Imagining an Inclusive Future for Shared Autonomous Vehicle Interiors: A Participatory Design Workshop Study

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ABSTRACT

The introduction of shared autonomous vehicles (SAVs) has the potential to provide better transport to people groups who currently experience transport exclusion. In this paper we describe a series of four workshops carried out with members of a range of transport excluded people groups- older people (65+), women, disabled people, neurodivergent people, and people with mental health conditions (N=11). Workshops explored existing experiences of transport with a journey mapping activity and participants generated inclusive design solutions for SAVs through a participatory design activity. Through thematic analysis of workshop data, we identified 3 main areas where design intervention in the interiors of SAVs could create more inclusive SAV journey experiences. These areas were adaptability, safety & security, and navigability & familiarity.

CCS CONCEPTS

• **Human-centered computing** → Accessibility; Empirical studies in accessibility; Accessibility; Accessibility design and evaluation methods; • **Social and professional topics** → User characteristics; Age; Seniors; User characteristics; People with disabilities; User characteristics; Gender; Women.

KEYWORDS

shared autonomous vehicles, inclusive design, vehicle design, interior design

1 INTRODUCTION

Many people experience transport exclusion due to factors including ageing, disability, gender, location, income, and ethnicity [9]. The introduction of Shared Autonomous Vehicles (SAVs) promises to improve transport for these groups with inclusivity benefits e.g. removing the need to drive for disabled people [8]. Despite this, attention needs to be paid to how the design of these vehicles can meet the needs of excluded groups.

Existing studies have explored the inclusion of older and disabled people in the design of SAVs [1–3, 6], and used participatory design methods to explore specific needs of excluded groups [5] and full scale SAV mock-ups to test accessibility of SAVs with disabled people [12, 14]. Despite these efforts to address the needs of individual excluded groups, it is important to explore how the needs of multiple excluded groups can be met by identifying common areas of exclusion and developing solutions which address these areas.

In this paper, a series of four workshops with members of different transport-excluded groups (N=11) were used to explore areas where the design of SAVs might create more inclusive journey experiences. These workshops took an *Inclusive Design for Transport* approach [10] addressing the needs of groups beyond the age-ability construct. Journey mapping activities based around the whole transport experience were used to ensure that the *Inclusive Design for Transport* issues of usability, availability and experience were addressed. The groups selected for these workshops were older people, women, disabled people, neurodivergent people and people with mental health conditions, with attention paid to ensuring that a diversity of other potentially excluding factors such as ethnicity and location were represented within these groups.

The workshops incorporated journey mapping and participatory design activities based around a full scale SAV mock-up (Figure 1) to generate ideas and prototypes for inclusive SAV designs. While several areas of exclusion were discussed in these workshops including inclusive digital interfaces, infrastructure and vehicle exteriors, this paper presents three areas identified which relate to the inclusive design of SAV interiors and answer the research question: How might design be used to create more inclusive SAV interiors?

Figure 1: SAV mock-up

2 METHOD

2.1 Workshop structure

Participatory research activities focused on the design of future products and services i.e. SAVs, can present challenges for participants discussing an unfamiliar and hypothetical scenario. In order to ensure that participants ideas for inclusive SAVs were well-founded in their own experiences, each workshop was structured as a *Future Workshop* [13].

At the start of the workshop, participants filled out an initial "about me" page with details about themselves and their general experiences with transport. Participants then began by discussing these experiences with each other. After this, participants engaged in a *critique phase* focused on journey mapping of existing transport experiences. The second half of each workshop then served as a *fantasy/ implementation* phase, focused on participatory design and prototyping of inclusive solutions that could be applied to an SAV service, as well as allowing for the discussion of potential barriers arising from the introduction of SAVs.

2.2 Journey mapping

As SAVs present an entirely new journey experience, it was necessary to situate participants' thoughts within the context of their current experiences. Journey mapping is a method which encourages researchers to consider the complete experience of users and has been suggested as a useful tool in considering the experiences of excluded groups, particularly disabled people [7].

A journey mapping resource was created which divided a typical journey into 8 stages (Table 1). Each stage contained a number of specific questions and an area to write general positives and negatives. While completing this activity, participants were encouraged to discuss their thoughts with each other. A workshop assistant scribed for the visually impaired participants. The journey maps were then arranged on a pin board, so they could be referred to later on.

2.3 Participatory design

Participatory design [11] was used in the second phase of the workshops to engage participants in considering future scenarios and developing ideas for how SAVs could be made more inclusive.

To help participants understand SAVs, they were given a short introductory presentation about SAVs. Visually impaired participants were given a 3D printed tactile model of a SAV (Figure 2) which enabled them to feel a potential interior layout and the exterior shape of the vehicle. Participants were then given some time to ask questions about SAVs before the participatory design phase began.

The participatory design phase of the workshop followed the same stages of the journey mapping activity, with participants being asked to imagine their desired experience of a SAV service and potential barriers to use. Initial stages of booking, planning, preparing and waiting were discussed around a table with ideas recorded on a whiteboard by the workshop assistant. From the boarding stage onwards, participants were invited to enact their desired journey experience within a full-scale mock-up of an 8-12 seater SAV (Figure 1). This mock-up served as a blank canvas which could be reconfigured and tested during the workshops with moveable seating, step and ramp. A number of foamboard props (Figure 2) were also provided to represent interface elements and interior features such as power outlets, lighting and plants to allow for discussions around functional and desirable features alike. Participants were encouraged to add these elements to the vehicle mock-up when discussing design ideas and provided with materials to make their own.

2.4 Participants

Participants were recruited through mailing lists and snowball sampling. 11 participants attended one of four workshops, each focusing on a different excluding factor to create discussions around shared experiences of transport (Table 2). These groups were women (N=4), disabled people (N=2), older people (65+) (N=3), and neurodivergent people/ people with mental health conditions (N=2). While members of these groups had the main excluding factor in common, certain people who fit into additional excluded groups were selected to encourage discussions around intersectionality of different excluding factors e.g. P7 who participated in the older people workshop but was also visually and mobility impaired. Participants were also selected to ensure a diversity of other factors related to transport exclusion, such as ethnicity and location, within each group.

2.5 Analysis

All discussions during the workshops were recorded and transcribed. Completed journey map resources were photographed. Thematic analysis [4] was used to code and analyse data from both workshop transcripts and photographed journey maps. Initial codes were sorted into broad categories to identify the prevalence of different areas of the transport experience in the conversation and identify the areas where inclusive design intervention may be most likely to make an impact. Themes were then generated with specific attention paid to codes referring to inclusive SAV solutions.

3 RESULTS- CREATING AN INCLUSIVE SAV INTERIOR SPACE

While a number of themes were generated from the data covering a variety of areas, for the purpose of this paper the themes described

Table 1: Journey mapping questions

Stage	Question number	Question
1. Booking and planning	1	How do you plan your journey?
	2	Do you book in advance?
2. Preparing for the journey	3	How do you remember the details of your journey?
	4	What items are you taking with you?
3. Getting to the vehicle	5	How do you get to the vehicle?
	6	Where do you board the vehicle?
4. Waiting	7	How long do you have to wait?
	8	What waiting facilities are available?
5. Getting on the vehicle	9	How easy is it to board?
	10	How do you find your seat?
	11	Where do you put your luggage/ other items?
6. On the journey	12	What do you do while on the journey?
7. Getting off the vehicle	13	How easy is it to exit the vehicle?
	14	Where do you exit the vehicle?
	15	Where do you put your luggage/ other items?
8. From the vehicle to your destination	16	How do you travel from the vehicle to your destination?
	17	How far do you travel from the vehicle to your destination?
	18	How do you navigate from the vehicle to your destination?

Figure 2: Tactile model of a SAV and Foamboard props

below all relate to the research question: How might design be used to create more inclusive SAV interiors?

The design of the interior space is a key consideration in the development of inclusive transport. Throughout the workshops, participants mentioned how addressing areas of adaptability, safety & security, and navigability & familiarity could all ensure that SAV interiors meet the needs of the excluded groups represented. Table 3 shows several quotes from the workshops that relate to each area and theme. In the following sections a quote number (e.g. Q1) is used to reference these quotes.

3.1 Adaptability

One commonly occurring theme in discussions with participants was the diversity of exclusion and variety of transport needs and the desire that an inclusive SAV should meet the needs of a broad spectrum of excluded groups (Q1). Because of this diversity of needs, several participants suggested ways in which the SAV could adapt with design features such as folding seating (Q2) allowing

for wheelchair occupancy and creating space for assistance dogs, luggage and pushchairs. Participants also discussed the need for the SAV to be made aware of passengers' needs before they board the vehicle and adapt accordingly. Suggestions for how a SAV may do this included options given during the booking process (Q3) and biometric recognition (Q4).

3.2 Safety & security

Issues of safety and security within the SAV service were discussed in all workshops. These issues were discussed in the light of two aspects of SAV services: absence of a driver & staff (Q5) and sharing with strangers (Q6).

Specific fears based around the behaviour of other passengers included those relating to potential for sexual assault on shared vehicles, as well as other crimes such as theft and vandalism. Potential security features suggested by participants fit into two main categories: active interventions- that respond to dangerous situations, and passive interventions- that increase perceived security.

Table 2: Workshop participants

Workshop	Participant	Age	Gender	Ethnicity	Disability/ Health condition / Neurodivergent	Location
Disabled people	P1	25-34	M	Asian or Asian British	Blind/ visually impaired	Urban - Major city
	P2	65-74	M	White	Deaf/ hard of hearing	Rural - Town
Neurodivergent/ Mental health/	P3	25-34	F	Asian or Asian British	Neurodivergent, Jawbone Syndrome (TMJ)	Urban - Major city
	P4	55-64	M	Asian or Asian British	Mobility impaired (not wheelchair user), Chronic illness /long- term health condition, Mental health condition	Urban - Major city
Older people	P5	65-74	M	White	Deaf/ hard of hearing	Suburban
	P6	65-74	M	White	Non-disabled	Urban - Major city
	P7	75-84	M	Asian or Asian British	Blind/ visually impaired, Mobility impaired (not wheelchair user)	Suburban
Women	P8	25-34	F	Asian or Asian British	Non-disabled	Urban - Major city
	P9	25-34	F	Mixed	Prefer not to say	Rural - Village
	P10	45-54	F	Black/African/ Caribbean/ Black British	Chronic illness /long- term health condition	Urban - Major city
	P11	55-64	F	White	Mobility impaired (not wheelchair user), Reaching, stretching or dexterity impaired	Urban - Major city

Figure 3: P3's "STOP THIEF!" button

Active interventions suggested by participants included control given to passengers through means of panic buttons (Q7) (Figure 3) and the use of the autonomous driving system to carry them to safety (Q8).

Passive interventions focused around the division of the interior space (Q9). Notably, there was a consensus in the women's workshop discussion that any physical divisions should not fully divide the space, like a wall, but instead offer a more permeable territorial prop to reduce feelings of claustrophobia (Q10).

Although discussions of dividing up the space were focused on security, suggestions of physical dividers were also used to respond to issues of hygiene and protection from viruses etc. for vulnerable groups (in the light of the Covid-19 pandemic) as well as a desire for privacy from crowding and unwanted social interaction.

3.3 Navigability & familiarity

Moving around inside the vehicle presented a number of potential issues for excluded groups, particularly those with visual impairments. In the journey mapping activity, all visually impaired participants mentioned difficulties with navigating inside and outside the vehicle due to a lack of standardised vehicle layouts (Q11), and not knowing which seats are occupied (Q12). Other participants also mentioned issues with moving around inside vehicles when they are moving (Q13).

Suggested physical solutions to these issues of on-board navigation included audio-based seat information (Q14), tactile flooring (Q15), and provision of a continuous guide rail which they could follow around the inside of the vehicle (Q16). The presence of handles and guiderails was also seen as a benefit to members of other excluded groups including mobility impaired people (Q17).

Another key issue when considering navigation within the SAV is the importance of familiarity and standardisation of the interior for visually impaired people (Q18, Q19). Visually impaired participants mentioned a number of ways in which they could be familiarised with the SAV interior before use, including using a full scale mock-up (Q20) or a smaller tactile model similar to the one used in the workshop itself (Q21). The use of methods to familiarise people with the vehicle interior before use was also suggested as a general benefit by other participants who were concerned about learning how to use SAVs. Simulators (Q22), visual information (Q23) and getting used to seeing SAVs on the road (Q24) were all suggested as ways of achieving this.

Table 3: Workshop quotes

Area of inclusive interior SAV design	Theme	Quote	Participant	Quote number
Adaptability	Need for universality	"I think the whole concept should be accessible to all"	P4	Q1
	Method of adaptation	"In a train, we've got foldable chairs... that would be good as well because that makes life a little bit easy."	P1	Q2
	Knowing people's needs	"when you're booking it, there should be tick boxes, what type of vehicle you're looking for"	P4	Q3
		"recognises your eyes or something. So, it knows who is actually on board."	P6	Q4
Safety & security	Absence of driver & staff	"I am quite alone… and there's no one at the ticket office so I can get quite anxious"	P9	Q5
	Sharing with strangers	"letting people on should depend on what time of day is… If on a night time by myself, probably no."	P10	Q6
	Active security interventions	" thief button so when somebody realises their phone gets stolen… press a button, the car is automatically locked"	P3	Q7
		"Does it drive to the police station?"	P6	Q8
	Passive security interventions	"if it's like a five seater… there's something here that separates them."	P10	Q9
		"you can feel trapped… you're already in a container, to reduce the container size again…"	P9	Q10
Navigability & familiarity	Difficulties navigating inside vehicles	"when I get off, I still struggle to find the door…"	P1	Q11
		"I want to say, "Excuse me Is anybody here"… sometimes people don't say anything."	P7	Q12
		"Buses, going upstairs or descending stairs whilst bus is moving."	P10	Q13
	In vehicle navigation solutions	"If I enter… it says, seat number nine and five has already filled?... so, I can count… nine must be this side."	P1	Q14
		"…tactile and I can feel it with my cane on the floor and reach to my seat."	P1	Q15
		"you can hold handrail and reach to your place"	P1	Q16
		"something to hold onto"	P11	Q17
	Standardisation of interior space	"seats are not standardised so difficult to find"	P7	Q18
		"I wish somebody… will put everything in the normal way. For example, at home. We are familiar with our home, right?"	P1	Q19
	Methods of familiarisation	"I really love if they give an opportunity to familiarise with it, that will be really great."	P7	Q20
		"when you showed me earlier on there, I wasn't really comfortable. When I see the small model. Now I know how."	P1	Q21
		"Maybe we need a simulator for a new… car."	P5	Q22
		"it has to be visible... and to just be aware of what's being offered."	P2	Q23
		"It's nice, like getting people familiar with seeing them about as well. It's quite alien."	P9	Q24

4 CONCLUSIONS, RECOMMENDATIONS AND LIMITATIONS

The three areas of inclusive design intervention for SAV interiors-Adaptability, Safety & security, and Navigability and familiarity-provide a starting point for further inclusive design research activities. Further participatory design activities should focus on each of these areas and prototype and develop ideas suggested in this paper. As these workshops primarily focused on the needs of older

people, disabled people and women, further research should also consider the relevance of these areas to other transport excluded groups as well as obtaining a greater variety of input across the range of neurodivergence, learning disability and mental health conditions. The Covid-19 pandemic meant that some groups such as wheelchair users, who had initially responded to the recruitment

survey were not able to attend an in-person workshop, future workshops following this format will seek to include these groups as well.

As these workshops covered a broad range of people groups, individuals' experiences were used to gain deeper insights into the ways in which people experience exclusion as a starting point for design intervention. Further quantitative research could be used to determine to what extent these experiences are universal within each excluded group.

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