Exploring the Needs, Preferences, and Concerns of Persons with Visual Impairments Regarding Autonomous Vehicles

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Fully autonomous or "self-driving" vehicles are an emerging technology that may hold tremendous mobility potential for blind or visually impaired persons who are currently unable to drive a conventional motor vehicle. Despite the considerable potential of self-driving vehicle technology to address this mobility issue, however, the needs and preferences of persons with visual disabilities regarding this technology have been insufficiently investigated. In this article, we present the results of two studies that are focused on exploring the needs, preferences, and concerns of persons with visual impairments as it relates to self-driving vehicles. Study one investigated user acceptance, concerns, and willingness to buy partially and fully automated vehicles using a 39-question Internet-based survey distributed in the United States to visually impaired respondents ($n = 516$). Study two explores the opinions of 38 participants who are blind and low vision, using focus group methodology, regarding emerging self-driving vehicle technology. Collectively our findings suggest that while persons with visual impairments may be optimistic regarding the potential for enhanced mobility and independence that may result from the emergence of self-driving vehicles, concerns exist regarding the implementation of this technology that have been largely unexplored and under investigated.

CCS Concepts: • **Human-centered computing → Accessibility**; **Empirical studies in accessibility**;

Additional Key Words and Phrases: Autonomous vehicles, self-driving vehicles, accessibility, visual impairment

ACM Reference format:
Julian Brinkley, Earl W. Huff Jr., Briana Posadas, Julia Woodward, Shaundra B. Daily, and Juan E. Gilbert. 2020. Exploring the Needs, Preferences, and Concerns of Persons with Visual Impairments Regarding Autonomous Vehicles. *ACM Trans. Access. Comput.* 13, 1, Article 3 (April 2020), 34 pages.
https://doi.org/10.1145/3372280

1 INTRODUCTION

As autonomous vehicle technology transitions from the realm of science fiction to scientific reality, the potential benefits of this technology have become ever more broadly discussed. Developers of this technology imagine that the most advanced of such vehicles, referred to as

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1936-7228/2020/04-ART3 $15.00
https://doi.org/10.1145/3372280

Level 5 Automation or fully "self-driving" vehicles [35, 51] will operate with minimal human interaction and no direct human manipulation of safety-critical controls (e.g., accelerator, brake pedals or steering apparatus). Removing error prone human beings from manual driving may reduce by as much as 90% [45, 61, 64] the types of motor vehicle crashes that claim thousands of lives annually and result in costly property damage and loss [35]. Self-driving vehicle technology itself may render personal vehicle ownership obsolete as transportation is increasingly consumed as a service [12]. This, in turn, may change the financial models of a host of major industries and the physical design of cities themselves [19, 58]. To realize these benefits consumer adoption of such a paradigm shifting technology is critical given the potentially high costs of the technology and the potential safety concerns of automated driving [13]. While discussions of the impact of self-driving vehicle technology taking place in academia, regulatory bodies and in industry are being accompanied by wide ranging consumer and user research, there are still large knowledge gaps as it relates to the needs and preferences of specific groups of users. It has been suggested, for instance, that most self-driving vehicle technology being developed is not in fact accessible to individuals with visual impairments [44]. We argue that this may be at least partially attributable to a knowledge gap as it relates to the needs and preferences of individuals with visual impairments regarding self-driving vehicle technology. A knowledge gap driven by the reality that most self-driving technologies are being designed around the *driver* of the present who in all cases is sighted as opposed to the *operator* of the future who need not necessarily be.

We present the results of two studies conducted with an intent to explore the needs, preferences and concerns of persons with visual impairments regarding self-driving vehicles. In the initial study, a 39-question Internet-based survey was distributed in the United States. The survey collected 516 useable responses from persons 18 years and older who self-identified as blind or visually impaired. Respondents were asked questions about their familiarity with emerging self-driving vehicle technology, their general opinion about such vehicles, the anticipated benefits of the technology and opinions on relevant issues related to visual impairment and blindness. In the subsequent study, using focus group methodology, 38 people who are blind and low vision participated in eight focus groups over a two-day period. Participants were asked to provide their general opinions regarding self-driving vehicles, comment on their hopes for the technology, reflect on their concerns, and express their preferences regarding interaction mechanisms in a semi-structured group discussion lasting approximately one hour. We believe that collectively this research furthers our goal of contributing to the literature research that furthers the understanding of the needs and preferences of users with a range of visual impairments as it relates to emerging self-driving vehicle technology. Research of this type will become increasingly critical if universal access to this technology is to be realized. The present article combines and significantly extends two previously published works; a paper presented at the ACM SIGACCESS Conference on Computers and Accessibility that is available within the conference proceedings [10], and an extended abstract presented at the CSUN Assistive Technology Conference that is available in the Journal on Technology and Persons with Disabilities [9].

2 RELATED WORK

The studies described in this manuscript were motivated by knowledge gaps in the related user research on autonomous vehicles. To provide context to the studies described, we provide background on vehicle automation levels, existing consumer/user research on autonomous vehicles, spatial cognition, and navigation for blind and visually impaired persons.

2.1 Levels of Vehicular Automation

The Society of Automotive Engineers (SAE) has described six levels of vehicular automation that have been adopted by the National Highway Transportation and Safety Administration (NHTSA), the regulatory body responsible for vehicle automation in the United States [45]. The SAE Automation Levels are described in the SAE J3016 standard [3, 51, 52] and describe levels 0 through 5, which represent escalating levels of vehicular automation. Level 0, for instance, represents no automation and completely conventional or manual driving. Level 3 vehicles, however, have technology for "conditional automation" meaning that automated driving is possible under certain conditions. With Level 3 vehicles, such as Tesla's equipped with Autopilot [41], the vehicle is capable of certain automated highway driving, but the driver must be prepared to assume manual control when notified by the vehicle. Level 5 vehicles, however, can perform all driving functions under all conditions though the driver may have the option of assuming manual control if desired. At present only automation levels 0 through 3 are commercially available in the United States. We primarily focus our discussion on Level 5 or fully "self-driving" vehicles given that this level of automation holds the most promise for blind and visually impaired (BVI) users who cannot legally operate a Level 0 through 3 vehicle with existing technology.

2.2 Consumer Opinions on Autonomous Vehicles

There have been a number of studies in recent years that have investigated public opinion regarding automated driving conceptually, have explored consumer preferences regarding specific self-driving vehicle technologies and have examined related user needs.

In a 2013 survey conducted by Continental AG in Germany, China, Japan, and the U.S., 59% of respondents considered automated driving to be a "useful advancement," but 31% of respondents in all three countries found the development of automated vehicles to be "unnerving" [59]. Sixty-six percent of U.S. respondents, for instance, indicated that they were "scared" by the concept of automated driving. Respondents were also skeptical of the reliability of the technology with 74% of respondents in China and 50% of respondents in the U.S., indicating that they did not believe that it would function reliably.

In 2013 professional services company KPMG conducted a focus group study with a total of 32 participants across California, Chicago and New Jersey [26]. 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). Safety was a dominant topic of discussion during the focus groups with many participants expressing skepticism that the technology would work properly. Participants were near unanimous in expressing a need to be able to take control of the vehicle at will for a variety of reasons. Some participants expressed a lack of trust in the automated systems and expressed comfort in having manual controls available. Participants also expressed 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, CA regarding self-driving vehicles [22]. Respondents indicated that safety (75%) and convenience (61%) were the most attractive features of the technology. 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 an option were made available. Respondents indicated that liability concerns and the potential cost were the least attractive features of the technology.

In a 2014 survey involving 1,533 respondents in the U.S., U.K., and Australia, Schoettle and Sivak found that more than 60% of respondents in all three countries were aware of the technology and more than 50% had positive expectations about its potential benefits (e.g., less traffic congestion, shorter travel time) [54]. Respondents in all three countries expressed concerns about self-driving vehicles, however. Across all three countries the most significant concerns were expressed regarding system/equipment failure, followed by vehicle performance in unexpected situations. Additionally, more than 90% of respondents expressed some degree of concern regarding the legal liability of drivers/owners of self-driving vehicles. A majority of respondents in all three countries expressed some interest in having self-driving technology but were generally unwilling to pay extra for it.

Payre, Cestac, and Delhomme conducted a public opinion survey in 2014 of French drivers to investigate opinions on fully automated driving [46]. The study examined attitudes and acceptability of fully automated driving technology among 421 drivers finding that men and those scoring highly on the driving-related sensation seeking scale were more willing to use a fully automated vehicle and were more inclined to purchase a self-driving vehicle. Older respondents were less likely to indicate that they would purchase such a 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 conducted a public opinion survey in 2014 involving 1,001 British respondents to investigate attitudes related to cars and technological developments surrounding the automotive industry [40]. Only 18% of those surveyed felt that it was important for car manufacturers to focus on driverless 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.

A similar study was conducted by Kyriakidis, Happee, and de Winter who conducted an international public opinion survey in 2015 involving 5,000 respondents from 109 countries to investigate user acceptance, concerns and willingness to buy partially, highly and fully automated vehicles [28]. A plurality of respondents (22%) indicated that they were unwilling to pay any money for a fully automated driving system, while 5% indicated a willingness to pay more than $30,000 for it. Respondents were most concerned about software hacking/misuse, legal issues and safety.

In a 2016 survey involving 618 respondents in the U.S., Schoettle and Sivak found that among those surveyed the most frequent preference for vehicle automation was, in fact, “no automation” followed by a preference for partially self-driving vehicles [55]. Approximately 16% of respondents indicated a preference for self-driving vehicles. Over 90% of respondents expressed some degree of concern regarding self-driving vehicles when presented with a scenario where a self-driving vehicle would be their only means of transportation. The vast majority of respondents also expressed a desire for manual vehicle controls (e.g., steering wheel, gas pedal and brake) with 94.5% of respondents indicating that they would like a self-driving car to have such controls to enable a human driver to take control in the event of an emergency. In terms of entering a route or destination in a self-driving vehicle, 38% of respondents preferred the use of a touchscreen compared to 34.5% who preferred the use of a voice commands, 7.9% preferred the use of a personal portable device.

Bansai, Kockelman, and Sing in a 2016 study involving 347 respondents in Austin, Texas found that respondents on average were willing to pay $7,253 to add Level 4 automation or full self-driving capabilities to their vehicles [4]. This stands in contrast to the findings of much of the previously described research but is largely consistent with the findings of Daziano, Sarria, and Leard [13], who found in a 2017 study involving 1,260 respondents that the average household was willing to pay $4,900 for self-driving capabilities.

Brewer and Kameswaran in a 2018 design-based focus group study involving 15 BVI participants explored preferences for varying levels of automation and the desire for control [8]. They found that despite being legally unable to drive, several participants indicated that they continued to drive with the assistance of telescopic devices. The biggest perceived benefit of autonomous vehicles for participants was in improved independence and quality of life. This factor, while of significance to participants of the design-based focus groups, was largely unexplored by prior research given the de facto focus on consumers with sight. Excitement regarding this potential was tempered, however, by concerns regarding control and the human-machine interface. Control was explored within the focus groups using a design activity wherein participants conceptualized assistive technologies that would be beneficial within the autonomous vehicle context. Brewer and Kameswaran found that participants broadly were interested in a means of exercising direct control of the vehicle, though the means of such control often differed between participants. Participants expressed concerns specifically that the voice and tactile systems used for control may malfunction or misinterpret a user's actions.

Similar in design to the study of Brewer and Kameswaran, Huff et al. conducted focus groups involving 39 African American older adults (55+), exploring participant perceptions regarding self-driving vehicles generally, the technology's development and its potential use [23]. They found that participants felt confident in their ability to operate a self-driving vehicle and take control in the event that a situation deemed that necessary, findings that largely mirror those of Schoettle and Sivak [54, 55], and were optimistic regarding the potential mobility benefits of the technology. Participants questioned, however, whether the needs of older adults and persons with disabilities were being properly considered in the design of automated vehicles broadly and were concerned that the absence of such consideration might render the technology ultimately inaccessible. These sentiments were followed by concerns regarding what was anticipated to be high initial costs of ownership and a general sentiment that such vehicles might be prone to errors and malfunctions.

Each of the previously described studies had specific foci but contributed generally to the understanding of public opinion and consumer preferences as it pertains to self-driving vehicles. Viewed collectively, while these studies advance the understanding or consumer needs and user preferences regarding vehicle automation, none but the study of Brewer and Kameswaran directly and specifically incorporated respondents and participants with visual disabilities. We argue that the present report is unique in its focus on the opinions of blind and low-vision persons whose preferences and concerns, we argue, have not been adequately explored in recent research.

2.3 Spatial Cognition of Blind and Visually Impaired Persons

To contextualize our studies on autonomous vehicle preferences of visually impaired persons, we provide background on the mobility, spatial cognition and navigation challenges faced by BVI individuals as well as mobility-related assistive technologies. This discussion is germane to the larger discussion of self-driving vehicles and BVI persons in the sense that self-driving vehicles may be viewed as an especially unique mobility technology. As such, there are both potential mobility benefits for visually impaired persons and potentially unique challenges with respect to spatial knowledge acquisition, orientation and navigation.

2.3.1 Spatial Navigation. Orientation and mobility are common terms found in the literature related to visual impairment and spatial navigation. Montello [43] distinguishes between both terms and provides an explanation of their use in the related literature. Mobility (locomotion) [43], which is inherently egocentric, pertains to the immediate response to environmental features such as stepping onto a sidewalk, avoiding an obstacle or gaining awareness of a nearby landmark [17]. Orientation (wayfinding) [43] involves reasoning about immediate [21] and remote [67] environments and accordingly may involve short term or long-term mental representations as well as egocentric or allocentric perspectives. Orientation is dependent upon mobility skills and requires both an awareness of a person's current position and heading in the environment with respect to their desired goal as well as the ability to update this information during travel. Golledge [18] has described orientation as being critical for planning and determining routes through an environment, especially if these routes have not been previously traveled.

Wayfinding may prompt a navigator to at times adopt either an egocentric or allocentric perspective. In an egocentric (self-based) perspective or frame of reference, information such as direction and distance is presented in relation to the position and orientation of the observer. In an allocentric or absolute frame of reference, information is presented independent of the observer but with respect to a fixed point of reference. Both frames of reference can be used to represent spaces at spatial scales that are described somewhat differently in the recent literature but with some degree of overlap. Schinazi et al. [53], for instance, identify three categorizations of scales: micro-, meso-, and macroscales. Giudice [17], however, presents four categorizations: figural, vista, environmental, and geographical space. Microscale and vista space refer to space that does not require fully-body movement, such as objects on a tabletop. Mesoscale and vista space describe space that is larger than the observer but can be seen from a single perspective such as an indoor room. Macroscale and geographical space describe space that is larger than the observer but can only be apprehended from multiple viewpoints.

2.3.2 Spatial Knowledge Acquisition. Researchers have described two frameworks for the acquisition of spatial knowledge in the discrete [42] and continuous [11] frameworks. In the discrete framework spatial knowledge is acquired via three distinct stages: landmark, route and survey [57]. In the landmark stage knowledge is gained regarding features of the environment that may be used for establishing a frame of reference. In the route stage, landmarks become connected through routes that may enable a navigator to draw inferences regarding the straight-line distance between two points. In the survey stage these mini-maps are integrated using an objective frame of reference into a global representation that is at times referred to as a cognitive map [56].

2.3.3 Models of Spatial Development. Fletcher [15] proposed the Difference, Deficiency, and Inefficiency theories of spatial development for BVI persons that have been subsequently extended to the Convergent model, Cumulative model, and Persistent model, respectively. These theories posit that vision provides sighted individuals with an initial advantage relative to blind individuals though, within the literature, there are cases in which the blind outperform the sighted [5].

The Difference/Convergent model [53] suggests that blind people begin at a disadvantage relative to sighted individuals but that the disparity decreases with experience until similar levels of performance are realized. The Deficiency/Cumulative model [53] suggests that vision is critical for the development of spatial representation. While blind people may be able to acquire spatial knowledge, the theory suggests, in the absence of vision blind persons are incapable of forming spatial representations. The Inefficiency/Persistent model [53] suggests that the absence of vision results in an initial disadvantage that remains constant with experience, because auditory and proprioceptive cues are less effective for spatial knowledge acquisition than vision. Of the three, Giudice [17] argues that literature on the Difference/Convergent model is mixed and therefore hard to interpret and the Deficiency/Cumulative model is not born out in the related literature. The Inefficiency/Persistent model, however, is supported by some studies in which early blind persons have worse performance on spatial tasks such as updating and cognitive map development compared to people with late-onset blindness or low vision on the same tasks [47, 48].

2.3.4 Spatial Processing and Representation. Research has suggested that spatial representations can be abstracted from different perceptual modalities [29, 30, 62]. These modalities differ with respect to simultaneous versus sequential information acquisition. Prior research has suggested that vision enables simultaneous perception [16, 38], whereas audition [7] and haptics [49] allow for sequential perception. Vision conveys an advantage, it is argued [53], in the speed with which the eyes can move compared to the speed of head and body movements. Vision provides rapid access to highly precise distance and direction information about positioning of various local and distant landmarks [17]. Vision also provides geometric information about spatial structures, affords object recognition over a large field of view and affords access to precise motion

Table 1. Breakdown of Survey Respondents by Gender

Gender	Percent ($n = 516$)
Female	54.41
Male	45.40

cues for changing self-to-object and object-to-object relations that occur during navigation [17]. While other senses may provide similar cues, they are more limited and less precise than what vision can produce. However, recent evidence has suggested that BVI persons can achieve similar spatial behavior and performance when learning from a combination of different spatial inputs, which is referred to as functional equivalence [17, 53]. Specifically, amodality or the Amodal Hypothesis claims that spatial representations can be abstracted from different perceptual modalities, thus building an amodal or sensory-independent representation that is not tied to any particular sensory or cognitive source [17, 32, 33].

Navigating large, unknown environments is arguably the most difficult task faced by blind and visually impaired travelers [17]. When coupled with the limited training typically experienced by BVI persons on complex spatial skills, self-driving vehicles represent a potential mobility solution that may also introduce new challenges with respect to BVI spatial cognition given the inherently large and unknown nature of the operating environment.

3 STUDY 1: AN ONLINE SURVEY REGARDING SELF-DRIVING VEHICLES

3.1 Method

3.1.1 Online Survey. The initial study was conducted as an online survey using the Qualtrics [65] survey platform. The questionnaire was adapted from a public opinion survey regarding self-driving vehicles in the U.S., U.K., and Australia conducted by Schoettle and Sivak [54], with format modifications designed to enable screen reader accessibility, scale adjustments and content modifications intended to address topics related to visual impairment. The order of the questions was the same for all respondents. The topics addressed by the survey are described below:

- Respondent familiarity with self-driving vehicles (1 Question: Q1)
- General opinions about self-driving vehicles (2 Questions: Q2, Q31)
- Concerns regarding self-driving vehicles (18 Questions: Q3–Q5, Q14–Q28)
- Anticipated benefits of self-driving vehicles (8 Questions: Q6–13)
- Willingness to pay for self-driving vehicle technology (2 Questions: Q29, Q30)
- Issues related to visual impairment and blindness (3 Questions: Q37–Q39)
- Demographic data (5 Questions: Q32–Q36)

Responses were gathered from January 4, 2017 through April 12, 2017.

3.1.2 Respondents. Participants were recruited through email notifications distributed by 16 state agencies for the blind and by the American Council of the Blind [2]. Participation was restricted to individuals 18 years of age and older whom self-identified as blind or visually impaired. Participants were entered into a drawing for a $300 prepaid gift card as compensation. This recruitment strategy resulted in 556 replies from potential respondents with completed surveys received from 516 respondents. The final response rate of the survey was 92.8%. The margin of error at the 95% confidence level for the results is +/− 4.0%. Demographic breakdowns for the respondents are provided in Tables 1 through 5. Approximately 54% of respondents were female and approximately 45% were male (Table 1). More than half of respondents were 45 years of age

Table 2. Breakdown of Survey Respondents by Age Group

Age group	Percent ($n = 516$)
18–24	7.69
25–34	18.65
35–44	17.11
45–54	18.26
55–64	24.23
65–69	8.00
70+	5.96

Table 3. Breakdown of Survey Respondents by Level of Education

Education	Percent ($n = 516$)
Some High School	0.96
High School	8.25
Some College	20.54
Two-year Degree/Associate Degree	11.32
Bachelor's Degree	31.86
Graduate Degree	27.06

Table 4. Breakdown of Survey Respondents by Level of Employment

Education	Percent ($n = 516$)
Employed Full-time	35.12
Employed Part-time	13.82
Not Currently Employed	19.77
Retired	21.31
Full-time Student	7.68
Part-time Student	2.30

or older, while those in the 18–44 age range made up 43.45% of those participating in the survey (Table 2). Nearly 60% of respondents held at least a bachelor's degree (58.92%), while fewer than 1% had less than a high school education (Table 3). Those employed full-time (35.12%) exceeded the combined number of respondents who were full-time students, part-time students and those employed part-time (23.8%) as illustrated in Table 4. More than half of respondents (55.34%) indicated that they had been blind or visually impaired all of their lives.

3.2 Results

3.2.1 General Opinion of Self-Driving Vehicles. The survey began with a paragraph-length overview of vehicle automation and a description of self-driving vehicles specifically. A majority of survey respondents had heard of self-driving vehicles prior to the survey (95.96%) with most respondents having a positive impression of the technology (50.18% extremely positive, 30.44% moderately positive, and 7.75% slightly positive). Fewer than 10% had a negative impression of the

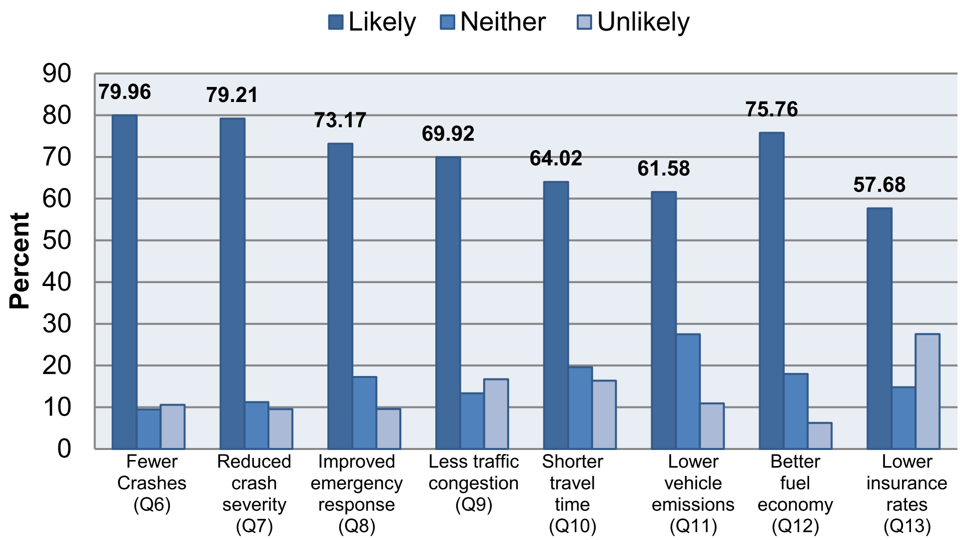

Fig. 1. Summary of responses to Q6–Q13: "*Regarding self-driving vehicles, how likely do you think the following benefits will occur…?"* All variations of "likely" and "unlikely" have been tallied.

technology with 2.03% of respondents indicating that they held an "extremely negative" impression of self-driving vehicle technology.

3.2.2 Expected Benefits of Self-Driving Vehicles. Respondents were asked eight questions related to the anticipated benefits that might occur through the use of self-driving vehicle technology. With each question they were asked to select "extremely likely," "moderately likely," "slightly likely," "neither likely nor unlikely," "slightly unlikely," "moderately unlikely" or "extremely unlikely." Figure 1 illustrates respondent perception of potential benefits accounting for all variations of "likely" ("extremely," "moderately," and "slightly"), "neither likely nor unlikely" and all variations of "unlikely" ("extremely," "moderately," and "slightly"). The majority of respondents felt that each of the expected benefits were likely to occur with self-driving vehicles with respondents expressing the most confidence in the likelihood of fewer automobile crashes (79.96% when all variations of "likely" combined), reduced severity of automobile crashes (79.21%) and better fuel economy (75.76%). Lower insurance rates were viewed as least likely (27.52% when all variations of "unlikely" combined).

3.2.3 Self-Driving Vehicle Operational Concerns. Respondents were asked how concerned they would be about riding in a fully autonomous or self-driving vehicle as the primary operator. A definition describing a fully autonomous or self-driving vehicle accompanied the question. The most frequently selected response was "slightly concerned" (38.96%), followed by "moderately concerned" (22.82%), "very concerned" (16.70%), and "not at all concerned" (21.52%). Subsequently, respondents were asked how concerned they would be about riding in a *partially* autonomous vehicle as the primary operator. A definition describing a partially autonomous vehicle accompanied the question. The most frequently selected response was "slightly concerned" (30.91%), followed by "very concerned" (27.56%), "not at all concerned" (23.84%), and "moderately concerned" (17.69%). A majority of respondents expressed some degree of concern regarding their ability to operate a self-driving vehicle if one was made available to them (32.16% slightly concerned, 15.80% moderately concerned, 17.66% very concerned). The most frequently selected response, however, was "not at all concerned" (34.49%).

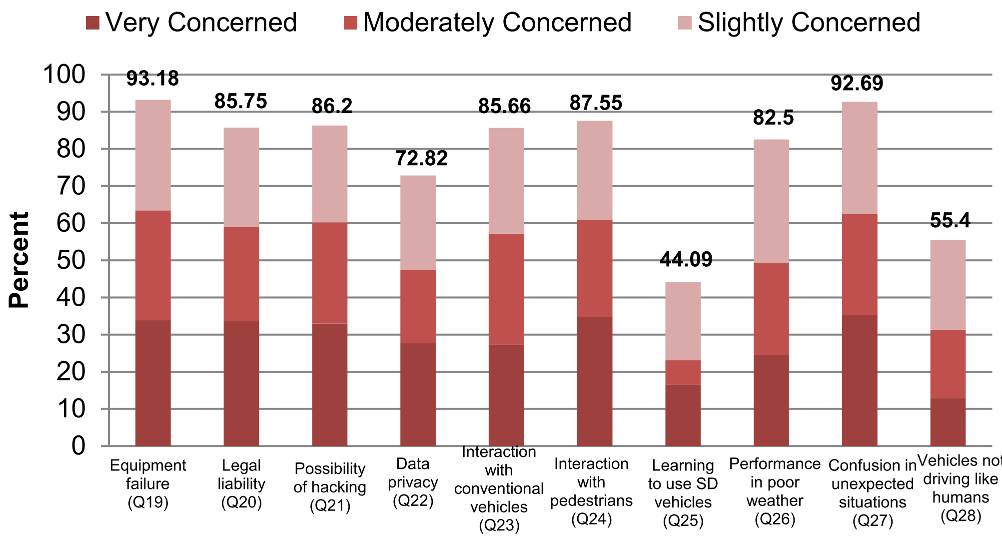

Fig. 2. Summary of responses to Q19–Q28; "not at all concerned" is not displayed: "*Regarding self-driving vehicles, how concerned are you about…*"

3.2.4 Self-Driving Vehicle Issue-based Concerns. Respondents were asked 10 questions related to self-driving vehicle related issues; Figure 2 provides a summary of their responses. For each question respondents were asked to select "very concerned," "moderately concerned," "slightly concerned," or "not at all concerned." Respondents expressed the most concern (when all variations of concern are accounted for) about equipment failure or system failure (93.18%), followed by vehicles getting confused in unexpected situations (92.69%) and the interaction between self-driving vehicles and pedestrians and bicycles (87.55%). The least concern was expressed about learning to use self-driving vehicles (44.09%).

3.2.5 Self-Driving Vehicle Scenario-based Concerns. Respondents were presented with five potential scenarios involving self-driving vehicles; Figure 3 provides a summary of their responses. For each scenario they were asked to select "very concerned," moderately concerned," "slightly concerned," or "not at all concerned." Respondents expressed the most concern (when all variations of concern are accounted for) about self-driving commercial vehicles (85.07%) followed by self-driving public transportation (e.g., buses, 80.5%). Respondents were least concerned about the prospect of self-driving vehicles moving by themselves from one location to another (39.01% "not at all concerned").

3.2.6 Ownership Interest and Willingness to Pay. More than 90% of respondents expressed some interest in owning self-driving vehicle technology with 93.31% indicating that they were "extremely/very/moderately/slightly interested." Respondents on average indicated that they were willing to pay $6,346 US extra for this technology with those at the 50th percentile indicating that they would pay $1,000 extra and those at the 90th percentile indicating that they would pay $10,000 extra. About a third (n = 171) of respondents (33.11%) indicated that they would not be willing to pay extra for self-driving vehicle technology.

3.2.7 Self-Driving Vehicle Travel Time. Respondents were asked how they would occupy their time were they to travel in a self-driving vehicle and were presented with a list of nine options

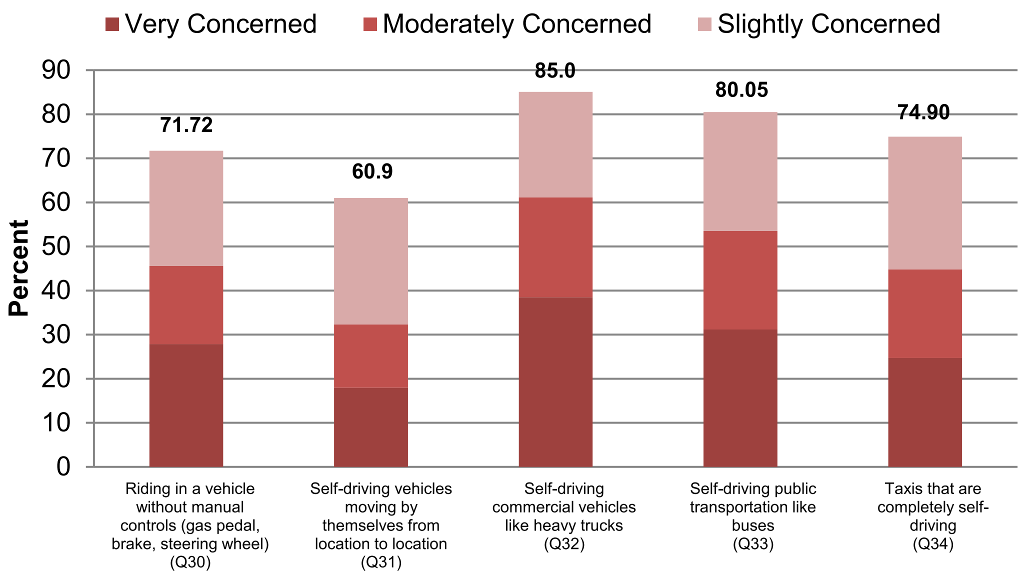

Fig. 3. Summary of responses to Q30–Q34; "not at all concerned" is not displayed: "*Regarding self-driving vehicles, how concerned are you about...*"

Table 5. Percentage of Responses to Q37: "If you Were to Ride in a Completely Self-driving Vehicle What Do You Think You Would Use the Extra Time Doing Instead of Monitoring the Roadway?"

Response	Percent
Text or Talk with Friends or Family	14.94
Read	20.31
Sleep	2.87
Watch movies/TV	1.92
Play Games	1.34
Work	12.07
Monitor the Road Even Though I Would Not Be Driving	31.99
Other	9.39
I Would Not Ride in a Completely Self-driving Vehicle	5.17

from which to choose from. Table 5 provides a summary of responses. The most frequently chosen response was "monitor the road even though I would not be driving" (31.99%), with "read" (20.31%) being the second most frequently chosen response.

3.2.8 Issues Related to Visual Impairment and Blindness. Each respondent was asked if they agreed that their needs, as a person with a visual disability, were being considered in the development of self-driving vehicles. More than half of respondents, 62.36%, said that they "strongly/somewhat/agreed" while 20.47% indicating that they "strongly/somewhat/disagreed."

When asked about their concern regarding laws being put in place to prevent people who are blind from operating self-driving vehicles, 94.37% stated that they were "very/moderately/slightly concerned"; 60.58% of whom indicated that they were "very concerned."

Table 6. Statistically Significant Effects of Demographic Groupings on Responses to Individual Questions as Presented Through Results from a Series of One-way ANOVAs

Question number	Ever heard of	General opinion	Length of visual disability	Employment status	Education	Transportation type	Age	Gender
Q3		***						
Q4		**				*		
Q5		***					*	*
Q6		***						*
Q7		***						**
Q8		***			**			**
Q9		***						***
Q10		***						*
Q11		***			**			
Q12		***			*			*
Q13		***			**			**
Q14		***	**	*	*			
Q15		***						
Q16		***	*	**			*	
Q17	**	***	*	*	*			
Q18		***						
Q19		***						
Q20		***	*					
Q21		***	*	*				
Q22		***	*	**				
Q23	*	***	*	**	**			
Q24		***		*				***
Q25	*	***	*	*	*			**
Q26	*	***		*			*	***
Q27	*	***						***
Q28		***						***
Q29		***					**	***
Q38	*	*		**	*			
Q39		***					*	

* = $p \leq 0.05$.
**= $p \leq 0.01$.
*** = $p \leq 0.001$.

3.3 Statistically Significant Demographic Effects

Multiple One-way Analyses of Variance (ANOVA) were used to compare responses to survey questions for each individual demographic variable. Using the D'Agostino-Pearson normality test it was determined that the collected data was non-normal [20]. Given the greater statistical power of parametric tests [20], coupled with research that suggests one-way ANOVA is acceptable even with non-normal data depending on sample size and grouping [39], the use of multiple one-way ANOVA was chosen over the use of the Kruskal-Wallis test [20]. Table 6 presents a summary matrix from the series of ANOVAs, indicating statistically significant effects of demographic grouping on individual questions, either at $p \leq 0.05$, $p \leq 0.01$, or $p \leq 0.001$.

3.3.1 Prior Awareness of Self-Driving Vehicles (Q1). Respondents who had not previously heard of self-driving vehicles expressed greater concerns about the technology than those who had.

These respondents were more concerned about data privacy, destination tracking, self-driving vehicles not driving as well as human beings, self-driving vehicles moving by themselves from location to location, self-driving public transportation like buses and self-driving heavy trucks and semis. Respondents who had not previously heard of self-driving vehicles expressed greater agreement with the contention that their needs were being considered in the development of the technology than those who had heard of it prior to the survey.

3.3.2 Initial Opinion of Self-Driving Vehicles (Q2). Respondents' initial opinion of self-driving vehicles had a significant effect on every response. Respondents who began the survey with an initial favorable opinion of the technology were more likely to expect the occurrence of its benefits (i.e., a reduction in vehicle crashes) and less likely to express concerns. Respondents who held initial unfavorable views of the technology were more likely to express concerns, viewing the technology as unsafe and unreliable for instance, and less likely to expect the occurrence of its benefits. This general principle holds for every question in the survey.

3.3.3 Gender (Q32). Female respondents were found to be generally more concerned than male respondents about the self-driving vehicle issues and topics investigated during the survey. With respect to respondent concerns about their ability to operate a self-driving vehicle if one was made available to them (Q5), a significant effect of gender was observed at the $p < 0.05$ level for the two conditions [$F(1, 517) = 6.18$, $p = 0.0132$]. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the female condition ($M = 2.26$, SD = 1.08) and the male condition ($M = 2.02$, SD = 1.06) were significantly different. Females were thus shown to be more concerned about their ability to operate a self-driving vehicle if one was made available to them. Females continued to express this relatively greater concern in response to questions about riding in a self-driving vehicle with no driver controls available (e.g., gas pedal, brake pedal or steering wheel), self-driving vehicles moving by themselves from one location to another while unoccupied, self-driving commercial vehicles like heavy trucks, self-driving public transportation like buses and self-driving taxis.

Males were more likely to express a belief that the majority of the benefits of self-driving vehicles were likely to occur. With respect to respondent belief in the likelihood that the use of self-driving vehicles would result in less traffic congestion for instance (Q9), a significant effect of gender was observed at the $p < 0.001$ level for the two conditions [$F(1, 516) = 14.09$, $p = 0.0002$]. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the female condition ($M = 4.94$, SD = 1.78) and the male condition ($M = 5.52$, SD = 1.70) were significantly different. Males were thus shown to have expressed a greater belief in the likelihood that self-driving vehicles would result in less traffic congestion. Males continued to express this relatively greater belief in response to questions about the likelihood of fewer automobile crashes, the reduced severity of crashes, an improved emergency response to crashes, shorter travel time, better fuel economy and lower insurance rates.

With respect to respondent interest in buying or leasing a self-driving vehicle (Q29), a significant effect of gender was observed at the $p < 0.001$ level for the two conditions [$F(1, 518) = 11.52$, $p = 0.0007$]. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the female condition ($M = 3.94$, SD = 1.37) and the male condition ($M = 4.32$, SD = 1.11) were significantly different. Mirroring their increased concerns and relative skepticism regarding their benefits, females were shown to be less interested in buying or leasing a self-driving vehicle than males.

3.3.4 Age (Q33). Older respondents (55+) were the most likely to express concerns about their ability to operate a self-driving vehicle, while those in the 35 to 44 age group were the least likely (Q5). A significant effect of age was observed at the $p < 0.05$ level for the five conditions

(18–24, 25–34, 35–44), 45–54, 55+) [F(4, 513) = 3.03, $p = 0.0172$]. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the 35–44 condition ($M = 1.95$, SD = 1.06) was significantly different than the 55+ condition ($M = 2.35$, SD = 1.14). Younger respondents were more concerned about the potential for self-driving vehicles to be compromised by hackers than older respondents (Q16). A significant effect of age was observed at the $p < 0.05$ level for the five conditions [F(4, 513) = 2.55, $p = 0.0384$]. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the 25–34 condition ($M = 2.84$, SD = 1.11) was significantly different than the 45–54 condition ($M = 2.62$, SD = 1.08). The youngest respondents were also more concerned about commercial self-driving vehicles like heavy trucks and semis (Q26). A significant effect of age was observed at the $p < 0.05$ level for the five conditions [F(4, 514) = 2.46, $p = 0.0445$]. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the 18–24 condition ($M = 3.25$, SD = 0.96) was significantly different than the 25–34 condition ($M = 2.62$, SD = 1.20). Younger respondents were more interested in owning or leasing a self-driving vehicle and older respondents (55+) were the least interested (Q29). A significant effect of age was observed at the $p < 0.01$ level for the five conditions [F(4, 514) = 4.68, $p = 0.0010$]. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the 25–34 condition ($M = 4.39$, SD = 1.08) and the mean score for 35–44 condition ($M = 4.37$, SD = 1.20) were both significantly different from the 55+ condition ($M = 3.86$, SD = 1.38). Older respondents also were the least concerned about the prospect of laws being enacted that would prevent people who are blind from operating self-driving vehicles whereas those in the 25 to 34 age group were the most concerned (Q39). A significant effect of age was observed at the $p < 0.05$ level for the five conditions [F(4, 509) = 2.75, $p = 0.0275$]. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the 25–34 condition ($M = 3.53$, SD = 0.78) was significantly different than the 55+ condition ($M = 3.19$, SD = 1.00).

3.3.5 Education (Q34). For four of the proposed benefits (i.e., likelihood of fewer crashes, reduced severity of crashes, reduced traffic congestion, and shorter travel time) of self-driving vehicles discussed within the survey higher education levels were not associated with higher or lower expectation regarding those benefits. For three of the four remaining proposed benefits, improved emergency response to crashes, lower vehicle emissions and better fuel economy, expectations increased with education level up to "Some College" but decreased as education increased further. For the potential benefit "lower insurance rates," expectations rose through the "Associates Degree" education level before decreasing. Respondents who stated their education level as "Some High School" were most likely to express concerns regarding system failure and data privacy and expressed the most concern about self-driving vehicles driving as well as human drivers. Higher education levels were associated with decreased concern regarding self-driving vehicles not driving as well as human drivers (Q23). A significant effect of education was observed at the $p < 0.01$ level for the six conditions [F(5, 512) = 3.53, $p = 0.0038$]. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the "Some High School" condition ($M = 3.40$, SD = 0.89) was significantly different than the "Some College" (M = 1.98, SD = 1.17), "Associate's Degree" ($M = 1.86$, SD = 0.91), and "Graduate Degree" conditions ($M = 1.84$, SD = 1.00). Lower education levels were associated with an increased belief in a respondent's agreement that this/her needs were being considered in the development of self-driving car technology (Q38). Respondents who indicated that they possessed a graduate degree expressed the least agreement that their needs were being considered. A significant effect of education was observed at the $p < 0.05$ level for the six conditions [F(5, 512) = 2.95, $p = 0.0122$]. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the "Some College" condition ($M = 5.10$, SD = 1.66) was significantly different than the "Graduate Degree" condition ($M = 4.43$, SD = 1.75).

3.3.6 Employment Status (Q35). Respondents who were part-time students were more concerned about the safety consequences of equipment failures, self-driving vehicles getting confused by unexpected situations, riding in a self-driving vehicle with no manual controls available, and unoccupied self-driving vehicles moving by themselves from one location to another. Regarding the potential for self-driving vehicles to be compromised by hackers (Q16), a significant effect of employment status was observed at the $p < 0.01$ level for the six conditions [F(5, 512) = 3.29, p = 0.0061]. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the "employed full-time" (M = 2.68, SD = 1.04) and "retired" (M = 2.69, SD = 1.02) conditions were significantly different than the 'employed part-time' condition (M = 3.66, SD = 0.49).

With respect to respondent concerns about self-driving vehicles driving as well as human drivers (Q23), a significant effect of employment status was observed at the $p < 0.01$ level for the six conditions [F(5, 512) = 3.61, p = 0.0032]. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the "employed full-time" condition (M = 1.81, SD = 1.00) and "not currently employed" condition (M = 2.24, SD = 1.08) were significantly different. Those not currently employed were thus shown to be more concerned about self-driving vehicles driving as well as humans.

3.3.7 Modes of Transportation (Q36). A respondent's mode of transportation was not found to be associated with a particular perspective relative to concerns regarding self-driving vehicles or the potential benefits that may occur as a result of self-driving vehicles. Regarding respondents' concern about riding in a partially autonomous vehicle as the primary operator (Q4), a significant effect of mode of transportation was observed at the $p < 0.05$ level for the six conditions [F(5, 512) = 2.34, p = 0.0407]. Post hoc comparisons using the Tukey HSD test, however, indicated that the mean scores for the "passenger car" (M = 2.39, SD = 1.11), "minivan/van" (M = 2.47, SD = 1.16), "pickup truck" (M = 2.38, SD = 1.12), "SUV" (M = 2.13, SD = 1.15), "motorcycle" (M = 1.60, SD = 0.54), and "public transportation" conditions (M = 2.62, SD = 1.12) were not significantly different from one another.

3.3.8 Length of Time of Visual Disability (Q37). Being blind or visually impaired for all of a respondent's life was associated with higher levels of concern regarding equipment failure, data privacy, learning to use self-driving vehicles and self-driving vehicles not driving as well as humans. Respondents who indicated that they had been blind or visually impaired for a shorter period of time, some of their life, were generally less concerned about system performance in poor weather and about self-driving vehicles getting confused in unexpected situations. Respondents who selected "I recently became blind" were associated with greater concern regarding unoccupied self-driving vehicles moving by themselves from one location to another but with lower concern about learning to use self-driving vehicles. With respect to respondent concerns about self-driving vehicles not driving as well as human drivers (Q23), a significant effect of length of visual disability was observed at the $p < 0.05$ level for the six conditions [F(3, 509) = 2.89, p = 0.0349]. Post hoc comparisons using the Tukey HSD test indicated that the mean score for the "some of my life" condition (M = 1.76, SD = 0.91) and "I recently became blind" condition (M = 2.37, SD = 1.11) were significantly different. Those who indicated that their visual disability was recent were thus shown to be more concerned about self-driving vehicles not driving as well as human drivers.

3.4 Discussion

3.4.1 General Opinions Regarding Self-Driving Vehicles. The vast majority of respondents had heard of self-driving vehicles prior to participating in the study (95.96%), the majority held a generally positive view of the technology and a majority of respondents had an optimistic view regarding the potential benefits. Our findings, in this regard, are similar to those of Schoettle and

Sivak [54], though respondents in the present study were most confident regarding the likelihood of fewer automobile crashes and least confident regarding lower vehicle emissions. In the Schoettle and Sivak study, respondents were most confident regarding better fuel economy and least confident regarding shorter travel time. In the present study, men were more confident regarding the likelihood of potential benefits whereas women were relatively more skeptical.

Significant concerns were raised regarding all issues addressed within the study with respondents most concerned about equipment and system failure, self-driving vehicles getting confused by unexpected situations, and interactions between self-driving vehicles, bicycles, and pedestrians. While these findings are consistent with the literature in that public opinion surveys have generally suggested that consumers have significant concerns regarding self-driving vehicle technology [13, 54, 55], our findings suggest that the concerns of blind and visually impaired consumers may be somewhat different than consumers generally. While concerns regarding legal liability for owners and drivers has been a primary concern of respondents in studies by Howard and Dai [22] and Schoettle and Sivak [54], it placed fifth on the list of concerns in the present study. The same is true for concerns regarding self-driving vehicles not driving as well as human drivers, which placed seventh on the list of concerns in the present study but was thrid in the Schoettle and Sivak study [54].

These differences continued through the five scenarios (Q30–Q34) of potential concern that were presented to respondents. While much of the literature has suggested that consumers are especially concerned about the potential absence of manual controls in self-driving vehicles [26, 54, 55], this was viewed as one of the least concerning scenarios for respondents of the present study. Respondents were most concerned regarding self-driving commercial vehicles (e.g., heavy trucks) and self-driving public transportation vehicles like buses. Overall, regarding the eight issues and five scenarios of potential concern, women expressed more concern than men and not surprisingly expressed the least interest in owning or leasing a self-driving vehicle.

3.4.2 The Ability to Operate Self-Driving Vehicles. While learning to use a self-driving vehicle was one of the least concerning issues for respondents of the eight presented, the ability to operate the technology was an area of concern for older respondents (55+). Respondents in both groups were more likely to express concerns regarding their ability to operate a self-driving vehicle while those in the 35–44 age group were least likely. The issue of the control of self-driving vehicles has typically been investigated only from the perspective of the inclusion or exclusion of manual controls [8] or the preferred type of route input device [55].

3.4.3 Interest in Ownership and Willingness to Pay. More than 90% of respondents expressed an interest in owning self-driving vehicle technology; high interest in ownership that is consistent with the literature [28, 54, 55], which has indicated that the majority of those surveyed would be interested in ownership. A majority of respondents, however, indicated a willingness to pay extra for self-driving vehicle technology. Much of the literature in this regard, which has presumably focused on sighted consumers, has indicated that consumers generally are unwilling to pay extra for self-driving vehicle technology [28, 54, 55]. Our findings indicate that blind and visually impaired consumers, on average, may be willing to pay more than $6,000 extra for self-driving vehicle technology, a sum higher than the $4900 found by Daziano et al. [13], presumably with sighted consumers and approaching the recent findings of Bansai et al. [4] of $7253.

3.4.4 Issues Related to Visual Impairment and Blindness. A majority of respondents indicated that they believed their needs were being considered in the development of self-driving vehicle technology, however, higher education levels were associated with a decrease in a respondent's belief that their needs were being considered. This finding is significant in that it has been suggested that most self-driving vehicle technology being developed is not in fact accessible to individuals with visual impairments [44]. There appears to be a mismatch between respondents' belief regarding the consideration of their needs and the actual accessibility of the self-driving vehicle technology being brought to market.

While additional research is needed to conclusively verify both sides of this question, the mismatch may be the result of influence of marketing efforts and the media. Google's Waymo, one of the leaders in the development of self-driving vehicle technology, has prominently featured a blind user operating of one of its self-driving cars in self-produced promotional videos for years [63]. The operation of its self-driving car by a blind person has also been covered with much fanfare by the media, being written about with titles like, "Blind man sets out alone in Google's Driverless Car" [6]. Given these types of marketing efforts and coverage in the media it is perhaps not surprising that many blind and visually impaired individuals believe that their needs are being considered in the development of self-driving vehicle technology. It is, of course, entirely possible that most self-driving vehicle technology being developed is, in fact, accessible to individuals with visual impairments and reports to the contrary are mistaken. The uncertainty in this regard underscores the need for additional research both as it pertains to consumer opinions on the topic as well as the actual accessibility of the technology.

Over the past five years, a number of laws and regulations have been proposed that, if enacted, would potentially prevent blind persons from operating self-driving vehicles. Laws that would require a licensed driver as the primary vehicle operator or require that the primary operator have the ability to take over control in the event of an emergency [14] would effectively prevent blind and many visually impaired individuals from operating self-driving vehicles using current technology. Over 90% of respondents indicated that they were concerned regarding the prospect of laws being put in place to prevent people who are blind from operating self-driving vehicles.

3.5 Limitations

In adapting the survey instrument of Schoettle and Sivak, we made a number of design choices related to content, accessibility and structure while attempting to preserve the general themes of the original survey to facilitate direct comparison. In the process, we omitted a question related to respondents medically diagnosed visual acuity that could have been used as a demographic variable during data analysis. The point of this exclusion was to view the survey and its data collectively as representing the perspective of blind and visually impaired consumers. An argument can be made, however, that an opportunity was missed to dig deeper into the data to identify differences between blind and low-vision consumers. A similar question (Q37) that explored the length of time of each respondent's visual impairment, used arbitrary time periods (e.g., "Recently," "Some of your life") and should have instead collected the actual length of time for grouping and analysis.

Questions may also be raised regarding the generalizability of our findings given that our sample is questionably representative of the target population. In terms of educational attainment, for instance, our sample is skewed toward those with college education. Within our study those holding bachelor's degrees or more education comprised approximately 59% of respondents. According to 2015 census figures, 45% of the population generally reported bachelor's degrees or advanced degrees such as master's or doctorates [50] and the National Federation of the Blind has indicated that for persons with visual impairments this figure was 14.9% in 2015 [60].

4 STUDY 2: FOCUS GROUP DISCUSSIONS

4.1 Method

While the data collected from the online survey added much to the literature on the opinions, preferences, and concerns of visually impaired persons regarding self-driving vehicles, our analysis

Table 7. Breakdown of Focus Group Participants by Degree of Vision Loss

Degree of vision loss	% Female (n = 20)	% Male (n = 18)
Blind	45.0	72.2
Low Vision	55.0	27.7

Table 8. Breakdown of Focus Group Participants by age Range

Age Range	% Female (n = 20)	% Male (n = 18)
18–24	10.0	22.2
25–34	0.0	16.6
35–44	5.0	11.1
45–54	15.0	11.1
55–64	30.0	27.7
65–74	30.0	5.5
75+	10.0	5.5

generated additional questions that were worthy of further investigation. Following the online survey, a qualitative study was planned to investigate many of the issues that became apparent in our analysis of the survey data; focus groups were ultimately undertaken to explore the identified issues in a more open-ended format. The use of focus group methodology [25, 68] specifically was chosen over other methods, because it provided the research team with an opportunity to elicit subjective perspectives regarding the research topics while allowing for a significant amount of flexibility to pursue themes that emerged during the course of discussion.

4.1.1 Participant Recruitment. Interested individuals were invited to participate if they fulfilled the following criteria: age 18 or above and currently considered themselves to be a visually impaired person based on an accompanying definition that defined that as blindness or with limited vision not correctable by glasses or contact lenses. Advertisements indicated that interested individuals should also have transportation to one of two focus group locations in north central Florida. Participants were recruited by email, newsletter and social media announcements distributed by organizations serving individuals with visual impairments in north central Florida and by vocational rehabilitation organizations. Those interested in participating were asked to call or email for additional information and scheduling. The Institutional Review Board of the authors' university approved this study and each participant provided written informed consent the day of his or her focus group session. Participants were compensated with a $20 prepaid gift card for their participation, which they were informed about prior to participating.

4.1.2 Description of Participants. Eight focus groups were conducted over a two-day period in two separate locations in north central Florida. In total, 38 participants were involved in the study in groups of between 4 and 6 people. Participant demographics are provided in Tables 7 through 9. Study participants had a mean age of 51.5 (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 based on an accompanying definition that described blindness as visual acuity in the better seeing eye of 20/200 or worse or a visual field limited to 20 degrees with conventional correction (e.g., glasses or contact lenses). Sixteen participants self-identified as low vision based on an accompanying definition that described low vision as visual acuity of between 20/70 to below 20/200

Table 9. Breakdown of Focus Group Participants by Ethnicity

Ethnicity	% Female ($n = 20$)	% Male ($n = 18$)
White/Caucasian	90.0	61.1
Black/African American	10.0	16.6
Hispanic	0.0	16.6
Mixed Race	0.0	5.5

in the better seeing eye with conventional correction. Krueger and Casey have argued that focus group participants should share similar characteristics (e.g., gender group, age-range, social class background) to encourage open dialogue within the group but with enough variation to allow for contrasting opinions [27]. An attempt was made to group participants near their preferred location in accordance with this principle with a primary factor of similarity being a participant's characterization of their vision loss and a secondary factor being their age. No other factors were considered for the purpose of constructing the focus groups (e.g., race, gender, education). During the screening and scheduling process participants were briefly presented with functional definitions of blindness and low vision [34]. They were then asked to choose the definition that best characterized their degree of vision loss. As a result of this approach, when feasible, participants were placed in a group with other individuals who similarly characterized their vision loss as either blind or low vision. Where placement in such a group was not possible, typically due to logistical or scheduling constraints, an attempt was made to place the participant in a group with at least one individual of similar age irrespective of whether or not the majority of the group's participants had expressed a different degree of vision loss. The approach resulted in one group that was predominantly composed of blind persons, one group predominantly composed of low-vision persons, one group evenly split by degree of vision loss, and three groups that were relatively homogeneous in terms of age and predominantly composed of blind persons, each consisting of older participants (55+). The remaining groups were each slightly weighted toward blind participants in terms of composition though each group contained at least two low-vision participants.

4.1.3 Procedure. Each focus group lasted approximately one hour with a procedure that was identical for each session. After each participant was seated in the meeting space, the informed consent document, which had been emailed to each participant in an accessible format the day before each focus group, was read aloud by the study moderator. 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 focus group moderator to introduce participants to one another and encourage interaction between participants. A semi-structured interview followed. Between three and five days following the focus group 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. This article reports on the results of the semi-structured interview as well as relevant demographic data.

4.1.4 Focus Group Guide (Written Script). We created a written semi-structured script to elicit information from participants about their understanding and awareness of current developments regarding self-driving vehicles, hopes and aspirations for future self-driving vehicle technologies, concerns related to the accessibility of self-driving vehicles and opinions regarding the legal environment for the use of this technology by individuals with visual impairments. The written script or focus group guide was pilot tested with three participants in a group setting prior to beginning data collection to ensure that it was comprehensible and comprehensive. Pilot test participants were not visually impaired, and the data was not included for analysis.

4.1.5 Data Capture and Transcription. Each focus group session 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.

4.1.6 Analysis. In preparation for analysis all transcripts were entered into MAXQDA [36], 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.

4.2 Results

Results of the analyses of focus group data are organized around six major thematic findings: (1) self-driving vehicle concerns, (2) potential benefits of self-driving vehicles, (3) licensing and training, (4) the human-machine interface of self-driving vehicles, (5) purchase considerations, and (6) risk and trust. Across the eight focus groups self-driving vehicle concerns were raised 223 times followed by 151 comments related to the potential benefits of self-driving vehicles. Comments associated with licensing and training occurred 121 times and were followed by comments related to the human-machine interface of self-driving vehicles (88) and vehicle purchase considerations (74). Issues related to risk and trust were the least discussed, occurring 33 times. In many instances more than one theme was addressed in a single conversational turn.

4.2.1 Self-Driving Vehicle Concerns. Are the needs of individuals with visual impairments being adequately considered in the development of autonomous vehicle technologies? While opinions varied, most participants expressed the view that the needs of individuals with visual impairments were not being adequately considered in the development of autonomous vehicle technologies (57%). Negative experiences with past technologies were frequently cited as examples of why they believed these needs were likely being ignored:

> No, I don't/I don't think they do. And they didn't when they invented the quiet car. And that's, you know, that was an invention that's plagued me. I mean, I love hybrid vehicles and what they do for the environment, but I hate hybrid vehicles and how dangerous they are. They're like sharks in the water now. You don't know when it's coming up behind you. It may strike. (P38)

> I know that in the past with all the new technology that's come out so far, blind people have been kind of an afterthought. (P37)

Many participants (37%) expressed a belief that the technology presently exists to solve most autonomous vehicle accessibility challenges but that manufacturers need to be made aware of the importance of the issue:

> Like, on the side like Tesla and Uber and whatnot, I'm sure there's someone somewhere thinking about that, but I don't think it's in, like, the forefront. (P34)

> If you KNOW of all these obstacles, then they can be overcome. And the technology, it pretty much exists now. It's just a matter of marrying that technology, you know? (P17)

Parking, Orientation, and Vehicle Location. A variety of issues were raised related to the parking of an autonomous vehicle, orientation to a destination upon parking and the location and identification of a visually impaired operator's vehicle at the conclusion of a trip.

Many participants expressed concerns regarding their ability to provide parking guidance to an autonomous vehicle without the ability to see the surrounding area. Some of the concerns expressed related to safety:

> How do you try to set a car to park where you want it to park if you can't see where to show it to park or tell it to park or whatever? You might be parking in the/across a railroad track. (P12)

Some expressed concerns related to convenience and practicality, with travel to shopping malls being a frequently provided example of the need to tell a self-driving vehicle specifically where to park:

> When you pull into a shopping mall, you know, you got like this one out here is, you got Penney's on one end, Sears in the back and Belk's on the other end. Well, you know, you need to be able to tell it… (P11)

The ability to orient oneself to the desired destination (e.g., a building's front door) upon arrival to a location was a widely discussed topic. Many participants felt that this was an unanswered question that would need to be addressed by the technology:

> Now, if I drive up in a car and get out of the car, how do I know where the door is? In other words, there's a…the car has to do a lot besides just drive. (P24)

One participant raised questions about how the technology would enable her to orient herself to her desired destination in the event that she were dropped off in a parking lot:

> And there's also, you know, if it takes you to a location and it like drops you off in the middle of like a parking lot, you know, which building or which direction that your actual destination is? You know, something that would also, like, help you figure that out and know where that is. (P23)

In response, another participant (P21) suggested dedicated autonomous vehicle parking to aide in general orientation.

> Twenty-eight percent of participants raised questions about the technology necessary to enable an autonomous vehicle operator with visual impairments to locate his or her vehicle in a large crowded space like a shopping center parking lot. A number of solutions were expressed across focus groups to include programming the vehicle to return at a specified time and location (P30, P32), to key chains designed to vibrate based on proximity to the vehicle (P34).

Location Verification. The desire for a vehicle feature that would enable an operator with visual impairments to verify his or her arrival at a desired location was a topic of great interest. A majority of participants across focus groups (53%) commented that such a feature was important to some degree and that they would be concerned about inadvertently getting out of the vehicle in the wrong place. A commonly expressed view was that the technology should provide some type of backup system to prevent such an occurrence:

> I think my operating system should take care of it. You know? It's like she'd... she'd take care of everything. So, I think the operating system should say, "Don't get out of the car. You're in the wrong... you're in a field." (P32)

In many cases the expressed desire for this feature closely related to negative experiences with automotive navigation systems where the participant had observed these systems lead others in the wrong direction, make errors or otherwise fail to operate properly. One participant's comment was representative of many regarding this topic:

> ... you know, I've experienced on MV, you know, our public transportation that, you know, the GPS saying "You have arrived at your destination" and, you know, and the driver says, "No, we haven't." So, you know, it's not all it seems. Like GPS is fallible, you know, at times. (P20)

Situational Awareness. The desire for a vehicle feature that would, at any given time, provide information on an operator vehicle's relationship to other vehicles, landmarks, pedestrians, obstacles and the final destination was frequently discussed. Forty-five percent of participants across focus groups expressed a view that the self-driving vehicle's technology should be able to provide such information in real time to mirror the type of information that a sighted operator would have available through the use of cameras, mirrors and sight:

> I think it would make the person sitting in the car feel a little bit more at ease. You know, that you know, since you can't see where you're going or where you're at, that it would tell you like, "Well, you know, we are like half a mile away from your destination." (P2)

> ... you don't necessarily know, like, where you are in relationship to where you're actually going. Something that might help you, like place, like where you are. (P23)

Interaction with Non-Autonomous Vehicles. Participants generally expressed skepticism that autonomous vehicles would be able to successfully operate alongside non-autonomous vehicles due to the unpredictability of human drivers (63%):

> I think that the fact that they have to interact with people driving is a downfall too, because, you know, people are really bad drivers. I ride with my daughter all the time and the people constantly running red lights, cutting us off and doing things, you know. And I would... you know, you would wonder how the car would react to things like that. (P33)

> My downside is... To me, my–this is my opinion–I just don't see an autonomous car being able to react to human error that quickly. (P25)

Many participants (39%) commented that as autonomous vehicles became more common and displaced non-autonomous vehicles on the road, they believed the interaction problem would lessen as captured in this exchange between three participants in group six:

> Well, I think the autonomous vehicles are like the flu shot. The more people that get the flu shot, (P25 laughs) the less chance of an epidemic. The more autonomous vehicles that are on the road... (P27)

> The more of them that are on the road, the safer the roads will be. (P26)

Help and Roadside Assistance. How to and who to ask for help in the event of a vehicle breakdown or unforeseen event was a topic that was brought up repeatedly in the study with 39% of study participants raising questions in this regard. While the overwhelming majority of participants stated that they had never owned or operated a vehicle, the suggested approaches took the form of a type of monitoring and assistance service similar to General Motors' OnStar [31], which was specifically named several times:

> Yeah, that would be good, if they had some kind of like, like a home center (P2: Yeah. Yeah), you know, that paid attention. Like a security system for cars that keeps track of where your car is going. So, if you're lost or something, you're able to get help. (P4)

> Well, I...I think about something along the lines of—and I've never used it before, but, you know, something along the lines of OnStar. In other words, you know, if you get into some trouble, if there's vehicle trouble, you know, with the actual vehicle itself, being able to call, you know, somebody to come and help you. 'Cause, obviously, if I was riding it by myself and the car had a problem and was maybe automatically pulled over, I wouldn't know where I was. (P20)

Legal Liability. A small number of participants raised questions regarding legal liability in the event of an accident (13%). Some participants expressed concerns about the seemingly unsettled liability questions in the event of an autonomous vehicle accident while several blind participants expressed concerns that they would be automatically assumed to be liable as captured in this exchange between two participants in group two:

> You can't even be your own witness? (laughs) (P6)
> (laughs) Yeah, you're just getting blamed for it for sure. (P5)

4.2.2 Potential Benefits of Self-Driving Vehicles. The majority of participant comments in the study that focused on the potential benefits of self-driving vehicles centered on the potential for increased independence, personal mobility, and the potential for time savings versus participants' existing means of transportation.

Independence and Mobility. Forty-seven percent of participants specifically referenced "independence" when referring to the potential benefits of self-driving vehicles with many participants expressing a hope that self-driving vehicles would enable them to no longer rely on friends, relatives or public transportation for their transportation needs:

> I would definitely say the benefit would be to not have rely on people to take you (P6 nods) around. That you could just get up and go whenever you want to, whenever you want to. (P7)

> Independence and the ability to go from point A to point B without having to ask somebody to drop what they're doing to do that for you. (P16)

Within the context of the discussion regarding independence several participants specifically discussed a desire for basic transportation capabilities that would enable them to return to work as expressed by one blind participant:

> You know, I think one of the things that's important to understand is, you know, everybody is looking at these high-end abilities, you know, things like luxury, comfort, you know, safety about, you know, an ability to go anywhere. I don't think that we have to start there. You know, if I could purchase an AV [autonomous vehicle] that...I was in home healthcare sales rep, but, you know, two years ago. You know, I...Every week, I called on the same doctor's offices, the same hospitals, the

> same nursing homes. You know, I ran the same route every day, on time. You know. And if I could have a vehicle that I could program to do nothing but that route and how to get here and maybe the grocery store, I would be totally 100% happy. (P16: Definitely, yeah.) You know? And I think that's one of the things that these engineers are missing is: they're trying to make the all-inclusive, you know, panacea, you know. And that's not really what people with disabilities are concerned with. (P14: Right.) Yeah, it would be nice to have. But we're just looking for the basic mobility and independence that most people totally take for granted.

Participants in the study commented on the impact that the inability to operate a personal vehicle had on their daily lives. Participants indicated that it impacted where they lived, their diet, their shopping habits, their medical care, their employment and their ability to visit friends and relatives. Nearly all participants responded positively to the potential independence and mobility benefits of self-driving vehicles (97%):

> Well, the idea of being able to get in a car at the time you wanted to and go wherever you want it to and get in it and come back home when you wanted to, it would mean an awful lot, I think. (P12)

One blind participant indicated that she did not see any benefits, however (P29).

Time Savings. Of participants commenting on the topic (18%), opinions were overwhelmingly positive about the potential time savings of the use of a self-driving vehicle over their current forms of transportation; in most cases was public transportation, friends or family. Many shared personal stories about their daily challenges or the challenges of friends with visual impairments and how these challenges could potentially be overcome with the use of a self-driving vehicle:

> I know a guy who goes to work, and he spends three hours to get there and like two hours coming home. And that's for 25 years he's been doing that. (P25: Oh my God!) So, can you imagine how valuable that time is that he is losing? (P26)

> And…And what you…What people don't realize what you could in 30 to 45 minutes, it takes on a bus two hours to four hours. [P28: Or more.] Like getting here. (P25)

4.2.3 Licensing and Training. The discussion of legal and regulatory issues related to self-driving vehicles centered on laws that could potentially restrict access to individuals with visual impairments. Broadly within the study these discussions generally focused on the potential requirement that self-driving vehicle operators possess a valid driver's license or on potential training requirements.

More than half of participants (55%) expressed concerns about the prospect of laws being put in place that would effectively prevent individuals with visual impairments from operating self-driving vehicles. The most concerning prospect for many was the requirement that a valid driver's license be required to operate a self-driving. Several participants expressed the view that this amounted to a form of discrimination.

> So, I think they would have to make some laws, like he was saying, to…for people not to do that. 'Cause we have rights too. (P3)

> But regardless, I'd really…I personally hate…That's what ADA is all about. (P25: Yeah.) (P24)

The topic elicited a variety of comments, however, and some degree of disagreement with several participants suggesting that a driver's or operator's license of some kind should be required to, at a minimum, promote safe operation and prevent children or individuals with limited cognitive abilities from operating self-driving vehicles alone:

> I think, the first thing that comes (P19: Safety.) to my mind would be, you know: Would... I mean, it seems logical that if we're gonna operate something like that we'd have to get a driver's license. And I... I'm just not sure how that's gonna work. (laughs) (P20)

> I would say, you don't put a 16-year-old behind the wheel. (P38)

In many of these discussions within the study a compromise of sorts that seemed acceptable to the group that emerged was the concept of an "operator's license" that could be earned through a training program and testing:

> When you drive a normal car you gotta go and get your driver's license and take a class, so there should probably be a class to take for this, too. I think. I mean, that would make sense. Maybe not that extensive or whatever, but, you know, just like all the safety issues and stuff like that. It would make sense to have that. (P5)

> And I think to be on the safe side and keep you from having some issues, I think it's better that you have to take a test. (P31)

4.2.4 The Human-Machine Interface of Self-Driving Vehicles. The discussion of the human machine interface (HMI) of self-driving vehicles focused on the manner in which participants anticipated that they would interact with a self-driving vehicle and their preferences in this regard.

The vast majority of participants (71%) anticipated that self-driving vehicles would implement some type of speech interaction capability. For example:

> I hope it's so that you can just get in the car and say, "I want to go to "such and such church" and it'll take you there. And I hope I can get in and say, "I want to go home," when it's over. (P11: Well) I hope they can simplify it somewhat. (P12)

Concerns were expressed about the accuracy of speech input, however, with personal experiences with voice recognition errors in Apple's Siri [24] being cited as examples by several participants.

Participants expressed a variety of opinions, however, regarding their preferred primary means of interacting with a self-driving vehicle. While some expressed a preference for speech input, several expressed a desire to interact with the vehicle primarily through the use of their smartphone as captured in this exchange in group five:

> Because like most visually impaired or blind individuals, like we have smart phones. So, is there a way to put it in through our phone that it will sync with the car? Well, I'm not saying "Is there a way?" but "Could there be a way?" I guess, that's what I'm asking. I guess, that would probably be the number one thing. (P21)

> I think that would probably be a good idea 'cause a phone is something I can, like, hold up closer to me so I can see it easier. And also, it will read it back to me, like, that's already accessible in that way versus like having to look at something else. And I'd also say to make like buttons or different things maybe more distinguishable, so you know which one is which. (P23)

The use of a touchscreen to interact with an autonomous vehicle was described by many participants as a backup means of interaction. One participant with low vision who favored the use of a smart phone as a primary means of interaction preferred the use of a touchscreen as a backup form of interaction in the event that her smartphone failed albeit with an iPhone like "voiceover" feature that would indicate what icon was being touched. Several blind participants disagreed with this comment, however, citing past problems with voiceover and the inaccessibility of standard touch screen displays.

4.2.5 Purchase Considerations. Vehicle purchase considerations as it related to self-driving vehicles largely revolved around cost, vehicle maintenance and the presence of backup systems.

Most participants who commented on the topic (24%) expressed a view that while the costs are at present unknown, self-driving vehicles would likely be costly, if not prohibitively so. For example:

> Let's face it, most of these vehicles to begin with, they're gonna be economically prohibitive for most of us to be able to purchase and maintain. (P36)

Several participants also commented about the uncertainty of repair costs or even where or how to get the vehicle repaired or maintained. For example:

> And since it's run mainly by technology, you know, where do you take it for its 50,000 overhaul or whatever? (P19)

A small number of participants (8%) expressed concerns about the reliability of primary self-driving vehicle systems. These participants questioned what would happen if primary systems failed during vehicle operation and considered the presence of a backup system to be a key purchase consideration. For instance:

> It must have. What if the main system malfunctions, you know, and it can't literally drive you? Well, if you're on the interstate and it malfunctions, would they have like a backup system? (P29)

4.2.6 Risk and Trust. Participants expressed a broad range of views as it related to whether or not they would trust in the safety and reliability of self-driving vehicle technology.

Some participants (5%) rejected the idea outright as too risky as did one blind participant:

> I just would not feel full trust at turning myself totally loose with any type of a/Even if it's a computer. And I've worked with computers too long that I know they can make/get a glitch in them. And I think there is still a possibility of risk. (P1)

Sixteen percent of study participants raised concerns regarding the possibility of malfunctions due to computer viruses and hacking. One participant stated for example:

> Computers aren't infallible. You know, they get viruses, they get/other people get in and take control. You know? So, you have to think about all that stuff, too. And that would make me very nervous. (P10)

Of the 76% of participants who commented on the topic, many indicated that they viewed riding in a self-driving vehicle as being no more risky than riding with a human driver:

> The risk involved. For me, it's no, even more than getting in the car of my wife. (P11)

Some participants, however, indicated that they would actually feel safer in a self-driving vehicle:

> But, we almost daily risk our lives by getting into a vehicle (P25: Oh yeah, I agree!) with a stranger who may be the worst driver. (P29: That's true, yes.) (P28: Yeah.) They may be drunk, they may be on drugs, they may have stayed up all night fighting with their girlfriend. Whereas the autonomous vehicle does not get distracted, does not get tired. I think it's just way, way, way safer. (P28: I agree.) (P27)

A blind participant who had recently lost his sight described to the group being driven by his wife who had never driven before and was in the process of learning to drive:

> She's got to learn it. So now I'm riding in a computer that's learning, you know, a self-taught computer. So instead of having, you know, the option of maybe a program glitch happening, I'm riding a computer that doesn't have a clue what it's doing yet. You know? So, I'd feel safer in an AV. (P17)

For some participants the potential independence and mobility benefits simply outweighed any risks. One participant who was progressively losing her sight and no longer had the ability to drive stated:

> Pitfalls? None. I don't care if they crash me into a wall, I'll wear a helmet. I just want to get out of my house. I don't care. I'll be a test driver. I just want out. I just want my freedom. They outweigh any/any problems. I'll sign a liability waiver. (P32)

4.3 Discussion

4.3.1 General Opinions Regarding Self-Driving Vehicles. Similar to Study 1, the vast majority of participants expressed an awareness of self-driving vehicle technology with all but one participant within the study indicating a belief in their general understanding of the technology when asked at the outset of their respective focus group. Participants expressed views that, while somewhat skeptical, were generally more positive than the related literature [54, 55], however, as it pertained to the benefits of self-driving vehicle technology. The overwhelming majority of participants were resolute regarding their belief that self-driving vehicles could potentially be life-changing technology for them personally. While the majority expressed a view that there are considerable unknowns regarding the technology that need to be addressed, they were generally optimistic about the potential personal benefits. Participants also expressed optimism for society at large believing that self-driving vehicles could potentially make driving generally safer, while reducing the impact on the environment.

Concerns regarding the potential legal liability of owners/drivers/operators of self-driving vehicles have been raised as a substantial concern in the related literature [22, 54]. Participants expressed similar concerns in the present study but generally related these concerns to their visual impairment and not the absence of an active driver, as is typically the case in the related literature. Several participants questioned whether there would be a presumption of their liability if a self-driving vehicle were to be operated by a person with visual impairments and how an individual would defend his or herself from spurious legal claims without the ability to provide visual testimony regarding an accident. These concerns, while similar, are somewhat different from the legal liability issues raised in the related literature that often explore whether legal liability should be assigned to the vehicle manufacturer or operator.

4.3.2 Human-Machine Interface. Our findings suggest that the Human Machine Interface (HMI) of a self-driving vehicle for a person who his blind or low vision will likely need to do more than simply allow an operator to input a route or destination. The HMI for an operator who is blind or low vision will likely need to serve this purpose while also satisfying the need for situational awareness, location verification and other, as yet unspecified needs.

Study participants' desires for a self-driving vehicle HMI closely aligned with their degree of vision loss and their age. Blind participants generally expressed preferences for both speech input capabilities and the use of a smartphone application. Many participants anticipated that self-driving vehicles would utilize speech input as a default means of interaction but were wary of the system inaccurately interpreting their utterances or of generally poor performance based on past experiences with Apple's Siri [24], Microsoft Cortana [37], and Amazon Alexa [1]. Many participants indicated that they found their personal smartphone to be very accessible and would prefer to control a self-driving vehicle using a smartphone application if possible though they acknowledged that a backup system would be necessary in the event that they did not have a smartphone, or their battery died. Blind participants were extremely resistant to a standard touchscreen, viewing them as being entirely inaccessible with several indicating some acceptance of a touchscreen with Apple "voiceover" [66] capabilities.

Participants with low vision also expressed preferences for both speech input capabilities and the use of a smartphone application but also expressed an interest in touchscreen interaction. Like blind participants, many participants with low vision expressed a belief that self-driving vehicles would utilize speech input as a default means of interaction but expressed somewhat less concern about the potential for voice recognition problems. Participants with low vision also found their personal smartphones to be very accessible and expressed a desire to control a self-driving vehicle using a smartphone application if possible. Participants with low vision expressed interest in the use of a touchscreen, largely as a backup to the use of a smartphone application, but suggested the incorporation of contrasting colors, enlarged buttons and Apple "voiceover" [66] capabilities. Our findings stand in contrast to those of Schoettle and Shivak [55] who, in a survey presumably of sighted respondents, found that a plurality of respondents preferred touchscreen interaction. It is important to note that relatively younger (under 30) blind and low-vision participants in the present study were the most emphatic about the desire to use their personal smartphone or a smartphone application as a control device for a self-driving vehicle with older participants accepting of the concept but open to other approaches.

Studies by Schoettle and Shivak [55] and KPMG [26] have suggested that a majority of potential operators of self-driving vehicles have a preference for manual controls to allow the vehicle to be controlled by a human operator in an emergency situation or for enjoyment. A very small number of the participants of the present study expressed a similar desire. All but one of these participants were people with low vision who felt that they should have some ability to control the vehicle in an emergency situation if they observed a potential hazard.

The need for the self-driving vehicle's technology to provide some means to satisfy the need for situational awareness while in transit and to aid the operator in verifying their arrival at the correct location was expressed by the majority of participants in the study. Most participants expressed some concerns about traveling without having some awareness of the direction that they were traveling in and their immediate surroundings (e.g., current street, surrounding vehicles, buildings, pedestrians). Participants also expressed hesitance about getting out of the vehicle upon arrival, especially in the case of a self-driving taxi that would perhaps immediately leave, without assurances that they had arrived in the correct location. These concerns were closely related to skepticism regarding the reliability of GPS technologies and negative assumptions regarding the technologies that would be used to input desired destinations (e.g., unreliable speech systems).

Older participants (55+) were especially concerned about the ability of the HMI to relay information regarding parking options and building locations. Many of these older participants expressed a belief that the challenge of getting from the vehicle to their desired building or final destination and back would be nearly as complicated a technical challenge as the development of the self-driving vehicle itself. While the majority of participants felt that these challenges could be solved with existing technology, they were unsure how. Findings in this regard are perhaps not surprising when viewed in the context of related research on BVI spatial orientation and navigation, which posits that navigating large unknown environments is one of the more challenging navigational tasks for visually impaired persons [17].

4.3.3 Interest in Ownership and Willingness to Pay. Much of the self-driving vehicle literature of the past decade has suggested that in cases where people would consider owning self-driving vehicle technology these same individuals in most instances would not consider paying extra for it [28, 54]. Recent studies [4, 13] have suggested a break from this trend, finding that consumers may be increasingly willing to pay for self-driving vehicle technology depending upon the cost. In the present study, only a few participants took the position that they were unwilling to pay anything extra for autonomous vehicle technology with very few being steadfast in this view. While not every participant verbalized a position on the issue, only one participant indicated during the discussion that they would not be willing to pay for a self-driving vehicle.

In the study the question for many participants was not whether they were willing to pay or pay a premium for this technology but rather whether they would be able to afford what many assumed would be very costly technology. This question was exacerbated by the fact that the overwhelming majority of participants had never owned or purchased a vehicle before and therefore many indicated that they had little direct frame of reference for vehicle costs, self-driving or otherwise. Several participants in the study expressed an interest in the Tesla brand and the "Autopilot" feature specifically [41], indicating that they had conducted research on related features and pricing. These participants, coupled with those who had exposure to vehicle pricing from past experience, friends and relatives, ultimately helped to frame the discussion around vehicle costs in several of the groups. The majority of groups arrived at an estimate at or near $100,000 that seemed to make reference to the believed cost of a near-autonomous Tesla that was often discussed in the same context. This cost for most participants was viewed as unaffordable though quite a few participants indicated that they were willing to pay that or more if that was what it would cost for a self-driving vehicle. Many of the participants espousing this latter view were older participants (55+) who questioned whether the technology would become commercially available soon enough for them to benefit.

4.3.4 Legal and Regulatory Issues, Licensing, and Training. Discussions related to the legal environment for self-driving vehicles, the licensing requirements for their operation and the need for training were cordial but generally contentious throughout the study. In some cases, participants indicated that their concerns were admittedly based on second-hand information or rumors. The majority of the study's participants, however, indicated that they had been following national and local discussions around these issues with many participants indicating that they believed, based on these discussions, that it was possible that individuals with visual impairments would effectively be blocked from owning or operating self-driving vehicles. Of particular concern were two types of laws: (1) laws requiring that an individual operating a self-driving vehicle have the ability to take over control in the event of an emergency and (2) laws that would require a licensed driver to operate a self-driving vehicle.

Participants were split regarding laws that would require an individual operating a self-driving vehicle to have the ability to take over as necessary. While some participants found this premise to be unreasonable given that such a vehicle would be designed to be fully automated, others argued that present or near-future technology would exist that would enable a blind or low-vision driver to safely bring a vehicle to a stop in the event of an emergency. These participants, while in a minority, did not believe that such a law would therefore prevent the operation of a self-driving vehicle by individuals with visual impairments.

While some participants were overtly against the idea of requiring a conventional driver's license, some participants felt that a license of some sort should be a requirement given the serious nature of vehicle operation, self-driving or otherwise. These participants repeatedly raised concerns about the prospect of children or people with cognitive disabilities operating self-driving vehicles. Those against licensing raised a number of arguments against it but the majority viewed it as an attack on their civil liberties and as overt discrimination against persons with disabilities. In all but two of the focus groups the discussion gradually trended toward the concept of an "operator's license" that would require a certain amount of training on the operation of self-driving vehicles generally but would not exclude individuals with physical disabilities from ownership or operation.

4.3.5 Risk, Trust, and Safety. Much of the recent literature on self-driving vehicles and reliability, risk, trust and safety find that most people are concerned that self-driving vehicles will not function reliably [26, 54]. While the present study included participants who held this view, the majority expressed the view that self-driving vehicles are at least as safe as human drivers. Some participants expressed a view that self-driving vehicles would be safer than humans and for some the potential independence and mobility benefits simply outweighed what they viewed as minimal safety risks. Overall, the attitude expressed toward the technology was generally more trusting than that expressed in much of the related literature. A small number of participants raised questions about the potential for software hacking, a topic found to be of importance to those surveyed by Kyriakidis et al. [28], but it was a topic of limited discussion within the study and the issue generally did not appear to undermine trust in the technology.

4.3.6 Consideration of User Needs. Many participants shared impassioned personal stories while discussing whether or not they felt the needs of people who are blind or low vision were being adequately considered in the development of self-driving vehicles. While opinions varied, most participants expressed the view that their needs were being largely ignored. In all cases, evidence for this was not any experience with an inaccessible self-driving vehicle, as none of the participants had first-hand experience with the technology but was instead negative experiences in other areas of their lives related to other technologies. Many participants expressed a view that technology was often designed and developed without adequate input from people with disabilities generally and was often forced upon them without adequate training or explanation. A number of participants commented that major companies routinely moved to new technologies without properly considering the needs of people with disabilities and potential concerns regarding inaccessibility. The movement toward touchscreen soda machines was cited several times by participants as a problematic technology that was being broadly introduced without proper consideration of accessibility concerns. Several participants described challenges that they had faced in having their accessibility concerns addressed on a local and state level and questioned their ability to have their concerns addressed by, arguably, much more difficult to reach international businesses. The majority of participants specifically cited awareness as a key issue. Many expressed a belief that the technology and technical capability currently exists to make self-driving vehicles universally accessible but questioned whether manufacturers and decision makers were generally aware of the importance of doing so. At a minimum these findings suggest that more needs to be done to reach out to organizations that serve people who are blind and low vision and to people directly to better inform them about what is being done to develop accessible self-driving technology. At the same time, more, in fact, may need to be done to make self-driving vehicle technology more accessible while including more stakeholders with a range of visual impairments in the design and development process.

4.3.7 Limitations. Despite our attempts to structure this research in manner that would hold up to scrutiny it is not without limitations. While the use of focus group methodology has its merits there are also weakness with this approach. Perhaps one of the major weaknesses may be found in the composition of the focus groups themselves. While we have and do argue the merits of our approach, we recognize that in implementing Krueger and Casey's [27] guidelines in the composition of our focus groups, our design choices may be called into question. Given the topic of study, we argue that our chosen variables, degree of vision loss and age, were rather logical choices. Disagreement can be found, however, in our manner of implementation. While our goal in implementing the guidelines was to structure each group according to degree of vision loss and participant age range, due largely to recruitment, scheduling and logistical constraints several of the focus groups ended somewhat mixed in terms of degree of vision loss and participant age range. Generally, low-vision persons were underrepresented in most groups as most groups were slightly weighted toward blind persons. Our use of a functional definition of vision loss as opposed to the use of a medical definition of visual acuity may have also practically limited our ability to precisely group participants by their degree of vision loss. Given the active participation of nearly all participants in the focus groups, it is our opinion that the aforementioned limitations had little impact on the discussions themselves, however.

5 CONCLUSION

Viewed collectively, both studies further the process of illuminating the under explored perspective of blind and visually impaired persons regarding self-driving vehicles. In both studies, visually impaired persons responded favorably to the concept of self-driving vehicles. The general consensus, from both the initial survey and subsequent focus groups, being that self-driving vehicles have considerable potential to aid visually impaired persons from the perspective of mobility and independence. This optimism, for some participants, even superseded concerns regarding risk and safety. Participants of both activities were also optimistic about societal benefits though focus group participants tended to view this prospect more optimistically than the survey respondents. Collectively, these findings suggest that blind and visually impaired persons may have an optimism regarding self-driving vehicle technology that surpasses that of the presumably sighted participants and respondents in the related literature.

While this initial optimism regarding the conceptual prospects of self-driving technology is noteworthy there are considerable warning signs for manufacturers and the research community that the described studies highlight. Older adults (55+) were especially concerned regarding their ability to operate emerging self-driving vehicle technologies. When viewed relative to the aging population this paints a troubling picture absent additional research in this regard. Visually impaired survey respondents expressed some concerns regarding legal liability in the event of an accident, that when furthered examined within the focus groups was associated with concerns of spurious claims tied to visual disability. Our findings also suggest that those with higher levels of educational attainment (e.g., bachelor's degree or more) have concerns about whether their needs are being adequately considered in the design of this emerging technology.

While we argue that the described studies have involved foundational research on self-driving vehicles that had not been conducted previously, the topic of self-driving vehicle accessibility is broad and requires much additional research. Specifically needed are studies that explore the use of this technology in a practical or naturalistic context.

ONLINE APPENDIX

We have provided an online Appendix, available within the ACM Digital Library, that contains the instrument used for Study 1, adapted from Schoettle and Sivak [54], as well as the focus group guide and final codes from Study 2.

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Received April 2018; revised July 2019; accepted January 2020