Visually impaired people's perceptions on how autonomous vehicles will impact everyday life

Peter A. Hayton

Open Lab – Newcastle University
Newcastle Upon Tyne, United Kingdom
p.a.hayton@newcastle.ac.uk

Abstract

Fully autonomous vehicles (FAVs) have the potential to enhance the quality of life of visually impaired people (VIP). However, while existing research has explored VIP's general enthusiasm towards FAVs, a contradictory range of solutions are proposed for VIP to control the route and modify in-vehicle settings like climate control. FAVs also have ethical implications for society in general, which can affect VIP's confidence and ability to operate FAVs independently. This position paper reviews existing literature on FAVs and VIP, to show that when engaging VIP in research on FAVs, these broader ethical considerations must be accounted for when exploring how FAVs can provide equitable and safe modes of transport for all.

1 Introduction

Fully autonomous vehicles (FAVs) have the potential to provide quality of life improvements for VIP, such as improved employment prospects [1, 2] and access to social activities [2, 3]. FAVs are expected to address issues such as drivers getting lost [4] and give VIP more control over their journey e.g. to set the temperature of their vehicle [5, 6]. Prior work has already demonstrated an interest in FAVs from the visually impaired community [2, 5, 7], with some people explicitly stating they would be happy to pay on average an extra $10,000 over the price of current cars to have access to this technology. It is possible to provide accessible digital interfaces to FAVs [6]. However, FAVs will probably not solve all existing infrastructure problems [8, 9].

This short paper will review findings from the most relevant research on VIP's perceptions of public transport, FAVs and independence from authors across the ACM SIGCHI and SIGACCESS communities as well as notable contributions from other journal publications (see Table 1). This will highlight how FAVs can impact on VIP and examine key ethical concerns, that must be considered, to ensure people feel safe while using FAVs.

Table 1: A categorised overview of existing research on VIP and transportation, FAVs and independence along with research around the opportunities and ethical concerns of FAVs. The top row contains categories, while the bottom row contains links to the most significant research at the time of writing.

VIP and transportation	VIP and FAVs	VIP and independence	Opportunities for future FAVs	Ethical concerns with FAVs
[4, 8, 10-15]	[2, 3, 5-7, 16-20]	[21-25]	[1, 26-29]	[30-36]

2 VIP and transportation

While some cities have effective public transport networks, VIP still face challenges using public transport such as being unable to access real time information (RTI) for live bus and train departure times and locations [8] and have difficulties locating some bus stops independently [11]. Therefore, VIP remain reliant on assistance from others in their journeys, due to unresolved accessibility barriers [8, 13, 14], while the lack of available public transport in rural areas and countries like the US causes VIP to rely on ridesharing and lifts from friends and family [2].

It is undeniable that today's transport infrastructure is inaccessible both physically and digitally, as VIP rely on a plethora of smartphone apps to plan their journey [2, 4, 8, 14, 24], experience difficulties finding a stop without assistance [8, 11] and cannot rely on features like stop announcements or driver assistance to guide them throughout a journey [8, 15]. These factors negatively impact on VIP's independence and self-confidence, such as in [2, 4, 14].

Fully autonomous bus (FAB) services are currently live in the City of Edinburgh, UK, using a full-size bus to operate a bus route between two locations, with initial passengers being optimistic towards FABs bringing improved service frequency and environmental benefits [37]. However, as defined by the operator, the UK's first full-size autonomous bus uses the same RTI systems as conventional buses [9] that VIP experience difficulties with [8], hinting that FABs may not solve the challenges VIP face in accessing public transportation. Furthermore, it may remain important for VIP to continue to seek

assistance from others when needed, indeed the notion of maintaining strong interdependence relationships is helpful in case of unreliable infrastructure [25].

3 VIP and FAVs

The HCI community has increasingly shown interest in FAVs since two studies in 2014 explored the trustworthiness of partially automated vehicles [28, 31]. As automation levels increased, interest from the HCI community towards the opportunities of future FAVs continued to grow, exploring the gamification of traffic jams [29] and the broader design space of FAVs [26]. More recently, HCI scholars have explored trustworthy external communication systems for FAVs that convey the vehicle's intent as it approaches a pedestrian crossing, to ensure VIP can cross the road safely [17]. At the time of writing, these concepts are being enhanced to convey a safe crossing message to more people [19].

Currently, companies such as Waymo are using FAVs to operate private ride-share taxi services within the United States [38]. Waymo have taken steps to provide accessible experiences for VIP, such as adding braille to buttons inside vehicles and allowing riders to honk the horn to aid with locating their vehicle, using a screen-reader friendly mobile app [39, 40]. We know from [6] that developing screen reader friendly mobile apps can be an effective method for VIP to control FAVs and prior work has shown that VIP have a preference towards smartphones as a control method because they are "already accessible" [2].

However, Waymo's newest vehicles have replaced the braille buttons with a touchscreen interface [41] which is not the preferred method for VIP to access FAVs [5] meaning the design of these vehicles might differ if VIP were included in the design process. VIP have also expressed a desire to understand how to operate FAV systems in case of emergencies and want finite control over a route [18], supporting findings that people feel more connected with a vehicle if they have more control over it [22].

VIP will also be impacted by the public's perceptions of FAVs, which may be negative. For example, a 2020 study found both drivers and pedestrians to act antagonistically towards FAVs, especially if there is no one in the vehicle [42]. These findings have been corroborated by actions in 2024, where a Waymo vehicle was set on fire whilst driving through San Francisco [43]. This behaviour presents challenges for urban planners and vehicle operators and manufacturers, who will need strategies to deal with violent public behaviour and this could become a source of concern for VIP and prevent them from using FAVs.

4 Ethical concerns with FAVs

As with the accessibility issues of autonomous bus services (see section 2), there is evidence to suggest that the needs of VIP are not being properly included in the design process of a new transport medium that could become mainstream in the coming years. For example, VIP are concerned about how current legislation in the US could impact developments and prevent them from independently operating FAVs [5]. Additionally, prior work has pointed to the danger of FAVs providing a false sense of security, and false promises of independence for VIP [3, 5], which could result in wider ethical implications around the role of FAVs in society. Ahead of new legislation, such as the Automated Vehicles Act in the UK [44], it is critical to ensure that the opportunities FAVs afford VIP are not overlooked. Broader ethical implications must also be considered so that VIP are not excluded or put at risk through using FAVs, due to concerns over personal safety [42] or cost [30].

Deploying FAVs also presents ethical challenges that are not unique to VIP users. For example, the trolley problem which focuses on the trade-offs between causing one death to prevent several more deaths [45] is of particular relevance to FAVs. This leads to a series of moral dilemmas because the correct ethical behaviour will have to be selected and in the event of a worst-case scenario, there are questions around who has the right to make these decisions [32]. However, HCI scholars have indicated the difficulties of making a "right" choice when presented with these scenarios, arguing that ethical dilemmas like the trolley problem cannot provide a de-facto answer on what the vehicle should do in any given scenario [34]. Additionally, critique of a study around the trolley problem and FAVs points out that we cannot say that a decision is morally "right" if a collective group of people decide to take any particular action [33].

Though not unique to VIP, designers will need to consider disabled users – both as pedestrians and vehicle occupants in their response to ethical questions such as the trolley problem. For instance, if every driver were to be given the choice to select an ethics setting [32], designers will need to consider how VI drivers could make an informed decision. Additionally, there are questions around the morality of replacing human drivers with autonomous vehicles, particularly with regard to the level of assistance VIP currently receive from human bus drivers [15, 36]. Current research is yet to determine how VIP will receive this assistance when using FABs, so more work will be needed to understand VIP's requirements when using autonomous bus services.

Given the array of sensors and cameras FAVs use for wayfinding, FAVs provide a channel of conversation for groups like local authorities to explore using this data. A recent study in Amsterdam used a fleet of camera cars to trial the automation of parking fines [46]. While this study did not involve FAVs, it is possible that such technologies could be adapted for use with FAVs, highlighting the importance of conversations around ethics and FAVs. Camera data from FABs may also play a role for groups such as insurers to aid with claims for accidents involving FAVs [35], where the UK's Automated Vehicles Act has laid the groundwork for establishing liability in the event of an accident [44], the question of

how data will be collected remains open with ongoing debates around the storage of this data and privacy concerns from other road users remaining unresolved [35].

Despite an overwhelming optimism from visually impaired communities [2, 3, 7, 47] towards FAVs and a willingness to pay extra to use the technology, the current estimated cost of building FAVs is substantially higher than the price of conventional cars – at around $250,000 [48]. Therefore, the cost of FAVs can present an access barrier for VIP and those with other disabilities, who may be on lower incomes [30]. This means FAVs will likely only be accessible to VIP on the highest incomes, meaning new inequalities could be created among visually impaired communities. One strategy may be to follow suggestions in [30] where a fleet of government-owned FAVs could be deployed in a shared capacity. Though this will necessitate additional discussions with stakeholders like local authorities, it will be necessary to ensure equitable access to FAVs.

5 Understanding the problem space

We know that FAVs, without a human operator, will impact VIP both as passengers and pedestrians [2, 8, 17, 20, 47, 49]. While there are opportunities for positive change, it remains likely that FAV technology could exclude visually impaired communities due to accessibility barriers and broader systemic issues, such as the high cost of manufacturing FAVs [48]. Therefore, the HCI community needs to come together in understanding VIP's requirements so that a standardised control mechanism that empowers VIP to take independent journeys can be developed.

5.1 Requirements of VIP in FAVs

Prior work such as [2, 3, 5-7, 16-18] has explored VIP's requirements in FAVs, adopting a collaborative co-design approach. Though there is a consensus among authors that VIP desire accessible control over their journey, this is achieved in vastly different ways. For example, Brewer and Kameswaran's 2018 study, adopts metaphorical design, where VIP suggest controls based on existing O&M devices like a long cane [18], expanding on VIP's interest in understanding their surroundings whilst in a FAV [2, 18]. In contrast, Fink et al, found success using a gestural and audio-based control mechanism [7].

These findings help steer conversations around the needs of VIP, but solely relying on small numbers of workshop participants and isolated test scenarios may not be a large enough dataset to represent the broader population [17]. Additionally, visual impairment is a broad term spanning a wide variety of conditions which impact people in different ways [50]. It can therefore be difficult to recruit a wide variety of participants, especially given the small percentages of the population made up by visually impaired communities, as shown in [4] where over 70% of visually impaired participants could still drive.

5.2 Accessible controls for FAVs

More advanced control systems are desired by VIP as a requirement to accessing FAVs, but as discussed these can take several forms from mobile apps [6], to in-vehicle touchscreens [16] and bespoke control systems [7, 14]. However, the end-goal of providing finite control over a FAV's behaviour remains the same. A previous study has highlighted that the more direct control a user has over a vehicle, the more confidence they can place in it, with this feeling being replicated for people with disabilities [22]. In a similar vein to Zhao's ladder of diagram access [23], getting the level of control right will be important to ensure that VIP feel a sense of confidence when operating FAVs. Assistive technology like screen readers often fails to find this balance, leaving VIP feeling more self-conscious about using screen readers [21]. This must be avoided in future work on developing accessible FAV interfaces, to ensure they are accessible to all.

6 Conclusion and future work

This paper has highlighted research (see Table 1), which proves there is optimism from the visually impaired community, that FAVs will provide positive change in the daily lives of VIP. It has also demonstrated that control systems will be needed to improve VIP's trust and confidence in FAVs. However, it also points to the danger of ignoring the broader ethical implications FAVs will have on society, that are not unique to VIP, where scholars are undecided on the "right" way for FAVs to approach some worst-case scenarios [33, 34].

Engagement with past workshops at the CHI conference [26, 27] shows appetite from the broader HCI community in this area. However, both workshops are preliminary and focus only on low-fidelity prototypes and calls for future work from [16] show there is limited work on complex in-vehicle interactions for FAVs. Additionally, given ethical concerns around how members of the public will react to FAVs [42] and concerns over cost barriers when FAVs are introduced [30], future work on VIP in FAVs should closely consider systemic issues and ethical implications to avoid exacerbating inequities, social exclusion and other risks for VIP.

Local government, urban planners and mobility professionals play a significant role in determining the accessibility of today's public transport infrastructure for VIP [8, 11, 12]. Meanwhile, the need for VIP to engage with mobility training often brings critical social problem solving skills and helps them engage with everyday tasks [10]. Therefore, future work should expand beyond the HCI community collaborating with these groups, particularly those who work most closely with VIP, to ensure that FAVs actually help to address challenges VIP face today.

7 About the author

Peter Hayton is a visually impaired second year part-time PhD student at OpenLab, Newcastle University. His PhD research topic is focused on how fully autonomous vehicles can be made accessible for visually impaired people. This research is currently within the first of three case studies, which is focused on how visually impaired people perceive autonomous cars and bus services to determine the requirements of visually impaired people in autonomous vehicles. Peter is also interested in research around making human centred design methods accessible for visually impaired HCI researchers. He welcomes any opportunity to be involved in discussions around accessibility, urban mobility and autonomous vehicles. Peter also works for the School of Computing at Newcastle University as a teaching assistant and lecturer in taught computing programmes. He previously worked for a national sight loss charity in the UK, working with clients to improve the accessibility of their products for visually impaired people.

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