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Give us something to chauffeur it: Exploring user needs in traditional and fully autonomous ridesharing for people who are blind or visually impaired

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ABSTRACT

As self-driving technology advances, there is enormous potential to optimize fully autonomous vehicles (FAVs) for use by people who are blind and visually impaired (BVI). Today, BVI users often rely on ridesharing services for daily travel, which present both challenges and opportunities for researchers interested in the accessible design of FAVs. The parallels between current BVI travel experiences in rideshares and predictions that FAV services will adopt rideshared models presents an enticing opportunity to use ridesharing as a proxy for understanding BVI needs in future FAV transportation. However, a key challenge is identifying the extent to which FAVs should be designed to provide the same assistance that human drivers currently provide for BVI travelers in rideshares. To address this issue, ridesharing users with visual impairment (n = 187) within the United States completed a survey instrument designed to assess and compare desires for interactions, information, and assistance between human operated and fully autonomous rideshare vehicles, as well as the modality of information delivery (auditory and/or haptic). Results indicate strong support for access to environmental information (e.g., spatial information about the destination) and contextual information (e.g., progress along the route) across the trip with automated vehicles via natural language interactions. Although results suggest significantly less desire for social interaction with the AI "at the wheel" of FAVs when compared to human drivers, findings indicate that participants desire some social collaboration and human-in-the-loop control during autonomous driving. By empirically comparing human and autonomous ridesharing and exploring both the information needs and modality preferences across information category, the study provides much-needed guidance for future design of humanlike, anthropomorphized, FAV AIs with important implications for social autonomous agents more generally. This study also speaks to the ways in which inclusive and accessible user interfaces should best support user needs across the range of vision loss in future transportation networks.

1. Introduction

Growing efforts to realize the full potential of fully autonomous vehicles (FAVs) have resulted in emerging research examining

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strategies to support people who are blind and visually impaired (BVI) in this new class of transportation technology. From survey and focus-group based designs (Brinkley et al., 2020), to approaches that involve imagining and designing interfaces for FAVs (Brewer & Kameswaran, 2018; Huff et al., 2020), researchers have deployed a myriad of methodological tools for understanding how BVI people should be supported in a technology that is, as of yet, not widely available. One important strategy has built on predictions that FAVs will operate much like ridesharing services operate today (Narayanan et al., 2020). This approach utilizes experiences with current human-driven ridesharing services (e.g., Uber or Lyft) as a proxy for understanding BVI needs in future AI-driven FAV transportation (Brewer & Ellison, 2020).

Beyond the primary task of driving, the extant literature suggests that human rideshare drivers often assume social roles to support BVI travelers. For instance, drivers engage in *emotional labor* by sharing information regarding their personal life or by simply listening to the passenger express their thoughts in order to provide comfort (Brewer et al., 2019). Drivers also serve to enhance *trust-building* with passengers through conversational small-talk, which can include discussing their lives or holding positive and friendly conversation to build shared social capital (Brewer & Kameswaran, 2019). By collaborating with BVI passengers when asked for help during the trip, drivers have also been noted to facilitate passenger independence (Kameswaran, Gupta, et al., 2018). These value-added roles assumed by human drivers during BVI ridesharing have coincided with more general research exploring highly human-like social AIs and the associated benefits of AIs assuming social roles, such as increased user trust (Toader et al., 2020) and satisfaction when meeting user expectations (Rapp et al., 2021). In the automotive space, anthropomorphized interfaces in FAVs have begun to gain traction for promoting trust and user acceptance (Niu et al., 2018; Ruijten et al., 2018; Waytz et al., 2014). Indeed, designers have sought to capitalize on these positive outcomes, which has manifested in onboard AI assistants like Volkswagen's Sedric (Biermann, 2022) and Toyota's Yui, "more pal than interface" (Coulter, 2019).

Taken together, this body of work would seem to suggest the importance of highly social human-like AIs 'at the wheel' of autonomous vehicles, both for the general public, and specifically for BVI people who may particularly benefit from social interaction with human rideshare drivers. However, the available research offers little guidance as to the prioritization of social parameters when transitioning from human rideshare drivers to FAV AIs, nor does it provide best practices for design along this translational path. While it is inevitable that people with visual impairments desire FAVs capable of providing *some* of the social interactions they value in human rideshares, it should not be assumed that people desire FAVs that attempt to convey *every* aspect of human-like interaction. Indeed, many of the valuable services provided by rideshare drivers and identified by BVI people in previous research do not include social aspects, instead pertaining to the context of the trip (i.e., route progress, entry and exit information, and environmental information) (Brinkley, 2021; Brinkley et al., 2017). To disambiguate this relationship, and to provide guidance to FAV designers, the present study aims to: (1) Evaluate the importance of social factors for BVI users between FAVs and human rideshares, (2) Identify important environmental factors for FAV ridesharing, and (3) Understand BVI modality preference for conveying social and environmental information within this future transportation mode. By doing so, results from the survey instrument designed to support the study and deployed within the United States not only identify a host of parameters that should be prioritized in FAV development, but also offer valuable theoretical insight into the use of rideshare models as proxies for FAV futures.

The survey-based study we detail in this paper is supported by prior research related to BVI users and FAVs as well as the experiences of rideshare drivers with BVI passengers. The subsequent two sections provide further context and rationale as to why these research areas are important primers for motivating the current study.

1.1. Related research with BVI users and FAVs

A growing body of work has begun to examine the perception of FAVs among BVI people and the needs of this demographic in the future of transportation. For instance, Bennett, Vijaygopal and Kottasz's (2020) survey study of 211 BVI respondents in the UK assessed attitudes towards Level 5 (fully autonomous) vehicles, with their findings suggesting that independence, safety, and affordability were significant factors for perceived future use (Bennett et al., 2020). Results also suggested concerns and skepticism among BVI people about being adequately considered, a central theme that also arose in related research in the U.S. (Brinkley et al., 2020; Fink et al., 2021). Specifically related to ridesharing, in Brewer and Ellison's (2020) interview study of 16 BVI rideshare users, findings suggest that common expectations for drivers include assistance in finding and entering the vehicle, ending the ride at an accessible location with assistance in exiting the vehicle, and desired communication including environmental descriptions and general conversation. Participants also described placing trust in their drivers to safely transport them to their destination, which increased with drivers whom they had previously driven with. Some concerns were raised with regard to difficulty in rideshare accessibility, such as ordering and locating a ride, as well as navigation after arriving at a destination (Brewer & Ellison, 2020; Brewer & Kameswaran, 2019). These results suggest that BVI rideshare users believe being able to interact with a driver is not only useful, but also important for safety and confidence. Interacting with the driver is understandably important for accurately receiving information about the route and the surrounding environment, raising concerns about whether FAVs will be designed to provide the same level of assistance. Referred to as situational awareness in the literature, recent studies have investigated ways to improve understanding of the driving environment nonvisually (Fink, Abou Allaban, et al., 2023; Fink, Dimitrov, et al., 2023). Although interactions with the driver are valuable in determining rideshare passengers' expectations in human rideshares, an empirical investigation of these interactions is necessary to determine effective transition to FAV ridesharing. By so doing, findings would help form the foundation for future research agendas supported by inclusive design guidelines for FAV development and successful Human-AI interactions with this new form of transportation. Related research from the perspective of rideshare drivers also elucidates the importance of this effort, as described in the following section.

1.2. Related research with ridesharing drivers

Prior research has explored the perspective of rideshare drivers with BVI passengers, revealing methods of interaction with these passengers and the important role that the driver plays in assisting people without vision. For instance, Brewer et al.'s (2019) interview study with 18 ridesharing drivers investigated ways in which drivers assist BVI passengers beyond the primary task of driving (Brewer et al., 2019). The authors found drivers engage in labor that falls within one of three domains: physical, emotional, and relational. Physical labor involved helping the passenger enter and exit the vehicle, as well as assisting them in reaching their destination. Although not explicitly discussed, drivers indicated they engaged in emotional labor through conversations about their personal lives and lending an ear for passengers to speak what is on their mind. The authors also found drivers who drove the same passenger on multiple occasions engaged in relational labor by building interpersonal connections with them, which was viewed positively by both parties. This finding regarding the importance of social interaction between driver and passenger in ridesharing was also supported in a related study with 13 rideshare drivers, where drivers discussed engaging in conversation as a means of emotional support as well as to build rapport (Kameswaran, Cameron, et al., 2018). Participants found that they benefited from these interactions as they became more knowledgeable with regard to culture and social conflicts, such as learning about the Black Lives Matter movement or about different types of food and music. Indeed, the benefits of social interaction with drivers of ridesharing services may well extend across user ability and age – a recent study with 169 older adult rideshare users found that passengers tend to appreciate friendly conversations with their drivers and are even inclined to build friendships throughout their trips (Bayne et al., 2021). Taken together, these findings suggest that physical, social, and informational engagement between rideshare drivers and passengers are an important aspect of the ridesharing experience. As such, further exploration is necessary to shed light on the extent to which these interactions should be conveyed as transportation systems transition from human drivers to AI-driven FAVs, as we seek to understand here.

2. Motivation and contributions of the present study

To better conceptualize the similarities and differences between human and autonomous rideshares, and to identify a host of features that would support BVI people in FAVs, a survey study was designed and completed by (n = 187) adults in the United States, with the selection criteria of (1) having some form of self-reported visual impairment and (2) having ridesharing experience. Of interest was determining the relative importance of features along two categorical domains, each derived from the existing BVI ridesharing research: (1) social interaction (e.g., small talk, social support, and collaborating on tasks) and (2) contextual/environment information (e.g., turn-by-turn directions, route-progress, and environmental information). By comparing responses from these two categories, and between assessments when using human operated (traditional) vs. AI operated (FAV) rideshares, we aimed to assess the ways in which the desire for information and services provided by a driver may change depending on the driving agent: human or AI. Aggregate results demonstrating a preference or distaste for a set of these features in the FAV compared to the human rideshare would be of important theoretical value in clarifying the use of ridesharing as a surrogate for BVI desires in future FAVs. Furthermore, by identifying a host of features to be prioritized in FAV interface development, results from the survey could be used as guidelines that contribute to the accessible design of future FAVs, as well as the high-fidelity simulators increasingly being used in user-driven FAV research. We contend that to realize the benefits of these efforts, results must include a set of accessible design guidelines to promote inclusive, usable, and trustworthy systems for both ongoing research and real-world deployment.

Of critical interest here is also the modality in which these features are presented. That is, in addition to knowing what types of information and interactions are important to BVI people in FAV transportation, effective information transfer and positive user experiences rely on *how* that information is presented. We feel this is an important variable to study, as all too often, an accessible, nonvisual user interface simply means that it uses speech and natural language (NL), which has become the de facto solution for providing information access to BVI users. Despite their significant benefit, the use of other modalities in inclusive user interface (UI) design, such as haptics, spatialized audio, and multisensory interactions are rarely considered or studied. Although interfaces relying solely on NL are effective, they are slower and require more cognitive load than more perceptual UIs (haptics, spatialized audio), especially when conveying spatial information that would be relevant to autonomous vehicle travel like inter-object relations and maps (Giudice, 2018). Therefore, a secondary goal of this research is to identify the ways in which multimodal UIs leveraging multisensory cues can support the types of information and interactions BVI people most desire in FAVs. This effort is important because the often-utilized approach to UI development in current semi-autonomous and emerging fully autonomous vehicles involves a visuocentric control center via a touchscreen that is inaccessible to BVI people (see (Palani et al., 2020, 2022) for a review of the limited examples of accessible touchscreen design). As such, for UIs and interaction styles to support BVI people in FAVs, there needs to be new multisensory or nonvisual approaches to support control and operation. Results are predicted to support the growing body of work emphasizing multimodal interfaces in FAVs for people with sensory impairments (Brinkley, 2021; Brinkley et al., 2019; Fink et al., 2021) while also providing much needed guidance in the inclusive FAV design space by providing per feature recommendations for multimodal interaction.

3. Research questions

The study was guided by the following research questions:

RQ1. What social factors are most important in human and FAV rideshares for BVI users?
RQ2. Is there a difference in importance for social factors between human rideshares and FAV rideshares?

RQ3. What environmental factors are perceived to be most important during FAV rideshares?
RQ4. Among the desired social and contextual/environmental information, what presentation modalities do BVI passengers prefer in FAV rideshares (i.e., haptic/vibratory, auditory based, combinations of both)?

In the following sections, the methodology is outlined for the study and results are reported in relation to each research question described above.

4. Methodology

This work utilized an online survey tool developed by Qualtrics (Qualtrics, Provo, UT), as used by Brinkley et al. (2020). Qualtrics deployed the survey, via the internet, to their database of U.S. respondents; those who self-reported being blind or visually impaired had their responses accepted (n = 205). 18 of the initial survey responses were eliminated due to the participants not having any ridesharing experience, leaving 187 responses that were analyzed. Participants took on average 5.5 min to complete the survey and were compensated by Qualtrics in line with the company's compensation guidelines. The survey situated questions in both a human rideshare scenario, where participants were tasked with imagining riding with a human driver, and in an FAV scenario, where

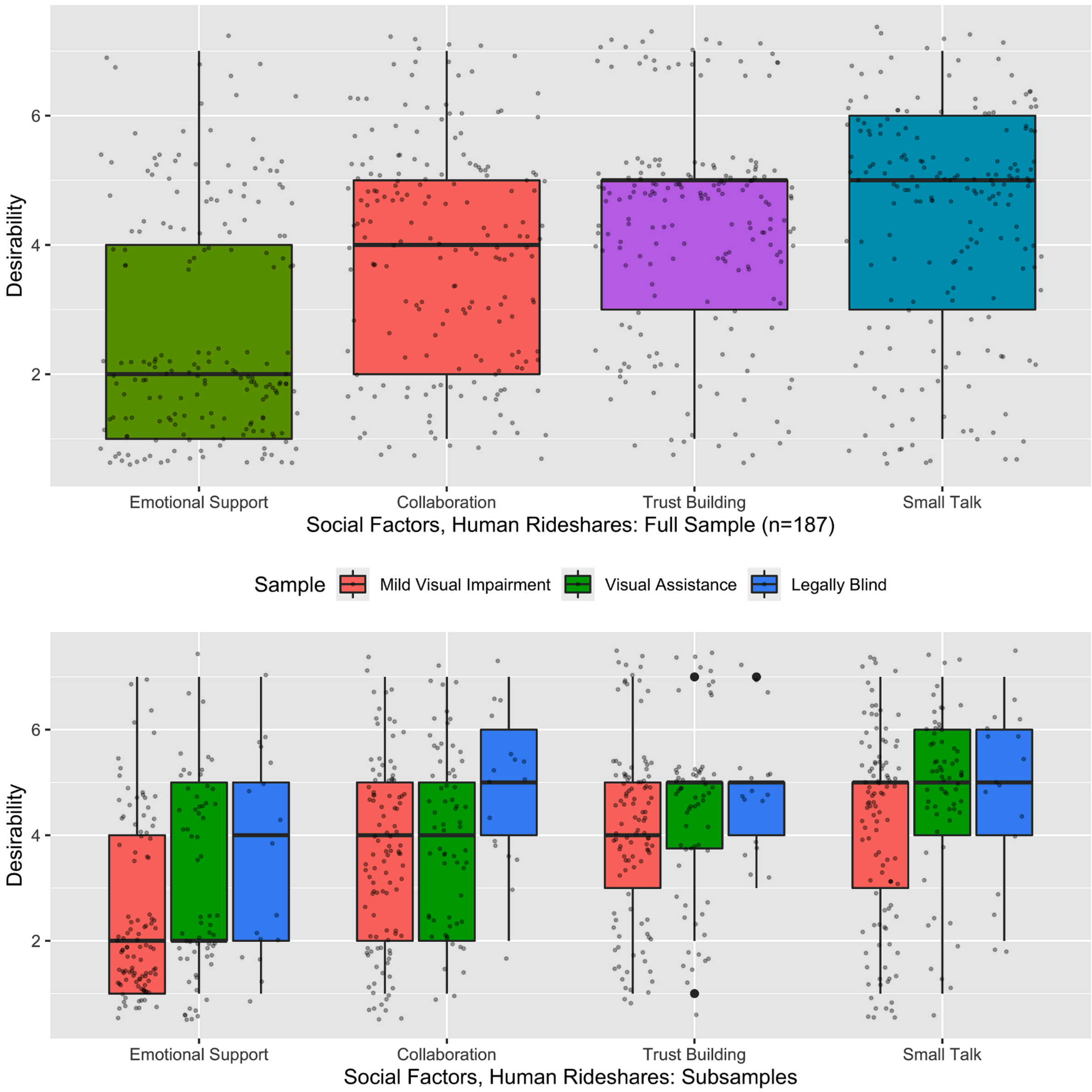

Fig. 1. Social factor importance for human rideshares for all participants (top) and three subsample groups (bottom).

participants were tasked with imagining riding with an autonomous AI driver. Items on the survey covered specific types of contextual/environmental information (e.g., landmarks of interest along the trip vs. turn-by-turn directions) and aspects of social interaction with the AI (e.g., social support vs. small-talk), each derived from the related literature with BVI users, FAVs, and ride-sharing. Participants began the survey with 13 demographic questions detailing factors such as the type and extent of their visual impairment and their frequency of rideshare usage. Then, participants undertook the inventory items related to social aspects in both the FAV and human scenarios. These questions were designed using a 7-point Likert scale, where 1: Strongly Disagree and 7: Strongly Agree represented the response range. Question items were derived from results in the BVI FAV research reviewed in Section 1 and the full inventory can be found in Appendix A. For each inventory item in the FAV scenario, participants were also asked to identify the ways in which the information or interaction should be presented (i.e., through an auditory interface, a tactile/haptic interface, or combinations thereof). These 'modality' questions were presented through multiple choice options. This research was approved by The University of Maine's Institutional Review Board.

4.1. Sample

From the 187-person sample, participant ages ranged from 18 to 82 (M = 40.12, SD = 15.84), with 78.72% of the sample being female. The survey was conducted in the United States, with 66.84% of the sample reported living in an urban area and the rest living

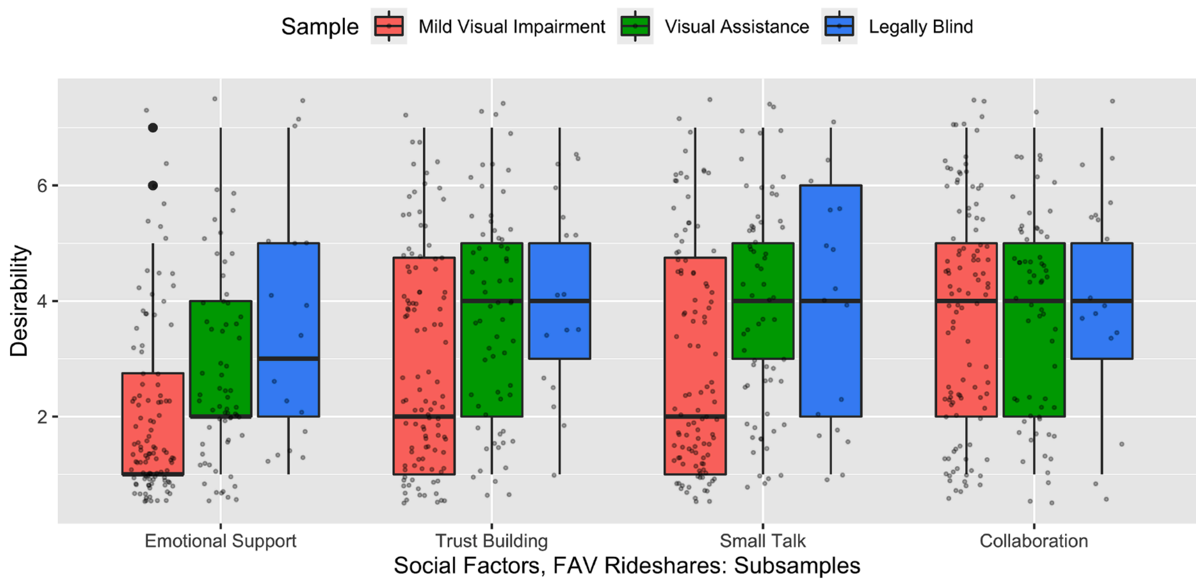

Fig. 2. Social factors in FAV rideshares for all participants (top) and visual status subsample groups (bottom).

in a rural area. All participants reported some type of visual impairment, with 80.85% of participants reporting a visual impairment in both eyes. The most common reported visual impairments included astigmatism (27.27%), nearsightedness (19.25%), and neuropathy or diabetic neuropathy (8.02%). Overall, 83.96% of participants reported having low vision and 9.63% reported being legally blind. Although this was self-reported data, low vision is typically defined as uncorrected visual acuity less than 20/70 and legally blind is typically defined as uncorrected visual acuity less than 20/200 or a visual field of view of 20 degrees or less (AFB, 2023). All but one participant used glasses or contacts and two participants used a white cane. Forty percent of participants reported using an accessibility feature while taking the survey, with the most common features including Google talkback (14.44%), Apple voiceover (10.70%), and magnification (9.09%). Sixty-five percent of participants reported that their vision has changed within the past 5 years, while the rest reported consistent vision during this time period. All participants reported prior ridesharing experience, with the most common usage frequencies being yearly (41.12%), monthly (34.22%), and weekly (12.30%). It is important to note that while this sample is not intended to represent the entire U.S. BVI population, it does provide insight into what trends might exist for this demographic in terms of attitudes toward FAV-passenger interactions.

5. Results

5.1. Social Interactions

When considering the importance for social interaction with the human driver in traditional rideshares and the AI driver in FAV rideshares (RQ1), we analyzed participant responses for each scenario in terms of items derived from the related research: emotional/psychological support, collaboration and giving input, building trust through interaction, and engaging in small talk. Given that our sample included a wide range of vision loss, we chose to analyze and report both the entire sample (n = 187) and three subsamples of vision loss: people who are legally blind (n = 17), people who identified as low vision but not legally blind and use assistive technology (n = 64), and the remaining sample who identified as having low vision but that is correctable such that they do not use assistive technology, which we define as mild vision loss (n = 106). Fig. 1 displays responses for the entire sample as well as the three subsamples in the human ridesharing scenario.

Descriptively, the values suggest that for the full sample, small talk with human rideshare drivers is the most important to people with vision loss, with 60.96% of participants generally agreeing (rating 5 or above on the Likert scale question) that they would like to engage in small talk. This finding was followed by trust building with the driver (51.87% generally agreeing), collaborating with the driver (41.71% generally agreeing), and finally receiving emotional support from the driver (22.99% generally agreeing). Across each of the four social factors, the subsamples in Fig. 1 suggest that there is a positive relationship between desirability for social interaction and the level of vision loss. That is, the desirability for social interaction increased from those with mild vision loss to those using assistive technology and even more so for the legally blind participants. Most notably, 70.59% of legally blind participants rated building trust as desirable, followed by small talk (64.71%), collaboration (58.82%), and emotional support (41.18%). As ordinal, non-parametric data a Kruskal-Wallis test was performed to identify if these differences were statistically significant. Indeed, desirability of social factors were significantly affected by the visual status subsample groups, $H(2) = 27.764$, $p < .001$, with post-hoc comparisons between the legally blind and mild visual impairment groups, as well as between the assistive technology users and mild visual impairment groups statistically significant (p's < 0.001). Potential explanations for this phenomenon are discussed in Section 5. To determine if the social factors themselves were significantly different in terms of desirability, a Friedman's test revealed that social interaction demonstrated a significant effect on participant Likert scores independent of the visual status groups $\chi^2(3) = 111.835$, $p < .001$. Post-hoc comparisons demonstrated that small talk was rated as significantly more desirable than collaboration and emotional support (p's < 0.001), as were trust building and collaboration from emotional support (p's < 0.001).

We undertook the same process of analysis for social interaction with the AI "driver" of FAVs. Fig. 2 displays responses for all participants in the FAV scenario, as well as responses for those in our three visual status subsample groups.

In the FAV scenario, descriptive values for the full group suggest that collaboration with the AI driver is most desirable with 42.45% of participants generally agreeing and 39.57% generally disagreeing (with 18.18% neither agreeing nor disagreeing). This was followed by small talk (33.16%), trust building (31.55%), and emotional support (12.83%). Much like in the human-operated ridesharing example, the sub-analyses as a function of visual status, shown in Fig. 2, suggests a positive association between greater vision loss and increased desire for social factors in FAVs. That is, for emotional support, trust building, and small talk, assistive technology users rated these factors more desirable than those with mild vision loss, with legally blind participants reporting higher scores than both groups overall. Notably, among the legally blind participants, collaboration was also rated as most important (47.06%), followed by building trust (41.18%), small talk (41.18%), and emotional support (35.29%). A Kruskal-Wallis test again revealed that the visual status subsample groups significantly impacted participant Likert scores, $H(2) = 32.098$, $p < .001$, with post-hoc comparisons demonstrating significant differences between the legally blind and mild visual impairment samples, as well as between the assistive technology users and mild visual impairment samples (p's < 0.001). In the full sample, a Friedman's test also revealed that the type of social interaction significantly impacted participant Likert scores $\chi^2(3) = 80.473$, $p < .001$, with post-hoc comparisons demonstrating that collaboration, small talk, and trust building were all rated significantly more important than emotional support (all p's < 0.001).

Whereas in RQ1 we were interested in the perceived importance *within* human or FAV driven rideshares, in RQ2, we sought to compare the importance of social factors *between* FAVs and human rideshares. To do so, we first conducted a paired *t*-test that compared the mean social importance score for each participant between the FAV and human scenario. This test suggests that there is greater preference for social interactions in human rideshares (M = 3.828, SD = 1.200) compared to FAV rideshares (M = 3.224, SD = 1.377), which was statistically significant ($p < .001$). We then conducted a within-subject analysis at the per question level using the non-parametric Wilcoxon test. Results of this test are summarized in Table 1.

Results indicate significant differences along all question types (p 's < 0.001), except for collaboration with the driver ($p = .400$). The boxplots in Fig. 1 and Fig. 2 support this finding, where collaboration shared a median score of 4 and trust building and small talk were of observably higher values in the human rideshare scenario (Fig. 1) than in the FAV rideshare scenario (Fig. 2). Taken together, these results suggest that although there is less desire for social interaction with autonomous drivers than with human drivers overall, BVI passengers still hope to collaborate with the AI driver and give input during the trip to the same extent as with human drivers.

5.2. Environmental information

For RQ3, we sought to assess the importance of different *environmental factors* in FAVs among BVI users. Fig. 3 displays all participant responses along the environmental information inventory items of interest and derived from the literature (top), as well as the visual status subsample groups (bottom). These items included entry and exit assistance, information about pedestrians, information about the surrounding environment around the vehicle, receiving turn-by-turn directions, information about accessing the destination, receiving a route overview prior to driving, information about changes in vehicle behavior, and information about progress along the route.

Descriptively, knowledge about route progress was rated as most desirable with 89.3% of all participants generally agreeing and 5.35% generally disagreeing (with 5.35% neither agreeing nor disagreeing). This was followed by knowledge about vehicle behavior (81.3%), route overview prior to the trip (80.22%), destination information (76.47%), turn-by-turn directions (62.02%), surrounding environment information (48.67%), pedestrian information (43.32%), and entry and exit assistance (22.47%). Much like in the social factors questions, Fig. 3 (bottom) suggests a positive relationship between the importance of information and level of vision loss. Indeed, legally blind participants rated the factors highest overall with route progress information rated as most important (94.12% generally agreeing), followed by route overview prior to the trip (88.24%), vehicle behavior (82.35%), turn-by-turn directions (76.45%), destination information (70.59%), pedestrian information (70.59%), surrounding environment information (70.59%), and entry and exit assistance (52.94%). To determine if the difference between visual status subsample groups were statistically significant, a Kruskal-Wallis test was performed, $H(2) = 70.421, p < .001$, indicating that the level of vision loss had an overall significant effect as a function of rating items. In the full sample, a Friedman's test revealed that the type of environmental information significantly impacted participant Likert scores $\chi^2(7) = 457.735$, $p < .001$. Post-hoc comparisons showed that route progress (during), vehicle behavior, route overview (prior), and destination information were all significantly different and rated as more important than turn-by-turn directions, surrounding environment descriptions, pedestrian knowledge, and entry & exit assistance (all p's < 0.001).

5.3. Modalities of information presentation

For RQ4, we aimed to evaluate which modalities of information presentation BVI users would prefer for the user interfaces used within FAVs (haptic, natural language, or both). The percentage of each response was evaluated for each individual question. It was found that across all questions, participants preferred natural language only (64.71%–73.97%), followed by both natural language and haptic (21.76%–26.55%), and haptic only (4.11%–12.35%). This was true for all participants as well as across the visual status subsample groups.

6. Discussion

Results from this research highlight the distinct differences that people with visual impairment desire between current human-operated rideshare vehicles and future AI-operated autonomous vehicles. Notably, though results suggest that BVI users want less social interaction in FAVs as a whole, collaborative engagement with the AI "driver" was desired to the same extent as with human drivers. Results also suggest that designers should be aware of the range of vision loss experienced by BVI people, as findings indicate across social and environmental factors that the extent of vision loss impacts desire for more information and interaction. Furthermore, findings demonstrate strong support for users desiring a battery of environmental/contextual information throughout travel with autonomous vehicles, an important corroboration of prior research indicating the need for increased situational awareness. The following offers insight on each of these findings in relation to previous literature and the future design of accessible FAVs.

6.1. Ridesharing as a proxy for the fully autonomous future

Results from this study indicate that researchers and designers should exercise caution when applying knowledge from the human-

Table 1
Wilcoxon Signed-rank Test.

Measure 1		Measure 2	W	z	p
Small Talk (Human)	–	Small Talk (FAV)	6739.5	6.438	< 0.001*
Emotional Support (Human)	–	Emotional Support (FAV)	2651.0	3.361	< 0.001*
Trust Building (Human)	–	Trust Building (FAV)	5293.0	5.699	< 0.001*
Collaboration (Human)	–	Collaboration (FAV)	3098.5	0.829	0.400

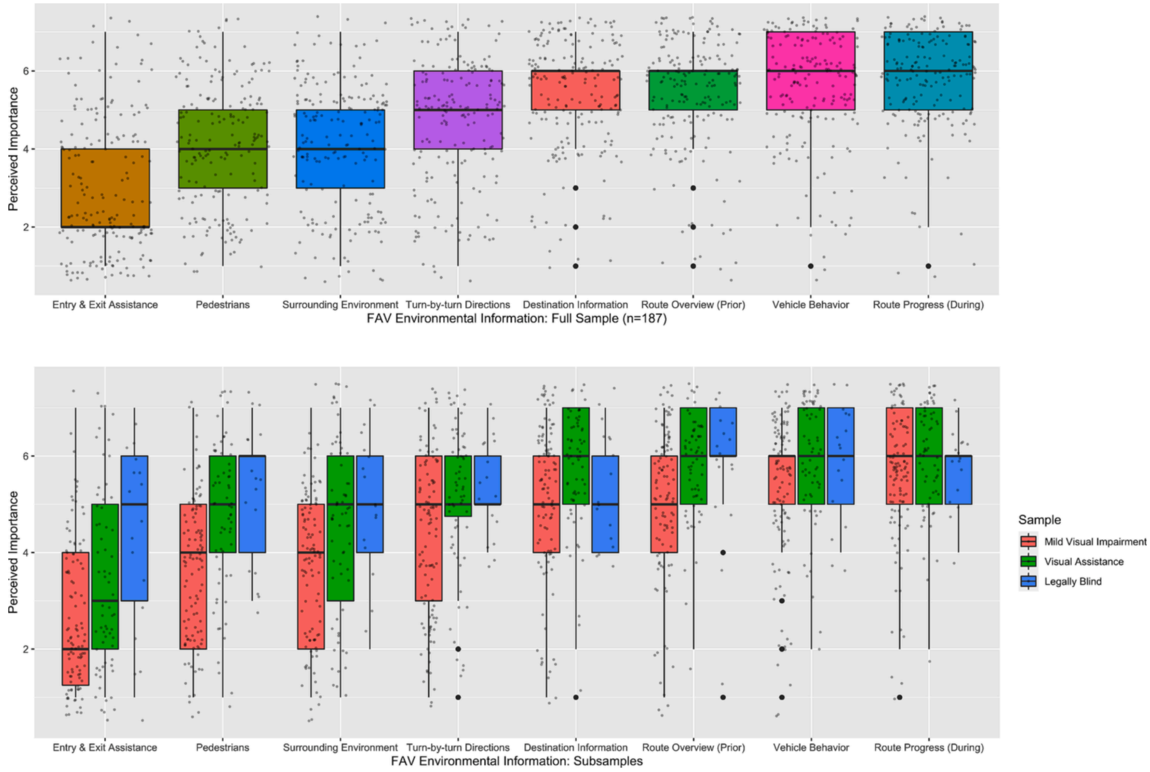

Fig. 3. Environmental information scores for all participants (top) and visual status subsample groups (bottom).

operated ridesharing domain to the design of accessible FAVs used in a rideshare context. Although ridesharing is a frequently mentioned pathway for studying autonomous transit (Brewer & Ellison, 2020; Brewer & Kameswaran, 2019; Fink et al., 2021; Kameswaran, Gupta, et al., 2018), it is logical that the needs and expectations of users in these two modes of travel do not necessarily translate 1:1. At a high level, our results suggest that people with visual impairment want much less social interaction in FAVs than they do with rideshare drivers, an important finding when contrasted with growing research lauding the benefits of anthropomorphic and conversational UIs in automated vehicles (Li & Suh, 2021; Niu et al., 2018; Ruijten et al., 2018; Verberne et al., 2015; Waytz et al., 2014). However, there is a critical caveat here: our results showed that the majority of participants wish to engage in collaboration with FAVs and give input on decisions to the same extent as with human drivers. We interpret this finding as an indication that even in fully autonomous vehicles, there is a desire to be “in-the-loop” of vehicle control and exercise some agency over the trip itself. Indeed, support for agency and control in automated vehicles has been found in related qualitative research with BVI travelers (Brewer & Kameswaran, 2018). We postulate that this desire for collaboration and input in the automated driving process likely manifests more for specific driving actions over others. For instance, people might want to give input on the vehicle’s route more so than its following distance. Indeed, recent research has suggested the importance of route-based control in automated vehicles and its role in human-vehicle collaboration (Fink, Dimitrov, et al., 2023). Logic would suggest that there is alignment between the types of information people desire during a trip and the types of vehicle control on which they wish to give input. Our results from the environmental/contextual questions, which showed preference for information on the route and changes in vehicle behavior, support this notion of route-based control in the literature. More research is needed to uncover how human-vehicle collaboration should be prioritized across driving action and how user interfaces should be designed to support multisensory access to information that enables this control. That is, designers should carefully consider how to include all people in control-based decision making in automated vehicles by developing vehicle interfaces – anthropomorphic or otherwise – that are inclusive rather than exclusionary of people with sensory impairments. Importantly, our results reveal that these considerations may vary as a function of vision loss, as discussed in the following.

6.2. Designing FAV rideshares across the range of vision loss

People with visual impairment are often studied as a homogenous group, when in actuality, the range of etiology, onset, and extent result in disparate needs and lived experiences. This phenomenon was borne out in our data, where the level of vision loss in our subsample groups led to significantly greater desires for interaction with both human drivers and FAVs. Indeed, a positive trend was observed where legally blind participants consistently rated higher scores than participants using assistive technology and both groups in turn rated higher scores than the remaining participants with more mild vision loss. We postulate that the increased desire for interaction and conversation in rideshares could be the result of desiring more access to information from the perspective of the "sighted" agent (human or AI) compared to their peers with more usable vision. In other words, since monitoring the surrounding environment, the vehicle's progress on a route, the proximity of the vehicle's location to a known location at pick-up or drop-off, and related distal tasks are difficult using nonvisual sensing (Giudice, 2018), we postulate that legally blind passengers with limited functional vision will require greater reliance on information access from the rideshare driver to obtain this knowledge. This suggests that a one-size-fits all model based on current design is inappropriate. To be inclusive, we must design our UIs, FAVs, and related tech to provide user selectable amounts of information, as the type, amount, and even modality may differ as a function of visual status. In pursuit of this goal, the existing literature suggests that supporting users across the range of vision loss in FAVs will involve multisensory access (Brewer & Kameswaran, 2018; Brinkley et al., 2019; Fink et al., 2021). While the current data tentatively support the need for increased multisensory information-exchange as a function of decreasing visual status of the passenger, more research is needed to empirically study this prediction.

6.3. Environmental information for situational awareness

Our results offer what we believe to be the first per-feature comparison of nonvisual environmental information to be conveyed in automated vehicles, which offers insight as to what information should be prioritized in inclusive FAV UIs. Turn-by-turn directions, destination information, information related to the route (both a pre-journey overview and enroute progress), and information regarding changes in vehicle behavior were the most highly rated by participants. Combined with our results regarding the modality for presentation, namely a priority across information type for natural language, these results can be used to guide the development of new nonvisual interfaces that increase spatial knowledge about the trip (e.g., accessible mapping) and audio interfaces that increase situational awareness in relation to the vehicle's decision-making. It is worth noting, however, the relatively low indicated preferences for haptic UIs should not be taken out of context, as these results are likely the outcome of participants lacking experience with navigational interfaces that rely on haptics. That is, people tend to be much more familiar with natural language navigational supports, as systems providing haptic information for environmental learning and navigation assistance are still largely experimental and thus unfamiliar (Giudice et al., 2020), thus impacting their reported preference. Regardless of the presentation modality, the need for increased situational awareness via these accessible, multisensory interfaces has often been cited in the BVI FAV literature (Brewer & Ellison, 2020; Brinkley, 2021; Brinkley et al., 2020; Fink, Abou Allaban, et al., 2023) and our results empirically corroborate much of these findings at a more granular and tractable level. Surprisingly, however, given the attention paid to entry, exit, and last meter assistance in these previous studies, as well as in the recent U.S. DOT Inclusive Design Challenge Projects (Inclusive Design Challenge, 2020), our participants rated entry and exit processes fairly low compared to the other information types. This was less the case for the legally blind participants versus the subsamples with more mild visual impairments, which suggests that preference for this type of information may increase as a function of visual loss and further supports our argument that researchers and designers must consider the broad range of vision loss and type of disability in general when designing for accessibility.

7. Conclusion

People who are blind and visually impaired (BVI) stand to greatly benefit from automated vehicles if they are designed to convey relevant information about the trip, accessibly and appropriately. Our survey-based results with ($n = 187$) BVI users within the United States revealed the need to exercise caution when translating current ridesharing models to fully autonomous vehicles, particularly related to emulating the driver via conversational and social AIs. Findings suggested that emotional support, small talk, and trust building are less desirable within FAV rideshares than human-operated rideshares. However, BVI participants indicated desires to collaborate with FAVs to the same extent as with human drivers, suggesting the need for human-in-the-loop control. Furthermore, there was a significant effect between the level of vision loss and desirability for social interaction, where participants in the low vision and legally blind sub-analysis groups rated more desire for interaction than those with mild visual impairment. Thus, designers should be aware of user needs across the range of vision loss, as our data suggest the extent of vision loss influences a passenger's desire for more or less social interaction. Environmental information relevant to FAV travel was also analyzed, with results demonstrating the importance of route-based and vehicle behavioral information for promoting situational awareness. Of the 8 environmental information categories, BVI users rated route progress (during), vehicle behavior, route overview (prior), and destination information to be the most important when riding in an FAV rideshare. Moreover, participants reported a strong preference for the environmental information to be presented with natural language — a familiar interface for BVI users.

Results from this research can be used to increase the accessible design of current simulator platforms and future FAV services that promote inclusive transportation. In support of this goal, the findings presented here enable future research programs to prioritize both the information type (i.e., vehicle behavior, route-based information, and information about the destination) and presentation modality (i.e., natural language) for near-term exploration. We suggest that additional research explores how this information and its presentation modality can best support multisensory access and control-based decision making for any user, with or without a sensory impairment. In addition, further research is needed to empirically study the ways in which information demands vary between broader sets of disability and vision loss.

Our survey-based approach was characterized by limitations that can also be addressed in future work. First, an increased sample size and diversity of participants would enable a more representative sample of BVI participants, particularly with regard to legally blind participants. Indeed, there is substantial variation in usable or residual vision within this demographic and testing the information needs between people who are legally blind but retain some usable vision versus those who have no usable vision is of interest. Our survey also did not compare environmental informational needs between human and FAV rideshares and we believe that future work similar to this study can explore this comparison, much like our comparison of the social factors. Future work may also involve more distinct participant demographic breakdowns that include participants' specific locations, their reliance on other forms of transportation, and more pointed questions about the extent of their vision loss and how it affects their mobility.

CRediT authorship contribution statement

Paul D.S. Fink: Conceptualization, Writing – original draft, Writing – review & editing, Methodology, Data curation, Formal analysis, Visualization. **Maher Alsamsam:** Methodology, Investigation, Formal analysis, Data curation, Writing – original draft. **Justin R. Brown:** Writing – review & editing, Resources. **Henry D. Kindler:** Resources, Writing – original draft. **Nicholas A. Giudice:** Conceptualization, Supervision, Project administration, Funding acquisition, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Survey questions

Q1. What device are you taking this survey on?
- Phone
- Computer

Q2. Do you utilize any of the following accessibility features? Please select all that apply.
- JAWS/NVDA screen reader
- Apple voiceover
- Google talk back
- Magnification
- High contrast
- Other (please specify)
- None

Q3. What is your age?

Q4. What gender do you identify as?
- Male
- Female
- Non-Binary/Other
- Prefer not to say

Q5. How would you describe the area that you live in, urban or rural?
- Urban
- Rural

Q6. Do you have a history of any diagnosed visual impairments?
- Yes
- No

Q7. Have you used a rideshare service (e.g., Uber, Lyft) before?
- Yes
- No

Q8. Briefly detail the name and cause of visual impairment (e.g., Leber's congenital amaurosis, present at birth; Diabetic neuropathy, present from age 10).

Q9. To which eye(s) does the visual impairment apply?
- Both
- Left
- Right

Q10. What is your visual status? Please select all that apply.
- Low vision
- Legally blind with no remaining vision

- Legally blind but use speech access
- Legally blind but use magnification
- Other (please specify)

Q11. Has your vision changed over the past 5 years?
- Yes
- No

Q12. Do you utilize any of the following accommodations for the visual impairment? Please select all that apply.
- Glasses/Contacts
- White cane
- Guide dog
- Other (please specify)
- None

Q13. How often do you utilize rideshare services? Please select one option.
- Daily
- Weekly
- Monthly
- Yearly
- Never

Imagine yourself in a rideshare scenario (e.g., Uber or Lyft) with a human driver. Please answer the following questions on a Likert scale from 1 to 7 (Strongly disagree to Strongly agree).

Q14. I want to engage in small talk with a human driver in rideshare scenarios (e.g., weather, local news, sports)
Q15. I want to rely on human drivers for emotional/psychological support when ridesharing (e.g., talk openly about emotional feelings, discuss personal details)
Q16. I want the human driver to build trust with me through social interactions that are friendly and conversational
Q17. I want to collaborate with the human driver by giving input into their decision making on tasks related to the ride (e.g., choosing highway vs. main road, parking on side of road vs. driveway)

Imagine yourself in a rideshare scenario (e.g., Uber or Lyft) with an autonomous vehicle driver. The difference in this scenario is that there is no human driver, but instead an AI-robot driver. Please answer the following questions on a Likert scale from 1 to 7 (Strongly disagree to Strongly agree).

Q18. I will want to engage in small talk with an AI driver in rideshare scenarios (e.g., weather, local news, sports)
Q19. I will want to rely on AI drivers for emotional/psychological support when ridesharing (e.g., talk openly about emotional feelings, discuss personal details)
Q20. I will want the AI driver to build trust with me through social interactions that are friendly and conversational
Q21. I will want to collaborate with the AI driver by giving input into their decision making on tasks related to the ride (e.g., choosing highway vs. main road, parking on side of road vs. driveway)

Imagine yourself in a rideshare scenario (e.g., Uber or Lyft) with an autonomous vehicle driver. In this scenario there is no human driver, but instead an AI-robot driver. Please answer the questions on the next pages on a Likert scale from 1 to 7 (Strongly disagree to Strongly agree). After several of the questions, you will be asked to imagine what type of interaction method you would prefer (natural language, haptic, or both). In these questions, “natural language” can be understood as an audio-based interaction using words and language with which you are familiar, and “haptic” can be understood as an active, touch based, process using vibration on a screen or a dedicated device.

Q22. I will want a route overview prior to the trip
  Q22.1. For a route overview prior to the trip, which modality would you prefer the information to be presented?
Q23. I will want turn-by-turn descriptions of the route throughout the trip
  Q23.1. For turn-by-turn descriptions of the route throughout the trip, which modality would you prefer the information to be presented?
Q24. I will want a description of the surrounding environment throughout the trip (e.g., restaurants, tourist attractions)
  Q24.1. For a description of the surrounding environment throughout the trip, which modality would you prefer the information to be presented?
Q25. I will want information about where the vehicle is in relation to pedestrians on the road (e.g., people at a crosswalk, cyclists on the road)
  Q25.1. For information about where the vehicle is in relation to pedestrians on the road, which modality would you prefer the information to be presented?
Q26. I will want information about sudden changes in the vehicle’s behavior (e.g., swerving, sharply braking, rapid acceleration)

Q26.1. For information about sudden changes in the vehicle's behavior, which modality would you prefer the information to be presented?

Q27. I will want information about where the vehicle is on the route in relation to my final destination (e.g., distance from destination, time until arrival)

Q27.1. For information about where the vehicle is on the route in relation to your final destination, which modality would you prefer the information to be presented?

Q28. I will want information about the vehicle in relation to the access point of my final destination (e.g., the door to a building)

Q28.1. For information about the vehicle in relation to the access point of your final destination, which modality would you prefer the information to be presented?

Q29. I will want assistance with entering and exiting the vehicle

Q29.1. For assistance with entering and exiting the vehicle, which modality would you prefer the information to be presented?

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