A MOBILE APPLICATION DESIGNED TO IMPROVE CLOTHING CHOICE FOR VISUALLY IMPAIRED USERS: AN APPLICATION OF HUMAN-CENTERED DESIGN

by

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DEDICATION

This thesis is dedicated to all the dreamers of the world who strive to work on projects for change. To my family and friends who have kept me motivated to stay the path on this rollercoaster journey. To my mom, Valarica, for nurturing and celebrating my creative ideas as well as for her sympathetic ear. To my dad, Mario, for encouraging me to remain persistent when going after my big dreams and goals. To my sister, Misty, for accepting me as the person I am and reminding me of my strengths. To my brother, Deric, for believing in me and sharing in my excitement of the future evolution of this project. To my husband, Alan, for his gracious support, his power to make me smile in moments of uncertainty, and never doubting that my hard work would lead me to great opportunities. My heart is always with you. To Trina, for her constant enthusiasm for my success and her positive attitude. To Bobby, for his curiosity and interest in this thesis. Lastly, to Uncle Bob for being my inspiration for this thesis concept and design outcome.

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LIST OF ABBREVIATIONS

Abbreviation	Description
VI	Visual Impairment
AT	Assistive Technology
NFB	National Federation of the Blind
AI	Artificial Intelligence

ABSTRACT

One's outward appearance becomes a dominating factor in a person's representation in social situations such as job interviews, first dates, and social events. With all of the visual indicators that identify stylish and socially appropriate clothing—pattern, color, and texture—choosing an outfit for the day is a simple task for most people. However, people with visual impairment must use alternative methods to complete this same task by relying mostly on touch, memory and sound. Vision loss often limits one's ability to identify colors and patterns making appropriate decisions about clothing combinations challenging. The goal of this thesis was to evaluate how a novel mobile application combined with a physical electronic device (i.e. RFID/radio-frequency identification device tags) could improve the daily task of identifying and locating clothing for people with visual impairment. The research approach, using human-centered design and design thinking processes, was dependent on user-focused input in combination with digital prototype testing, with two different user flows, using advanced smartphone accessibility features.

This thesis includes multiple phases of research, which led to the current outcomes and results, for the proposed accessible mobile application design. Using the design methods from the Inspiration, Ideation, and Implementation phases, of the IDEO human-centered approach, 92% of users found the application helpful when creating a matching outfit for the following occasions: casual, social, professional, and special. 76% of users inquired about when the mobile application would be available for download.

I. INTRODUCTION

"Clothing is an extension of who you are. Much like a turtle with its shell, we tell the world the who, the what, the where, and the when of our lives by what we wear on our backs." – Jennifer Baumgartner, *You Are What You Wear: What Your Clothes Reveal About You* (2012).

People make decisions about how they will visually represent themselves by choosing the most appropriate outfit to wear for the day's activities. Envision the process and steps you take when choosing an outfit for the day: What do you see and think when choosing the outfit? How do you make choices about matching colors or pattern? Now imagine completing this same daily task with little or no functional vision. How would you go about choosing clothes in this scenario? Does your memory guide you? Do the textures of the clothing seem familiar? Are you able to determine the color of a shirt by the texture of the fabric? People with visual impairment (VI) use alternative methods, aside from sight, to choose an outfit for the day. Touch and memory are the most commonly used methods for creating a mental catalogue of their closet. When purchasing an item of clothing the person with VI will keep a mental note of a voice description, provided by the customer service attendant or trusted individual assisting with the shopping process, at which point they then feel the textural characteristics of that item storing it in their memory. Using this process, they are able to identify and locate the specific items of clothing they intend to wear for the day. These alternative methods are used to match, what society would consider, an acceptable or appropriate outfit.

The two core perspectives of physical appearance are the "outside or social view" and the "inside view" (Rumsey & Harcourt, 2012, p. 7). The outside view, or social

perception of appearance, results in "appearance-based stereotyping" others make about one another (Rumsey & Harcourt, 2012, p.7). Judgments people make based on appearance can affect how other people live and make decisions (Rumsey & Harcourt, 2012). For example, as one VI study participant expressed when it comes to concern about visual appearance of clothing he is "really dressing for a world he agreed to participate in"—the sighted world. Standards set around appearance by the sighted world effect his decisions when dressing for professional meetings or special occasions. The "inside view" refers to self-perceptions or attitudes a person makes about their body image and how people think and feel about themselves (Rumsey & Harcourt, 2012, p.7). This perception influences "…how we see and evaluate our bodies and appearances, how we formulate ideas about who we are and what we are striving to accomplish, and how we present ourselves to others" (Kaiser, 1997, p.95). These two perspectives are core concepts that contribute to classifying the value and worth of ourselves and each other (Rumsey & Harcourt, 2012). Clothing and physical appearance, a type of visual code, can be used to interpret details about "status or socioeconomic position and about psychological character" (Rumsey & Harcourt, 2012, p.36). In this research study, focus on the influence of the social view classification, or society's assumptions and stereotypes, about the visual appearance of people with VI will be analyzed.

How Society Views People with Visual Impairment

The pressure to be well presented in social situations such as job interviews, first dates, and other social events is intensified for people with VI. When asked to share her point of view about society's scrutiny on appearance, one study participant stated, "When we walk out of the door, we many times might be the only blind person that the sighted

world sees. So, we have this pressure of making sure that we look good because we're not only representing ourselves but we're representing a whole section of people with disabilities. The sighted world is very judgmental and so appearances are everything". Society attaches stereotypes to people with VI, for example due to their disability they are viewed as mentally slow or less informed and that due to their vision loss they are unfashionable (Jernigan, 2017; Davison, 2013). However, these stereotypes do not hold true for many of those with impaired vision.

In order to complete daily living tasks that are often accomplished with sight, VI persons rely on their creative problem-solving skills to think up ways of completing daily living tasks with limited or no functional vision (Maurer, 2015). These creative ideas, stemming from their education or rehabilitation learning, demonstrate the capabilities of persons with vision loss; they find resourceful ways to achieve the same tasks that sighted people do with ease (Jernigan, 2017). Several of the participants in this research study have both mental and physical organization systems and methods for identifying and locating clothing. These efforts demonstrate how people with VI use considerable cognitive skills to achieve success in their every-day lives.

People with VI aim to defy societal stereotypes about their ability to be fashionable, by taking care in their clothing choices and appearance, and eliminating concerns about their dissimilarities with sighted people (Kaiser, 1997). Society has a reputation of assuming if someone has limited vision that appearance is not a concern they hold, however this assumption is incorrect (Davison & McCoy, 2014). Some people with VI take a considerable interest in fashion and style. For example, Steph McCoy and Emily Davison, two popular fashion and style bloggers who live with a VI, write about

the style preferences and ways to be fashionable with this disability. Both McCoy and Davison address their own theories around style and fashion in their blogs. McCoy, the creator of *Bold Blind Beauty*, defines style "…like art, a form of self-expression and communication which encompasses the whole person. An extension of oneself, style begins on the inside with our personality, lifestyle, values, likes, dislikes, mannerisms and it permeates all areas of our life" (McCoy, 2015). Davison, the creator of *Fashioneyesta*, states "…fashion is a language and its [sic] a way that we are able to articulate ourselves through what we wear (2013). Each garment tells a story about you and the person you are, fashion can be a mode of expression…" (Davison, 2013). Aside from the fact that a person has VI they still want to appear fashionable; clothing color and style are characteristics they consider during outfit selection (Strahan, 2016; McCarty, 2008).

Many times, people with VI take action to prove themselves by eliminating the chance of discrimination based on the appearance of their disability (Rumsey & Harcourt, 2012). Frequently, as one research participant indicated, it is difficult for someone with a disability to be taken seriously and can require that person to make extra improvements to present themselves more professionally. They choose to pick out clothing and make decisions about styling to reflect how they want to represent themselves but can become weary of whether society will disapprove of their selections (Crane, 2000).

Selecting an Outfit with Visual Impairment

Independent living is important for people with VI who are empowered to complete daily living tasks on their own, allows opportunities to open up for them in professional and social settings, and grants them freedom to make their own choices.

Living independently is making choices and carrying out actions on a daily basis and on one's own, like what to wear, just as sighted person would (Richards & Smith). Making independent choices and being considered part of everyday society is important to many of those with VI because it can validate that their disability does not limit them. Choosing an outfit for the day is one way to demonstrate independence by making a choice about appearance.

There are multiple techniques that people with VI use to match clothing: touch, memory, basic fashion knowledge, and tactile tags. Techniques implemented are based on what works best for the specific individual in their own environment. Some people with VI use the sense of touch to identify characteristics such as vinyl lettering, ruffles, lace, and buttons to choose outfits from their mental closet catalogue. Memory becomes a crucial tool when taking these approaches because if the systems become disorganized it can result in mismatched outfits and confusing appearance. Tommy Edison, a person with no functional vision and the creator of *The Tommy Edison Experience* vlog, follows the basic fashion rule his mom taught him when choosing an outfit for the day: "everything goes with blue jeans" (Edison, 2013). Another method is to use tactile tags such as different shaped clips, multiple safety pins, and braille tags sewn into the clothing to establish an organized identification system. One practice among people with VI, is to rely on sighted people to give direction about acceptable matching attire, as well as identify color or pattern. These simple inventive solutions help with the basics in locating clothing but still do not reach the full potential of matching outfits in one's closet and relying on sighted persons for assistance can restrict independence and expression of identity.

When Appearance is Important

There are specific situations in which appearance is vitally important—for example, when considering what to wear for a job interview. Visual appearance is an important factor to interviewers, or yearly reviews, of job applicants indicating the level of interest a person has in being part of that company (Knapp, Hall, 2006). Unfortunately, the NFB Blindness and Low Vision Fact Sheet reported that 70% of the working-aged adults with VI are unemployed (National Federation of the Blind [NFB], para. 10). With the emphasis on appearance as a contributing factor for employment consideration, one study participant emphasized, dressing well for a job interview is essential in making a good first impression. When someone with a disability is looking for employment they have to take extra care in their appearance, compared to a sighted person, because, as one study participant explained, "employers are already looking for an excuse not to hire them". As previously mentioned, people with VI use current tactile and cognitive methods to reach standards of desired acceptable personal style without limitations, which are also taught at rehabilitation centers and schools, but there is still an opportunity to assist them with alternative methods in expanding outfit options.

First impressions are influential in job interviews but are also important in other scenarios like a first date. Efforts made towards making a good first impression are observed by society and informs others about how that person values themselves. Some people use clothing as a form of expression to inform others about their identity and personality. Pride in appearance also exudes confidence, which is appealing too many individuals on a first date. By exhibiting attention to one's own visual appearance, favorable conclusions can be made about that person; which entices others to want to

know more about them (Horan, 2014). In the pursuit of finding a companion, values of self-worth, confidence, and being stylish are all effective in making a memorable first impression, even for individuals with VI.

When people participate in social integration they learn to form opinions about their visual identity (Kaiser, 1997). Wearing acceptable and fashionable clothing is one way to send a message to others about mood, character, and even state of mind (Pine, 2014). This individualism can demonstrate the qualities and intelligence a person with VI can bring to a group, defying the stereotype that they are mentally slow or less informed. When an individual has a visual impairment, it is important to show confidence through visual appearance amongst their peers, because it eliminates any preconceived judgments about their ability or knowledge. Acceptable appearance through clothing is achieved by the VI community through the use of methods and tools in combination with their own creative solutions. When comparing the variety of options for choosing and identifying clothing some are more successful than others in reaching the user's goal.

Comparative Audit

Outside of the manual methods to choose an outfit, such as touch, memory, tactile tags, basic fashion knowledge, articulate organizations systems, and sighted assistance; people with VI can explore technological approaches. Technical solutions range from clothing specifically designed for the VI community, to Assistive Technology (AT) alternatives. For example, Michele Burton's *Fashion for the Blind: A study of Perspectives* sought to understand what unique characteristics people with VI use to define clothing, when analyzing items on their own, and if those characteristics would be beneficial if applied to clothing specifically made for them (2011). After interviewing

eight participants, the conclusions suggest the best option for clothing enhancement is to integrate accessibility features by fashion manufacturers (Burton, 2011).

Runway of Dreams Foundation (RODF), a nonprofit organization located in Livingston, New Jersey, is focused on bringing awareness and expanding the scope of fashion, targeting the dominant fashion industry, for people with disabilities. Founder, Mindy Scheier put this endeavor in to motion in 2014 after being inspired her son Oliver, who has Muscular Dystrophy, and his physical struggle to wear a pair of jeans (Runway of Dreams Foundation [RODF], para. 1). This experience started her adventure to bring awareness and action to creating "adaptive clothing" to the mainstream market (Scheier, 2017). Today, Scheier has made significant progress in spreading awareness by partnering with Tommy Hilfiger who has added an "adaptive clothing" collection to their repertoire of women's, children's, and men's clothing (Tommy Hilfiger, 2017). The collection's adaptive clothing features include Velcro and MagnaReady®, magnetic closures, to make opening and closing cuffs, dresses, pants, and tops easier to operate (Tommy Hilfiger, 2017). This partnership has made a breakthrough in having an all-encompassing mindset about fashion for people with disabilities but does not provide solutions for matching outfits or locating clothing items when a person has limited or no functional vision.

One company determined to make an impact on the funding of VI research, is Two Blind Brothers, owned by Branford Manning and Bryan Manning, who both live with Stagardt's Disease, a form of macular degeneration which effects the central vision. Pulling inspiration from their own shopping experiences as persons with VI, they set out to design what they consider is the perfect t-shirt. The brothers' main focus is to donate

one hundred percent of their sales from the soft material t-shirt designs to help fund research and cures of VI and blindness (Two Blind Brothers, 2017). Feeling the fabric texture is one of the ways people VI decide if they like an item of clothing so the idea is soft material will appeal to many people with this disability. The shirts range in price from $30 for a basic tee to over $100 for a standard hoodie; which may not be a price too many people with this disability could afford. Cost is an important factor when considering clothing options because, as the International Agency for the Prevention of Blindness (IAPB) established in their 2015 Global Data Report, approximately 89% of visually impaired persons live in low-income environments (International Agency for the Prevention of Blindness (IAPB), 2015). There are no indications that the company has proposals for possible resolutions of matching outfits or broadening the style in a person's wardrobe.

Fashion designer, Camila Chiriboga, has designed a clothing line specifically for men with VI. The menswear is meant to be all inclusive, meaning any man can benefit from wearing the clothing, but there are some unique features included that were inspired from her collaboration with the VI community. Included in the menswear designs are features like the multifaceted, double sided tops for generating multiple looks, the variety of texture styles, and special features to help with safety and security. A color-coded braille tagging system, leveraging QR code technology, identifies the clothing items and provides the user with an audio description. The QR code patterns are incorporated into the clothing via sewing them into the garments, so they are always accessible. While attending the Parsons School of Design, Camila developed this concept during her participation in the AARP and Parsons School of Design competition where she won first

place. The concept is unique and including people with VI in the process was essential to the success of the design. However, while this is an acceptable option for some, one research participant, questioned why people with VI need clothing specifically designed for their disability the visually impaired community would prefer to shop where the general public shops and are more concerned about wanting easy access to the styles of clothing all people are selecting from (Burton, 2011). Though the tagging solution used in this design is helpful for identifying clothing, it does not provide a solution for matching multiple items to create an outfit.

Another fashion designer, Rugilė Gumuliauskaitė focuses on creating custom one-of-a-kind pieces incorporating an involved experience for her customers. Patterns of the clothing are die cut on to paper so that people with VI can touch and examine the design before committing to the creation of the clothing item. Rugilė operates locally out of her Luthinian studio and interacts with her customers on a one-on-one basis. This design approach is another example of how the needs of visually impaired individuals are being recognized. However, the custom nature of the clothes does not solve the overall challenge of matching and styling the clothes a person with VI already owns. The custom solution is for individual pieces and could be costly depending on how many items of customized clothing articles would be needed to make a full wardrobe.

Colorino and *Color Teller* by Brytech, are handheld color identifiers that VI persons use to identify colors of physical objects. When the handheld device is pressed against the chosen object, the user pushes the button on the top of the device, and a voice dictation of the color is announced. While this device is helpful in identifying color, device responses are inaccurate most of the time. In fact, many of the participants

interviewed during this research study claimed that the same item can be scanned twice and respond with two different colors each time. Accuracy in responses, from the color identifiers, is highly dependent on ideal lighting situations. Color identifiers do not decipher patterns, do not assist in determining the best outfit solution, and are costly ranging from $194 to $350.

Another hand held digital solution for identifying colors, *PenFriend*, is a recording device that synchs with adhesive tags, allowing the user to add whatever voice description they wish to the tag. This device is proprietary, meaning it does not synch with any popular mobile devices and must be purchased with the tags in order to work. The initial cost for the device plus the tags is high, ranging from $140 to $240, and may not be financially possible for individuals with VI. Adapting this device to identify clothing items can also become a drawn-out process, because tagging the large number of items in one's closet requires a lot of invested time and existing manual methods can complete the task in less time.

Other advanced solutions using AT rely on the use of software in assisting people with VI in identifying and locating clothing. *Closet Buddy*: *Dressing the Visually Impaired*, a study highlighting the technical aspects of a possible clothing pairing system designed by Joseph Rose, combines the use of a PDA, RFID Reader, a Personal Computer and online database. All of these components work in concert order to generate clothing matching suggestions. While the technical aspects and development of this study were pushing the limits of technology, when it was created (2006), a web of components is required to achieve the end goal. User-centered research methods conducted as part of this study were minimal with feedback from only one subject in a two-question interview.

Mobile Accessibility Tools for the Visually Impaired, a dissertation by Nektarios Paisios, provided an analysis of how an algorithm technology solution in combination with a database can determine if a solid colored top could be matched with a patterned tie. Paisios' project used a color histogram, clothing classification rules provided by fashion experts, and images collected of shirts and ties from existing websites to calculate and determine if clothing items matched. The testing completed for this project was focused on the technical success of the shirt and tie pairing algorithms. The study proved that some algorithm methods were more successful than others. In addition, the database could only work with images scraped from other websites and did not highlight how the user could filter the algorithms to use only the clothing they own. Results defined in the dissertation were on software outcomes and did not include user-testing. The accessibility tool being implemented in this study featured the matching aspect of very specific clothing items but did not have a suggestion of how to accurately physically detect the items chosen.

Smartphone applications to aid in closet organization also exist, such as *Closet+* and *Stylebook,* which are used for cataloguing and managing a clothing library. These applications contain many features that help users in remembering the clothing in their closet using a visual representation of items. The user adds clothing to the digital closet by taking photos with their smartphone camera. In the *Stylebook* application, after the photo is taken, an edit bar displays at the bottom of the save screen; where the user can add details such as brand, color, description, size, etc. After taking a photo with *Closet+* two short fields to enter notes along with other editing icons appear, the user can then select a category or tag for that item. Once the closet is catalogued, both applications

provide a space for users to browse the clothing they have and make selections about what to wear. *Stylebook* provides outfit recommendations by using the "Shuffle" feature but does not include professional input on whether the outfit matches or not. *Closet+'s* outfit feature is a manual process only and relies completely on user selection. The user experience of *Stylebook* is inconsistent with the add-button shifting locations as the user navigates from the home screen to the closet catalogue. When considering the user experience of any design consistent actions are a best practice, so moving buttons around within the tool is not an ideal experience. Most importantly, after launching the application, it becomes inaccessible once the user reaches the select item screen. The images of clothing act like actionable buttons to select items when using the application but when the user tries to complete this task using *VoiceOver,* an iOS accessibility feature, on their smartphone the items are not recognized as clickable buttons or text descriptions. In *VoiceOver* mode, *Closet+* labels are not accurate with the menu selections on the main screen; this makes it impossible to navigate within the application as the experience was intended.

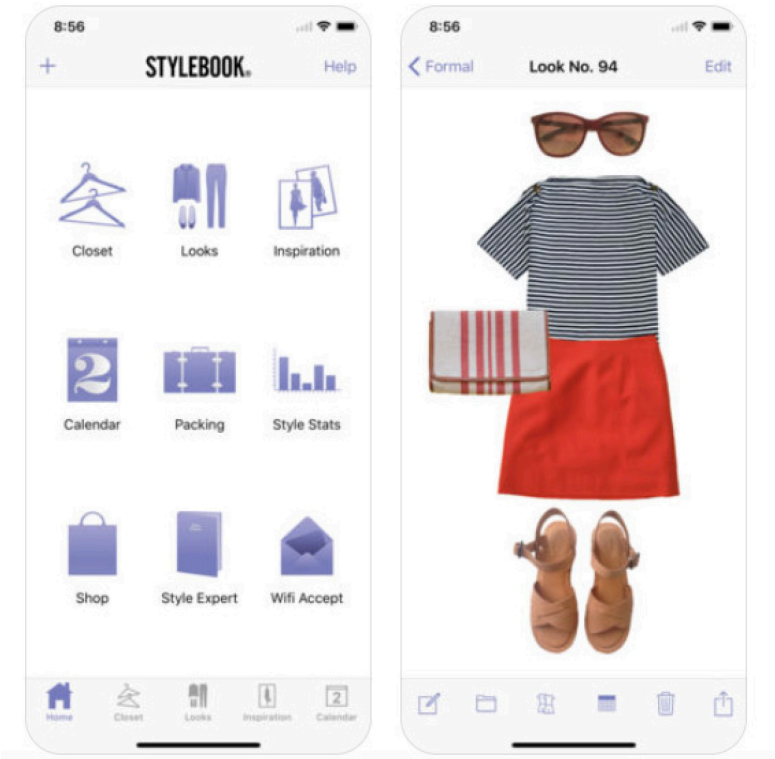

Figure 1. Style Book Mobile Application Screens

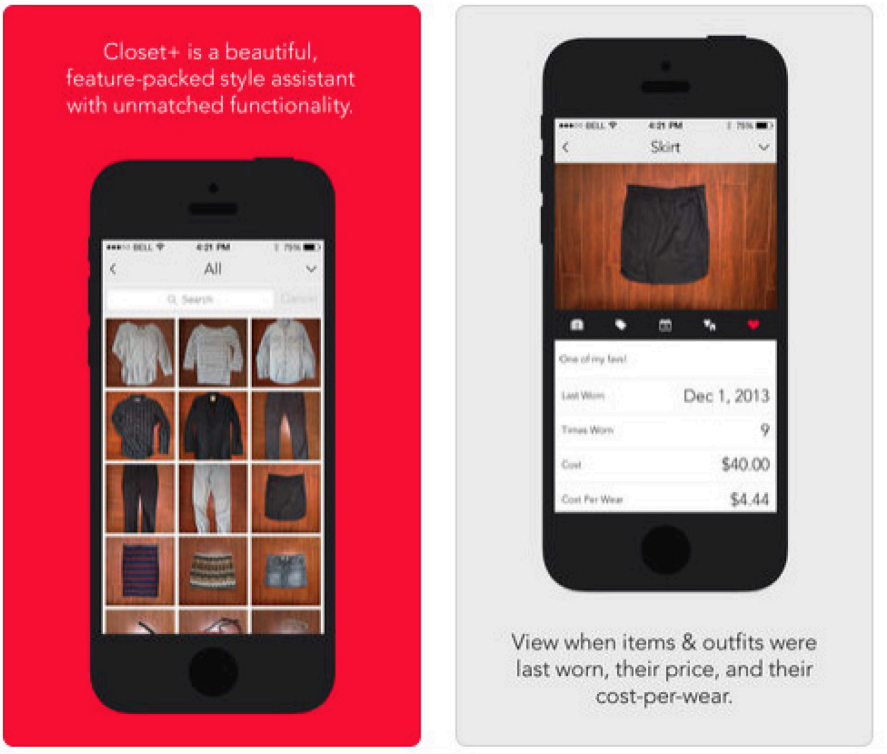

Figure 2. Closet + Mobile Application Screens

Other existing mobile applications, like *Color ID Free*, use a smartphone camera to identify color and a set number objects pulled from the applications supported database. These applications require the user to position themselves directly in front of the object to be scanned. However, results are not always ideal as some dissatisfied users have received varying color responses of the same object, scanned multiple times, with slight adjustments in positioning (Apple Inc., 2015). Mobile applications looking to improve color identification can be helpful in identifying clothing items but do not assist with how to pair colors or patterns together.

Digit-eyes, is a mobile application used to identify items by scanning self-recorded audio labels and Universal Product Code (UPC) or European Article Number (EAN) barcodes; which are paper tags containing algorithms of black and white bars that store virtual information and are attached to consumer products. The washable and dryer safe audio labels used in combination with this application can be purchased and glued or sewn in to the clothing. The user can then apply these audio labels to their wardrobe and pair their own self-recorded voice dictations to items assisting in identifying the articles. Using this AT solution users can easily categorize and organize clothing items but still need assistance in determining outfit options. Identifying clothing using this method can also be time consuming as the user must scan every item until they locate the desired option.

TapTap See is an accessible mobile application that allows the user to take a picture by double tapping on the app's camera screen of whatever object they would like to receive a description about. The description is provided within seconds, using *VoiceOver* on the individual's phone. For example, if the user takes a picture of a plastic

cup, the voice response will say: “red and white plastic party cup”. Many research participants said they used the application mostly to identify color but that the responses were not 100% accurate. The application also requires the user to be familiar with using the smartphone camera. When it comes to picking an outfit for the day the entire closet has to be photographed for recognition, as one research subject indicated, this would take too much time and is not an improvement from current methods.

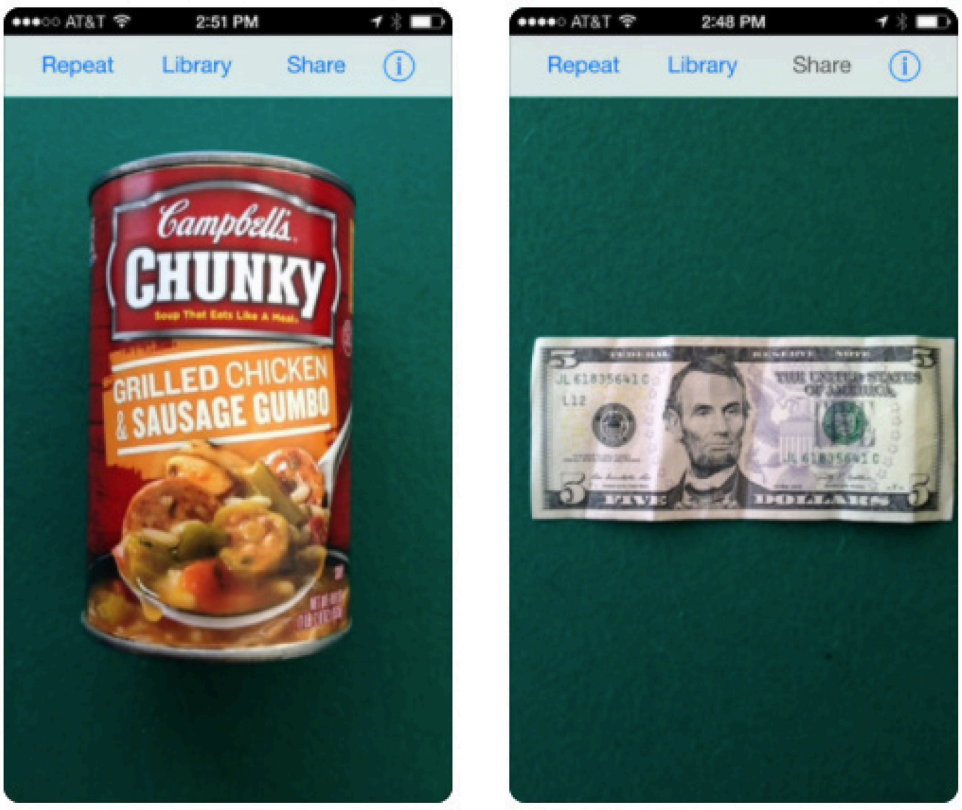

Figure 3. Tap Tap See Mobile Application Screens

Be My Eyes is another mobile application used for identifying items but provides a human interaction by the way of volunteers. The process starts with the user submitting a request for a sighted volunteer to describe the object that the VI person has in front of them. A sighted volunteer then connects with the user through an audio/video connection within the app. The user is able to request descriptive feedback of the object. During

interviews, research participants expressed having concerns about using random volunteers for feedback, instead of a paid professional, because there is no standard in quality of descriptions provided.

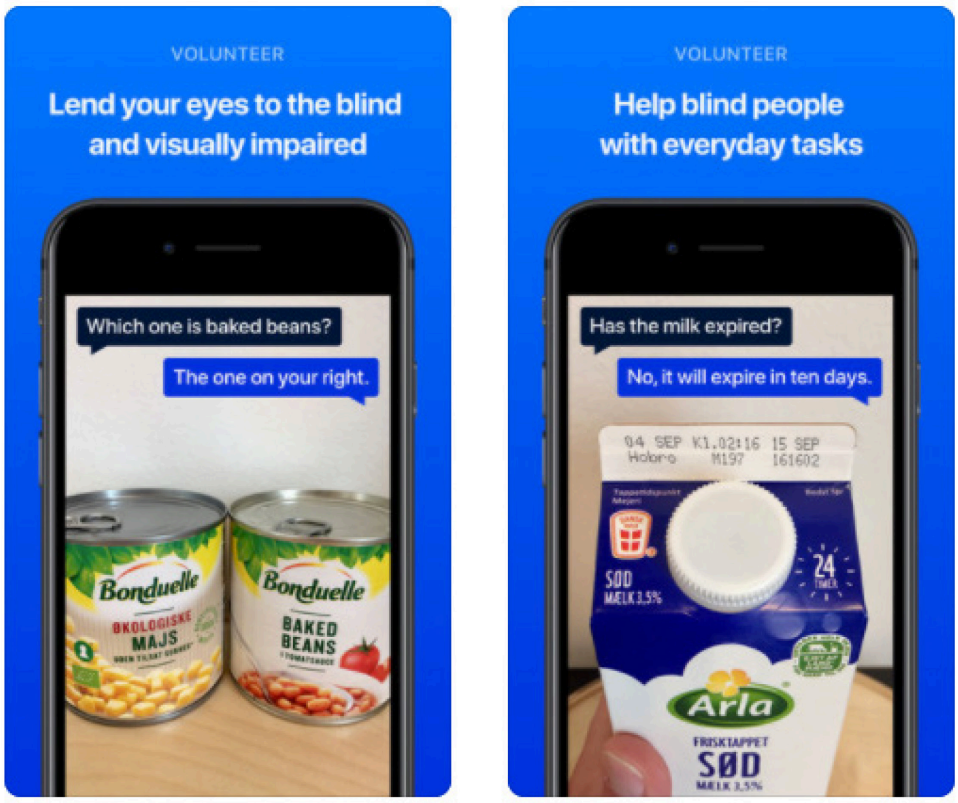

Figure 4. Be My Eyes Mobile Application Screens

Aira is a mobile application that works in combination with wearable, *Google Glass* technology to immediately assist people with VI by using sighted people who are trained in providing descriptive feedback. The *Google Glass* view of the person with VI is transmitted via live-stream to a trained professional then provides a detailed description. A research participant shared feedback about the app saying that the trained professionals were very objective in relaying what they see avoiding giving their opinion about the object or view. In order to access the application features the user has to purchase a minutes-plan. The minutes range from one hundred to unlimited, with prices

ranging from $89 - $329 a month, which includes the glasses. This is not the ideal situation when considering choosing an outfit every day and the high cost associated with the service. When considering matching clothing and getting opinions on what looks best this AT would not be the right solution.

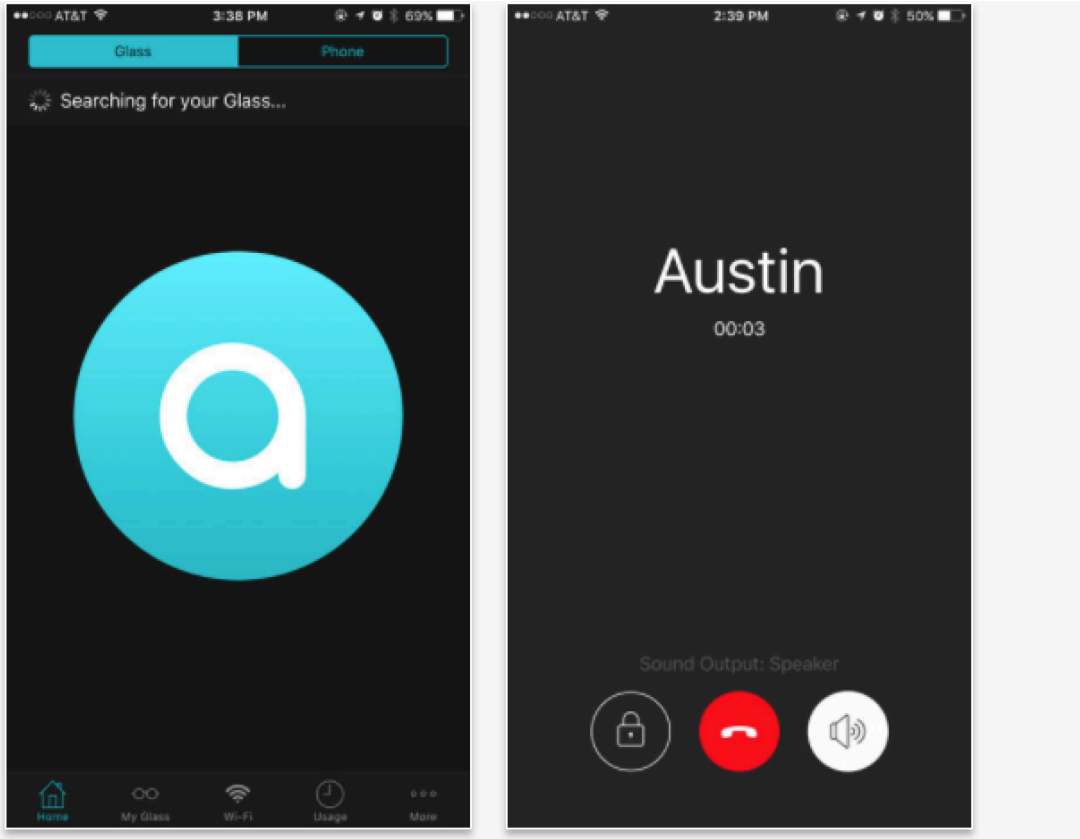

Figure 5. AIRA Mobile Application Screens

Amazon Echo Look is a hands-free voice-activated camera, used in combination with *Alexa* and a mobile application, that captures a full-length photo or video of the user in their outfit to create a collection of looks. *Echo Look* also includes a feature called "Style Check", a style-assistant service, which analyzes two looks submitted by the user, combining algorithms and advice from fashion specialists to determine what the best option is when comparing two outfits the user owns. The user is provided a suggestion, from the two outfit options, based on trends and what flatters the users body type. Other

features include a calendar of clothing items worn and a section to keep record of favorite outfits. The *Echo Look* is priced higher than other AT devices typically paired with a mobile application, at $200. The mobile application is free to download and is only available by invitation at the time of writing. While the solution potentially checks many of the boxes for hands-free interaction and accessibility, the device needed to accomplish this task is a costly solution for people with VI and is limited to style suggestions of only two outfits at a time. At this time, there is no indication of how long it takes to receive feedback or advice from the stylist behind the scenes. One participant who received an invitation to access the *Echo Look* had concerns about the use she would get from taking a photo using the *Echo Look* camera. For example, it does not seem she can interact with the photo to get more detailed information real time: like the color of an item or share the photo with others. The features of this application can help with fit and style suggestions, but does take time to get a response, and does not assist the user in matching an outfit with everything they own in mind.

Statement of Problem

People with VI face challenges when completing the very important task of choosing and matching an outfit for the day. While manual methods are helpful, the process can become cumbersome when locating a specific item as these methods only allows for so many matching options in a person's wardrobe. Alternative solutions exist to assist with these tasks, however they use designs that are not accessible, are too expensive, are too time intensive, and don't provide matching suggestions from the specific individuals full wardrobe. Using Assistive Technologies (AT), known as conceptual ideas leveraging technology, digital, hand held and user experience tools to

assist people with disabilities in completing desired tasks (Assistive Technology Industry Association), successful solutions can be developed.

Thesis Statement

By using an accessible smartphone application design paired with a physical electronic device, (i.e. RFID/radio-frequency identification device tags), improvements in increased accuracy and decreased time-on-task to create a variety of acceptable matching outfit options in a users' wardrobe, can be achieved by individuals with VI.

II. IDEATION: AN ASSISTIVE TECHNOLOGY SOLUTION

IDEO: an agency specializing in design for human factors, defines the human-centered approach to design as: "a process that starts with the people you're designing for and ends with new solutions that are tailor made to suit their needs" (IDEO.org, para. 1). Using the Human-Centered Design Approach the ideal design and user experiences to help people with VI locate clothing and match an outfit are discovered. Preliminary research includes discussing details about current methods and organization systems.

The Human-Centered Design Approach

The IDEO human-centered design process is split in to three distinct sections: Inspiration, Ideation, and Implementation. In this preliminary research phase, the Inspiration, is gathered by discussing, observing, and understanding current methods of how people with VI identify and match clothing in their own places of living. That inspiration is applied in the Ideation phase where results for time-on-task and accuracy in current manual methods are evaluated to determine the best areas of focus for design solutions. The user experience and mobile application design concepts strive to improve accuracy of locating clothing items as well as decrease the time-on-task for matching an outfit. These influences and design theories are then used as part of the Implementation phase, in which a working digital mobile webpage prototype is used to generate user-testing feedback.

Inspiration Phase: Observing Current Methods of Clothing Choice

Study participants, for the preliminary research phase of this study, were selected from the iBug (iOS iBlind Users Group), a nonprofit organization headquartered in Houston, Texas, who promotes individual technological independence to their monthly

meeting attendees. After attending a meeting, the project concept was presented to recruit interested subjects. There were six curious individuals from the group of members with VI interested in participating; two members with low vision and four members with no functional vision. The group of individual participants consisted of five females and one male. Two research subjects were employed while the other four were unemployed. Four of the participants lived in their residence alone while the other two lived together as a couple. Meetings were arranged at their place of dwelling to understand and observe how each participant completed choosing an outfit for the day.

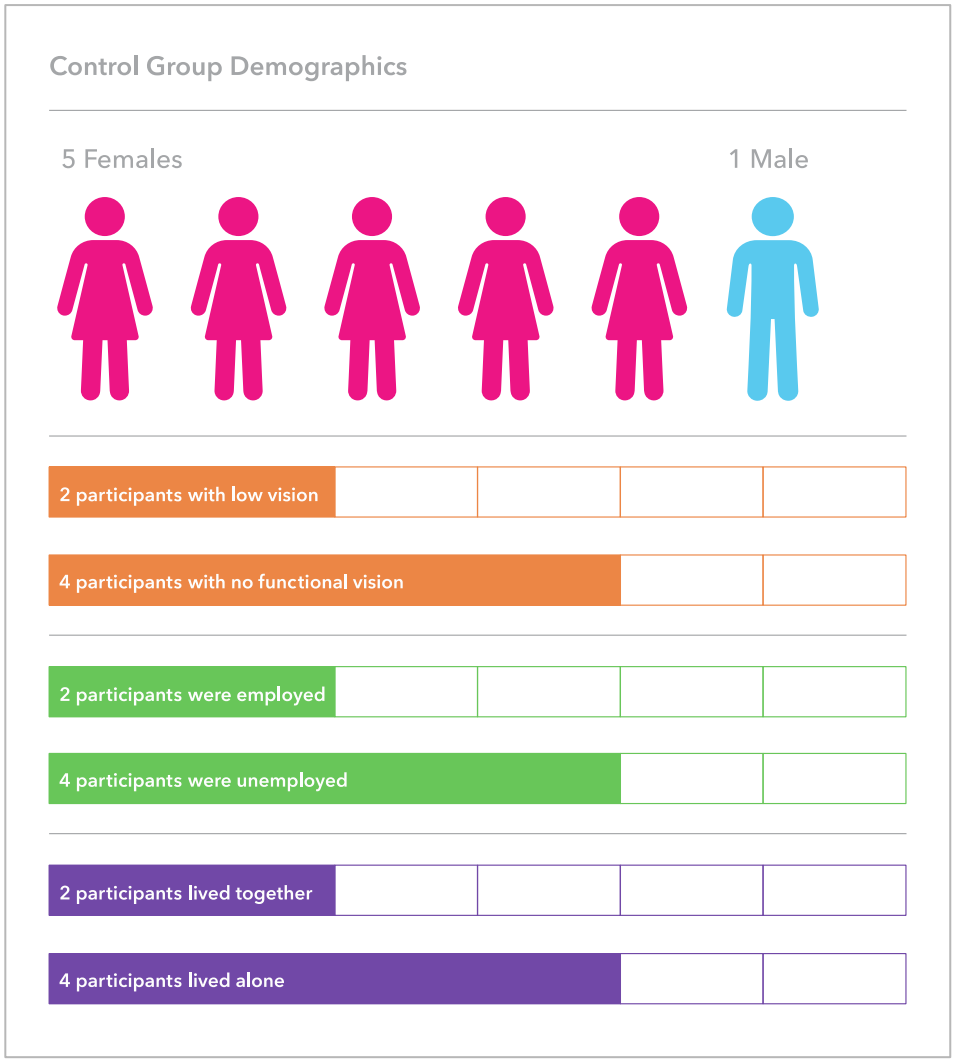

Figure 6. Control Group Demographics Summary

Design method: User interviews.

Interviews were conducted in-person and followed a script (reference Appendix A) of questions allowing for flexible detours in a conversational format (Hanington and Martin, 2012, p.102). During the interviews, the questions focused on clothing style, challenges in choosing an outfit, and details about their familiarity with smartphone mobile applications. The first part of the interview provided details about the personal organization system of each participant. Interview outcomes indicated that 6 out of 6 (100% of participants), preferred to shop in-store, versus online, so that they could touch the clothing and try on the items. 4 out of 6 (67%) participants indicated they have a trusted sighted person that shops with them. 2 out of 6 (33%) participants stated that they obtain the help of a customer service employee to answer questions about color and design.

When considering clothing organization, many participants responded that they create separate closets or sections where they keep clothing for specific occasions. For example, professional clothing was located in one closet while casual tops and pants belonged in a separate closet. When participants asked for assistance in their own homes they required very descriptive details and asked someone they trust to gather that information. 4 out 6 (67%) participants stated they typically avoid asking for help, but that it was acceptable when trying to identify complicated items of clothing. Challenging items of clothing to identify, based on task observation, consisted of items with patterns, multiple colors, graphic t-shirts, and button-up tops that were only distinctively different by color. The solution that all study participants indicated was useful in preventing an awkward outfit match, was to stay safe with a neutral colored bottom. When selecting

outfits for this study, this solution was used by all six individuals to maintain a consistent and manageable look. However, the opportunity to expand the style of an outfit with ease was not readily available to them. Some participants had a wardrobe with many options but gravitated to clothing that was familiar because they were easier to identify. Five out of six (83%) participants were interested in expanding their matching options.

Design method: immersion.

Immersion is a human-centered design method that puts the designer in the location where the people they are designing for complete daily living activities such as home, work, school, favorite hangouts etc. (IDEO.org, 2015). In the Inspiration phase, data gathered during the Immersion method provided details and insights into what users' current identifiable issues were, challenges they faced, and what their thoughts and opinions were about these challenges (Dam & Siang, 2017).

When the study participants chose an outfit for the day, they were typically in their home where they could evaluate all of the items they own to make the best choice for the occasion. Asking a person about how they organize their clothing is a very different experience than actually observing how and where the action is completed. Closet organization varied from subject to subject, with some participants being particular about where specific items go and how they were placed in that location, while others grouped many items together and would use their sense of touch to work through large drawers to find items. Participants typically organized their clothing in multiple locations by dividing pants and tops in separate closets for easier identification (See Figures 7-11). Study participants were observed tracking down the particular item they were looking for which provided first-hand knowledge of which techniques were

successful and which needed improvement. Memory and touch were essential to the organization and identification methods of the preliminary phase.

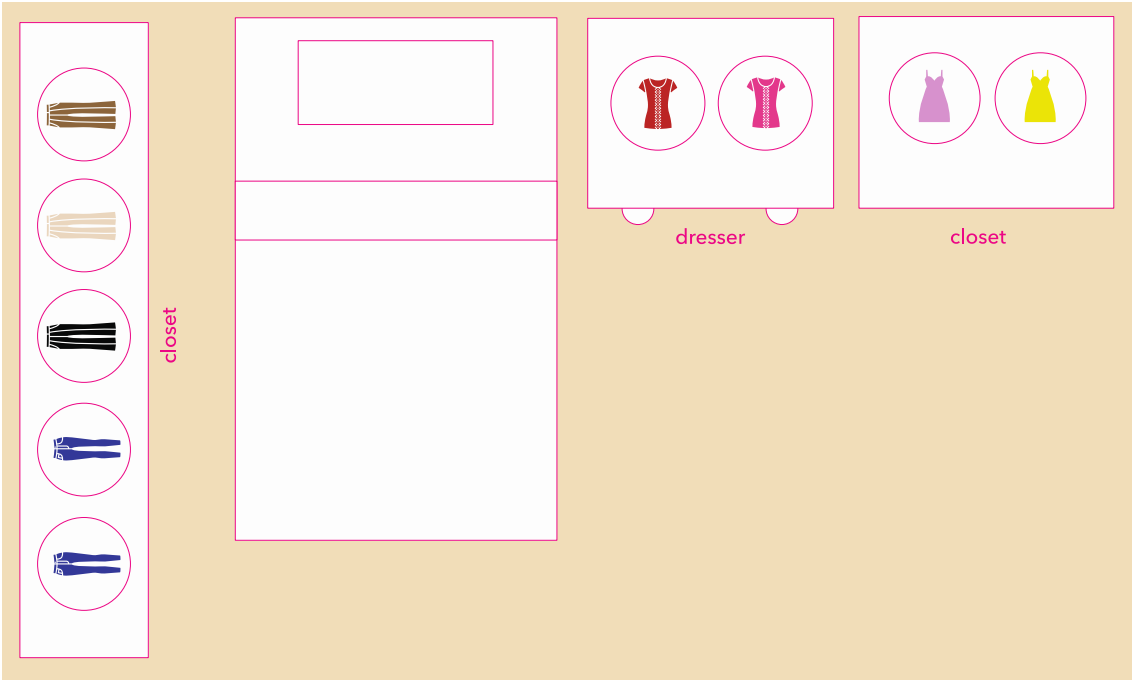

Figure 7. Participant 1 closet layout

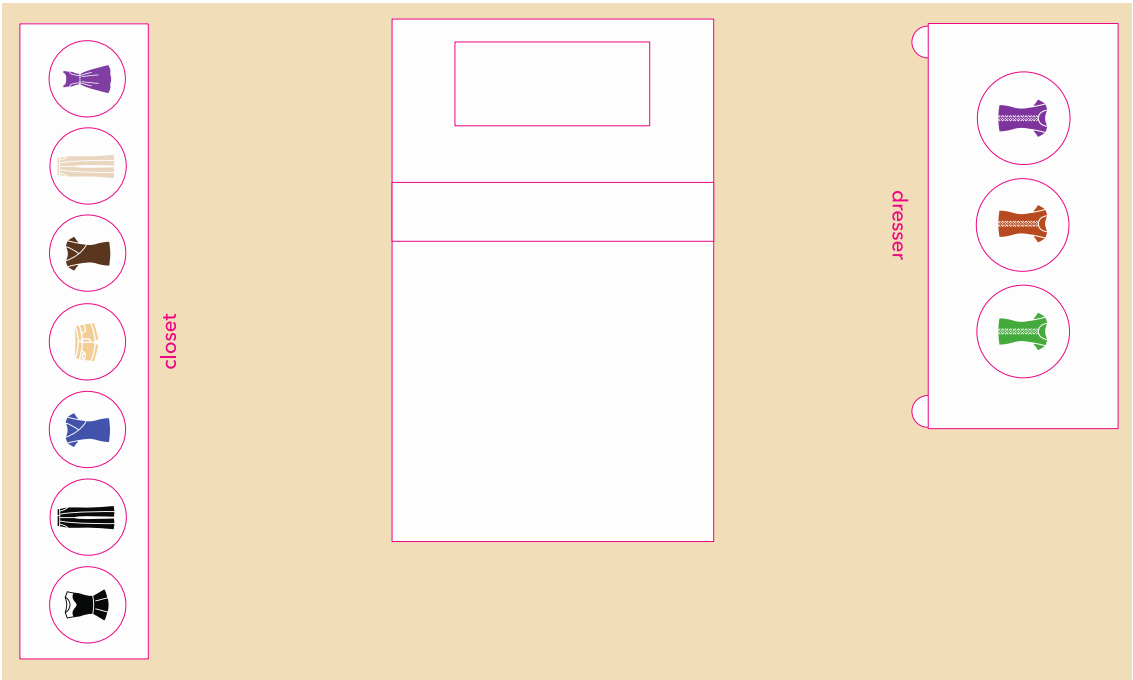

Figure 8. Participant 2 closet layout

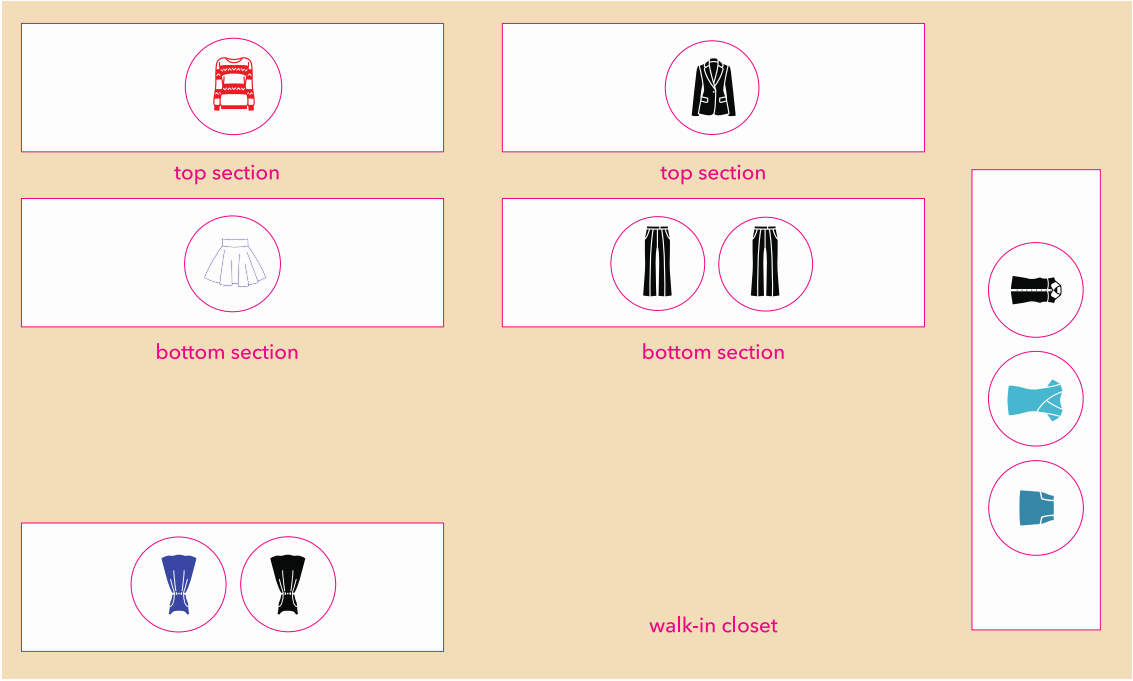

Figure 9. Participant 3 closet layout

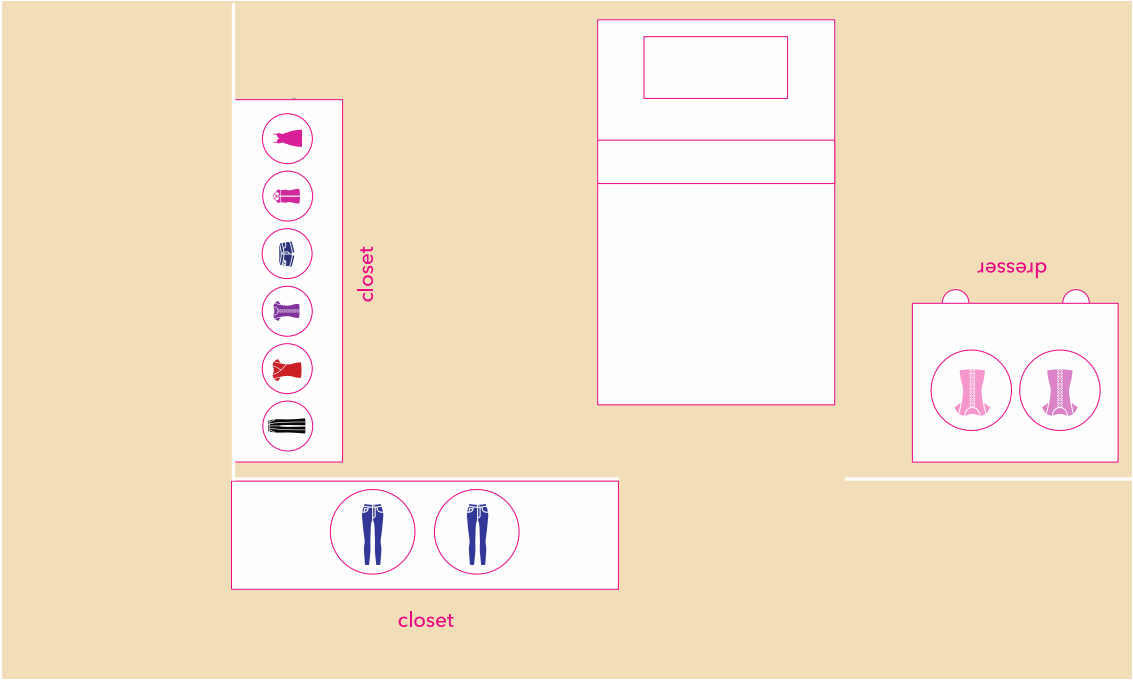

Figure 10. Participant 4 closet layout

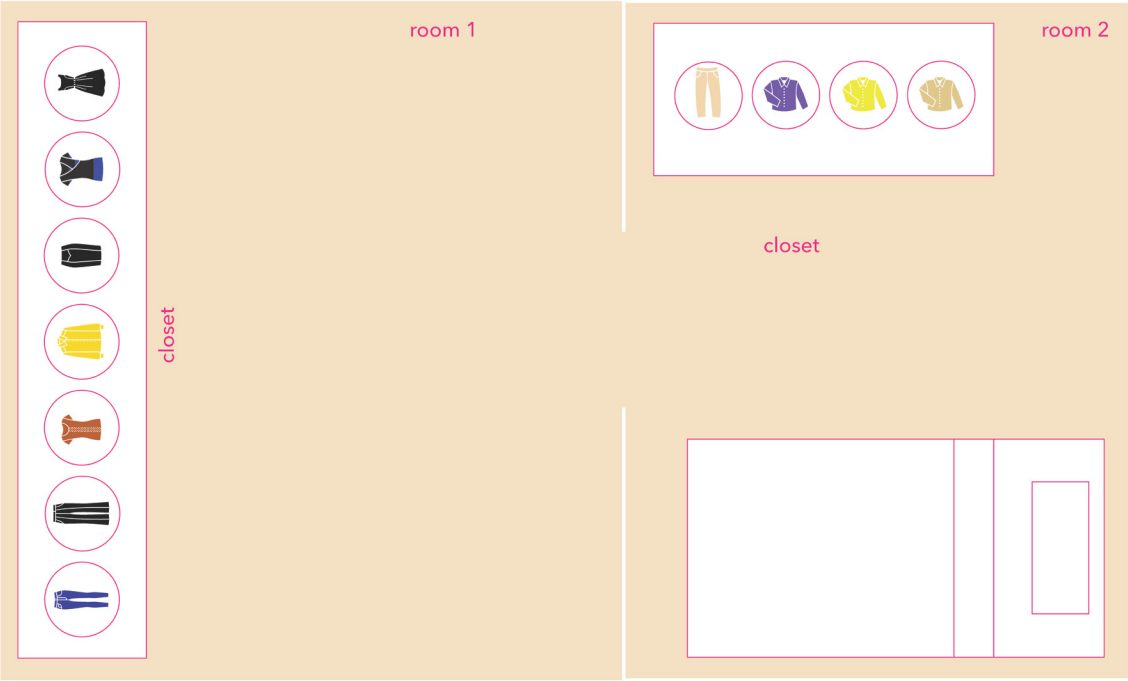

Figure 11. Participant 5 closet layout in room 1 and Participant 6 closet layout in room 2

Design method: task analysis.

Task analysis was used to isolate key elements of human behavior, key decision points, and monitor time and motion for completing the requested tasks (Hanington and Martin, 2012, p.174). A task list was read out loud to study participants to complete in-person at their place of living. The list requested that the participants find an outfit for a specific occasion; which allowed for current methods to be observed. Outfit occasion requests included: casual outfit, social outfit, professional outfit, and special outfit. Time-on-task and accuracy of identification were documented while tasks were completed. This documented time-on-task provided a standard time to measure improvements or flaws in the mobile application digital prototype user experience.

Design method: expert interviews.

Key informants, also known as experts, can provide knowledgeable input or have

a specialty experience that can contribute specific insights into the area of research through interviews (Hanington and Martin, 2012, p.102). Key persons of interest who work with individuals that have VI, were consulted about the current methods and challenges they have observed in their daily work. In an inquiry with Tad Doezema, Assistant Principal at the Texas School for the Blind and Visually Impaired, shared insight into current methods students consider using and the importance of dress for people with VI. Tools that may be used are: color identifiers, but they are not always accurate and do not always assist in matching and identifying clothing successfully; or common low-tech solutions students use include tactile tags such as attaching a number of safety pins to clothing labels. Visual appearance is an important concept for students because it prepares them for adult life. Doezema stated that appearance is one of the most important concerns because being well presented and appropriately dressed can help in leading a successful life.

Chelsea Nguyen, a specialized professional image consultant for people who are blind or otherwise disabled, and general public, has been teaching the blind community techniques for achieving well-polished visual appearance over the past six years. Her teaching methodology, which she started developing in 2012, lead to working with the State of Texas in an effort to teach people with VI methods for acceptable appearance with a goal of finding employment. Through trial-and-error she discovered the most successful approaches were multi-sensory incorporating touch, smell, sound and AT. Based on her client experience, she believes AT is an important teaching tool to assist with matching an outfit for the day. There are mental and psychological barriers that can sometimes discourage persons using alternative techniques to complete this task but, as

Nguyen suggests, with practice self-doubt can be eliminated. When it comes to matching outfits the most challenging aspect for her clients is pairing clothing in new and innovative ways while being budget conscious.

Summary of Inspiration Phase Data

Many different methods were used by the 6 participants in the preliminary research conducted as Inspiration phase of this study. Immersion was a key design method in understanding the thought process of each individual as they completed the requested tasks. Thirty three percent of participants owned a minimal number of articles of clothing, which was intentional, so that they could keep their closets and dresses organized to find specific articles of clothing. The most organized participant had three pairs of identical navy-blue shorts as part of her strategy for matching clothing items. Five out of six (83%) participants stored pants and shirts in opposite locations to also assist in successful identification.

When asked to demonstrate how they find a social, casual, professional, or special outfit, 100% of the participants used the sense of touch to feel the clothing characteristics to determine what item they had chosen or were trying to identify. Memory was another key factor in completing the requested tasks. One hundred percent of participants knew all the clothing items available in their closets, which they had stored in their memory, but the most challenging part was remembering where those clothing items were in their organization system. Cataloguing the clothes in their memory typically occurred during the shopping process. Often times participants mentioned they went with a trusted friend or asked assistance from the customer service employee at the store. When it came time to complete the task analysis to find specific outfits using the manual process, leveraging

various techniques such as touch, color identifiers, and recalling their mental clothing library, there were drastic differences in the length of time of completion. For example, aside from never locating the desired article of clothing, the longest time recorded for a participant was 4:05 seconds and the fastest time recorded was 25 seconds. The average time to accurately choose and identify specific outfits, between the 6 study participants, was 1:56 time-on-task for the social outfit, 1:43 time-on-task for the professional outfit, 1:24 time-on-task for the casual outfit, and 1:15 time-on-task for the special occasion outfit. Using these manual methods 78% of items chosen were accurately selected, leaving 22% of items inaccurately selected.

Many of the VI participants in the Inspiration phase were confident they knew what was in their closet and where the items were located. Based on the documented 22% of inaccurate selections, the task analysis demonstrated, that accuracy of choosing clothing items left room for improvement. It was observed that many of the incorrectly identified items were clothing that had patterns or a combination of colors. Some of the participants mentioned they typically pick out their clothes the night before, which could take up to an hour, to make sure they are ready for the next day. Graphic tees were a clothing item that 100% of participants identified as challenging due to the similarities of vinyl characteristics when comparing the tees to one another, as one study participant stated they mostly all feel the same.

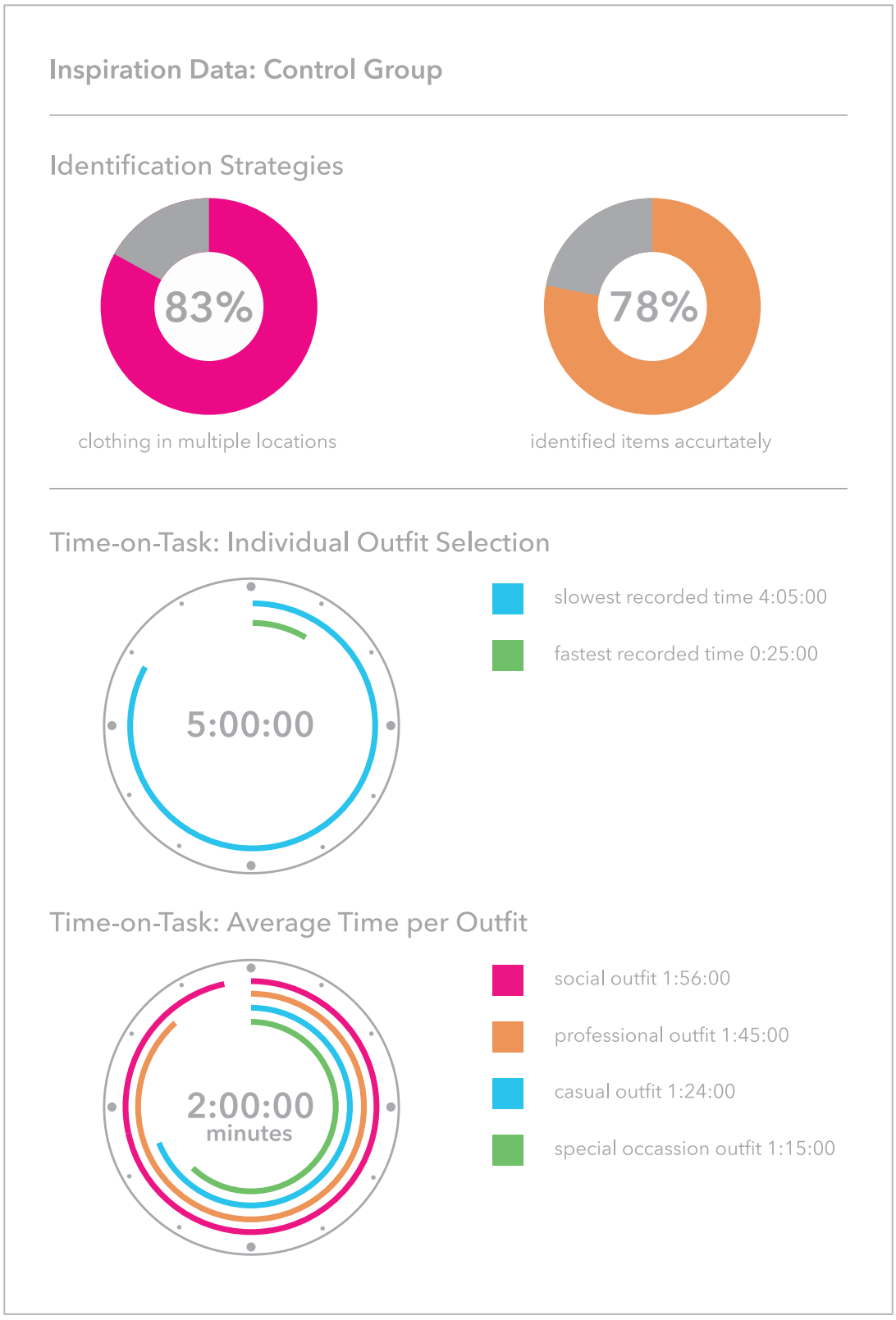

Figure 12. Summary of Inspiration Phase Data

Inspiration Phase: Design Influenced by Users and Inspiration

The concept of accessibility design is designing digital experiences that are all-inclusive and readily available for users (Kalbag, 2017). Accessibility design influenced many of the visuals, user flow, and interactions of this mobile application proposal. Considerations made for successful productive accessible design outcomes included the design of a linear architecture that avoids dead-end actions in user flow of the tool (Campbell, 2017). Linear architecture places the sequence of call to actions for next steps in a clearly defined order so that the user understands the goals of the proposed design (Campbell, 2017). Accessible design also uses simple text and specific wording to clearly indicate meaning, action, or next steps. Generic wording, abbreviations, and acronyms are sometimes unclear to users, so using clear short sentences and full-length words provided them with distinct instructions and information within the application (Campbell, 2017). Finally, clear usability patterns are also essential to productive accessibility design. Usability patterns are repetitive design solutions that solve for user experience problems. The usability pattern approach was applied to this accessible design through consistency of screen layouts and user interface elements, which guided users to complete tasks quickly and easily.

For this study, the individuals used the *VoiceOver* accessibility feature available on the iPhone since the 3GS model, which provides speech output of text information on the phone. The solution for the Ideation phase user-testing resulted in a mobile application that syncs with an RFID sticker, using two-way radio waves, that stores a photo and description of the item and information for matching and identifying the location of articles of clothing, creating an outfit. After the user has completed adding all

clothing items to the closet they then select a top or bottom, from within the app, to form a matching outfit. Upon selection, using sensory features, each item of the outfit is individually located and grabbed.

Design elements.

It is important to maintain accessibility best practices in designing AT solutions for VI. One characteristic of accessibility—simplicity—can be accomplished by avoiding complicated interactions, explaining exactly what actions do within a tool, and providing straightforward user experience that any one person can comprehend (Elam, Lidwell, Holden & Butler, 2010). Clearly providing descriptive information in *VoiceOver* mode, an audio tool many people with VI use to complete tasks on their smartphone, can be achieved using purposeful HTML tags within the prototype (Kalbag, 2017). Using exact text for navigation tags applied to buttons and other user interface elements clears up any confusion about literal action the menu items will perform upon selection (Lupton, 2014, p.106). Tags applied to buttons should tell the user exactly what happens when the button is pressed (Kalbag, 2017). When thinking about body text on the page obvious labeling can be used to communicate information through the use of "text-only, text-to-speech, or Braille output devices" (Lupton 2014, p.70).

Using these best practices, the design of the digital Prototype 1 and Prototype 2 were built with HTML and CSS to simulate the mobile application concept tested in this study. The digital Prototypes 1 & 2 used a vertical grid, of one column, for navigation entities making sure maneuvering through the user path options and actions were clear. Rectangular buttons were stacked, vertically aligned, and were created with larger than average length and height dimensions avoiding missed attempts when selecting next steps

and actions (Kalbag, 2017). Increased font sizes were also applied to display legible text sizes for those with low vision. Visual design techniques were minimal, using high-contrast black and white wireframes, creating a simple aesthetic, so that the focus and discussions were prominently about content and user flow to complete tasks during user-testing. These techniques are also beneficial to low vision users leveraging the zoom accessibility feature available on iOS devices.

User experience.

Focus on user flow and task completion was paramount when designing the prototype of this accessible concept (Quesenbery, 2010). The purpose of this design was to assist people with VI in achieving the desired goal of expanding their wardrobe by matching items in their closet. Digital design decisions made about the user experience of this mobile application were strategically implemented to attain the main user goals of efficiently matching and locating clothing (Johnson, 2014). A vertically aligned content layout was carried over from the navigation approach permitting information to be presented in a vertical hierarchy demonstrating the order of tasks needed to identify, match, and locate clothing. Logical order of tasks, consistency of button placement, and essential HTML labeling was applied to the user interface of the digital prototype. The objective with this strategy was to improve simplicity of usability patterns when completing familiar actions in order to minimize time-on-task and increase correct clothing identification (Johnson, 2014).

User flow of main features for Prototype 1.

Because smartphones have small screens main tasks were clearly illustrated with minimal and exact instruction for completing user flow actions (Quesenbery, 2010).

Using the simple main menu of the digital prototype for step one, building the digital closet, navigation options for selecting “Add Top” or “Add Bottom” were presented. When either button was pressed, the smartphone camera would then promptly open with detailed instruction taking the user down the step-by-step process to add an article of clothing. Steps included in the user flow to fill the digital closet, using Prototype 1, were step one-take a photo, step two-tap a button on the screen while physically touching the phone on the RFID tag to pair the item, step three-add a self-description by voice dictation, and step four-save each item of clothing to the closet (Seen in Figure 13 & Figure. 14).

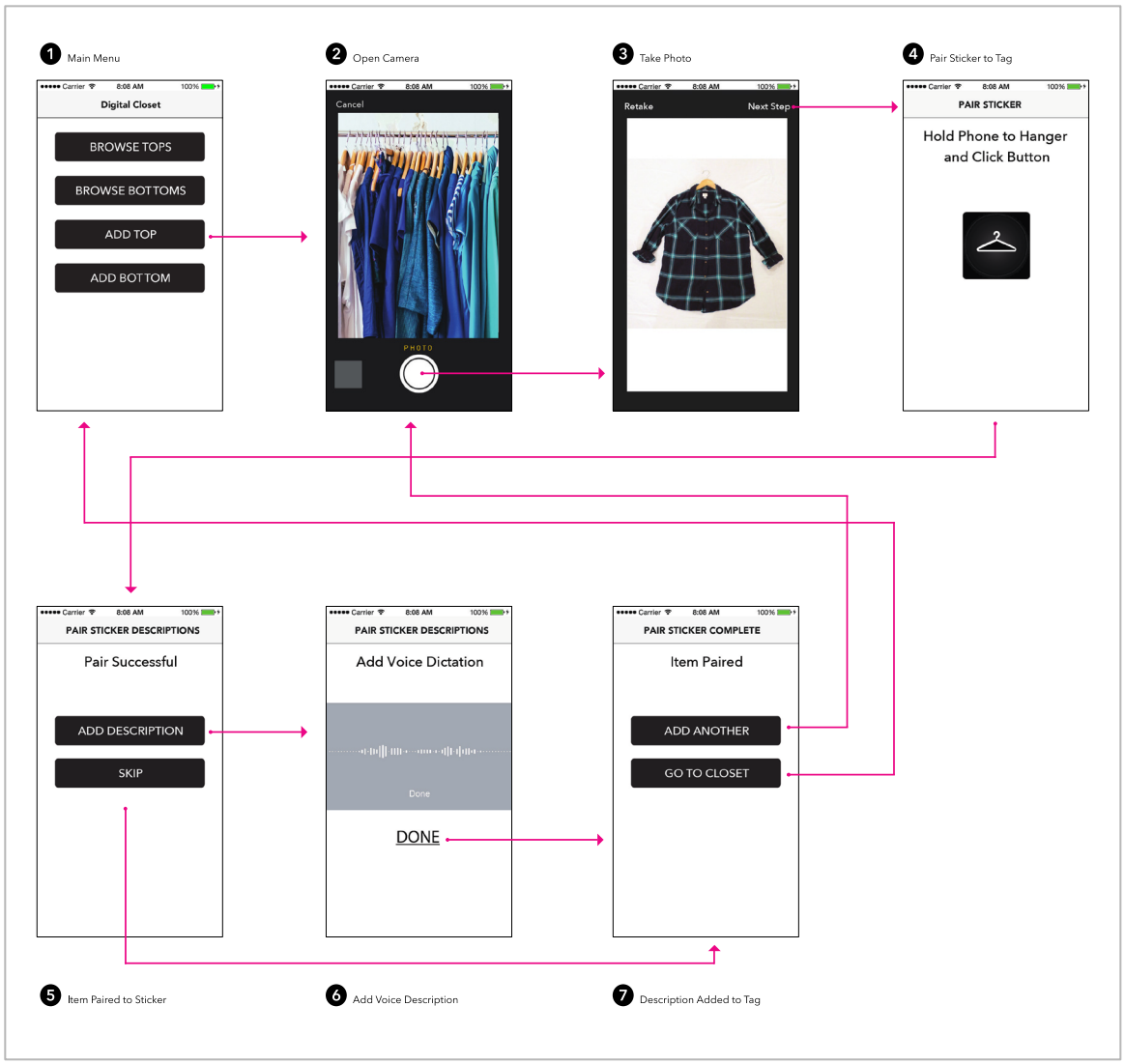

Figure 13. Add Top User Flow with Camera Prototype 1

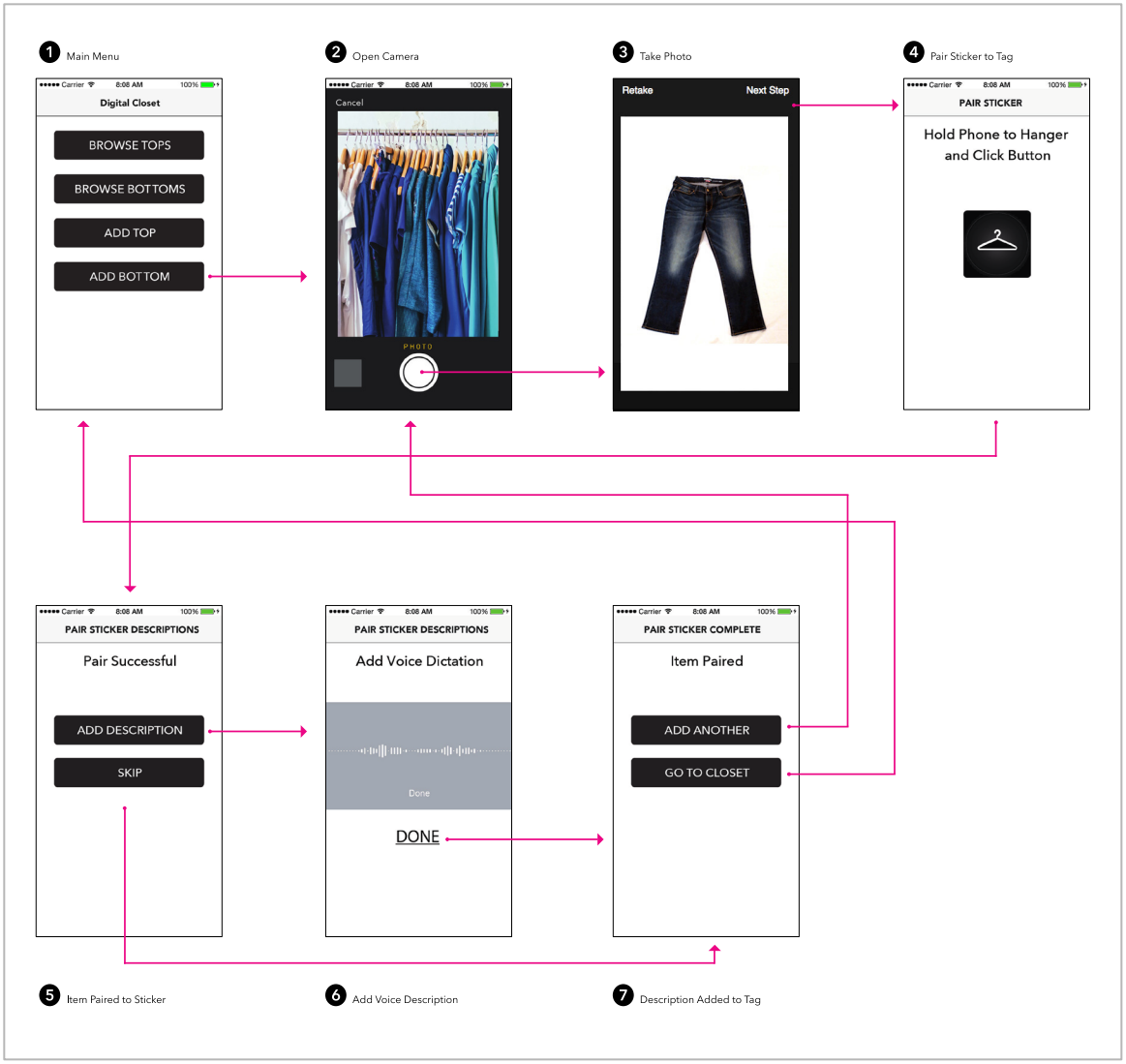

Figure 14. Add Bottom User Flow with Camera Prototype 1

Once all clothing was added to the closet the items were chosen to wear, within the mobile application, by physically locating the items hanging on a vibrating clothes hanger. After selecting the top and bottom pieces of clothing in the application (Figure 15) the RFID tag sets off the hanger vibration, triggered by the application, indicating which specific items of clothing were selected and their exact location. Incorporating touch in the form of haptic feedback, one of the current methods people with VI use to locate clothing, the vibration was located by brushing the hand across the items of

clothing detecting the selected item. After items were grabbed the information stored was cleared from the clothes hanger sticker and required re-dictation after being worn to re-sync to the hanger.

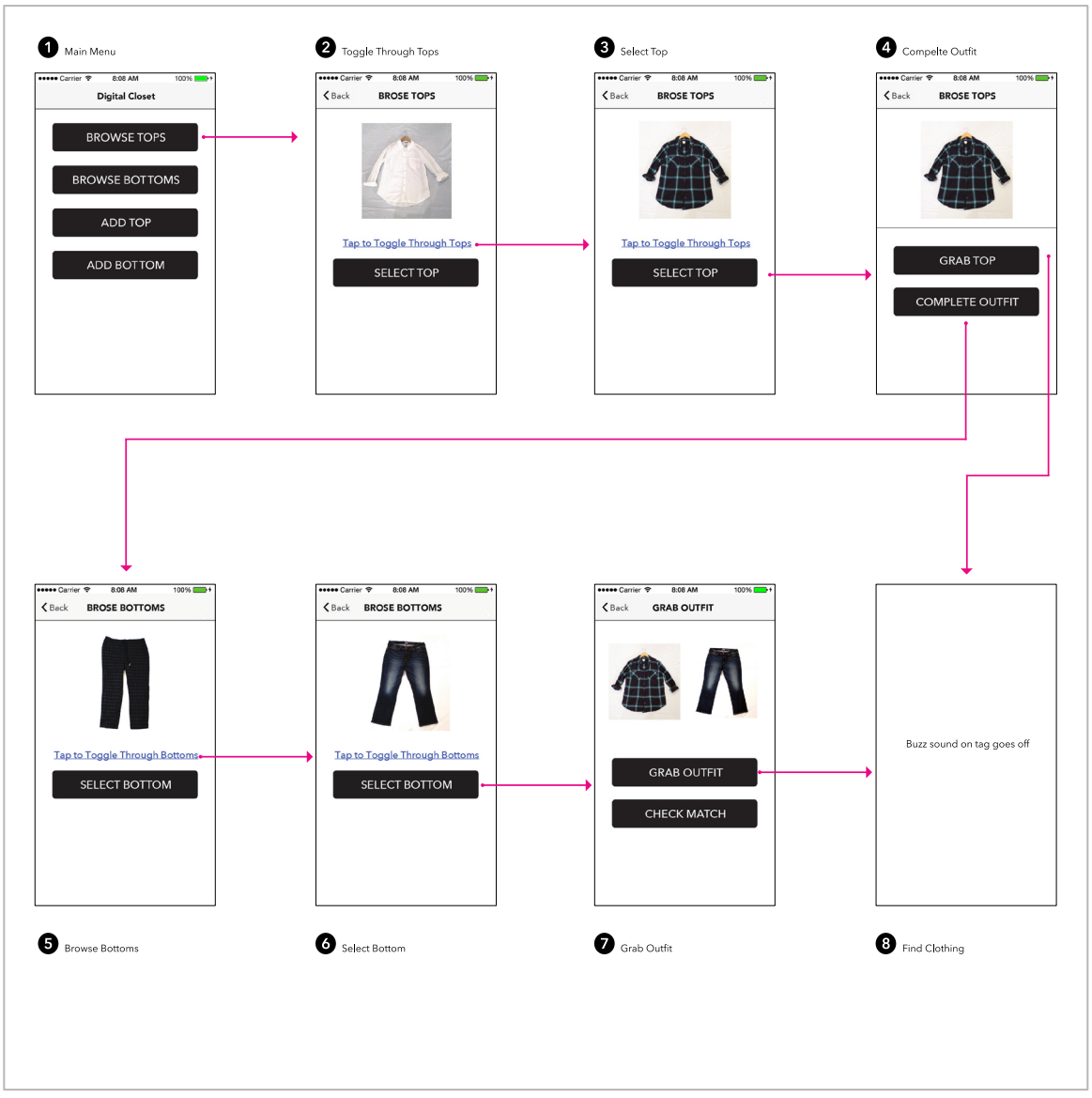

Figure 15. Choose Outfit User Flow Prototype 1

If the user is not confident in the match they have selected, on the final outfit screen the user chooses to “check match” requesting a friend’s opinion on the specific outfit selected before setting off the vibration mechanism. A friend from their existing

contact list is chosen as the receiver of the request. The photos that already exist in the digital closet are sent to the user's friend through text message starting the conversation. This solution eliminates waiting time for a sighted person to physically be present and provide trusted feedback to the people with VI.

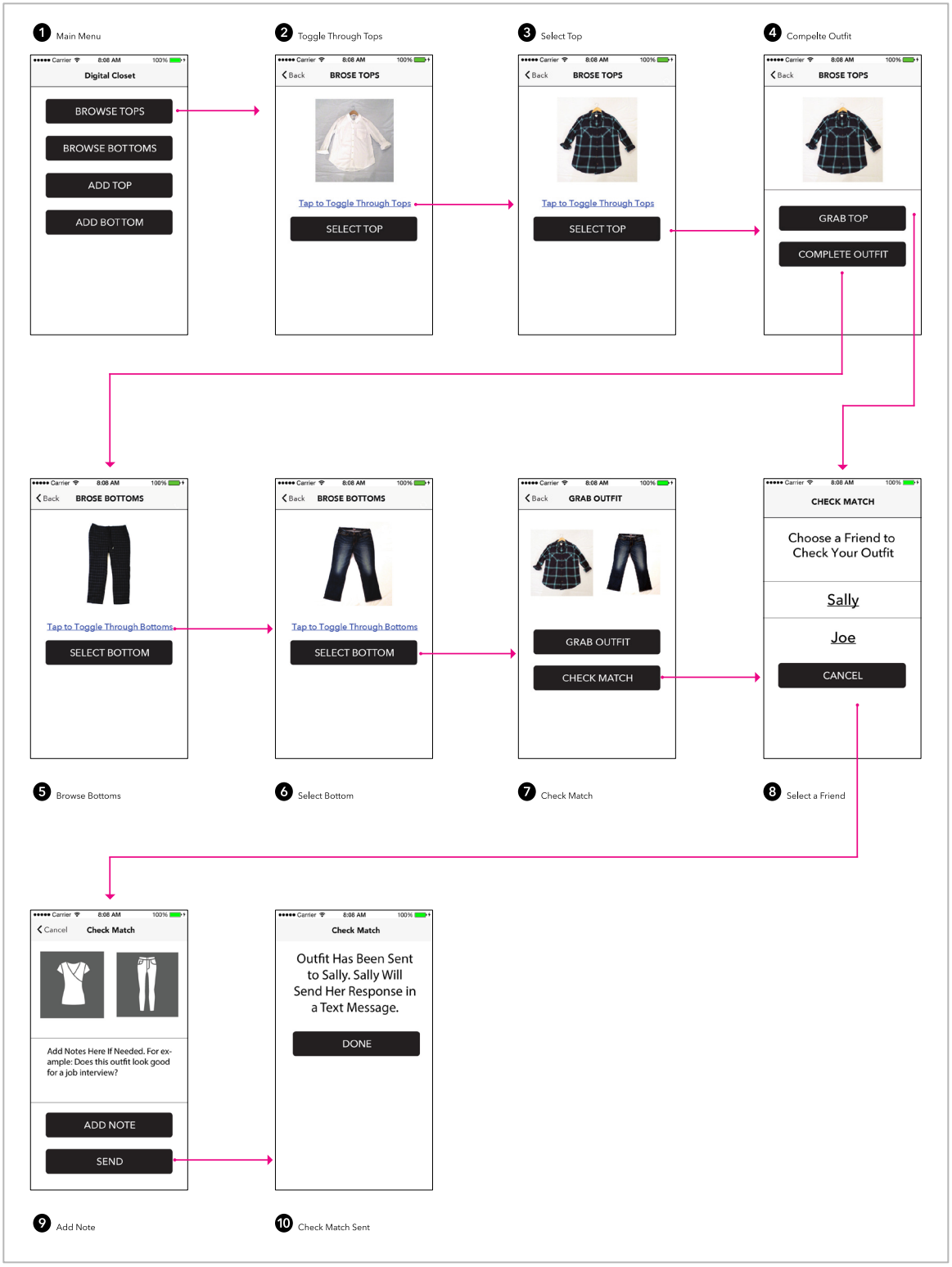

Figure 16. Check Match User Flow Prototype 1

Implementation: Generative Research

Using Hanington and Martin's (2012) Prototyping method, in the Implementation phase of this research study, two digital accessible design prototypes were tested (p.138). In the Implementation phase testing was conducted with Prototype 1 and Prototype 2, with completely new participants aside from the participants from the control group. Data was gathered from the Inspiration phase (with the control group of 6 participants), through measurement of time-on-task when identifying clothing locations, clothing color, and matching clothing items, using their current non-digital methods. Implementation phase of Prototype 1, user-testing with 5 participants, and Prototype 2, user-testing with 7 participants, were observed establishing time-on-task and accuracy data for comparison to the control group data. The results from usability testing of the two prototypes indicated if time-on-task was reduced, if users felt they could achieve tasks independently, and if this tool could assist in choosing clothing combinations.

Digital Prototype Testing: Prototype 1

User-testing for Prototype 1 was completed at the Lighthouse San Francisco location, in San Francisco, California, where the organization is active in participating in user experience testing for other companies in the surrounding area. Erin Lauridsen, the Director of Access Technology at Lighthouse San Francisco, shared this opportunity with their members who showed a lot of interest in assistive technology and were open to sharing their opinions and feedback. Many of the recruited participants were savvy in using smartphone mobile applications. Most of them used mobile apps to keep up with news, identify specific bus routes for travel, and to communicate with others via email, phone calls, texts, and social media. None of the participants were using any mobile

applications to help identify and match clothing at the time of this research. The Lighthouse San Francisco research participants were very active in the organizations activities such as teaching, learning, and working with assistive technology and made for ideal research candidates. Five members of the Lighthouse San Francisco participated in the testing of Prototype 1. Among the members two participants had low vision and three participants had no functional vision. The user-testing individuals consisted of four females and one male. Only one of the participants was employed, while one participant was retired, and the other three participants were unemployed. Three of the participants lived with a family member or spouse and two participants lived alone.

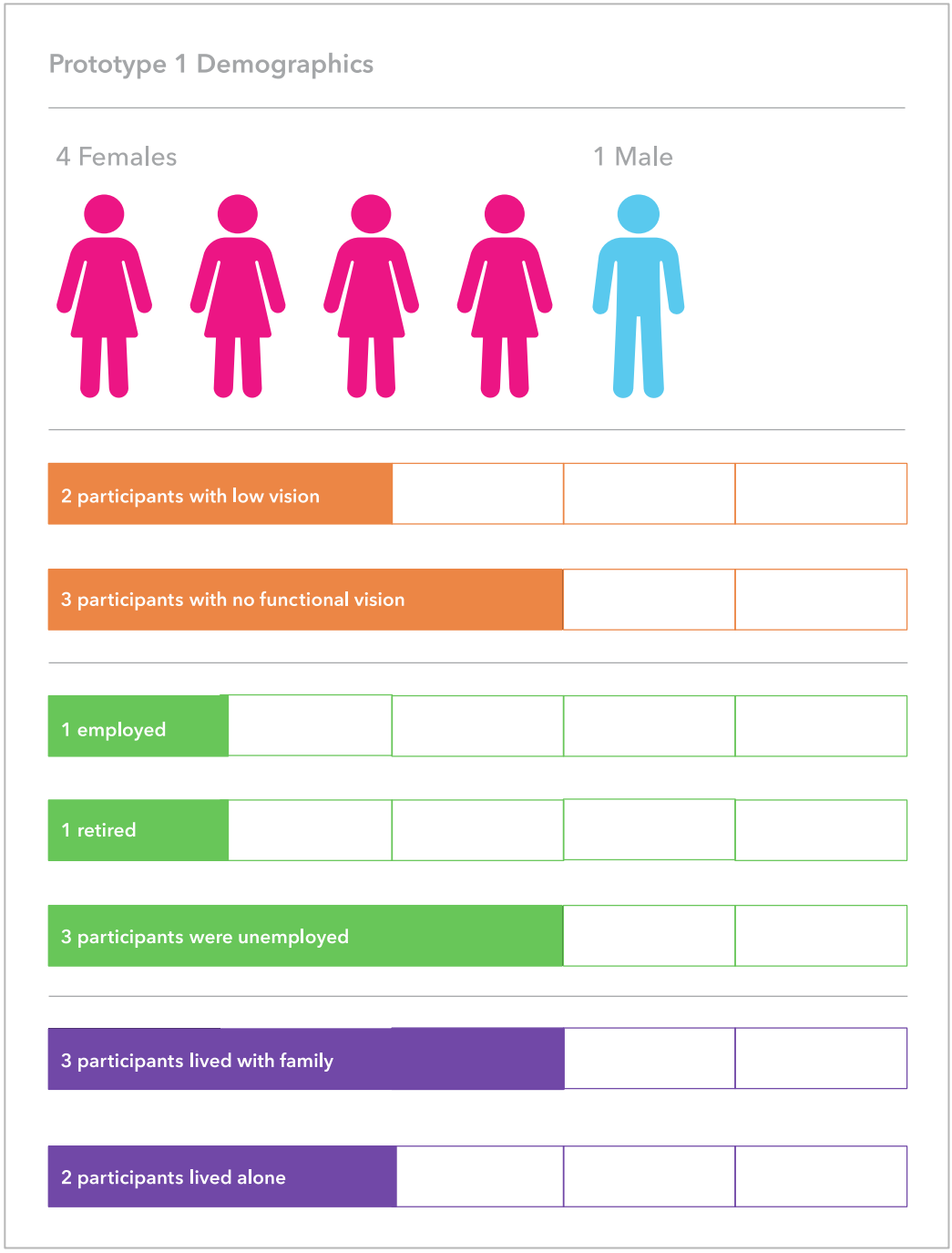

Figure 17. Prototype 1 Demographics Summary

Design method: User interviews.

Interviews were conducted with the research participants to determine how important appearance was to them in their daily lives. Many Lighthouse members were

passionate about their appearance and how they represent themselves in professional environments. One participant shared a theory that when it comes to matching it is not a matter of an opinion that an outfit is fine but a matter of some things are better than others. When asked about current clothing choice methods, some participants mentioned the dress code rules they follow: black goes with everything and do not pair a pattern with another pattern because they will never be right together unless they were made to match. The opinions of these participants tie in to the expectations society has put in place and how they manage to keep up with visual appearances.

Figure 18. Lighthouse San Francisco Testing Location

Design method: prototype testing of Prototype 1.

Prototype testing is a tangible example of a product or interactive concept to be evaluated by the user. This checkpoint lets the user provide positive and negative feedback about functionality and user flow (Hanington and Martin, 2012, p.138). The digital prototype for this thesis simulated the interactive representation of a mobile

application experience to collect feedback on functionality of proposed features. Each research participant was presented with a short description about the mobile application, its functionality, and proposed goals before working with the digital prototype.

Prototype 1 materials included the accessible digital prototype, wooden hangers (Figure 19), wireless vibrating transmitters set off with remote control in order to mimic the haptic feedback (Figure 20), three shirts (Figure. 21), three pants (Figure 21), and a portable hanging clothes rack (Figure 22). In combination, all of these items simulated the full user experience of the mobile application and RFID tag concept for gathering usability testing data.

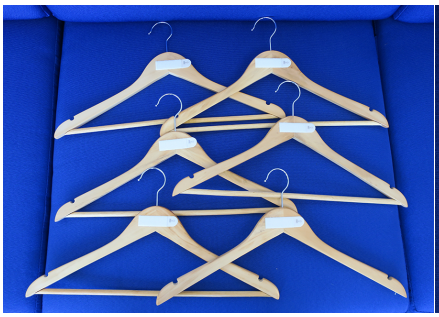

Figure 19. Wooden hangers

Figure 20. Wireless transmitters

Figure 21. Wireless transmitters on hangers on portable clothes rack with clothes

Figure 22. Clothing rack with clothing on hangers and transmitter attached

Design method: usability testing of Prototype 1.

Usability testing was used as a design tool to observe users completing tasks and to gather data about proposed design solutions in this research study. A Think-aloud Protocol, saying thoughts about tasks out loud during the usability testing process, was put in place to make sure all feedback and concerns were collected (Hanington and Martin, 2012, p.194). Using the digital prototype designed for this thesis time-on-task and accuracy data was collected during the following task analysis.

The first task asked of research participants was to use the digital prototype to enter a plaid shirt in to the digital closet (See Figure 13). This task required the user to be familiar with using the smartphone camera. Secondly, the participants were asked to identify specific items of clothing, for example a white top, and physically locate the item by feeling for the vibration on the hangers, set off by the RFID tag and application communication. Included in the selection of specific clothing items were three tops, one

of them with plaid pattern, and three bottoms, one with pinstripe pattern. The test proctor called out the outfits for participants to identify, while using the prototype, which they located by following the button user flow of: “Browse Top”, “Select Top”, “Select Bottom” and “Grab It” (See Figure 15). Outfits the users were asked to find were among the following categories: casual outfit consisting of the plaid top and jeans, professional outfit consisting of a white top and pinstripe pants, and social outfit consisting of a white top with jeans.

Summary of Data: Prototype 1

Positive outcomes from the Prototype 1 user-testing resulted in improvements in accuracy of identifying items at 100%, versus the 78% percent accuracy observed during the manual methods of the control group, and improvement in the successful identification of clothing items with patterns or multiple colors decreasing the time-on-task at an average of 23 seconds per item. In Prototype 1 testing the longest time recorded out of the 5 participants was 2:23 seconds and the fastest time recorded was 47 seconds. Both the professional and casual outfits time-on-task were decreased by an average of 2 seconds. While the social outfit average was increased by 36 seconds.

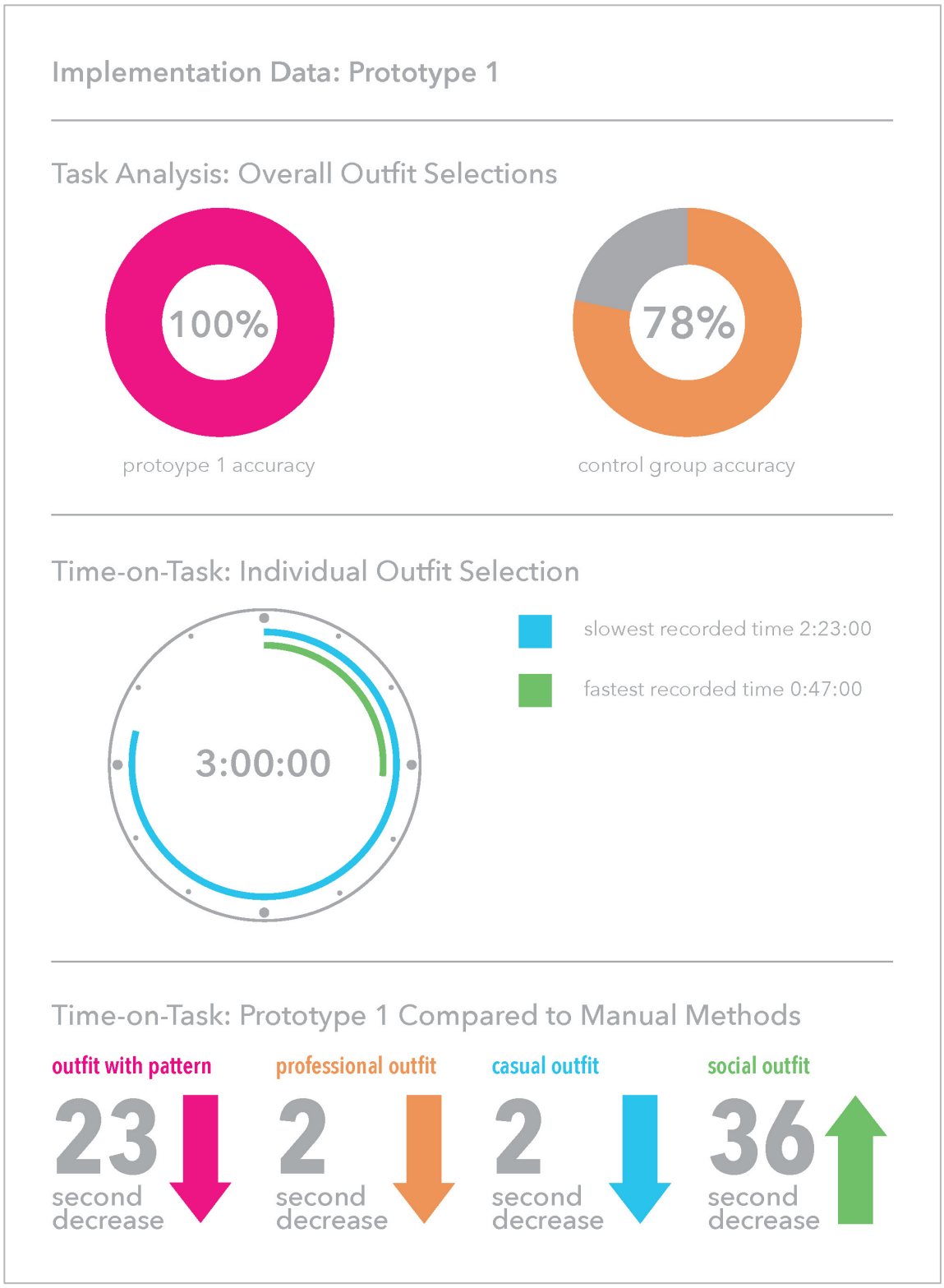

Figure 23. Summary of Prototype 1 Data

Post user-testing feedback provided some clear evaluations of the mobile

application concept and experience. Better solutions for entering clothing in to the digital closet were requested. As participants catalogued the plaid shirt in to the digital library the overall consensus suggested this step was very time consuming. Considering the number of clothes subjects own, it was noted that it would take a lot of effort and time to catalogue every article of clothing using the proposed smartphone camera method. Participants valued how their time was spent and thought in most cases their current methods would be faster than the mobile application catalogue entry process. Due to this concern, efficient use of time as a valued user experience goal was one of the essential design factors to revisit in the second iteration. Another suggestion was to add the RFID tag to the clothing instead of the hangers to eliminate concerns about continuously having to pair clothes with hangers after washing. This would be especially beneficial for new clothing items. Treating this mobile application as more of an outfit finder, versus locating the clothing item, was a popular alternative scenario. A crowdsourcing aspect was also appealing for people that do not live with someone sighted for opinion and guidance for the Check Match function. All of these suggestions indicated that the next iteration should be a more simplified design by cutting down steps and clearly defining the desired goals (Quesenbery, 2010).

Prototype Testing and the Iterative Design Process Prototype 2

Feedback from Prototype 1 user-testing was applied to version two of the digital Prototype 2 for user-testing. This design technique known as Rapid Iterative Testing & Evaluation (RITE) is a method that can help designers identify and fix major problems of the interface in an early stage of the design process before final production. (Hanington and Martin, p.142). The “rapid test-fix-test-fix approach” brought to light what features

of the mobile application prototype were successful and what tasks the user's found problematic.

User flow of main features for Prototype 2.

Improvements sought in the interaction for the Prototype 2 user-testing focused on decreasing the amount of time it took to add clothing to the digital closet. Also, the RFID tag concept was updated by embedding the tag in to the standard fabric garment label, already attached to the item of clothing when purchased, on which, manufacturers would include a pre-determined description. The description determined by the manufacturer includes characteristics like color, pattern, fabric, and form that syncs with the mobile application. It was theorized that adding clothing to the digital closet by tapping the RFID tag to store the item's information would become a more streamlined process. After items are added to the closet a professional stylist, who would have access to the user's digital closet behind the scenes, would designate the best pairing options to match that specific item within 24 hours of adding. For example, if the user selects a top only the stylist's suggested bottoms are visible and available as options to pair with. The user then hovers their phone over the clothing in their closet prompting a voice dictation from the mobile application in *VoiceOver* mode, locating the selected item, when the item is within hands reach. The vibrating hangers were eliminated from the process, along with the requirements to add clothing via the smartphone's camera. An additional feature, for those who do not have someone readily available for assistance or opinions, was the "Ask the Crowd" button. Selecting this action sends the previously stored images and description for the outfit to the Smart Closet Facebook page, or the user's Facebook page, asking for feedback from followers and friends. Users would then be notified of

likes and comments applied to the outfit post receiving feedback from the crowd. Crowdsourcing the outfit on a social media site for input and opinions was an option for those seeking friendly advice on their outfit selections. With these updates the user flow for adding clothing to the digital closet using Prototype 2 were as follows: step one-with mobile application open, tap phone to the garment tag and step two-accept to add description and image to closet.

Design method: prototype testing of Prototype 2.

After implementing the changes in Prototype 2, participants were recruited from the Texas State University Offices of Disability and The National Federation of the Blind Austin Chapter. 3 Texas State students were recruited from the Offices of Disabilities mailing list and was completed at the campus in San Marcos, Texas. With the help of Jeanine Lineback, 4 members of the National Federation of the Blind Austin Chapter signed up and completed user-testing at the state conference in Houston, Texas. This brought the total number for user-testing participants of Prototype 2 to 7. The user-testing group for Prototype 2 consisted of 4 males and 3 females. All 7 research subjects had no functional vision. Three participants were employed, while the other four participants were attending college. In this group, five participants lived with a family member or spouse and the other two participants lived alone.

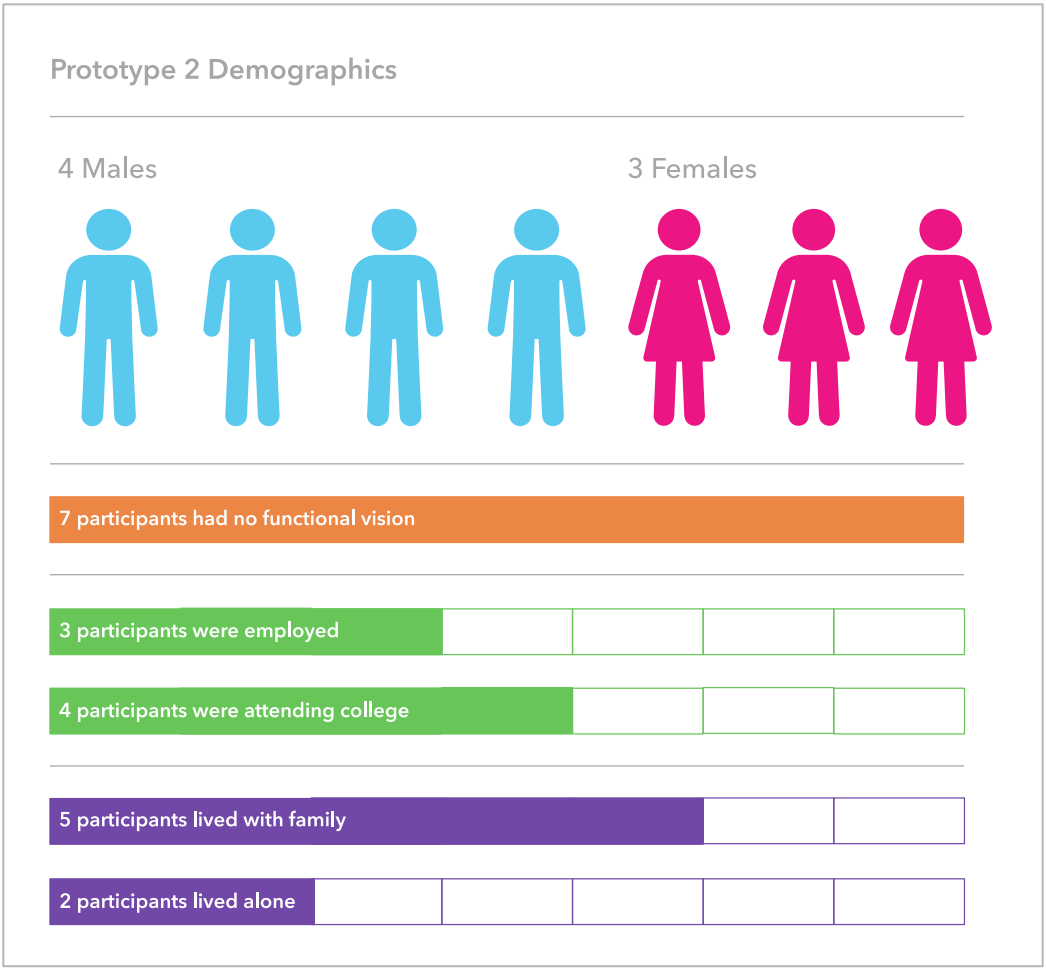

Figure 24. Prototype 2 Demographics Summary

Design method: usability testing of Prototype 2.

The first task for the user-testing of Prototype 2 was to add the plaid top by selecting the "Add Top" button and then tapping the tag of the clothing with the user's phone (Figure 25). After the user tapped the tag with the phone the pre-determined description was announced and an image, provided by the manufacturer, was automatically added to the digital closet (Figure 26). Following the clothing addition, participants were asked to then select an outfit from the "Main Menu". From the main menu users then chose "Select Top" to begin the outfit selection process. The available tops, and bottoms, options were available in a two-column grid system allowing the user

to browse all the tops, compared to the one-at-time description approach in Prototype 1 (Figure 27). After choosing the preferred top the next screen took the user to the suggested bottoms to choose from, in which professional stylist provided acceptable pairing options with suggested bottom selections (Figure 28).

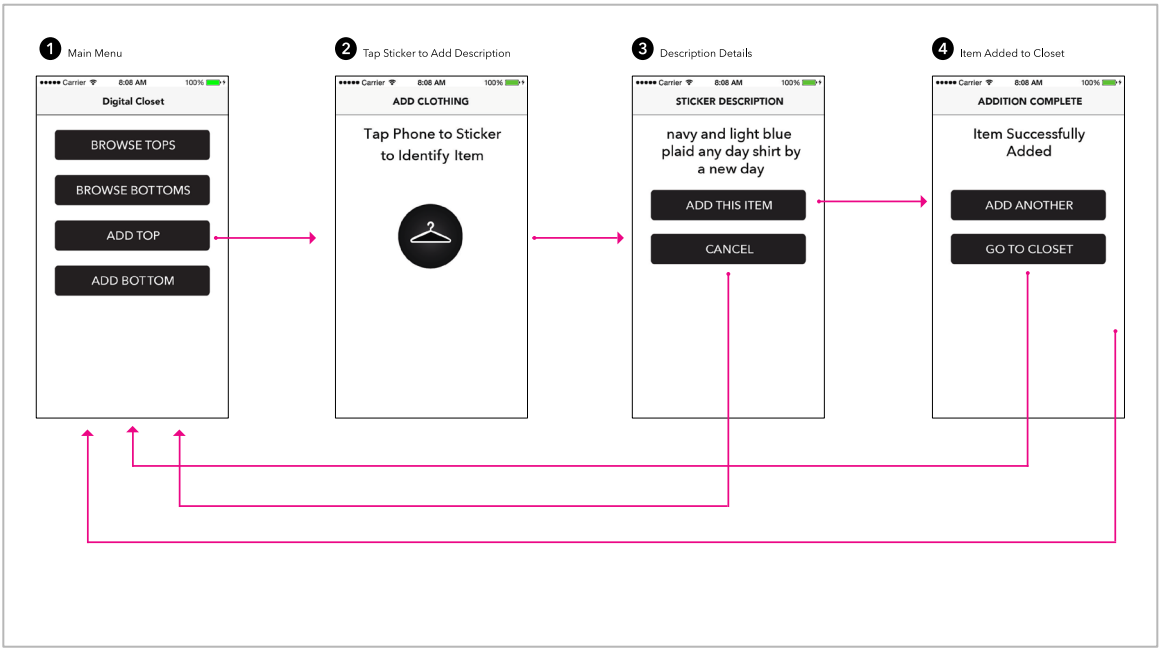

Figure 25. Add Top User Flow by tapping on clothing item Prototype 2

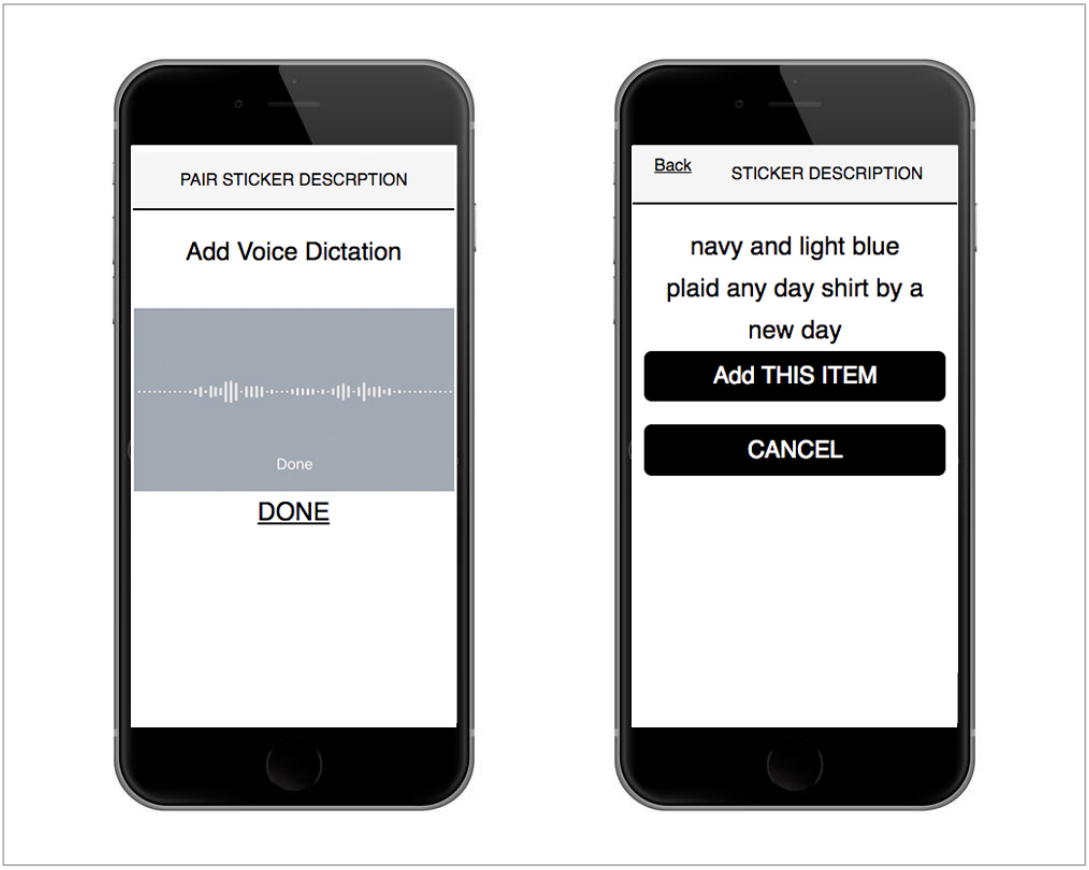

Figure 26. Choice Screens Comparison of Add Description: Prototype 1 (left) changes to Prototype 2 (right)

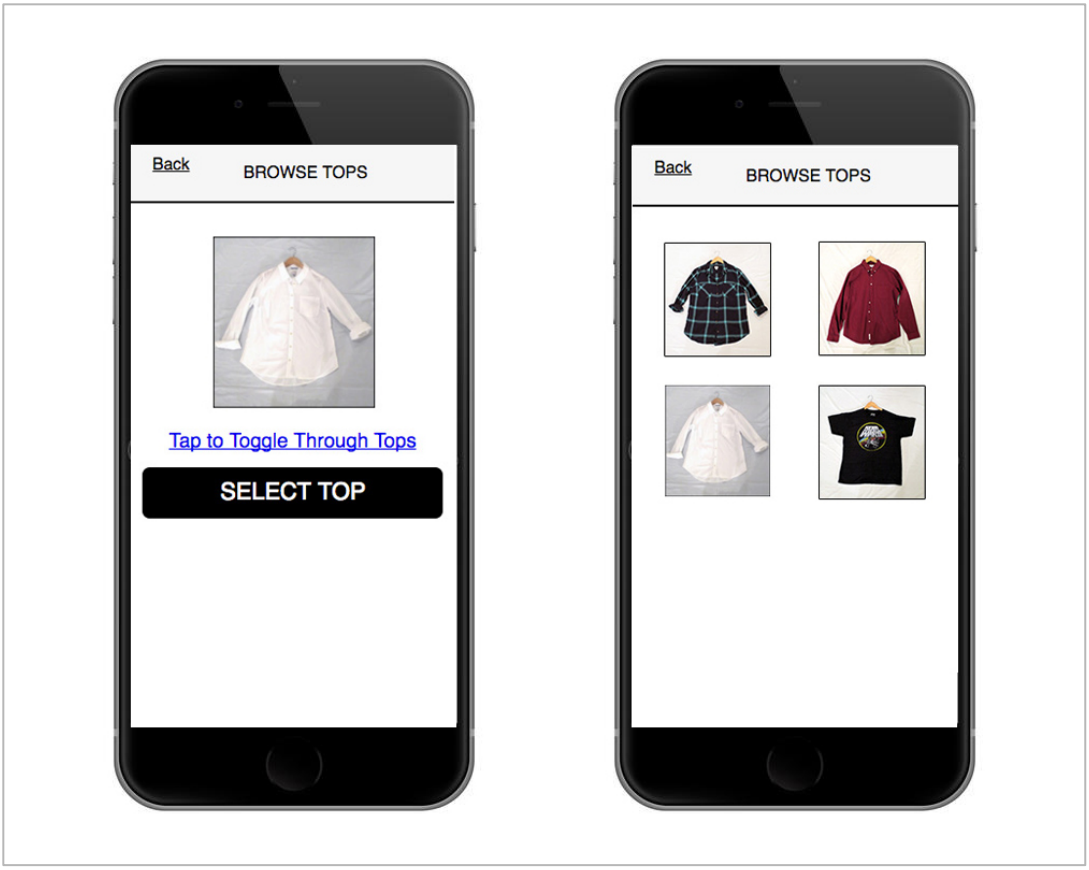

Figure 27. Choice Screens Comparison of Browse Tops: Prototype 1 (left) changes to Prototype 2 (right)

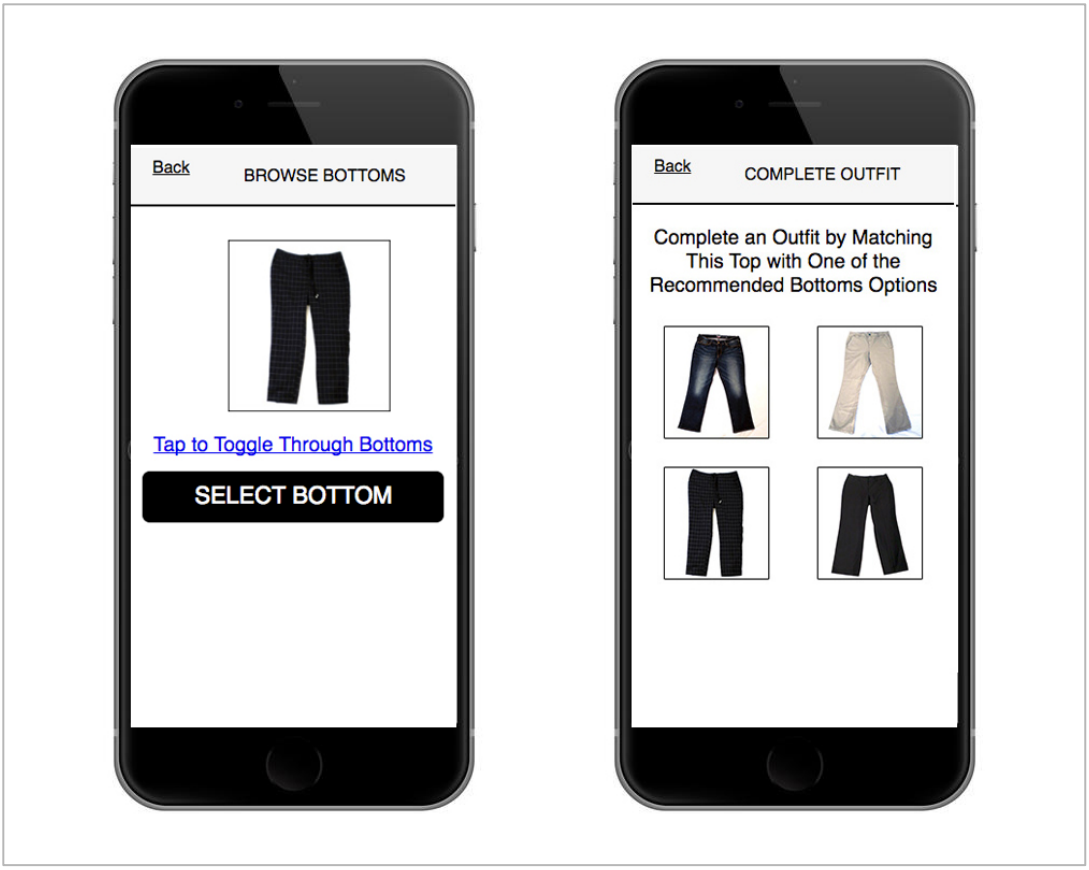

Figure 28. Choice Screens Comparison of Browse Bottoms: Prototype 1(left) changes to Prototype 2 (right)

Each participant was tasked with choosing four outfits including a social outfit: plaid top and jeans, a casual outfit: graphic tee and whichever bottom they preferred from the options, a special outfit: red button up top and black pants, and professional outfit: white button up top and blue pinstriped pants. Prompted to select a social outfit the user then chose the "Select Top" button upon which the next screen provided the available bottom options, options were determined by a stylist's opinion of best matches who have access to the digital closet. The user then had options with reassurance that the appearance of the outfit was acceptable. After selecting a bottom, the user was presented with three options to choose from: "Grab Outfit" (Figure 29), "Ask a Friend" (Figure 30),

or “Ask the Crowd” (Figure 31).

“Grab Outfit” directed the user to hover their phone over the items of clothing in their closet. When the phone reached the selected items of clothing a voice command announcing the selected item would follow a beep sound within the application. “Ask a Friend” was also a well-received feature as users liked the opportunity to add their own request or question for a friend to consider.

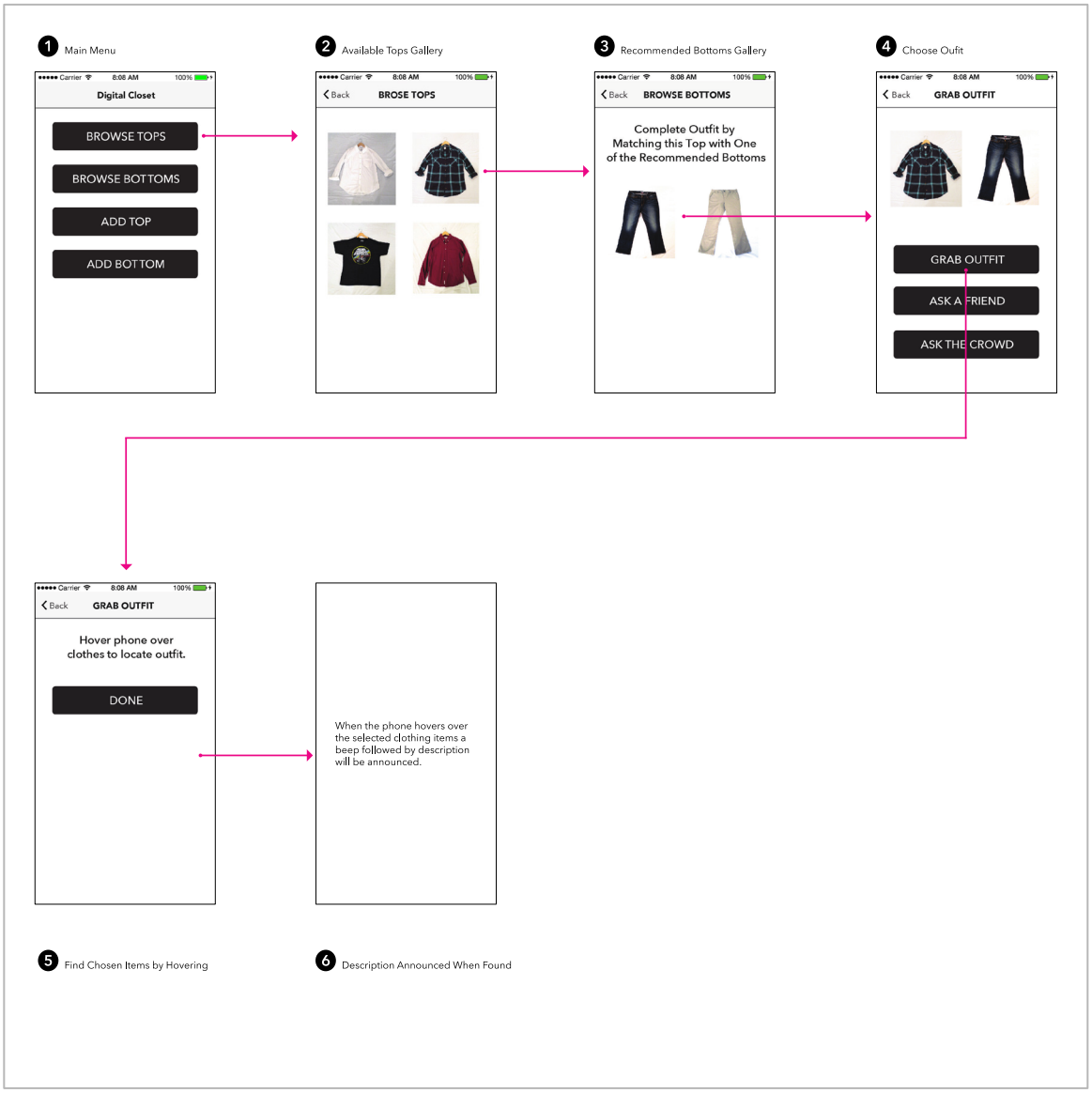

Figure 29. Grab Outfit User Flow Prototype 2

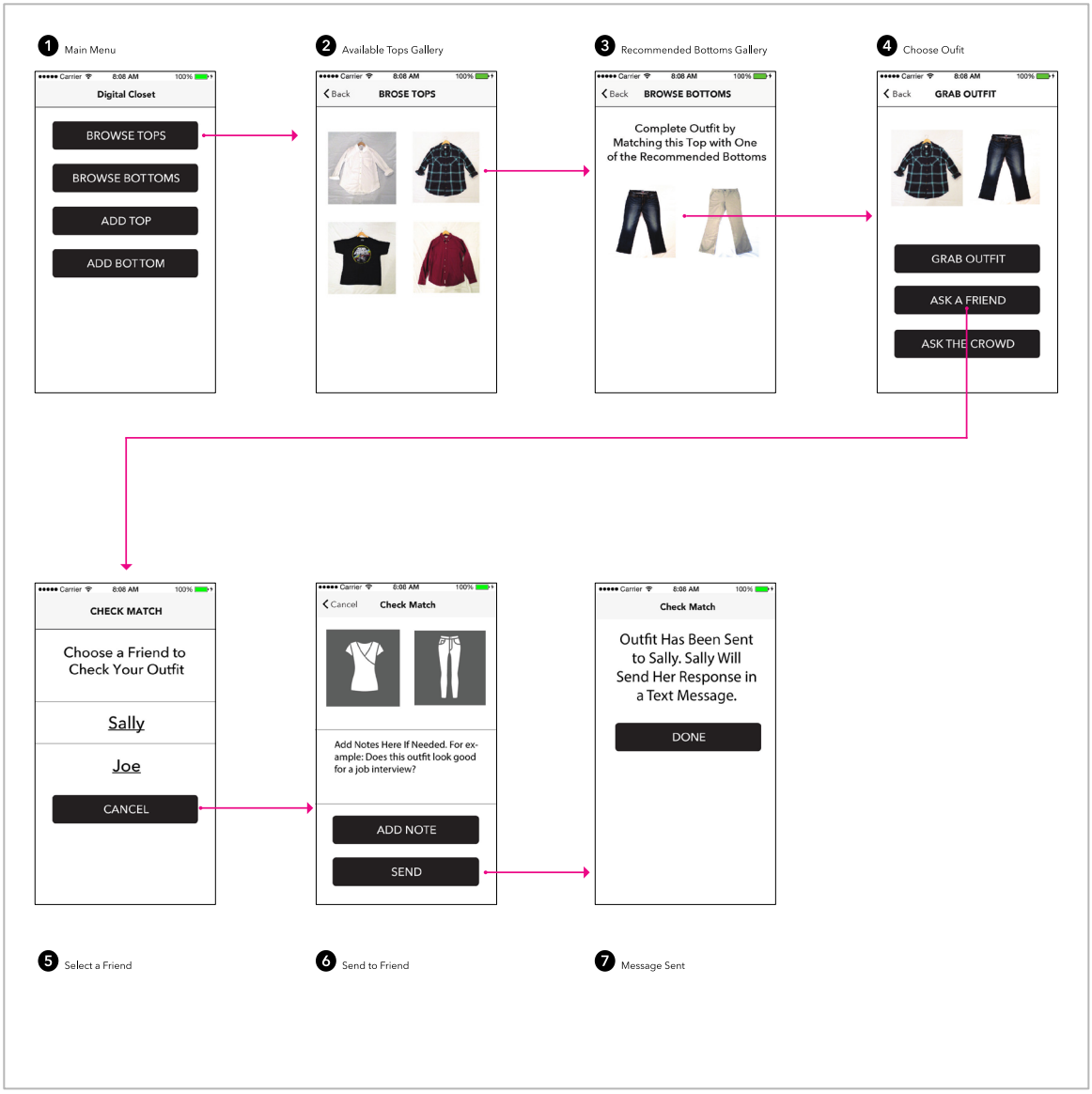

Figure 30. Ask a Friend User Flow Prototype 2.

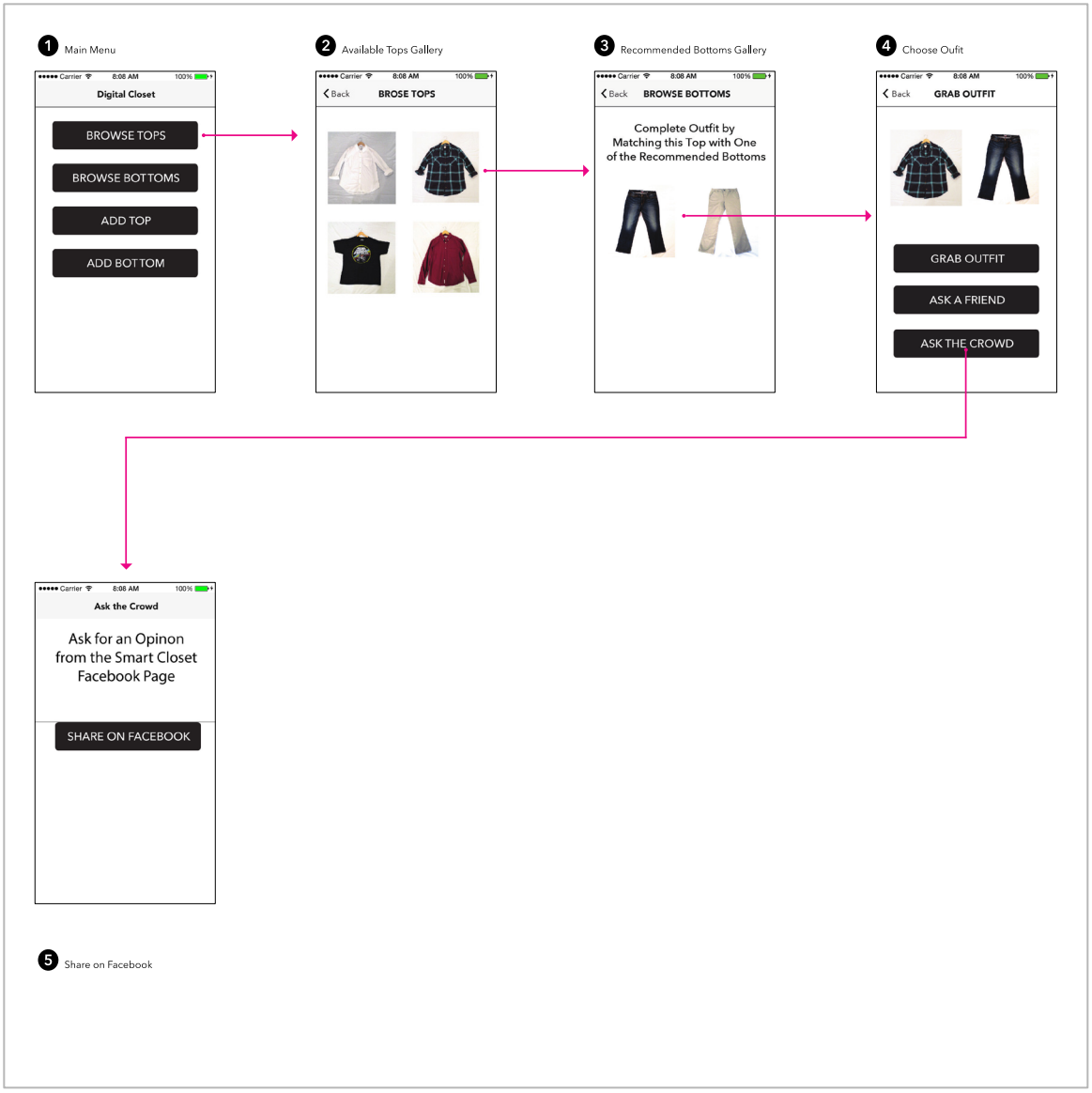

Figure 31. Ask the Crowd User Flow Prototype 2

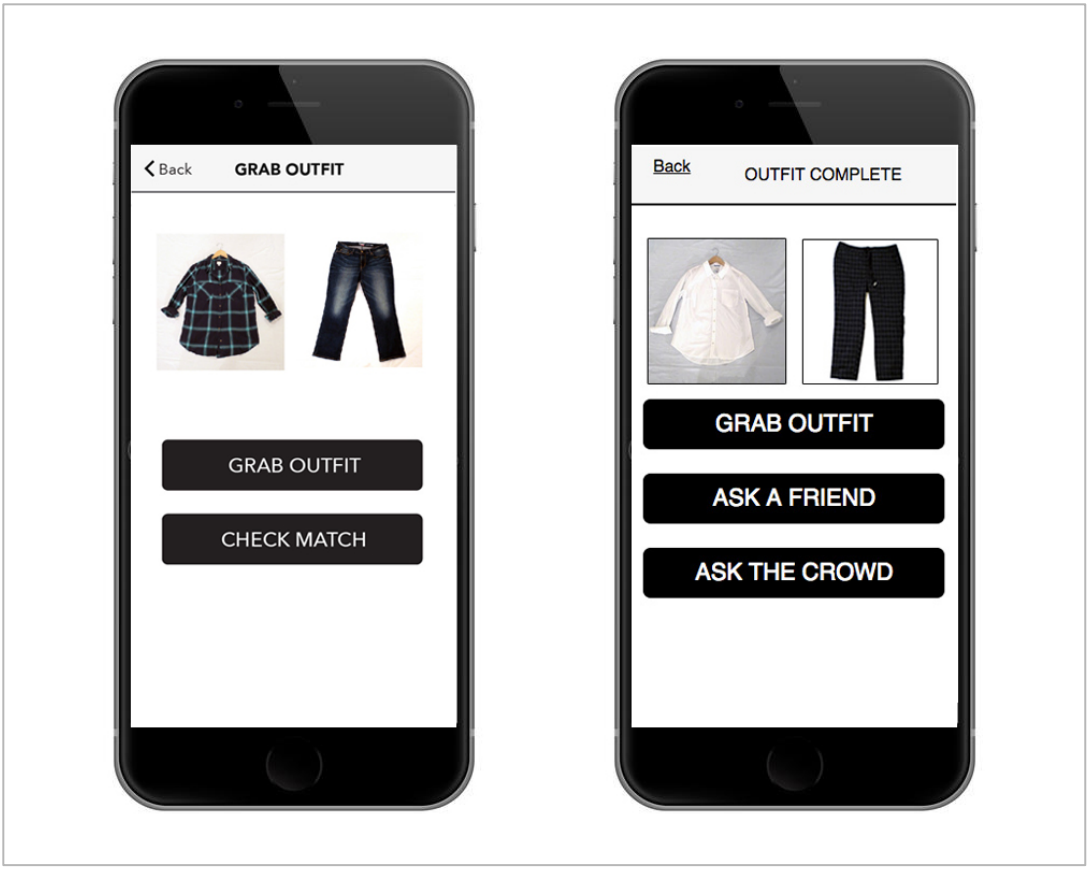

Figure 32. Choice Screens Comparison of Final Step: Prototype 1(left) changes to Prototype 2 (right)

Summary of Data: Prototype 2

Changes made to the user flow of digital Prototype 2 for user-testing were very well received. Users expressed surprise at the ease of adding clothing to the closet and agreed that the information provided, color, pattern, sleeve length, brand, and embellishments, were very clear in the description of the item. Accuracy in locating articles of clothing remained at 100% during Prototype 2 user-testing. Other successful measurements, in comparison with control group data, included a 9.14 second decrease when selecting a social outfit, 45.86 second decrease when selecting the professional outfit, 29.71 second decrease when selecting the casual outfit, and a 28.29 second

decrease when choosing a special outfit. There was less variation in time-on-task during Prototype 2 testing versus the many varying times in the control group data. The fastest time for selecting an outfit using the digital Prototype 2 was recorded at 20 seconds, with the slowest time recorded at 1:22 seconds. 7 out of 7 (100%) of users were very interested in having this mobile application to improve their current methods for choosing clothing on their own. 7 out of 7 (100%) of participants said minimal improvements were needed and admitted this mobile application would help them match clothing they already own. 7 out of 7 (100%) of participants thought they would use the mobile application everyday for outfit assistance. One participant stated if he had this app, even with [his wife] in the same room with him, he would still use it. 7 out of 7 (100%) of participants were impressed with the ease of use and accessible design of Prototype 2 saying it was really clear and easy to understand, the labeling was on point, and all buttons were well labeled. Finally, 7 out of 7 100% of participants showed interest in the idea of the "Ask the Crowd" share feature, a new feature added when compared to Prototype 1, because when the option becomes functional it could provide feedback they did not consider. (Figure 31).

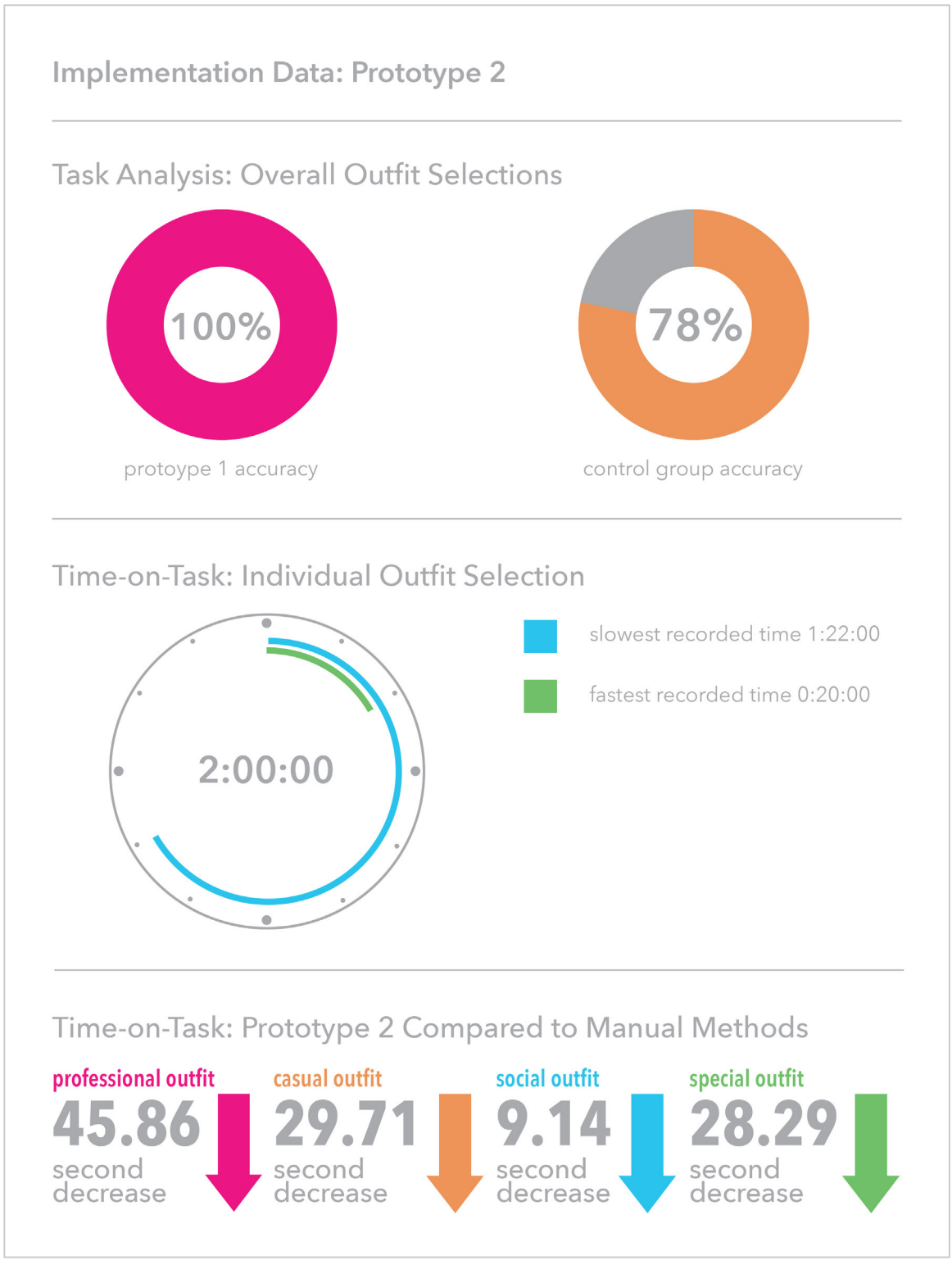

Figure 33. Summary of Prototype 2 Data

III. RESULTS

Data gathered in this thesis research study indicates that improvement is possible with a mobile application and RFID tag combination, in decreasing time-on-task and achieving successful identification, when assisting people with VI in choosing an outfit for the day. When comparing Prototype 2 to control group data accuracy in clothing identification was improved by 22%. When selecting and outfit for the day time-on-task decrease improvements using Prototype 2, versus control group data, by occasion were 13% for the social, 44% for the professional outfit, 35% for the casual outfit, and 37% for the special occasion outfit. The lowest recorded time-on-task in Prototype 2 was faster than Prototype 1 by 36%. The highest recorded time for Prototype 2 was faster than Prototype 1 by 44%. 60% of Prototype 1 user-testing participants said they would be interested in using this mobile application. 100% of Prototype 2 participants said they were also interested in using this mobile application.

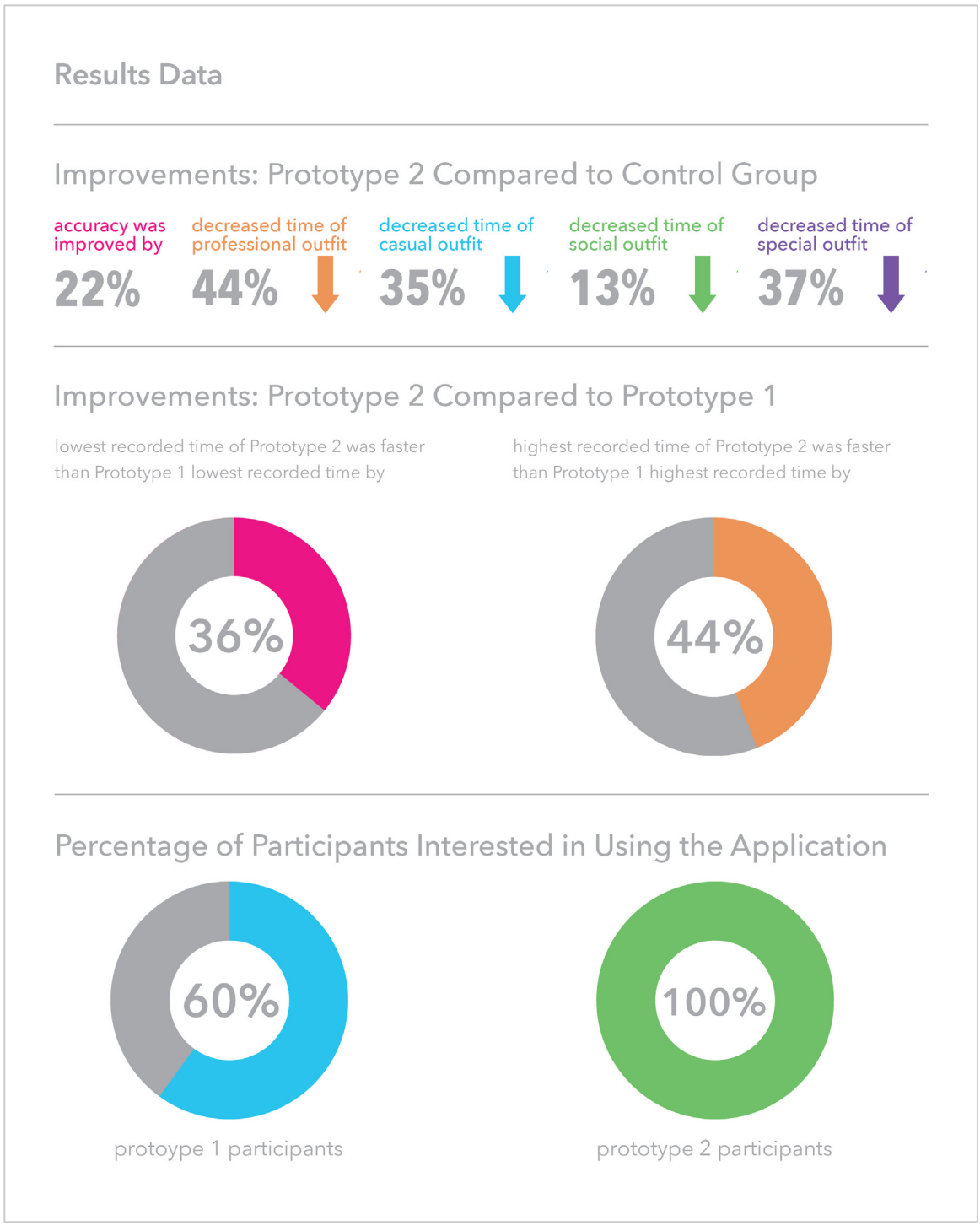

Figure 34. Summary of Results Data

By designing this mobile application user experience for people with VI as the initial audience the goal of a final inclusive design, a design that is accessible by as many

people as possible, is achievable. Through immersive research, the visually impaired participants were able to establish how they complete tasks independently and provided insight in to target areas of exploration this design could improve. Specific areas uncovered focused mostly on matching of outfits and less about the concern of choosing the wrong items. After refinements were made and user testing was completed for Prototype II, all 7 (100%) of participants inquired about when this product would be available for use. They were eager to integrate this tool into their daily lives. Features such as the pre-determined outfit matches, Ask a Friend, and Ask the Crowd showed potential for eliminating the worry of burdening others on a daily basis for assisting when matching clothing. Choosing an outfit for the day can potentially be a more advantageous experience for people with VI using this tool.

IV. CONCLUSION

The results of this research study indicate marked improvements when considering an accessible smartphone mobile application design solution, in combination with an RFID device, to identify matching articles of clothing accurately and to decrease time-on-task when choosing what to wear. Data collected indicates that when comparing Prototype 2 data, using AT, to control group data, using manual methods these goals are achieved. This conclusion was reached by using the IDEO Inspiration, Ideation, and Implementation methods. During the Inspiration phase interviews about current techniques, observations of task analysis, recording of standard times for choosing an outfit, and identifying pain points during the clothing selection process was completed. This was important because as Graham Pullin mentions in his book *Design Meets Disability* "disabled people do not all share a single experience of their impairment, and these experiences are inseparable from the rest of their lives…"(2009, pp.6-7). This theory was evident when observing participants use various identification methods for choosing clothing and from the sporadic differences in time when locating the articles of clothing manually. In the Ideation phase the concept for solving the problems in the current process of choosing clothing, by those with VI, was developed and applied to a digital prototype using accessibility design best practices. This digital prototype was then user tested in the Implementation phase while time-on-task was recorded to analyze against standard times from the Inspiration phase. In order to confirm if results will generalize to larger populations more user-testing of Prototype 2 is needed.

Future Research

There are many opportunities and features that could be considered in future iterations of this smartphone mobile application and RFID tag solution. Testing with other populations in the following categories, Autism, Alzheimer's, Color Blindness, Seniors, and Down Syndrome could better define if this design is applicable to as many people as possible. First, would be to fully develop the application and test the functioning tags with smaller stores or boutiques before approaching larger manufacturers. Once the tags have been tested and final iterative adjustments are completed, this system could also be leveraged by larger manufacturers. Not only would the larger companies aid an underserved populations but could also use the RFID tags as a tool to keep stock of items in a warehouse or keep stock of items purchased.

An additional user experience, as a feature of version 2.0 for caretakers assisting people with disabilities, other users could also have access to an individual's digital closet. For example, allowing a family member, such as a parent of someone who is disabled, access to the digital closet could provide ways for them to give guidance when teaching about clothing matching and identification. Additional categories of fashion such as shoes, belts, jewelry, and other accessories could also be added to the menu of selections that can be paired when polishing off a whole ensemble. Expanding on the consideration of assisting in the overall image of an individual, one study participant suggested, branching out to other areas concerning visual appearance such as assistance with applying make-up. With Artificial Intelligence (AI) and face recognition features application of make-up by facial shape and color placement instruction could be provided. Incorporating AI could also be beneficial in scanning clothing to check for

stains or fading of clothing items, this was a popular concern amongst study subjects. The RFID tags can also include information about wash and care instructions to maintain the quality of clothing.

A request made during the digital prototype testing, when getting stylist input, is that body type be considered in the options provided. This mobile application solution could work in conjunction with other existing AT solutions to take a photo of the person and analyze body type when stylist's suggestions are made. Other features might include assisting an individual with clothing selection by providing access to resources, such as blogs and accessible news with detailed in-style descriptions. There is also the opportunity to educate users about fashion rules around color and pattern combinations. For example, which colors look good together and which colors clash with each other. When a clothing item is selected optional descriptive notifications about what clothing items owned are trending throughout the seasons could help with choices about attire. To save even more time-on-task, users could bookmark favorite suggested outfits to access quickly when they want to wear them again. This mobile application could also assist in the shopping process by making suggestions of certain bottoms that would go well with a specific top that the user already owns. The article of clothing could then be purchased within the mobile application. All of these additional features have the potential to enhance and grow the overall user experience of the mobile application and can be published the various versions with software updates.

Designers have the opportunity to solve endless problems with their design expertise, design methods, and user experience analysis. Focusing on accessibility design and AT as tools for improving the lives of people with disabilities, like the VI

community, in completing daily living tasks is a valid approach. The VI population can use these creative systems and inventions to feel included as part of society and the sighted community. User experience testing with disabled people can impact accessibility design solutions and bring new outcomes and ideas that will materialize in to successful tools to assist these groups with daily living tasks (Pullin, 2009). These approaches, solutions, and systems can also bring awareness to the types of users interacting with product design allowing for everyone to access, benefit, and enjoy the intended experience.

APPENDIX SECTION

APPENDIX A: User Interview Questions

Q1: How would you define your style?

Q2: Do you think your current wardrobe is representative of your style and personality?

Q3: What are the challenges you face when getting dressed for the day?

Q4: What is your organization method for locating and combining clothing?

Q5: How often do you rely on others to help you with identifying and matching clothing?
Q5b: How does this make you feel?

Q6: How often do you use smartphone devices?

Q7: What do you use your smartphone for?

Q8: Are you comfortable with smartphone apps?

Q9: Have you used any smartphone apps or other technology solutions for organizing clothing or helping you to select an outfit?

Q10: What are your likes and dislikes about your current process?

Q11: Tell me about the moments when you need assistance choosing an outfit?

Q12: Does this person need to be some one you trust?

APPENDIX B: Inspiration Phase Task List

Task 1: Show me how your clothing is organized?

Task 2: Show me how your method for identifying clothing?

Task 3: Walk me through how you would match an outfit?

Task 4: Show me how you choose an outfit for a social occasion?

Task 5: Show me how you choose an outfit for a work/job interview?

Task 6: Show me how you choose a casual outfit?

Task 7: Show me how you choose an outfit for a special occasion?

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