Using Personas with Visual Impairments to Explore the Design of an Accessible Self-Driving Vehicle Human-Machine Interface

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Recent reports have suggested that most self-driving vehicle technology being developed is not currently accessible to users with disabilities. We purport that this problem may be at least partially attributable to knowledge gaps in practice-oriented user-centered design research. Missing, we argue, are studies that demonstrate the practical application of user-centered design methodologies in capturing the needs of users with disabilities in the design of automotive systems specifically. We have investigated user-centered design, specifically the use of personas, as a methodological tool to inform the design of a self-driving vehicle human-machine interface for blind and low vision users. We then explore the use of these derived personas in a series of participatory design sessions involving visually impaired co-designers. Our findings suggest that a robust, multi-method UCD process culminating with persona development may be effective in capturing the conceptual model of persons with disabilities and informing the design of automotive system.

INTRODUCTION

User-centered design (UCD) is a design philosophy that is focused on the needs of a product or system's end users and brings a focus on these needs into the design process (Veryzer & Borja de Mozota, 2005; Vredenburg et al., 2002). It has been suggested that the popularization of this philosophy has resulted in products that are more usable and better satisfy end user needs. Despite the widespread adoption of user-centered design principles and the trend towards improved usability generally, the frustration of many disabled users with emerging technologies has not abated. One such emerging technology is the fully autonomous or self-driving vehicle. Recent reports have suggested that most self-driving vehicle technology is not currently accessible to users with visual disabilities specifically (National Federation of the Blind, 2016). Given the increasing prevalence of the use of user-center design in industry, we purport that this lack of accessibility may be at least partially attributable to the limited practice-oriented research that demonstrates the application of user-centered design methodologies in capturing the needs of users with disabilities in the design of automotive systems. In essence, the design of automotive systems at present is focused on the needs of the driver of the present, who it is assumed is sighted, as opposed to the user/operator of the future, who may not necessarily be. Underrepresented in the existing research, we argue, are studies that demonstrate, in concrete terms, the application of user-centered design methodologies in capturing the needs of the emerging user/operator with disabilities with the purpose of informing the design of automotive systems.

In this report we investigate user-centered design (UCD), specifically the use of personas with disabilities, as a methodological tool to inform the design of accessible automotive systems. As a case study, an ongoing project involving the design of a self-driving vehicle human machine interface (HMI) for blind and low vision users is examined. The step-by-step process used to capture user needs and construct personas for this project is presented. The present research was designed to contribute to the literature a practical demonstration of applied user-centered design methodologies in the design of an accessible automotive system. As humans interact with automotive systems less as active drivers and more as operators, opportunities will increase for users with a range of disabilities to engage with this technology. As a result, we argue, research that investigates how to best capture the needs of users with disabilities in the design of automotive technology will increase in relevance.

RELATED WORK

Personas, popularized by Cooper (Cooper, 1999) are fictional people with names, ages, genders and any number of other characteristics that aide designers in grounding their design decisions around user needs. Typically, these characters are accompanied by a picture and a textual narrative that is written to make the persona seem like a real person while also providing a story that relates the specific needs and personal goals of the persona in the context of the product being designed. The use of personas has been integrated into the design process of many Fortune 500 companies (Nielsen, 2013) and, according to Cooper and Reimann (Cooper et al., 2003), using personas during the design process can ultimately improve the usability of a final product. While research focused on the creation of personas with disabilities specifically for the design of automotive systems is not readily found in the literature, several studies in recent years have explored the use of personas absent disabilities in the design of advanced driver assistance systems and the creation and use of personas with disabilities in the design of other products.

Personas for Advanced Driver Assistance Systems

Lindgren, Chen, Amdahl and Chaikiat (2007)have proposed the use of personas as an interface design tool in the development of advanced driver assistance systems (ADAS). The authors conducted a human factors workshop with eight participants, three systems developers, two interaction engineers, one technical psychologist and two interaction designers. Participants were presented with four personas and 15 ADAS, and were asked to identify specific systems that they believed would be relevant for specific personas, rank these

systems and comment on the basis for their choices from the perspective of the persona. The results indicated that the four personas each had different needs as was reflected in the type of ADAS chosen for them by the study's participants. The authors argue that their findings suggest that the use of this approach was effective in surfacing design issues and considerations that would not become apparent using more traditional approaches.

Personas with Disabilities

Schulz and Fuglerud (2012) have proposed a process for the creation of personas with disabilities, which is based on the collection and analysis of real data. Their process suggests the use of focus groups, interviews, surveys or observation as a means of collecting information regarding disabled individuals, their use of assistive technologies and their environment. Morris and Mueller (2016) have discussed the development and use of personas as a tool to help stakeholders understand the needs and preferences of consumers with disabilities and to promote inclusion during the design process of mobile technology. The authors presented data from a biennial survey distributed in the United States on the actions, activities, and attitudes of 590 respondents who are blind, low vision, deaf and hard of hearing as it pertains to mobile technology. Pascaul, Ribera and Granollers (2015) studied the use of personas with disabilities as a means of personalizing the communication of website accessibility errors on content management systems. The authors describe an interview and testing process involving users with visual, auditory, motor and cognitive disabilities to gather personal and spontaneous comments to be used for persona creation. Finally, Pretorius and Sangham (2016) conducted user research that culminated in the development of personas informing the design of an online government services portal in South Africa. A total of 72 rural users and 90 staff members participated in focus groups and interviews, to include interviews with disabled citizens to understand their accessibility needs. Two different surveys of 1,275 and 344 respondents were conducted with users of the existing government website. Twelve personas were developed as a result of the research process to include a persona designed to represent the needs of the disabled interviewees and respondents involved in the research process.

The review of the provided literature suggests that while persona-driven design and participatory design involving persons with disabilities have been used to explore the design of a variety of products, there are few studies which have explored the use of persona driven participatory design specifically in the context of inclusive automotive system design. Within this paper we describe a process for the development of personas with disabilities and present a case study on the use of our derived personas to develop an accessible self-driving vehicle human-machine interface. down

METHOD

A case study has been used to investigate the use of personas with disabilities within a participatory design process as a methodological tool to inform the design of accessible automotive technology.

Context of Case Study

Self-driving vehicles are a paradigm-shifting technology that may prove to be the biggest change in personal transportation of the past century. These vehicles, which automate the operation of primary vehicle functions, may save thousands of lives and untold sums of money annually by removing error and accident-prone human beings from the driving process (Marinik et al., 2014). Recent studies suggest that self-driving vehicles may be especially beneficial for people with significant visual disabilities such as blindness or moderate to severe low vision as well as older adults who, due to the nature of their disability, have been unable to operate conventional motor vehicles (Claypool & Bin-Nun, n.d.; Gluck, Boateng, et al., 2020; Gluck, Huff, et al., 2020b, 2020a; Huff et al., 2019). Despite the potentially significant benefit, only recently have researchers begun to explore the perspectives of blind and low vision consumers on self-driving technologies and the likely accessibility barriers in their use (Brewer & Kameswaran, 2018; Brinkley, Daily, et al., 2019a, 2019b; Brinkley et al., 2018; Brinkley, Huff Jr., et al., 2020; Brinkley, Huff Jr., et al., 2020; Brinkley, Posadas, et al., 2019; Carvalho et al., 2020). As a case study, an ongoing project involving the design and development of a self-driving vehicle human machine interface (HMI) for blind and low vision users is examined. The proposed internal HMI, when complete, will enable users to specify route and destination information using their preferred means of interaction (e.g. speech input, touch, etc.) while satisfying users' situational awareness and information needs both in transit and upon arrival at their destination(s). The design and development of the system is being guided by UCD methodologies to include the use of personas and the iterative creation and evaluation of interactive prototypes.

Persona Development Process

The process described within this report involves data collection and analysis activities which are illustrated in Figure 1.

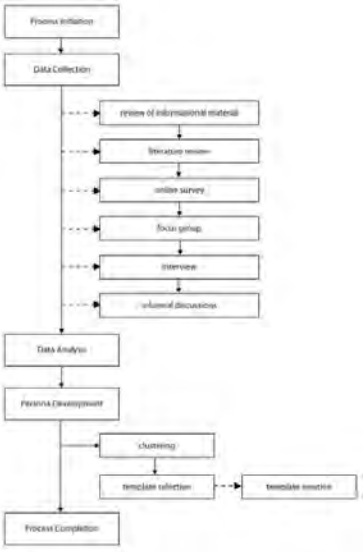

Figure 1. Data collections activities of our persona creation process.

Process Initiation. The process borrows heavily from community-based participatory research (CBPR), which is a collaborative research approach in the social sciences that

relies heavily on community partners (Minkler et al., 2003). According to Lazar, Feng and Hochheiser, one of the greatest challenges of conducting research with users with disabilities is gaining access to the participants themselves (Lazar et al., 2017). Recognizing this, the process was initiated by working outward, attempting to establish relationships with the closest candidate community partner (local chapter of the National Federation of the Blind) while identifying larger candidate partners at the state and national level. Once the local partnership was established, this relationship was leveraged to established relationships with other organizations at a state level, regional level, etc. This process was followed until contacts had been established nationally for the project.

Data Collection. Data collection closely followed our plan (Figure 1) and utilized a broad set of data sources to provide a deep understanding of the target population, blind and low vision persons, and their potential needs relative to self-driving vehicle technology. Print and online informational material on blindness and low vision were reviewed in conjunction with the scientific literature on visual impairment to provide a foundational understanding of vision loss. An online survey was conducted to investigate the opinions of blind and visually impaired respondents regarding self-driving vehicles. Participation was restricted to individuals 18 years of age and older whom self-identified as blind or visually impaired. This recruitment strategy resulted in 556 replies from potential respondents with completed surveys received from 516 respondents. Eight focus groups were conducted with 38 participants in groups of four and six people. Participants had a mean age of 51.5 years (range = 18 to 90 years old) and a household annual income that ranged from under $15,000 to over $99,000. Twenty-two participants self-identified as blind and 16 self-identified as low vision. Telephone interviews were conducted with focus group participants following each participant's final focus group session.

Data Analysis for Persona and Profile Characteristics. In preparation for analysis, all focus group transcripts were entered into MAXQDA (Verbi GmbH, 2017), a computer program for qualitative data analysis. After initially familiarizing ourselves with the data, two investigators independently coded all quotations from participants. For each researcher, this hybrid process began with a small set of a priori codes agreed upon by the research team in advance then continued with codes inductively identified within the data. Each coding was then categorized and refined by each researcher independently. Both independent analyses were then merged into a single definitive version by a third researcher with any disagreements in coding and categorization settled by this third researcher and agreed upon by the research team collectively. Survey responses were analyzed, and multiple One-Way Analyses of Variance (ANOVA) were used to compare responses to survey questions for each individual demographic variable.

Development of Personas. Personas were developed iteratively, through a process of categorization and refinement, relying on the initial coding of responses conducted during data analysis. Using MAXQDA, four clusters were used to organize the data from the focus groups and interviews: characteristics, disability, technology, and transportation. The Characteristics cluster represents personal and family attributes that may impact the system under design including demographic and background information. The Disability cluster represents physical or mental disabilities that impact the system under design. The Technology cluster represents technical factors (e.g. attitude towards technology and use of digital platforms) that may impact the system under design. While the Transportation cluster represents factors related to transportation to include motivations for the use of specific transportation types, frustrations regarding transportation and overall degree of mobility. Each coded response was placed within one of the four clusters and was traceable back to the participant. Using this approach, themes emerged within each cluster. One theme that emerged in the Transportation cluster, for instance, was the desire for alternatives to public transportation. Three codes were associated with this theme: (1) independence, (2) mobility and (3) time savings. Clusters, themes, and codes were color coded to facilitate visual recognition of patterns that appeared within and across the coding system.

A persona template was developed that extended the general and technology characteristics collected by the persona template of Nielsen (2013) (e.g. computer skills, educational level, description of daily life, etc.) with characteristics that focused on disability and domain specific (transportation) characteristics. An iterative process of clustering and tracing, associating coded responses with each participant to review participant characteristics (e.g. degree of vision loss, age, gender, ethnicity), was followed until several distinct groups emerged. Personas were developed, representing each group, following the described template. Demographic information from the public opinion survey of blind and visually impaired consumers was used to add demographic information to each created character and information gleaned during the data collection process was used to add depth.

Personas

Our analysis revealed patterns that led to the development of three personas: (1) Cassie, a 24-year-old graduate student with low vision who relies on public transportation to commute between home and campus, (2) Walter, a 48-year-old columnist and editor for an online financial magazine who has been blind since birth who is looking for an alternative to his lengthy public transit commute, and (3) Hannah a 72-year-old grandmother who is legally blind with limited access to public transit due to her rural address. While the race/ethnicity of the personas was randomly assigned in order to be representative of the study's participants, the personas otherwise reflect differences identified during analysis.

CASE STYDY: PERSONA DRIVEN PARTICIPATORY DESIGN

Our primary research question, following the persona development activities was: To what degree are the personas derived using our defined process effective in designing automotive systems for persons with disabilities? To answer this

question, we engaged blind and low vision participants in a persona driven participatory design process.

Participants

Participants were recruited with the assistance of a vision rehabilitation and resource center in north-central Florida Advertisements regarding the study were distributed via email to center clients inviting individuals interested in participating to call or email study staff for additional information and scheduling. Participation was restricted to individuals aged 18 and older with a degree of vision loss that ranged between moderate visual impairment (Dandona & Dandona, 2006) in the better seeing eye with conventional correction to blindness (e.g. 20/200 or worse in the better seeing eye with conventional correction). Participation was further limited by age given the need for a specific number of participants from specific age ranges; a maximum of five blind participants above the age of 55 were needed for instance. The Institutional Review Board of the author's university approved this study and each participant provided written informed consent the day of each design session. Participants were not compensated for their participation.

Sixteen one-hour design sessions were conducted over a five-month period at a center for visually impaired persons in Florida. In total, 13 participants were involved in the study in two groups of four people and one group of five. Group size and composition had been specified prior to participant recruiting, and groups were differentiated by desired age range and degree of vision loss. Group one was intended to include participants who self-identified as having low vision in the 18-35 age range. Group two was intended to include participants who self-identified as blind in the 18-54 age range. Group three was intended to include participants who self-identified as blind age 55 or older. During recruitment, participants were placed in the associated group that most closely aligned with their age and degree of vision loss. No other factors were considered for the purpose of constructing the groups (e.g. race/ethnicity, gender, education). Group one, composed of two male and two female participants, had a mean age of 31 years old (range = 23 to 36 years old), a household annual income that ranged from under $15,000 to $45,000 and was composed entirely of persons with low vision. One member of Group one held a four-year degree, one had some college experience and the remaining group members held high school diplomas/GEDs. Group two, composed of three male and two female participants, had a mean age of 35.2 (range = 32 to 41 years old), a household annual income that ranged from under $15,000 to $55,000 and was composed entirely of blind persons. Three members of Group two had some college experience, and the remaining group members held a high school diploma/GED. Group three, composed of one male and three female participants, had a mean age of 75.25 (range = 64 to 81 years old), a household annual income that ranged from $25,000 to over $76,500 and was composed entirely of blind persons over age 55. One member of Group three held a graduate degree, two held four-year degrees and the remaining group members held a high school diploma/GED.

Procedure

Each design session lasted approximately one hour and followed a consent/refreshment/ice breaker process that was identical. After each participant was seated in the meeting space, the informed consent document, which had been emailed to participants with email addresses in an accessible format prior to the design session, was read aloud by the study facilitator. Participants were then provided with assistance, as needed, signing the informed consent document. After being provided light refreshments, a brief ice breaking exercise was led by the design session facilitator to encourage interaction between participants. Though the use of an ice breaking exercise enabled participants to become familiar with each other after the initial session, it was continued in subsequent sessions to encourage dialogue. In all sessions the design activity followed this consent/refreshment/ice breaker process.

As a rule, attendance by at least two members of each group was required to conduct a design session. If fewer than two members were present, the session was canceled. In total, two of the originally planned 18 sessions where canceled while five sessions were rescheduled and occurred on alternate dates. Sessions were conducted on average approximately 3.5 weeks apart. Sessions were video recorded for later analysis. Between three and five days following the final design session a telephone interview was conducted with each participant to provide an opportunity to ask follow up questions after a period of reflection and to gather additional demographic information.

RESULTS

Aggregating feedback from all sessions participants described the need for:

1. Comprehensive vehicle status warnings.
2. Location information regarding the distance and direction to the entryway of the final destination upon vehicle arrival.
3. Location of the vehicle's door to facilitate entry.
4. Self-parking capabilities or other means of locating the vehicle in space upon return.
5. Speech, touch, and smartphone interaction capabilities.
6. En route distance information to the final destination.
7. Information regarding the posted speed limit.
8. Information to support situational awareness (e.g. presence and location of other vehicles, emergency vehicles, and pedestrians).
9. Information regarding the vehicle's anticipated actions (e.g. preparing to stop, changing route, etc.).

DISCUSSION

While the described process of persona creation is arguably time consuming it provides a level of depth and comprehensiveness that would have been difficult to achieve otherwise. We do not argue, however, that each aspect of our data collection process, should be replicated for every project. While we reviewed the related literature on vision loss, conducted interviews, conducted focus groups, and distributed an online survey, we would argue that depending upon the project, it would be reasonable to restrict data collection to two or three of these activities depending upon project size and budget.

What cannot be minimized during the data collection process are the relationship building activities of the process that aide in establishing close ties to individuals in the community in question (e.g. persons who are blind, persons who are deaf, etc.). In the present case study, conducting the focus groups, interviews or even distributing the online survey would have been unlikely or even impossible without active

participation from community partners. In addition, the many informal conversations addressed a number of "unknown unknowns" regarding visual disabilities that the research team would likely have been unaware of given that they are not readily addressed in the literature. We argue that researchers may benefit from a similar process when investigating user needs and constructing personas with disabilities generally. Moving forward, the derived personas will be used in further participatory design activities. In the interim, the conceptual user models resulting from the persona development process have proved invaluable as tools within our described persona-driven participatory design activities.

CONCLUSION

The present study was designed to contribute to the literature an investigation of the use of personas with disabilities as a methodological tool to inform the design of accessible automotive systems. We presented a case study of an ongoing project involving the design of a self-driving vehicle human machine interface for blind and low vision users and examined the process used to capture user needs and develop personas for this project as well as the use of these personas in a participatory design process. Our hope is that the demonstration of applied user-centered design will aide practitioners in the development of accessible automotive technologies. The need for accessibility in this regard will only increase as users with a range of disabilities begin to engage with automotive technology previously reserved for users without physical impediments. The need for research that demonstrates the use of user focused processes and methodologies will increase in kind, and it is our hope that this research will be of value in that regard.

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