CYBORG-CENTERED DESIGN

Designing a User Interface for Cochlear Implant Recipients Through User-Sensitive Inclusive Design

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May 10, 2017

Master of Graphic Design

Submitted in partial fulfillment for the degree of Master of Graphic Design

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GRAZIE MILLE!

To all the participants in my studies, thank you for your generosity with your time and thoughtful comments and ideas.

To my committee members and my professors in the College of Design, you've been an enormous source of knowledge and inspiration. You've opened my eyes to an exciting world I had no idea existed and I'm forever grateful.

Lu, thank you for your always enthusiastic help.

Thank you to my studio mates, and to Gigi, Dashiell, Mom, Dad and Peter.

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ABSTRACT

Assistive technology has been slow to adopt the highly regarded methods of Human-Centered Design (HCD), participatory design, and design empathy. In the niche market of assistive technology, design decisions are not fueled by the need to attract and retain users. The Cochlear Implant (CI) is a biotechnological feat that provides deaf and hard-of-hearing recipients digital hearing. CIs act as the user's connection to the hearing world, making the CI user a deeply invested stakeholder. Unlike mainstream devices such as laptops that provide consumers with a wide array of product choices, CI recipients are locked-in users of one company's devices for life.

Research gathered from literature confirmed that aspects of the current user interface do not adhere to HCD principles. For example, the CI remote interface's linear navigation forces CI users to arduously wade through several options to change the volume. An online poll revealed that most users end up not using their remote.

User-Sensitive Inclusive Design (USID) is a design research method devised by HCD researcher Alan Newell. It combines traditional design methods to foster a rich understanding of users, their experiences, and their emotions, resulting in design that responds to users' distinct needs. Using this as a method for the design of a more user-centered CI Interface, this study utilized polls, surveys, and interviews to create personas and corresponding user journey maps. Design explorations range from the basic elements of usability in controls to possibilities in customizable, connected, contextual interface. Using David Rose's concept of "enchanted objects" as a framework, this investigation also looks at how the Internet of Things (IoT) can connect and empower CI users.

Mindful of the larger question of what it means to design for disability, these visual explorations seek avenues in which designers can grant assistive device users a stronger role in the design process. These design investigations look into how networked assistive technology can help foster communication between users and designers. While these investigations center on the design of a Cochlear Implant user interface (UI) for users who are hearing impaired, the results of this research will benefit all designers who are creating for users with specific needs.

THE BIONIC MILLENNIAL

I was born profoundly deaf in 1983, which – much to my chagrin – means I am considered a Millennial. Generational ill repute aside, I consider myself incredibly lucky have grown up during a time where new technology became available at an extraordinary pace. My parents decided I would go down the oral route (learning to speak and read lips) as opposed to the signing route. I was outfitted with high-powered hearing aids and enrolled in an intensive oral auditory program that centered on speech therapy and hearing training. To my great fortune, new tools became available just as I sought more independence. In middle school, I went from having my parents call my friends to set up play dates to being able to make my own plans via AOL Instant Messenger and email. In high school, I got my first cell phone with texting capabilities, and video chats became the norm. These tools not only granted me greater autonomy, but their widespread adoption allowed me to define my deafness on my own terms.

The technological advance that had greatest impact on my life was when I swapped my hearing aids for my first Cochlear Implant in 1999. The Cochlear Implant is a biotechnological feat that gives users digital hearing. Once I learned to hear in this vastly different, digital way, I had access to far more sound than I ever did with my hearing aids.

When I got my second implant in 2016, I upgraded my Cochlear Implants from the Cochlear Nucleus Freedom to the Cochlear Nucleus 6 last year (2016). I was thrilled to find that there was an external remote. I conjured up images of being able to create and change settings on-the-go, quickly upping the volume when somebody spoke softly and increasing the sensitivity when I wanted to hear somebody across the room. However, my idea of a James Bond-like device was quickly dashed. My personal user experience with the remote control was not only counter-intuitive and confusing, but tedious. I took this poor design as an insult to all CI users who depend on assistive technology for their way of life. The quality of their user experience should be held to the highest standard.

This investigation informs the design of a smart, connected, contextual interface for controlling sound settings of a Cochlear Implant. However, this investigation also examines the larger questions: What does it mean to design for assistive technology and how can design give users a voice? Cochlear Implants grant users hearing, but its designers and producers are the ones who should start listening.

COCHLEAR IMPLANTS AND THE REMOTE ASSISTANT

The designs in this investigation focus on the UI of a Cochlear Implant. Cochlear Implants are digital devices that replace the function of a damaged inner ear in people with severe to profound hearing loss. The Cochlear Implant is made up of two parts: an external processor that sits behind the user's ear and a receiver with a coil that is surgically implanted in the user's cochlea. The latest iteration offered by the company Cochlear Americas is the Nucleus 6. This has an option for a Remote Assistant, a small, handheld device that allows users to adjust settings wirelessly. It is meant to give users greater control. (Cochlear.com, 2017) Instead, users report that its interface is difficult and time consuming to operate. (Google Poll, 2017)

Figure 1: ***The Cochlear Implant and The Remote Assistant***

THE USABILITY OF THE CURRENT UI

In describing what makes clear interaction design, Gillan Crampton Smith (Moggridge, 2013) lists the following:

- It offers users a clear mental model.
- It gives reassuring feedback.
- It is easily navigable.
- It is consistent.

If one judges the usability of the CI remote based on these qualities, it is clear that the design does not work around the user. Instead, the onus is on the user to learn and memorize the functions of the Remote Assistant. The CI remote uses a linear navigation interface that requires users to click through many screens to make critical sound adjustments such as volume or sensitivity. The icons and language used in the interface do not clearly inform users of their functions. Obfuscation of functions goes against Don Norman's characteristics of good design: discoverability and understanding (Norman, 2013). The linear navigation is problematic because it is difficult for users to know "where they are" unless they have the order memorized.

In the case of a bilateral CI user, it takes 10 steps to reach the screen that allows the user to change the volume of their left ear. If the same CI user wants to adjust the sensitivity of the left ear, it takes 7 steps. If a user has a microphone accessory, the user has the ability to control the volume of the microphone input as well as the ratio of sound between the microphone input and environmental sounds. If the user wants to change the volume, it takes them 11 steps.

Changing settings with the current navigation takes many steps and requires a significant amount of the user's cognitive load. An online poll (2017) I conducted in a closed Cochlear Implant user group revealed that out of 62 participants, 55% no longer used the remote because they did not find it useful enough. A survey I posted in the same Facebook group showed that those who used and appreciated the remote had many ideas on how to make it better. My design explorations look to the principles of User-Centered Design to create a user experience that takes fewer steps and requires less learning on the part of the user.

JUSTIFICATION

THE CURRENT CI REMOTE USER EXPERIENCE

TASK: CHANGE LEFT CI VOLUME

7 STEPS

In the case of a bilateral CI user, it takes 7 steps to be able to change the volume of their left ear with the Remote Assistant.

There is a physical switch on the left side of the remote assistant for users to unlock the device to make changes.

The user must press "OK" to modify any variable.

TASK: CHANGE LEFT CI SENSITIVITY

10 STEPS It takes 10 steps to change the sensitivity of the left ear.

TASK: CHANGE VOLUME OF ACCESSORY

14 STEPS If a user has a microphone accessory, the user has the ability to control the volume of the microphone input. If the user wants to change the volume, it takes them 14 steps.

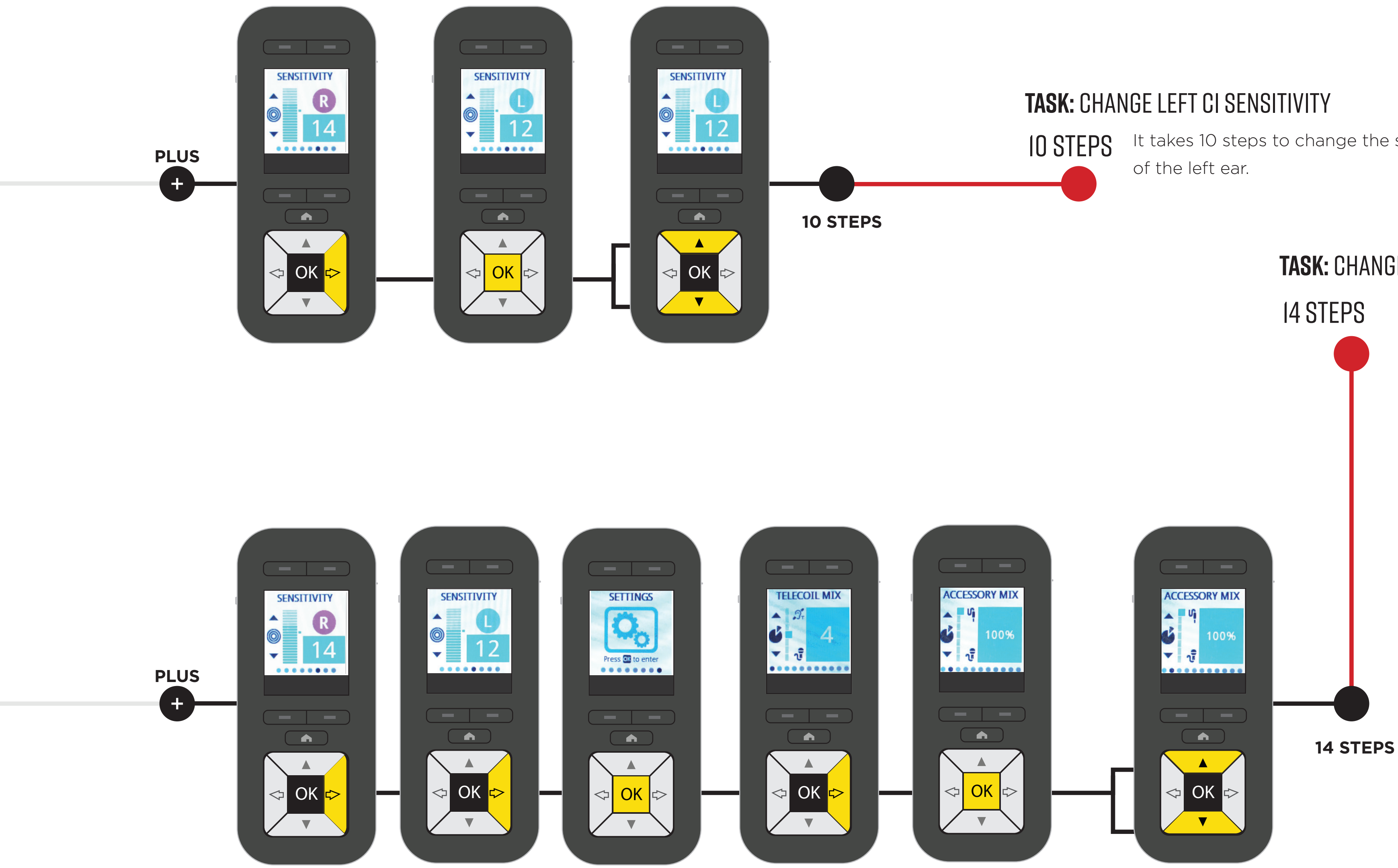


Figure 2: ***The Current User Experience***

DESIGNING FOR DISABILITY

Users rely on assistive technology for their way of life. With the exception of one participant who has normal hearing in one ear, all of my interviewees spoke of how important their hearing devices were to them. Lisa F. called her hearing aids a "lifeline." Ashlee spoke of how important her CI was in her role as a mother to a hearing child. The standards for designs of assistive technology should be higher to better meet their needs.

Alan Newell, a Human Computer Interaction expert at the University of Dundee says that older and disabled users are currently an afterthought in the design process. (Newell, 2011) He argues that the current method does not truly address specific needs and that the user must be included in all steps of the design process. Newell coined the design method "User-Sensitive Inclusive Design" which combines the design research methods of User-Centered Design (USID) and participatory design while encouraging design empathy. (Newell, 2011) By learning about the users, the designer learns what's important to them. To better understand CI users, I conducted interviews with deaf and hard of hearing participants. I asked them to critique their current user experience with their hearing devices. In doing so, my participants revealed their preferences and suggested functions they wished existed. Their proposed "dream remote" inspired a plethora of new ideas for my project.

Graham Pullin's book, *Design Meets Disability* (2009), challenges the way we design for disability and suggests how design can help fight stigmas attached to disabilities. Since their inception, hearing devices have been designed to hide the user's inability to hear. Glasses, on the other hand, went from being a solely medical device to being a fashion statement. Pullin asks: why can't hearing devices go down the same path? (Pullin, 2009) Rather than focusing on overturning stigma associated with the CI product design, my design explorations use Pullin's concept to make the user experience of the CI Remote closer to the intuitive hearing experience of a normally hearing person. Then I take the project a step further to explore how the CI user experience might incorporate intuitive "super hearing," abilities that people with normal hearing do not have.

My design prompts also work to address issues that are not currently the responsibility of a hearing device, but would alleviate common frustrations for a deaf and hard-of-hearing user base. For example, almost 6 out 7 of my interviewees spoke of how it is difficult for them to follow along in group conversations. To address this, I devised the concept of

“Scriber,” a feature that automatically transcribes the world around the user. This feature would eliminate confusion for the users and it would also minimize the number of times that CI users have to ask people around them what’s going on.

A CONNECTED INTERFACE

In his book *Enchanted Objects* (2014), researcher David Rose at MIT Media Labs argues that the Internet of Things is the key to a more human, “enchanted” future that can work to unglue our attention from screens and “glass slabs.” The current CI remote UI lives on a closed physical device. My exploration examines possibilities of an interface that lives in different types of devices: an array of smart objects with a variety of inputs. A smart interface would allow for automation, a contextual menu that learns the user’s preferences and patterns and the elimination of manual input.

The Internet and computers have enabled users to work with many new forms of media to produce, share, and reproduce or repurpose. This has allowed the phenomenon of participatory culture to flourish. Participatory culture happens when online communities allow participants to become co-creators. Henry Jenkins (2015) argues that allowing for co-creation empowers the user and allows for progress as a whole to grow exponentially. My designs consider how users could benefit from a private social media outlet built into the CI ecosystem.

PRIMARY RESEARCH QUESTION

How can **User-Sensitive Inclusive Design** be applied to create a **customizable** user experience for Cochlear Implant users?

SUB-QUESTIONS

How can David Rose's criteria for **enchanted objects** and the **Internet of Things** elevate and expand the design mindset towards **assistive technology**?

How can the design of a smart interface that allows users to **create** settings and **share** them with others empower its users?

KEYWORDS

User Interface, User Experience, User Sensitive Inclusive Design, Human-Centered Design, Contextual Interface, Inclusive/Accessible/ Universal Design, Participatory Design, Cochlear Implants, Sound and Volume Controls, the Internet of Things, Smart Devices, Haptic Feedback, Auditory Feedback, Linear Navigation

DEFINITION OF KEY TERMS

COCHLEAR IMPLANTS (CI) are electronic medical devices that give deaf and hard of hearing users digital sound. Unlike hearing aids that make sounds louder, CIs do the work of damaged parts of the inner ear (cochlea) to provide sound signals to the brain. CIs are made up of two parts: an internal part that is surgically implanted and an external part that users wear behind the ear. (Cochlear.com, 2017)

PROCESSOR refers to the externally worn part of the Cochlear Implant. The Cochlear processor has a microphone that captures sound and processes the sound through a profile that the user creates with their audiologist. The CI processor transmits audio information to the internally implanted coil. (Cochlear.com, 2017)

REMOTE ASSISTANT is a small handheld device that allows users to control their Cochlear Nucleus 6 CI. (Cochlear.com, 2017)

PROGRAMS are sound profiles that CI users can create with their audiologist for sound settings in different environments. Currently processors are able to hold up to four programs. (Cochlear.com, 2017)

HUMAN-CENTERED DESIGN (HCD) a design approach that puts human needs, capabilities, and behavior first, then designs to accommodate those capabilities, needs, and ways of behaving. (Norman, 2013)

PARTICIPATORY DESIGN is a design process that incorporates the user into the design process. (Newell, 2011)

PARTICIPATORY CULTURE is a culture with low barriers to artistic expression and civic engagement, strong support for creating and sharing one's creations, and informal mentorship, whereby what is known by the most experienced is passed along to novices. A participatory culture is also one in which members believe their contributions matter, and feel a social connection with one another. (Jenkins, 2015)

INCLUSIVE DESIGN refers to the design of products and services accessible to all, including users with disabilities. The language around designing for disability has shifted and changed from Design for All and Universal Design, to Inclusive Design. These are all linguistically imperfect, reflecting the delicate nature of how disability is viewed as well as the impossible concept of designing for all users. (Pullin, 2009). In this context, I use “Inclusive Design” to encompass design for assistive needs as well as inclusivity.

DESIGN EMPATHY is the design process that factors in the user’s emotion into problem solving. This is an integral component of USID. Newel argues that it is important for designers to develop an empathy for the user population, rather than narrowly focus on rules and standards. This involves studying and working closely with the users. (Newel, 2011)

USER-SENSITIVE INCLUSIVE DESIGN (USID) is a design methodology coined by Alan Newell that combines the practices of HCD with participatory design and encourages empathy in the design process for users with disabilities. (Newel, 2011)

INTERNET OF THINGS (IOT) was coined by Kevin Ashton and has also been referred to as ubiquitous computing (Ubicomp), pervasive computing, and connected things. In 2013 the Global Standards Initiative on Internet of Things (IoT-GSI) defined the IoT as “a global infrastructure for the information society, enabling advanced services by interconnecting physical and virtual things based on existing and evolving interoperable information and communication technologies.” (Global Standards Initiative, 2013)

CONTEXTUAL INTERFACE is an interface that primarily exists on smart devices and works to anticipate users’ needs. A contextual interface relies on data such as time and location to automate preset or predictable actions. Context-aware systems sense or remember information about the user and their situation in order to reduce computer-user communication and effort. (Selker, T.; Burleson, W., 2000)

LINEAR NAVIGATION is a type of menu structure that forces users to go through pages in a specific, sequential order. (Hornbæk, Kasper, and Erik Frøkjær, 2001)

ASSUMPTIONS

The user connects to the world of sound through their Cochlear Implant(s).

This exploration focuses on users who rely heavily on their other senses, specifically vision.

My designs will focus on the needs of specific types of users that represent the largest portion of the user base.

LIMITATIONS

I will not be able to represent all user types in my research or design explorations.

My designs explore opportunities for functions that currently do not exist on Cochlear Implants.

Design explorations will be limited to UI prototypes and screenshots.

USER-SENSITIVE INCLUSIVE DESIGN

Researcher Alan Newell of the University of Dundee is a Human Computer Interaction expert who heads one of the world's largest academic groups devoted to research of digital systems for older and disabled people. Using the insight he has gained from his 40+ years of research, Newell developed a design protocol that is meant to be an extension of Human Centered Design called User-Sensitive Inclusive Design (USID). This design method promotes empathy and mutual inspiration between researchers and users. USID seeks to incorporate older and disabled users into the design process from the beginning.
(Newell, 2011)

Using this as a method for the design of a more user-centered CI Interface, this investigation uses polls, surveys and interviews to form a deeper understanding of the users. Findings in this research informed the creation of three common "types" of users in the form of personas. Detailed user journey maps helped map out ideas in the design exploration by addressing the question, "How can this experience be better for this persona?"

ENCHANTED OBJECTS

In his book, *Enchanted Objects* (2014), researcher David Rose of MIT Media labs argues that Internet of Things is the key to a more human, “enchanted” future that can work to unglue our attention away from screens and “glass slabs.” As our technological landscape becomes “smarter” and objects become capable of working with other devices via the internet, Rose encourages designers to draw inspiration from fairy tales and interject “magic” and whimsy into everyday items that already exist. Rose defines an “enchanted object” as follows:

- An ordinary object augmented with technology and connected to internet services.
- Passive sensing which precludes the need for manual entry of information.
- Ever-present, ambient information that is displayed with a goal of continual feedback.
- Personal, emotional engagement with a social component and incentive structure.

LITERATURE REVIEW

HUMAN CENTERED DESIGN

DESIGN AND THE DIGITAL DIVIDE

INSIGHTS FROM 40 YEARS IN COMPUTER SUPPORT FOR OLDER AND DISABLED PEOPLE

A. F. NEWELL (2011)

This book outlines the design method that the primary author and researcher, Alan F. Newell, devised to create meaningful ways to include users who are older and/or disabled. The author argues that the Universal Design and Design For All movements have been beneficial in encouraging designers to consider accessibility. However, these movements promote an impossible goal of making designs accessible to all users. They have yet to offer a design methodology that enables a deep understanding of users with specific needs. Currently, the typical design approach for inclusivity or universality is to proceed as usual and tack on modifications after a prototype is developed. The authors declare that these changes are often ineffective and even detrimental to the overall design. The authors propose "User-Sensitive Inclusive Design" as a more appropriate design method. Using the principles of Human-Centered Design, Participatory Design and Design Empathy, they believe that designers can learn what their users truly need to be "included." As there is no "one-size-fits" all in design, they argue that designers must also evaluate and formulate research methods on a case-by-case basis.

LITERATURE REVIEW

HUMAN CENTERED DESIGN

THE DESIGN OF EVERYDAY THINGS REVISED

DON NORMAN (2013)

Norman coined the term User-Centered Design to label the design process of involving the user throughout a system's design and development cycles. This concept is an important aspect of Human-Computer Interaction where designers use information from the user's experience to inform their design decisions. In outlining what makes good design, Norman offers the following principles:

VISIBILITY: When functions are visible, users know what their options are and what to do. Conversely, when functions are hidden, the user has to work to understand what functions are available and how to access them.

FEEDBACK: Feedback informs users about what actions have taken place and where they can go from there to proceed. In interaction design, the tools for feedback include audio, tactile, verbal, and visual cues.

CONSTRAINTS: As important as knowing what the user can do is what they cannot do at a given point in the design.

MAPPING: Mapping refers to the correlation between controls and their actions. Clear mapping is intuitive to the user. As an example, buttons with up arrows should trigger an action that goes up while and down arrow buttons go down.

CONSISTENCY: Consistency is when the design in a system follows the same rules throughout, so that users do not need to learn new rules at each turn.

AFFORDANCE: Affordance informs users how to operate a control. If a button is offered, the clue is to push the button.

DISABILITY AND DESIGN

DESIGN MEETS DISABILITY

GRAHAM PULLIN (2009)

In *Design Meets Disability*, Pullin explores how design and disability can inspire each other. In the first section of the book, Pullin shows how design has the ability to reframe how we see assistive technology and disabilities. Pullin illustrates this in the example of the trajectory of eye glasses from a purely functional assistive device to a fashion statement. One of the main questions Pullin posits is whether or not there are simple design solutions to complicated accessibility features. In the second half of the book, Pullin interviews well-known designers of different disciplines who have been asked to tackle the design of different assistive devices. The results are many speculative designs that challenge negative connotations of disability.

LITERATURE REVIEW

DISABILITY AND DESIGN

THE END OF NORMAL

IDENTITY IN A BIOCULTURAL ERA

LENNARD J. DAVIS (2014)

Davis explores how the concept of “normal” has given way to “diversity” in many areas such as race and sexual identity, but not in the context of disability. Davis argues that we still see disability in a narrow view of medical terms. According to the author, this perspective casts a negative light on what disability stands for: it is portrayed as “abnormal,” and something to be fixed.

DISABILITY AND DESIGN

MORE THAN HUMAN

EMBRACING THE PROMISE OF BIOLOGICAL ENHANCEMENT

RAMEZ NAAM (2005)

In deep contrast with Lennard Davis, Naam explores the concept of augmenting the body to new extremes and makes the argument that we should embrace scientific and technical superpowers. Naam makes the case that as a culture we stand to benefit more as a society if we embrace, rather than fear human enhancements.

PARTICIPATORY CULTURE

THE WEALTH OF NETWORKS

HOW SOCIAL PRODUCTION TRANSFORMS MARKETS AND FREEDOM

YOCHAI BENKLER (2006)

In *The Wealth of Networks*, Benkler examines how the information age has transformed our culture and where he believes it will take us. The Internet has drastically reduced barriers to once expensive or otherwise unavailable tools, and computers have created many new forms of media to produce, share, and reproduce or repurpose. The author makes the point that this readily available access can create a more democratic society, and our current economic and political system will need to adjust to allow progress to thrive. For example, Benkler dives into the phenomenon of people who create and “work” for fun within a participatory context rather than for profit. He uses this as a basis to propose a new type of economic model that switches the value placed on the end-product over to the ideation, creation and production process. Benkler goes on to argue that success of this type of economy would require an open source or creative commons approach, so that various components of the work are available to all. Others may begin with what has already been built, rather than starting from scratch each time. Benkler makes the argument that building upon knowledge will directly drive progress in all fields and benefit culture as a whole.

LITERATURE REVIEW

PARTICIPATORY CULTURE

PARTICIPATORY CULTURE IN A NETWORKED ERA

HENRY JENKINS, MIZUKO ITO, DANAH BOYD (2015)

Jenkins et al (2015) attributes successful examples of participatory culture to the following properties: low barriers to artistic expression and civic engagement; strong support for creating and sharing creations; and informal mentorship among participants. Successful examples of participatory culture are communities that are made up of members who have formed a bond with other members. These members believe that their input matters. The authors break down participatory culture into four types:

AFFILIATIONS: This refers to membership-based communities that center around various forms of media.

EXPRESSIONS: This kind of participatory culture is devoted to new modes of creativity.

COLLABORATIVE PROBLEM-SOLVING: These communities rise from users working together in teams to complete tasks and develop new knowledge.

CIRCULATIONS: These examples of participatory cultures emerge from users shaping the flow of media.

USABILITY

USABILITY OF LINEAR, FISHEYE AND OVERVIEW + DETAIL INTERFACES

KASPER HORNBÆK AND ERIK FRØKJÆR (2001)

The authors in this research article conducted an experiment in 2001 to test the usability of different types of navigation systems. Their study focused on Linear, Fisheye, and Overview + Detail Interfaces. The study involved 20 participants who were asked to write essays and answer questions about scientific documents they read electronically using these different interfaces. The researchers found that their participants scored lowest while reading on a system that used a Linear Interface and they concluded that, though it is the most common interface in practical use, the Linear Interface is the least effective concerning usability.

LITERATURE REVIEW

USABILITY

A QUANTITATIVE EVALUATION OF THE DIFFERENCES BETWEEN KNOBS AND SLIDERS

STEVEN GELINECK AND STEFANIA SERAFIN (2009)

In their study Gelineck and Serafin set out to evaluate the user experience of different physical inputs for controlling sound. While their user tests did not show much difference in the user experience of knobs versus sliders, their research explained usability differences: knobs are best used when controlling parameters that have little to do relative to other controls whereas sliders are best for controlling components that are more comparable. In the context of designing sound controls, designers have predominantly modeled graphical interfaces after real world knobs and sliders. This decision is rooted in the fact that users have knowledge of the real world counterpart.

TYPES OF SOUND CONTROL INPUTS	GRAPHICAL USER INTERFACE CONTROLS
Physical Controls	Sliders
Sliders	Knobs
2D Sliders	Thumb Wheel
Knobs	Touch Input
Crank	Controls with Haptic Feedback
Thumb Wheel	Checkboxes (Mute)

USABILITY

HOW DO DIRECTIONAL DIVERSITY AND CONGRUENCE IN USER INTERFACES AFFECT USABILITY?

KWAN MYUNG KIM AND WOOHUN LEE (2009)

In a study on directional diversity and congruity in user interfaces, industrial design researchers Kwan Myung Kim and Woohun Lee found that if the volume controls on a television remote were vertical and showed a horizontal visual on the television, it was confusing to the user. They developed and tested four prototypes with different directions for volume control and changing the channels. When Kim and Lee applied Don Norman's concept of full natural mapping to a remote control prototype and the controls matched the visuals, it became an intuitive design where the user did not need to learn or memorize anything. Their test participants completed their tasks faster confirming their design hypothesis. They also found that users had a better "visual map" of how to change channel and the volume controls going up and down (rather than side to side) when they recorded longer task completion times in their tests.

LITERATURE REVIEW

USABILITY

DESIGNING FOR FEEL

HOW SOCIAL PRODUCTION TRANSFORMS MARKETS AND FREEDOM

COLIN SWINDELLS, KARON E. MACLEAN AND KELLOGG S. BOOTH (2009)

Graphical representation of knobs and sliders inform the users that their functions exist; however, tactile information has gotten lost in translation between physical controls and their graphical interface counterparts. Physical knobs and sliders support the User-Centered Design element of feedback through elements that the user can feel such as stiffness, detents (resistance in the control that indicates increments) and damping (reduction of amplitude). In a graphical interface, these elements of feedback disappear, making the graphical interface of sliders less precise than mechanical controls.

In addressing the loss of touch feedback when switching from physical knobs and sliders to graphical interfaces, Swindells, MacLean, and Booth propose the use of haptic controls. Their study focused on technical details of haptic input in knob controls, and their findings concluded that haptic feedback could successfully bring back precision through tactile feedback and create a better user experience.

SURVEYS AND POLLS

I posted a poll and a survey in a closed Facebook group called "Cochlear Implant Experiences." This group has over 15,000 members. It is meant to provide a forum for CI users, potential CI users and their family members to share their experiences, ask questions and learn about their devices or new assistive technology.

SURVEYS AND POLLS

FACEBOOK POLL

DO YOU LIKE AND USE YOUR REMOTE ASSISTANT?

The poll was created on Facebook and posted as a comment on the main page. The poll asked Cochlear Nucleus 6 users how they liked their remote assistant. 72 members of the group answered the poll, and the majority (55%) responded that they had the remote assistant, but did not use it. However, 6 of 9 commenters took the time to explain why they loved their remote assistant. Those who appreciated their remote assistants were the most vocal about it.

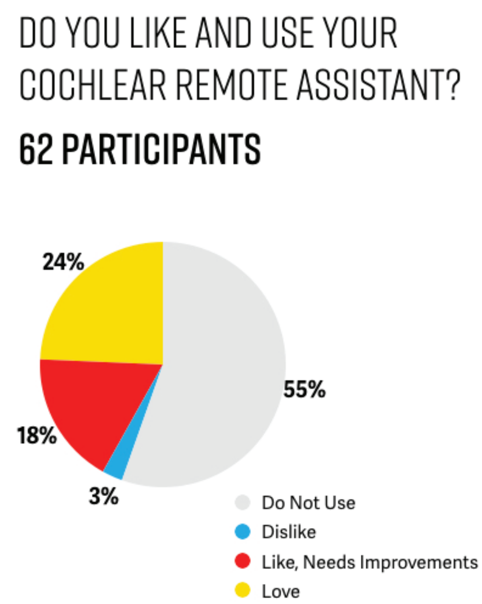


Figure 3: ***Facebook Poll Results***

SURVEYS AND POLLS

GOOGLE SURVEY

REMOTE ASSISTANT USER EXPERIENCE

To get more information about the Facebook group's user experience, I created a Google survey. The survey sought to find specifics of what Cochlear Implant users liked or did not like about the remote control. I wanted to find out what features they use the most and what features they would like to have, with spaces for participants to write answers as long as they wanted.

The Google Survey ended up with answers from a demographic of mostly 50-70 year olds who lost their hearing later in life. This is not representative of the Cochlear Implant community in general, but rather was represents those most likely to join a community online to share their Cochlear Implant stories.

PRIMARY FUNCTIONS OF THE REMOTE:

- Adjusting volume
- Adjusting sensitivity
- Switching between programs

WHAT PARTICIPANTS LIKE ABOUT THEIR REMOTE ASSISTANTS:

- Volume, Sensitivity and Program Control
- Not having to touch CIs to make changes
- Being able to check the battery level
- Easy switch to tele-coil mode

REMOTE ASSISTANT WISH LIST

- Easier and faster navigation
- Smartphone integration
- Customizability
- Ability to create their own Programs
- Pair CIs with more devices
- Better background noise reduction
- Ability to control hearing aids as well
- Voice activated controls

SOUND CONTROL STUDY

PURPOSE

The purpose of this study was to examine how users change volume with different sound control inputs. In this investigation, I sought to learn different preferences for controls and try to decipher reasons for these preferences. I conducted this study with four participants in a wide range of ages and with varying levels of technological knowledge. I asked my participants to adjust the volume on four devices: a sound mixer with sliders and dials, an older speaker with volume, bass and treble knobs, an iPhone 6 running Spotify, and a Macbook Pro running iTunes.

METHOD OF DATA COLLECTION

Since I needed to explore my participants' thought processes in order to understand my participants' user experience, I needed to ask questions in addition to making observations. With this in mind, I created an Observation Protocol with a list of questions. I developed questions to ask before the observable activity, during the activity, as well as following the activity. This study borrows research elements of both contextual inquiry and task analysis. For the observation sections of my protocol, I included images of each device so that I could map out my participant's interactions.

SUMMARY OF DATA

Though my data sample was too small to draw any major conclusions, it did show that those who are more familiar with analog music systems prefer a constant hardware input for sound control rather than software menus. My oldest participant was in her 70s and did not consider herself knowledgeable about technology. Research showed that she favored the physical inputs over the software inputs. While she understood the software images used to indicate volume control she became easily frustrated with having to go through multiple steps to find the controls and make changes.

Another one of my participants was in her 30s and considered her technological abilities to be average. My questions revealed that she was an avid music listener and has a deep familiarity with music apps including Spotify and iTunes. My observations and questions allowed me to conclude that the feature most important to her was being able to play music in any setting. This participant was not concerned about the detail of control or the physicality of the control. She favored the Spotify and iTunes sound controls best. My only male participant was very concerned about having full control over the sound. Though he was able to change music controls on any device expertly, he preferred the sound mixer because of the number of controls, as well as being able to see all the settings at one glance. He also mentioned he liked the physicality of it.

My fourth participant was in her 20s and well-versed in technology. She was not, however, particularly musically driven or meticulous about quality of sounds. She usually listens to music on her iPhone through earbuds. Her preferences were close to the preferences of my 72-year-old participant for what I surmise is a similar reason: ease of use.

SOUND CONTROL USABILITY STUDY

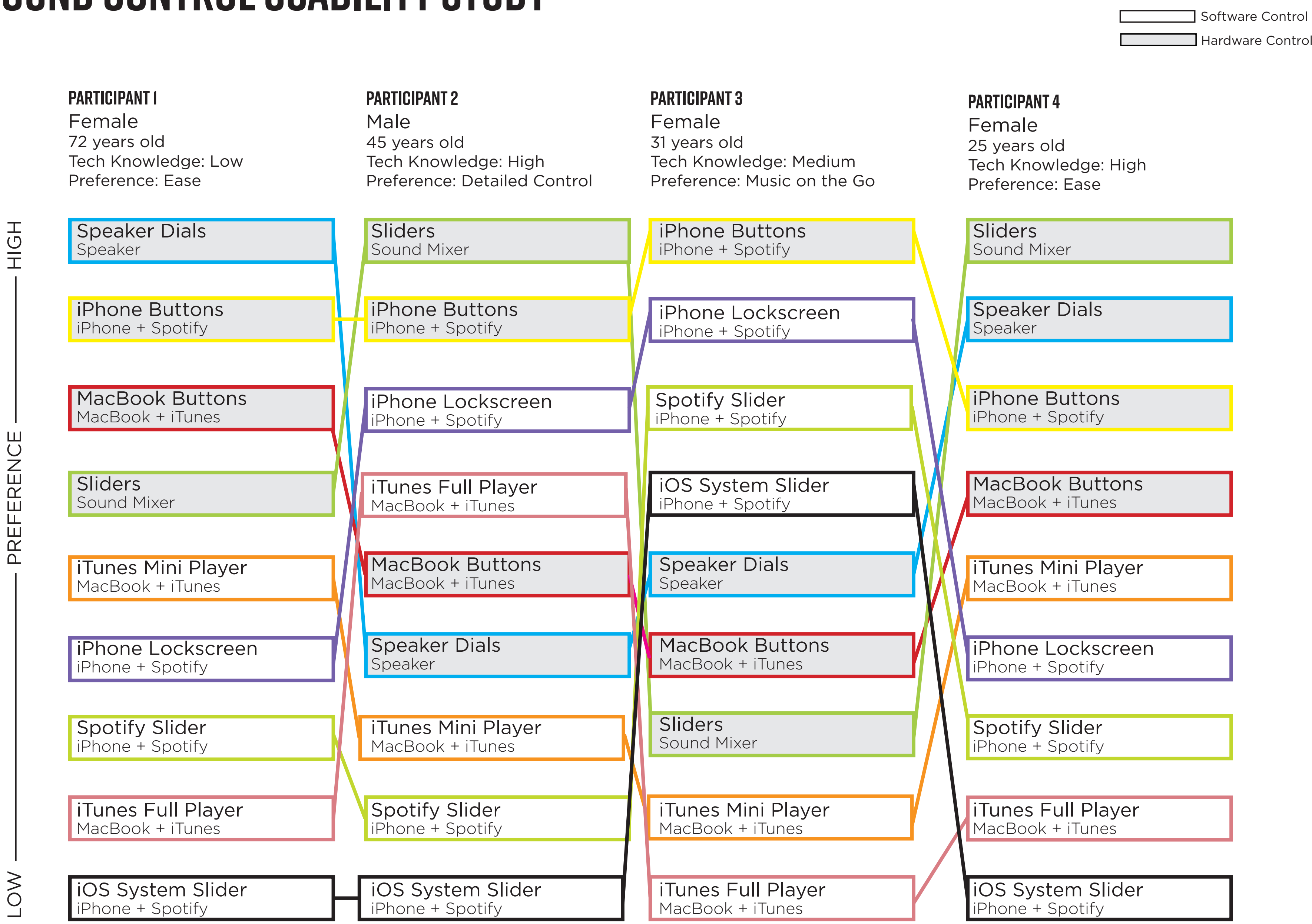


Figure 4: ***Sound Control Usability Study***

INTERVIEWS

In-person interviews gave me the most insight into the overall CI User Experience. My interview participants walked me through their day as a CI user. This is where I was given the most inspiration for where improvements in the design could be made. I also looked for inspiration in common challenges amongst them that are not necessarily a direct cause of their hearing devices.

Due to time-constraints and my limited access to Cochlear Implant recipients, I opened up my participant pool to users of hearing aids as well. Hearing aids also offer sound variables for users to adjust. While hearing aid users may have more flexibility in switching between hearing devices, they are no less of an invested stakeholder. Out of a total of seven interviewees, three were CI users and four were hearing aid users.

INTERVIEWS

Updating a Cochlear Implant The cochlear implant receiver is designed to be compatible with new sound processors. Users can update their external sound processors without getting surgery.

Lip Reading Many deaf and hard of hearing people supplement their listening skills with lip reading. And, for some, the combination of lip reading and sound input is essential.

PRESCHOOL TEACHER

ASHLEE | 31 YEARS OLD

LEFT EAR: NOTHING OR HEARING AID | RIGHT EAR: COCHLEAR IMPLANT

- Ashlee recently upgraded from a Freedom Cochlear (the older model) to the Nucleus 6 in her right ear. Ashlee is profoundly deaf in both ears, but she only has an implant in her left ear. She used to wear a behind-the-ear (BTE) high-powered hearing aid in her right ear as well, but now she wears just her Cochlear Implant. She hopes her health insurance will approve her second Cochlear Implant. Ashlee does not use the remote control to make changes. She instead relies on its buttons, lights and beeps to understand her settings.
- Ashlee finds it jarring to go from silence all night while sleeping to a cacophony of sounds in the morning. Ashlee would love a feature that allowed users to turn on their processors at a near silent setting and then gradually get louder and arrive at the normal loudness of that specific program. Ashlee envisioned a setting that would allow her to decide how long this would take.
- Ashlee's programs go from soft to loud. She prefers to change programs instead of changing the volume. This is due to the placement of the volume button and finding that she often hits the wrong button on her processor.
- At school, Ashlee teaches four classes a day and her preschoolers are between the ages of 2 and 6 years old. Two of the classes she teaches tend to be loud. During these times, she usually uses a softer Sound Profile. Ashlee cited "Legos crashing," and "screaming and squealing" as noises she wants to minimize.

- Ashlee's workday ends at 3pm. She turns off her Cochlear System in the car. For the 20 minutes it takes her to go pick up her daughter, Ashlee appreciates the silent break. Then she turns her Cochlear Processor on when she sees her daughter.
- Ashlee talked about how much she relies on her Cochlear Implant in her role as a mother.
- She finds that ambient noise bothers her. She will turn to a softer Sound Profile when a television is on in the background or if music is playing.
- Despite the fact she likes the quiet, Ashlee loves listening to music and uses her microphone to stream the music to her CIs wirelessly. She loves the fact that she can block out environmental sounds while listening to music.
- Sometimes Ashlee can understand people over the phone, but she does not feel comfortable enough to use the phone to call anybody whose voice she's not very familiar with. Ashlee prefers texting and Facetime, which allows Ashlee to read lips.

INTERVIEWS

SOFTWARE TESTER

STEVE | 73 YEARS OLD

LEFT EAR: COCHLEAR IMPLANT | RIGHT EAR: NOTHING

- Steve was diagnosed with progressive hearing loss when he was 35 years old.
- Steve started wearing hearing aids at 43 years old.
- By his late 60s, hearing aids could no longer help Steve hear, and Steve decided to get his right ear implanted (his left ear was inoperable due to damage caused by tumors).
- Steve is eagerly waiting for insurance to approve an upgrade to the Nucleus 6 from his deteriorating Cochlear Freedom (an older model). The soft plastic that covers two buttons has disintegrated and makes it very difficult, if not impossible, for Steve to change settings. He liked his Freedom when it was in better shape, and he is looking forward to having more control with the remote assistant when he upgrades.
- Steve uses the tele coil setting the most on his CI.
- He uses it to talk on the phone, and he uses it with his Neckloop, which picks up FM signals from either a microphone or a broadcast signal where available.
- Steve misses being able to enjoy music. He will still listen to “simpler” songs, but they don’t sound like anything like they did when he had normal hearing.
- Steve prefers to be “on” at all times, however he commented that his wife gets frustrated when she tries to talk to him when he gets out of the shower and has not put on his processor yet.

Updating a Cochlear Implant The cochlear implant receiver is designed to be compatible with new sound processors. Users can update their external sound processors without getting surgery.

Neckloop An FM Neckloop sends signals from a microphone through the Neckloop receiver and to the hearing aid or sound processor via tele coil.

Tele Coil/ T-coil/ T-switch Available in most hearing devices. A tele coil is a small receiver inside most hearing devices that picks up signals from a loop system acting as an electromagnetic field.

SINGER AND RESEARCHER FOR MED-EL

JOHANNA | 31 YEARS OLD

LEFT EAR: COCHLEAR IMPLANT | RIGHT EAR: NORMAL HEARING

- Johanna is from Germany. She was in college, studying music as a singer, when she contracted Meningitis and lost her hearing in her left ear.
- Johanna decided to get implanted because she missed having bilateral auditory feedback and sound directionality.
- She wears an off-the-ear processor offered by Med-El called the Rondo. The Rondo is held in place on the side of the user's head with a magnet.
- Johanna felt she had an advantage over other users because her musical background allowed her to fine-tune her sound profiles.
- She admits that the sound quality of the Cochlear Implant cannot offer high fidelity quality when it comes to music,. She finds that she is a better singer when she has her Cochlear Implant on, as opposed to wearing nothing in her deaf ear.

Off-The-Ear Applies to Cochlear Implants when the Sound processor is a single piece that is held in place on the user's head through a magnet.

INTERVIEWS

COLLEGE FRESHMAN | COMPUTER AND ELECTRICAL ENGINEERING MAJOR

NOLAND | 19 YEARS OLD

LEFT EAR: IN-EAR HEARING AID | RIGHT EAR: NORMAL HEARING

- Noland was born deaf in his left ear and has worn a hearing aid since he was 5. He does not sign and he does not consider himself to be a part of the Deaf community or the Hard of Hearing community.
- He is unhappy with his current hearing aid because he finds it physically uncomfortable to wear as an in-ear hearing aid.
- Changing settings is also labor intensive. With no remote or screen available to display information, users of this specific hearing aid must cycle through programs and volume settings with taps on a button and audible feedback in the form of beeps.
- Noland prefers his old hearing aid, a behind-the-ear model, which was larger and more visible but more comfortable.
- Noland feels that visibility doesn't matter as much as it did when he was growing up. Noland credits the rise of iPods and wearable technology for the declining stigmas of hearing aids.
- His "dream hearing device" would be customizable and modular for additional function.
- Noland also wears glasses, and he said he would love to be able to combine his hearing aids and glasses into one device that worked with gestures to make adjustments.

COLLEGE JUNIOR | SOCIAL WORK MAJOR

JIMMY | 22 YEARS OLD

BILATERAL BTE HEARING AIDS

- Jimmy was diagnosed with hearing loss due to a genetic condition at the age of six.
- His mother is also Hard of Hearing, and they are active in the Hard of Hearing community. They do not know sign language.
- Jimmy wears a Phonak BTE, and he's satisfied with his hearing aids. He he finds them comfortable, water resistant, and the batteries last a long time. These are features and qualities that his previous hearing aids did not have.
- Jimmy wishes his hearing aids were Bluetooth compatible, so that he could connect to his smart phone directly.
- He does not like wearing headphones over his hearing aids to listen to music. The sounds of the headphones rubbing on the hearing aid's microphone bother him.
- For additional assistance in classes, Jimmy uses a LiveScribe recording pen that records while writing. He finds this an invaluable resource, since he finds it difficult to write notes while listening and lip reading the professor.
- Jimmy loves going to the movies, which he has been going to regularly since Regal Cinemas started offering Closed Captioning Glasses. He would love to have the subtitles stream directly to his iPhone so that he could go to any movie theater.

Bilateral This means the user wears two hearing aids or two Cochlear Implants.

Unilateral In the context of hearing devices, this means the user only wears a hearing aid or Cochlear Implant in one ear.

Behind-The-Ear (BTE) This type of Cochlear Implant or hearing aid hooks over the top of your ear and rests behind the ear

Livescribe Echo A smart pen that records sounds as the user is writing. The sound is connected to the writing on the page. When the user taps a word in their notes, the pen plays back what was recorded when that word was written down.

INTERVIEWS

Mainstream education means going to a local school with hearing students. The deaf student may be verbal or have an interpreter throughout the day interpreting what is being taught by the non-signing hearing teacher.

ASL American Sign Language.

Deaf, deaf and Hard of Hearing titles all have different implications and are a very fragmented group.

SOCIAL WORKER

LISA F. | 40 YEARS OLD

BILATERAL BTE HEARING AIDS

- Lisa F. was diagnosed as profoundly deaf at 18 months of age.
- She went to public school and learned to both speak and write growing up. She has as many hearing friends as she does Deaf friends who communicate primarily through American Sign Language (ASL).
- Recently, Lisa has made a conscientious decision to not immerse herself in the Deaf community much because of “all the drama, all the time.”
- Lisa feels she is stuck between the hearing world and Deaf Community and does not feel like she truly belongs to either world.
- Lisa uses two BTE hearing aids and she referred to them as her “lifeline.”
- She does not make many adjustments to her hearing aids once she puts them on.
- Her favorite way to listen to music is on the car radio.
- If Lisa could create her dream hearing aids, they would be able to decrease background noise really well.

CHEMESTRY TECHNICIAN

LISA M. | 55 YEARS OLD

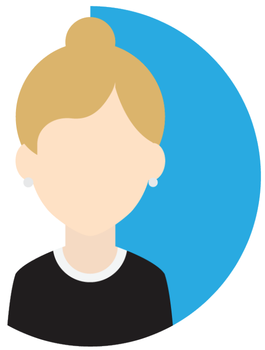
BILATERAL BTE HEARING AIDS

- Lisa M. lost her hearing when she was 19 and wears bilateral high-powered hearing aids.
- She took ASL classes in college, but communicates verbally.
- She is happy with her hearing aids, though she wishes they were louder.
- She does not make changes to her sound controls because she says she “likes to put them on and forget about them.”
- Though she uses a computer and emails regularly, Lisa prefers not to carry a cell phone. Because of her allergy to metals, she is averse to wearing jewelry or watches, much less a wearable device.
- Hearing aid functions that matter most to her are changing automatically between settings, but she admits that there is not a big difference in the sound quality.
- Lisa M uses a TTY to make phone calls.
- Lisa talked about the great difficulty she has communicating in big groups. She prefers to spend time with friends one-on-one.
- Towards the end of our discussion, Lisa spoke about the stigma with hearing aids concerning age. She was speaking about some of her hearing friends who were starting to lose their hearing but were reluctant to get hearing aids. Loss of hearing in their case means getting older. The connotation of this kind of deafness can mean isolation and depression.

PERSONAS

REPRESENTATIVE USER TYPES

Based on my research, I created three personas who represent the largest types of users.

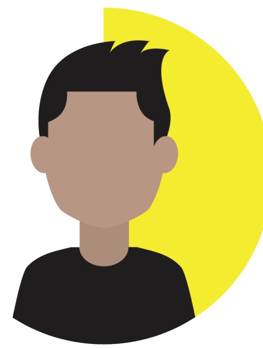


CHLOE

TEACHER | 30 YEARS OLD

WEARS A CI IN ONE EAR AND A HEARING AID IN THE OTHER

Chloe lives in the suburbs with her husband and two hearing children. Deaf since birth, Chloe wore hearing aids until she got implanted at 17 years old. She knows sign language and has struggled being between the hearing and the deaf world. She wears a Cochlear Implant in one ear and a hearing aid in the other.



MAX

PROGRAMMER | 24 YEARS OLD

WEARS BILATERAL CIS

Max lives in an apartment with roommates in a big urban city. He uses public transportation to go to his job at an internet startup. During his downtime, Max goes to clubs and he enjoys loud concerts. Max lost his hearing when he was 5 and got implanted shortly after. He is very comfortable in the hearing world and he has never learned to sign.

INGRID

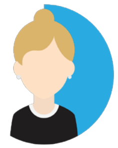
RETIREE | 71

WEARS BILATERAL CIS

Ingrid lives in a condo in a small city and spends her days socializing, entertaining and traveling. Ingrid started losing her hearing when she was 50. She wore hearing aids until she recently received bilateral implants. Ingrid is adjusting to her different-sounding world, but she is thrilled to be able to talk on the phone with her grandchildren again.

Figure 5: ***Personas***

A DAY IN THE LIFE OF CHLOE



MORNING

6:00 AM | WAKE UP

MOOD

Sleepy

ACTIVITY

Chloe wakes up and drinks coffee before putting on her processors and waking up her kids, starting a usually chaotic work/school day. She uses the "slow start" feature to slowly raise the volume of her Cochlear Implants over the course of an hour.

CONTEXT

A kindergarten teacher and the mom of two rambunctious elementary school kids, Chloe's days are loud and chaotic. Chloe prefers to block out as much sound as possible without losing important feedback with the kids in her lives.

OPPORTUNITY

- Give Chloe a peaceful morning, by starting her day quietly as she acclimates to the sounds.

6:45 AM | BREAKFAST

MOOD

Focused

ACTIVITY

With the kids getting ready for school, Chloe and her husband are making breakfast. Chloe uses the blender to make smoothies. The sound of the blender drives her crazy, so she uses her smart phone to block out the noise.

CONTEXT

Chloe grew up wearing high powered hearing aids. While she is grateful for her Cochlear Implants she has never grown to like the sounds they provide. Certain noises are especially odious.

OPPORTUNITY

- Promote user control over what they want to hear and what they want to filter out.

7:15 AM | MOM DUTY

MOOD

Focused

ACTIVITY

While Chloe is helping her son tie his shoes, her daughter calls her from the next room. Chloe's Amazon Echo recognizes that her daughter is calling for her and glows as the CI raises the volume to alert.

CONTEXT

As a busy, working mother, Chloe's attention is often divided. The User Interface of the CI has the ability to filter out what's needed and what's superfluous.

OPPORTUNITY

- Allow Chloe to wake up peacefully as well as be alert and aware for her family.

7:30 AM | DOORBELL

MOOD

Preoccupied

ACTIVITY

Chloe is preoccupied helping the kids when the doorbell rings. Her smartphone vibrates to notify Chloe of doorbell sound.

CONTEXT

Chloe's kids carpool with neighbors and parents rotate dropping them off to school.

OPPORTUNITY

- Allow Chloe to pay attention to what's at hand, rather than having to be hyper-vigilant about looking and listening intently to hear the doorbell.

NOON EVENING BED

8:45 AM | CLASS I

MOOD

Professional

ACTIVITY

Chloe is explaining an exercise to the class when the intercom comes on asking that one of the students come to the front desk. Chloe enables “Scriber” on her smart phone to find out who was called.

CONTEXT

The school’s intercom is old and shrouds messages in static. Chloe often cannot understand them without assistance.

OPPORTUNITY

- Use voice recognition software to give Chloe transcription in real time.

1:45 PM | CLASS II

MOOD

Professional

ACTIVITY

Chloe is walking around the room when a student calls her name. Unsure of where the student is calling her from, she looks down at her wearable which shows pulsing from the direction where noises are coming from. Red symbolizes voice and the pulse comes from the top right corner of her wearable. She looks up to see her student holding up his hand and calling to her.

CONTEXT

Though she is deaf in both ears, Chloe only has one ear implanted. She has no sense of sound location.

OPPORTUNITY

- Use an omni-directional microphone to determine where sound is coming from and show users in a visually pleasing manner.

5:45 PM | DRIVE THRU

MOOD

Relaxed

ACTIVITY

Chloe has picked up her daughter from soccer practice and decides to take her for a treat at McDonald’s. They go through the drive thru. The car detects the drive thru and pulls up a live transcription.

CONTEXT

Chloe can make sure she’s hearing the person clearly by reading the live transcription.

OPPORTUNITY

- The car’s large console screen and capacity for modularity allows for many additions that work with the SoundSpace.

7:45 PM | TELEVISION

MOOD

Relaxed

ACTIVITY

Chloe and her family sit down to watch the latest Pixar offering. She pulls up the streaming menu on the SoundSpace app on her phone to pick her input of choice. The SONOS stereo, land line telephone and television show up. Chloe choses the Television and it starts a direct connection to Chloe’s CI.

CONTEXT

Chloe watches TV with closed captioning, but likes to practice her hearing with a direct connection.

OPPORTUNITY

- SoundSpace can determine what devices can be streamed.

*Figure 6: **The User Journey Map of Chloe***

THE DAY ACCORDING TO MAX

MORNING

7:00 AM | WAKE UP

MOOD

Groggy

ACTIVITY

Max wakes up to his wearable device's haptic alarm. He showers and puts on his Sound Processors. This initiates a sequence that Max has previously compiled: music streaming a morning music playlist that grows in volume over time.

CONTEXT

Max lives in Brooklyn with three normally hearing roommates.

OPPORTUNITY

- "Slow Start" option to slowly increase volume over time.
- A familiar playlist also eases the transition from total silence to a world of cacophony.

8:00 AM | CAFE I

MOOD

Content

ACTIVITY

Still listening to music, Max walks to a busy nearby cafe for his morning buzz. Not wanting to stop his pre-set sequence, Max uses his smart watch to pause the music and place his caffeinated order.

CONTEXT

Max uses his smart watch to pause the music and switch to environmental sounds before automatically resuming his playlist

OPPORTUNITY

- A quick pause allows for minimal disruption in Max's morning cycle.
- Pause options include a timed pause or an indefinite pause.

8:15 AM | CAFE II

MOOD

Energized

ACTIVITY

Max's coffee order is ready and the barrista calls out his name. Max is listening to music, but his smartphone recognizes that his name being called and alerts him.

CONTEXT

Max does not have to stop listening to music in the hectic cafe.

OPPORTUNITY

- Max can control the proportion of how much hearing is music and how much is environmental.
- If Max fails to hear his name in the busy cafe, voice recognition software in his smart devices can alert him.

10:30 AM | MEETING

MOOD

Focused

ACTIVITY

Max is in a company-wide meeting in a large conference room. He loses track of who is talking and misses part of the conversation. Max activates a "Scriber" feature which saves a transcription of the last hour of speech.

CONTEXT

Cochlear Implant users still rely on lipreading to communicate

OPPORTUNITY

- Using an Alexa or Siri type of feature, the interface can keep a recording of a user-defined length of time and use speech recognition software to transcribe it on devices for the user.

NOON

EVENING

BED

12:30 PM | LUNCH

MOOD

Hungry

ACTIVITY

Max eats lunch in a noisy cafeteria. Based on the time and location, his CIs switch to cafeteria mode. Max reduces the diameter of sound to better hear his colleagues.

CONTEXT

Interviews with Cochlear Implant users reveal that they often avoid noisy places. Making the settings simple to understand can offer the users greater control and enable the confidence to enter these situations.

OPPORTUNITY

- Currently, this feature on the Cochlear implant is labeled "Sensitivity." Making the language and visuals clearer will make the interface easier for users to operate.

7:30 PM | DINNER

MOOD

Hungry

ACTIVITY

Max microwaves some ramen noodles. The microwave alerts Max when the noodles are done.

CONTEXT

Max easily misses auditory notifications.

OPPORTUNITY

- The user interface can connect to smart objects to get Max's attention.

9:30 PM | CLUB I

MOOD

Social

ACTIVITY

Max and friends enter a club. New to the venue, Max downloads a profile from the Interface's social network which stores profiles by location information.

CONTEXT

Rather than having to build a new sound profile, Max is able to download one that another user has created based on the location and the type of environment.

OPPORTUNITY

- Browses settings for new location Tries it, adjusts it and saves it to his account.

10:00 PM | CLUB II

MOOD

Social

ACTIVITY

As Max enjoys the concert, Max makes sound adjustments on the spot. He first applies a filter for rock music, then adjusts the EQ. He saves this setting and uploads it to the shared depository of sound profiles.

CONTEXT

The ease of sharing in the user interface encourages participation among users.

OPPORTUNITY

- The user base of Cochlear Implants becomes a community that learns how to best augment their Cochlear Implants collectively.

11:30 PM | BED

MOOD

Tired

ACTIVITY

Max takes off his processors to take a shower and get ready for bed. 15 minutes pass without activity and the processor alerts Max's wearable device to charge his Cochlear Implants batteries.

CONTEXT

Max is tired and forgetful.

OPPORTUNITY

- Help users charge maintain their Cochlear Implants.

Figure 7: ***The User Journey Map of Max***

WALKING IN INGRID'S SHOES

MORNING

NOON

8:45 AM | SETTING UP

MOOD

Nervous

ACTIVITY

Ingrid is a new SoundSpace user and she is setting up her system for the first time.

CONTEXT

Ingrid does not consider herself technologically savvy, but she has an iPhone and uses Siri frequently.

OPPORTUNITY

- Walk new users through the process of creating a new SoundSpace account that is ready to start learning user patterns.

10:45 AM | PHONE

MOOD

Happy

ACTIVITY

Ingrid is calling her grandson, who lives across the country.

CONTEXT

Ingrid has not been able to hear on the phone since her hearing deteriorated beyond the help of Hearing Aids around 2 years ago. This is the moment she has been looking forward to most.

OPPORTUNITY

- Create a seamless experience, so as not to take away from joy of connecting with loved ones across the world.

11:45 AM | AIRPORT

MOOD

Excited

ACTIVITY

Ingrid is catching a plane to visit her friends in another country. She must go through security where she is asked to go through the metal detector.

CONTEXT

Being a CI user and traveler is a source of stress because she does not want to risk erasing the map on her CI by going through the metal detectors.

OPPORTUNITY

- Show pertinent information on her smart phone to show to the TSA that fully informs them of the situation.

EVENING

BED

1:45 PM | IN THE AIR

MOOD

Sleepy

ACTIVITY

Ingrid is trying to practice listening with her new ears with a listening exercise built into the interface, but the droning of the airplane is bothering her.

CONTEXT

Certain noises can sound terrible to the CI user regardless of how much they love their Cochlear Implants. Ingrid activates the Noise Remover and mutes the frequency that the offending noise is emitting.

OPPORTUNITY

- Motivate users to practice listening and instill the idea that this works if you put in the work.
- Filter out unwanted sounds to create a more welcoming sounding world.

5:45 PM | AIRPORT

MOOD

Tired

ACTIVITY

Ingrid wants to turn up the volume of her Cochlear Implants to hear the announcements.

CONTEXT

Ingrid is disembarking the plane and has her hands full with her carry on bags. She activates Siri on her phone and asks to turn down the volume.

OPPORTUNITY

- Create Voice commands for changing controls.

8:45 PM | FIRE ALARM

MOOD

Tired

ACTIVITY

Ingrid is staying at a friend's apartment in an old building. She is getting ready for bed when the fire alarm goes off.

CONTEXT

There is a chance that Ingrid could miss out on the noisy fire alarm if her CIs are turned off and there are no flashing lights to alert her. The screens of all her devices flash, haptic controls on her wearable device go off, and if her processors are on, they turn on as well.

OPPORTUNITY

- Make the world safer for users by listening out for dangers and alerting users in as many ways as possible.

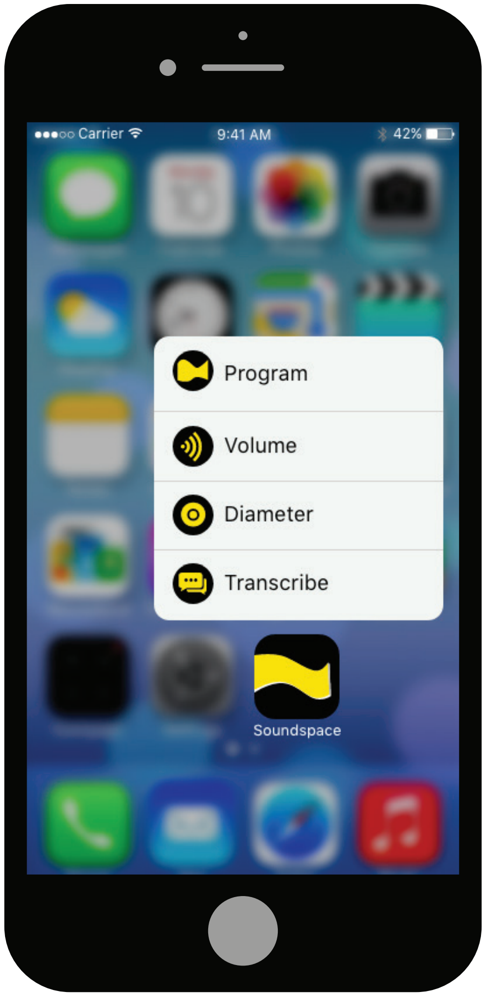
Figure 8: ***The User Journey Map of Ingrid***

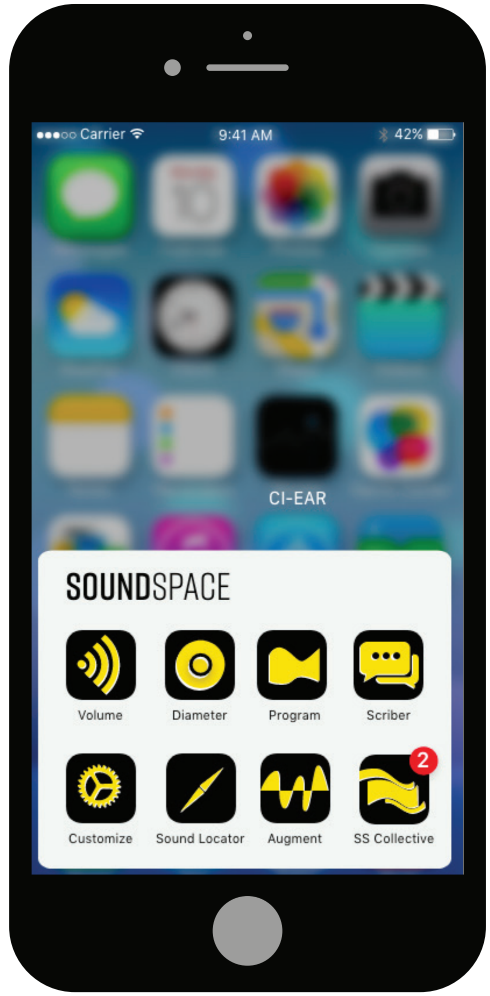
SOUNDSPACE

DESIGNED BY YOU, HEARD BY ALL

SoundSpace is a CI remote control interface that is connected to the internet and lives on many connected devices. This is a highly customizable, contextual interface that learns the user's habits and preferences.

USABILITY





QUICK ACCESS

CONTROL PANEL

Integrate customizable menus in system-wide user controls, such as the iPhone's Control Panel and 3D Touch Menu to ensure quick access

CUSTOM GESTURES

Allow users to create unique gestures that instantly access the controls of their choice.

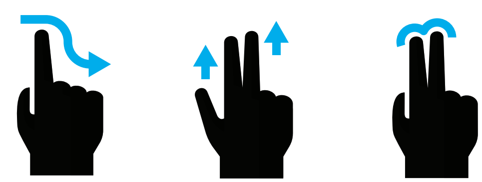


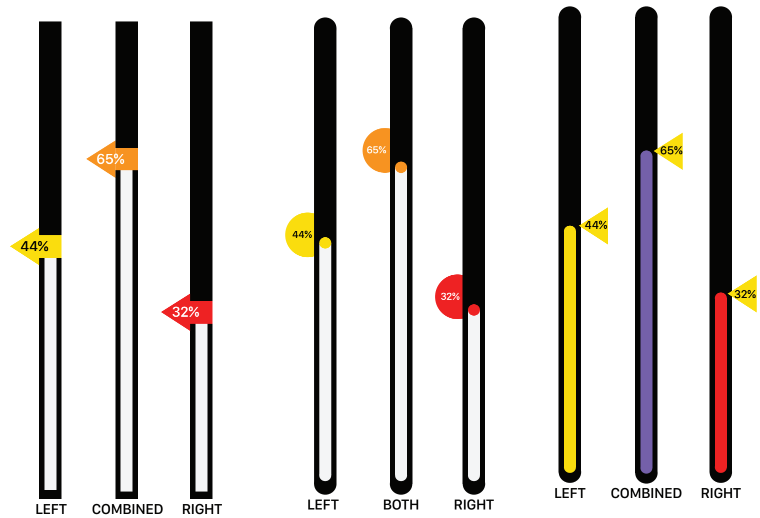
Figure 9: ***Design Explorations | Usability 1***

USABILITY

VOLUME

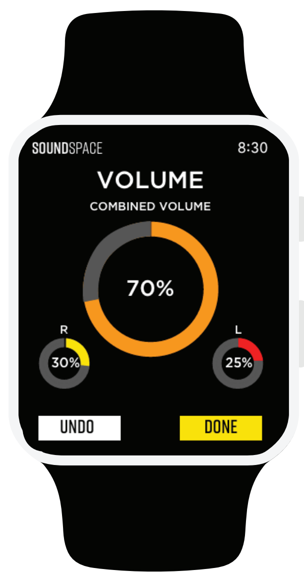
UP & DOWN SLIDERS

To abide by Don Norman's rules of good design (2013), map the placement of controls and variables in a way that users will intuitively understand. The volume should go up and down, the left ear control should be on the left and the right ear on the right side. The center slider allows users to boost the volume while keeping the percentage for each ear the same.



DIALS WITH HAPTIC FEEDBACK

Connected wearables such as the Apple Watch are the perfect vessel for a dial interface for controlling the volume. A dial visual takes advantage of the fact the Apple Watch has a dial on its side and the built-in haptic capabilities that provide feedback and precision.



COLOR SENSE

Yellow and red are consistently used to represent the left and right ear respectively. The combined volume is orange to represent a mixture of the two colors.

HEARING DIAMETER

GOING IN CIRCLES

The current system for changing this variable is an up and down slider that requires trial and error to learn how to make the changes the user wants to make. Circles are a more appropriate visual. Users can use a pinching gesture to widen or decrease their depth of sound.

~~SENSITIVITY~~

SOUND DIAMETER

LANGUAGE MATTERS

Currently this variable is called “Sensitivity,” which is confusing when the other main variable is Volume. An interviewee described Sensitivity as a diameter of sound that the CI picks up. My design proposes a change from “Sensitivity” to “Sound Diameter.”

Figure 10: ***Design Explorations | Usability 2***

DESIGN EXPLORATIONS

CUSTOMIZATION

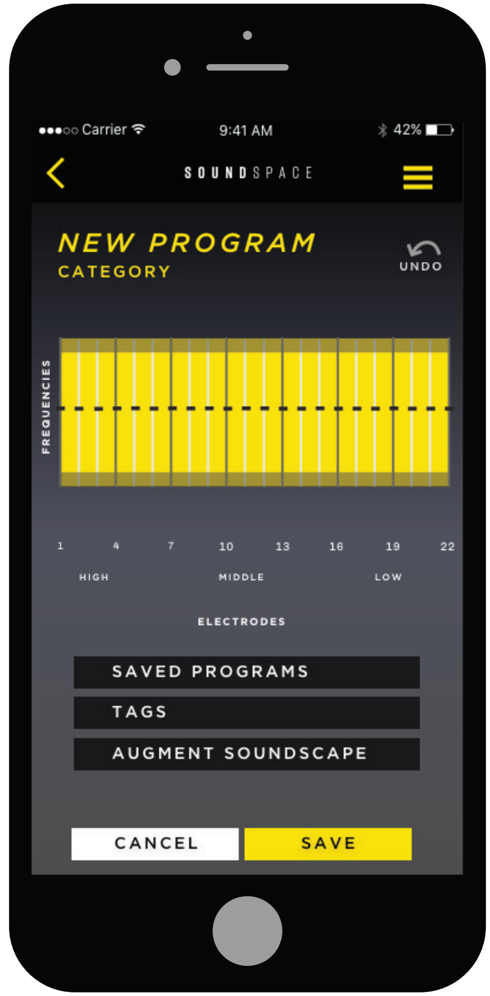
USER PROGRAMING

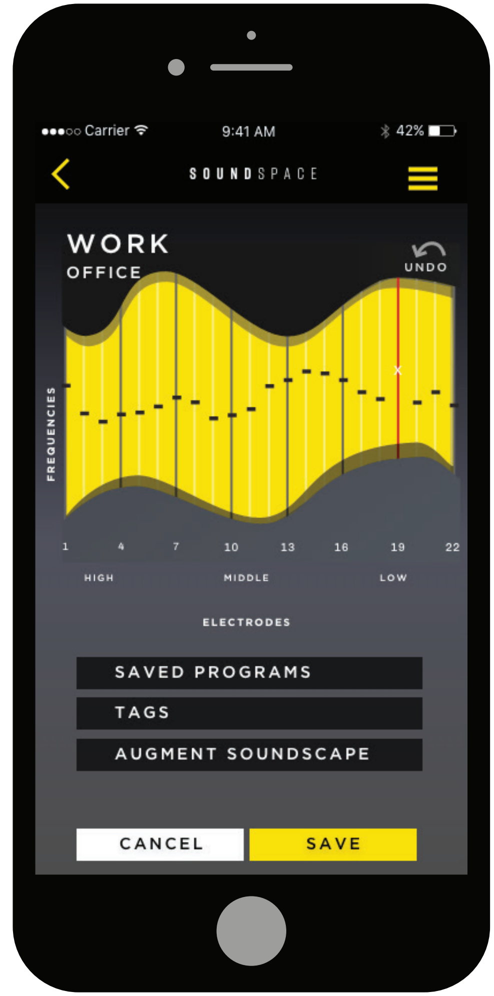
COUTURE HEARING

Since the sound produced on a Cochlear Implant is completely digital, users have the incredible ability to create different sound programs for different environments.

However, users today must visit an audiologist to create up to four programs that their devices can store. If the Cochlear interface were connected to the Internet, a cloud-based storage solution would allow users to create and save many programs.

My interviews revealed a common frustration: users were designing these programs in a quiet audiologist's office. This meant they were not able to test out these settings in the appropriate environment.





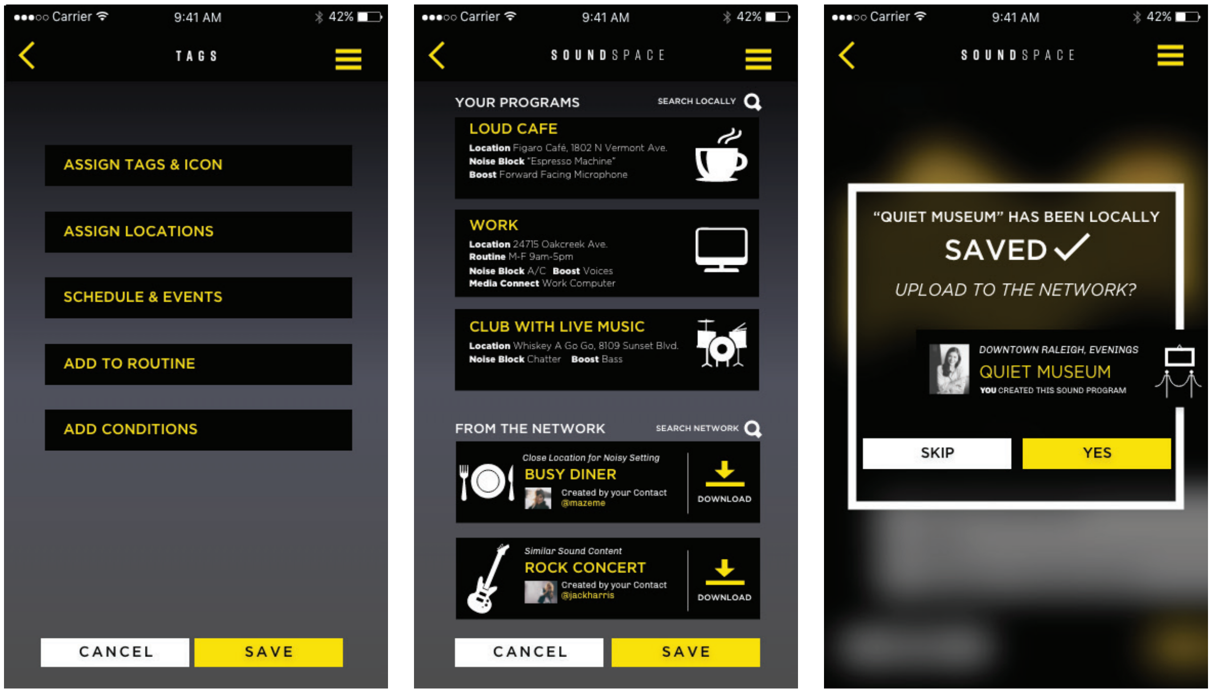


Figure 11: ***Design Explorations* | *Customizations***

TAGGED FOR AUTOMATION

This design concept allows users to tag their profiles with location, scheduled events, time of day, weather conditions and proximity to specific people. This gives the interface the ability to learn the user's preferences and behaviors.

POWER TO THE USER

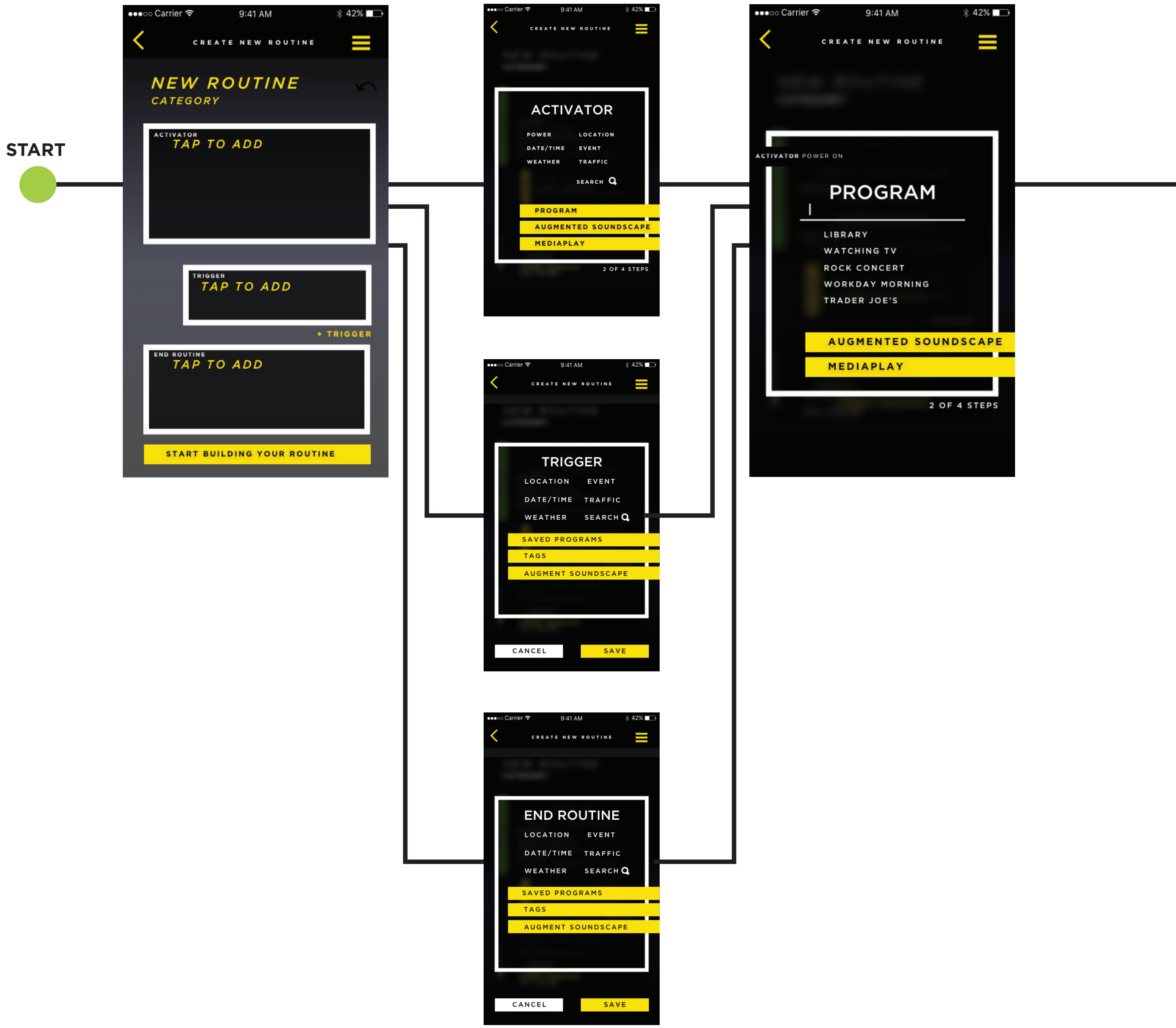
Currently, the remote assistant offers four slots for Sound Programs that the user creates at the audiologist's office. Once these programs are uploaded, users can only make changes if they make another appointment with the audiologist. This is an expensive, as well as a time consuming, endeavor. Allowing users to create their own profiles grants them autonomy and gives them a greater sense of control over their hearing.

A CONNECTED INTERFACE

ROUTINES

A SEQUENCE OF EVENTS

Routines allows users to design an automated series of actions that follows rules based on time, location and data available online. This walk-through of routine creation shows the parameters that users can set in their routines.



DESIGN EXPLORATIONS

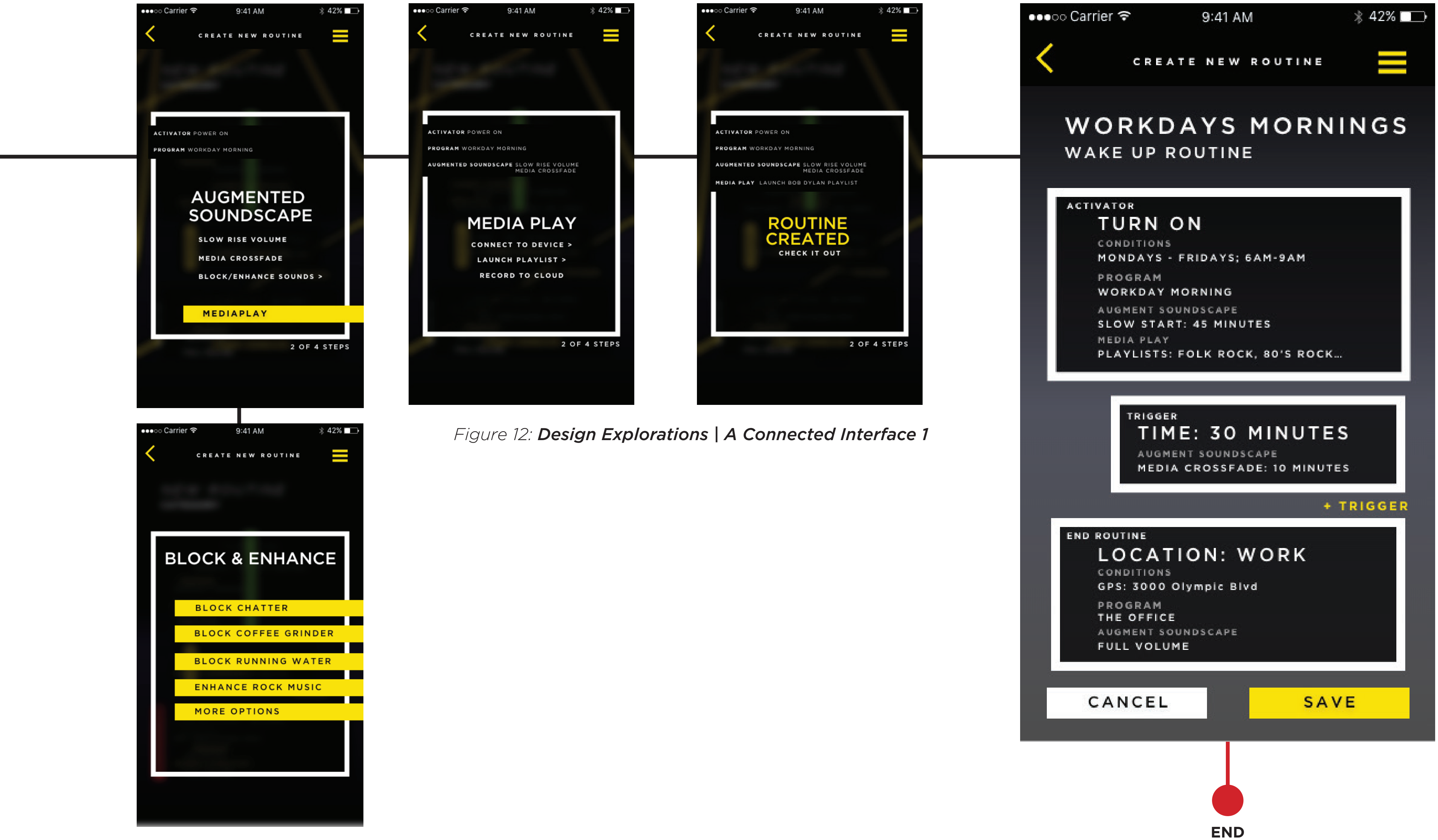


*Figure 12: **Design Explorations | A Connected Interface 1***

A CONNECTED INTERFACE

A ROUTINE IN ACTION

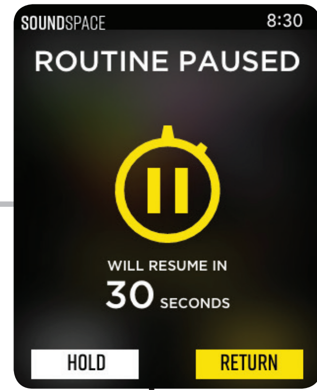
Here is an example of how a routine works.

“Turning on” initiates a sequence that Max has previously compiled. This specific routine is set to run on work day mornings.

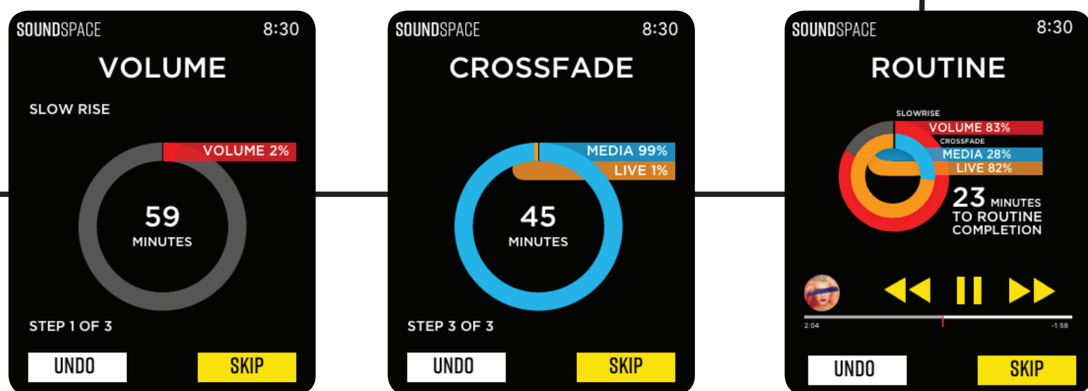
Max likes to “warm up his ears” in the morning to ease the transition between total silence while sleeping and full sound. This routine is set to wirelessly stream a morning playlist.

Max wakes up to his wearable device’s haptic alarm. He showers and puts on his Processors. His smart watch recognizes this and opens SoundSpace automatically.

The Quick Pause function automatically resumes where the music and the routine left off after 30 seconds.



Not wanting to stop his pre-set routine, Max uses his wearable device to pause the music and place his caffeinated order.



This routine is set to rise in volume and transition slowly into environmental sounds in a crossfade feature.

Still listening to music, Max walks to a busy nearby cafe for his morning buzz.

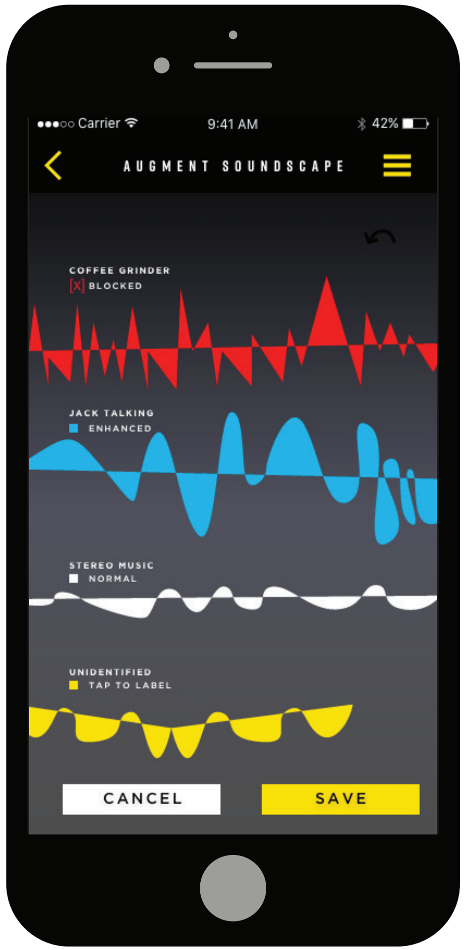
Figure 13: ***Design Explorations | A Connected Interface 2***

SUPER HUMAN

SOUND AUGMENTATION

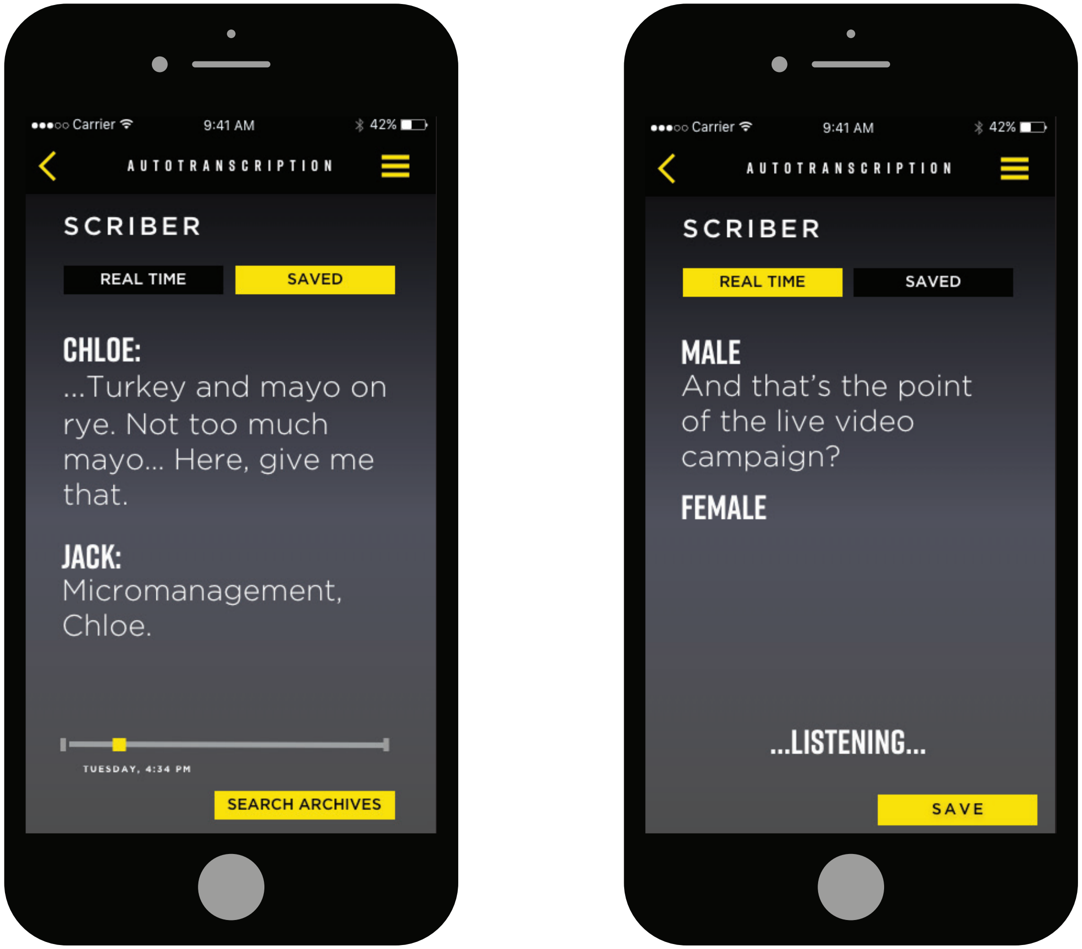
SELECTIVE HEARING

David Rose (2014) talks about people's willingness to spend money on filtering out things. Many of my interview participants discussed certain sounds they disliked: loud noises, running water. This design exploration posits the question of how could an interface allow users to block certain noises? How could the UI translate sound?



IS THERE A MAX IN THE HOUSE?

Name Detection is a feature that alerts users when their name has been called. This feature will activate even when the user is listening to music.



SCRIBER

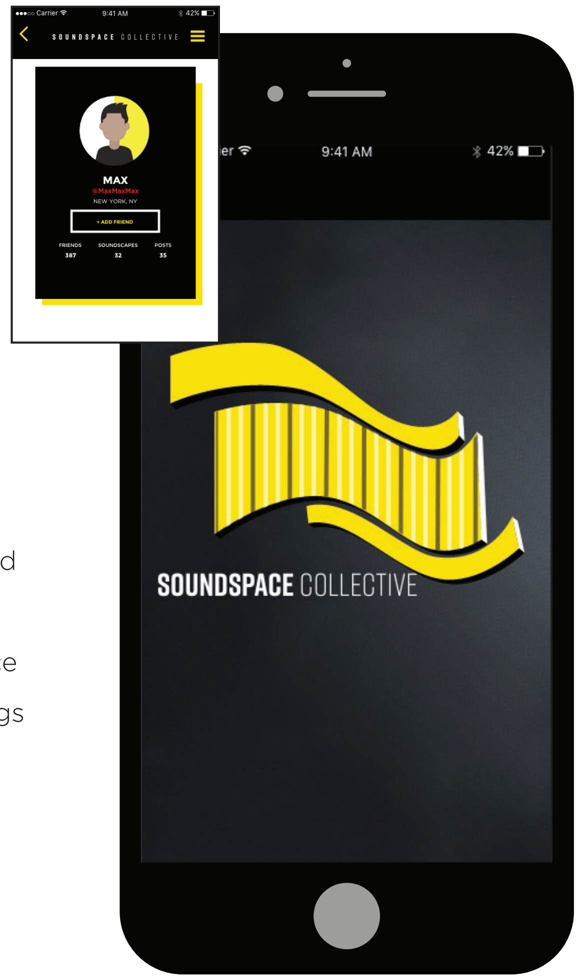
WHAT? HUH? COME AGAIN?

The SoundSpace interface seeks to alleviate common challenges that Cochlear Implant users face. These features are outside the realm of what a typical hearing device can do. With this auto-transcription feature, the recording feature on smart devices can keep a recording of a user-defined length of time. It can then use speech recognition software to transcribe it on devices for the user.

*Figure 14: **Design Explorations | Super Human***

NETWORK

SOUNDSPACE COLLECTIVE



TO LEARN & SHARE

A major component of SoundSpace is a private, built in social media network called the SoundSpace Collective. This would be a forum solely for the users of SoundSpace to be able to download and upload settings and new features.

GIVE USERS A VOICE & A FORUM

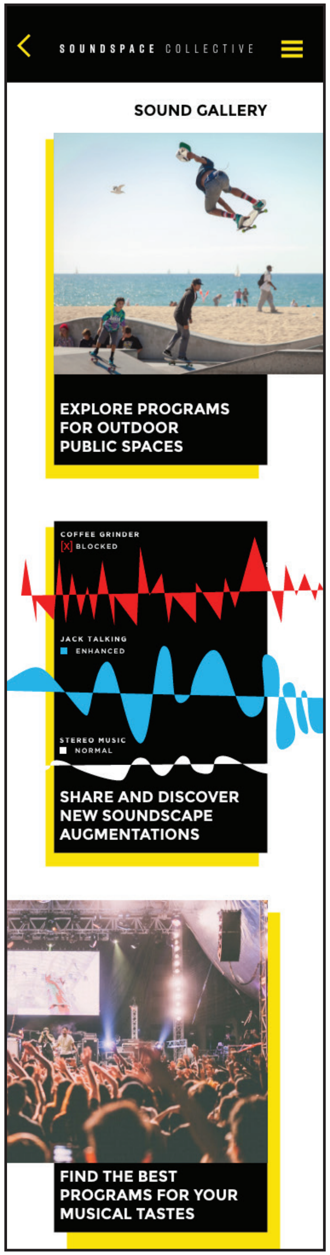
A forum would grant users the power to have their voices and criticisms heard.

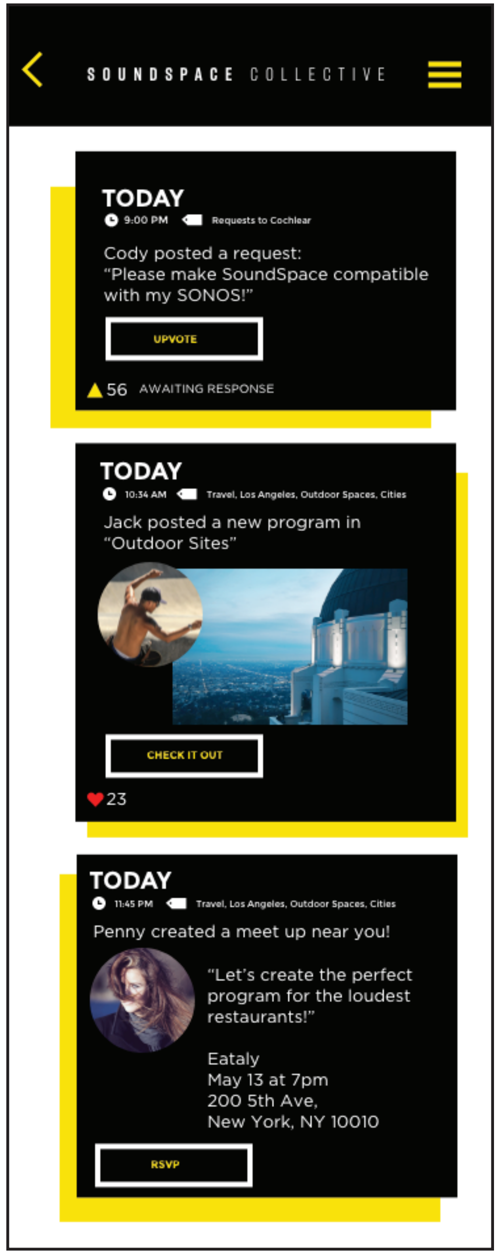
PUSHING FOR EVOLUTION

The SoundSpace Collective looks at how an open-source approach to sharing and remixing settings can push the progress of a CI interface tremendously.

BIG DATA, BIG PROGRESS

The data generated by users would be invaluable to CI manufactures, designers and researchers in the field.





BRIDGE THE DIVIDE

The deaf community is very fragmented there is a great divide between those who sign and those who are verbal communicators. Another positive aspect of a private social media component is that it would give CI users easy access to a community with other CI users. This could be incredibly helpful in bringing together different factions of the deaf community.

Figure 15: ***Design Explorations | Network***

RISK ASSESSMENT

ADDRESSING SAFETY CONCERNS

PRACTICE SAFE DEAFNESS

Designing an interface for assistive technology will invariably draw closer scrutiny of whether or not features are safe or harmful for users. Following my design explorations, I conducted a risk assessment study. I designed solutions to address some of the safety concerns that could potentially exist with this type of interface. For example, if a user decides to block a sound that could indicate a dangerous situation, the interface could learn different warning sounds and use haptic controls on a wearable to alert the user.

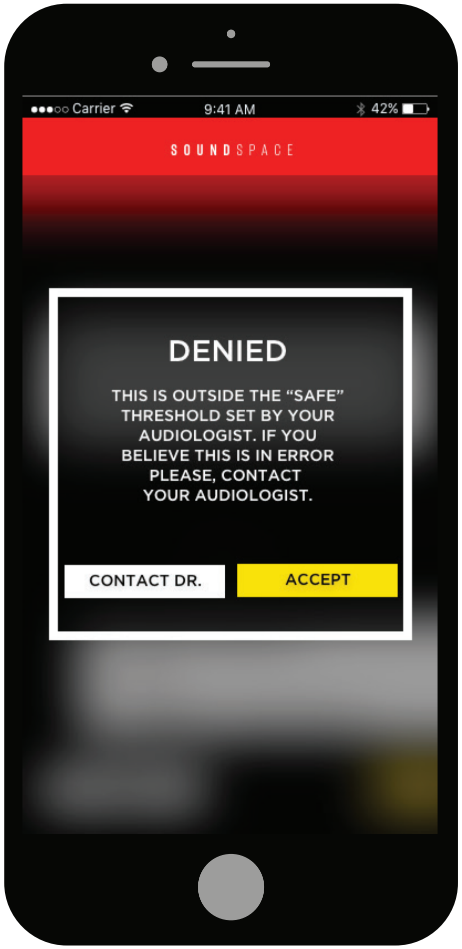
FUNCTION	USER NEEDS	DEVICE REQUIREMENTS
QUICK ACCESS MENU	User needs to be able to quickly access their most used and/or important functions.	The interface requires a flexible navigation structure. The interface must have many ways to access many pages.
VOLUME	User needs to be able to quickly adjust the volume of their Cochlear Implants.	The device must have a touch screen with haptic feedback capabilities.
SOUND PROGRAM CREATION	User needs to be able to test sound programs in the environment for which the program is intended.	The device must have the ability to create, store and switch between hearing programs.
TAG PROGRAMS TO LOCATION, EVENTS, WEATHER, ETC.	User needs to be able to tag sound programs to relevant information such as time of day, location or events in their calendar.	The interface must exist on a multi-functional, internet-connected device that has access to the user's information across several systems
CREATION OF SEQUENCES AND ROUTINES	The user needs to be able to move from different sound settings without having to manually change sound programs.	The interface must allow tags assigned to profiles to act as triggers for automation.
SCRIBER	The user needs to be able to understand what is being said when they have difficulty hearing or keeping up with whomever is talking.	The device must have a microphone, the ability to record and decipher speech and transcribe it for the user to read.
NOISE BLOCKER	The user needs to be able to block out unwanted sounds.	The device must be able to pick up sound and display the sound visually.
COMMUNITY	The user needs to be able to communicate with other CI users and share their settings with other users.	The interface must exist on a multi-functional, Internet-connected device.

DESIGN IMPLEMENTATION	RISK	MITIGATION
A customizable menu on a mobile device with touch screen capabilities. Allow the CI controls menu to live in the system control menus that are accessible with special gestures (swipe up; 3d touch). Allow users to prioritize functions.	The user conducts an unwanted action.	The interface also has to offer a quick “undo” feature and the fast access will help the user backtrack on any unwanted actions.
A touch screen on a mobile device that allows for a custom gesture that pulls up the volume control and allows users to quickly and easily change the volume.	The user turns the volume up to a dangerous level.	The audiologist will set safety parameters that limit these controls to safe levels.
The interface houses the function of designing sound profiles “on the go.” This alleviates trips to the audiologist’s office and allows users to test their programs in the environment they intend to use the program.	User’s privacy could be compromised.	Encrypt data.
Allow users to tag information to their sound programs either during or after creating and saving a program. Allow users to connect sound programs from other programs.	The user is unable to quickly exit The routine or sequence.	Offer access to a function that allows users to pause or stop sequences.
Allow users to create sequences of events based on relevant information. For example, if a user prefers one program at home and another at work, the user can set this automatically to happen based on GPS.	The user creates programs that are unsafe for both the user and/or the internal device.	The audiologist will set safety parameters that limit these controls to safe levels.
Aid users beyond helping them hear as well as they can and give users a backup plan for when they are not able to catch everything. This feature automatically saves audio and can either transcribe speech in real time or reach back in time with a saved transcript that users can refer to after the fact.	Privacy is a concern.	Encrypt data. Make this an optional feature. Automatically delete unsaved data.
Give users better control over their hearing experience by allowing them to block out unwanted sounds.	This feature could block out sounds to user that inform them of danger.	Build in safety alerts that send alerts on users’ devices that indicates danger.
Implement a new social media network just for users of this CI remote ecosystem. The network allows users to post questions and share their settings with other users. Make this an optional portion of the remote app.	The user’s privacy is at risk.	Make this social network available only to users who opt-in.

Figure 16: ***Design Explorations | Risk Assessment***

SAFETY

DESIGNING FOR SAFETY



SETTING LIMITS

To protect the user and their devices, this concept relies on the user's audiologist to set safety constraints as to what they can adjust and the range of sounds that is safest for them.

KEEP ALERT

If a user decides to block a sound that could indicate a dangerous situation, the interface could learn different warning sounds and use haptic controls on a wearable to alert the user.

A caution screen could also provide resources for CI users in case of an emergency. Having the ability to text 911 would be very helpful for users who don't feel comfortable talking on the phone.

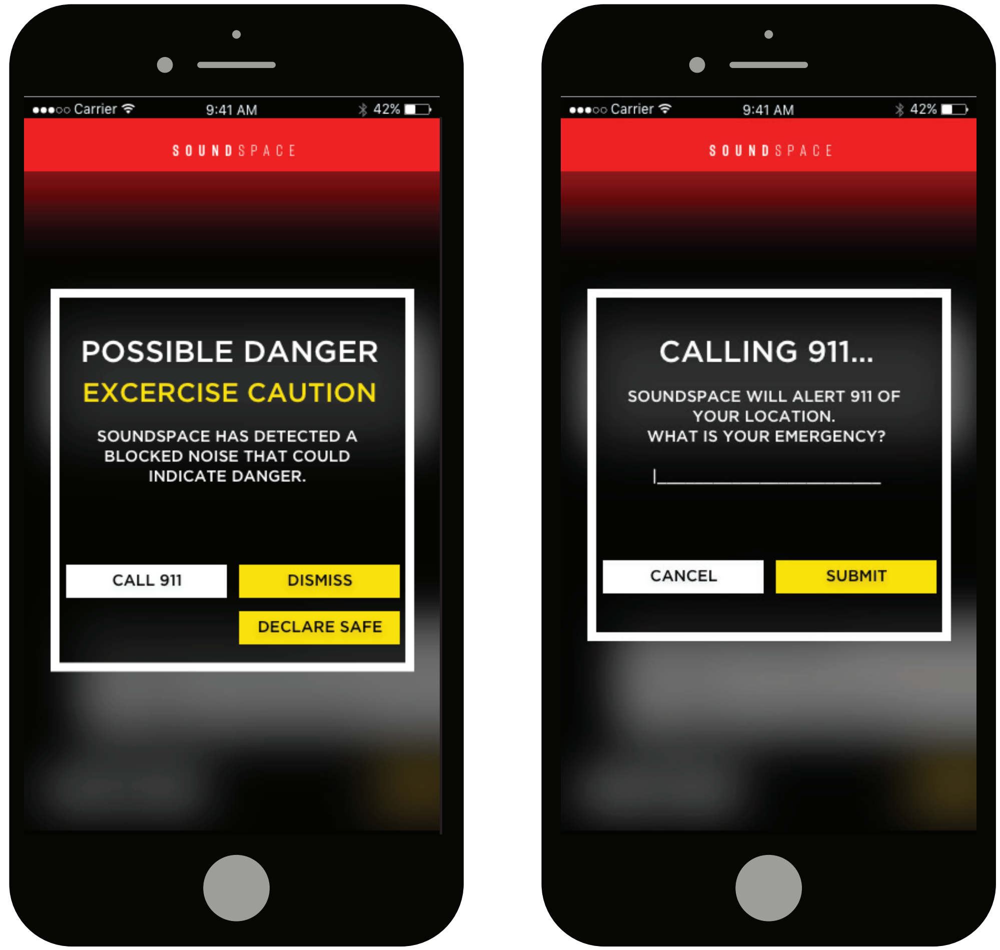


Figure 17: ***Design Explorations | Safety***

CONCLUSIONS AND FUTURE IMPLICATIONS

Disabled users have been disenfranchised consumers of the very technology they rely on for their way of life. Including the user into the design is key to producing a user experience that is beneficially responsive to the specific needs of users with disabilities. My interviews with hearing device users gave me a deeper understanding about how different users utilize their devices. Asking participants to imagine new functionality for a CI interface brought forth many ideas that I would never have come up with on my own. My interviewee Steve (2017) commented that he had never thought to think of his Cochlear Implant critically, but with a simple prompt, he quickly became a rich source of design ideas. Users of Assistive Technology are invested stakeholders and their input should be one of the designer's most important resources.

The goal behind designs for hearing devices has primarily been to masks the user's disability. Shifting the paradigm of what it means to design for disability can also enable innovation. Some of my designs explored the question, 'what if designs raised the benchmark to Super Hearing?' Features such as customized sound programs, the ability to selectively augment sounds and an auto transcription feature could easily be repurposed to suit the consumer market. They could become new, helpful tools for the future for all.

David Rose's concept of enchanted objects explores ways to reduce manual user input. Untethering CI users from manually make adjustments allows them to focus more on the world around them. The Internet of Things enables a contextual interface where the system gathers data to learn and predict the user's actions subsequently triggering prompts. This not only benefits the individual user, but the generated data would be an incredible resource for designers and producers as well as doctors and audiologists. If CI remotes fed data to cloud-based systems, designers and producers could gain access to an enormous amount of data that could be helpful in making educated design decisions for future iterations. It would push the evolution of the system at a much greater pace than a closed interface could. Further investigations should examine how the concept of Big Data could promote progress in the assistive technology arena.

The SoundSpace Collective would give CI users easy access to a community with other CI users. Connecting CI users to the Internet opens a world of possibilities and would empower users by giving them a voice and the opportunity to think critically about the technology upon which they are so dependent.

The deaf community is deeply fragmented. There is a great divide between those who sign and those who are verbal communicators. The SoundSpace Collective could be incredibly helpful in bridging the divide between different factions of the deaf community. Further research should explore possibilities in opening up this type of interface to all hearing device users, not just those who use one brand or one type. This would expand the benefits of these designs to cover all deaf and hard of hearing people who use hearing technology. It would build subcommunities of support within the larger deaf community.

The questions and possibilities this investigation explores should be applied to the disability community as a whole. How could people with other types of disabilities benefit from a social media outlet comparable to SoundSpace? What innovative features in an interface for blind and low vision users could be helpful to mainstream audiences? My explorations in this research seek to push boundaries while using user-centered design. While I cover a wide range of topics and ideas, I only scratch the surface of limitless possibilities. Further investigations should continue to draw inspiration from the user and continue to dare ask, “what if?” and “why not?”

FACEBOOK POLL

DO YOU LIKE AND USE YOUR COCHLEAR REMOTE ASSISTANT?

Posted February 16, 2017

Option 1: I have the Remote Assistant, but I don't use it often.

Option 2: I love the Remote Assistant, and I use it all the time.

Option 3: I like the Remote Assistant, but I think improvements could be made.

Option 4: I do not like the Remote Assistant.

GOOGLE SURVEY

WHAT DO YOU LIKE AND DISLIKE ABOUT COCHLEAR'S REMOTE ASSISTANT?

Posted February 20, 2017

Name

Email

How old are you?

How old were you when you got your CI?

Do you have one or two CIs?

Are you comfortable with your Cochlear Implant(s)?

What adjustments do you tweak the most on your CI?

What are your three favorite things about the Remote Assistant?

What are your three least favorite things about the Remote Assistant?

If you could build your dream Remote Assistant, how would it be different than the current one?

If you could build your dream Cochlear Implant Processor(s), how would it be different than the current one? What features would you add?

Is there something else you want to say about your experience with your CI Remote Assistant or your general CI experience?

INTERVIEW QUESTIONS

HEARING DEVICE USER EXPERIENCE

Conducted between

October 2016 - April 2017

Hearing Device User Experience

Name:

Age:

Profession (or what is your Year and Major if you are a student):

When were you first diagnosed with hearing loss?

How did you lose your hearing?

Do you sign?

Do you consider yourself a part of the Deaf community? Why or why not?

What hearing devices do you use?

Are you happy with your hearing device? Why or why not?

Do your hearing devices have a remote control or an app that allows you to change settings?

Do you use Sound Profiles on your hearing device?

What features do you adjust most with your hearing devices?

What three features do you most appreciate in your hearing device?

What three features do you wish your hearing device had?

Do you listen to music? If so, what is the best way for you to listen to music?

Do you talk on the phone? If so, what is the best way for you to hear well on the phone?

Do you use a microphone or FM system? If so, when do you use this? Does it have features you wish your hearing aids had?

Do you use a smartphone?

Do you use a smart wearable such as an Apple Watch or a Fitbit?

Would you like to use your smartphone or smartwatch to control your settings?

How do you envision your “dream hearing” device?

Any other information you think I should know/ be aware of?

SOUND STUDY OBSERVATION PROTOCOL

Conducted October, 2016

Name:

Age:

When are regular occurrences when you change the volume on a device?

How comfortable are you with Technology?

Do you have a preference for which types of volume control you prefer?

Which kinds did you find confusing?

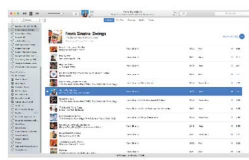
What feature is important to you about sound control?

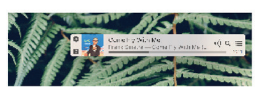
Put the sound controls in order of your preference.

MULTI-CHANNEL MIC/ LINE MIXER

SPEAKER WITH BASS AND TREBLE DIALS

MACBOOK PRO RUNNING ITUNES


Full iTunes Player and Browser

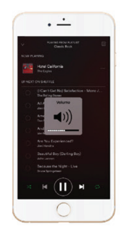

iTunes Mini Player

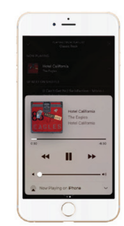

Keyboard Buttons

IPHONE 6 RUNNING SPOTIFY


Spotify Controls

Lockscreen Controls


iPhone Volume Buttons


iPhone System Wide Sound Controls

WORKS CITED

Benkler, Yochai. ***The Wealth of Networks***. New Haven, Conn. [u.a.]: Yale Univ. Press, 2006. Web.

Cochlear.com. “**Cochlear Implants and Cochlear Implant Technology.**”http://www.cochlear.com/wps/wcm/connect/au/home/understand/hearing-and-hl/hl-treatments/cochlear-implant. Web. October 5, 2016 <http://www.cochlear.com/wps/wcm/connect/au/home/understand/hearing-and-hl/hl-treatments/cochlear-implant>.

Davis, Lennard. ***The End of Normal: Identity in a Biocultural Era.*** Ann Arbor: University of Michigan Press, 2014. Print.

Galineck, Steven, and Stefania Serafin. “**A Quantitative Evaluation of the Differences Between Knobs and Slider**s”. NIME 2009: New Interfaces for Musical Expression. June 4, 2009 - June 6, 2009, Eds. Noel Zahler and Roger Dannenberg.Pittsburgh, Pennsylvania: June, 2009. Print.

Hornbæk, Kasper, and Erik Frøkjær. “**Reading of Electronic Documents: the Usability of Linear, Fisheye, and Overview + Detail Interfaces**“.ACM , March 1, 2001. 293-300. Print.

“**Internet of Things Global Standards Initiative.**” Web. May 8, 2017 <http://www.itu.int/en/ITU-T/gsi/iot/Pages/default.aspx>.

Jenkins, Henry, Mizuko ItĐ, and Danah Boyd. ***Participatory Culture in a Networked Era.*** Cambridge, UK ; Malden, MA: Polity, 2016. Web.

Kim, Kwan Mung, and Woohun Lee. “**How do Directional Diversity and Congruence in User Interfaces Affect Usability?**”. IASDR. October 2009, Seoul: Print.

Moggridge, Bill. ***Designing Interactions.*** Cambridge, MA: The MIT Press, 2007. Print.

Naam, Ramez. ***More than Human: Embracing the Promise of Biological Enhancement***. 1. ed. New York [u.a.]: Broadway Books, 2005. Print.

Newell, Alan F. ***Design and the Digital Divide : Insights from 40 Years in Computer Support for Older and Disabled People.*** 1. Vol. San Rafael: Morgan & Claypool Publishers, 2011. Synthesis Lectures on Assistive, Rehabilitative, and Health-Preserving Technologies Web.

Norman, Don. ***The Design of Everyday Things : Revised and Expanded Edition***. Revised ed. New York: Basic Books, 2013. Web.

Pullin, Graham. ***Design Meets Disability***. Cambridge, Mass.: MIT Press, 2009. Web.

Rose, David. ***Enchanted Objects: Design, Human Desire, and the Internet of Things***. 1. Scribner trade paperback ed. ed., 2015. Web.

Stary, Chris. “**Shifting Knowledge from Analysis to Design: Requirements for Contextual User Interface Development**.” Behaviour & Information Technology 21.6 (2002): 425-40. CrossRef. Web.

WORKS CITED

T Selker, and W Burleson. "**Context-Aware Design and Interaction in Computer Systems**." IBM Systems Journal 39.3/4 (2000): 880-91. ProQuest Illustrata: Technology Collection. Web.

Swindells, Colin, Karon E. MacLean, and Kellogg S. Booth. "**Designing for Feel: Contrasts between Human and Automated Parametric Capture of Knob Physics.**" Ieee Transactions on Haptics 2.4 (2009): 200-11. Print.

STUDIES

Grossi, Alexandra. **"Do you like and use your Cochlear Remote Assistant?". Facebook Poll.** 16 Feb. 2017.

Grossi, Alexandra. **"Cochlear Remote Assistant Survey". Google Survey.** 19 Feb. 2017.

Grossi, Alexandra. **"Sound Controls Observation and Contextual Inquiry".** Study. 14 Oct. 2017.

INTERVIEWS

Ashlee. Personal Interview. 2 Oct. 2016.

Jimmy. Personal Interview. 29 Mar. 2017.

Johanna. Personal Interview. 31 Jan. 2017.

Lisa F. Personal Interview. 16 Mar. 2017.

Lisa M. Personal Interview. 21 Mar. 2017.

Noland. Personal Interview. 2 Mar. 2017.

Steve. Personal Interview. 8 Mar. 2017.

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