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Security Issues in Shared Automated Mobility Systems: A Feminist HCI Perspective

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Abstract: The spread of automated vehicles (AVs) is expected to disrupt our mobility behavior. Currently, a male bias is prevalent in the technology industry in general, and in the automotive industry in particular, mainly focusing on white men. This leads to an under-representation of groups of people with other social, physiological, and psychological characteristics. The advent of automated driving (AD) should be taken as an opportunity to mitigate this bias and consider a diverse variety of people within the development process. We conducted a qualitative, exploratory study to investigate how shared automated vehicles (SAVs) should be designed from a pluralistic perspective considering a holistic viewpoint on the whole passenger journey by including booking, pick-up, and drop-off points. Both, men and women, emphasized the importance of SAVs being flexible and clean, whereas security issues were mentioned exclusively by our female participants. While proposing different potential solutions to mitigate security matters, we discuss them through the lens of the feminist HCI framework.

Keywords: shared automated vehicles; feminist HCI; gender-bias; automated systems

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1. Introduction

AI-driven technology, with potential fields of application such as healthcare, finance, or law, is expected to penetrate our society in the future while making our lives easier. Automated vehicles (AVs) are another example and promise to increase drivers' safety and comfort, while also improving traffic flow and reducing air pollution [1]. An emerging problem with such systems, or to be precise, digital products in general, is that they are suspected to carry a white, male bias in them [2,3]. Such biases have been demonstrated in several real-life examples, such as face recognition software and soap dispensers struggling to detect darker skin tones, or AI-supported recruiting software sorting out female applicants [2,4]. These biases are not necessarily implemented by intention but can evolve due to the fact that the tech industry is dominated by a white male workforce [3,5], resulting in the over-representation of their specific points of view, while excluding individuals with other physical, psychological and social characteristics, such as people from other cultural backgrounds (e.g., Africans, Asians, Latin Americans), people with physical disabilities (e.g., blind people, people in wheelchairs), but also children and women. Given that the automotive industry is a highly male-dominated field, it is not surprising that the needs of other target groups are not always considered to the necessary extent. This is manifested in profane examples, such as the female crash test dummy that lies on the 5th percentile of the female body [6], which increases women's risk for severe injuries in traffic accidents [6,7]. Consequently, it is highly important to not make similar mistakes in the ongoing development of AV technology. We argue that the current interim status between the development and deployment of AVs is a great opportunity to overcome these and other existing biases in the transportation system. Recent research already indicates that women have a different

perception of AVs than men—they have a more negative attitude [8,9], experience more anxiety and less pleasure [10–12], while expressing more safety concerns [13,14] and less trust [15] towards this technology than men do. Furthermore, women may adopt and enjoy AVs less [16] than men. This is supported by recent surveys, where women rated this technology as less necessary [17], while being less willing to pay extra for AVs than men [18]. Thus, it is highly important to investigate the needs of women and design AVs in a way that supports their needs. Still, we want to emphasize that women are certainly not the only currently under-represented target group that must be considered for more inclusive mobility solutions, and the same applies for other potential user groups like children, elderly people, immigrants, lower socio-economic status individuals, or users with special needs. At the same time, it is unclear how automated vehicles will be implemented in the future, as the technology would allow multiple future scenarios [19]. One possibility would be private vehicles (with or without driving controls), but as soon as higher "levels of automation" [20] are technically feasible, shared mobility solutions will be plausible. Shared mobility could be implemented in a more private setting (i.e., booking individual vehicles for certain trips, just like booking an Uber or Lyft today), but also as an extension of public transportation ("shared transit" [19]). Although AV variants will likely exist side-by-side in the future, it is clear that the highest benefit of this technology, in terms of a reduction in congestion [21], pollution [22], or the number of vehicles/distances traveled [23,24], can be achieved with shared mobility. Consequently, designing shared mobility in a way to satisfy important user requirements is essential for their success on both the individual and the societal level, which forms the underlying research case of this work.

Accordingly, we aimed at deriving requirements for shared automated vehicles (SAVs) to satisfy relevant user needs from multiple perspectives. Therefore, we conducted a qualitative, exploratory user study and combined interviews, user enactment and UX cards to derive insights about the perceptions of shared mobility. First, we interviewed our participants on their opinion on shared versions of AVs and how these would change their own mobility. We then let them enact a ride with a SAV using a low-fidelity prototype and props and closed our session with a post-session interview using UX cards. Our results reveal a wide range of issues, requirements, but also potential solutions to mitigate these issues, which should be taken into account in future vehicle design. In addition, we took into consideration Bardzell's "feminist HCI qualities" [25], to identify potential positive and negative effects when implementing AVs according to the design suggestions expressed by study participants.Her framework proposes to focus on feminism while at the same time including scientific objectives. This allows us to discuss our findings through a feminist perspective and to derive system requirements that do not continue with the biases that are perpetuated in the status quo transportation system.

2. Related Work

Given that nobody can predict how a future with highly or fully automated vehicles (AVs) will actually look like in the long run, it is unclear to which degree AVs can contribute to a more sustainable future by reducing pollution [22], congestion [21], or the number of vehicles/distance traveled [23,24]. Thus, some of the positive effects of AVs (e.g., if they will contribute to a reduction in total emissions is at least questionable. Nevertheless, most likely benefits can be optimized if shared mobility and low private vehicle ownership will dominate future reality [19,26]. In this context, not only the sharing of vehicles but the sharing of rides is of particular importance [27], making this mobility mode similar to existing forms of public transportation (PT). Although the implementation of a specific form of automated transportation 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, as described above.

2.1. Gendered Mobility Patterns

Women, children, or minorities will have other requirements than wealthy and tech-savvy men. In the context of gendered mobility and considering that women usually have lower access to a private car [7], SAVs become even more important. Interestingly, women's opinion on shared mobility solutions are contrasting: Delhomme et al. [28] evaluated that women's readiness to use car-sharing is higher than men's due to the fact that they emphasize more on environmental protection and saving fuel consumption. This suggests that they might be more willing to use shared versions of AVs, as well. Indeed, a study in Chicago revealed Uber Pool—Uber's ridesharing carpooling service where a driver picks up multiple passengers going in the same direction—is being considerably faster than public transportation for short trips around the neighbourhood [29]. Since these are the trips especially performed by women, SAVs might be a convenient mode of transportation especially for them. On the other hand, the dependency on other passengers is expected to make shared services unsuitable for the time-sensitive character of female's trip-chaining behaviors [30]. Pettigrew et al. [31] underline that women will more likely adopt SAVs than men but only if these are designed focusing on everyday and social trips. To understand the distinctions between how women and men travel, it has to be considered that their mobility patterns result from prevalent gender patterns in our society. Women all over the world cover for 75% of unpaid work [32] defined as housework, childcare or elderly care, shopping, other tasks around the house, and family, as well as honorary positions, with the latter accounting for the tiniest part. As a result, women trip-chain more [33,34], which means they usually take several short trips around their neighbourhood to combine their abundant duties. For example, women drop off children at daycare or school on their way to work, or go grocery shopping and other errands on their way home. Compared to men, they walk more and their space of movement is more centered around the neighborhood, whereas men frequently take fewer and longer trips in terms of time and distance. It is also women who travel accompanied by children or elderly more often than men, and it is them who carry more luggage with them. Their responsibilities within the unpaid care work many times drives women to opt for part-time jobs, which, in combination with the gender pay gap, results in having less economical power than men [32]. As a consequence, women have less money at their disposal for mobility. It has been demonstrated that even in Western countries, which supposedly are more gender equal, it is the man that primarily has access to the household's car given that only one car is available [7]. Perhaps it is a combination of both facts that leads females to use public transportation more [34]. It is women who make up two thirds of public transportation users [35]. In this context, we would like to point to [36], who conducted an exploratory user study on parents' decisions about allowing their child to ride in an AV unaccompanied. We hypothesize that children being able to drive without their parents could take a considerable amount of responsibility off women who are the ones that usually take their kids from A to B.

2.2. Gender Bias in Public Transportation

Several examples in PT research show, that in the past women have not been sufficiently considered in the planning process. In London, bus passengers were charged every time they boarded a new bus, especially affecting women and their trip-chaining routines. This changed for the better in 2016 with the introduction of the 'hopper fare', allowing passengers to use one ticket for two trips within one hour [7]. Moreover, the reformation of the PT system in Medellín in Colombia [37] neglected the commutes of domestic workers—consisting of low-income women. Through focusing on the male workers traveling from low-income areas to the industrial zone, female workers have not been considered during the redesign, resulting in an increase in travel time, cost, and effort for this group. Despite being the ones using PT systems more, simultaneously, women all over the world are exposed to gender violence in such situations [34]. This does not solely include physical abuse but also visual and verbal abuses, such as cat calling, staring, stalking, and inappropriate touching [38]. These experiences make women and girls feel less secure in PT. Although

females in Latin America and India are the ones that statistically run higher risks of becoming victims of sexual violence when using PT [34], women in general, due to their physical characteristics, feel more vulnerable than men do [39]. Thus, women in countries generally considered to be safer, such as EU member states, feel insecure in transit environments. This leads them to the adoption of strategies to avoid these negative feelings, such as not using buses or metros during certain times of the day or night, avoiding certain stations by accepting detours to other stations, altering their clothes [38], or—in the worst of all cases—by not traveling at all and excluding themselves from a participation in public and professional life [7,34]. In addition, this is especially true for older women, who, generally, give up driving a car earlier than men do [34]. Several solutions measurably lower these feelings of insecurity, such as appropriate lighting of PT stations and their surroundings, the location of PT stations themselves (e.g., positioning stops at more frequented locations), or bus stops in between formal stops [34]. Nevertheless, statistics demonstrate that these interventions only address the tip of the iceberg [7,34,35].

2.3. Taking a Qualitative and Holistic Approach to Ensure Pluralism

In public's adoption of technologies, gender plays a considerable role [40]. Therefore, it is necessary that developers, designers, and programmers include all gender's perspectives in the development process to ensure diversity and inclusion. Females have good reasons for these negative attitudes towards AVs considering the male bias in the development of vehicles [30], as 75% of the automotive industry is male-dominated and in the past mobility solutions have not necessarily been designed *with the women in mind* [13]. In addition, research in the field of AD mainly uses quantitative methods, mostly (online-) surveys, and more male participants than females [41]. Pflugfelder [13] 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, men and women, we opt for a qualitative approach that includes a balanced number of women and men. Moreover, user enactments allow doing *"fieldwork of the future"* [42], 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 analyze 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 feminist HCI [25] theory, urging to take embodiment into account during the design process. In this framework, a set of qualities is presented including pluralism, participation, advocacy, ecology, and embodiment. Pluralism, as argued in the framework, consists in including a variety of viewpoints into research because "human" as in human-centered design is too diverse, too "complex and diverse to bear a universal solution." [25]. Participation "refers to valuing participatory processes that lead to the creation and evaluation of design prototypes" [25] and stimulates pluralism. We addressed this quality by including a user enactment part where our participants created and evaluated how a ride with a SAV could be and should be from their perspective. Ecology supports a more holistic viewpoint considering how a technology also shapes the environment in which it is used, whereas advocacy ensures feminist designs to not only promote political emancipation but additionally challenges researchers to verify their own viewpoints by taking ethics into account and question how to achieve an "improved society" [25] without imposing their own biases. Furthermore, the "development on the quality of embodiment, needs to push embodiment in the direction of gender commonalities and differences, gender identity, human sexuality, pleasure and desire, and emotion" [25]. As Bardzell argues much has been done recently to overcome the purely disembodied view on the user and by conducting a user enactment we aspire to contribute to a more embodied view on the user experience with a SAV. Although ecology and advocacy are mainly handled in our discussions section, the qualities of pluralism, participation, and embodiment are tackled by the methods we used (user enactment) and the diverse and gender-balanced sample we intentionally included into our exploratory research. The framework aims to contribute

on two levels: (1) critique-based contributions to analyze design processes in order to bring negative consequences to light, and (2) generative contributions that apply feminist approaches in decision-making and design processes. These contributions support the analysis of user needs and requirements and open up design opportunities. In this paper we took a pluralistic standpoint by including different genders and cultural backgrounds into our study. From our findings we derived design implications that the feminist HCI framework allowed us to reflect upon in our discussion. With our reflection upon possible design solutions we want to contribute substantially to the development of SAVs by critically questioning them. The manifest has recently been widely discussed [43,44] and Chivukula's and Gray's [45] literature review on papers citing the manifest revealed that the papers mostly pointed to her framework while not applying it extensively or explicitly. With this paper we aim to close the gap by addressing the two contributions mentioned in the previous paragraph and to comply with Bardzell's manifest that rejects universal designs.

Considering the above-mentioned issues, we investigated potential users' perceptions of SAVs in a user study, which combined qualitative methods (interviews, enactment, UX cards) to identify relevant requirements from multiple perspectives. We were particularly interested in what factors might keep people from using SAVs and how a ride should be designed from participant's point of view. Therefore, we analyzed the journey from a holistic angle considering the booking, departure, and arrival, as well as the ride in the vehicle itself.

3. User Study

We invited a sample of diverse participants (gender-balanced, including 3 immigrants) and asked them how their perfect form of transportation would look like in the future, assuming driving automation has become a fail-safe technology. After an introductory interview, we included a user enactment part to allow participants to emerge in AV scenarios. Participants of the experiment were not solely questioned about SAVs—we also evaluated their perception of private automated vehicles in both the interviews and enactment parts. However, in this paper we focus only on results that have implications for the design of shared mobility and that came up during the enactment part of our study.

3.1. Method and Research Question

We presented participants two variants of shared mobility solutions in the context of AVs: shared automated vehicles (SAVs) and shared transit (ST). In both scenarios, the vehicles exclusively drive in automated mode. The SAVs can be booked for a single person or a group for any desired distance either in advance or on-demand. This reduces travel costs (compared to privately owned vehicles) and has positive effects on the environment (less vehicles need to be produced, less parking space required, higher utilization). In the ST scenario, vehicles 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 vehicles occasionally have to be shared with strangers. In addition, it has the largest effect on the environment and space recovery in urban areas, as most part of the trips are carried out in PT. Further, referring to claims from HCI researchers to include embodiment into research [25,46,47], and inspired by previous research work in the context of AD [48–50], we combined the interviews with the method of enactment (see Section 3.3). The study guide was developed iteratively; preliminary test sessions were conducted and the interview guideline and order of activities were, respectively, redefined. By the evaluation of the obtained results (content analysis of interview statements and enactments using inductive coding), we aimed at answering our main research question (RQ): How should shared automated mobility be designed from a pluralistic perspective?

3.2. Participants

In total, 11 participants (6 female, 5 male; from 21 to 57 years; $M = 34.4$; $SD = 10.3$ years) from different cultural backgrounds (German, Hungarian, Italian, and Portuguese) took part in this study. Our participants were mainly university staff, students, or people interested in the topic. All participants were recruited through the university's mailing-list and word-of-mouth and attended our study voluntarily and without any compensation. Our study was conducted in summer 2020 during the COVID-19 pandemic when in Germany the number of cases was very low and it was allowed for up to 10 people to be together in one room. The study was conducted in a hall and distances between the researchers and the participants were complied with. After each participant the chairs, table, and used props were disinfected to prevent participants and researchers being exposed to the risk of contagion. Although all participants were from Western countries, we included 3 migrants from Hungary, Italy, and Portugal. They all used PT and had access to a private car.

3.3. Procedure and Measurements

After an introductory briefing (including written consent) we conducted an in-depth, semi-structured interview about participant's mobility preferences, their opinion on shared automated mobility solutions, and how these would change their mobility in positive or negative ways. Participants were told to imagine two potential implementation scenarios of shared automated vehicles (SAVs and ST) in the 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 interviewees were encouraged to speak openly on their own mobility preferences, their opinion on the scenarios and their expectations and concerns towards them. We also motivated them to tell us about the advantages and disadvantages of these scenarios 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. During the subsequent enactment part participants embodied one shared AV scenario. Some details, such as whether the shared AV would allow to complete overall trips or is interconnected with PT, were left open to our participants and we asked them to enact a typical ride they take in everyday life. Thus, a variety of trips was enacted, such as picking up kids on the way home from work, going to work in the morning, going to university, or going on a leisure trip. The only precondition for the shared AV was, that they had to share the ride with a stranger, represented by one of the experimenters. We offered our participants 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. After boarding the SAV, we emphasized participants to imagine a typical trip they would take in their real-life (see Figure 1).

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 (i.e., utopian), but also a (c) dystopian, experience would look like (and what can be done to reduce the chance of dystopian events happening), thus meeting the urge for participation [25]. The sessions were finished with a short interview part talking about the experiences during the enactment. The whole process took about 90 min per participant.

Figure 1. In the enactment part, participants were equipped with self-selected props and simulated a trip in an SAV shared with a stranger (enacted by one of our experimenters).

4. Results

All interviews were audio recorded and the enactment parts were video recorded. The material was transcribed and analyzed using qualitative content analysis [51] and the inductive codes were generated in an iterative process. During the enactment part our participants played different daily travel routes such as going from home to work, going from work to pick up the kids from school, traveling to see acquaintances and friends, or going from home to an excursion on a weekend. In the following we present our main findings (statements expressed during the interviews and enactment) with their number of mentions (n) and number of female and male participants mentioning them. Furthermore, we derived a passenger journey including utopian and dystopian scenes from our qualitative results (see Figure 2). We clustered the results into the four important phases booking process, pick-up and boarding, riding, as well as arrival and disembarking.

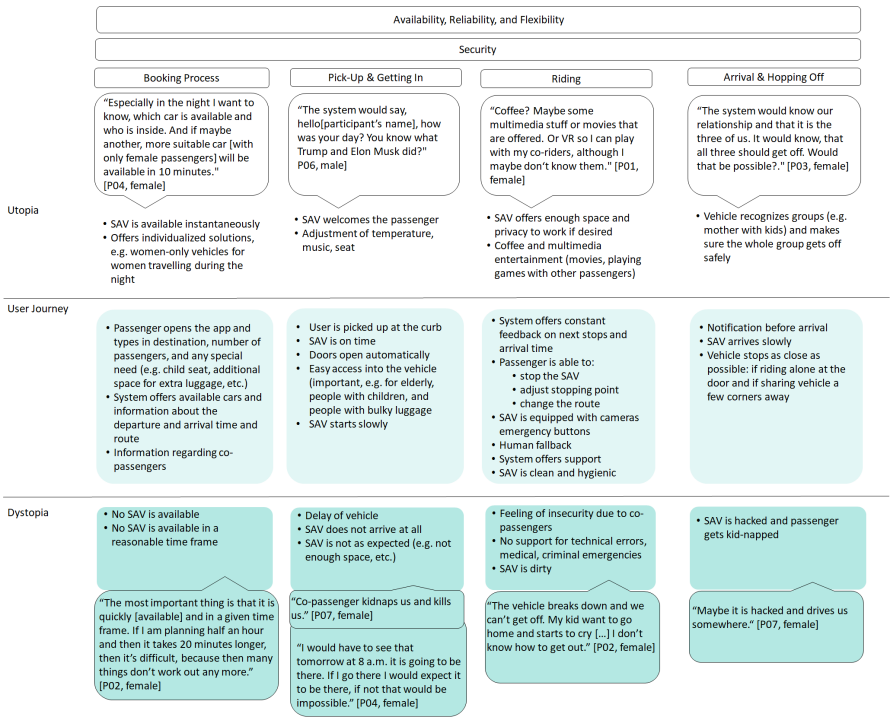

Figure 2. Derived passenger journey derived from participants' statements, structured according to the different phases of a trip. Statements referring to utopian (**top**) and dystopian (**bottom**) fantasies were integrated to derive common themes. Derived design requirements are visible in the center.

4.1. Booking Process

During the booking process, the most important factor indicated by our study participants was time (n = 54). Either a SAV was booked beforehand or on-demand, the information on the departure of the vehicle (n = 8, 4 female, 4 male), the duration of the ride (n = 8, 4 female, 4 male), and its arrival (n = 9, 4 female, 5 male) were emphasized. It was considered important to know when the vehicle would arrive to pick them up and when it would drop them off at their destination. In this regard, study participants especially emphasized how important the reliability of the arrival time would be to them (n = 12, 4 female, 4 male) and that it would be available within a short period of time (n = 18, 6 female, 5 male).

4.1.1. Information about Other Passengers

Our participants expected to have information on the vehicle's occupation with other passengers during the booking process (n = 13, 3 female, 2 male). They wished to know whether someone is already inside the vehicle when they got on, whether someone would join the ride and where, and the destination the other person had. On the one hand, our participants reasoned with pragmatic motivations such as checking the vehicle's capacity when planning a ride for the family (*"I have two kids so I need a vehicle with three free seats, I couldn't book [a vehicle] with less."* P03, female), or when traveling with luggage (*"How many people are in the vehicle? Maybe I want to take my bike along or a lot of luggage."* P01, female). On the other hand, the presence of other passengers was also linked to security concerns (*"It is also an issue of security, so you know what you should expect."* P01, female). Some participants feared becoming victims of crimes like pick-pocketing, harassment, or even rape and abduction (n = 14, 6 female, 1 male), 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 [...] during the day the destination of the person is enough —but in the night I would want to know how many people, their age, their gender. Then it would also be okay to reveal this information [about myself]."* P07, female. During the enactment our female participants engaged in the situation of traveling alone during the night and elaborated on the system supporting them proactively by offering more suitable compositions of passenger groups for specific situations, such as, for example, vehicles for women only: *"[...] 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 min. Then I'd rather wait."* P04, female.

4.2. Pick-Up and Boarding

Participants expected the vehicle to give them constant feedback on the arrival status of the vehicles (n = 9, 4 female, 5 male), which they supposed would pick them up at the curb. Doors should open automatically and an easy access (n = 3, 2 female, 1 male) was presumed so one could enter the vehicle even when carrying bulky luggage, being accompanied by children or elderly passengers, or when carrying a stroller or walker. After being seated, people expected the vehicle to start smoothly instead of abruptly (n = 3, 2 female). Here, again time was mentioned frequently (n = 18, 6 female, 5 male) and a late arrival or no arrival at all were considered as *"impossible"* P04, female. Additionally, it was emphasized that it should be made sure the booked vehicle with the necessary capacity should arrive (n = 5, 2 female, 2 male). Inside the vehicle participants expected a personalized welcoming message (n = 5, 2 female, 1 male): *"It would be nice if the vehicle would say something like: 'Good morning Mrs. [participant's name], I wish you a pleasant ride."'* P07, female.

4.3. Riding

When en route, participants anticipated to have abundant offerings of distractions (n = 11, 5 female, 2 male) such as music, films, or multimedia entertainment that they

could either consume by themselves or share with their co-passengers. Even coffee was mentioned as a comforting factor.

4.3.1. Route

Unsurprisingly, people are unfamiliar with the fact that SAV and ST systems may not have fixed routes but depend on the individual destinations of the passengers (n = 12, 3 female, 4 male). Certainly, study participants wished to have knowledge of the route already during the booking process (n = 8, 3 female, 3 male) and required to be kept up-to-date on it during the ride: *"Hold on a sec, these vehicles don't have a fixed route, it depends on who will be picked up. It would be good to know which stop or street it is heading to next."* P05, female. Likewise, participants wanted to take advantage of the freedom that no given routes provided and expected the system to provide the flexibility of changing routes and stops "on-the-fly" depending on the situation. This was true for cases of (medical) emergencies (*"I want to get off when I get sick, for example"* P07, female), as well as for adjusting the stop to the individual preferences (*"I still want to decide for myself. If I suddenly think that I need flowers and there's a flower shop in front or if my child gets sick or spills something. That I [am able to] intervene."* P04, female).

4.3.2. Handling Safety and Security Issues

When asked how shared mobility should deal with safety (=accident prevention) and security (=prevention of crime) [34] issues, participants emphasized to include an interaction with a human fallback (n = 11, 5 female, 2 male). Even presupposing cameras, such as in today's PT systems, they expressed concerns about the absence of any kind of security-staff (n = 8, female 5): *"In the bus there is at least the bus driver who would stand up for me, but here not. Some sort of surveillance system would be good, a camera and an emergency button. That would give me a feeling of security but I would need to know that it really works."* P05, female. During the enactment, a button allowing to stop the car for safety or security reasons was highlighted (n = 10, 4 female, 3 male). Participants were intuitively "pressing" an emergency knob either right next to them or under their seats in order to reach out for help that—as subsequently explained—they imagined to be some kind of security personnel. Correspondingly, participants expected an interaction with a human either asking what the problem was, giving feedback on the situation, or proactively communicating that help was already underway. Multiple interaction modalities, such as a camera, voice chat, or in-person, were proposed in this context all having in common involving a "real" human (*"I want to talk to a person from the company."* P07, female, *"I want to speak to a person —not a system."* P08, male).

4.3.3. Cleanliness of the SAVs

Regarding SAVs our participants expressed hygiene concerns (n = 11, 4 female, 5 male). Due to extensive use and high fluctuation of people, the vehicles would be dirty and worn-away: *"Usually there is no hygieniec standard. People treat things differently when they not own them and that's why [PT] is so dirty."* P10, male. Hereby, they attributed responsibility to other passengers, as well as the service providers: *"It will probably depend on the company how clean they are. I guess there will be different types and tariffs."* P08, male. Stressing the current pandemic situation due to COVID-19, our sample mentioned even further concerns: (*"In times of the Coronavirus, this matters because people are sick and don't stick to the rules, so, yes, this is definitely a disadvantage."* P01, female. Again, the SAVs were compared to PT with its disadvantages: *"They should be cleaner than trains."* P11, male.

4.4. Arrival and Disembarking

4.4.1. Arrival Time

During the ride itself our study participants expected the system to deliver constant feedback on the time of arrival (n = 17, 6 female, 5 male). Our sample indicated ambiguity regarding how the system should provide this information. Some participants supposed

the information would be displayed on some kind of screen (n = 12, 4 female, 4 male), or via voice (n = 8, 2 female, 3 male), whereas others imagined details were not exposed to all passengers but rather provided to them individually via their smartphone (n = 8, 2 female, 3 male). Especially when traveling with children or luggage, participants desired a notification before the arrival to be able to prepare themselves to get off (n = 6, 2 female, 4 male): *"I have to prepare my kids for getting off at least one minute before, with the backpacks and all. I have to anticipate the [exact] arrival."* P03, female. In this context it would be helpful for passengers that the system would recognize groups to assure that no group member—especially a kid or elderly passenger—is left behind.

4.4.2. Privacy Concerns Regarding Stopping Points

Regarding the stopping points of the SAVs, privacy concerns about disclosing their address to other passengers, our interviewees were trading off security and comfort. On the one hand, interviewees wished that the vehicle would pick them up or drop them off in front of their door (n = 18, 6 female, 5 male) or *"as close as possible"* P09, male. On the other hand, they did not want others to know where they got off (n = 15, female 5, male 4). This was highly dependent on the context. For example, during the day, females would rather get off a few corners away from their home and take the burden to walk the last bit: *"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 contrast, in the evenings or nights, which are the times of the day where most security issues were mentioned, our female participants emphasized they would want the vehicle to drive them directly in front of their home to not have to walk the last bit on their own. Furthermore, the exact stopping point also depends on the other passengers sharing the ride. In that regard, if traveling with *"a certain type"* P07, female, the system should offer enough flexibility to change the exact location of the stop: *"I would like to change the stop during the ride depending on who is inside [the SAV]."* P08, male. Here, our participants elaborated on the fact that even if the system would not display their private address to other passengers, these would know where they lived when they got off: *"Maybe I can anonymize my stop in the settings? But when I get off, he would know anyway."* P04, female. It is particularly worth mentioning that whereas security concerns were mentioned exclusively by our female participants (see Section 4.1.1), privacy concerns regarding the disclosure of one's address were expressed by men and women alike.

5. Discussion

Including a diverse sample does not necessarily imply finding differences between their perceptions—for example, we did not see differences between immigrants and local participants of our study. We did not aim to find differences between different cultural backgrounds or genders but included them to ensure a pluralistic viewpoint on SAV requirements and the reasons why people would adopt them, or not. Unsurprisingly, and in line with our related work, we found distinctions related to security issues which had a high priority for our female participants. All other topics where equivalently expressed by males and females. In the following we will derive system requirements for shared AVs and discuss our results through the lens of Bardzell's feminist HCI qualities (pluralism, participation, ecology, advocacy) [25]. In this theory, pluralism refers to adding multiple viewpoints in the design and research process, participation means appreciating participatory processes which promote the quality of advocacy which, in turn, supports the researcher to question his or her standpoint and to what type of society his or her designs might lead [25]. Ecology refers to the broad spectrum of stakeholders implied in the development and evaluation of designs and the artifacts involved [25]. Although the qualities pluralism (including a diverse sample) and participation (enactment and interviews) have been included in the design of our experiment, we address the advocacy and ecology in the following discussion, where we present a requirements catalogue and open questions for shared automated mobility solutions in general (either SAVs or ST). We start with

topics applying to all phases of the ride (booking process, pick-up and boarding, riding, and arrival and disembarking) and finish with arguments concerning specific phases of the ride.

5.1. Availability, Reliability, and Flexibility

Availability has been emphasized by our participants in several contexts: when using shared mobility solutions it would be important that vehicles would be available and that they would be available within a given time frame. Participants also wanted to be able to rely upon the mobility solution. The vehicle should arrive on time, it has to be the one that passenger ordered, and with the seats he or she ordered to allow for precise planning and a smooth work–life balance. In our view, this demands to rethink the labelling of SAVs, which are often called "on-demand" solutions. In fact, for many participants it is important to schedule and plan upcoming trips in detail in advance. Thus, SAVs must provide much more flexible booking options than what one would typically understand by "on demand". Additionally, en route, the vehicles should allow for flexibility: participants wished to be able to change routes and stops, to get off earlier, and to adjust the disclosure of their stopping points to other passengers. From our point of view, such flexibility should be gone through by taking into account the quality of ecology. Although such options make perfect sense from the perspective of a single individual, we believe it to be difficult to simultaneously act upon such desires when multiple passengers are on board, as such requests would reduce predictability for both the involved passengers and the service itself. However, passengers' desire for high flexibility might be addressed more holistically, for example, by including several artifacts, such as adjustment of the seats, temperature, multi-media offerings, or (as described above), by offering personalized adjustments already in the booking process. Especially flexible configuration of the compartment could account for participants' needs: sometimes, passengers prefer privacy to relax, work, or be with their friends and family, other times they enjoy to relate to strangers. Here, several solutions already have been proposed [52] and we would like to highlight Layer's Jon [53] solution that has been inspired by airplane cabins and allows for opening or closing the personal area of each seat by pushing or pulling the "wings" attached to each seat.

5.2. Security

Security topics in the context of shared rides have different characteristics and are important during the whole journey, from the booking process over the whole trip, until the time of disembarking the vehicle. During the ride passengers were presupposing cameras but they additionally wished for safety and security buttons that would allow them to call for help actively. In this context the participants clearly expressed they would want to communicate with a human. Although the installation of cameras and safety buttons measurably helps [34], our findings confirm that especially women expect to have a human that would help them [7,54]. However, the analysis of our qualitative material goes beyond: to feel safe, women would like to change destinations during the trip, drive alone or with other women only (especially at night), or share location/trip details with relatives. It has already been studied that getting in touch via ICTs with family or friends when not feeling secure is an often applied strategy [55]. Approaches addressing this already exist, such as Uber offering the possibility to share information on the trip with up to five trusted contacts. Future work could focus on how solutions inside AVs could support the feeling of having a social network to rely on while traveling on one's own by designing ICT solutions that foster the feeling of being "accompanied". Although security issues are relevant throughout the trip, a high feeling of being secure could be already guaranteed by a proper booking process, as discussed in the next section.

5.3. Booking Process

The booking and reservation of seats in an automated shuttle has been studied by [56], who found that a freedom of seat choice mattered to people. We additionally identified

women's desire to get information about co-passengers before entering the vehicle to feel more secure. However, this need falls into the category of privacy vs. security dilemmas: on the one hand, it is important to have information about co-passengers, on the other hand, our data showed considerable privacy concerns regarding disclosing their private address to others. Thus, it is indispensable to study which information would support passengers' need for security in their decision of whether to book a vehicle or opt for another one (e.g., a woman choosing a vehicle with only other women as co-passengers during the night or when traveling alone), while also identifying which information people are willing to reveal about themselves in the first place. Here, a balance between an increased security feeling and privacy concerns has to be found. However, we feel this need must also be discussed through the lens of advocacy. Let us imagine the consequences of people deciding for or against a vehicle based on personal characteristics of other passengers—could this lead to a society where race, gender, and class are segregated? Could this lead to a disadvantage for some passengers, for example, when their bodies, clothing, etc. do not comply with certain "norms"? In the worst case, the cost for a slightly higher feeling of security could be a loss of privacy and inclusiveness—consequences we would definitely reject. Ge et al. [57] already revealed a racial discrimination in Uber and Lyft drivers putting African-American passengers at disadvantages by cancelling accepted rides after reading their African American-sounding names in the booking app. Taking a feminist point of view on this important issue, we reason that other solutions have to be designed to foster security feelings in SAVs and ST and these solutions under no circumstances should exclude groups with certain physical, psychological, or social characteristics.

We would like to push the discussion even further and reflect upon the possibility of a rating system. Evidence exists that Uber drivers do not rate passengers negatively even though these might have behaved inappropriately because they feared getting a low rating back. Ruha Benjamin [2] discusses how rating systems might impose discrimination in societies while referencing "Nosedive", an episode of the series "Black Mirror". In the episode the protagonist Lacie lives in a society where every interaction is being rated and people have access to privileges according to their rank. After losing her high level ranking due to a series of unlucky incidents she finds herself being cut off from mobility: the last available seat in the plane that would fly her to the wedding of a friend is only available for people with higher rankings so she has to queue for a low quality car with no comfort in front of the car rental service. Thus, and within the scope of advocacy we support an anonymous booking system for SAV and ST solutions to make them accessible for everyone, just like PT is today. In this context, another solution which should be reflected upon is the women-only SAV mentioned by our female participants for certain times of the day or trips. This is again an approach that has been proposed [52] and implemented several times and that has its advantages, as well as its disadvantages: Delatte et al. [58] argue that while ensuring privacy and security, the "Pink Taxi" did not eliminate the problem of sexual harassment because women were assaulted on the streets when disembarking the cabs and furthermore, it favoured gender-segregation. Due to its pink look, women were infantilized instead of being empowered and taken seriously. In their evaluation on women-only transport services in Mexico, Abenoza et al. [59] conclude that whether women-only transportation increases the level of security and trip satisfaction could neither be confirmed nor disconfirmed and that these types of services remain to have an ambiguous character. Again, we would like to regard this through the lens of advocacy and reflect upon this approach while taking a feminist standpoint. Although we argue that a women-only version has to be very carefully designed so women feel respected instead of being ridiculed, we would at the same time question whether a women-only vehicle would be the appropriate solution in the first place because, again, it would exclude people due to their physical characteristics, in this case, non-female individuals (and further could lead to conflicting situations with non-binary people). We argue that instead, research is needed on how to enhance women's security while not leaving other groups of people out.

5.4. Cleanliness of the Vehicles

Another important point that we would like to discuss through the lens of ecology are the hygienic concerns expressed by our participants. Here it becomes evident how the general openness to use shared mobility solutions goes hand in hand with a sense of well-being which, in turn, is related to the vehicle's design and state of the interior. Thus, we propose that vehicles should be kept clean and nice and several stakeholders should be considered when designing for such cleanliness: obviously the service providers have to make sure the vehicles are maintained and cleaned regularly, but, furthermore, the passengers themselves should be engaged. As one of our participant emphasizes: *"It [SAV] doesn't correspond to hygienic standards because it's highly used. People treat their own property differently than things that don't belong to them."*, P10, male. Sanguinetti et al. [52] use territoriality in defensible space theory to discuss that identifying with a vehicle would provide the feeling of control and ownership and, thus, would enhance natural surveillance for security reasons. We argue that in the design of SAVs territoriality should be taken into account to nudge passengers to treat the vehicles properly. We agree with [52] who state that clean vehicles would support security. They rely upon the broken windows theory (BWT) [60] to argue that neglected places are more prone to crimes due to the unobserved impression they make. Although the BWT has been been disproved [61], we believe that clean and maintained vehicles will furthermore enhance the perceived security of passengers—a circumstance that should be researched before SAVs are fully deployed on our streets.

6. Limitations and Future Work

The results of our study are not generalizable. We had a small sample of participants and all our participants had a high educational level. However, the aim of our study was to attain rich qualitative insights on why people would prefer private or shared mobility solutions and the reasons behind their choice rather than proofing hypothesis with quantitative results. In the future, our results should be tested with a large amount of participants that cover an even more abundant variety of characteristics. We propose to conduct more qualitative studies and include a broader spectrum of participants, for example, an even broader spectrum of cultural backgrounds (Asia, Africa, Latin America, etc.) and different levels of education and age groups. Our participants all identified as either female or male and we would like to emphasize that a broader look on gender should be taken in future research by including non-binary people. Furthermore, we would recommend to work on possible design solutions for the issues we uncovered in our study and to include people in the process with participatory methods. From our point of view, tackling the security problem would be a good starting point. We used user enactment with a very low-fidelity prototype of an AV as a method to attain first insights into how the journey could be perceived by participants. Therefore, our results cannot claim to reflect a real-world user experience. As the method suits our exploratory approach very well, studies using real AVs are needed in the future to verify our results. However, with the user enactment we were able to cover the context of use without exposing participants to the risk of possible accidents that AVs in their current technological state could bring along.

7. Conclusions

In this work we have explored how shared mobility solutions in the context of AVs should be designed from a gender-inclusive perspective. Despite related work from mobility and AD research that shows that gender-biases still exist, we wanted to gain rich insights on how people expect to be mobile when using SAVs and ST, as well as which concerns might keep them from adopting these mobility modes and why. Thus, we followed a qualitative approach and combined in-depth interviews with an enactment part. From the analysis of our qualitative data we derived a requirements catalogue taking a holistic viewpoint on the whole ride and discussed topics that were brought up by our participants using qualities from the feminist HCI framework. Our results indicate that

women especially have security concerns towards shared mobility solutions, and that these challenges not only hold true for the ride itself but additionally to the booking process and the location and design of pick-up and drop-off points. Although we argue that these security concerns must be taken seriously into account for ensuring a successful proliferation of SAVs, we also claim that solutions to mitigate these difficulties must be carefully designed to prevent negative side effects. Although, on the one hand, the identity during the booking process for SAVs should be anonymous, we, on the other hand, raised the question whether the disadvantages of female-only vehicles outweigh their advantages.

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