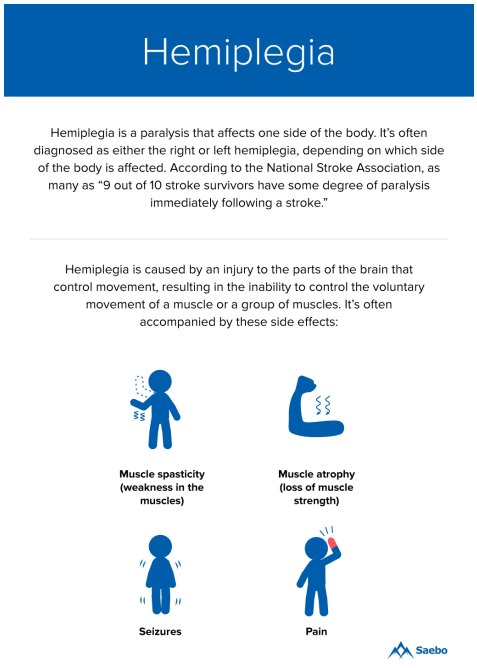
Appendix A: Background Research Summary

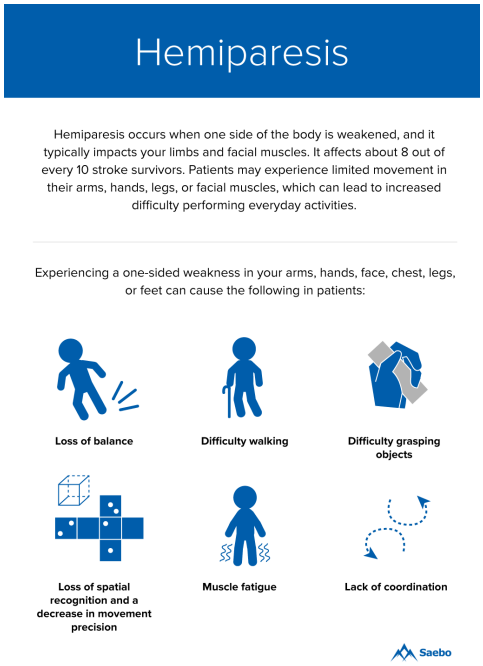
Cause / Typical Age Group Affected

Hemiplegia is a fairly common condition, affecting roughly 1/1000 children. About 80% of hemiplegia cases are congenital, and around 20% are acquired later in life. Of the congenital cases, most happen by chance during pregnancy. In the case that the condition is acquired, the most common cause is stroke (when a blood clot damages part of the brain), but it can also result from head injuries or infection.

Extent of Effects

The effects of hemiplegia range in severity. Effects can be extreme, such as loss of mobility of one side of the body (i.e. an arm or a hand), or relatively mild (i.e. slight weakness/lack of control of one side of the body). In either case, hemiplegia can affects an entire side of the body, and can be caused by injury to the brain. Hemiparesis is a condition often associated with hemiplegia, although there are some minute differences. For instance, hemiplegia is partial paralysis of one side of the body, while hemiparesis is just weakness in one side of the body. The images found below demonstrate some of the effects of these two conditions.





Effect on Quality of Life

Hemiplegia impairs patients' ability to complete everyday tasks. Due to their limited functionality, people with hemiplegia are sometimes dissatisfied with their life. Furthermore, hemiplegia patients have to be more aware of the positioning of their affected arm, and they must avoid neglecting it throughout their daily lives. Arm slings are occasionally used by people with

hemiplegia to mitigate some of the effects of hemiplegia, including uncontrollable movements and loss of balance.

Existing Physical Therapy Methods

There are many physical therapy techniques that are currently being employed to help people with hemiplegia regain control of their affected side. The list includes:

a) Range-of-Motion Exercises
    i) Range-of-motion exercises can help to prevent muscle stiffness and contractures by moving the weakened or paralyzed limb.
        1) Passive
        2) Active-assistive
        3) Active
b) Flexibility Training
    i) Flexibility training improves blood circulation and can help you regain the balance and coordination that can be lost after a stroke. When paired with strength training, flexibility training can lead to improved posture and ability.
    ii) Flexibility training is important if you have limited mobility on your non-dominant side. Often, the muscles on your dominant side of your body will be more flexible, so working to keep your dominant side as flexible as possible can help to increase mobility on your non-dominant side.
c) Electrical Stimulation
    i) Electrical stimulation has been used to strengthen muscles in the arm and improve range of motion in patients with hemiparesis. During electrical stimulation, small electrical pads are placed on the weakened muscles of the arm. A small electrical charge will trigger a shock to the muscles to make them contract while you work to move your arm.
d) Modified Constraint-Induced Therapy (mCIT)
    i) This therapy involves constraining movements of the less-affected arm, usually with a sling or mitt, while intensively inducing the use of the more-affected arm.
    ii) Research has shown that mCIT can be useful in increasing the movement in an arm affected by hemiplegia, but only in patients who are able to move their wrists or fingers voluntarily.
e) Motor Imagery (MI)
    i) Patients imagine themself using a certain part of their body. As they imagine these body parts moving, certain areas of their brain and muscles may be active as if they were actually doing the activity.

ii) This mental practice has been shown to improve arm movement in patients with hemiparesis, and research suggests that motor-imagery exercises may be useful in helping patients walk.

f) Assistive Devices

Assistive devices, such as braces, canes, walkers, and wheelchairs, can increase strength and movement in patients with weakened or paralyzed limbs.

Appendix B: Client Interview Summary

We had our interview with our clients, Amanda Hoffman and Maggie Bulleri, both occupational therapists at Shirley Ryan AbilityLab, on Tuesday January 15, 2018 at 6:30 pm in the Ford building. The purpose of the meeting was to understand more about the users' problems with a normal umbrella and how the users specifically are affected by hemiplegia, so that we can better understand their problem and how to solve it. This appendix summarizes what we learned about the design problem, requirements, and users.

Users

The main idea our group got out of the client interview was that instead of one specific user we will be working with a variety of users with a range of ages, preferences, body types, and even abilities. The client mentioned possibly making our device compatible for wheelchair users as an added bonus; however the focus should be on independent users with hemiplegia.
Discluding wheelchair users, all of our users have generally the same ability level and reason for needing this device.

- They are independent people who will be using our device for everyday activities like going to work or the store.
- They will not need much other assistance, such as a helper or other devices, aside from their cane.
- They are able to stand stationary without using the cane, which is important to note for the opening and closing of an umbrella.

Problems

Our client explained the main two problems the users face with umbrellas and other rain-protecting devices:

- The users cannot hold both their cane and an umbrella as they only have reliable use of one hand.
- Umbrella hats and similar smaller devices do not work as they do not keep the users' belongings dry as well.

Requirements

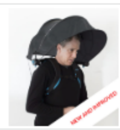
Our client also laid out the below specific requirements for the design. It must:

- Be discreet
    - The device should be as discreet as possible so the users can integrate it easily into their everyday lives.
- Protect belongings
    - The device must protect the users' belongings as well as their person.
        - Although not what the client and users originally imagined, a non-umbrella-like device (such as a poncho) may be possible as long as it sufficiently protects the users' personal items and keeps them dry.
- Keep hands and arms free

        - The client informed us that it would be best not to use either arm for support of the device because:
            - The affected arm is not very strong.
            - The users will likely want full mobility of their dominant arm.
            - The affected arm may be completely stuck at the users' sides or experience involuntary movements, which would make it hard to use for supporting the device.
- Ease of putting on
    - The users must be able to put on the device themselves with only one hand.
        - For this, the client suggested one-handed buckles or Velcro.

The interview provided important information on the problem and how to direct our future research. Learning that we should avoid use of either arm altogether changed our approach to the problem slightly. We were originally playing with the idea of a sling or wrist strap; however we will now direct our attention to researching other ways to support the umbrella, such as chest straps. We will also be looking into different existing ways of securing straps with one hand so that we can create a device that the users can take on and off by themselves with ease. From here we will also be widening our view of the project from one specific user to incorporate the range of people for whom we will be developing the product.

Appendix C: Competitive and Model Products

#	IMAGE OF PRODUCT	PRODUCT NAME	COMP OR MODEL	MANUFACTURER	STORE	PRICE	DIMENSIONS	MATERIALS	FEATURES	AREAS OF IMPROVEMENT
1		Weightlifting Velco Wrist Strap	Model	byKottos	Amazon	$14.00	22" x 3.5"	synthetic fiber, velcro	Provides wrist support for people lifting weights or other wrist-strenuous activities.	Coule be made to be easier to put on and tighten, it is kind of hard when you onky have one hand to put it on.
2		Umbrella	Model	Repel	Amazon	$22.00	11.5" collapsed 42" over the top when open	metal, fiber glass, water repellant canvas, plastic	Protects user from rain and other weather conditions with a protective dome.	Could be hands free. Also not 100% perfect for rain/other weather peotection
3		Umbrella Backpack	Comp	Nubrella	nubrella.com	$110.00	26" across top	metal, fiber glass, water repellant canvas, plastic	Uses backpack-style straps and suoports on the back to hold up a dome style hands-free shelter.	Says it can be used with a backpack, but seems like it would be difficult. Also looks very bulky and unappealing.
5		Umbrella Hat	Comp	Luwint	Amazon	$15.00	36" diameter	metal, fiber glass, water resistant canvas, plastic	Hat that straps under chin to support umbrella top.	Looks very unappealing.
6		Gun Holster	Model	Linxu	Amazon	$20.00	Medium-XLarge (33-50")	elastic, padding	Over the shoulder and around the body straps that have a holster for a gun or other object.	
		Stroller Canopy	Model	Veer	Backcountry.com	$49.00		Fabric	Canopy with magnets to attach to a stroller.	Too wide to for a body.
		Magnetic Clasp	Model	CleverDelights	Amazon	$10.44		Metal	Magnetic jewlery clasp	Limited ways to attach to a mockup.
		Collapsible Cup	Model	Parita	Amazon	$4.99		Silicone	Collapsible cup made for travel.	Very small and difficult to combine with other products.

Appendix D: Project Definition

Project Name: Weather protection device for individuals with hemiplegia
Client: Maggie and Amanda, Shirley Ryan AbilityLab - Chicago
Team Members: Joel, Aimee, Brooklyn, Nick
Date: February 25, 2019

Mission Statement: Our mission is to design and build a compact, portable, and easy to use device to protect Aziz, an individual with hemiplegia, from rain while allowing him to maintain a high level of independence and mobility.

Project Deliverables:

1. Final Prototype
2. Bound copy of Final Report
3. Poster for presentation at Design Expo

Constraints:

1. Budget = $100
2. All items due by March, 16 2019 (Design Expo date)
3. User must be able to use a cane and/or a wheelchair in addition to the device
4. User is limited to using only their left side for operating the device

Users and Stakeholders:

1. Aziz, the primary user, will use the apparatus in the rain in Chicago, and possibly to shade himself from sun as well
2. Aziz's family are the secondary users as they will be spending time with him in the rain
3. Maggie and Amanda are occupational therapists who work with Aziz at Shirley Ryan AbilityLab

User Profile

Aziz is a middle-aged man who has hemiplegia, a condition that affects his right side. His primary profession is a surgeon, but he can no longer operate with his condition. He currently uses an AFO to prevent his ankle from drooping, and he uses a cane occasionally to walk. His independence is very important, and enjoys walking without the cane. On long walks he may utilize a wheelchair. Aziz's favorite color is blue, and would like a device to protect his legs and valuables from rain and sun.

User Scenario - Initial

Aziz wakes up on a cold Chicago morning and looks outside to discover that it is raining. That day he was planning to attend a theatre performance. He gets out of bed, brushes his teeth with his left arm only and then goes to the kitchen to eat breakfast. He watches TV while he eats a bowl of cereal, then goes back to the bedroom to get dressed for the day. Aziz puts on a suit, tie, and dress shoes, the dress code for the theatre. He also puts on his AFO so that he doesn't

have to use the cane to walk to the theatre, which is only a few blocks away. As he glimpses back outside, he notices that it is still raining and grabs his raincoat as well. Fully capable of putting on his coat, Aziz dons the raincoat and walks outside. By the time he gets to the theatre, his suit pants and dress shoes are soaking wet from the rain that the raincoat did not stop. He looks down in disappointment, and wishes there were a better solution.

User Scenario - Advanced

Aziz wakes up on a wet Chicago morning and decides to walk to the grocery store nearby to get some regular items he needs as well as ingredients to prepare dinner. Before he leaves he makes sure to check the weather, while the sun is out right now the report confirms his suspicion that there is a chance it will rain later. Based off that he packs an umbrella and the device in the outer pocket of his backpack. He grabs his cane and leaves for the store. After purchasing all the groceries he needed he comes back out of the store to see that the sky has become gray and overcast. He gets right on his way home hoping to outrun the impending storm. However, a few minutes later his luck runs out and he starts to feel a couple of large rain droplets. This prompts him to stop, take his backpack off, and get the device and his umbrella out. He loops the device over his shoulder and secures the straps in a few seconds. Then he opens the umbrella and secures it in the device. He puts his backpack back on and continues on his way only stopping for under thirty seconds. He makes it back home almost completely dry despite the buckets of rain that poured out of the sky after those first warning droplets, and cooks an excellent dinner.

REQUIREMENTS	**SPECIFICATIONS**
Portability - The device should be lightweight and easy to carry	- The whole apparatus, including the umbrella, must be **< 5 lbs**
Compactness - The device should be compressible so that it doesn't take up a large amount of space - The device should be able to fit into a bag (e.g. backpack)	- The device must be able to be compressed to a length of at least **9 inches** to fit inside of a standard backpack
Stability - The cup on the device should be wide enough to fit the handle of an umbrella - The depth of the cup should reflect the length needed to keep the umbrella stable to the device	- The cup must have a diameter of at least **4 inches** - The cup must have a height of at least **3 inches**
Comfort - To feel comfortable in the device, it	- The device(excluding the umbrella) should not extend further than **6**

must be discreet so as not to draw attention to Aziz	**inches** from the body
Safety - The device should have straps that will not press into Aziz's skin as he moves	- The torso strap must have a width of at least **2 inches** - The length of the shoulder strap should be at least **2 inches.**
Usability - The device should be attached/detached quickly	- The device can be attached and secured in under **1 minute**
Coverage - The device covers the users body and bags, protecting them from weather	- The device should cover at least **80%** of Aziz"s body
Mobility - The user can still utilize a cane and/or wheelchair while using the device - The device's weight does not impede the user's mobility	- The device needs to be used while walking or in wheelchair for at least **5 minutes** - The device should weigh **< 5 lbs**

Appendix E: User Observation Summary

The observation took place at Shirley Ryan AbilityLab, 345 E. Superior St. on Wednesday, January 23. Our DTC class spoke to Abdul-Aziz, a patient with hemiplegia from Kuwait.

How the User is Affected

Aziz was a surgeon before his episode which gave him hemiplegia. He can no longer operate because of the condition and its effects on the use of his right hand. He still has some movement in the arm; however, it is limited and strenuous. For example, he can hold things with his right hand but he can't engage the fingers. He wears an ankle-foot orthosis, or AFO, on his right ankle to prevent his foot from drooping and dragging. He has a cane with him but can get by without using it. If he has to travel longer distances he usually will need a wheelchair.

- He has some use his right arm.
- He can hold things and use his right hand.
- He can stand and walk short distances without his cane.
- He can put on a backpack and accomplish similar tasks.
- He can open a door with a lot of struggle.
- Overall he is in much better condition than most other people affected by hemiplegia

User's Personal Insight

The main request that the user gave to us was that he wanted something that he could adjust and control on his left side, so he would have easier and quicker control. He wanted to be able to deploy and close the weather protection quickly and easily with his unaffected, left side. The other challenge is the fact that he needs to ride in a wheelchair for longer distances and weather protection for this could look alot different. Easily accessible possibilities could be to attach an umbrella to a backpack or the cane on the dominant side, or to have an attachment that folds and swivels out of the wheelchair.

Appendix F: Performance Testing Results

Test Procedures for Strap Mockup

1. Unbuckle and loosen all straps with one hand
2. Using the left hand, slide the shoulder loop over the right arm
    a. Note: Do not utilize the right arm in any way b/c it simulates the arm affected with hemiplegia
3. Tighten shoulder strap to desired height
4. Insert torso clip into buckle and pull to tighten
5. Open up umbrella
6. Place umbrella bottom into the cup, leaning the shaft of the umbrella against the plastic plate
7. Press umbrella shaft into broom clip on the shoulder strap
8. Tighten velcro over the shaft
9. Pull elastic loop over the umbrella shaft and secure the loop on the hook
10. Move around with umbrella, testing for any weaknesses in stability
11. Reverse steps 2-9 to take out umbrella, close it, and remove the device

Tests	**Observations**	**Areas for Improvement**
Unbuckle and loosen all straps with one hand	The elastic in the shoulder strap made it difficult to loosen, and the clips themselves kept getting stuck together.	Use webbing on shoulder strap, and a backpack buckle instead of two loops
Slide shoulder strap on and tighten it	If the loop was too small, it was difficult to slide over the immobilized arm	Make sure to express in the instructions that the shoulder strap is loosened before putting it on
Insert torso clip and tighten it	The torso clip moved around while we tried to insert it with one hand	Add a thumb support to stabilize the clip
Open umbrella and insert into cup	Worked well	
Insert umbrella into broom clip and tighten velcro	Easy to insert, velcro helps hold the umbrella in	Easier to use velcro strap
Use elastic to secure umbrella onto the plate	Worked well, elastic was too low was a bit far, plate was not sturdy enough	Move elastic as high as possible to increase stability, attach plate lower on the torso strap to prevent forward

		rotation
Move around with umbrella	Umbrella is stable, we were able to walk and move around, turn, and bend over.	Make sure that umbrella doesn't move around too much
Loosen and undo elastic restraining strap	Easy to tighten elastic but much harder to loosen, especially with one hand.	Could use regular strap material instead of elastic to make it easier to adjust.
Pull umbrella out of broom clip and velcro	Worked well	Is harder to do with one hand when the device isn't attached to the body
Take umbrella out of the cup and close it	Worked well	
Collapse and fold up the cup	Worked well	
Unbuckle torso strap	Worked well	

Appendix G: User Testing Results

Purpose

The purpose of user testing was to learn what our user, Aziz, likes and dislikes about the mockups we have designed and to determine which design worked the best. We were also interested in receiving feedback from him to improve each design and decide which device we will use for our final mockup.

Methodology

Team members Joel and Brooklyn conducted testing on February 14 at the Shirley Ryan Abilitylab. There were 10 minutes allotted to work with Aziz and present our mockups. Our first mockup was a body strap design. Figures 1-3 show this mockup and its key features. The use of this mockup was explained and demonstrated for Aziz. Then, he tested the mockup on himself and provided feedback.

Figure 1: Entire body strap mockup

Figure 2: Cup attached to the torso strap to hold the umbrella handle and a band to secure the shaft

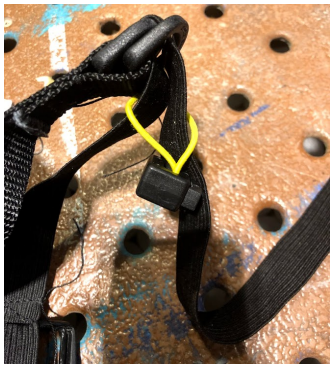


Figure 3: Elastic used to tighten the umbrella to the shoulder strap

The second design was the backpack and cup attachment shown in figures 4 and 5. This mockup was presented to Aziz and the application techniques were demonstrated on a backpack.

Figure 4: Backpack and cup mockup

Figure 5: Hook and loops used to secure the attachment to the backpack

Our final mockup combines the backpack attachment with a canopy. The process of attaching this design was shown to Aziz. Figures 6 and 7 show this mockup, in both the open and closed positions.

Figure 6: Canopy mockup

Figure 7: Canopy in the closed position

Results

Aziz provided feedback for each mockup, and it is summarized in the following table.

Mockup	**Observations and User Comments**
Body/torso strap	Observations: difficulty with tightening the shoulder strap and the velcro torso strap User Comments: liked the hooked elastic and would prefer to have a second one for better stability in the wind
Backpack Cup	User Comments: the cup was too far back to fully cover the entire body with the umbrella
Backpack Canopy	User Comments: thinks wearing the canopy would look funny and does not like this design

Analysis

Aziz preferred both designs that incorporated the umbrella: the body strap and the backpack + cup attachment.

a. Body Strap: The mechanisms for tightening both the body and umbrella on the device both were difficult for Aziz. The hook and elastic component were the most favorable in securing the umbrella.
b. Backpack + Cup: The cup on the device was in a position that Aziz was concerned about providing enough protection.

Conclusion

The results of the testing suggest that the ideal design would include simple, adjustable straps that also secure the umbrella effectively and provide good coverage to the user. The decision

between a body attachment or a backpack will be based on the following criteria: mobility, usability, and support.

Limitations

One limitation during our testing was the length of the umbrella used. The shaft was too short to accommodate Aziz's height when using the body strap mockup, so he was forced to tilt his head when underneath the umbrella. In future testing and for our final design, we must provide an umbrella with a longer shaft to fit Aziz comfortably.

Appendix H: Instructions for Construction

Table 1: Materials Used for Construction

Item	Specification	Qty.
Plastic Clip	- Black - For 3/16” - 5/16” tools	1
Cup	- Black - For 1 ¼” diameter	1
Webbing	- Green - Soft cotton - ¾” wide - 46” long	1
Light Duty Buckle	- For 2” max webbing width - Sew on - Squeeze release	1
Light Duty Buckle	- For ¾” webbing - Sew on - Feed through	1
Plastic Shim stock	- 2” by 6” sheet - 0.125” thick	1
Velcro Buckle	- Black velcro - 3.5”	1
Reusable Adhesive Back Hooks	- Small hook anchored by adhesive material on back - White - ⅝” deep	1
Windproof Compact Travel Umbrella	- Black - Auto close and open - 41.2” in diameter - 12.6” unexpanded height, 25.3” expanded	1

Rivets	- 0.181” diameter	6
Ultra Strength Basalt Fabric	- 1/16th in thickness - 1 in width - 26”	1
Nylon Cable Tie	- 4” long - Breaking strength 10lb	1

The following tools are required to construct this device:

- Sewing machine
- Rivet gun
- Exacto knife
- File
- Drill
- Scissors
- Sheet metal scorer/needle

Figure 1: Mesh-wrapped elastic strap sewn onto buckle

Figure 2: Wrap and sew waterproof fabric around strap.

Figure 3: Wrap and sew webbing around torso strap

Fabricating the Straps

1. Start out with at least 4’ of elastic fabric strap, take one end and loop it through the right side of the buckle and sew it to itself so that it is tight around the end of the buckle.
2. Next, take about 2.5’ of plastic mesh and fold it around the elastic strap starting at the end that was just attached to the buckle.
3. Cut it to remove any excess mesh. Make sure it is tight on the elastic and then add hot glue to bond the mesh to itself and the elastic.
4. After letting it dry and strengthen, cut the waterproof fabric to fit around the mesh snuggly.
5. Use the sewing machine to stitch the sides together tightly around the mesh.
6. Cut the elastic fabric to 4’ and loop the end through the left side of the buckle.
7. Now take the cotton webbing and wrap the end of it tightly around the the torso strap 4” from the end of the mesh wrapped section, and sew it to itself so that it is securely attached.
8. Measure 1.5’ of this from the top of the torso strap and cut it off at that point with scissors.

9. Sew the other end to the light duty buckle with a width of ¾" around the end opposite to the one with the adjustment tab.
10. Next, take the end of the rest of the webbing and wrap it around the torso strap 2" to the right of the right half of the buckle and sew it to itself so that it is securely attached.
11. Cut this off with 1' of webbing to spare, and loop it through the other side of the clip you just sewed. Loop it under and then over the bar in the middle of the clip so that the loose end is on top and can be easily reached to adjust the size.
12. Now, to attach the clip to the strap, take a sheet metal scorer or needle and poke a hole in the webbing 1" above the light duty buckle. Use the tool and scissors to make the hole bigger.
13. Next take the small screw, put it through the black plastic clip then the hole that was just made in the webbing and screw it into the backing. Make sure the clip is securely attached to the webbing but not to tight as to keep it from rotating.
14. Lastly, take the small loop in the velcro strap put it through the other hole in the plastic clip and fasten it to itself. Leave the bigger velcro loop loose to wrap around the umbrella.

Building the Tube & Plate

1. Take the tube attachment of 1¼" diameter and cut away the top part of where it gets flat. Leave the side that is flat with the tube section but cut away all of the material on top up until it turns into a cylinder.
2. Take one plate of plastic shim stock, break it along the two fault lines and take one of the pieces that is the same height and roughly ⅓ the width of the original piece.
3. Use an exacto knife to trim the rough edges left from the break lines. So that it is flat all along the thin side.
4. Then take a file and file down the corners so that they are rounded and not sharp.
5. Cut a 2" by 2" square of sheet metal that is less than 1/16" in width.
6. Use a file to round the corners and remove any other sharp edges or snags on the metal.
7. Now take a 3/32" drill bit and drill 4 holes in a 1" square through the long plastic plate and the square metal plate that were just created. Start the holes at least ¼" up from the bottom. Make sure the plates are held in the same place together while this is done so that the holes line up.

8. Now secure the metal plate, plastic plate and flat side of tube all together. Using the same drill bit, drill two holes through all of them about 1” apart and mid-way up between the previous holes.
9. Using the same bit drill another set of holes 1” apart just in the plastic plate this time. Drill them centered and about ¾ of the way up the plate.
10. Keep the same bit once more and drill a hole in the top of the plastic at least ⅛” from the right edge and ¼” from the top edge.
11. Now take a 3/16” drill bit and drill a hole at least ¼” from the top left corner of the plastic.
12. Take a command hook and remove the adhesive in the back.
13. Now try fitting the hook through the back of the larger hole in the top left corner of the plate, so that the hook points towards the left. Then use an exacto knife to trim the hook so that it sits flat against the back of the plate and doesn’t stick out behind it.
14. Use duct tape to secure the hook in this place.
15. Take a hair band and stick it part of the way through the back of the hole on the top right side. Then pull the other end of the band around and through the loop that was just made by sticking it through. Then pull this tight to secure the band.

Attaching the Plate to the Torso Strap

1. Start by using the sheet metal scorer to poke holes in the torso strap in the same places as the 6 hole made through both the metal and plastic plate. Use one of these as a stencil to ensure accuracy.
2. Take the metal plate and slide it into the back of the torso strap under the waterproof fabric. Line it up with the holes that were just poked.
3. Now line the plastic plate up in the front of the strap with these holes. Then take 4 of the 0.181” diameter rivets and push them through the back to the front in the 4 holes that the plastic and metal share. Use the rivet gun to tighten and permanently fasten them there.
4. Now do the same but with the tube and the 2 holes that are drilled into it.
5. Finally, take a zip tie and run it through the back of one of the holes ¾ the way up the plastic, around the circular part of the tube, and back into itself. Cut the excess off.

Appendix I: Instructions for Use

Putting on the Device

1. Using your left hand, pull the shoulder loop through your right arm and onto your right shoulder.
2. Bring the left half of the buckle around your body and into the right half of the buckle.
3. Pull the loose part of the shoulder strap to tighten it and bring the torso strap to a comfortable height.
4. Pull the elastic attached to the buckle away from it to secure the device to your body.

Figure 1: Bring buckle around and insert

Figure 2: Adjust shoulder strap

Figure 3: Tighten torso strap

Securing the Umbrella

1. Open up the umbrella.
2. Slide the umbrella handle down into the tube making sure the wrist strap doesn't get caught as well.
3. Pull the hair band over the top of the umbrella handle and onto the hook.
4. Push the rod of the umbrella into the clip on the shoulder strap.
5. Take the attached velcro strap, wrap it around the rod, behind the stap, and secure it on itself.

Figure 4: Place handle into tube

Figure 5: Hook elastic band around handle

Figure 6: Place umbrella rod into clip and wrap the velcro around it.

Removing Device

1. Pull the velcro strap off of itself and take the umbrella rod out of the clip.
2. Pull the hair band back over the hook and top of the handle.
3. Pull umbrella out of the tube and close it.
4. Loosen the shoulder and torso straps.
5. Take off of right shoulder and out of the right arm.

Appendix J: Bill of Materials

Item	Description	Qty.	Vendor	Pt. Num.	Unit Cost	Total Cost
Plastic Clip	- Black - For 3/16” - 5/16” tools	1	McMaster-Carr	1171A68	0.93	0.93
Cup	- Black - For 1 ¼” diameter	1	McMaster-Carr	7494T69	13.98	13.98
Webbing	- Green - Soft cotton - ¾” wide - 46” long	1	McMaster-Carr	3643T91	2.49	2.49
Light Duty Buckle	- For 2” max webbing width - Sew on - Squeeze release	1	McMaster-Carr	29705T17	2.58	2.58
Light Duty Buckle	- For ¾” webbing - Sew on - Feed through	1	McMaster-Carr	29506T11	.26	.26
Plastic Shim stock	- 2” by 6” sheet - 0.125” thick	1	McMaster-Carr	95015K6	0.29	.29
Velcro Buckle	- Black velcro - 3.5”	1	McMaster-Carr	3955T88	1.40	1.40
Reusable Adhesive Back Hooks	- Small hook anchored by adhesive material on back - White - ⅝” deep	1	McMaster-Carr	1024A21	1.62	1.62
Windproof	- Black	1	Banana	B07MKG51FM	18.59	18.59

Compact Travel Umbrella	- Auto close and open - 41.2” in diameter - 12.6” unexpanded height, 25.3” expanded		Umbrella - via Amazon			
Rivets	- 0.181” diameter	6	McMaster-Carr	97537A192	0.32	1.92
Ultra Strength Basalt Fabric	- 1/16th in thickness - 1 in width - 26”	1	McMaster-Carr	1727T12	1.11	2.41
Nylon Cable Tie	- 4” long - Breaking strength 10lb	1	McMaster-Carr	7130K52	.029	.029
TOTAL						46.50