How do we design an assistive tech system that enables people with mobility impairments to better interact with the world?

HUMAN CENTERED DESIGN & ENGINEERING
UNIVERSITY of WASHINGTON

TARV

Rethinking Assistive Technology

PROJECT PROCESS BOOK

SPRING 2016 CAPSTONE PROJECT

Torin Blankensmith
Arnavi Chheda
Rashmi Srinivas
Visavakorn Toongtong

Executive Summary

PROJECT PROCESS BOOK

TARV

As a team of Human Centered Design & Engineering undergraduate students, we wanted to focus our capstone project in a problem space that is often overlooked and under-designed for. We are all aware of the lack of resources for differently-abled individuals, and saw a great need for improvement in the currently used accessible technologies. Through competitive analysis, survey results, and interviews with subject matter experts, we learned that there is a lack of technology that enables disabled individuals to retain a sense of autonomy in their personal homes and/or work environments. Specifically, simple interfaces such as light switches, elevator buttons, and accessible automatic door switches are currently out of reach for individuals who have limited mobility.

Individuals with spinal cord injuries (SCI) are often paralyzed from the neck down, limiting mobility to their eyes and facial muscles. Keeping this in mind, our team explored eye tracking technology to enhance accessibility for a user group with limited mobility. Through the help of the Taskar Center for Accessible Technology (TCAT), we identified an eye tracking headset created by Pupil Labs. This headset, used with a microprocessor, enables the user to control simple appliances around their environment.

With the technology at hand, our team focused on creating an intuitive interface for our user group to interact with. Accessible technologies that are currently available include interfaces that are often regarded as frustrating and difficult to navigate. Through usability testing and design iteration, we created a minimalistic interface that is quick in response time and intuitive to use. In this process book, you will find detailed reports on each phase we went through to create the TARV system, including research, ideation, design iteration, usability testing, and our final design specifications.

TARV

PROCESS BOOK

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Team TARV

Get to know the team, our strengths, goal, beginnings of how we formed, and our interests.

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T A R V

Torin Blankensmith
Design & Programming

Arnavi Chheda
Research & Development

Rashmi Srinivas
PM & User Research

Visavakorn Toongtong
Visual, UX & Industrial Design

My interest are at the intersection of art and programming. I love being a part of the design process and continuing to implement it into a finished product.

- Prototyping
- Full Stack Development
- Interaction Design (UX/UI)
- Adobe Creative & Marketing Cloud
- Cross Platform Mobile App Development
- Data Visualization: Tableau & Three.js
- Physical Computing: Arduino & Processing

What gets me excited is how usability, innovation, and tech ethics affects the technical process of creating the product or technology.

- Full Stack Development
- Software Design
- Software Testing & TDD
- Project Management
- User Research
- Entrepreneurship
- Product Ideation

I specialize in the ideation phase - where ideas are conceptualized and made into low or high fidelity prototypes. I am very organized and fluent in project management.

- Project Management
- Prototyping
- Information Architecture
- Interaction design (UX/UI)
- User Research
- Android development
- Data visualization

I love ideating and designing. I strive for a perfect balance between design aspects and to find where great aesthetics, ergonomics, and usability can meet for different solutions.

- Visual & Industrial Design
- Adobe Creative Suite
- Interaction Design (UX/UI)
- AutoCad, SolidWorks
- Java, Python, HTML, CSS
- Brand Development & Marketing
- Photo & Videography

TARV

WHO ARE WE?

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UNIVERSITY of WASHINGTON

TARV

SPRING 2016

Group Formation

TARV formed as a result of a group formation exercise conducted during the capstone planning class, HCDE 492. During this exercise, students gathered together around ideas and themes that they had a common interest in, and the members of TARV found themselves in spaces that revolved around a central theme of accessibility and assistive technology. The group initially attempted to reach out to Google's Accessibility team, but after not hearing back from them for a couple of weeks, the team began exploring other avenues of connecting with mentors to help guide their accessibility-focused ideation.

Connecting with TCAT

One of the members of the team had taken classes with various professors who are a part of the Taskar Center for Accessible Technology (TCAT), and thus the team was able to get connected with the Director of TCAT, Dr. Anat Caspi. The Taskar Center is a group comprised of Computer Science and Engineering faculty and professors who are working on using technology to enhance the lives of those with motor or speech impairments. Meeting with Dr. Caspi for the first time in the winter allowed us to start talking about different accessible technology avenues we could explore that TCAT already had some experience with.

Picking a Topic

Working on a topic that TCAT had explored in the past gave the team a steady mentorship through Dr. Caspi, and easy access to some of the technologies that the Taskar Center has worked with. Dr. Caspi presented the team with a few different ideas of projects that would be doable within the time and scope of capstone, and these ideas included things like a virtual keyboard, reworking an android interface, and of course eye tracking as a means of enhancing personal autonomy. The team felt particularly drawn to eye tracking, and specifically towards generating a user friendly and intuitive interface for eye tracking because it was a new concept for all of the team members and the challenge presented there was extremely exciting. Thus the team settled on exploring eye tracking for their capstone project.

CAPSTONE PLANNING

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Initial Research

Get an initial understanding of what day to day lives of target users are like, and how we could possibly improve on any negative experiences.

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TARV

Section Summary

INITIAL RESEARCH PHASE

Following from our exploration during Capstone Planning, we chose to focus our project on eye tracking technologies to enhance accessibility for physically disabled individuals, with an end goal of creating an interface that is ubiquitous to any user with or without accessibility needs.

After comparative analyses, literature reviews, consultation with experts, and distribution of surveys, the team found that many of the existing solutions are very con- dition specific, expensive, and not user friendly. Eye trackers have been rendered useful for diagnosis of conditions, text based communication, use of an onscreen interface, but have not been actively used for interacting with the physical world in an extensible way. This realization inspired the desire to design for eye tracking as a means of interacting with the physical world, and the team followed suit with this intention. Additionally, a major epiphany that the team had in regards to existing eye-tracking technologies is that almost all of them use dwell time for selection. This means that the user has to look at the item they want to select for a certain amount of time before the system recognizes it as having been selected, thus causing time to be a huge bottleneck in the usage of these systems. The team thus went into the rest of the project wanting to eliminate this bottleneck (and thus inherently avoid using dwell time).

The team chose to work with a smart headset called Pupil Labs, which was issued to them by the Taskar Center for Accessible Technology. Developed at MIT, this headset tracks the wearer's precise eye movements through an infrared camera and a gray scale camera, and recognizes objects in front of the wearer via a front facing camera. Using this technology, our team focused on assisting individuals who have little to no mobility below their necks. Entering the first phase of our project, we wanted to design a new type of interaction that allowed the wearer of the smart headset to use eye gestures in order to access and control the core functionality of their physical surroundings and/or other Internet of Things devices that they require in day to day use.

INITIAL RESEARCH

Structured Interviews

RESEARCH METHODS

Due to restrictions on time and resources, we were not able to directly access our user group to interview and conduct deeper user research studies at the beginning of the project. We had to creatively utilize contacts with professional experience in the accessible technology field that were within our reach, and thus organized interview-style meetings (transcripts under [Appendix 3]) with the following subject matter experts:

"Typing can be triggered by blink but it gets tedious and is unreliable"

Microsoft

Shaun Kane
Microsoft Research

We met with Shaun Kane, a visiting researcher at Microsoft Research and an Assistant Professor of Computer Science at University of Colorado, Boulder. Shaun agreed to sponsor our project and provided us with valuable insight on his work with disabled individuals, infrequent assistive technologies, and also good experience design practices to improve eye tracking.

"Primarily immobile patients translates to having difficulty controlling their physical environment"

TCAT

"Being in command of your home makes it your home"

Dr. Anat Caspi
Director of TCAT

We consulted with Dr. Anat Caspi of the Taskar Center for Accessible Technology (TCAT) and decided that we want to design and implement our solution in a way that is accessible to a broader population. Our goal was to ensure that the technology we develop can have a direct impact on the individuals that we work with, while maintaining the ability to reach a larger group of users with, or without similar disabilities. Ultimately, this would help with the commercialization and adoption of our solution.

Dr. Caspi is an experienced professional who has dealt with a large number of accessibility problem spaces (including eye tracking technology to work with the physically impaired), and conducting formal interviews with her helped enable us to gain better insight on how technology is being utilized to aid disabled individuals.

Competetive Analysis & Literature Review

RESEARCH METHODS

Doing competitive analysis and reading more about existing means of tackling lack of mobility within physically impaired individuals allowed us to learn more about the products and techniques that are being used. Much of the information was either directly obtained from the structured interviews with experts, or was alluded by the experts we consulted allowing us to do further research on the technique or products through literature reviews. Within this research, some of the prominent eye tracking devices and solutions that currently exist include the following:

Click & Touch Input

Sip & Puff [Appendix 4]
A controller used to interact with computers by allowing a user to click by puffing on a straw like device and sipping to right click. The device can be connected to any computer. Depending on the individual's mobility a joystick can also be attached so that head movements move the cursor.

Adaptive Stylus [Appendix 4]
Allows an individual with limited motor movement to tap specific points on a touch screen. A non conductive tape can be wrapped around the user's hand to ensure that their palm doesn't activate the screen.

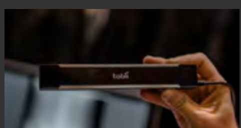
MaKey MaKey [Appendix 5]
Turns anything slightly conductive into a button that can control a variety of actions on a computer. The user can turn anything ranging from a banana to a drawing in pencil into a switch for a computer by attaching alligator clips, or a set of wires to the small makey makey usb chip and the object.

INITIAL RESEARCH

Competetive Analysis & Literature Review

Eye Tracking Inputs

Eye Controlled Robot [Appendix 6] - Allows the user to interact with their physical environment by controlling a sphero robot via a head mounted camera and allowing the user to control the robot through eye gestures. This project uses the pupil labs, a small Arduino, a webcam and a Sphero Robot. A switch was developed so that the user could quickly enable or disable eye-gesture control of the Sphero in if the wearer wanted to make eye contact with someone.



Tobii Eye Tracker [Appendix 7] - A PC based eye tracker in the form of a bar that can be placed on top of a computer screen to track the user's eye. Currently marketed for gaming and research, cited as inaccurate by many experts.

EyeCan+ [Appendix 8] - A version of an eye mouse that allows people to edit documents and send emails on the internet via eye motion, it takes around 20 minutes to compose one email and is developed by Samsung Engineers.

Eyewriter [Appendix 9] - Eye-tracking software developed for TEMPONE a graffiti artist based out of LA that was diagnosed with ALS, who is now paralyzed except for the movement of his eyes. This project tracks the wearer's eye movements and allows them to create vector artwork, similar to a pen tool in Adobe Illustrator. The user can fixate at a point on a canvas to place a vector and can look at 'undo' button to remove the previous point.

EyeHome Prototype [Appendix 10] - An eye-tracking solution for physical disabilities being researching at UC San Diego that allows an individual to navigate a 'phone-like' interface for communication. Gazing at different parts of the screen allows user to dictate a message, while gazing at another sections allow for specialized e-book readers, or social network features.

Based off the preliminary competitive analysis there was an overwhelming amount of technology that can be pivoted to helping individuals with physical disabilities with a focus on communication. Given that a focus on communication and soft user interaction has already been established, our team saw potential in allowing the user to interact with their environment using eye-tracking technology to meet the user's needs on a daily basis.

INITIAL RESEARCH

Survey Distribution

RESEARCH METHODS

As a precursor to the second part of our user research, we formulated our survey to provide us with better informed design decisions and help usher our project in the most advantageous direction. The survey questions were designed to give us a better understanding of how our target users go through day-to-day events. We specifically asked about technologies or do-it-yourself solutions participants may use to complete daily tasks. While we intended our survey to be completed by our target users themselves, we included submissions filled out by individuals who may be more familiar with assistive technologies and DIY solutions.The full version of the survey can be viewed online as linked under Appendix [2].

The survey was distributed to our target users via our interviewees mentioned above, and also through related forums on Facebook groups, the disability sub-Reddit, and also our contacts who are affiliated with disability centers. Our team explored various methods for survey circulation and ended up distributing through the following channels:

- UW Disability Center
- UW DRS (Disability Resources for Students)
- UW Department of Rehabilitation Medicine
- Reddit (the subreddit: r/disability)
- Personal social media channels and profiles

After 2 weeks of circulation, we received 5 responses. Participants of the survey ranged from ages 20 to 52; 4 out of 5 of the participants identified as female, while 1 out of 5 identified as male. 4 out of 5 of the participants said that either they themselves were disabled or they knew of somebody who identified themselves as physically disabled. Our survey participants and/or their acquaintances used the following assistive technologies: eye tracking, speech recognition, wheelchairs, joysticks, walkers, and crutches. Our survey results included some DIY techniques that persons with physical disabilities have attempted, such as off the shelf technologies for various switch capabilities, and relying on the help of caregivers. Additionally, our respondents told us that some of their daily barriers include self-transportation and keyboard usage. After contacting our survey respondents, we were able to get in touch with Timothy Rich who informed our research further after an SME interview, which we will elaborate on in the next section. The full responses from the online survey can be found under [Appendix 1] and the survey itself can be accessed under [Appendix 2].

Preliminary Key Findings

EYE TRACKING LIMITATIONS

The interviews with Shaun and Dr. Caspi were extremely influential in terms of our key findings. One of the biggest takeaways for us was that eye tracking technology is by no means perfect and still has several limitations. Some specific concerns within this are the fact that many current eye tracking technologies (including Pupil Labs) uses dwell time, i.e. the time that a user stares at a spot, as a trigger. The issue with this is that while it works, the human eyeball is not steady, and moves even when focusing on an object or a location. Discussing this with Shaun, we learned that the human eye is steadiest when it is tracking a moving object, due to an effect named the saccades eye movements. To this point, there has to be something there for the eye to track in order to ensure steadiness, and it doesn't work if the person attempts to trace an imaginary path. Additionally, both experts stressed the inaccuracy of even modern expensive eye trackers, and that a better results and user experience can be acheived through better interaction designs.

TARGET USER ASSUMPTIONS

Discussions with Dr. Caspi and Shaun also led to us understanding the importance of our users being able to have a sense of agency (and ideally, having some control over the design) with our end product. Existing technologies aren't the most conducive to a positive user experience within this target demographic. For example, according to Dr. Caspi, the average person speaks at around 180 words per minute. A proficient user who is attempting to use an eye-tracking or stylus-enabled communication tool will 'speak' at around 19 words per minute. This often interferes with the level of communication that these users can have using these tools, and is an example of a technology helping in the sense that these users have a means to communicate, but leaving the user's feeling unable to engage in a "normal" conversation. Giving the individual ownership of the end design was kept in mind as we continued throughout our process.

Preliminary Key Findings

TRENDS OF EYE TRACKING FOR ACCESSIBILITY

A major finding that came out of the competitive analysis was that most existing eye tracking technologies were focused on communication, or helping an individual interface with a computer/mobile device. We found that there was very little out there that involves allowing an individual to use eye tracking as a tool for interacting with the physical environment around them. We also found that many existing solutions had been adapted from generic consumer editions to support accesibility rather than focusing on accssibility and targeting users like the physically impaired first. Other solutions that are focused on manipulation of the physical environment include an underlying assumption in the person's ability to move their heads or have clear vocal capabilities, and a good example of this is the Amazon Echo assistant Alexa. Existing nontechnical solutions often lead to fatigue since they require a large amount of engagement from the limited mobility that users have; for example, imagine a person who constantly has to move their head to use an adaptive stylus that is attached to their forehead.

2 Further Research & Ideation

Summary of additional research results and how the team ideat-ed to perfect design directions

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Section Summary

PHASE TWO

FURTHER RESEARCH / IDEATION PHASE

In the second phase of the project, the team continued conducting user research through survey analysis, further Subject Matter Expert (SME) interviews, and an ethnographic study through shadowing in an inpatient rehabilitation ward for physically disabled or injured individuals. The team also began their ideation phase which included sketching and initial video prototyping, setting up the eye tracking technology that is being used in this project (Pupil Labs), and coming up with evaluation metrics.

This phase allowed the team to refine the vision for TARV. After the inpatient rehab ward shadowing and conversing with Kavita Krishnaswamy, a PhD candidate at the University of Maryland, the team was able to clearly identify three different user goals and three different types of input that can be connected via interfaces that are currently being brainstormed as a part of the ideation process.

The team realized that customizability of the system is key; since no person's experience with physical disability is alike, each individual's needs and desires from such a system will be inherently different. Kavita in particular commented on the fact that for her, physical autonomy was far more important than environmental control, and she would wish such a system could be used to help her operate different machines that could enhance her mobility. Thus this phase allowed the team to focus on designing a modular system that can be easily personalized. This also spearheaded the team to focus more on the eye gestures and user interactions instead of getting too bogged down in the "output" of the system. Thus while the team continued developing for environmental triggers (such as triggering lights or a stereo system), the ingenuity of the system (and the focus of the team) was in the ideation of the interface and eye gesture interaction.

RESEARCH / IDEATION

SME Interviews

FURTHER RESEARCH METHODS

In addition to Dr. Shaun Kane and Dr. Anat Caspi who we closely worked with, we were able to reach two additional SMEs for interviews and mentorship on our project. They provided key insight that helped shape our project vision and design direction. Summaries of the interviews are on the right, and detailed notes from all interviews can be found under [Appendix 3].

"AR might be inappropriate for a patient because of neck pain and motion sickness"

HARBORVIEW MEDICAL CENTER UW Medicine

Timothy Rich

UW Department of Rehabilitation Medicine

We were able to get in contact with Timothy Rich, an Occupational Therapist and a PhD candidate in the UW Department of Rehabilitation Medicine. Tim works on the inpatient rehabilitation ward at Harborview, and by interviewing him, we were able to better understand the pain points that physically impaired patients (and specifically patients with Spinal Cord Injuries, or SCIs) face whilst in rehabilitation. Tim identified nurse-calling and cellphone interaction as two major difficulties that SCI patients face, and talked about the ineffectiveness of the integration of existing assistive technologies like the Sip and Puff or speech recognition in regards to these problem spaces. He also enabled us to shadow him and his patients at Harborview for further research.

"Somewhere we need to concentrate on the human and on the needs of the human"

UNIVERSITY OF MARYLAND

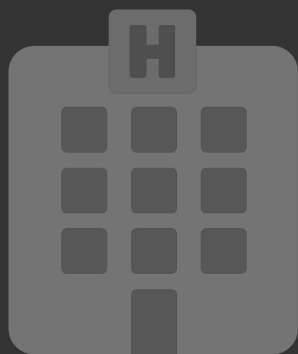
Kavita Krishnaswamy

University of Maryland - CS PhD Candidate

We had the opportunity to connect with Kavita through a referral by Dr. Shaun Kane. She is a Computer Science PhD candidate at the University of Maryland, Baltimore County and is physically disabled herself. Her research revolves around creating systems that help provide autonomy to the user. Talking to Kavita helped us identify physical autonomy as an extremely powerful and pressing goal for an individual who is dealing with a physical impairment, and she encouraged us to think about how eye tracking could be used as an input mode to work with such robotic systems to help achieve autonomy.

Harborview Medical Center Rehab In-Patient Shadowing

FURTHER RESEARCH METHODS



After connecting with Tim, we had the opportunity to go shadow him on the inpatient rehabilitation ward at Harborview. Two of our team members went to Harborview and sat in on therapy sessions in the "gym", where they observed patients with varying levels of physical injuries and impairments, including one patient who had a Spinal Cord Injury. We were unfortunately not allowed to take detailed notes or any photos for privacy and legal reasons. Interactions with patients was also quite limited due to constraints.

Key Observations & Lessons Learned

- Current assistive technologies used in the medical field are fairly expensive.
- One of the patients had physical switches next to his head that he could manipulate by moving his head side to side; the mechanism of these switches is quite simple, and could be replicated through technology found online for $10-$15. However, these particular switches themselves can cost between $60 to $80.
- Patients who don't speak or understand English had translators present throughout their sessions, but would often rely on physical movements and gestures to communicate immediate pain or discomfort.
- One patient going through some leg exercises used his hands to gesture towards his knees when a particular exercise hurt or caused a sharp pain, and then communicated later to his translator. This showed the urgency for immediate relief and caused us to think about settings in which the patient may not have mobility, and how they might communicate the immediate pain in those scenarios.
- Individuals who are in a hospital setting as a patient already have several medicinal and technological gadgets connected to them.
- Seeing this forced us to think about the fact that an additional piece of hardware that a patient would have to put on in a hospital setting may be cumbersome. That said, the rehabilitation sessions themselves only last for a couple of hours on any given day for most patients, so an eye tracking headset may be better suited for patients to use when they're in their rooms and may potentially be alone.

FURTHER RESEARCH

Our Vision

DESIGN IDEATION

TARV's problem statement is: "How can we design an assistive technology for individuals with physical disabilities to better interact with the world around them?" Based off our competitive analysis, user research, and interviews with subject matter experts our team developed the following vision:

> *TARV is the medium for eye-tracking user experience that maps communication, environmental interaction and the physical autonomy of an individual through the input of a screen, augmented reality, or physical objects in the environment. Focusing on accessibility allowed us to narrow down the set interactions and functionality that we provide to our users.*

TARV

Throughout our first two phases, we found design opportunities to improve the following areas of our target user's experience using the advantages eye-tracking has to offer:

- Communication
- Environmental Interaction
- Physical Autonomy

A system map diagram on the next page may help to visualize what TARVs' system aims to do to act as a medium between user input and these target user's experiance or goal.

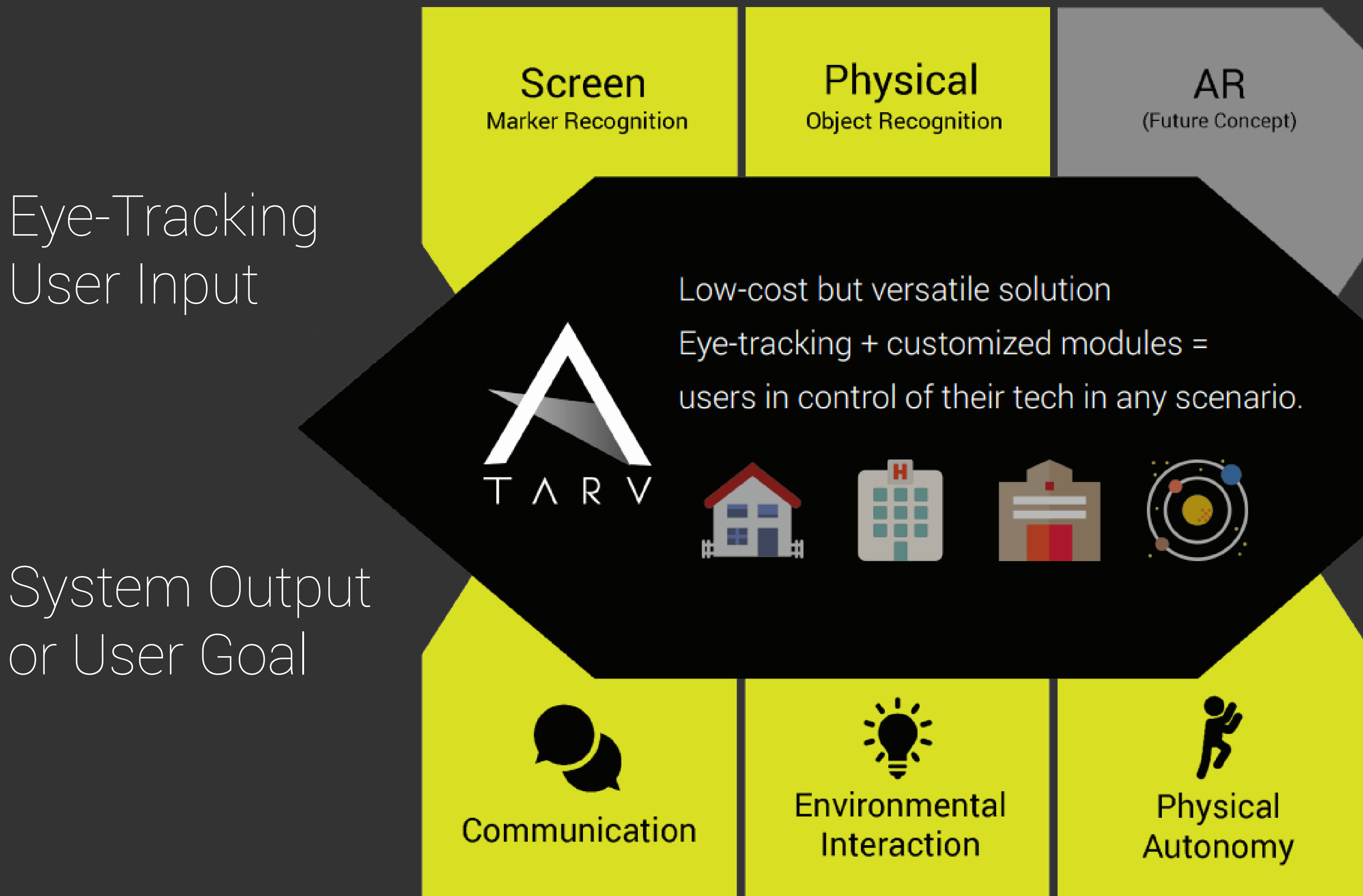
DESIGN IDEATION

TARV System Map

DESIGN IDEATION

DESIGN IDEATION

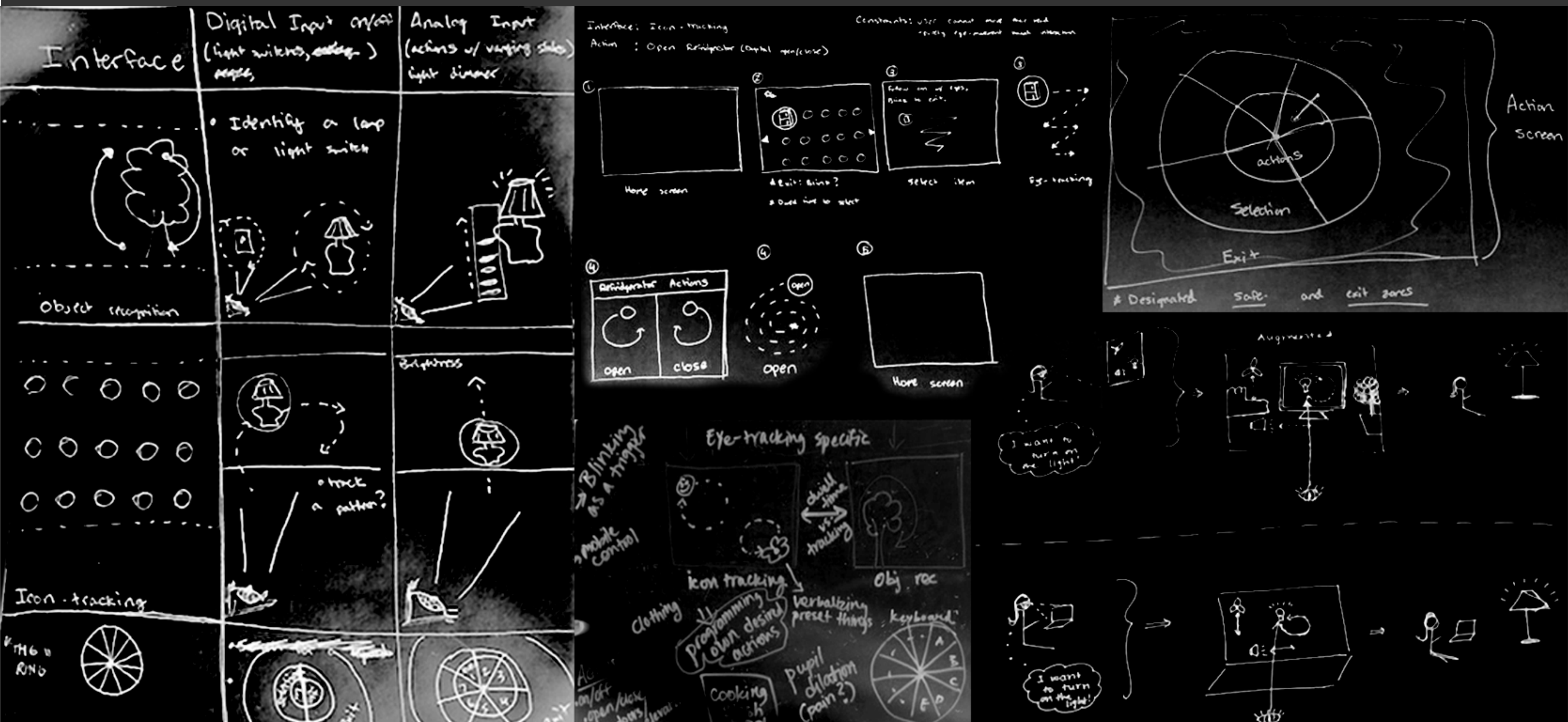
We ideated on different kinds of eye tracking interfaces that would ideally prove useful but remain versatile for our target user group. After many sketches and three team design ideation workshops focusing on what we had found through research, we narrowed down our exploration to three different user inputs and system output (user goals) concepts. We can think of TARV as a versatile medium for eye-tracking user input and output through modular designs and an eye tracker headset. Some sample of team sketches can be found on the next page.



Team Ideation Sessions

DESIGN IDEATION

Affinity diagramming, whiteboarding, and sketches helped to form the project vision and TARV system map. The sketches show ideation of a UI-less physical object recognition input to environmental interaction output system, a circular eye-tracking keyboard we are nicknaming 'the ring' that will reduce communication time, and an icon onscreen based environmental interaction system. The sketches also lead to the creation of TARVs first medium fidelity prototype, the prototype is introduced and detailed on the subsequent page.



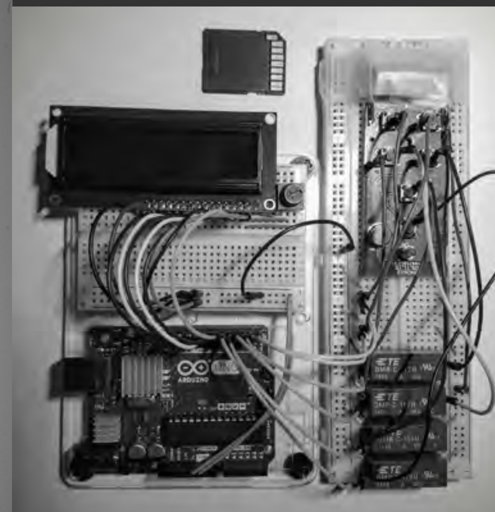
Medium Fidelity Prototype Mk1

DESIGN IDEATION

Eye Tracking Headset Prototype

Wireless Switch Module Prototype

Typical TARV system size (including module) running off battery. SD Card for size comparison



Materials List

Headset ~ $100
- 1x Front HD Webcam
- 1x Infrared Webcam
- 1x 3D Printed Headset
- 1x Haptic Feedback Motor

Wireless Switch Module ~ $30
- 1x Arduino Uno ($9.99 for clone versions)
- 1x Wireless Switch Module with 6 relays and 6 channel 440mhz transmitter
- 3x Low Frequency Wireless 110v Outlet Switches

Physical Object Recognition to Environmental Interaction Prototype

- Features **no software UI**, only requireing eye-tracking input. The user theoretically looks at the object they want to interact with. TARV's eye-tracking headset would recognize the user's gaze on the object and the object itself, then provides haptic feedback that the object has been locked on to. User can then use glance gestures (e.g. up or down) to trigger actions like on or off.

- During initial ideation, activation would require the user to draw a circle around the object with their gaze to trigger the object on, or off, but later this was changed to looking up for on, down for off and left to deactivate.switching system to turn the object on or off.

DESIGN IDEATION

Medium Fidelity Prototype Mk1 (Continued)

DESIGN IDEATION

An Intel Edison kit including a full size Arduino Uno with power in and USB ports.

- The interaction is rather hard to show due to the lack of visible UI, but key takeaway from this is that the minimal intrusion follows the principle that the **best UI is no UI**. Furthermore, the user has privacy and independence over what they are doing or looking at.
- The test video under [Appendix 19] shows the eye tracking system working to track and draw the user's gaze. Another video ([Appendix 20]) shows the wireless low frequency switch module, working to turn house lights on and off.
- The headset endedup running off a laptop for development purposes, but as per our initial objective, we wanted to make the eye-tracking technology portable. There were limitations compiling the required software on the Raspberry Pi, and we also looked into alternative portable computers such as the Intel Edison kit for Arduino.

Heuristic Evaluation

After ideating on various eye tracking interfaces and working on the technical aspects of the first physical prototype, we went on to document a set of heuristics to determine how to evaluate our mk1 initial prototype design, and also the screenbased user interface designs that were later prototyped on software. The heuristic evaluation is organized by the two main user input types on the TARV system map: screen based input (icon tracking and ring keyboard outlined earlier in the design ideation sketches), and physical object recognition (as seen on mk1 prototype). These user interfaces were iterated on for the final project presentation, so testing and evaluating these interfaces were crucial to optimize our user experience. The heuristic evaluation worked hand in hand with a usability test kit for the TARV system and is attached as [Appendix 21].

3 Usability Testing & Iterations

Summary of all logistics, findings, and iterations made from the user studies and events.

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TARV

Section Summary

PHASE THREE > FOUR

USABILITY TESTING & ITERATION PHASE

In the third to fourth phase of the project, the team further refined and iterated on the prototypes including the screen interface, and conducted multiple rounds of usability tests with the initial and iterated prototypes. The team also presented at a Disability Studies symposium and attended a DUB seminar hosted at the UW, where they were able to demo the screen interface of the prototype and get feedback accordingly.

This phase allowed the team to get critiques of the working prototype and design, and think about the design decisions going forward with the refinement of the interface. After the first round of usability tests, the team realized the inaccuracies of the eye tracker, and the need to design a system that accommodates for that. During this phase, the team changed the interface completely, from originally having a bar across the screen with different icons to the first iteration of the "ring" design that would ultimately become the team's final system design.

The team also performed the initial rounds of usability tests with a mockup of the object recognition system, but the need to have a working prototype by the Disability Symposium caused the team to end up focusing on refining the screen interface to a point where it worked fairly accurately. Thus it was during this phase that the parallel tracks of developing both the screen interface and the object recognition interface came to an end, and the focus for the rest of the project became the screen interface.

Additionally, the team had the chance to meet with Dr. Shaun Kane again, and he inspired the idea of a "jumping" interface, where the ring of selection options would move around the screen in the line of sight of the user. This would allow proficient users to essentially have a series of known gestures and eye-tracking paths to activate their desired selections. This feedback allowed the team to make a final iteration of the prototype in time for the HCDE Open House, and for a couple of final usability sessions that the team conducted with their capstone advisor John Porter and with Dr. Caspi. This final iteration of the prototype also included options to toggle between the stationary and jumping interface in addition to the other changes described above.

USABILITY TESTING & ITERATIONS

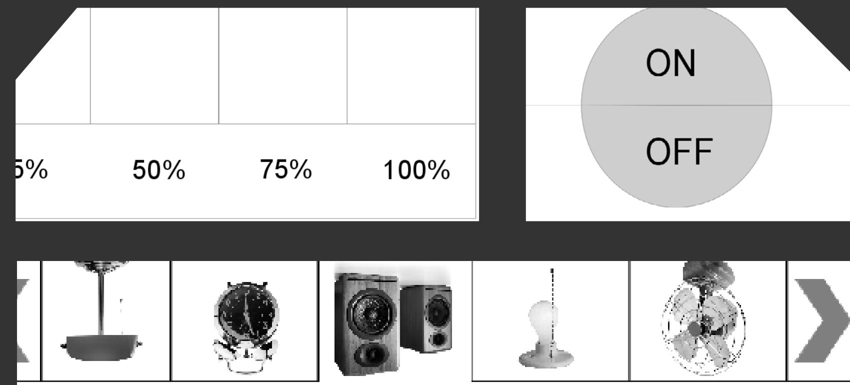
Refining Our First Prototype

ITERATIONS

We worked on refining our mk1 prototype to work for two specific interfaces (screen and no-screen). First, we incorporated the usage of intentional gestures into our 'no software UI' interface. The steps with this are as follows (video of our prototype in action during a usability test under [Appendix 17]):

- *Look at the desired object, and the technology will recognize what you are looking at thereby "selecting" the object and providing haptic feedback about the selection.*
- *Direct your gaze upwards from the object to turn it on*
- *Direct your gaze downwards from the object to turn it off*
- *Direct your gaze to the left of the object to "deselect" it (this is essentially an escape functionality)*

Secondly, we worked on modifying our screen interface design and getting that connected to the Pupil Labs headset. We kept the designs very simple and close to wireframes to save development time as we were not sure at the time if we were headed in the right direction with the UI design. We were also able to get the Pupil Labs set up so that when looking at a screen, the eye tracker works as a cursor and a user is able to navigate the screen with their eyes. Unfortunately we couldn't figure out how to "click" using the headset, so we modified our interface design to work with hover states instead.



After going through several different design ideas, we ended up performing usability tests with a preliminary interactive mock up (see [Appendix 15]) of the interface partially shown above. The steps with this interface are as follows:

- *Direct your gaze to the object you wish to activate within the bar*
- *Direct your gaze upwards to "select" the object*
- *Look at either "on" or "off" depending on which action you choose to perform, and then direct your gaze either up or down respectively (outside of the "safe zone") to activate the on or off control*
- *If the object has a gradient of options, look along the bar to the level that you would like to choose, and then direct your gaze upwards to select it*
- *Direct your gaze towards the blue bar at the bottom to go "back" to the main menu (i.e. the menu with all object options)*

We then performed usability tests with both of these interfaces, which is described in the subsequent pages of this section.

Logistics & Setting Up: Round 1

USABILITY STUDIES

We were initially hoping to go through Tim (one of our SMEs who works at Harborview) to recruit SCI patients at Harborview for usability testing for our first round of testing, but there was some confusion surrounding the need for an IRB to do so, and multiple logistics issues. Since we required feedback on our initial designs and prototype and we found ourselves temporarily deadlocked with this IRB issue, we decided to run a round of usability tests by recruiting students in the HUB. Additionally, after talking to our instructor John and getting further information about the exemption of coursework-related testing from needing an IRB, one of our team members met with Tim again, at which point he suggested he'd be open to having us test our final product with his patients.

We also met with Dr. Caspi, who suggested that we set up a booth at the Disability Studies Symposium occurring on campus on Friday, May 13th and Saturday, May 14th. This provided us with an opportunity to talk about our project and get feedback from people with interests that align with those of our target demographic. Our experience from the first day of the symposium is discussed later in this milestone.

Premliminary Testing

USABILITY STUDIES

For our preliminary round of usability testing, we ended up recruiting students and testing our prototype in the HUB. We set up at a table on the first floor, and had 3 participants (2 female, 1 male). After narrating a pre-test script, we had them sign a consent form [Appendix 11] and answer some pre-test questions. We then guided each of our participants through tasks navigating the screen interface and the no-software interface. We ended each of our tests with some post-test questions and follow up questions that varied based on each participant's experiences with the test. Our full usability test kit, and some videos of our participants going through the test and testing environment can be found under [Appendix 17].

USABILITY TESTING

Findings Summary for Round 1

USABILITY STUDY RESULTS

Headset Wearability

1 out of 3 participants mentioned that the headset felt intuitive to wear and resembled the wearability of glasses. 2 out of 3 participants mentioned that they were unsure how to wear the headset; one participant removed their glasses to wear the headset. While all 3 participants mentioned that they did not need to touch the headset after wearing it, our team observed each participant using their hands to adjust the device camera as well as placement on their nose. Between the screen-interface tasks and the object recognition tasks, all 3 participants needed assistance in adjusting the headset to re-focus the view of the camera and pupil tracker.

Mouse Control (on Screen Interface)

When using the Pupil Labs headset to control the mouse, all 3 participants expressed concern that moving the cursor with their eyes was "not as easy as [they] wanted it to be". Issues faced with moving the cursor included the cursor lagging and/or not aligning with where the participants were actually looking (3 of 3 participants) and moving the cursor to select items towards the edges of the laptop screen (3 of 3 participants). The discrepancy between where the participants were looking and where the mouse moved was a cause for frustration. All participants claimed that they probably "move [their] eyes a lot" to explain for the pupil-mouse movement inaccuracy.

USABILITY TESTING

Findings Summary for Round 1 (Continued)

USABILITY STUDY RESULTS

Screen Interface

For the screen-based interface itself, all participants expressed frustration that they were unable to easily bring the mouse cursor to the bottom menu bar where object options were presented. This frustration was observed in the menu screen as well as in screens where the participant tried to access the menu bar. One participant mentioned that when trying to go back to the menu from the speaker on/off screen, looking down to the menu bar unintentionally triggers the "speakers off" function. 2 out of 3 participants responded favorably to the vertical selection zone above each menu item stating that "it makes sense to look up...like the way I use my phone...I like things to be fast". One participant mentioned that they would not respond positively to dwell time because they "do not like the delayed gratification".

Terminology

Confusion with terminology came up in two main areas of our test: "safe" versus "selection" area in the screen interface; and describing the state of an object as active and actions as on/off. For the screen interface, "safe area" was intended to refer to an area on the screen in which no action would be triggered by eye movement. 1 out of 3 participants mentioned that "safe" did not provide them with an accurate description of what the area was designed for. Similarly, the difference between a "safe" area and "selection" area was not clear. For the object recognition task, participants interpreted the tasks "activate the object" as "turn the object on" as one gesture versus two gestures/tasks as intended.

Disability Studies Symposium

SYMPOSIUM EXPERIENCE

Through Dr. Caspi and the Taskar Center, we had the opportunity to set up a booth at the Disability Studies Symposium on May 13th and 14th. We put together a poster and had our screen interface prototype there for people to interact with as well. A closer look at the project poster which has been updated to a final version can be found under [Appendix 25]. Several people that interacted with us on the first day of presenting asked questions about our design decisions and the steps that we took to get to our current prototype. The individuals who we interacted with really emphasized the human-centered aspect of designing for those who are differently abled, and hearing their perspectives and seeing them align with feedback that we'd gotten from shadowing and interacting with our SMEs was encouraging. This is also a great space to get feedback on our design, and while we were only there for a half hour on the first day, we were also excited to be back on the second day with our prototype demo for a longer amount of time, a few notes on that on the next page.

Disability Studies Symposium

SYMPOSIUM EXPERIENCE

As briefly mentioned, TARV was invited by Dr. Caspi to present and demo our project at the Disability Symposium. At the second day of the Disability Studies Symposium, we had a longer time slot for our poster session. Thus, we were able to test our demo out with 4-5 participants. Some of the feedback we received from these sessions and from interacting with various attendees at the symposium included:

Using icons instead of or with text

- One of the attendees talked to us about her younger sister who had grown up with a physical disability that affected her ability to learn how to read. As a result, her sister can recognize images and icons but still can't read text, and our system that we demonstrated only used text.
- Another attendee commented that as she normally wears glasses and took them off to use the headset, the text was hard for her to read.

Suggestions for improvement to headset design

- Particularly for those who wear glasses and put the headset on top of their glasses
- This included adjustable joints, less obtrusive eye tracking camera

Making the safe zone or inactive zone circle larger

- This gave us the idea of enabling customization options such as user adjustable safezone size.

Colorcoding

- Sectioning off the quadrants and their correlating words and icons in the inactive zone with colors

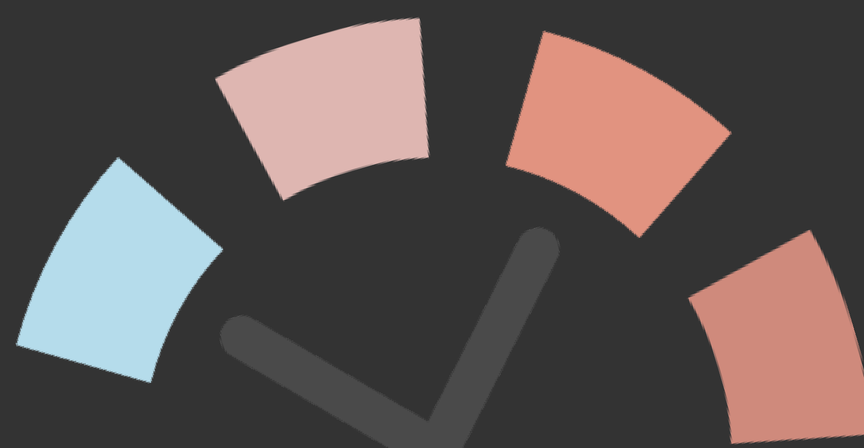
Overall, we got positive responses from the seminar and valuable feedback from individuals who had disabilities or were highly involved in the field of assistive technology. People were very interested to see howTARV would evolve into a larger system.

Design Implications from Round 1

USABILITY TESTING & ITERATION

Based on our findings, a major change that we made to our interface design included placement and shapes of the interactive elements. From user feedback and technology constraints, we found that it was most difficult to control the cursor towards the edges of the computer screen, thus decreasing accuracy of the cursor movement further out from the center. For this reason we decided we would modify our circular selection screens so that areas of interactivity (formerly referred to as selection areas) will be moved in towards the center 2/3rds of the screen, with screen edges acting as inactive areas (formerly referred to as safe areas). We also retained the horizontal menu list and vertical active area for the main menu screen, but moved the entire layout up and away from the bottom of the screen. We also saw that issues we faced through verbal instruction or understanding of terminology could be prospectively diminished by switching to the use of icons and better area highlighting to convey the function and actions of a menu area.

Similarly, we decided to create an inactive pathway from the the screen towards the collapsed menu bar in screens where the user must select an on/off state for an object. Overall, active areas (items that users must select) would be made large enough to account for any inaccuracies in the eye tracking cursor control.



USABILITY TESTING

DUB Seminar

SYMPOSIUM EXPERIENCE

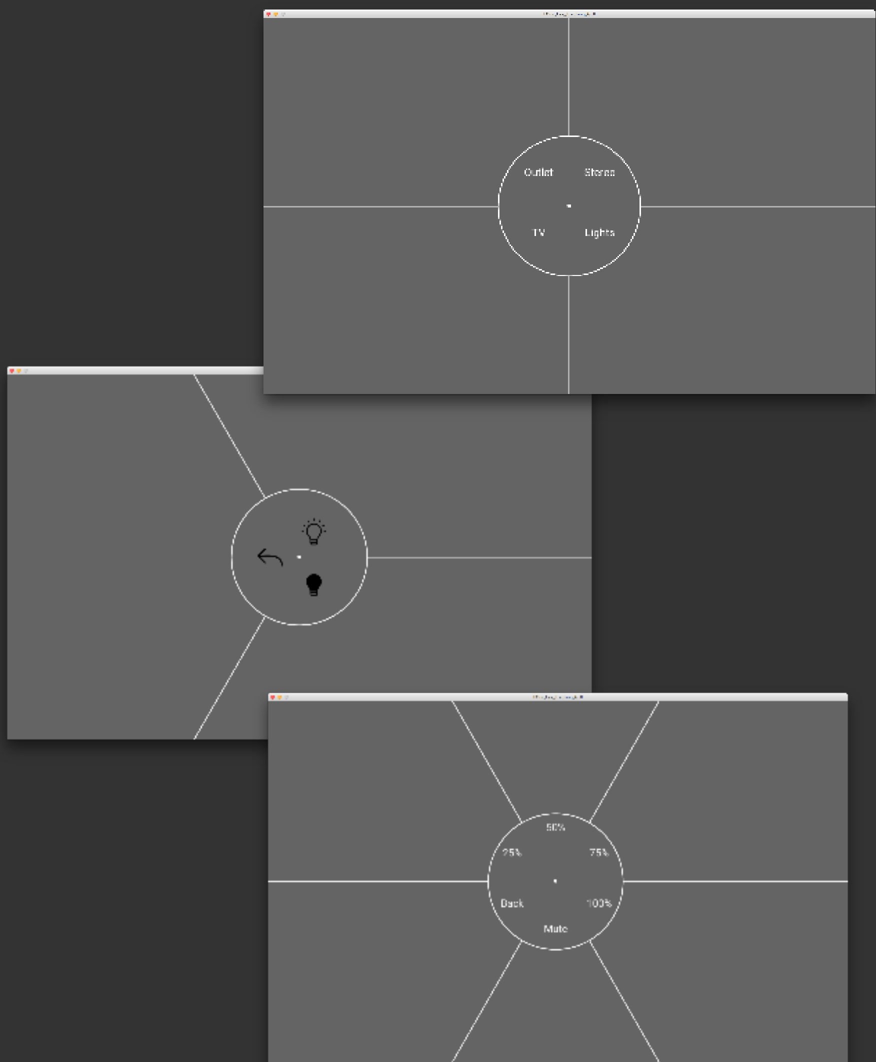
At the DUBs seminar Shaun Kane brought up a number of ideas that centered around giving an experienced eye-tracker the ability to navigate the interface quicker, while still allowing a new user to pick up the interactions quickly. After seeing the circular interface for the first time, Shaun wanted the ability to control the width of the 'inactive' zone so that a new user could have use a larger circle to start off with, while an experienced user could simply use smaller eye motions to trigger an action.

The second key change that Shaun suggested was to have the center of a sub menu appear at at the boundary of the 'inactive' zone where a user just selected. Originally a user would keep their gaze in the inactive zone and glance out into one of the pie segments just beyond the inactive-zone, which would either trigger an action, or bring up a new circular interface on top, where they would need to move their gaze back to the center of the screen to make another selection. Shaun's suggestion would allow an experience eye-tracker to make their first selection by moving their gaze just outside the safe-zone, which would create a new circular interface already centered around the user's gaze. This small translation of the interface allows experienced users to memorize a series of eye-gestures in order to trigger a series of actions.

USABILITY TESTING

Revising Prototypes: Round 1

ITERATIONS



Based on feedback from our initial rounds of usability studies and from the Disability Studies Symposium, we revised our "ring" prototype to have a darker grey background with white elements to improve easiness on the eyes, and include text or icon (or both) modes. We scrapped our other interface that included a bar to navigate across different potential household appliances, and instead we transferred all of those functionalities into our "ring" type design, sample screenshots of the software UI can be seen to the left (additional under [Appendix 22]). One example of added functionality that we incorporated into the ring design is a percentage wheel for gradient variable actions (i.e. different percentages of the volume when attempting to control a stereo or sound system).

Additionally, based on discussions with Dr. Shaun Kane at the DUBs seminar, we worked on developing another prototype that still has the "ring" design, but that replaces the central inactive zone of the menu options to be where the user would have had to glance to activate a particular appliance or option. This design has been shown to allow users to learn quick gestures similar to muscle-memory as they become more proficient using the interface to be able to activate options quickly and intuitively.

ITERATIONS

Logistics: Round 2

USABILITY STUDIES

For the second round of usability testing, we focused on how the user interacted with the user interface of our prototype. We made substantial changes to our previous interface iteration and were interested to see whether we were progressing in a positive way for our users.

Following the first round of usability testing, we contacted Tim (our SME) about having a few of his patients at Harborview test out our prototype. Tim had expressed concern about having SCI patients involved in our research as they are already asked to be included in many other related trials. Because our interfaces relies purely off eye movement, any participant would be able to test out the effectiveness of our interface, which would translate over to patients with a SCI. In addition through our initial observations shadowing Tim at Harborview we were able to identify and incorporate functionality that would be beneficial for the patients. For this reason, our second prototype iteration was tested on students recruited in the HUB.

USABILITY TESTING

Setting Up: Round 2

USABILITY STUDIES

For this round of testing, we recruited participants in the HUB (2 male, 1 female). All three of our participants were undergraduate students at UW and did not express that they had any physical impairments or exposure to assistive technology. We set up at a table on the first floor in the same area as our first testing round and had the participants sit facing the laptop screen.

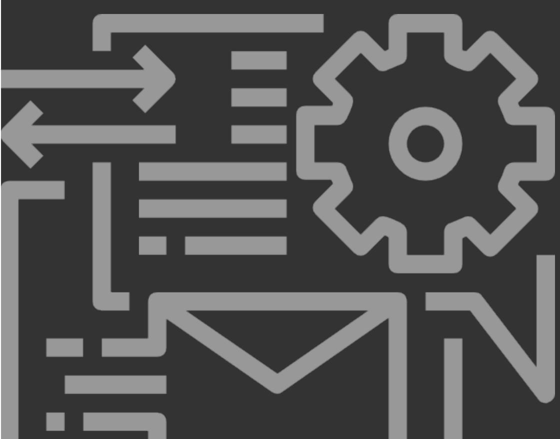
After going through the moderator's script and asking the participants pre-test questions, we had each participant read and sign a consent form. Participants were then guided through the process of wearing the headset, calibrating the eye-tracking piece, and and controlling the laptop cursor with their eyes. Participants were asked to navigate the screen interface to first, turn on or off the lights on the tree across from the testing table; and second, vary the volume of the song playing on the laptop. Each test ended with post-test and follow-up questions based on the participants' experience using the prototype. Our usability study materials such as notes, test kit, tasks, and other details can be found under [Appendices 11-18].

Findings Summary for Round 2

USABILITY STUDY RESULTS

Inactive (Safezone) Area

Two out of three participants commented that the size of the inactive area could be larger. This was in response to both participants expressing difficulty in getting the cursor to align with where they were actually looking. One participant mentioned that a larger inactive circle would allow them to move their eyes more freely around the object/action icons without accidentally "drifting" into an active area. Another mentioned that the correlation between the active area and labels/icons in the inactive area could be made more clear by using some combination of color and/or extending the lines form the active area to the inactive area. Another participant commented that they were not confident about whether or not they were correctly switching the light on and off. The interface did not inform the participant that any action had taken place, so they were forced to look away from the computer to check on the light.



Text versus Icons

During the testing, each participant was first exposed to a design version using icons to imply actions and objects, followed by a second design version using text instead of icons. All three participants preferred the visual including icons as they were "intuitive...made sense what the icons meant". Users were introduced to objects/actions including Lights, Stereo, TV, Back, On, and Off. On, Off, and Back were the actions that could show either text or icons.

USABILITY TESTING

Findings Summary for Round 2 (Continued)

USABILITY STUDY RESULTS

"Jumping" Interface

Participants were shown two interfaces. The first, a static interface, maintains the position of the inactive area for each screen. The second, a "jumping" interface, bases the next screen's inactive area off of the previous screen's selection zone area. For example, if a participant selects the light object and the active area for the light object is in the top right part of the screen, the inactive zone will be shifted towards the top-right of the screen in the next screen.

After experiencing both interfaces, one participant expressed that they preferred the static interface, and called the second interface "jarring". Another participant preferred the second interface, observing that it "gave immediate feedback...[it was] intuitive that something has changed".

Tracking Navigation

2 out of 3 participants expressed that they had a hard time remembering or tracking what page they were on as they navigated through the screen interface. Specifically, the interface for selecting an object to control and turning a light on or off are both similar to one another, and it was suggested by a participant to indicate what screen the user is on at all times. The confusion around navigation tracking was present in both the static and the "jumping" interface.

Design Implications from Round 2

USABILITY TESTING & ITERATION

Changes To Be Made

Based on feedback from our final round of formal usability studies, we focused our time refining the interaction between the user and the inactive to active areas for our final prototype. Overall, our participants were looking for feedback on what they were selecting, and whether or not the action had been carried out. This led to the design decision to highlight selected active areas and/or create a dialogue box pop up. We also created headings and page titles to allow the user to track where they are in terms of navigation. To increase the accuracy of what the users are looking at, we revisited the customization of the size of the inactive area and added lines to separate each object or action within the inactive area.

What Stays The Same?

Participants responded favorably to the icons presented. Due to the fact that the participants we tested in this round were not our ideal user group, we created modes in which the user can choose to view icons and/or text to fully customize the interface for their needs. We also continued to create more robust versions of both the static and jumping interfaces to test at a further date.

USABILITY TESTING

4

Final Solutions

Summary of final specifications of our prototype, reflections on the project, and future considerations

< BACK TO CONTENTS

TARV

Section Summary

FINAL SOLUTIONS & WRAPPING UP

In the last stages of the two quarter project timeline, the team focused on working towards wrapping up the project with a final prototype to present at the HCDE Open house event and reflecting on the work we had done over the two quarters. This phase allowed the team to focus on documentation and bringing the project to a proper close.

The team also thought about how to immortalize and present TARV to the public so that our work may be used to create something useful or beneficial for society. We have coordinated with some of our project advisors such as Dr. Caspi to ensure that TARV will be well documented and persist to provide people with interests in assistive technology and eye-tracking to be able to continue or build on top of TARV. This section of the process book will summarize what we have acheived in terms of the final specifications of our prototype software and hardware, our reflections, and also any future considerations for TARV.

FINAL SOLUTIONS

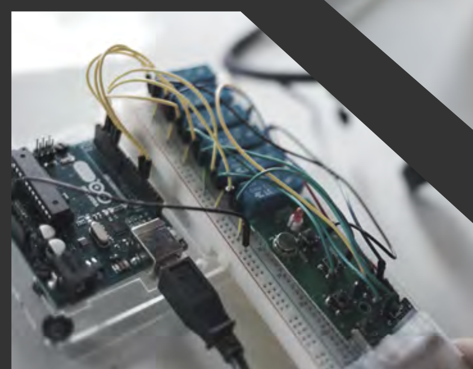
Final Prototype Summary

OPEN HOUSE PROTOTYPE

Photos of the hardware and UI we had for the HCDE open house are shown below (see more under [Appendix 23]). The hardware fully functions as an eye-tracker with haptic feedback and the wireless outlet switching module can be plugged in as well and works beautifully. The screen UI software also currently works as an appliance or outlet switcher and volume control, and can be easily modified to include other variables.

Mk1 - Screen-based Software UI, only requires eye-tracking input

Glancing outwards from safezone on a screen activates specific commands. Can be used to control advanced variables like volume or light color. Current Bottleneck is the eye-tracking hardware but usability testing showed that it is quick, intuitive, and has minimal learning curve.



Mk2 - QR Code / Object Recognition Features no software UI

User looks at object they want to interact with and headset recognizes gaze on object or QR code . Headset provides haptic feedback that recognition is locked on, and a simple eye gesture up or down triggers action associated with the object. Can be used to control simple cases like turning outlets and appliances on or off. Minimal intrusion and transparency of interface follows principle that best UI is no UI. User get privacy and independence over what they are doing or looking at.

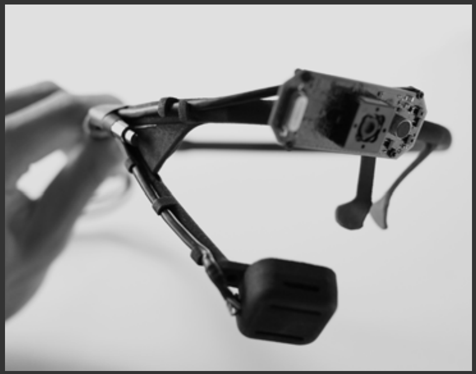
FINAL SOLUTIONS

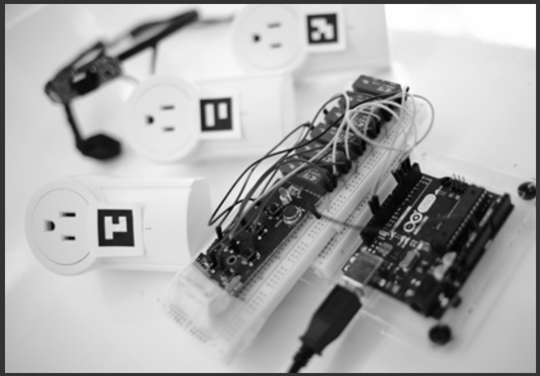
Overview of Components

FINAL DELIVERABLE PROTOTYPE

TARV Uses Eye-Tracking as user input and maps it to either a screen, or physical objects in the environment. The system acts as a medium through which the user can communicate, and control environmental interactions - all of which allow the user to gain physical autonomy. The systems' map can be reviewed on page 20 of this process book within the design ideation section, and the following are the main hardware and software components that we worked with in the scope of our two quarter project timeline:

- Modified Pupil Labs Eye-Tracking Headset (elaborated on previous page)
- Custom cross platform desktop application, triggered purely through cursor movement
    - Jumping Interface: Link to video
    - Static Interface: Link to video
- An Arduino microcontroller with Switching Outlets
    - Acts as a digital to physical environment medium or trigger to activate various physical devices such as lights, outlets, and stereos based on input from the desktop app. TARV uses a set of wirelessly controlled outlets that are activated by an arduino microprocessor in order to trigger on and off objects in the user's environment. It operates on a safe 433Mhz low frequency that requires minimal setup like a WiFi network would otherwise require. Built using a low frequency fixed channel wireless breakout board, and some relays in conjunction with receivers and 110v relays in the outlets.





Overview of Components (Continued)

FINAL DELIVERABLE PROTOTYPE

TARV Uses the Pupil Labs headset, which was developed through the MIT Media Lab. The Pupil Labs has a front facing webcam to capture what is in front of the user, as well as an eye camera that captures infrared video in order to detect where the user is looking. The Pupil Labs differentiates itself from other eye tracking technology through its open source software and off the shelf parts, which helps to continue innovation and keep the overall cost low.

By placing QR codes on all four corners of a computer screen the headset is able to detect the computer screen as a 'surface' and the location of the wearer's gaze on the screen is broadcast over a server. Using this data TARV is able to allow the user to control the cursor on the computer through their eye movement.

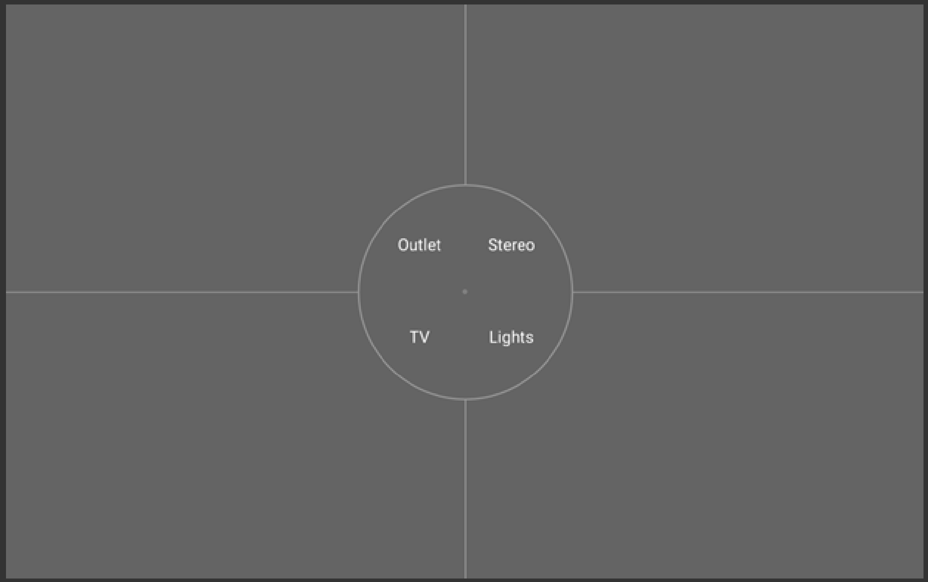
One of the leading drawbacks to software that takes advantage of eye-tracking technology is the use of dwell time to activate an action, or UI element. Normally the user needs to look at an object for a specific amount of time to activate it, which creates a bottleneck in the speed at which a user can trigger actions. In addition the use of dwell time for activation forces the user to focus on one object which goes against the natural saccadic eye movement where the eye quickly moves around building up a three-dimensional mental representation of a scene.

The TARV application was developed specifically to remove the bottleneck of dwell time, and eliminate extraeneous eye movement or tiring selections by utilizing a circular interface that is activated purely by moving the mouse into different quadrants of the interface, which is illustrated by screenshots on the subsequent pages.

Desktop Application Walkthrough

FINAL STATIC INTERFACE PROTOTYPE

In the following example screenshots, the green circles and lines represent the user's gaze location and direction, but they are not visible or show up on the actual interface.



When the user starts up the application if their gaze is outside of the center circle the interface is deactivated and no actions can be triggered.

After the user's gaze is brought into the center of the circle the UI activates. This interface was designed so that the list of menu options are in a non-active zone, which allows a new user to comfortably look at their set of options without selecting any of them. The user can select an element by moving their gaze from the inactive-zone into any area of the desired quadrant.

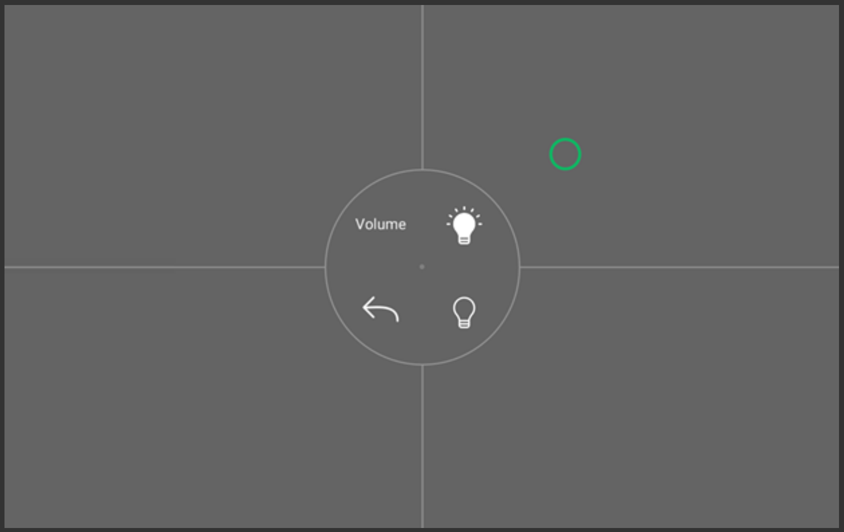
FINAL SOLUTIONS

Desktop Application Walkthrough (Continued)

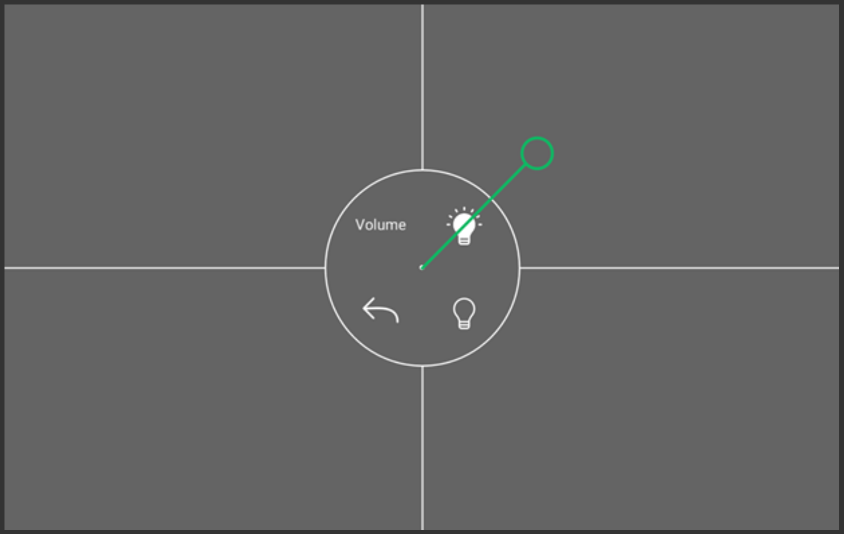
FINAL STATIC INTERFACE PROTOTYPE

Here the user had selected the Stereo menu by glancing towards the top right on the previous screen.

The menu changes accordingly and the interface remains inactive until the user's gaze is brought back into the center. They are now on this screen shown to the right.



When the user selects the On switch within the Stereo section the Arduino microprocessor activates the outlet associated with speakers.



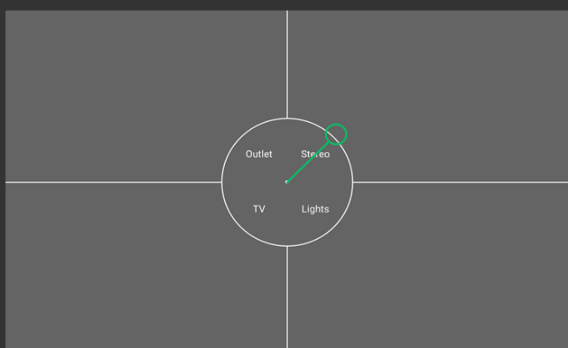
FINAL SOLUTIONS

Desktop Application Walkthrough

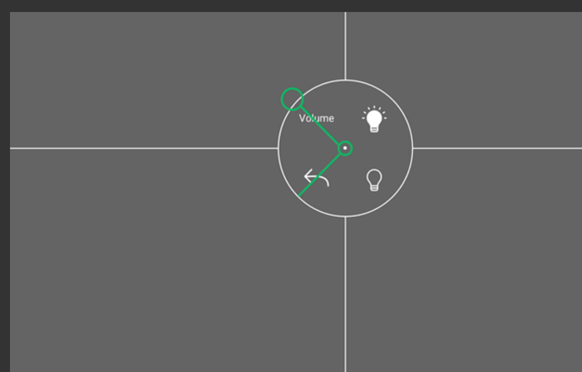
FINAL JUMPING INTERFACE PROTOTYPE

After performing user research, it became apparent that more experienced eye-trackers could have the ability to keep their gaze in specific regions more easily, which lead to a second interaction mode in the TARV desktop app. In the 'gesture' mode, after the user moves their gaze just beyond the inactive-zone into a selection the center of the next menu is translated so that the menu is already activated, allowing the user to make their next selection quicker. This simple translation allows the user to activate an end action by performing an 'eye-gesture.' The following images illustrates a user setting the volume to 75%.

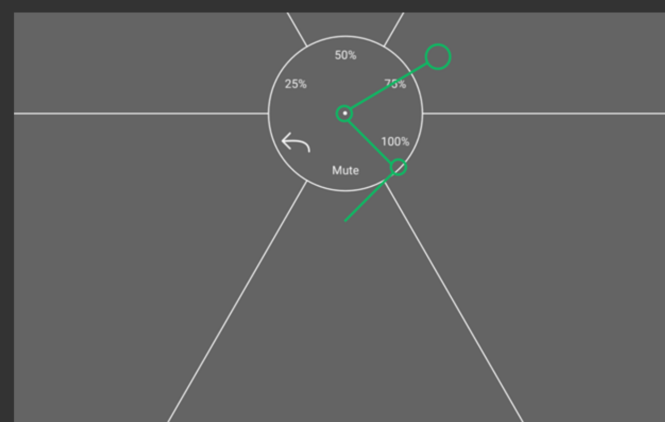
Here the user selects the Stereo section and keeps their gaze close to the edge of the inactive-zone.



The Stereo menu is shown translated up and to the right so that the user's gaze is already at the center and the menu is active. Next the user moves their gaze from the center of the Stereo section into Volume.



Lastly the user moves their gaze from the center of the Volume menu and selects 75%. The previous eye movements are left in this image to illustrate the 'eye gesture' that a user could memorize in order to quickly set their volume to 75%.



FINAL SOLUTIONS

Future of TARV / Considerations

FINAL DELIVERABLE PROTOTYPE

In addition to the desktop app TARV was also designed to activate objects in the user's environment through the use of QR codes, but due to time limitations this feature is currently unavailable. As an example, to trigger one of the wireless outlets without the use of a screen interface a QR code would be place on the outlet. This would allow the Pupil Labs headset to recognize the outlet as a surface, so the user could look at the QR code to activate a selection and either glance up to turn it on, down for off, or left to deactivate.

Calibration is normally done through the use of the Pupil Labs software, which requires the use of mouse and keyboard input. Future changes would include a settings section on the Home screen that allows the user to calibrate without using the mouse or keyboard. In addition the current way to change between 'normal' and 'gesture' mode is through keyboard input, so the option to select an interface layout would be provided in the settings.

Users seemed fairly comfortable with their location within the app in the 'normal' mode, however the 'gesture' made it much easier for the user to accidentally trigger the wrong section leaving them lost in the navigation. A future improvement would be including the name of the current menu at the center of the interface instead of the white dot.

HCDE Open House

On Tuesday, May 31st we presented our poster (see [Appendix 25]) for the Human-Centered Design and Engineering Open House. This included explaining our project and running demos. We prepared our prototype so that attendees were able to test out the eye-tracking device and interface. We also submitted our final deliverables including a project video [Appendix 29] and Milestones 1 to 4 [Appendix 30] that will serve to help immortalize and showcase TARV.

Future TARV Modules

Beyond the scope of this school year and the HCDE Capstone project, we are hoping to be able to get together as a team outside our work hours post-graduation to conceptualize and prototype the Object Recognition and Augmented Reality interfaces of TARV. Broadening the functionality of our prototype will also broaden our target user group and bring TARV closer to the consumer world, which would fulfill our goal of making this device helpful and accesible to as many people as possible.

Immortalizing TARV

Some important next steps for us also involve thinking about immortalizing the project or making our work be of service to the public by open sourcing and setting up a website where TARV can be showcased. We are discussing the future of the developed prototype with mentors and SMEs to determine the best route for releasing codebase and designs.

Team Project Reflection

TARV 2016 Capstone Project

Overall, we're extremely excited about the direction our project ended up going in, and we've received positive and constructive feedback from our mentors, usability test participants, and other individuals who have tested out our system in various symposium and open house settings. Our team worked fluidly, and all of the members were flexible about taking on different roles and responsibilities throughout the process. That said, there are absolutely things we would have changed or done differently.

One of the biggest things we wish we had more time to work on implementing is the object recognition interface. In ideating, we settled on the two interfaces (the screen interface as shown throughout the rest of this Process Book, and an object recognition interface that has no actual visible interface) after several rounds of user research and usability testing. The object recognition interface embodies the "no interface is the best interface" principle, and thus creates a simplistic, gesture-based navigation mechanism where users can use real world objects in their environment to control their surroundings. During ideation, our plan was to implement a version of this using QR codes, where we would put QR codes on objects (a light, a stereo, etc.), and a person could look up or down from the item to activate it. Had we gotten a version of this interface working, we would have been able to conduct usability tests on it and get feedback about whether this is a feasible and convenient idea for physically impaired individuals.

Leading in from this discussion of "given more time...", one of the things that we feel in hindsight really took a lot out of our time in the beginning weeks of spring quarter was our attempts to get the Pupil Labs headset working on a microprocessor. We had convinced ourselves that making the system lightweight and mobile was extremely important for individuals with physical impairments, but the hardware we attempted to use did not work well with compiling the Pupil Labs software and we spent too long finding other hardware tools and ways of getting the system to work with a smaller machine. Ultimately, a couple of our subject matter experts advised us against continuing to try it with microprocessors; they also stated that in their experience, they found that for individuals who are physically impaired and potentially wheelchair bound, having a small laptop on their wheelchair isn't much of an issue. While the idea of making the system as mobile as possible is definitely worth exploring given more time, we ended up wasting too much of our early time on this when it could have been better used if focused somewhere else.

One other big thing that we wish we had the opportunity to do is recruiting physically impaired individuals, specifically those with little to no mobility from the neck down, to do some usability tests for our system. We ran into some confusions regarding the need for IRBs, and while we were in talks with Tim (one of our subject matter experts and an Occupational Therapist at Harborview) to potentially test with some of his patients, since there were hospital administration rules and regulations regarding human subject tests we ran into some resistance. Having had the opportunity to shadow some of Tim's patients for our user research earlier on in the quarter, and with that user research having heavily influenced our ideation, we do wish we had the chance to usability test with them.

To conclude, time and access to our target demographic were two major things we have reflected on, both throughout the quarter and as our project is wrapping up. We definitely wish we had taken more time earlier on in our capstone to focus in on our problem space and work on tackling some of these foreseeable issues.

5 Acknowledgements

Thanking all our Project Advisors and Subject Matter Experts (SMEs) who provided us with valuable advice and insight and made TARV possible

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TO OUR ADVISORS & SMEs

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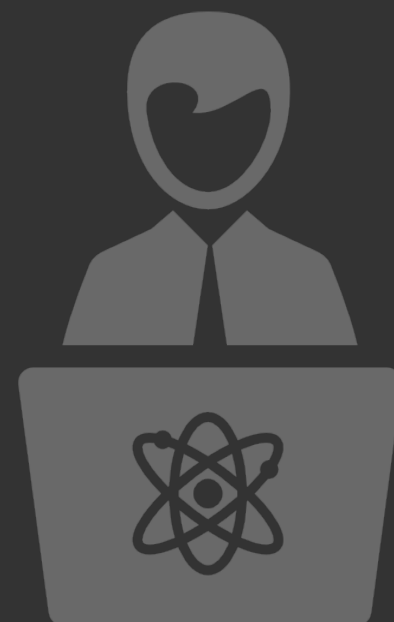

ACKNOWLEDGEMENTS

6 Appendix

Team contact information and links to additional resources and references mentioned to within this process book.

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Survey & Interview Material

[1] Survey Results - Link
[2] TARV Target Demographic Survey - Link
[3] Interview Notes & Questions - Link

Literary Review Material

[4] DIY Assistive Tech Blog Feed - Link 1 - Link 2
[5] Instructables - Link 1 (MaKey)
[6] Instructables - Link 2 (Eye Controlled Robot)
[7] Tobii Eye Tracker - Link
[8] EyeCan Project - Link
[9] EyeWriter - Link
[10] Engadget EyeHome Comm. Article - Link

Usability Test Rounds 1 & 2 Material

[11] Consent Form - Link
[12] Moderator Script - Link
[13] Usability Tasks (Round 1) - Link
[14] Usability Tasks (Round 2) - Link
[15] UI Mockup Used for Initial Testing - Link
[16] Test Notes for Round 1 Participants (x3) - Link
[17] Study Videos / Photos (Round 1 & 2) - Link
[18] Test Notes for Round 2 Participants (x4) - Link

Design Ideation & Prototyping Material

[19] Eye-Tracking Test Prototype Video - Link
[20] Wireless Switch Module Prototype Video - Link
[21] TARV System Heuristics Form - Link
[22] Revised Screen Prototype UI Screenshots - Link
[23] Final Prototype Photos / Screenshots - Link

Disability Symposium & Poster Material

[24] Summary of Symposium - Link
[25] TARV HCDE Open House Poster - Link

Other Project Material

[26] TARV Capstone Project Initial Proposal - Link
[27] TARV Capstone Team Information - Link
[28] HCDE Capstone Grant Proposal - Link

Final Deliverable Materials

[29] TARV Project Video - Link
[30] Milestones 1 to 4 - Link

APPENDIX

Resource Links

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