flexibrella

Prepared for:
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Eden Supportive Living Center
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People who use mobility devices, such as wheelchairs and scooters, have difficulty protecting themselves from inclement weather.

Figure 1:Flexibrella

Purpose and Scope

Our team aimed to create a device that would make going out in inclement weather easier and more comfortable for people who use mobility devices. The design had to be easy to use, adjustable, and secure. The primary users are people who utilize mobility devices at Eden Supportive Living who desire to leave the indoors without being hindered by weather conditions.

Methodology

With the information gathered from our client interviews and user observations, we were able to design several mockups for user and performance testing. Feedback on the mockups and initial prototype was then used to finalize our design. The final prototype of the Flexibrella (Figure 1) was chosen due to its secure attachment, wide range of adjustment, and ease of use.

Figure 2: Flexibrella in use

Design

The Flexibrella is a simple and intuitive device that keeps people who use mobility devices protected during any weather by attaching to different wheelchairs and adjusting to different angles and heights (Figure 2).

Its features include:

Part	**Description**
Cup	Plastic cylinder where umbrella is held.
U-Channel	Aluminum clamp that attaches to the armrest of the mobility device.
Gooseneck	Stem that connects the cup to the U-channel. The gooseneck is adjustable to accommodate users of different heights and adjusts to different angles they may want to position the umbrella.
Knobs	Thumbscrews that tighten to secure both the umbrella to the cup and the U-Channel to the wheelchair.

Table 1: Parts and descriptions

Introduction

Problem

Rain is a particularly difficult issue to deal with when using mobility devices such as wheelchairs outside (Figures 3 & 4). People using manual wheelchairs have limited use of their hands and often cannot comfortably use an umbrella in the rain (Figure 3). Additionally, people using electronic wheelchairs must protect their handheld controller from getting soaked while positioning their umbrellas (Figure 4).

Figure 3: Manual wheelchair
< http://jitmedical.com/wp-content/uploads/2013/04/manual-wheelchairs.jpg>

Figure 4: Electric wheelchair
< http://wheelchairassistance.com/power-wheelchair/29.jpg>

The difficulty of staying dry in the rain while using a wheelchair discourages users from venturing outside during cloudy days because of the complications that rain may bring. This can limit the mobility and independence of people using wheelchairs.

Our team worked with Eden Supportive Living (ESL) to design a product that could protect people using wheelchairs from the rain and thus promote their mobility.

Major Requirements

In designing a device that could help shield wheelchair users from the rain, users and clients advised us to ensure the device could easily attach to wheelchairs. The device was also designed to be easily adjustable as users may have different preferences on where to position their umbrella depending on the direction of the rain, the height of the user, and other individual preferences. Lastly, the device was designed to be stowable so the user doesn't have to worry about the umbrella once they enter a building.

Please refer to *Appendix A: Project Definition* for more information.

Existing Solutions

When researching existing solutions, we found devices that attached to strollers and wheelchairs similar to the Pram Stroller Umbrella Holder Connector featured below (Figure 6). While the device was functional, the design appeared to be difficult to operate.

Figure 5: Pram stroller umbrella holder connector
<http://www.aliexpress.com/promotion/promotion_toddler-umbrella-stroller-promotion.html>

Other alternative solutions were explored such as attaching an umbrella to a sling which the user could wear or a backpack such as the Nubrella. However, these devices attracted unnecessary attention which users found distracting (see *Appendix B: Background Research*).

When asked what they currently use for rain protection, the residents at Eden Supportive Living often replied that they used ponchos. However, they found the ponchos inconvenient because they are not easy to put on or remove once indoors.

Design: Flexibrella

The Flexibrella (Figure 6 & 7) is a device that attaches to a wheelchair and holds an umbrella. It consists of three main parts: the attachment to the wheelchair, the adjustability mechanism, and the umbrella holder.

How it works:

- U-Channel: The attachment part of the Flexibrella consists of a clamp-like attachment device. It includes a screw for users to tighten when attaching it to the wheelchair, which makes it adaptable to different wheelchairs and attachment points.

- Gooseneck: A gooseneck is included between the attachments to the wheelchair and umbrella. It allows the user to adjust the umbrella based on personal preferences. It also affords portability to the device, as it can be stored easily.
- Cup: At the end of the gooseneck is a cylinder with a knob screwed into it. The umbrella can be placed in this holder, and then secured by twisting the knob.

Figure 6: Flexibrella in context

Figure 7: Flexibrella

Report Overview

The rest of the report contains the following sections:

- Users and Requirements: explains users' circumstances and major issues we considered
- Design Concept: describes design and potential usage
- Rationale: provides evidence that impacted the final design choices
- Limitations and Next Steps: includes recommendations for further development of design
- Conclusion: summary of design

Users and Requirements

In designing our product we set up parameters for what features our device should have and how it should function.

Users and Stakeholders

Users and stakeholders were found through the client interview, user observation, and other discussions (see *Appendix C: Client Interview Summary* and *Appendix D:User Observation Summary).*

Primary Users:

- Resident of Eden Supportive Living (ESL) who use mobility devices
- People who use mobility devices, including wheelchairs, scooters, and walkers

Secondary Users:

- Health care professionals and family members
- People who may want to use an umbrella without occupying their hands (e.g. Bikers, People who use strollers)

Stakeholders:

- David Johnson, employee at ESL
- Eden Supportive Living
- DTC and Segal Design Institute

Requirements

The major requirements of our project were obtained from the user observation and client interview (see *Appendix A: Project Definition*).

Requirements	**Specifications**
Attaches to walker/wheelchair easily	• Device can be attached in less than 20 seconds • Device can be attached without strain from the users • Users can attach device without assistance
Not distracting	• User has full range of vision when using the device • User does not receive excessive attention while using the device
Device can be stored easily	• When the user is done using the device, device can be stowed in a size no larger than 10.5”x 5”x 4.5”
Able to accommodate majority of heights	• Able to keep users with a seated height of up to 5.5’ dry during bad rain
Angle adjustment	• Can adjust to about 180 degrees in any direction

Intuitive	• User does not require any detailed instructions to operate
Lightweight	• The device weighs 1 pound and 7 ounces.

Table 2: Requirements and specifications

Fulfilling these requirements is a major criteria for success in this project.

Design Concept and Rationale

What is it?

The Flexibrella is an umbrella holder designed to protect people who use wheelchairs from the rain and sun so they can keep doing their daily activities in any weather (Figure 8). The design includes a U-channel with a screw to attach the Flexibrella to the wheelchair, a gooseneck to adjust angle and height, and a cup with screws where the umbrella is held.

For measurements of the device and its parts (see *Appendix G: Dimensioned Sketches*).

For instructions for constructing this device as well as the materials used (see *Appendix I: Instructions for Construction* and *Appendix H: Bill of Materials).*

Figure 8: Flexibrella on a wheelchair

How does it work?

The user attaches the clamp to the armrest of the wheelchair by simply placing the U-channel in the desired location, and screwing it into place (Figure 9). Then the user opens the umbrella and places it inside the cup, where he or she then turns the screws to secure the umbrella (see *Appendix J: Instructions for Use*). Now the user is ready to enjoy the outdoors rain or shine.

Figure 9: Using the Flexibrella

U-Channel

Design Concept

The U-channel is an aluminum clamp-like attachment with an outer width of 3 inches (Figure 10). Its purpose is to secure the Flexibrella to the user's wheelchair. It includes a thumb screw with a knob, so it can be adjusted to fit on multiple armrests or even wheelchair handles. The edges are rounded and the inside of the device is lined with blue plastic to prevent damage to the wheelchair.

Figure 10: U-channel

Design Rationale

The Flexibrella needed to be easily removed from the wheelchair and fit several widths of armrests (see *Appendix C: Client Interview Summary* and *Appendix D: User Observation Summary*). After testing alligator clamps and realizing that it took most users two hands to open them (see *Appendix E: User Testing*) and would slip off of handles (see *Appendix F: Performance Testing*), a U-channel with a screw was chosen as a simple, stable, non-permanent, adjustable attaching device.

We decided to attach the U-channel to the armrest because users said that was where it was easiest to set up (see *Appendix E: User Testing*). Also, most of the wheelchairs used in Eden

Supportive Living are powered so they do not have back handles where the Flexibrella could otherwise be fastened (see *Appendix C: Client Interview Summary*). Because the U-channel is designed to go on armrests, the shape is rectangular and has an inner width of 2 ⅛ inches which accommodates most armrests.

The U-channel is lined with a blue plastic piece because the aluminum could damage the armrest of the wheelchair (see *Appendix F: Performance Testing).*

Gooseneck

Design Concept

The gooseneck is the adjusting mechanism on the Flexibrella (Figure 11). It is a black, 15 inch long, flexible arm and is attached to both the U-channel and the umbrella holder cup.

Figure 11: Gooseneck

Design Rationale

The gooseneck was chosen as the adjusting device because users consistently rated it as the best option due to its ease of use (see *Appendix E: User Testing*). In fact, during performance testing, the adjustment process for the gooseneck was almost instantaneous since it only required the user to bend it to its desired location (see *Appendix F: Performance Testing*). This fixes one of the major issues with products on the market, which is that they require time or hand dexterity to adjust the umbrella (see *Appendix B: Background Research*).

Moreover, during performance testing, the wheelchair and user were about 50% drier with the gooseneck model than with the "crutch tube" device (see *Appendix F: Performance Testing*). This is probably due to the fact that most angles can be reached with the gooseneck while the crutch tube can only move up and down. Because ease of use is an important factor in the design, the gooseneck on the Flexibrella is easily manipulated.

The gooseneck is long enough to cover most users and has a 1.1 pound weight capacity which is sufficient to carry a lightweight automatic umbrella and a plastic cup (see *Appendix B: Backgroud Research*).

Cup

Design Concept

The cup, where the umbrella is held, is a polyethylene tube with a plexiglass bottom (Figure 12). It has one thumb screw to stabilize the umbrella inside it, and the gooseneck is attached to the base of the cup.

Figure 12: Cup holder

Design Rationale

The cup is made out of polyethylene because it is a lightweight and inexpensive plastic, which are two of the criteria that the users and client gave us (see *Appendix C: Client Interview Summary* and *Appendix D: User Observation Summary*). The bottom of the cup is made out of plexiglass, which is also lightweight, and allows users to see where the umbrella is in relation to the cup, facilitating the adjustment of the umbrella.

The cup has an outer diameter of 2.25 inches, an inner diameter of 1.75 inches, and a length of 3.25 inches, which is sufficient to hold most automatic lightweight umbrellas (see *Appendix B: Secondary Research*). The cup with a knob is simple and intuitive, as observed when users immediately knew to put the umbrella into the cup (see *Appendix E: User Testing*).

Knobs

Design Concept

The knobs are the method to stabilize both the U-channel on the armrest and the umbrella in the cup (Figure 13). There is one knob on the U-channel and one on the cup. They have a 1.5 inch diameter, wheel-shaped head, and a 1.5 inch long screw.

Figure 13: Knobs

Design Rationale

The knobs are necessary for adaptability, one of the main criteria given to us by the client and users (see *Appendix C: Client Interview Summary* and *Appendix D: User Observation Summary*). The knob on the U-channel ensures that the Flexibrella can be used on a variety of wheelchairs, mainly those with armrests that are at most 3 inches.

The knob has a round and relatively large diameter because users responded well to the knob mockup. They thought the size and shape led them to correctly assume how to secure the

umbrella, and do so comfortably. However, the knob seemed to get in the way after actually sitting in the wheelchair, which is why the diameter was decreased from the mockup (see *Appendix E: User Testing*). Moreover, the knob is slightly larger than the size of a water bottle cap, which is something that users can easily handle (see *Appendix C: Client interview Summary*).

The length of the screw, 1.5 inches, is enough to tightly hold umbrellas (see *Appendix B: Background Research*). Foam was added to the ends of the screws because the screws were creating dents on the umbrella when tightened (see *Appendix F: Performance Testing*).

Limitations and Next Steps

The Flexibrella meets all the specifications of this project. However, this section displays changes to the Flexibrella that can be considered to improve the design in the future.

Ease of Use

The user must open the umbrella before placing it inside the cup and tightening it. Performance testing showed that this may be an uncomfortable process for users (see *Appendix F:Performance Testing*). An opening in the cup where users can press the open/close button or a softer material that allows the button to be pressed could be considered.

Stability

The stability of the Flexibrella could be improved. Despite the handle being tightly held inside the cup, the stick of the umbrella still wobbles (see *Appendix F: Performance Testing*). This could pose a problem in extreme wind. Further performance testing with different stabilizers could be performed to ensure that the Flexibrella is usable even in extreme wind.

Gooseneck

The gooseneck can be difficult to adjust because it requires force (see *Appendix F: Performance testing*). More materials research and performance testing could be done to find a gooseneck that is able to hold the weight of the umbrella and cup and still be flexible enough that it is easy to adjust with less strength.

Range of Testing

Testing was not done with Eden Supportive Living residents (see *Appendix E: User Testing*), so further testing should be performed with them. Moreover, user testing will need to be conducted with different people who have different levels of hand dexterity and strength to see how well they can adjust and tighten the Flexibrella.

Testing with various mobile devices such as scooters, wheelchairs, and walkers of different types and sizes could be done to analyze the ability of the Flexibrella's attachment. More trials will need to be conducted in the rain, wind, and sunshine, to test the umbrella's adaptability and effectiveness in different weather conditions.

Conclusion

In summary, the Flexibrella is meant to help people who utilize mobility devices protected from inclement weather.

Our design includes the following parts:

- U-Channel: A 3 inch wide, adjustable, light aluminum attachment for the wheelchair armrest.
- Gooseneck: A flexible, 15 inch long arm used to position the umbrella to different heights.
- Cup: A white polyethylene tube with a plexiglass bottom used to hold the umbrella
- Knobs: Thumb screws used to secure the umbrella to the cup and the U-channel to the armrest.

The design focuses on ease of use and adjustability. Its simple and intuitive components make it simple for the user to understand and use the Flexibrella. The U-channel makes the device adaptable to different wheelchair armrests. The gooseneck makes the design not only functional, but practical for people of different heights because it is able to efficiently change angles to protect them from the weather. The cup is also an important part of the design because it holds the umbrella tightly and safely.

The Flexibrella is designed to assist the people of Eden Supportive Living and other mobility device users continue with their daily life even during harsh weather.

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Appendix A: Project Definition

Appendix A gives an overview of the team's purpose, goals, and project guidelines.

Project Name: Flexibrella
Client: David Johnson, Eden Supportive Living
Team members: Amanda Mirande, Evan Tang, Whitney Tesi, Nancy Yao
Date: December 5, 2015

Mission Statement

To design a device that shelters people who use walkers or wheelchairs from the rain, snow, and wind, and will keep them dry when their hands are occupied.

Project Deliverables

- A prototype of the design.
- A formal report detailing the design.
- A poster and a presentation that display the design.

Constraints

- Time: Needs to be done by December 5th.
- Money: Maximum budget of $100.

Users and Stakeholders

- Eden Supportive Living (the assisted living facility we are working with)
- Residents of Eden Supportive Living who use mobility devices such as wheelchairs, walkers, and scooters
- Other people who use mobility devices

Requirements	**Specifications**
Attaches to walker/wheelchair easily	• Device can be attached in less than 20 seconds • Device can be attached without strain from the users • Users can attach device without assistance
Not distracting	• User has full range of vision when using the device • User does not receive excessive attention while using the device
Device can be stored easily	• When the user is done using the device, device can be stowed in a size no larger than 10.5"x 5"x 4.5"
Able to accommodate majority of heights	• Able to keep users with a seated height of up to 5.5' dry during the rain

Angle adjustment	• Can adjust 180 degrees in any direction
Intuitive	• User does not require any detailed instructions to operate
Lightweight	• Weighs 1 pound with 7 ounces.

Table 2: Requirements and Specifications

Appendix B: Background Research

Appendix B details the research all teams in our class conducted. After receiving the problem from David Johnson from Eden Supportive Living, an extensive list of questions arose that was divided into the following categories: umbrellas, umbrella alternatives, and wheelchairs/walkers from various online sources.

Umbrellas

Umbrellas have been used since ancient times, yet they have changed very little over the years. A few improvements and innovations include the automatic open and close button, a taller, bubble shaped canopy, and pressure vents in the canopy to better protect from wind. Most umbrella canopies have eight panels and are made of nylon taffeta ("Umbrellas"). The best reviewed umbrellas are lightweight (about 1lb) and have a diameter that ranges from 40 to 68 inches. These widths would mostly cover the standard width of wheelchairs and walkers (24 to 27 inches) (Dimensions of Adult-Sized Wheelchairs). Automatic umbrella handles are usually less than 2 inches wide and less than 3 inches high (Best Sellers in Umbrellas).

Alternatives

There are several different alternatives to holding an umbrella but they are not very durable, usable, or affordable. For example, the Nubrella (Figure 14) has been reviewed to be uncomfortable, attract unwanted attention and have technical issues such as screws falling off (Nubrella New Aerodynamic, Clear, One Size).

Figure 14: Nubrella
<https://www.fundable.com/nubrella>

There are also some options where the person is required to carry a sort of backpack or sling (Figure 15) to which the umbrella attaches. These usually receive negative reviews because they are unstable and often times uncomfortable for the user (Baby Blooms Hands Free Sling Umbrella).

Figure 15: Sling umbrella
<http://www.hammacher.com/product/81203>

There are also devices that attach to walkers or wheelchairs already such as the Xlentcare extension, which is an accessory that holds umbrellas for walkers. It has received decent reviews but it is close to $200 (Walker Accessories). Other options include the Pram Stroller Umbrella Holder Connector (Figure 16). This device seemed difficult to attach and adjust according to their advertising video.

Figure 16: Pram stroller umbrella holder connector
<http://www.aliexpress.com/promotion/promotion_toddler-umbrella-stroller-promotion.html>

Users

There are about 2.2 million people in the United States who depend on a wheelchair for daily activities. Moreover, there are 6.5 million people in the U.S who depend on canes, walkers, or crutches to assist with moving (“How many people use assistive devices?”). A person may need one of these devices for several reasons, including spinal cord (the most common one), cancer, arthritis, and multiple sclerosis (“Wheelchair Use”). Some of the people who use wheelchairs or walkers do not need to use them all the time, but only when their muscles are fatigued or in pain. A few common courtesy rules to use towards the users is to never push or touch their wheelchair without explicit permission, crouch down to get to eye level when speaking to them, avoid walking behind them, and do not make jokes about the wheelchair (“Lesser-known things about being a wheelchair user”).

Walkers and wheelchairs

There are several different types of wheelchairs designed to fit different needs. For example there is the bariatric wheelchair (Figure 17) that has a large weight capacity (550 lbs.), the active wheelchair that is used in sports, and the motorized wheelchair which makes controlling movement easier (“How to Choose the Right Wheelchair”) .

Figure 17: Active wheelchair
<http://www.karmanhealthcare.com/blog/2013/07/22/disabled-how-to-choose-a-wheelchair/>

Important dimensions for wheelchairs are seat width, seat depth, seat to floor height, and back height. Seat widths are usually 16, 18, or 20 inches. An average wheelchair height is about 3 feet (Figure 18). There are two types of leg rests: swing away which allows for easy access to the seat of the chair or elevating which allows raising legs to prevent swelling. There are also two types of armrests: desk length, used to easily reach tables, and full length for increased support (“How to Choose the Right Wheelchair”).

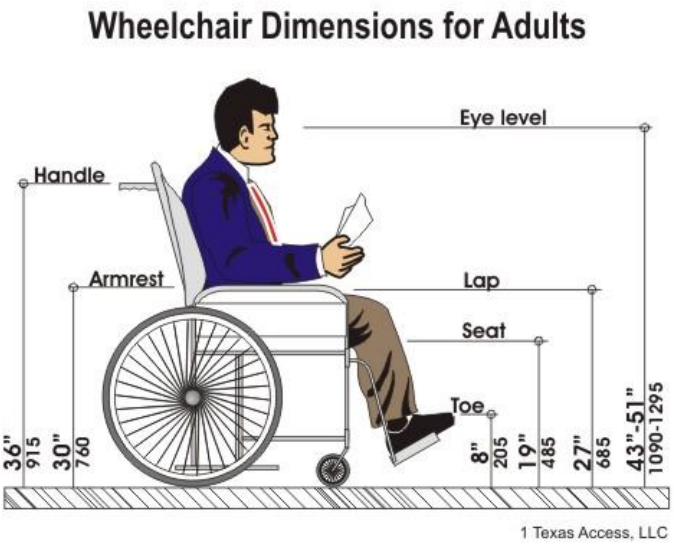

Figure 18: Wheelchair dimensions
<http://www.karmanhealthcare.com/how-wide-does-a-doorway-need-to-be-for-a-wheelchair/>

There are three main types of walkers: no wheels, two wheels, and four wheels. Walkers without wheels are used by people whose major concern is stability, while walkers with four wheels are used by people who do not use it for stability but for support. Most walkers have grips to avoid slipping and for added comfort. People with arthritis or nerve problems tend to use larger grips. There are several accessories for walkers such as pouches, trays, seats, etc. (Figure 19) ("Healthy aging: Tips for choosing and using walkers").

Figure 19: Two-wheel walker with accessories.
<http://www.mayoclinic.org/healthy-lifestyle/healthy-aging/multimedia/walker/sls-20076469?s=8>

Walkers are usually less than 40 inches high and about 30 inches wide but there are several variances depending on the preferences of the user (Walker Sizing Chart).

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Appendix C: Client Interview Summary

Appendix C summarizes insights gained from our interview with the client, David Johnson from Eden Supportive Living.

We had our initial interview with Mr. David Johnson from Eden Supportive living on September 29th, 2015 in the Ford building at 5:30. The purpose of this meeting was to help us design a user-centered product to keep people using walkers and/or wheelchairs dry outside when it is raining. The questions mostly concern the problem itself, the possible users, and any preferences/recommendations.

Problem

- People currently solve the issue by wearing ponchos or not dealing with the rain at all by staying in.
- The residents of Eden Supportive Living will usually travel along a 1-mile radius.
- The residents have several group outings. For example, they were going to go to a botanic garden.
- Mr. David Johnson said that the residents “get around”. They like to go to Jewel-Osco.

Users

- The residents have a wider age range than expected, 24-65 years old.
- About 50% of the residents use a walker or wheelchair. Of this population, the use of walkers or the use of wheelchairs is equally divided.
- Many switch from a walker to a wheelchair depending on their needs for the day.
- They have a fixed income, with very little extra money.
- Most of the chairs used are electrically.
- Residents consider safety against theft very important.
- Residents do not have trouble asking for help if needed.
- Residents are able to leave the establishment alone if desired.
- Physical abilities have a wide range across the residence, yet Johnson believes that most can open a water bottle.

Note: See pictures of common wheelchairs and walkers provided by Mr. Johnson.

Requirements/Preferences

- Our client identified certain desirable characteristics:
    - ❖ compact
    - ❖ light
    - ❖ simple to manage (no great need for fine motor skills)
    - ❖ compatible with multiple devices/sizes
    - ❖ not permanent (detachable)
    - ❖ big enough to cover joystick

Summary/Conclusions

The interview helped define the problem better, understand our users, and define certain desirable traits. More will be determined in our observation/interview session with the residents.

Appendix D: User Observation Summary

On Sunday, October 4th, 2015, Evan Tang, Whitney Tesi, and Nancy Yao observed and spoke to a wheelchair user at Eden Supportive Living. The objective was to understand how the user interacts with his wheelchair, difficulties he and others face, the structure of the wheelchair itself, and the user's preferences for a device attaching to his wheelchair that would allow him to stay dry in the rain. The session lasted about an hour. This appendix will clarify how the observation was conducted, describe the wheelchair, and outline the results and conclusions that were reached.

Methodology

The observation took place in the Eden Living Center activities room, where users can lounge, meet with their children/grandchildren or do activities such as art and crafts. The user was interviewed about his daily routines but most importantly his routines when it is raining outside. He was asked about his preferences regarding whether or not to have an umbrella, where it should be placed, and the design. Since he was sitting in a regular wheelchair, he then went on to show us the characteristics of his powered wheelchair upstairs. There, we took pictures of both of the wheelchairs and recorded their measurements.

Information about user's interaction with wheelchair

The user is a man in his 50s who is a wheelchair user. He typically uses his power wheelchair when leaving the facility and typically goes to stores within a one mile radius. The user states that he frequently travels to the community around him. He views his power wheelchair as a source of independence and freedom, even joking that whenever his wheelchair runs out of battery he is stuck in "jail."

Regarding his wheelchair, we noted that when he goes to the store he uses both the steel plate near his feet and his armrest to hold grocery bags. Additionally he was easily able to transfer himself between both his manual and electronic wheelchair. The powered wheelchair is controlled by a joystick. When the user did not engage the joystick, the wheelchair remained firmly in place.

Information about wheelchair

Both a normal wheelchair and a power wheelchair were observed, and it was discovered that the majority of residents at Eden Supportive Living use power chairs. A constraint that we will face on our project is that this design must be compatible with multiple types of wheelchairs.
The user additionally specified a preference that the device attach at the joint between the joystick and armrest on his power chair. Additionally he preferred that the device be attached to the front of his wheelchair rather behind him as it would be easier to attach and would not negatively affect his visibility.

Measurements**:**

- Arm Rest
  - 3.5 inches tall
  - 10.25 inch circumference
- Connecting joint between joystick and arm rest
  - 2.0 inches wide

Pictures

Figure 20: Side View of the Joystick Controller

Figure 21: Angled View of the Electric Wheelchair

Appendix E: User Testing

This appendix summarizes five user testing sessions conducted at Northwestern University with students and faculty between October 30th and 31st.

Purpose

The purpose of the first round of testing was to determine the most effective way for the user to attach the device to the wheelchair and attach the umbrella to the device. Users were asked to attach the different mockups to the wheelchair and place the umbrella in the holder. From these tests, we wanted to learn two things: (1) where would be the best place to attach the device to the wheelchair, and (2), if the adjustment mechanisms are easy to handle.

Test Methodology

Three team members conducted five user test sessions with our mockups on October 30 and 31. The mockups were constructed of cardboard tubes, PVC tubing, and plastic. The gooseneck/clamp demonstrates both the attachment device to the wheelchair (clamp) and the means for adjusting the height of the device (gooseneck) (Figure 22). The "crutch tube" (Figure 23) demonstrates a device with a similar purpose to the gooseneck/clamp. The outer tube of the device was fixed to the wheelchair, while the inner tube was able to move to adjust height.

The users that we conducted the testing with were other students at Northwestern University who did not use mobility devices. Thus they did not have the same limitation with hand dexterity and strength that users of mobility devices may have had. Nevertheless, their insight was helpful in determining what potential problems each mock-up could pose and what

Figure 22: Gooseneck/clamp

Figure 23: Crutch tube

The Velcro cylinder (Figures 24 and 25) represents a cylinder which would hold the umbrella by placing it in the larger cardboard tube, while the plastic tube is used to attach the tube to the gooseneck. The Velcro strap on the back allows the user to place larger umbrellas into the device.

Figure 24: Cylinder with Velcro

Figure 25: Cylinder with Velcro and umbrella

The knob cylinder device (Figure 26 & 27) depicts a cylinder where users could place the umbrella into the tube and then use the knob to tighten the umbrella.

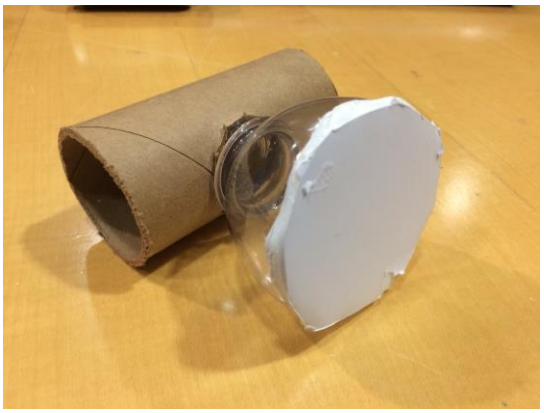

Figure 26: Knob/cylinder attachment

Figure 27: User turning knob

Tests were conducted in the lounge of Slivka Residential College and in the DTC classroom. Users sat in a chair and were told the general function of each mockup and asked to attach the device in various positions. All five sessions were conducted with individual users, each lasting 15 minutes.
During the test, one team member focused on describing the devices while one team member asked questions regarding the user's experience attaching the device. Two members were then took notes of the user's response.

Results

These tables detail user testing results.

Task 1: Attaching device to wheelchair

The users ranked the different positions of where to attach the device from 1 to 3, with 1 being the best.

	Between back rest and handle	Back Handle	Armrest	Comment
User 1	2	1	3	• hard to clamp • had to use 2 hands • likes it in the back handle the best • had to twist a lot to attach to back handle
User 2	3	2	1	• seemed to struggle more with armrest because it was wider than the handle • in the armrest, did not have to twist to attach
User 3	3	2	1	
User 4	3	1	2	• stood up to attach to the backrest and back handle • likes it in the back handle the best.
User 5	3	1	2	
Total	14	7	9	

Table 3: Attaching the device to the wheelchair with clamp

	Armrest	Back Handle	Between Back Rest & Handle	Comment
User 1	3	2	1	• thought it was “weapon-like”
User 2	2	3	1	
User 3	2	3	1	• did not understand how the tube would work • said in back handle it would stick out too much • liked it on the armrest because it easier to adjust
User 4	2	3	1	• did not understand it

User 5	1	3	2	
Total	10	14	6	

Table 4: Attaching the “crutch tube” device

Overall
Gooseneck: 5 votes
Crutch Tube: 0 votes

Task 2: Attaching umbrella to device
The users were asked to rank from 1 to 2, with 1 being the best.

	Velcro cylinder (Figure 3)	Knob cylinder (Figure 4)	Comment
User 1	-	-	• velcro attachment confusing • unstable tube with velcro cylinder • knob is more intuitive • knob seems like obtrusive object in face
User 2	1	2	
User 3	2	1	• did not use the velcro opening; only stuck the umbrella in the cylinder. • likes the round knob.
User 4	2	1	• immediately started turning the knob • Velcro was not used • thought screwing in knob would be too much work
User 5	2	1	
Total	7	5	

Table 5: Attaching umbrella to device

Analysis of results

Our results can be split up into three main observations.

- Attaching to wheelchair: Attaching the device to the armrest was easier because the users did not need to twist their torso to reach the back. However, once the umbrella was attached to the device, many found it slightly obtrusive to have the device directly in front of them. (See Table 3 & 4)

- Attaching the Umbrella: According to users, the knob is a slightly better attachment than the Velcro cylinder because the combination of the knob and cylinder makes for an intuitive design. However, the large knob was described as obtrusive once the user was finished attaching the umbrella. (See Table 5)
- Comparison of gooseneck/ clamp and "crutch tube": Since we did not have a viable means to attach the "crutch tube" to the wheelchair, users were instead asked to imagine how the device would function when attached to different parts of the wheelchair. Users preferred the gooseneck/clamp due to the fact that the adjustability device was more intuitive and it took up less space. (See Table 3 & 4)

Conclusion

- People responded positively to the gooseneck as an adjustability mechanism because it was simple, unobtrusive, and able to be adjusted to various angles and heights. The "crutch tube" was not liked and has been eliminated as an option.
- The knob cylinder device seemed like the better option to hold the umbrella. It was more intuitive and seemed to actually tighten the umbrella to increase stability. However, the knob should be modified to be less obtrusive.
- The device should be designed to attach to the back handles, so that it can be attached to the wheelchair prior to the excursion into the rain, and is unobtrusive to the user while they are in transit.

Limitations

Since there was no way for the crutch tube to be attached to the wheelchair, it may not have been as well received by the users as the gooseneck. Additionally, the cylinder with Velcro fell apart during testing.

Appendix F: Performance Testing

This appendix summarizes two sessions of performance testing: the first one done with mockups in the earlier stage of development and the second one done with a prototype to iterate on the design and make improvements.

Performance Testing I

This session was performed with mockups to determine what features better address our mission statement, shelter people in inclement weather.

Date: October 31st, 2015
Time: 11:30 am-12:30 pm
Location: Ford and Sargent Hall

Purpose

1. Is the adjustment mechanism stable?
2. Are the positions obtained sufficient to protect from rain and wind?

Methodology

1. Attachment:
    a. A gooseneck was clamped onto the handgrip of the wheelchair. The umbrella was taped to a cylinder which was stuck on the gooseneck (Figure 28).
    b. The crutch tube was taped to the wheelchair and the umbrella was stuck to the inside of the cylinder. The cylinder with the knob was taped to the armrest and the umbrella was fit into it (Figure 29).
2. A person sat on the wheelchair and first went in a straight path. Then, they made sharp turns and went up and down the ramp.

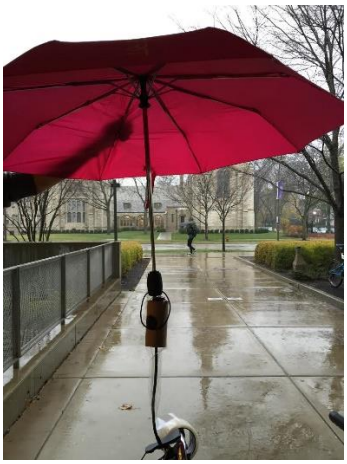

Figure 28: Gooseneck/clamp on wheelchair

Figure 29: Crutch tube on wheelchair

Results

The gooseneck could reach the best angle to protect from rain. However, a stronger gooseneck is needed. The “crutch tube” did not protect well from rain and almost fell on the user. The time to adjust to desired location was almost instantaneous for the gooseneck (see Table 5).

Characteristic	Gooseneck	Crutch Tube	Knob
	less than 2 seconds	30 seconds	
Durability	It lasted a few seconds and then bent over.	The umbrella fell out.	-
Stableness	It bent down with the weight of the umbrella.	The umbrella wobbled in the tube.	-
Safety	The gooseneck hit the top of the shoulder of the person.	Not safe.	-
Dryness	The wheelchair and person was dry. Only the wheels and edge of feet slightly wet.	The person got wet because the crutch tube only went higher and not at an angle.	-

Table 6: Performance testing results

Limitations

The mockups were not ready for performance testing, mainly because there was no way to attach the umbrella to the different devices (except tape). Further performance testing is needed for different features.

Performance Testing II

This appendix summarizes performance testing that was conducted on November 13, 2015.

Date: November 13, 2015
Time: 3:00-4:20 pm
Location: Ford Building

Purpose

To test stability of the prototype.

Methodology

1. The prototype was put on the wheelchair (Figure 30).
2. A person sat on the wheelchair and made sharp turns.
3. The cup was shaken for 30 seconds.

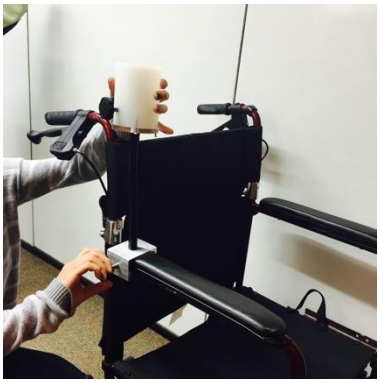

Figure 30: Set up of device

Results

The umbrella wobbled inside the cup throughout the testing. It slanted during turns (Figure 31) and nearly fell out when the cup was being wobbled.

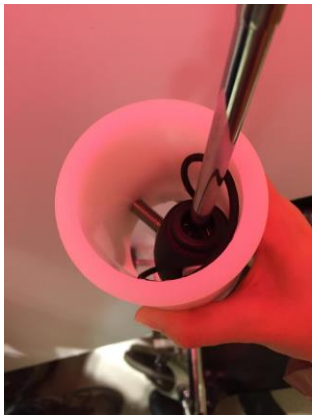

Figure 31: Umbrella slanted with one screw

Conclusion and next steps

- A smaller cup should be implemented to better stabilize the umbrella. Another option is to use two screws to completely push the umbrella to one side of the cup, increasing stability.
- Although not the intention of the test, it revealed that the device is too short for most users, and that the cup is unnecessarily large. Moreover, a longer gooseneck may also solve the issue of it being hard to move. A longer gooseneck and smaller cup will be used for the next prototype.
- The screw creates dents on the umbrella after tightening (Figure 32). Some sort of protectant should be glued to the end of the screws.
- The U-channel may also cause damage to the armrest after extended use so a liner should be added.
- The process of tightening the umbrella while it was open was slightly uncomfortable. A solution is still to be determined.

Figure 32: Dents

Appendix G: Dimensioned Sketches

Appendix H includes dimensioned sketches of different views of the aspects of the design. Dimensions are in inches.

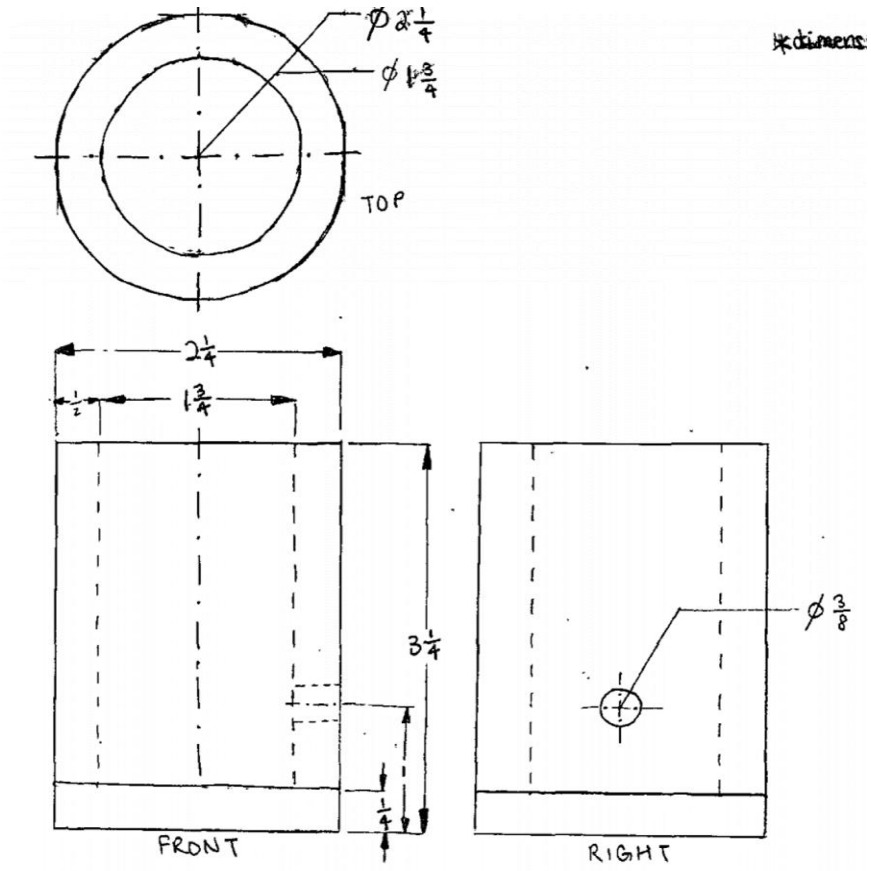

Figure 33: Dimensioned orthographic view of the umbrella cup

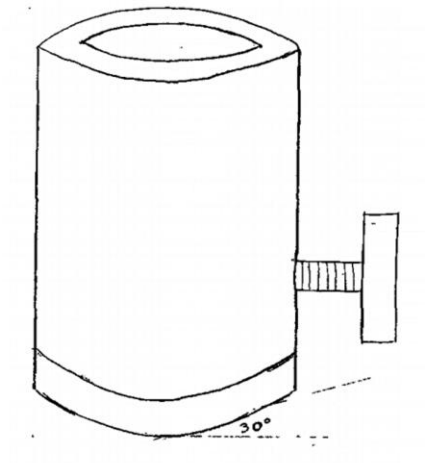

Figure 34: Isometric view of the umbrella cup

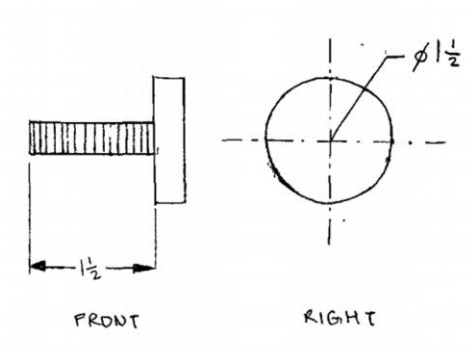

Figure 35: Dimensioned orthographic views of the thumb screw/knob

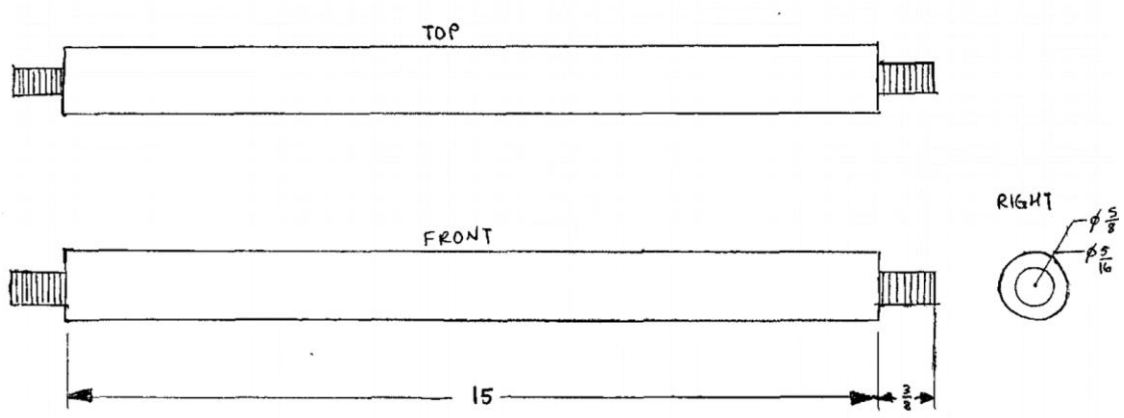

Figure 36: Dimensioned orthographic views of the gooseneck

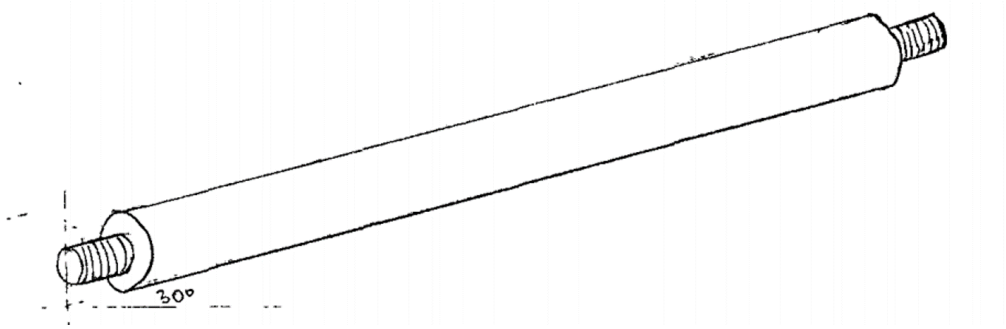

Figure 37: Isometric view of the gooseneck

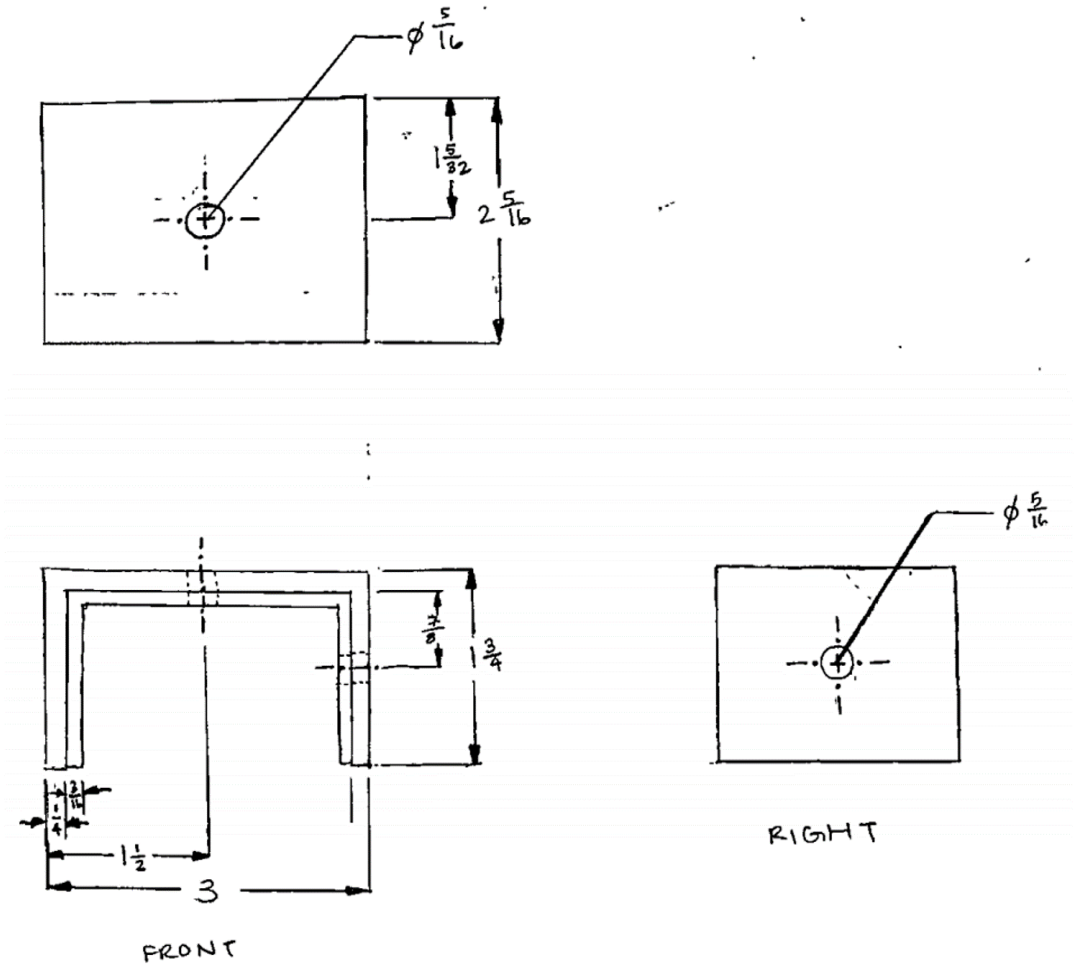

Figure 38: Dimensioned orthographic views of the U-channel

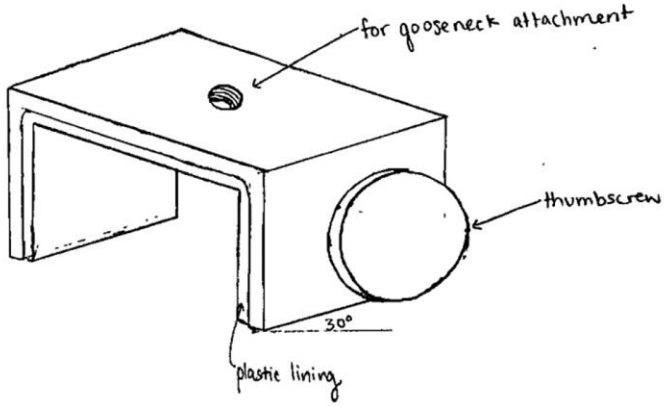

Figure 39: Isometric view of the U-channel

Appendix H: Bill of Materials

Appendix H lists all the materials necessary to build the Flexibrella, as well as their costs (see Table 7).

Date	Description of Purchase	Qty	Vendor	Part Number	Cost
11/2/2015	Multipurpose 6061 Aluminum, U-Channel, 3" Base x 1-3/4" Leg, 1/2' Long	½ ft	McMaster-Carr	1630T32	$8.45
11/2/2015	Plastic Head Thumb Screw, Black Rosette Head, 3/8"-16 Thread, 1-1/2" Long, packs of 5	1 pack	McMaster-Carr	91185A871	$13.12
11/13/2015	Impact-Resistant UHMW Polyethylene Tube 2-1/4" OD X 1-3/4" ID, 1 ft. Length	1 ft	McMaster-Carr	8705K74	$17.06
11/13/2015	Ultra-Flexible Positioning Arm Threaded Mnt, Black Vinyl-Coated STL, 15" Max Proj	1	McMaster-Carr	50035A682	$9.88
12/1/2015	3D printed liner		-		-
12/2/2015	Blue foam	1 inch	-		-
12/2/2015	Self adhesive foam	½ inch	-		-

Table 7: Bill of Materials

Appendix I: Instructions for Construction

Appendix I details the procedures to take in order to build the Flexibrella. Proper safety precautions should be taken when constructing the device.

Materials

- ½ ft Multipurpose 6061 Aluminum, U-Channel, 3" Base x 1-3/4" Leg
- 2 Plastic Head Thumb Screw, Black Rosette Head, 3/8"-16 Thread, 1-1/2" Long
- 1 ft Impact-Resistant UHMW Polyethylene Tube 2-1/4" OD X 1-3/4" ID
- 1 Ultra-Flexible Positioning Arm Threaded Mnt, Black Vinyl-Coated STL, 15" Max Proj
- 4 8-32, 1 inch long screws
- 1 ¼" thick plexiglass sheet, at least 3.5" by 3.5"
- self-adhesive foam
- blue foam

Equipment

- Vertical band saw
- Horizontal band saw
- Mill
- Lathe
- Electric sander
- Laser cutter
- Hand Tap
- Drill bits:
    - 5/16"
    - S
    - #29
- Taps:
    - ⅜ - 16
    - ⅛ - 27
    - 8-32

Instructions

U-Channel

1. Using a vertical band saw, cut off a 2.5 inch long section of the aluminum U-channel.
2. Use the lathe to smoothly cut the edges of this section so that the sides are parallel.
3. Using the electric sander, sand the edges of the aluminum piece so that they are not sharp.
4. Using the mill, drill a 5/16 inch diameter hole in the center of one side face of the aluminum piece.
5. Tap this 5/16 inch hole with a ⅜ - 16 tap.
6. Using the mill and an S drill bit, drill a hole in the center of the top face of the aluminum piece.

Figure 40: U-Channel

7. Tap this hole with a ⅛ - 27 tap (Figure 40).

Lining

1. Using the software SolidWorks, 3D print out the lining to place under the U-Channel
2. The lining should have a height of 1.5 inches, a right side circle diameter of 5/16 inches, and a width of 3/16 inches.

Plastic Tube

1. Using a horizontal band saw, cut a section of the polyethylene tube that is slightly more than 3 inches.
2. Use the lathe to smoothly cut the ends of this section so that the top and bottom are parallel, and the length is 3 inches.
3. Using the mill, drill a 5/16 inch diameter hole in the tube, ¾ inches up from the bottom of the tube.
4. Tap this 5/16 inch hole with a ⅜ - 16 tap.
5. Using the mill and a #29 (0.1360 inch) drill bit, on the top surface of the tube, drill three equally-spaced out holes in the center of the rim of the tube.
6. Tap these holes with an 8-32 tap.

Figure 41: Tapping holes

Cup Bottom

1. Using the laser cutter, cut a 3” diameter circle of plexi glass including:
    a. Three 0.1770 inch clearance holes that line up with the holes on the top of the plastic tube.
    b. One 0.348 inch hole in the center of the circle.
2. Tap the center hole using a ⅛ - 27 tap (Figure 41).

Figure 42: Bottom of cup

Assembly

1. Attach the plexi glass bottom to the plastic tube using three 8-32, 1 inch screws (Figure 42)
2. Screw a thumb screw in the hole in the side of the plastic tube.
3. Attach one end of the gooseneck positioning arm to the plexi glass bottom.
4. Attach the other end of the gooseneck to the top face of the aluminum U-channel.
5. Screw another thumb screw in the hole in the side of the aluminum U-channel (Figure 43).
6. Use a hot glue gun to secure adhesive foam to the ends of two thumb screws.
7. Use hot glue gun to glue blue foam onto the 3D printed lining to cover the gooseneck hole.

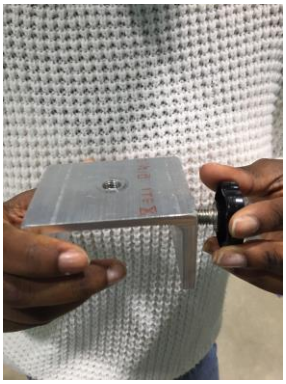

Figure 43: U-Channel and thumbscrew

Appendix J: Instructions for Use

Appendix J details how to use the Flexibrella to attach an umbrella to a wheelchair.

Attaching to wheelchair

1. Place the U-channel on the wheelchair armrest. Make sure the top surface of the armrest is flush with the top plate of the U-channel (Figure 44).
2. Twist the thumb screw clockwise so that the end of the screw presses against the side of the armrest. Twist until the U-channel is stable and tight on the armrest (Figure 45).

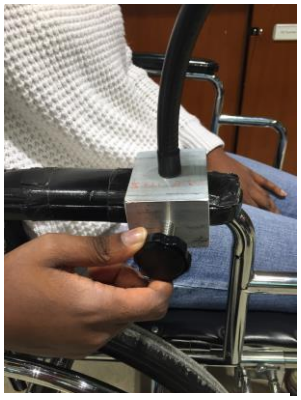

Figure 44: Attaching to wheelchair

Figure 45: Final Set-Up of the U-Channel

Attaching to umbrella

1. First open the umbrella.
2. Place the umbrella handle in the plastic cup.
3. Twist the thumb screw clockwise so that the end of the screw presses the umbrella handle onto the opposite wall of the cup. Make sure the umbrella handle does not wobble in the cup (Figure 46).

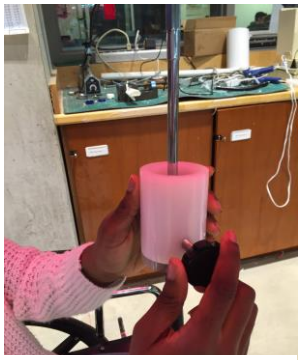

Figure 46: Attaching to umbrella

Adjusting device for optimal use

1. Once the device is attached properly, bend the gooseneck arm to adjust the umbrella based on wind and rain direction (Figure 47).

Figure 47: Final set-up of the Flexibrella

Removing the device

1. First loosen the cup by twisting the thumbscrew counter-clockwise.
2. Remove the umbrella and close it.
3. Loosen the U-channel clamp on the armrest by twisting the thumbscrew counter-clockwise, and remove.