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An Open Road Evaluation of a Self-Driving Vehicle Human–Machine Interface Designed for Visually Impaired Users

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To cite this article: Julian Brinkley, Brianna Posadas, Imani Sherman, Shaundra B. Daily & Juan E. Gilbert (2019): An Open Road Evaluation of a Self-Driving Vehicle Human–Machine Interface Designed for Visually Impaired Users, International Journal of Human–Computer Interaction

To link to this article: https://doi.org/10.1080/10447318.2018.1561787

Published online: 08 Jan 2019.

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An Open Road Evaluation of a Self-Driving Vehicle Human–Machine Interface Designed for Visually Impaired Users

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ABSTRACT

Fully autonomous or “self-driving” vehicles are an emerging technology that may hold tremendous mobility potential for individuals who are visually impaired who have been previously disadvantaged by an inability to operate conventional motor vehicles. Prior studies however, have suggested that these consumers have significant concerns regarding the accessibility of this technology and their ability to effectively interact with it. We present the results of a quasi-naturalistic study, conducted on public roads with 20 visually impaired users, designed to test a self-driving vehicle human–machine interface. This prototype system, ATLAS, was designed in participatory workshops in collaboration with visually impaired persons with the intent of satisfying the experiential needs of blind and low vision users. Our results show that following interaction with the prototype, participants expressed an increased trust in self-driving vehicle technology, an increased belief in its likely usability, an increased desire to purchase it and a reduced fear of operational failures. These findings suggest that interaction with even a simulated self-driving vehicle may be sufficient to ameliorate feelings of distrust regarding the technology and that existing technologies, properly combined, are promising solutions in addressing the experiential needs of visually impaired persons in similar contexts.

It is only recently that the most advanced autonomous vehicle (AV) technologies, capable of full autonomy or “self-driving”, have transcended the confines of the science fiction and academic literature and begun to emerge as a practical technology. Due largely to its potential impact, the emergence of AV technology has been met with significant fanfare by both the scientific and mainstream media. It has been argued that vehicles capable of driving themselves could potentially spell the end of personal vehicle ownership (Neil, 2015); upending a host of industries from automotive manufacturing to insurance (Scism, 2016). This consumption of Transportation as a Service (TaaS) (Cusumano, 2014) may also prove to be a boon for both the fight against man-made climate change and the movement toward environmentally friendly cities (Greenblatt & Saxena, 2015; Snyder, 2016). The aforementioned benefits may pale in comparison to the life and property saving benefits of AV technology however (Bertoncello & Wee, 2015; Marinik et al., 2014). Vehicles capable of driving themselves by definition minimize the impact of error-prone human beings on vehicle operation and may, as some studies suggest, reduce automobile accidents by as much as 90% (Ramsey, 2015). This may have the net effect of saving thousands of lives and millions of dollars’ worth of property in the process (Bertoncello & Wee, 2015). While these inarguably world and society-changing benefits are being broadly discussed from many angles, we argue that the question of universal access to AV technology has been insufficiently addressed. Put simply, will self-driving vehicles be accessible to persons with disabilities? If recent reports are to be believed, the answer may be No. Organizations like the National Federation of the Blind (NFB), for instance, have argued that for persons with visual impairments emerging self-driving vehicle technology is being designed in a manner that will render it largely inaccessible (2016).

In this report we present a study of a self-driving vehicle human-machine interface (HMI), designed for and by persons with visual impairments, with the goal of addressing the accessibility and experiential needs of low vision and blind users. The Accessible Technology Leveraged for Autonomous vehicles System or ATLAS combines spatial audio, affective computing principles and natural language processing to augment the spatial abilities of visually impaired self-driving vehicle operators. We have conducted a study of the ATLAS system involving 20 blind and low-vision participants in a non-autonomous vehicle on public roads. The study was designed using a Wizard of Oz approach and involved participants interacting with the ATLAS prototype in a scenario designed to mimic interaction with an actual self-driving vehicle. We argue that research of this type, which explores the
accessibility and experiential needs of persons with disabilities, will become increasingly critical as self-driving vehicle technology becomes commercially available.

1. Background and related work

The economic and social impact of limited mobility for individuals who are blind or significantly visually impaired cannot be overstated. A number of studies suggest that individuals with significant visual impairments like blindness are more likely to have difficulty finding work and are less likely to participate in the workforce relative to sighted individuals when all other factors are eliminated (Harrabi, Aubin, Zunzunegui, Haddad, & Freeman, 2014). The National Federation of the Blind’s most recent data (Bell & Mino, 2015) indicate that less than 41% of working age adults who reported significant vision loss were employed in 2014 as compared to nearly 60% of the population generally during this period (US Census Bureau, 2016).

A number of factors have been cited for this disparity, but personal mobility has been identified as a key concern (Cradden, McDonnell, & Hierholzer, 2015). While it is important to avoid generalizations, it is a reality that it is often difficult for individuals who are blind to travel to receive the requisite education and training required for many positions. In circumstances where education is not an issue, securing travel to job interviews and to jobs themselves often is (Cradden et al., 2015; Lazar, Feng, & Hochheiser, 2010). In many circumstances individuals who are blind must rely on public transportation, which has its own costs and complexities (Hara et al., 2015) or rely on the assistance of friends and relatives (Lazar et al., 2010). In either case, the lack of personal mobility made possible by the automobile severely disadvantages individuals who are blind in an already competitive job market.

The self-driving vehicle, properly implemented, could therefore prove to be life changing for many individuals who are significantly visually impaired. With this technology, the type of personal mobility that may be taken for granted by sighted individuals with personal transportation would be equally available to those with visual impairments. The National Federation of the Blind (NFB), however, has suggested that most self-driving vehicle technology being presently developed is in practice inaccessible to users with visual impairments (2016). Despite this contention, there have been few formal studies that have investigated this issue. The present research is informed by both the limited research regarding persons with visual impairments and self-driving vehicles, consumer research regarding self-driving vehicles generally and research focused on enabling persons with visual impairments to operate conventional motor vehicles.

1.1. Opinions and preferences of visually impaired consumers

Due perhaps to the emerging nature of AV technology, research that explores the needs, preferences and concerns of visually impaired persons as it relates to self-driving vehicles is limited and relatively recent. In a 2017 survey of 516 visually impaired respondents, Brinkley, Daily, and Gilbert (2018) investigated respondents’ belief in the occurrence of societal benefits as a result of the introduction of self-driving vehicles, concerns regarding the technology and respondents’ attitude toward its use. They found that while respondents were generally optimistic about the potential benefits of self-driving vehicles, the majority of respondents expressed a variety of concerns regarding the technology. Respondents were especially concerned about the possibility of system failures and the ability of self-driving vehicles to safely interact with pedestrians and conventional vehicles. In a subsequent focus group study Brinkley, Posadas, Woodward, and Gilbert (2017) investigated the needs, preferences and concerns of 38 blind and low vision participants regarding self-driving vehicles. Similar to Brinkley, Daily and Gilbert, they also found that participants were generally optimistic about the potential of self-driving vehicles but that participants were concerned about the accessibility of the human–machine interface (HMI). Participants were especially concerned about the ability of the self-driving vehicle HMIs to satisfy their situational awareness and location verification needs. Brewer and Kameswaran (2018) used a similar methodology in their focus groups with 15 blind and low vision participants. Mirroring the findings of prior research, they found that participants were optimistic about the potential independence that access to a self-driving vehicle would enable while expressing concerns about the means of controlling and interacting with such a vehicle.

1.2. Opinions and preferences of consumers generally

In contrast with the limited studies focused on consumers with disabilities specifically, numerous studies in recent years have investigated public opinion regarding self-driving vehicle technologies generally. Collectively, these studies have explored consumer preferences regarding specific self-driving systems and consumers’ general willingness to pay for automated driving technologies.

In a 2013 telephone survey conducted by Continental AG in Germany, China, Japan and the U.S., 54% of the survey’s 4000 respondents indicated that they did not believe self-driving vehicles would function reliably (Sommer, 2013). For example, 66% percent of U.S. respondents indicated that they were “scared” by the concept of automated driving. A majority of respondents expressed an intention to use the technology more frequently on long freeway/highway journeys (67%) in traffic jams (52%) and less in city traffic (34%).

In 2013 professional services company KPMG conducted a focus group study with a total of 32 participants across California, Chicago and New Jersey (2013). Their results showed that women (median = 8.5 on a scale from 1 to 10) were more willing to use self-driving vehicles than men (median 7.5). A dominant topic of discussion during the focus groups was safety, with many participants expressing skepticism that the technology would function properly. During the discussions, there was a near unanimous expression of a desire for a feature that would enable an operator to take
control of a self-driving vehicle on demand. Some desired such a feature as a backup; anticipating that the automated systems of the vehicle would malfunction. Others expressed a joy in driving and appreciated having manual controls as an option.

Howard and Dai in a 2013 survey explored the opinions of 107 respondents in Berkley, California regarding self-driving vehicles (2014). Safety (75%) and convenience (61%) were identified by respondents as the most attractive features of self-driving vehicle technology. Additionally, 46% of respondents indicated that self-driving vehicles should operate with normal traffic while 38% believed they should operate in designated lanes. More than 40% of respondents expressed willingness to either purchase a fully self-driving vehicle as their next vehicle or to retrofit their existing vehicle with self-driving technology if such a vehicle modification was possible. A plurality of respondents (35%) was also interested in having the purchase of their self-driving vehicle subsidized in some manner.

In a 2014 survey involving 1,533 respondents in the U.S, U.K. and Australia, Schoettle and Sivak investigated public opinion and concerns regarding self-driving vehicles (2014). They found that more than 50% of respondents in all three countries had positive expectations about the technology’s potential benefits with respondents expressing the most confidence in the likelihood of better fuel economy occurring as a result of self-driving vehicles. Respondents in all three countries expressed significant concerns however, regarding the technology with nearly 87% of respondents expressing some degree of concern regarding the safety consequences of equipment failure for instance. Women were found to be more concerned about the technology generally than men and were more skeptical of its benefits. A majority of respondents in all three countries expressed some interest in having self-driving technology but were generally unwilling to pay extra.

Payre, Cestac and Delhomme conducted a public opinion survey in 2014 of 421 French drivers to investigate opinions on fully automated driving (2014). Men and those scoring highly on the driving-related sensation-seeking scale were more willing to use a self-driving vehicle and were more inclined to purchase one whereas older respondents were less likely to indicate that they would purchase a self-driving vehicle but showed higher acceptance of the technology. Respondents expressed a preference for full automation on highways, in traffic congestion, for automatic parking and when impaired by drug use or alcohol.

Ipsos MORI in a 2014 public opinion survey involving 1001 British respondents 16 to 75 years old investigated attitudes related to cars and technological developments surrounding the automotive industry (Missel, 2014). Of those surveyed, 18% felt that it was important for automobile manufacturers to focus on self-driving vehicle technologies while 41% indicated that it was unimportant. Older people (55+) were less likely to embrace the technology than the youngest group (16 to 24) and 50% of those aged 55+ felt that the technology was unimportant compared to 30% of those in the 16 to 24 age group. Findings additionally indicated that respondents who lived in cities found self-driving vehicle technology to be more important than those living in rural environments.

In 2015, Kyriakidis, Happee and de Winter conducted a similar international public opinion survey involving 5000 respondents from 109 countries to investigate user acceptance, concerns and willingness to buy partially, highly and fully automated vehicles (2015). Respondents were most concerned about software hacking/misuse, legal issues and safety. A plurality of respondents (22%) indicated that they were unwilling to pay any money for a fully automated driving system while 5% indicating a willingness to pay more than $30,000 for such technology.

In a 2016 survey involving 618 respondents in the U.S, Schoettle and Sivak found that “no automation” was the preference for most respondents followed by partially self-driving vehicles (2016); approximately 16% of respondents expressed a preference for completely self-driving vehicles. Over 95% of respondents expressed some degree of concern (when all variations of concern are accounted for) regarding riding in a self-driving vehicle if there were no other transportation option available. Respondents overwhelmingly expressed a desire for manual vehicle controls to enable a human driver to take over vehicle operations at will, with 94.5% of respondents indicating that they would like a fully self-driving vehicle to have a steering wheel, gas and brake pedals. In terms of entering route and destination information, 38% of respondents preferred the use of a touchscreen compared to 34.5% who preferred the use of a voice commands while 7.9% preferred the use of a personal portable device.

In a 2016 study involving 347 respondents in Austin, Texas, Bansal, Kockelman and Sing found that respondents on average were willing to pay $7,253 to add Level 4 automation or full self-driving capabilities to their vehicles (2016). This stands in contrast to the findings of much of the previously described research, which found that respondents where interested in the technology but were unwilling to pay extra. These findings are largely consistent with the findings of Daziano, Sarria and Leard (2017) however, who found in a 2017 study involving 1,260 respondents that the average household in their study was willing to pay $4,900 extra for self-driving capabilities.

1.3. Conventional motor vehicle operation by visually impaired persons

Very limited research exists that focuses specifically on enabling the operation of autonomous and non-autonomous vehicles, under non-naturalistic conditions, by blind drivers. One example is the National Federation of the Blind (NFB)’s 2004 commissioned project, called the “Blind Driver Initiative,” which had the high-level goal of supporting the development of technology that would enable a blind driver to operate a conventional motor vehicle (“Blind Driver Challenge,” n.d.; National Federation of the Blind, 2018). A small body of literature has emerged from this research that has experimentally focused on enabling blind drivers to operate motor vehicles under non-naturalistic, and often simulated conditions. The NFB’s study has also furthered
research around nonvisual automotive interfaces generally. In another example, Hong et al. modified a self-driving vehicle designed for the Defense Advanced Research Projects Agency’s (DARPA) Urban Challenge (“DARPA Urban Challenge,” 2007) to allow a blind driver to operate the vehicle with directional cues provided through the use of audible tones (Hong et al., 2008). This is similar to the research of Sucu and Folmer that explored the use of haptics-based steering directional cues in the steering wheel (2014).

The present study is differentiated from prior work in that it was designed to specifically investigate key issues related to self-driving vehicles that we argue have been insufficiently investigated as it pertains to consumers who are blind or visually impaired. The study additionally investigates the effect of interacting with what is purported to be a self-driving vehicle on participants’ pre-interaction opinions regarding the technology.

2. Study design

To effectively design interfaces for self-driving vehicles, the study of human interactions with this technology is a logical prerequisite. Given the emerging nature of the technology, however, there are few approaches available to researchers that are both safe and capable of producing ecologically valid results. Road testing of self-driving vehicle technology would be ideal however, there are significant legal and regulatory hurdles and the risk to life and property due to the possibility of significant system failures. While advanced driving simulators provide controlled conditions where all manner of human interaction with automotive systems have been studied, driving simulators have limitations in testing autonomous technologies. Present simulator technology is limited in its ability to accurately replicate inertial forces and realistically depict all aspects of the real world believably (De Winter, Van Leuween, & Happee, 2012), which may undermine participants’ suspension of disbelief (Böcking, 2008). Study results may therefore lack ecological validity and be of limited value in predicting how users might interact with an autonomous system in similar real-life settings.

The Real Road Autonomous Driving Simulator (RRADS) methodology of Baltodano, Sibi, Martelaro, Gowda, and Ju (2015) was designed to address these issues by creating a physical as opposed to digital simulation of a self-driving vehicle. The RRADS methodology uses a traditional Wizard of Oz (Lazar et al., 2010; Mok, Sirkin, Sibi, Miller, & Ju, 2015; Poláček, Grill, & Tscheligi, 2012) approach involving two wizards and a single vehicle; a Driving Wizard and an Interaction Wizard. The Driving Wizard drives the vehicle on a predetermined route in a manner that is designed to simulate the driving behavior of a self-driving vehicle system. The Interaction Wizard, seated in the rear of the vehicle, is available to assist the participant in the event that they require assistance or wish to terminate the study. Participants approach the vehicle, are seated within the vehicle and exit the vehicle in a manner that completely obscures the presence of the Driving Wizard during the trial. An opaque partition is used within the vehicle to block the participant’s view of the Driving Wizard or the vehicle’s primary controls (e.g. steering wheel, pedals or shifting mechanism). While testing using the RRADS methodology poses obvious risks, perhaps the most significant being the risk of accident or injury, it is hypothesized that the mental leap necessary to suspend disbelief is lowered under these conditions. The RRADS approach eschews the simulator testing approach that asks participant to imagine that a simulated vehicle and an entire digitally created world are real. RRADS instead asks the participant to simply imagine the absence of a human driver who cannot be seen in an otherwise real context.

In an effort to increase the ecological validity of the study while testing the ATLAS system under quasi-naturalistic conditions the RRADS methodology was determined to be a preferred approach relative to a simulator study. Conditions are described as “ quasi-naturalistic” given that participants were not randomly assigned to a condition.

3. Method

3.1. Research questions and hypotheses

The primary goals of the study were to gauge users’ perception of the ATLAS system’s operation, to evaluate how well the system satisfied users’ experiential needs, to determine if design inconsistencies exist with respect to the system’s user interface and to determine if interaction with the prototype affected users’ perception of self-driving vehicles broadly. The study aimed to answer the following research questions:

R1: To what extent do individuals who are visually impaired face barriers when interacting with the ATLAS system?

R2: What is the association between interacting with the ATLAS system and users’ perception of self-driving vehicles?

Based on these questions the following hypotheses were developed:

HA1: Participants will, on average, find the ATLAS system to have “good” or better usability as measured using the system usability scale questionnaire.

HA2: After interacting with the ATLAS system, participants will express an increased belief in the likely ease of use of self-driving vehicles as measured using the self-driving car assessment scale.

HA3: After interacting with the ATLAS system, participants will express an increased degree of trust in self-driving vehicles as measured using the self-driving car assessment scale.

3.2. Participants

Participants were recruited by email, newsletter and social media announcements distributed by organization serving individuals with visual impairments in north central Florida
and vocational rehabilitation organizations. Interested individuals aged 18 or above who identified as visually impaired were invited to participate. Visual impairment for the purpose of the advertisement was defined as blindness or limited vision not correctable by glasses or contact lenses. Those interested in participating were asked to call or email for additional information and scheduling. The authors’ university’s General Consul’s Office, Office of Risk Management and Institutional Review Board approved the study and each participant provided written informed consent the day of his or her study session. Participants were compensated with a $40 prepaid gift card for their participation.

In total, 20 participants were involved in the study, which was conducted over a ten-day period. Demographic breakdowns for the respondents are provided in Tables 1 through 5. Eleven participants were female and nine were male. In total, 70% of participants were between the ages of 45 and 64, while those 35 and under made up 15% of those participating in the study (see Table 1). Eighty percent of participants had at least some college education (see Table 2). Those not currently employed (50%) exceeded the combined number of respondents who were full-time students, part-time students and the 10% of those employed full or part time (see Table 3).

During the screening and scheduling process participants were presented with functional definitions of blindness and low vision (Duffy, 2015). They were then asked to choose the definition that best characterized their degree of vision loss; five participants self-identified as blind and fifteen self-identified as low vision using this approach. The day of the study session and after providing written consent, participants were compensated with a $40 prepaid gift card for their participation.

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3.3. Apparatus and testing environment

3.3.1. ATLAS prototype

The Accessible Technology Leveraged for Autonomous vehicles System, or ATLAS was designed and developed over a period of approximately six months within a series of participatory design sessions involving visually impaired persons. Within these sessions, blind and low vision participants identified potential accessibility problems with self-driving vehicle technology and suggested features that might address their concerns. Participants were chiefly concerned about their ability to control such a vehicle using speech, to maintain situational awareness while in transit (e.g. the location of other vehicles and pedestrians) and to verify their arrival at the appropriate final destination using non-visual means. Members of the research team iteratively produced prototypes designed to address these concerns while satisfying users’ experiential needs. The ATLAS system combines what was learned through this process into a service oriented Universal Windows Platform application written in C#. The system, deployed to a Microsoft Surface tablet, enables users to specify a destination or series of destinations using natural language (e.g. “Atlas, take me to the nearest Publix grocery store.”) or the system’s graphical user interface (see Figure 1). The system supports users’ situational awareness needs through the use of audible location cues in transit (e.g. “Passing [location] on your right”), while supporting users’ location verification needs using spatial audio and computer vision technologies. Upon arrival at a final location ATLAS captures images of the vehicle’s exterior, mines these images for content and vocalizes a description of the vehicle’s immediate surroundings (e.g. “You are in a parking lot. There are people walking. There is a building to your left”). In transit, the system uses

<table>
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<th>Table 1. Breakdown of study participants by age group.</th>
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<td>Age group</td>
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<td>18–24</td>
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<td>65+</td>
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<th>Table 2. Breakdown of study participants by level of education.</th>
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<td>Education</td>
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<td>Some High School</td>
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<td>High School Diploma/GED</td>
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<tr>
<td>Some College</td>
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<td>2 Year Degree/Associate’s Degree</td>
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<td>Bachelor’s Degree</td>
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<td>Graduate Degree</td>
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<th>Table 3. Breakdown of study participants by employment status.</th>
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<td>Education</td>
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<td>Employed Full-time</td>
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<td>Employed Part-time</td>
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<td>Not Currently Employed</td>
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<td>Retired</td>
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<td>Full-time Student</td>
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<td>Part-time Student</td>
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<th>Table 4. Breakdown of study participants by characterization of visual impairment.</th>
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<td>Legal characterization of visual impairment</td>
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<tr>
<td>Blind</td>
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<td>Low Vision</td>
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<th>Table 5. Breakdown of study participants by length of time of visual impairment.</th>
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<tr>
<td>Length of visual impairment</td>
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<td>Some of Your Life</td>
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<td>Most of Your Life</td>
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<tr>
<td>All of Your Life</td>
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<tr>
<td>I Am Newly Visually Impaired</td>
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principles of affective computing to monitor the user for distress and discomfort; providing options to adjust the vehicle’s driving behavior if distress or discomfort is detected.

3.3.2. Test vehicle
A 2018 Volkswagen Atlas sport utility vehicle was used as a test vehicle. To provide clarity given that the Volkswagen and system under test share the same name, ATLAS will be specifically used to refer to the system under test while Volkswagen will be used to refer specifically to the test vehicle. The Microsoft Surface tablet, on which the ATLAS system was deployed, was affixed to the rear of the front passenger seat of the Volkswagen using a Kenu Airvue tablet-mounting device (see Figure 2). The system’s speakers were placed unobtrusively under the front seats and the USB global positioning sensor was taped to the front passenger side window. The smartphone used to provide Internet connectivity to the system was placed on the rear seat. The tablet, speakers and smartphone received continuous power from a 750 W power inverter connected to a 12-volt outlet located in the rear of the front console.

3.3.3. Camera placement
A Vivitar DVR 917 HD action camera was affixed to the rear passenger window closest to the participant using a suction mount to capture participant interaction with the ATLAS system. An Insignia NS-CT1DC8 dash camera was affixed to the front windshield using a suction mount to capture a clear view of the road.

3.3.4. Partition
An opaque partition, necessary to obscure the Driver Wizard and vehicle controls from participant view, was constructed of black, two-centimeter thick foam board, black Velcro straps and duct tape (see Figure 3). The partition was primarily secured to the vehicle by its weight, shape and position, as one side was wedged between the front passenger seat and the center console. Additional support was provided through the use of zip ties, black duct tape and black Velcro straps. The partition was designed to obscure a driver shorter than 186 centimeters and was trimmed to allow line of sight to the passenger mirror and passenger side blind spot sensor.

3.3.5. Pilot study
A pilot study was conducted with five participants to evaluate the feasibility of the procedure, evaluate the preliminary road course and prepare for any adverse events that might occur during the actual study. Based on the findings of the pilot the road course was expanded from approximately two miles to 3.9 miles to better balance the distance between identified waypoints. Modifications were also made to the number of tasks (reduced from six to four) and the number of questionnaires (reduced by one) to better align the study procedure with the one-hour time span that had been allotted for each trial.

3.3.6. Road course
A 3.9-mile course spanning six roads was selected in Ocala, Florida (see Figure 4). The course was selected for its relatively light traffic, mixture of commercial and residential conditions and proximity to the study’s staging area. Speeds ranged from 25 miles per hour to 45 miles per hour and the course included interaction with traffic lights and stop signs. Seven practice trials completed by the authors suggested that the course could be completed in as little as 14 minutes in light to moderate traffic.

3.3.7. Procedure
The procedure was designed to fit within a single one-hour session and consisted of a single scenario and its corresponding tasks. Participants began their session seated in a closed room with a member of the study team who would serve as

![Figure 1. User interacting with the ATLAS prototype via the voice user interface.](image)
the Interaction Wizard. As a preliminary activity, each participant was read the IRB approved informed consent document that had been emailed in an accessible format prior to the study session. Overt deception was not used, and participants were told that they would be interacting with a prototype in a simulated, as opposed to real, self-driving vehicle. Participants were also told that a licensed driver would be behind the wheel at all times. Permission was also explicitly requested to video record the study for later transcription. After obtaining consent participants completed a demographic questionnaire that was read aloud. Participants then verbally completed the Self Driving Car Assessment Scale (SDCA) (Nees, 2016). The SDCA is a 24-item, seven-point Likert scale (from 1 = strongly disagree to 7 = strongly agree) instrument designed to assess respondents’ perception of self-driving vehicles across eight dimensions: 1) perceived reliability, 2) cost, 3) appropriateness, 4) enjoyment, 5) perceived usefulness, 6) perceived ease of use, 7) user experience and 8) intention to use. Participants were then walked to the waiting test vehicle, approaching from the rear passenger side to obscure their view of the driver area. The Interaction Wizard ensured that all participants were buckled prior to attempt the tasks.

Once seated and buckled within the vehicle participants were read the scenario introduction and informed that they would complete a tutorial and receive task instructions as the study progressed. Participants were given no further instructions regarding system operation. Participants were asked to refrain from speaking to the Interaction Wizard unless they needed to have the current task repeated, wanted to end the trial or had a safety related question or concern. Participants were asked to hold all other questions until their return to the staging area. After receiving consent to begin, participants attempted the study’s tasks and the driving activity began. Task performance data (e.g. attempts, successful/unsuccessful) was recorded. In the event that the participant was unsuccessful at specifying the appropriate waypoint following three attempts, the Interaction Wizard interceded and manually entered the correct information to continue the study on the defined route. All participants were presented with the same scenario and tasks. Upon the vehicle’s return to the staging area, the participant was returned to the interview room by the Interaction Wizard. Another member of the study team entered and asked the user to verbally complete the System Usability Scale Questionnaire (SUS) (Brooke, 1996), which was read aloud. The SUS is a 10-item, five-point Likert scale (from 1 = strongly disagree to 5 = strongly agree) that provides a global view of system usability through a weighted score in the range of 0–100. Following the administration of the SUS a video recorded semi-structured interview was conducted and a two-item seven-point Likert questionnaire was administered (from 1 = strongly disagree to 7 = strongly agree), referred to subsequently in this article as the Situation-Location scale.
I found that the ATLAS system was helpful in making me aware of my surroundings and location during the scenario. I found that the ATLAS system was effective in helping me to verify that I arrived at the correct location during the scenario.

The trial concluded with the Self-Driving Car Assessment Scale, which was administered for a second time, following participant interaction with the prototype.

### 3.3.8. Scenario

In the study’s single scenario participants were told that they had been given access to a self-driving vehicle for one day:

As part of a new program from a self-driving vehicle manufacturer you have been given access to a new self-driving vehicle for one day. A self-driving vehicle is a vehicle that controls steering, acceleration and braking without direct driver input. You have decided to use the vehicle to run a few errands. This self-driving vehicle is equipped with the ATLAS system that you can use to control most functions of the vehicle. ATLAS also monitors you throughout the trip to determine if you are experiencing discomfort.

Participants were then asked to use the ATLAS system to navigate to four waypoints using the study staging area as a starting point: the nearest Kmart, the nearest Wendy’s, the nearest Autozone and the Florida Center for the Blind, in that order. Waypoints were provided one at a time by the Interaction Wizard. The ATLAS system was preconfigured to search specifically within Ocala, Florida to prevent participants from specifying a destination outside of the predefined area approved for the study. Geofences (Microsoft, 2017) were programmatically inserted within the route at approximately half-mile intervals (see Figure 5) when the distance between waypoints was more than ¾ mile (e.g. between waypoints 1 and 2, 2 and 3, 3 and 4). The geofences provided a consistent geographic point where information regarding the trip would be vocalized (e.g. direction, traffic conditions, points of interest, etc.). Geofences were also programmatically inserted around the four waypoints to consistently trigger arrival notifications.

### 3.3.9. Data capture and transcription

Each semi-structured interview was video recorded and transcribed verbatim by a professional transcriptionist prior to analysis. The completed transcript was then verified by a member of the research team against the original recordings.

### 3.3.10. Analysis

System usability scale questionnaire: Following the process of (Bangor, Kortum, & Miller, 2009), raw SUS scores, from 0 to 40, were converted to a normalized score between 0 and 100. This normalized score was then mapped to an adjective rating scale from “worst imaginable [usability]” to “best imaginable [usability]”. Self-driving car assessment scale: Descriptive statistics (i.e., means, medians and standard deviations) were calculated for each of the variables. Paired t-tests were used to compare responses to the SDCAS pre and post interaction with the ATLAS prototype (see Table 6).

![Figure 4. The study road course with five waypoints: 1) The Florida Center for the Blind, 2) Kmart, 3) Wendy’s, 4) Autozone and 5) The Florida Center for the Blind.](image-url)
Analysis of interview data: In preparation for analysis all transcripts were entered into MAXQDA (Verbi GmbH, 2017), a computer program for qualitative data analysis. After initially familiarization with the data the authors coded all quotations from participants. This hybrid process began with a small set of a priori codes developed in advance based on the interview questions and then continued with codes inductively identified within the data. Each coding was then categorized and refined. Results of the qualitative analysis process have been excluded from the present article.

4. Results

4.1. Task completion

The success rate for all tasks in the study was 93.75%. Attempts were deemed “successful” if the participant was able to correctly enter his or her provided destination when given three tries, using either the voice user interface (VUI) or graphical user interface (GUI). All but one participant used the VUI exclusively. This one participant attempted to use the GUI for one task attempt but switched mid-attempt to the VUI. One participant initiated the stop process but elected to have the vehicle continue to its destination. All participants elected to complete the tutorial and one participant repeated it. In-vehicle time attempting the tasks ranged from 28 to 41 minutes.

4.2. General opinion of system usability

The mean SUS score for all participants, on a 0 to 100 scale, was 87.62 (SD = 10.95, range = 52.5 to 100, mode = 85, 100, median = 88.75). The mean SUS score for low vision participants was 86.87 (SD = 5.93, range = 75 to 92.5, mode = 92.5, 90, median = 88.75) whereas the mean score for blind participants was 88.12 (SD = 13.57, range = 52.5 to 100, mode = 100). Unpaired t-tests were conducted to compare mean SUS scores between the blind and low vision groups and between male and female participants. No significant difference was observed in the mean scores of the blind and low vision groups, \( t(18) = 0.2437, p = 0.8102 \). No significant difference was observed in the mean scores of the male (\( M = 88.61, SD = 6.26 \)) and female (\( M = 86.81, SD = 13.96 \)) participants, \( t(18) = 0.3556, p = 0.7263 \), an adjective rating scale (12.5 = worst imaginable to 90.9 = Best Imaginable); all five scores fell within the range of “Excellent” (85.6 to 90.8).

4.3. Situational awareness

On a seven-item Likert scale (1 = strongly disagree to 7 = strongly agree), participants were asked to indicate their agreement or disagreement with the statement that the ATLAS system was helpful in making them aware of their surroundings and location during the scenario. The most frequently selected response was “strongly agree”
Statistically significant effects of interaction with the ATLAS prototype on responses to individual statements as presented through results from a series of t-tests.

<table>
<thead>
<tr>
<th>Question number</th>
<th>Question</th>
<th>t*</th>
<th>p</th>
<th>Percent Increase/Decrease in agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Self-driving cars are safe</td>
<td>4.211</td>
<td>0.0005</td>
<td>+28.26</td>
</tr>
<tr>
<td>2</td>
<td>I would trust a self-driving car to get me to my destination</td>
<td>3.052</td>
<td>0.0065</td>
<td>+20.75</td>
</tr>
<tr>
<td>3</td>
<td>People will need to watch self-driving cars closely to be sure the computers don’t make mistakes</td>
<td>2.929</td>
<td>0.0086</td>
<td>−24.22</td>
</tr>
<tr>
<td>4</td>
<td>I would be willing to pay more for a self-driving car compared to what I would pay for a traditional car</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>The benefits of a self-driving car would outweigh the amount of money it would cost</td>
<td>3.217</td>
<td>0.0045</td>
<td>+21.10</td>
</tr>
<tr>
<td>6</td>
<td>The cost of a self-driving car would be the most important thing I would consider before purchasing one</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>I do not think computers should be driving cars</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>It is important for a human to be able to take back control from a self-driving car</td>
<td>2.703</td>
<td>0.0141</td>
<td>−11.49%</td>
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<tr>
<td>9</td>
<td>There are some driving scenarios that will be too difficult for a self-driving car to handle</td>
<td>3.676</td>
<td>0.0016</td>
<td>−35.48</td>
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<tr>
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<td>I would enjoy driving a car</td>
<td>2.297</td>
<td>0.0331</td>
<td>−14.28</td>
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<tr>
<td>11</td>
<td>I would prefer to be the driver rather than the passenger</td>
<td>2.099</td>
<td>0.0493</td>
<td>−15.38</td>
</tr>
<tr>
<td>12</td>
<td>I enjoy cruising or going for joy rides</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>A self-driving car would allow me to be more productive</td>
<td>2.516</td>
<td>0.0210</td>
<td>+3.84</td>
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<tr>
<td>14</td>
<td>A self-driving car would allow me to be more safe while in the car</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Self-driving cars will reduce traffic problems*, the most frequently selected response of all participants prior to interacting with the prototype was four or “neither agree nor disagree”</td>
<td>2.449</td>
<td>0.0242</td>
<td>+11.65</td>
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<tr>
<td>16</td>
<td>Self-driving cars will be easy to use</td>
<td>3.942</td>
<td>0.0009</td>
<td>+26.73</td>
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<td>17</td>
<td>It will be a lot of work to figure out how to use a self-driving car</td>
<td>5.002</td>
<td>0.0001</td>
<td>−51.42</td>
</tr>
<tr>
<td>18</td>
<td>It would take me a long time to figure out how to use a self-driving car</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>I like to use technology to make tasks easier for more</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>I have bad experiences when I try to use new technology instead of doing things the old-fashioned way</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>There are tasks in my life that have been made easier by computers doing the work for me</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>I would like to own a self-driving car</td>
<td>2.896</td>
<td>0.0093</td>
<td>+11.47</td>
</tr>
<tr>
<td>23</td>
<td>Even if I had a self-driving car, I would still want to drive myself most of the time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>In a self-driving car, it will be important to me to have the option to turn off the computer and drive myself</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*df = 19

(75%), followed by “mostly agree” (20%); no participant “strongly disagreed” with this statement. When analyzed based on degree of vision loss, 75% of low vision participants “strongly agreed” with this statement, while 83.3% of blind participants “strongly agreed”. The response mean was 6.55 (SD = 0.887, range 1 to 7).

4.4. Location verification

On a seven-item Likert scale (1 = strongly disagree to 7 = strongly agree), participants were asked to indicate their agreement or disagreement with the statement that the ATLAS system was effective in helping them to verify their arrival at the correct location. The most frequently selected response was “strongly agree” (80%), followed by “mostly agree” (10%); one participant “somewhat disagreed” with this statement. When analyzed based on degree of vision loss, 87.5% of low vision participants “strongly agreed” with this statement, while 75% of blind participants “strongly agreed”. The response mean was 6.55 (SD = 1.099, range 1 to 7).

4.5. Familiarity with the testing area

Participants were read the statement, “I am familiar with the roads and landmarks in the immediate vicinity of the Florida Center for the Blind”, and asked to indicate their agreement or disagreement on a seven-item Likert scale (1 = strongly disagree to 7 = strongly agree). The most frequently selected response was seven or “strongly agree” (45%). The response mean was 5.45 (SD = 1.98, range 1 to 7). A nonparametric procedure, the Spearman’s rank order correlation coefficient (i.e., Spearman’s rho) was conducted and no statistically significant correlation could be found between familiarity with the testing area and either participants’ stated satisfaction with the prototype’s situational awareness features used during the scenario (rs = −0.34342, p = 0.138) or satisfaction with the prototype’s location verification features (rs = −0.04201, p = 0.8604).

4.6. Self-driving car acceptance scale

Multiple t-tests were used to determine statistically significant effects of interaction with the ATLAS prototype on responses to individual statements of the Self-Driving Car Acceptance Scale. Table 6 presents results from a series of t-tests, indicating statistically significant effects of prototype interaction on individuals’ statements, either at p < .05, p < .01 or p < .001.

4.6.1. Perceived reliability of automation/trust

Participants were presented with three statements related to their perception of the reliability of self-driving vehicles and their general trust in the technology. They were then asked to indicate their agreement or disagreement with each statement on a seven-item Likert scale (1 = strongly disagree to 7 = strongly agree). Paired t-tests were conducted to compare mean responses of all participants pre and post interaction. For the statement, “self-driving cars are safe”, a significant difference was observed between the mean response for the pre-interaction (M = 4.6, SD = 1.23) and post interaction...
(M = 5.9, SD = 1.33) conditions; (19) = 4.211, p = 0.0005. For the statement, “I would trust a self-driving car to get me to my destination”, a significant difference was observed between the mean response for the pre-interaction (M = 5.3, SD = 1.41) and post interaction (M = 6.35, SD = 1.30) conditions. For the statement, “People will need to watch self-driving cars closely to be sure the computers don’t make mistakes”, a significant difference was observed between the mean response for the pre-interaction (M = 4.75, SD = 1.52) and post interaction (M = 3.60, SD = 2.11) conditions.

4.6.2. Cost of automation
Participants were presented with three statements related to their willingness to pay for a self-driving car and perception of the value of such a vehicle compared to its associated costs. They were then asked to indicate their agreement or disagreement with each statement on a seven-item Likert scale (1 = strongly disagree to 7 = strongly agree). Paired t-tests were conducted to compare mean responses of all participants pre and post interaction. For the statement, “I would be willing to pay more for a self-driving car compared to what I would pay for a traditional car”, the difference between the mean response for the pre-interaction and post interaction conditions was found to be statistically insignificant. For the statement, “The benefits of a self-driving car would outweigh the amount of money it would cost”, a significant difference was observed between the mean response for the pre-interaction (M = 5.45, SD = 1.90) and post interaction (M = 6.60, SD = 0.88) conditions. For the statement, “The cost of a self-driving car would be the most important thing I would consider before purchasing one”, the difference between the mean response for the pre-interaction and post interaction conditions was found to be statistically insignificant.

4.6.3. Appropriateness and compatibility of automation
Participants were presented with three statements related to their general perception of the appropriateness of vehicular automation. They were then asked to indicate their agreement or disagreement with each statement on a seven-item Likert scale (1 = strongly disagree to 7 = strongly agree). Paired t-tests were conducted to compare mean responses to all statements pre and post interaction. For statement seven, “I do not think that computers should be driving cars”, the difference between the mean response for the pre-interaction and post interaction conditions was found to be statistically insignificant. For statement eight, “It is important for a human to be able to take back control from a self-driving car”, a significant difference was observed between the mean response for the pre-interaction (M = 4.35, SD = 1.9) and post interaction (M = 3.85, SD = 2.01) conditions. For statement nine, “There are some driving scenarios that will be too difficult for a self-driving car”, a significant difference was observed between the mean response for the pre-interaction (M = 4.65, SD = 1.87) and post interaction (M = 3.0, SD = 1.56) conditions.

4.6.4. Enjoyment
Participants were presented with three statements related to their enjoyment of driving and desire to ride in an automobile. They were then asked to indicate their agreement or disagreement with each statement on a seven-item Likert scale (1 = strongly disagree to 7 = strongly agree). Paired t-tests were conducted to compare mean responses to all statements pre and post interaction. For statement 10, “I would enjoy driving a car”, a significant difference was observed between the mean response for the pre-interaction (M = 6.65, SD = 0.81) and post interaction (M = 5.7, SD = 2.39) conditions. For statement 11, “I would prefer to be the driver rather than the passenger”, a significant difference was observed between the mean response for the pre-interaction (M = 5.78, SD = 1.3) and post interaction (M = 4.95, SD = 2.39) conditions. For statement 12, “I enjoy cruising or going for joy rides”, the difference between the mean response for the pre-interaction and post interaction conditions was found to be statistically insignificant.

4.6.5. Perceived usefulness
Participants were presented with three statements related to the potential usefulness of self-driving vehicles. They were then asked to indicate their agreement or disagreement with each statement on a seven-item Likert scale (1 = strongly disagree to 7 = strongly agree). Paired t-tests were conducted to compare mean responses to all statements pre and post interaction. For statement 13, “A self-driving car would allow me to be more productive”, a significant difference was observed between the mean response for the pre-interaction (M = 6.50, SD = 1.15) and post interaction (M = 6.75, SD = 1.12) conditions. For statement 14, “A self-driving car would allow me to be more safe while in the car”, the difference between the mean response for the pre-interaction and post interaction conditions was found to be statistically insignificant. For statement 15, “Self-driving cars will reduce traffic problems”, a significant difference was observed between the mean response for the pre-interaction (M = 5.15, SD = 1.04) and post interaction (M = 5.75, SD = 1.07) conditions.

4.6.6. Perceived ease of use
Participants were presented with three statements related to the perceived ease of use of self-driving cars. They were then asked to indicate their agreement or disagreement with each statement on a seven-item Likert scale (1 = strongly disagree to 7 = strongly agree). Paired t-tests were conducted to compare mean responses to all statements pre- and post-interaction. For statement 16, “Self-driving cars will be easy to use”, a significant difference was observed between the mean response for the pre-interaction (M = 5.05, SD = 1.43) and post-interaction (M = 6.40, SD = 0.88) conditions. For statement 17, “It will be a lot of work to figure out how to use a self-driving car”, a significant difference was observed between the mean response for the pre-interaction (M = 3.50, SD = 1.61) and post-interaction (M = 1.7, SD = 1.13) conditions. For statement 18, “It would take me a long time to figure out how to use a self-driving vehicle”, the
difference between the mean response for the pre-interaction and post-interaction conditions was found to be statistically insignificant.

4.6.7. Experience with automation

Participants were presented with three statements related to their experiences with technology and opinion of automation. They were then asked to indicate their agreement or disagreement with each statement on a seven-item Likert scale (1 = strongly disagree to 7 = strongly agree). Paired t-tests were conducted to compare mean responses to all statements pre and post interaction. For statement 19, "I like to use technology to make tasks easier for more", the difference between the mean response for the pre-interaction and post interaction conditions was found to be statistically insignificant. For statement 20, "I have bad experiences when I try to use new technology instead of doing things the old fashioned way", the difference between the mean response for the pre-interaction and post interaction conditions was found to be statistically insignificant. For statement 21, "There are tasks in my life that have been made easier by computers doing the work for me", the difference between the mean response for the pre-interaction and post interaction conditions was found to be statistically insignificant.

4.6.8. Intention to use

Participants were presented with three statements related to their intention to use self-driving vehicles. They were then asked to indicate their agreement or disagreement with each statement on a seven-item Likert scale (1 = strongly disagree to 7 = strongly agree). Paired t-tests were conducted to compare mean responses to all statements pre- and post-interaction. For statement 22, "I would like to own a self-driving car", a significant difference was observed between the mean response for the pre-interaction (M = 6.1, SD = 1.52) and post interaction (M = 6.8, SD = 0.70) conditions. For statement 23, "Even if I had a self-driving car, I would still want to drive myself most of the time", the difference between the mean response for the pre-interaction and post interaction conditions was found to be statistically insignificant. For statement 24, "In a self-driving car, it will be important to me to have the option to turn off the computer and drive myself", the difference between the mean response for the pre-interaction and post interaction conditions was found to be statistically insignificant.

5. Discussion

5.1. Overall perception of the ATLAS system

Overall, participants expressed a decidedly positive view of the usability of the ATLAS prototype. Participants on average rated the usability of the system as "Excellent" as measured on the SUS, with no statistical differences observed between the perceptions of male, female, blind and low vision participants. Based on these findings the null hypotheses, H01 is rejected and the alternate hypothesis HA1 is accepted. Participants also expressed significant satisfaction with the situational awareness and location verification features of the prototype. When asked whether ATLAS satisfied their situational awareness and location verification needs, the mean response to both questions was 6.55 (between “mostly” and “strongly” agree) with variations in standard deviation observed. A comparison of the pre and post scenario responses to the Self-Driving Car Acceptance Scale also provides guidance regarding participant's perception of the system’s usability. Following interaction with the system, participants’ stated perception that self-driving cars will be easy to use increased by 26.73% while the belief that it would be "a lot of work" to learn how to use a self-driving car decreased by 51.42%. Based on these findings the null hypotheses, H02 is rejected and the alternate hypothesis HA2 is accepted.

5.2. Risk and trust in self-driving vehicles

Further comparisons of the pre- and post-scenario responses of the Self-Driving Car Acceptance Scale also provide guidance as to participant perception of the safety of self-driving vehicles. Following their interaction with the prototype, participants’ perception of the safety of the technology improved by 28.26%, stated trust in the technology increased by 20.75% while the belief in the need to closely monitor a self-driving vehicle for errors decreased by 24.22%. Participants’ belief in the need for features that would allow them to take back control from the automated system decreased by 11.49% while participant perception that there are some driving scenarios that will be too difficult for a self-driving vehicle decreased by 35.48%. These findings are indicative of a general increase in the perception of safety and trust in the technology and based on these findings the null hypothesis, H03 is rejected and the alternate hypothesis HA3 is accepted. Study findings relative to trust provide additional support to the findings of a qualitative study conducted by Intel where users expressed an increased degree of comfort with self-driving vehicle technology after having a first-hand experience with it. The findings of the Intel study have questionable generalizability given the small number of participants involved (10). Beyond proving our hypothesis, these findings are significant for two reasons. The present study suggests that even an interaction with a simulated self-driving vehicle, where participants are overtly told that a licensed driver is in the driver’s seat, may ameliorate feelings of concern and apprehension that users have regarding this technology. These results are perhaps even more significant when viewed in the context of consumer adoption broadly. Studies have consistently found that consumers generally are afraid to ride in self-driving vehicles (Stepp, 2017) and are significantly concerned about the potential for dangerous equipment failures (Schoettle & Sivak, 2014; Sommer, 2013). A recent AAA study for instance, found that 75% of respondents indicated that they were afraid to ride in a self-driving vehicle (Stepp, 2017). The present study provides additional support to the contention that increased user interaction with the technology, simulated or otherwise, may effectively address this issue.

Findings suggest that interaction with the ATLAS prototype also increased participant comfort with the concept of being a passenger as opposed to an active driver. Participants’ stated enjoyment of driving a conventional vehicle post-
interaction decreased by 14.28% while the stated preference for being the driver rather than the passenger decreased by 15.38%. Given that the stated enjoyment of being in a vehicle generally did not change significantly, these findings imply a changing interpretation of participants’ relationship to personal transportation post interaction with the prototype.

The focus groups of Brinkley et al. (2017), suggest that visually impaired persons are relatively optimistic about self-driving vehicles and this optimism is driven largely by a belief that the technology will improve personal mobility and productivity. While participants of the present study began with a generally positive perception of the technology, post-interaction this perception relative to a belief in increased personal productivity improved by 3.84%. While it cannot be stated definitively whether this increase was driven by interaction with what participants believed to be a self-driving vehicle or interaction with the ATLAS system specifically, the latter contention is supported by the 90% of participants who indicated that they would purchase a self-driving vehicle with the ATLAS system if cost were not a factor. Post interaction, participants’ stated desire to own a self-driving vehicle increased by 11.47% while belief that benefits of a self-driving car would outweigh the amount of money it would cost increased by 21.1%. These findings stand in contrast with much of the literature, which has suggested that while consumers have a generally favorable view of the concept of vehicular automation, most consumers would not actually pay more to have access to it (Kyriakidis et al., 2015; Schoettle & Sivak, 2014).

Viewed collectively, the findings suggest that the features of the ATLAS system, borne of a lengthy process of investigation, development and refinement, are effective in satisfying the experiential needs of visually impaired persons in interacting with self-driving vehicles.

6. Limitations

While every effort was made in the design, execution and analysis of the present study to conduct research that could withstand scrutiny, there are limitations that must be mentioned. With respect to design and execution, it is arguable that limiting the participant interaction activity to four tasks may be a limitation. Given the desire to limit each trial to under two hours, the logically interdependent nature of tasks within a quasi-naturalistic scenario and the lack of similar studies that have investigated even the most rudimentary aspects of self-driving vehicle interaction involving visually impaired persons, four tasks were deemed sufficient for this initial investigation. Future work will investigate more elaborate and complex in-vehicle interactions with the ATLAS prototype.

The manner in which the Self-Driving Car Acceptance Scale (SDCAS) was used within the study may also be viewed as a limitation. Given that the SDCAS was administered immediately following interaction with the ATLAS prototype, acquiescence bias is a legitimate concern. We argue that the instrument and associated questions are framed in such a way as to minimize the potential impact of this type of response bias. We have chosen to present findings that evaluate the effect of interaction on individual SDCAS items in an attempt to enable the reader to draw conclusions regarding SDCAS responses collectively based on discrete item results.

7. Conclusion

The present study was designed to contribute to the growing body of self-driving vehicle literature that specifically explores the opinions and preferences of visually impaired consumers within the context of a usability study of a self-driving vehicle human-machine interface. Using Wizard of Oz methodology, we have evaluated the usability of a self-driving vehicle HMI, explored the effect of interaction with the prototype on participants’ opinions of self-driving vehicles, concerns and willingness to pay for this technology. Our findings demonstrate that following interaction with the prototype, participant expressions of fear regarding self-driving vehicles diminished while expressions of trust and a belief in the likely usability the technology increased dramatically. Research of this type will become increasingly critical as self-driving vehicle technology becomes commercially available and consumer adoption beyond sighted persons is to be realized.

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