Let's Share a Ride into the Future

A Qualitative Study Comparing Hypothetical Implementation Scenarios of Automated Vehicles

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ABSTRACT

Automated Vehicles (AVs) are expected to radically disrupt our mobility. Whereas much is speculated about how AVs will actually be implemented in the future, we argue that their advent should be taken as an opportunity to enhance all people's mobility and improve their lives. Thus, it is important to focus on both the environment and the needs of target groups that have not been sufficiently considered in the past. In this paper, we present the findings from a qualitative study (N=11) of public attitude on hypothetical implementation scenarios for AVs. Our results indicate that people are aware of the benefits of shared mobility for the environment and society, and are generally open to using it. However, 1) emotional factors mitigate this openness and 2) security concerns were expressed by female participants. We recommend that identified concerns must be addressed to allow AVs fully exploiting their benefits for society and environment.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**; *Interaction design.*

KEYWORDS

Automated driving, enactment, shared automated vehicles, inclusive design.

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1 INTRODUCTION

Automated driving frequently claims to be a disruptive technology that will not only increase drivers' safety and comfort, but also improve traffic flow and reduce air pollution [38]. Delivering these promises demands transformations in society, legislation, and individual mobility behavior. The implementation of technical advances typically allows multiple future realities and developments often come with great enthusiasm in early stages. For example, during the blooming period of the "Atomic Age" in the middle of the 20th century, scientists and designers promised nuclear powered automobiles, airplanes, and even household appliances [10, 41]. Similar enthusiasm seems to be put into automated driving (AD) technology. Beyond graspable concepts such as platooning [33] or shared mobility in first/last mile [9], futuristic plans describe ideas like dynamic lane reversal (lanes with changing driving directions based on demand/traffic volume) [56], managed intersections (vehicles passing the intersection in different directions simultaneously and with high speed) [1], or even self-driving homes and businesses [27, 55]. All these ideas should contribute to a more livable and sustainable world.

However, nobody can predict how a future with highly/fully automated vehicles (AVs) will actually look like in the long run. It is not clear whether AVs will increase or decrease congestion [11], pollution [64], or the number of vehicles/distance traveled [23]. Thus, the positive effect of AVs, for example, if they will contribute to a reduction of total emissions is at least questionable. The technology would allow several implementation scenarios, such as private vehicles (PAVs) with or without driving controls (steering wheel/pedals, etc.), but also forms of shared mobility, either in a private setting or as part of public transportation systems [37]. Although these variants will exist in the future side-by-side, one form of mobility will likely dominate – just as private, gas-powered vehicles dominate the markets today.

How transportation systems in the future will look like depends on various aspects (consumer demand, political/societal situation, economy, etc.), but there will be winners and losers in this transformation process. Relevant stakeholders include human users from diverse target groups, companies involved in the transportation sector, but ultimately also the environment itself. Recent studies suggest that the implementation of AVs will not necessarily change humans' mobility behavior and ownership models, and that a major risk of the technology is ultimately threatening public transportation rather than private vehicles [48], and the result may even *"reinforce the problems of car dependency, and its environmental, health-related, and social negative consequences"* [50].

We argue that it is also the responsibility of the scientific community to strive towards a livable future and, without doubts, the

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potentially most positive effects can be achieved when shared mobility and low private vehicle ownership will dominate future reality [37, 50]. Although this involves important decisions on different levels, including legislation, scientific project funding, etc.; consumers play an important role as those will finally favor the one or other mobility concept. Thus, it is important to identify their doubts and requirements in detail, thereby including target groups that have not been considered in the past to the necessary extent, such as women and minorities like immigrants [4, 17, 51]. In this work we compared potential future implementation scenarios of automated vehicles in a user study, which combined qualitative methods (interviews, enactment, UX cards) to identify relevant requirements to make shared automated vehicles (SAVs) successful. We included immigrants in our sample to address the need of a pluralistic viewpoint, rather than hypothesizing about potential differences.

2 ACCEPTABILITY AND USER NEEDS AS FACTORS FOR THE ADOPTION OF SUSTAINABLE AUTOMATED VEHICLES

Research has shown that the most sustainable and cost-effective transportation of the future are SAVs connected to public transportation to cover up for the first/last mile [9]. Thus, SAVs substituting trips in private vehicles should become an attractive alternative [18]. When predicting the role of public transportation (PT) in the future, the assertions are divergent: some claim that mass PT such as rails will be extincted by the introduction of AVs [67], others argue that the highest environmental and societal benefits will be achieved by AVs supplementing PT instead of replacing it [12, 19]. Researchers argue that the most important factor influencing traffic, pollution, as well as urban space occupied by cars [25] is the occupancy rate [12], which is just slightly above one persons per vehicle [40]. Hence, shared mobility will require high public acceptance to facilitate its proliferation. Several prior works have investigated user acceptance of AVs, frequently using online surveys [34, 35, 60]. Nordhoff et al. [46] propose a conceptual model for user acceptance of level 4 AVs and adopt a holistic view of user acceptance by adding a large number of factors that may determine acceptance. In their investigation of surveys on the acceptance of AVs Becker et al. [3] point out that apart from age and gender also the income influences the level of acceptance, and Rödel et al. [58] found that user acceptance and user experience (UX) of different levels of AVs are influenced by age, gender as well as participant's pre-experience with Advanced Driver Assistance Systems (ADAS). User acceptance of automated shuttles has also been evaluated in real environments. Wintersberger et al. [65] showed that potential users perceive this technology similar to human-driven taxi services, and participants of an interview study by Nordhoff et al. [45] expressed positive attitudes towards AVs as part of public transport systems. According to [62] the biggest obstacles concerning a successful dissemination of AVs are not technological but psychological ones. The future cannot be predicted for certain and at the moment highly and fully AVs are not expected on public roads in the near future. Therefore, and due to the hypothetical character that mobility implementations of AVs currently have, the framework of acceptance [61], which is defined as the attitude, behaviour and reaction towards an interactive system after having experienced it, is too early when comparing future implementation scenarios of AVs. Instead, and as a first step, we opted to explore the acceptability, which refers to the anticipated attitude that users have before having interacted with a product [59, 61]. Existing research underlines that psychological needs are regarded as important [24] and that these should be considered when designing products and interactions [20], as well as when investigating acceptability [15]. Frison et al. [20] emphasize the importance to take psychological needs [63] into account when designing interfaces in the context of AD and found that automation does not fulfill certain needs (competence, stimulation, autonomy and meaning), claiming that the fulfillment of other needs should mitigate appearing negative effects. Distler et al. [15] included UX cards [36] which are based on the user needs into the focus groups they conducted to evaluate users attitude towards Autonomous Mobility on Demand (AMoD). Both of these studies addressed certain forms of mobility individually, but, to the best of our knowledge, no studies directly compare different implementation scenarios. Yet, in order to ensure the successful advent of AVs in general and SAVs in particular, we have to understand which factors (i.e., underlying psychological needs) are relevant for peoples' transport decisions.

3 GENDER-INCLUSIVENESS AS A FACTOR FOR THE SUCCESSFUL ADOPTION OF SUSTAINABLE AUTOMATED VEHICLES

In public's adoption of technologies, gender plays a considerable role [31]. Therefore, it is necessary that developers, designers, and programmers include all gender's perspectives in the development process to ensure diversity and inclusion. Most recent research shows that society generally has a positive opinion about automated driving (AD) [5]. However, the most negative attitudes towards AVs [8, 29], the highest anxiety, and lowest pleasure [7, 26, 54] in the context of AVs are expressed by women. It is them who particularly articulate more safety concerns [53], concerns to the general use of AVs [66], and less trust [28] toward AVs. Women's adoption and enjoyment of self-driving cars is lower [32], they rate AVs as less necessary [43], and they are more worried and willing to pay less for them than men [35]. Females have good reasons for these negative attitudes towards AVs considering the male bias in the development of vehicles [17], as a 75% of the automotive industry is male-dominated and in the past mobility solutions have not necessarily been designed *"with the women in mind"* [53]. In addition, most of the above listed studies used quantitative methods, mostly (online-) surveys, and had more male participants than females. [53] criticizes that mobility as a gendered and embodied experienced cannot be depicted in surveys, arguing to use qualitative methods, such as enactments. Thus, to get insights how future scenarios could look like for both, males and females, we opted for a qualitative approach and included a balanced number of women and men in our study, including an enactment part to cover the embodied experience of a ride in future AV scenarios. Moreover, user enactments allow doing *"fieldwork of the future"* [47], meaning that not yet implemented technologies can be simulated. That way, first insights on how users will experience and interact with the technology can be gained. Subsequently, we aimed to analyse how

a potential interaction in private and shared travel modes might look like by putting them into relation in an enactment part. The enactment part is in line with Bardzell's Female HCI [2] theory, urging to take embodiment into account during the design process to ensure feminist interaction. In compliance with the Female HCI manifest, we additionally recruited participants from different age levels and from cultural backgrounds to assure for a pluralistic view.

4 USER STUDY

We conducted a qualitative user study with diverse participants (gender-balanced, including 3 immigrants) and asked them how their perfect form of transportation would look like in 20+ years, assuming driving automation to become a fail-safe technology. We presented different hypothetical implementation scenarios of AVs based on relevant literature [37], such as different forms of private (PAV) and shared AVs (SAVs) (see 4.2), included a short user enactment part to allow participants to emerge in such future scenarios, evaluated their mobility preferences and conducted interviews supported by UX cards [36] to identify relevant user needs contributing to their decisions. The results allow deriving requirements to be considered in the design of future shared automated vehicles.

4.1 Method and Research Question

We presented participants drawings (see Figure 1) and narratives (see 4.2 for abbreviated version) of four potential future AV scenarios to be ranked according to their personal preferences. Further, referring to claims from HCI researchers to include embodiment into research [2, 16, 57], and inspired by previous research work in the context of AD [13, 44, 52], we combined the following interviews with the method of enactment. In addition, we aimed to explore the effect of different mobility solutions on the fulfillment of psychological needs [63]. Hassenzahl et al. [24] argue that the application of psychological needs is a supportive method for products or solutions in the early analysis phase, making this approach suitable for exploration of possible AV variants. The study guide was developed iteratively; preliminary test sessions were conducted and the interview guideline and order of activities were respectively redefined. By evaluation of the obtained results (ranking of AV concepts, content analysis of interview statements, and underlying psychological needs), we aimed at answering the following research question:

RQ: Which future automated vehicle scenarios are preferred by potential users, and what are the underlying reasons for their decision?

4.2 Automated Vehicle Scenarios

The four future hypothetical scenarios presented to study participants incorporated their implications on different relevant parameters, such as their **potential for reducing traffic volume** (congestion, free space in urban environments), **controllability** (driver able to engage in driving), **privacy** (being alone or with familiar people vs. strangers), **ownership model** including consequences (leaving personal stuff in a private vehicle; remaining dirt/waste in shared vehicles), and **costs**. The scenarios were derived from Litman [37] as well as existing product images taken from the web (redrawn). Thereby, the following four scenarios have been illustrated with a description (narrative) and a sketch (see Figure 1):

- **Private Fully Automated Vehicles (FAV)**: In this scenario the vehicle drives exclusively in automated mode and vehicles are mostly privately owned (high costs). The driver has no option to control the vehicle, but plenty of space for non-driving related activities like sleeping, working, etc. Intelligent traffic control systems can fully operate traffic in order to reduce traffic jams. This mobility scenario is the most expensive one but it offers a lot of privacy and comfort. Such a form of future AVs is frequently outlined by car manufacturers (for example the Volvo 360c concept car[1]).
- **Private Highly Automated Vehicles (HAV)**: In this scenario it can be chosen whether to drive manually or in automated mode and the vehicles are mostly privately owned (high costs). Due to the possibility to intervene any time (for reasons such as the "fun of driving" [21]), intelligent traffic control systems can only partly manage traffic in order to reduce traffic jams due to the persisting possibility to drive in manual mode. On account of driving controls, the space is less customizable as the first scenario, while the other advantages/disadvantages are identical.

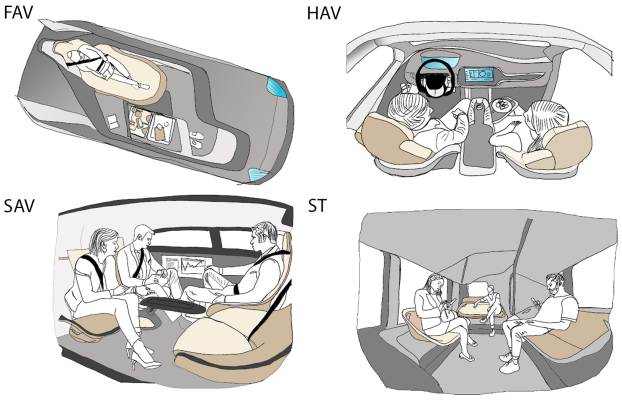

Figure 1: Four scenarios of the future of mobility in the context of AVs: (upper left) Private Fully Automated Vehicles (FAV), (upper right) Private Highly Automated Vehicles (HAV), (lower left) Shared Automated Vehicles (SAV), (lower right) Shared Automated Transit (ST).

- **Shared Automated Vehicles (SAV)**: In this scenario the vehicle drives exclusively in automated mode and the vehicles are owned by mobility providers (medium costs, payment on-demand or subscription based). Intelligent traffic control systems can fully operate traffic in order to reduce traffic jams. The vehicles can be booked for a single person or a group for any desired distance either in advance, or on-demand. Intelligent traffic control systems can fully operate traffic in order to reduce traffic jams.

[1] https://www.volvocars.com/intl/cars/concepts/360c?redirect=true

- **Shared Automated Transit (ST)**: In this scenario the vehicle drives exclusively in automated mode and the vehicles are owned by mobility providers. Intelligent traffic control systems can fully operate traffic in order to reduce traffic jams These SAVs are an extension of the public transportation (PT) and cover the first/last mile of an entire route. This mobility scenario is the cheapest one but has to be shared with strangers. In addition, it has the largest effect on space recovery in urban areas as most part of the trips carried out in PT.

4.3 Participants

In total, 11 participants (6 female, 5 male; from 21 to 57 years; M = 34.4; SD = 10.3 years) took part in this study. Participants consisted of university staff, students, and people interested in the topic. All participants were recruited through university's mailing-list and word-of-mouth and attended our study voluntarily and without any compensation. Their national background was German, Italian, Hungarian, and Portuguese, and all used public transportation and had a private car to their disposition. The study took place during the COVID-19 pandemic in early summer of 2020.

4.4 Procedure and Measurements

After a briefing and the signing of the consignment form we presented the four AV scenarios in randomized order. Participants were told that the narratives/sketches represent potential implementation scenarios in a distant (20+ years) future, and that during the whole interview they should not worry about technical limitations (i.e., doubts frequently expressed about AVs, such as bad sensors, faulty algorithms, etc.). The participants were then asked to sort the scenarios according to their personal preferences. Afterwards, the interview started and the interviewees were encouraged to speak openly on their own mobility preferences, their opinion on the four scenarios, and their expectations and concerns towards them. We also motivated them to tell us about the advantages and disadvantages of the respective scenario and how it would affect their own mobility, the society in general and elderly people and children in particular, the environment, and themselves in their gender roles.

As our pilot study showed enactment of all four scenarios being too time consuming and also sometimes confusing for our participants, we decided to embody one shared and one private AV for the subsequent enactment part (in randomized order). Thereby, we left some details open to our participants' imagination and preferences – for example, if the private AV should be fully automated or provide driving controls, or if the shared AV would allow to complete overall trips or is interconnected with PT. The only precondition for the shared AV was, that they had to share the ride with a stranger, enacted by one of the experimenters. By that we wanted to at least cover two contrary facets of private and public atmosphere. Participants were supposed to imagine a typical trip they would take in their real-life (see Figure 2). They were free to chose from a variety of props to take along, such as backpacks, bags, diaper bags, laptops, newspapers, books, coffee mugs, a baby doll (representing a child), a stroller, as well as a cuddly toy dog to make the experience as realistic as possible.

Figure 2: Examples of setup for the Shared Transit (ST) during the enactment.

Throughout the enactment part, we asked participants to speak aloud and express their expectations regarding selected topics. We asked them how they would imagine (a) to start the ride (i.e., booking or navigation), (b) how an optimal, but also a (c) dystopian experience would look like (and what can be done to reduce the chance of dystopian events happening). Afterwards, the psychological needs of each enacted scenario were explored by using Hassenzahl's UX cards toolbox [24]. The toolbox consists of eight cards representing the basic needs in the context of interactive systems as proposed by [63]: autonomy, competence, meaning, physicalness, popularity, relatedness, safety (please note that for this paper we used the term safety instead of the original term security to account for the safety-critical driving context), and stimulation. These cards were presented to our participants and they were invited to express which needs they believe being fulfilled, not fulfilled, or not relevant in both enacted scenarios (see Figure 3). Subsequently, each needs and scenarios were discussed in detail to reveal the underlying reasons. The whole process took about 90 minutes per participant.

Figure 3: Psychological needs sorted by fulfillment, non-fulfilment and non-relevance for the Shared Transit scenario (ST).

5 RESULTS

All interviews were audio recorded and the enactment parts were video recorded. The material was transcribed and analyzed using

qualitative content analysis [39]. We used inductive coding and refined themes and codes in an iterative process until the final themes and codes were identified. A Borda count analysis (see Table 1) of our participant's ranking of the four scenarios showed that SAV (SAV) and SA Transit (ST) systems were equally well evaluated (33 points), followed by the personal highly AVs (HAV; 28 points), and the fully automated AVs (FAV) as the least preferred solution (20 points). However, a statistical analysis of the orderings (Friedman tests) yielded no statistically significant effect.

Table 1: Borda Count Results of the Scenarios

SAV	ST	HAV	FAV
33	33	28	20

In the following we present our main findings (interview statements, enactment, and need card results) with their number of mentions and their number of participants (nm/np) resulting from the qualitative analysis of our material. Table 2 summarizes the advantages/disadvantages of the individual scenarios investigated and for which situations private and shared modes are suitable from our participants' point of view.

5.1 Private Automated Vehicles

The expressed advantages of PAVs were frequently personally flavoured. Participants emphasized the flexibility (22m/9p) and privacy aspects (15m/8p) as the main improvements. Flexibility thereby has different facets. Frequently, it was linked to the freedom of one's mobility in terms of when (permanent availability of the car), from where (i.e., directly from the garage or in front of one's door), where to (being completely free about chosen destinations), and how (navigation or relevant place en route) to go. In this regard, time was the most important resource which can be saved by private vehicle ownership, as it solved first/last mile issues. A mother of two children described it as follows: *"It is the flexibility and the freedom to decide when to drive [...emphasizing she has to balance between child care and work...] when a meeting lasts longer I have security that the car is waiting and my children don't have to wait because I missed a shared vehicle"* [P03, female]. The privacy aspect, defined as being alone or with family, comes along with a feeling of freedom (*"behaving like one wants to"* [P05, female]; *"being able to choose whom to take along"* [P08, male]), as well as increased productivity. Participants stated working as a major advantage of AVs and argued that private vehicles reduce disturbance from other passengers as experienced in public transportation. Another important aspect was higher security (13m/6p). Especially female participants depicted private vehicles as secure places (*"I feel secure because I have it for myself. In the evenings I see it as an advantage to be alone"*). During the interviews and enactments with our female participants a clear linkage between the self-perception as a woman and the importance of the feeling of security regarding their mobility became evident. Participants rated PAVs to be especially suitable for particular journeys, such as family trips, traveling, for situations with time pressure, within rural or suburban areas, as well as during the night (mentioned by female participants for security reasons).

However, also disadvantages of PAVs have been expressed by study participants. Those frequently had a societal flavor. Mainly environmental impacts (33m/9p) such as the higher number of vehicles in general or on the road (15m/8p) were emphasized, and especially the low occupancy rate was considered being a *"disaster for the environment and climate"* [P05, female], which clearly were important to them (*"To me, sustainability is important. The environment is important"* [P02, female]). Some also worried about social isolation (9m/5p) when everyone just uses their own car, and a social gap between people who can afford such *"luxury"* [P06, male] and others who would have to stick to SAVs or PT. Interestingly, it became evident that this luxuriousness was considered as a disadvantage (14m/8p) with participants stating that despite the aforementioned personal advantages they considered a private automated car as *"unnecessary"* [P06, male] and *"needless"* [P11, male].

Private Highly Automated Vehicles (HAV). Many interviewees favoured the highly over the fully automated vehicle with emotional arguments, stating that *"If I choose the version that is worse for the environment, then at least I want to have the fun of driving"* [P02, female] or *"I need to do something, I want to brake and steer. I would only tolerate the passivity within the shared version."*. Driving pleasure (11m/5p) and controllability (13m/7p) were highlighted as exclusive advantages of this vehicle type. Even some participants who preferred fully automated vehicles told us they like to drive and described it as stimulating, adventurous, and diverse as *"there is no ride like the other"* [P05, female]. Participants liked being able to accelerate, brake, and steer, as well as having the flexibility to spontaneously change the route. They compared the steering wheel with power and control that is lost in fully automated driving: *"We know [the steering wheel] well and it gives us control. We can drive as we want and where we want. [...] And in a couple of years there will be a bunch of people thinking of the 1980s and the music from the 1980s and think 'aw, how nice' and I think we will miss it. In [manual driving] we have power"* [P03, female]. Still, participants were aware of the disadvantages of such a situation. It was expressed that traffic systems could not fully exploit their advantages to optimize and reduce traffic (7m/5p), as this would be impaired by manually driven cars, which, on the other hand, would have a negative impact on the environment.

Private Fully Automated Vehicles (FAV). Statements in favor of vehicles without driving controls, in contrary, were more pragmatic. The ride with an automated vehicle was described to be a ride *"from A to B, not more not less"* [P08, male]. Participants liked being able to spend their time doing other things such as working or reading. Productivity and efficiency were frequently emphasized (18m/6p). Furthermore, mobility for everyone (20m/8p) independently of the physical/mental state or age was highlighted as important benefit of this scenario. Children, elderly and disabled people could use automated vehicles, as well as people without a driver's license. Also, being able to drive after restricting medical examinations or under the influence of alcohol were mentioned. Additionally, driving in automated mode was seen as convenient and also comfortable, due to the stressful character of manual driving (9m/6p). Some participants accentuated the increased safety (12m/7p) of the automated variant: *"The three completely automated versions are the safest."*

Table 2: Summary of advantages, disadvantages and the suitability of the different mobility implementations.

Private modes are suitable for... ... during the night, ... when under time pressure, ... for particular journeys such as family trips or travels, ... in suburban areas.	**Private Fully AVs (FAV)** + High flexibility + High autonomy + Highest privacy + High security + High safety + High hygienic conditions - Low sustainability - Highest costs	**Shared AVs (SAV)** + High sustainability + High safety + Low costs - Low flexibility - Low autonomy - Low security - Low privacy and efficiency - Low hygienic conditions	**Shared modes are suitable for...** ... during the day, ... when not under time pressure, ... for daily routines, such as going to work ... in urban areas.
	Private Highly AVs (HAV) + Fun of driving + Highest flexibility + Highest autonomy + High privacy + High security + High hygienic conditions - Lowest sustainability - Lowest safety - High costs	**Shared Transit (ST)** + Highest sustainability + Highest safety + Lowest costs - Lowest flexibility - Lowest autonomy - Lowest security - Lowest privacy and efficiency - Lowest hygienic conditions	

[P04, female] leading to fewer accidents and deaths. The increased safety was connected to the fact that other people were not able to drive. The driving style of other drivers was described as fast, reckless, even dangerous and this *"elimination of the human factor"* [P05, female] made our participants feel safer with an automated vehicle than with another human *"I feel safer as humans always make errors. I feel safer with the car than with people, people can be tired or crash against something by purpose."* [P07, female]. However, some participants criticized the automated systems as *"error-prone"* [P02, female] and trusted their own ability more (11m/5p): *"I can evaluate dangerous situations differently than an algorithm."* [P04, female].

5.2 Shared Automated Vehicles

Arguments for SAVs where often socially flavoured. The most frequently expressed benefit was their contribution to a more sustainable future (44m/11p), as they lead to a more balanced occupancy rate (11m/8p), fewer cars on the road (7m/5p), and consequently fewer pollution through traffic jams and emissions caused by the production of cars. In this context, it is worth mentioning that our data supports a *mind shift* towards more sustainability and environmental consciousness. In our participants we examined that owning a car is seen as something negative and egoistic whereas using a shared mobility version was equated with *"doing the right thing"* [P08, male]. As we explicitly asked for advantages of the different vehicle types for society, there might be some interviewer bias; however, participants also mentioned how they are perceived by other people such as friends and family (*"My friends would say: 'What? You don't have a car? Wow, you are so cool. How do you manage?'"*[P03, female]; *"Because it is reasonable. This one [private version] is the luxury version, but acting reasonably is more important to me. For the society, for the environment."* [P02, female]). Another advantage indicated by study participants addressed the financial benefits (14m/8p) emerging when not owning a private vehicle (*"I only have to pay for the distance I traveled that's all"* [P03, female]). Not having to bother with running costs and maintenance (7m/3p) would save even more money and personal resources making mobility in a car available to a broad public not only to the privileged ones that could afford it, thus, making it *"beneficial for everyone"*[P02, female]. Further, it was articulated that SAVs work best for daily routines such as the way to work, for situations with no time pressure, within urban areas, and during the day.

Unsurprisingly, the disadvantages (often personally flavoured) of SAVs oppose the advantages of private ownership: lower flexibility and availability (28m/7p) leading to more time and organizational effort (7m/3p) and a decreased efficiency (5m/3p) were described as especially cumbersome (*"I cannot just go there and take one. I have to plan and that is exhausting for me, because I have to plan many things anyway, the kids and so on, so this can be very exhausting."* [P03, female]). In the context of planning participants stated that they would need several information about the vehicle, such as the occupation and space of the vehicle (*"I want to know, if I have enough space with two persons and luggage. So I have to know, if another passenger is inside."* [P04, female]; *"I have two kids so I need a vehicle with three free seats, I couldn't book [a vehicle] with less."* [P03, female]). In this sense, an easy and straightforward booking process was seen as indispensable. Some participants stated complicated booking to be an obstacle for elderly or impaired people (6m/3p). Fast availability of the service was considered as important (18m/9p): *"The most important thing is that it is quickly [available] and in a given time frame. If I am planning half an hour and then it takes 20 minutes longer, then it's difficult, because then many things don't work out any more"* [P02, female].

Additionally, our sample commented on hygienic concerns (11m/8p) stressing the current pandemic situation due to COVID-19 and the probability of the cars being *"dirty"* [P03, female] and *"not conforming to hygienic standards"* [P10, male] because of the high fluctuation of people (*"In times of Corona this matters because people are sick and don't stick to the rules, so, yes, this is definitely a disadvantage."* [P01, female].

Shared Transit (ST). The most frequently expressed disadvantage of shared transit was linked to the presence of other passengers. Thereby, two main themes existed. First, some participants feared

becoming victim of crimes like pick-pocketing, harassment, or even rape and abduction (14m/6p), stating that the risk is comparable to PT. All but one of these statements were expressed by women, while the male proposition was *"This might be a problem for women I guess. I don't think about that."* [P09, male]. Women emphasized security concerns especially during the night *"It depends on the time of the day[...]. Especially in the night I want to know, which car is available and who is inside. And if maybe another, more suitable car [with only female passengers] will be available in 10 minutes."* [P04, female]. When asked how shared mobility should deal with such issues, participants emphasized to include a human fallback – either via camera, voice chat, or in-person. In this context, a button allowing to stop the car for safety (= accident prevention) or security (= prevention of crime) reasons, or to reach out to security personal was highlighted. Regarding privacy concerns about disclosing their address to other passengers, our interviewees were weighing off security and comfort. On the one hand, interviewees wished that the vehicle would pick them up or drop them off *"as close as possible"* [P09, male] or *"in front of the door."* [P08, male]. On the other hand, they did not want others to know where they got off: *"I don't want others to know where I live. I want it [SAV] to stop at home but only, if nobody is on board with me. Otherwise, it should stop one or two corners away."* [P04, female]. In this context, the system should offer enough flexibility: *"I would like to change the stop during the ride depending on who is inside [the SAV]."* [P08, male].

In contrast, the second main theme was only expressed by males. Those feared to be disturbed (5m/4p; noise, other passengers hopping on/off) by other passengers in their activities (such as working). Despite the disadvantages emerging from driving with strangers, this leads to advantages, too. In this light a connectedness with others was especially underlined by our participants (28m/9p). They liked encountering strangers and talk to them, listen to their opinions on things because it prevented them of being *"trapped in [their] own bubble"* [P07, female]. Some interviewees found it stimulating to see what others read or wear and especially enriching for elderly people and children. In this matter, it would be possible to offer help in case of emergencies such as, for example, an elderly person suddenly getting sick.

Shared Automated Vehicles (SAV). Beside the general advantages and disadvantages of shared mobility, some emphasized the flexibility (5m/4p) of this vehicle type as it could be booked when needed, making it more flexible than public transportation. It also was stated offering more security and privacy than shared transit.

5.3 Psychological Need Fulfillment

In the final session after the enactment part, we used UX cards to further collect participants' attitude towards PAVs and SAVs. For each of the needs, participants were encouraged to state whether they believe it fulfilled, not fulfilled, or not relevant in the given situation, and provide a justification for their decision. The results (need profiles and selected statements) can be seen in Figure 4 and Table 3. A statistical analysis (Stuart-Maxwell test) of the differences of non-/fulfillment of user needs in shared and private mobility modes were only significant for autonomy ($SM(df = 2, cat. = 3) = 6.0; p = .025$). Thus, the results are reported descriptively.

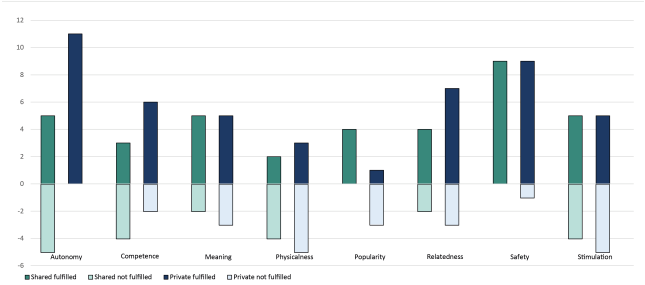

Figure 4: Fulfilled and not fulfilled psychological needs.

Autonomy is completely fulfilled for the private AV scenario and balanced out between fulfilled and not fulfilled for the SAV scenario. The high fulfillment of autonomy for PAVs is related to the high flexibility of this form of mobility. In SAVs our participants see their autonomy as less fulfilled as they consider themselves as highly dependent on the car's availability, route, and have no impact on who else they have to share the vehicle with. Nevertheless, half of our participants still rated their autonomy as fulfilled due to the freedom of choice to book it and when to book it.

Competency shows a higher fulfillment for PAVs than for the SAVs. This is connected to the fact that one is able to drive manually which requires certain skills. However, meaning, physicalness, relatedness, safety and stimulation are balanced out between shared and private AVs. Participants related meaning to the time one can spend with family and friends when the vehicle drives in automated mode. Physicalness is low for both scenarios due to the low physical effort that is needed for *"just sitting there"* [P05, female]. Safety is highly fulfilled for both scenarios and here is related to the high trust in the automated mode that our participants emphasized. Stimulation is balanced out between fulfilled and not fulfilled. In this context, our participants expressed that once one is used to AVs in general, the stimulation will decrease. In contrast to the aforementioned security aspect, no gender differences were found with respect to the need of safety. Overall, no differences between immigrants and non-immigrants emerged in our results.

Although only a subgroup considered the need for popularity as relevant, those four of eleven participants argued it being fulfilled in SAVs, and not fulfilled in PAVs. This highlights the before mentioned *mind shift*: vehicles seem to gradually loose their image of being a status symbol (only one participant stated a private vehicle would satisfy the need for popularity), while in the future, popularity may mean not to own a vehicle and utilize sustainable transportation.

6 DISCUSSION AND IMPLICATIONS

Overall, the obtained results indicate people's willingness to contribute to a more sustainable future by using shared mobility modes. This contradicts previous findings, for example, the works of Pakusch et al. [49], who conducted an online-survey and concluded that private cars will persist as the dominant mobility mode. In our experiment, shared mobility was perceived more positively – both shared variants received the highest score in a Borda count analysis of the ordered concepts, and participants expressed various advantages such as the largest positive impact on the environment,

Table 3: Non-/Fulfillment of psychological needs in the private and shared implementation scenarios and example statements of participants.

Need	Description [24]	PAVs +/-	Statements	SAVs +/-	Statements (if available)
Autonomy	Feeling like you are the cause of your own actions rather than the feeling that external forces or pressure are the cause of your actions.	+	„We can go when and where we want to. It is the freedom that we have nowadays in a regular car.“	+	„I can book it whenever I need it and I don't have to ask anyone whether he has time to drive me."
		-		-	„I don't have any influence on when and where to go because there are other people also.“
Competence	Feeling that you are capable and effective in your actions rather than feeling not competent or effective.	+	„Because I can drive manually and show, that I am capable of it.“	+	„I dare to use it, I engage in the aspect of sharing it and I am doing what's best for the society."
		-	„No, because I am acting in an egoistic way [when having a private car].“	-	„It drives itself. I don't have to have any competence to sit there."
Meaning	Feeling that you are developing your best potentials and making life meaningful rather than not getting anywhere and experiencing nothing of importance.	+	„It is more [than in SAVs] because I can listen to the music I want, or just dream.“	+	"I can focus on the people I am with."
		-	„I have a bad consciousness because I drive in my own car. It is bad for the environment."	-	"I don't know if it can have any meaning to drive from A to B."
Physicalness	Feeling that your body is healthy and well-taken care of rather than feeling out of shape or unhealthy.	+	„I am more relaxed due to the automated mode.“	+	„I don't have stress [of driving] and that is good for my body."
		-	„I only sit there. There is no fitness in that."	-	„Would rather be fulfilled when I ride by bike."
Popularity	Feeling that you are liked, respected, and have influence over others rather than feeling like a person whose advice or opinions nobody is interested in.	+	„I am popular, I am such a good driver."	+	„I am popular because I don't own a car and my friends say I am cool."
		-	„No, I would excuse myself for having a car and say, well, I have kids, live in the suburbs and commute 20 miles every day."	-	
Relatedness	Feeling that you have regular intimated contact with people who care about you rather than feeling lonely and uncared for.	+	„I can talk to my kids instead of having to drive [manually]."	+	„I am with other people, I have the chance to talk and relate to others."
		-	"No, it is not fulfilled here because I sit there alone. Everyone in his own car."	-	„I am together with strangers that I don't know."
Safety	Feeling safe and in control of your life rather than feeling uncertain and threatened by your circumstances.	+	"The automated part is safe, the one that takes over when I am not able to."	+	„The system works and there are not accidents."
		-	„Because of the human factor. The part that drives in automated mode is safe but the manual part is not safe."	-	
Stimulation	Feeling that you get plenty of enjoyment and pleasure rather than feeling bored and understimulated by life.	+	„I can have cool conversations when I don't have to concentrate on driving."	+	„You have the chance to get in touch with others and you are not in your own bubble but together with others.
		-	„Maybe it's stimulating in the first 10 minutes but then you get used to it."	-	„After taking it a couple of times it is not exciting anymore."

lower costs, or social benefits for everyone. We are well aware that the discrepancy to the findings of [49] could have been partly influenced by social desirability bias (anonymous online survey vs. interviews). However, we believe the result not only emerging from such a bias, as participants frequently emphasized the importance of making an environmental-friendly impression also to fellow friends or family, what indicates a *mind shift* towards more sustainable behavior in general. Another interesting finding regarding desired future AV scenarios is, that fully automated driving was rejected by many participants, what contradicts the expectations of vehicle manufacturers that have presented future concept cars. Although concerns such as the fear of loosing control or the fun of driving have been revealed in literature [21] already, we were surprised that participants expressed those also when imagining a much more distant future.

Despite the rankings, participants feared shared vehicles not being able to satisfy their need for autonomy as good as private vehicles. Shared mobility was not considered being flexible with respect to have control over when, from where, where to, and how to go. Participants feared not being able to exploit all benefits when driving with strangers because they might get disturbed or feel insecure. Summarizing, essential concerns towards shared mobility solutions were expressed by our participants, as well. Taking advantage of shared mobility in the future demands to take their anxieties seriously into account. Based on our qualitative insights, we have derived the following design requirements, which we believe to be highly relevant for the design of SAVs:

6.1 Maximize Autonomy for Diverse Target Groups

To make SAVs users' transport modality of choice, it will be necessary to design them as flexible as possible for the needs of the diverse user groups. Systems should provide options for customizing pick up and drop off locations, reservation of multiple seats, a possibility to pick up other passengers en route (for example, picking up children from school on the way home), and navigation details. Such requests should be supported by pre-scheduled, recurring, as well as on-demand service solutions. Thus, we claim the frequently used term "mobility-on-demand" to be misleading as it neglects highly relevant user needs – such services must not only be available on demand, they must allow precise planning for potentially complex situations.

6.2 Maintain Privacy and Efficiency, but also Relatedness

Brown et al. [6] found that time becomes less relevant if it can be used efficiently. An often mentioned advantage of AVs is the possibility to engage in non-driving related activities, such as working. However, it was emphasized by study participants that concentrated

work that conveys a feeling of efficiency is associated with privacy. In addition, also relatedness (i.e., having a peaceful chat with friends, children, etc.) can be increased through privacy. Thus, the interior designs of SAVs should support as much privacy as possible to support those needs, for example, by providing not only seats but also compartments. However, at the same time people increasingly fear being isolated in the future, and participants also mentioned positive aspects of driving with strangers. Systems should account for both aspects, for example by using social network services to match with other passenger of similar interests.

6.3 Increase the Feeling of Security/Safety

Security concerns were clearly gender-based. Our female participants expressed anxiety and fear when reflecting on the shared versions of mobility underlining the evenings or nights as the times of the day related to the most negative emotions. A broad spectrum of research in the PT area [30] shows that women's considerations in this regard is appropriate. In our study, women suggested a human fallback, someone who they could rely upon when riding with strangers, or cameras to prevent crimes (in line with existing studies [5, 22]). However, the analysis of our qualitative material goes beyond: to feel safe, women would like to have options such as being informed about the age/gender and number of other passengers in the vehicle, changing destinations during the trip, driving alone or with other females only (especially at night), or to share location/trip details with relatives, who are informed when they deviate from their planned path. Such options, even though they were mainly expressed by women in our interviews, could of course raise the feeling of security for other target groups, as well. Still, it will be important that these options are integrated in existing services rather than "special purpose" solutions to prevent gender-segregation or the infantilization of women as criticised by [14].

7 LIMITATIONS AND FUTURE WORK

The presented work has some limitations. Our study was conducted in Germany with a small sample, mainly participants employed at a university. Although we intentionally included immigrants in our sample, we plan to conduct this study with an even more diverse group of participants, in order to get a broader understanding of public's attitudes and user need fulfillment in different implementation scenarios of AVs. Our study included a small sample (N=11) with a high educational level who was recruited through university mailing lists and word-of-mouth, which might have lead to a self-selection bias and the inclusion of people already interested ind and motivated to use to use autonomous forms of transportation. Therefore, our results are not generalizable. However, our aim with this study was to explore the potentials of the different scenarios rather than generalizable results and we believe that this has no negative impact on the general insights of our work. Especially regarding the feeling of security of females a cross-cultural approach might provide additional insights. [30] report that women are exposed to sexual harassment in PT systems especially across Latin America. Thus, there might be cultural differences in the choice of PAV or SAV mobility modes and also in the fulfillment of user needs. Furthermore, all of our participants defined themselves as either male or female. In order to cover the whole gender aspect of mobility non-binary gender groups should also be included in future studies. We used a qualitative approach to get rich insights in the reasons for people's mobility choices. Thus, our results aimed to develop hypotheses [42] on why people prefer certain mobility implementations of AVs instead of quantitative, general results.

8 CONCLUSION

In this work we have explored people's preferred mobility modes of AVs in an imaginary distant future (20+ years). We wanted to gain rich insights on how people expect the implementation of AVs, as well how their attitude towards different implementation scenarios might influence their mobility choices. Thus, we followed a qualitative approach and combined in-depth interviews with an enactment part and the use of UX cards. Our results indicate that many users might be willed to used shared mobility in the future to contribute to a more livable world both for society and the environment. However, to translate such positive attitudes into actual behavior, SAVs must provide high flexibility to allow users maintaining full control of their mobility behavior. In addition, specific needs of diverse target groups, such as women, must be seriously taken into account. Expressed requirements include precise trip planning for multiple users (including other family members such as children) or changing drop-off locations, both on-demand but also in form of pre-scheduled bookings. Also privacy (for example, not being disturbed while working) and relatedness (getting into contact with other people) have to be balanced to raise acceptance in the future. Finally, various concerns regarding security have been expressed especially be female study participants. We argue to include a diverse variety of age groups, cultures, and educational levels in the early design process to make our mobility of the future accessible and desirable for everyone.

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