Multimodal Technologies and Interaction

Article

Understanding Operator Influence in Automated Urban Shuttle Buses and Recommendations for Future Development

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Abstract: The automation of our vehicles is an all-present topic with great benefits for society, particularly in the area of public transport and pilot projects of automated shuttle buses are already underway. However, they do not show the full potential of using them as a supplement to public transport, since single-occupancy registration of the vehicles usually allows only slow speeds and also requires a substitute driver on board. In our study, we aim to (1) examine the status quo of its user acceptance and (2) identify the roles of the operators and their tasks in automated urban shuttle buses. We conducted a mixed-method study including in-depth interviews, questionnaires, and in-the-field observations visiting pilot projects of the two most widespread pilot projects on German streets. Our results uncover the multiple roles and tasks the human operators currently assume. Furthermore, we developed design approaches for a digital companion substituting the operator in a long run and evaluated these concepts. A remote operator or a hologram were preferred solutions and we propose further design requirements for such companions. This work helps to understand the individual roles that operators currently occupy and provides a good basis for concepts of technologies that will perform these tasks in the future.

Keywords: automated shuttles buses; operators; user acceptance; automated vehicles; pilot projects; on-site study

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1. Introduction

The main trends in the automotive industry include electrification and the development of automated vehicles [1]. It is, therefore, not surprising that automated systems are expected to increasingly penetrate our society in the future, to make our lives easier. Automated driving will contribute to a fundamental change in the mobility system. Unexpectedly, the innovation has led to much discussion about the potential and associated concerns. Both academia and industry from the automotive and IT sectors have very different positions on introducing automated driving in public transport. One approach is the further development of driver assistance systems and the step-by-step introduction of these systems in the driver's car [2]. However, the automation of personal automobiles is a steady but lengthy process. Furthermore, this process contributes to a reduction in public transport. A faster approach here is the introduction of automated shuttle buses or automated cabs without personal ownership, as this could be an opportunity to reduce individual car traffic and increase the attractiveness of public transport [2]. In this context, existing pilot projects of automated shuttle buses show how they could provide more flexible services for passenger transport. The resulting benefits for both rural and urban areas are promising. In rural areas, automated shuttle buses can help provide better transportation services and greater comfort for the same price [3]. They are expected to increase residents' quality of life in metropolitan areas, for example, with more efficient use of traffic space [4].

Despite the numerous advantages that automation of shuttle buses would bring, a rapid implementation of this technology is usually impossible. Road traffic must slowly be adapted to AVs, and society must be convinced of the benefits of this new technology. Therefore, the users' wishes, problems, and needs must be identified, and as a result, the factors that support the use of AV from their point of view must be considered. If these are not taken into account, the new technology may not be used by society, despite flawless implementation and functioning. In this way, factors that guarantee the successful use of AV can also be seen as reasons why a sound system integration does not occur.

Two main areas can be identified in analyzing user needs for automated shuttle buses. Firstly, the interior area, including the entire design inside the shuttle bus, the tasks of the (human) operator, and the user's needs during the ride from the passengers' point of view. Secondly, the exterior of the automated shuttle bus includes the design and the information visualization in the exterior, the communication with other road users, and the user needs of the passengers before and after the ride (e.g., the bus stops). The interior design primarily focuses on the needs, misunderstandings, safety, and acceptance of the passenger of the automated shuttle bus. The exterior design primarily focuses on the needs, misunderstandings, safety, and acceptance of other road users who interact and communicate with the automated shuttle bus in road traffic. There may also be overlaps between the two areas; for example, certain forms of information visualization in the entrance and exit areas may provide a smooth transition between the interior and exterior spaces. Accordingly, research in both areas is necessary for a successful feeling of acceptance and a positive societal experience regarding innovative technology.

2. Related Work

2.1. Pilot Projects

Several pilot projects already operate on our roads. Pioneers in the international market for automated vehicles are companies such as the San Francisco-based Nuro [5] with automobile services such as driverless delivery, Cruise [6,7] with the first fully automated cab service in California or the France company Navya [8] with the Navya's Arma shuttle for passenger transportation for a wide variety of uses, such as businesses, amusement parks, or the city. It is also worth mentioning the Chinese tech giant Baidu, which establish self-driving buses and cabs in China's cities such as Wuhan and Chongqing [9,10]. The Transdev project is one of Latin America's pilots and aims to introduce automated shuttle buses in Chile [11]. Until now (status 2022), the Association of German Transport Companies (in German: Verband Deutscher Verkehrsunternehmen, VDV) [12] has recorded 44 cities with 61 automated shuttle bus projects in Germany. These include, for example, the ongoing SMO project (Shuttle-Modellregion Oberbayern) [13] with the Navya Arma vehicle type in Kronach, the active KelRide [14] funding project with the EasyMile EZ10 vehicle type in Kelheim, or the Bad Birnbach Shuttle (Line 7015) [15] also with the EasyMile EZ10, which has already been running since April 2017. These automated shuttle buses serve short fixed routes, usually in the old town, and, during their pilot phase, are free of charge for the passengers. Earlier shuttle bus projects are the EVA shuttle [16] in Karlsruhe, which was in operation from 2020 to August 2021, or the CUBe (Continental Urban Mobility Experience) [17], which was circulated on the Frankfurt university campus for students and stopped test operation in 2018.

Despite these large pilot projects, the state of the technology is not as advanced yet. The concept sold to the public usually is an SAE level 5 [18] shuttle bus driving in fully automated mode and with no human operator on board. However, in Germany, this is not a reality yet. The fully automated shuttle buses on the road are vehicles for six to nine passengers that travel at a maximum speed of app. nine mph (15 km/h) and follow a pre-defined route. This technology detects obstacles independently through many sensors that react reliably in case of any impediment [19]. Furthermore, all vehicles have a human operator who must take on various roles during the journey. This includes intervention in vehicle control if the technology is overwhelmed.

2.2. Acceptance and Accessibility of Shared Automated Vehicles

Social acceptance is an important factor influencing how quickly and in what way automated driving technologies and services spread. According to Davis [20] and Eden et al. [21], social acceptance is even one of the critical factors for the success of a technical system. The social acceptance of technology products can be defined as the intention of a user to use a specific system depending on their internal attitudes [20]. Furthermore, social acceptance can be further subdivided into acceptance and accessibility. While acceptance defines the attitude, behavior, and reaction towards an interactive system after experiencing it, accessibility describes users' expected attitude before interacting with a product [22,23]. Consequently, a new technology that lacks acceptance and accessibility will not be successful. It should also be considered that the traffic-related consequences of a lack of acceptance and accessibility affect not only the user and society as a whole [24].

A positive attitude toward automated vehicles can be fostered by allowing people to try out automated vehicles in a safe, real-world environment [25], as is already the case in pilot projects with human operators as a fallback. Acceptability issues also depend on the role of the individual and their relation to the automated shuttle bus [2]. For example, citizens could relate to the automated shuttle bus as a passenger or an external road user (e.g., driver, cyclist, pedestrian). Here, citizens have different requirements for the use of public space or safety expectations for the shuttle bus, depending on their role. Thus, a passenger's safety of the vehicle's occupants is the priority, as well as trust in the technology. Other road users primarily need clear communication with the AV to keep uncertainty to a minimum. The issue of acceptance can not only lead to different requirements depending on the role; it can also lead to different demands in the same role (e.g., passenger) due to socio-demographic characteristics such as gender or age [2]. For example, the willingness to use an automated vehicle is slightly higher among men and young people than among women and older people [26]. One reason for this could be the increased fear of losing control while driving, which is more pronounced in women than in men, according to a study by Wicki and Bernauer [27]. Furthermore, subjective well-being in automated vehicles is consistently significantly lower among older people than among younger people [2]. This is also reflected in the requirements. Older people hope that the introduction of new mobility systems will make transportation more stress-free and orderly but would not necessarily use them themselves. At the same time, young adults see using automated vehicles as a time-saver and a way to execute activities [2].

2.3. Roles of the Operator and Accompanying Challenges for Automated Shuttle Buses

Shared mobility could experience a considerable increase through shared automated shuttle buses [28]. This concept is expected to bring the most environmental and economic benefits [29]. With rides being shared among several passengers, congestion and emission reduction is possible [30]. For passengers, automated buses and people mover are promised to become affordable means of transport with equivalent prices of today's shared mobility [31–33]. However, to exploit all the potential benefits of these buses, many individuals would have to switch from private to shared transportation [34], which at least is questionable [35]. Prior work found a general willingness to use shared automated vehicles (SAVs), particularly for their environmental advantages [36]. Still, studies also show that security issues could prevent people from using SAVs [37]. As a matter of security, the absence of a human driver is indispensable [25,36,38,39] as they are seen as "guardians" [40]. This might keep passengers away from using mobility systems without a human on board. In this context, Biermann et al. confirm [41] that there seems to be an increased need for security, and suggestions for design solutions accounting for the absence of a human driver on board are already underway [37]. When aiming for SAE level 5 automated shuttle buses, the system will have to substitute for the driver in terms of operation and security aspects. To achieve this, first, the roles of operators today have to be identified, and concepts have to be developed for how automated shuttle buses will take over these roles. In the context of ride-sharing services, a study by Brewer revealed that taxi drivers occupy several additional tasks (physical, relational, etc.) apart from driving [42]. To the best of our knowledge, no literature yet analyses the role of the operator on board today's automated shuttle buses. In on-site studies, the safety operator is disguised as a co-passenger to examine people's acceptance when riding without personnel on board [43,44].

Accordingly, we pose the following research questions:

- RQ1: What are the roles of operators in automated shuttle buses?
- RQ2: What are the preferred concepts for replacing operators aboard automated shuttle buses for the targeted SAE Level 5 scenario?

To answer these questions, we followed a mixed-method approach and combined in-depth interviews with operators employed in current pilot projects in Kelheim and Kronach, online questionnaires, observations, and interviews with passengers using the shuttle buses in these projects and with people that never used such buses. Through this combination of methods and participants, we aimed to gain holistic insights into the operator's role from several perspectives and to evaluate concepts proposed by Schuß et al. as a substitute for the driver on board [37]. In their co-creation sessions, they derived the idea of virtual operators or "digital companions" that would appear on the screen or in the vehicle's interior as a substitute for a driver or operator. In their paper, they present different implementation scenarios ((a) a human tele-assistant, (b) a hologram or avatar, (c) a chatbot, (d) ear pods) that we adapted by replacing their concept of the "ear pods" with an assistant robot. A companion based exclusively on voice interaction is less embodied [45] than other human-like appearances as, e.g., robots and the other three concepts are more materialized. Building upon Sanguinetti et al. [46], who propose a remote human or a robot to monitor the vehicle's inside and account for the absence of a driver, we included a robot in our study. Our resulting four concepts are ((1) a human tele-assistant from the service provider, (2) a hologram, (3) a robot, and (4) a chat (bot) communicating with passengers through the app or a screen integrated into the seats, see Figure 1), and have been evaluated during our study. As we aimed to take the concept of the digital companion [37] to a different level, we also explored what roles, characteristics, and personalities a digital companion should represent from a user perspective and investigated them in an online questionnaire. Thereby, we were guided by the design space that Bouquet et al. [47] propose for assistants in video games, which emphasizes the importance of their behavior, personality, and relation to the player.

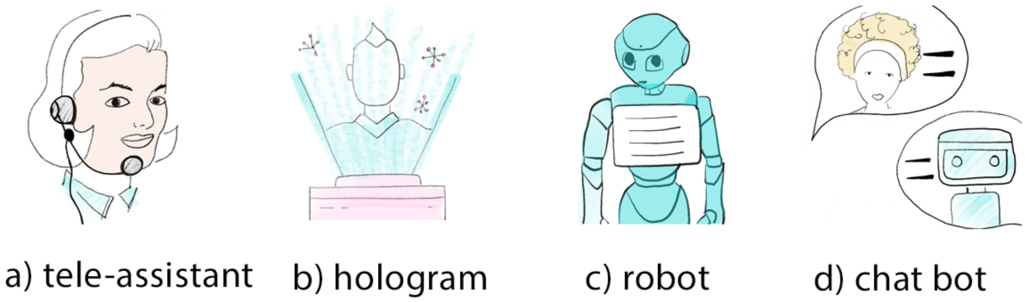

Figure 1. Four Concepts: (**a**) human tele-assistant, (**b**) hologram, (**c**) robot, (**d**) chatbot.

3. Study

3.1. Interviews with Operators and Observations

For our interviews and observations, we visited two pilot projects of automated shuttle buses on-site: Kelheim with the corresponding project KelRide [14] operating an EasyMile EZ10 and Kronach, which is part of the SMO [13] operating with a Navya. During our two on-site visits, we interviewed five operators (4 men, one woman; from 22 to 63 years old, $M(SD) = 45.4.0(16.6)$, $Median = 45$). Two in-depth interviews with chief operators were conducted at the headquarters of the shuttle bus service provider with a duration of approx. 90 min each. Additionally, we accompanied three operators during their shifts in the automated shuttle bus for 12 h in total and conducted contextual interviews. For the interviews, we used a semi-structured interview guide and started with warming-up questions and continued with open-ended questions about the following topics:

(a) *Operators' tasks:* What activities do operators perform during a normal workday? What does a typical workday look like?

(b) *Passengers:* What works particularly well for passengers in their everyday use of the shuttle bus? What are the challenges for passengers in their everyday shuttle bus use? As an operator, what requests do you receive from passengers, and how do you respond to them?

(c) *Roles and Characteristics:* What roles do you have as an operator? What are the expectations/needs of the passengers from you? What qualities should an operator have? Which of these roles do you find particularly challenging? Which of these roles could be taken on by a technical system, and which not?

(d) *General Challenges:* What are the biggest challenges in your everyday professional life? The interviews with the chief operators were audio recorded and transcribed verbatim afterward. The interviews with the three operators were combined with observations during the regular shuttle bus operation and were partly video and audio recorded and transcribed afterward. Additionally, one of the researchers took notes.

3.2. Interviews and Online Questionnaire with Passengers

In total, we interviewed 40 participants (21 girls/women, 19 boys/men, 0 diverse, 0 n/a; from 8 to 85 years old, $M(SD) = 49.0(21.3)$, $Median = 44.5$) of which 25 participants were interviewed during our on-site visits after their rides with the automated shuttle buses (5 in Kelheim, 20 in Kronach) and 15 participants were interviewed during an on-campus festival at our university and had no experience with automated shuttle buses. Additionally, 40 people (18 women, 21 men, 0 diverse, one n/a; from 18 to 72 years old, $M(SD) = 32.3.0(14.6)$, $Median = 24$) filled out our online questionnaire.

3.2.1. On-Site Interviews

During our observations in the automated shuttle bus, we took notes about the passengers' reactions towards the vehicle and any other incidents that took place during the rides. When passengers entered the bus, we informed them about us observing the rides, and we were not actively engaging with the passengers. After the rides, we kindly asked them whether they would participate in the interview. All interviews took place inside the bus as it usually had a 15 min break at the final stops. One of the researchers conducted the interviews and the other researcher took notes. The interviews were semi-structured and covered the following topics:

(a) *General Usage:* Was that your first ride with an automated shuttle bus? What was the purpose of your ride? Do you use it regularly? Why do you use it?

(b) *General Impression:* What is your general impression of the shuttle bus? Which aspects/functions did you enjoy the most? What could be improved?

(c) *Operator:* From your perspective, what is the operator's role? What influence would it have on your shuttle bus usage if no operators were on board anymore? How could a technology replace the operator? We then introduced different concepts of how technology could replace the human operator (see Figure 1) and asked our participants which concept they preferred and why. Additionally, we asked open-ended questions when participants came up with new topics.

The first five interviews were audio recorded and transcribed verbatim afterward. During the 20 interviews that took place throughout the second on-site visit, one of the researchers took notes, as we were given restrictions by the service provider about the audio recording of passengers.

3.2.2. On-Campus Interviews

During an on-campus event at our university, we interviewed people with no prior experience of automated shuttle buses. We briefly introduced the concept of such people movers and explained that, currently, an operator has to be on board for safety reasons. We explained that in the future, the role of the operator will be replaced by technology and introduced four prototypical concepts (see Figure 1) of how this technology could look like and asked participants to rank them by which concept they desired for trips in an automated shuttle bus with no operator on board. We then asked open-ended questions about each concept and the respective rankings. The rankings of the concepts were photographed, and the main researcher took notes of the interviews. The focus of this study was to gain qualitative insights about the reasons for preferring one concept over another.

3.2.3. Online Questionnaire

We recruited participants for our online study through an announcement in a university newsletter and through flyers that we distributed during our on-site studies, The questionnaire included open and closed questions and was structured as follows:

First, participants were asked about their experiences with automated shuttle buses. Participants with experience with shuttle buses were asked follow-up questions about the advantages and disadvantages of a people mover, their opinion about the operators, and in which situations they needed assistance.

Second, participants were asked whether they would use automated shuttle buses without an operator on board, and an introduction was given about the operator being replaced by technology. The following questions were about the modality, appearance, roles, personality, and several characteristics of such technology. We used polarity profiles of two opposing with an 11-scale slider to indicate the preference and multiple-choice questions.

Third, we introduced the four concepts (see Figure 1) that were used during the interviews on-campus and asked about participants' most and least favored concept for trips in an automated shuttle bus with no operator on board, and why. We did not specify any capabilities and limitations of the concepts to our participants, as we followed an exploratory approach of their evaluation. As these concepts are set in a future scenario with the vehicle being able to drive in fully automated mode, these concepts do not provide any driving functions. Finally, we closed the questionnaire with demographics.

In this questionnaire, we focused on gaining quantitative insights about the preferred concepts and further requirements for a technology as a substitute for the operator. The online questionnaire took approx. 10–15 min.

3.2.4. Data Collection and Analysis

Part of our qualitative material (in-depth interviews with the two chief operators and five semi-structured interviews with passengers) was transcribed verbatim and analyzed using qualitative content analysis [48,49]. We used inductive coding and refined the themes and codes in an iterative process until the final themes and codes were identified. The main researcher conducted the analysis using MAXQDA [50]. Other parts of our data (observations inside the automated shuttle buses, 20 semi-structured interviews, and interviews that took place at the on-campus festival) were not recorded. Instead, one of the researchers took notes, and the results were synthesized with the transcribed results. We clustered the results from the interviews and observations iteratively during discussion sessions among the researchers combining statements from the transcribed and analyzed material and the observations. Here, our primary focus was the status quo of the usage of automated shuttle buses, passengers' opinions on them, and a collection of incidents inside and outside the vehicle. Thus, we are not quantifying our qualitative materials and instead are following the good practice of qualitative content analysis [48,49] by presenting the obtained categories. For the evaluation of the four concepts that we presented to our participants, we will offer descriptive statistics of the respective rankings, as well as for the online questionnaires.

4. Results

In the following, we will introduce the synthesized findings from our interviews, observations, and the online questionnaire, which we structured according to their content. First, we report on the roles that operators assume. Second, we report on other road users' interactions with the automated shuttle bus. Third, we explore how the perceived and actual roles of operators differ. Finally, we report on the evaluation of the concepts of digital companions and further requirements for them.

4.1. Roles of the Operators

From a legal point of view, the operator is an indispensable technical supervisor who acts as a monitor and emergency level of the automated driving function [51]. However, our interviews with the operators and passengers and our observations show that the operator has multiple additional roles beyond, which we will present in the following.

4.1.1. Traffic Controller and Road Safety Educator

One dominant function of the operator is communicating with and regulating other traffic participants, such as car drivers, cyclists, or other vulnerable road users. We observed that the operator used hand movements to give a short signal to other drivers (mostly cars that followed the automated shuttle bus for a slightly longer time) for safe overtaking maneuvers. Many drivers would not overtake the shuttle bus despite its very low speed because they were hesitant and expected a human signal as a reassurance. As a result, minor traffic jams frequently occurred behind the automated shuttle bus—especially in narrow streets (see Figure 2)—leading to nervousness and impatience among the drivers. Again, the operator waves them through by hand gestures and manually stops the bus to clear the congestion. Other drivers stop, although they have the right of way because they are unsure how the automated bus will react. In these cases, the operator waves them through to reassure their way of right. At the same time, we observed risky overtaking maneuvers by both car drivers and cyclists. These sometimes cut the automated vehicle so that it also triggered an emergency stop.

Figure 2. Slow moving traffic behind the automatic shuttle bus.

The operators explained that one of the most frequent reasons for the vehicle's unplanned stops is wrong parking cars that are in the vehicle's way and sometimes even prevent its onward journey. If possible, the operators talk to the car drivers to ensure they do not park the cars wrongly in the future: *"I then tell them 'You know, it is an automated bus, it has sensors, and when you park here it detects your car as an obstacle and cannot continue its ride. Please, do not park here next time" [Operator4].*

4.1.2. Technician

Apart from wrongly parked cars, obstacles in the vehicle's way may cause the people mover to stop and have to be removed by the operators. In such cases, the operators clean the sensors and clear away small obstacles. If the shuttle bus has any technical problems and errors they cannot solve themselves, they dump the vehicle's backlog and forward it to the technical support from the vehicle manufacturer.

4.1.3. "Driver"

The operators act like drivers as they permanently monitor the vehicle's surroundings and other traffic users through the windows and the mirrors. When the vehicle stops, it either finds its way back on route, or the operator has to put it back on track with the joystick as the vehicle can only continue its trip from the precise position. The process is cumbersome and has to be carried out *"by experience" [Operator1, Operator5]* with the vehicle's position that is displayed inside the vehicle. At dedicated points where the vehicle stops on purpose, the operators react with foresight, for example, by looking into the intersection and proactively switching into manual mode to avoid a stop when it is possible to continue safely.

4.1.4. The Psychologist

One of the essential parts of the operators is being a *"psychologist" [Operator1]* as the majority of the passengers are tourists and use the automated vehicle for the first time and are cautious, reserved, or even anxious. During the observations, it became evident that each operator had their strategy of *"taking away the fear" [Operator3]*: One operator explained: *"I start with a joke. For example, I say "Is this your first time on the autonomous bus?" and when they say "yes" I say "me too.". And then everybody laughs, and it breaks the ice." [Operator1].* Other operators stated they would be explaining how the automated system works to calm passengers down, and all of them emphasized the importance of their presence in the context of anxiety and insecurity that passengers go through when traveling for the first time.

4.1.5. Informant

During the observations, it became evident that passengers desired information on the vehicle's behavior. The observed shuttle bus projects are currently in their pilot phases, and the system's sensors are very sensitive. This leads to many (unnecessary) stops, irritating passengers. In these situations, we could observe that passengers usually turn to the operator and ask them why the vehicle stopped, and the operator then explains the reasons. Passengers also asked diverse questions about how the autonomous system works and about future prognostics towards automated systems in general. The operator must have versatile technological knowledge about the system to be able to respond appropriately. All operators undergo a two-week training about the handling of the vehicle and information about its technology and this training has to be renewed every year.

4.1.6. Supervisor

The operator acts as a supervisor who reacts to the behavior of the passengers with instructions. Often the vehicle breaks abruptly, and it is indispensable for passengers' safety to have their seat belts fastened. Furthermore, it is not allowed to drink or eat during the rides to avoid choking, and suffocation, and these instructions have to be given to the passengers as they are not accustomed to it from regular public buses.

4.2. Other Road Users

Our observations and the interviews with the operators clarified that other road users generally are annoyed by the shuttle bus. Due to its many stops and switches from automated to manual mode and its average velocity of around 3 miles per hour, the bus is a slow means of transport. This underlines the gap between car drivers', cyclists', and pedestrians' expectations and the reality, leading them to say: *"Why doesn't it keep on moving? Why doesn't it drive around the obstacle?"* [Operator 1]. Car drivers and cyclists behind the automated vehicle become impatient, grumble and overtake it, which results in abrupt stops of the bus if cars or bicycles shear in too tightly in front of it. On the other hand, our video material shows that cars sometimes do not drive, although they have the right of way and are hesitant and unsure of what the people mover's next move will be. In these cases, the operator signalizes other traffic participants that driving is safe. Still, others accept the way the shuttle bus works and even make space in oncoming traffic sometimes because they know that there are sensors and if the distance is too short, the bus would reduce its speed. Pedestrians react with enthusiasm and awe towards the self-driving bus. They turn their heads toward it and point to it with their fingers or take pictures with their smartphones when it passes them.

4.3. Disparity between Perceived and Actual Roles of Operators and Their Importance

From our questionnaire interviewees' point of view, the central role of an operator on board the automated shuttle bus is the informant (55%) followed by the supervisor (22.5%). Service personnel (7.5%) and entertainer (5%), bodyguard (5%), and guardian (5%) were less mentioned, and surveillance was not mentioned at all. Interestingly, informant and supervisor are among the dominant roles we could observe during the rides in the shuttle buses. These responsibilities have rational and distanced attributes. However, as explained in the previous section, we noticed that many operators' tasks also have emotional and approaching attributes. They calm and reassure nervous passengers and embody the human guardian to rely upon. While these roles could be underestimated at first sight, they are crucial for passengers' trust and comfort, especially during the introduction of automated shuttle buses, as many passengers may be first-time users that will need guidance and information. The results of our online questionnaire show that the ratio of responses that perceive the presence of an operator as unimportant (44%) and those that perceive it as important is balanced (48%), with only a few participants being indifferent about it (8%). Despite that, most of the participants in the online questionnaire indicated they would use the automated shuttle bus without an operator on board (68%), and around one quarter stated they would not use it (24%, and 8% were indifferent). More detailed descriptive statistics of the answers on an 11-scale slider are presented in Table 1. Our findings show that the operator is regarded as essential, but most of our interviewees would use an automated shuttle bus without an operator on board (see Table 1).

Table 1. Descriptive Statistics: Importance of Human Operator from 0 (=not at all/unlikely) to 10 (=very important/very likely).

How Important Do You Consider the Presence of a Human Operator?										
0	1	2	3	4	5	6	7	8	9	10
8%	16%	12%	4%	8%	8%	8%	16%	4%	0 %	16%
How Likely Would You Use the Shuttle Bus Without a Human Operator?										
0	1	2	3	4	5	6	7	8	9	10
8%	4%	0%	8%	4%	8%	0%	16%	16%	12 %	24%

Even though there is a general openness towards using the automated shuttle bus without an operator on board, we argue that concepts are needed to account for the operator's multiple rational and emotional roles.

4.3.1. Acceptance

In general, the acceptance of the automated shuttle bus is ambiguous. From the passengers' and other traffic users' perspective, its slow velocity is considered the main disadvantage leading to the bus being a traffic obstacle. Even though people do consider the operator as an important and supportive factor (see Section 4.3), at the same time, their presence on board confuses people (*When will it drive by itself? We thought it was an autonomous bus, what is the man doing in there?"*, [P02].) and they question the vehicles "automation". Indeed, at the moment, around 50% of the time, the vehicle operates in manual mode with the support of the operators (these numbers were communicated to us by the service providers who track the status of their vehicles permanently). On the other hand, passengers' confusion about operators inside the vehicle reflects that a large part of the population is unfamiliar with the experimental and early stages of automated driving.

Due to the missing awareness of how the sensors of the vehicle function, other road users are a challenge for the bus as they pass it too closely or park their cars and bicycles in the vehicle's way leading to stops. Due to their velocity and the few stops, the people mover as they currently operate in Kelheim and Kronach are not suitable for daily use and instead function as a highlight for tourists. Still, passengers are impressed by the comfort of the vehicle's interior and its orientation towards the future of mobility and pedestrians stop and take photos as the vehicle passes by (see Figure 3).

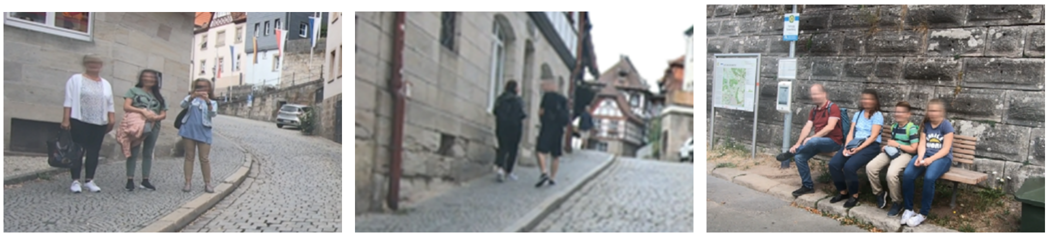

Figure 3. Reaction of pedestrians to automated bus.

4.3.2. Technical Maturity

The biggest challenge currently is the technical maturity of the automated mode and the vehicle's ability to react to obstacles, wrongly parked cars, and unforeseen events. Its inability to maneuver itself out of these situations is its greatest drawback and is at the same time deeply connected to people's disagreement towards this technology. In such cases, the operator has to put the vehicle back on track with the joystick. As one of the interviewees puts it: *"Because that is now just an obstacle here. If they want to sell this as a vision of the future for the young generation, they should improve the technology first, because at the moment it will rather scare people away."* [P04].

4.4. Concepts of Digital Companion

We synthesized the results of the questionnaires and the interviews at the on-campus festival and will present the derived themes and topics in the following.

4.4.1. Human or AI?

In the online questionnaire, we asked for the solution they liked the most and they liked the least and present the descriptive statistics of the results (see Table 2). In the interviews that we conducted on campus and in the online questionnaire, we presented four different concepts of a digital companion as a substitute for the operator to our participants. During the interviews, we let participants rank the four concepts and asked follow-up questions on why they (did not) choose one or the other design solutions. We created a Borda count analysis of the results (see Table 3).

Table 2. Descriptive Statistics: Preference for Digital Companions.

Which Concept Do You Like the Most?			
Tele-assistant	Hologram	Chat-Bot	Robot
40%	30%	22.5%	7.5%
Which Concept Do You Like the Least?			
Tele-assistant	Hologram	Chat-Bot	Robot
15%	17.5%	27.5%	40%

Table 3. Borda Count Results: Preferences for Digital Companions.

Tele-Assistant	**Hologram**	**Chat-Bot**	**Robot**
54	42	40	28

In both data collection methods, the human tele-assistant and, surprisingly, the hologram were the most favored concepts, whereas the robot and the chatbot were the least liked concepts. As expected, people prefer having a human assistant even in automated concepts such as automated vehicles. Some of our participants explained that they would trust a person more than an automated system (*"I wouldn't ride without the operator. That's where I lack confidence in the technology."* [P28]) and expressed skepticism towards the flawless functioning of automated shuttle buses (*"It's a real person who is able to react in cases of emergency."* [P15]). As an example, our participants mentioned their poor experiences with nowadays chatbots and how frustrating it was when there were real problems that the system would not be capable to resolve (*"We already have them today, so we already know, that they won't work."* [P20]). These experiences explain the chatbot's bad ratings during the interviews and in the questionnaire alike. Apart from that, its modality was considered cumbersome and inefficient as it is *"totally annoying that you have to write there"* [P15]. Despite the fact that the hologram still is a very futuristic concept more known from science fiction movies, such as Star Wars, Blade Runner, or Iron Man, participants were very open towards this form of a digital companion precisely because of its futuristic character. Participants emphasized the concept of being fancy and a good fit for the vehicle's forward-oriented flavor. Another reason was the *visibility* and *presence* of this solution, as *"it can also be a human and as I can see it clearly, it gives me this sense of security"* [P09].

4.4.2. Characteristics of the Digital Companion

Apart from the modality and technology of the digital companion we researched the characteristics that people would prefer for it. Accordingly, we proposed duties that the digital companion could have and presented polarity profiles of two opposing adjectives to our participants. On an 11-scale slider, they expressed their preferences for a companion.

Participants were indifferent about whether a human (40%) or artificial intelligence (40%) should be behind the digital companion. The reasons for the human were flavored "with gut feeling", if the technology does not work properly a human could still intervene, whereas the reasons for an AI were more rationally flavored with being more efficient in terms of time and money, and capable of neutral evaluations of situations.

In the following table, the opposing adjectives are listed together with the percentage of participants that indicated the respective values between 0 and 10. For better readability, we illustrate them in Table 4. Interestingly, the clearest result is about the companion's gender with 55% of our participants indicating a neutral 5 between male and female. Another 37.5% of participants tended towards the female spectrum of the polarity profile which seems to be preferred over a male. With 62.5%, 65%, and 60% of answers lying in the spectrum of light, human, and realistic we see a tendency towards these adjectives in comparison to their opposite poles dark, imaginative, and abstract. Furthermore, futuristic (45%) and soft (55%) are preferred slightly over traditional and hard with a considerable amount of answers in the neutral five. It should behave in a friendly (45%), reserved (22.5%), open (12.5%), and calming (7.5%) way.

Table 4. Descriptive Statistics: Characteristics of Digital Companion

How Should a Digital Companion for Automated Shuttle buses Be Designed?										
0 (=male) 7.5%	1 2.5%	2 0%	3 2.5%	4 0%	5 55%	6 5%	7 7.5%	8 2.5%	9 2.5%	10 (=female) 20%
0 (=light) 20%	5%	20%	17.5%	0%	17.5%	5%	5%	7.5%	0 %	10 (=dark) 2.5%
0 (=naturalistic) 12.5%	2.5%	12.5%	5%	0%	22.5%	5%	15%	10%	2.5%	10 (=futuristic) 12.5%
0 (=hard) 5%	0%	2.5%	2.5%	7.5%	27.5%	20%	7.5%	12.5%	7.5%	10 (=soft) 7.5%
0 (=human) 15%	10%	7.5%	22.5%	10%	15%	2.5%	7.5%	7.5%	0%	10 (=imaginative) 2.5%
0 (=realistic) 20%	12.5%	10%	15%	2.5%	20%	5%	2.5%	5%	5%	10 (=abstract) 2.5%

4.5. Discussion

4.5.1. Acceptance Challenges

From our results, we conclude that, at the moment, pilot projects of automated shuttle buses still have considerable acceptance hurdles to overcome. Due to their low velocity, they are considered an obstacle for other road users and not feasible for passengers' everyday mobility. Moreover, precisely because of this, they are almost exclusively used by tourists, mainly first-time users. The technology does not work as passengers and other road users expect it to, which leads to negative user experiences and can have a significant unfavorable influence on the acceptance of automated shuttle buses. This is especially problematic when considering that, e.g., younger people hope that automated vehicles will save them time [2]. Furthermore, the presence of a human operator and their dominant intervention in "driving" and their influence on the trust in automated shuttle buses is at least ambiguous. Operators do function as a source of security and human backup for many passengers, while at the same time, people are disappointed that the vehicles still need a human on board. The broad public seems to overestimate the shuttle buses' technical maturity, which leads to frustration on the one side and misconduct on the other side. We propose that citizens, particularly at locations where pilot projects are running, should be proactively informed about the shuttle buses' state of technology and included in the design and development processes to foster awareness and acceptance. This could be through educational work and participatory events such as workshops. These activities should also include other stakeholders in the ecosystem, such as pedestrians, cyclists, and car drivers, as they will have to interact with the automated shuttle buses in the future.

4.5.2. Communication with the External World

At the moment, the operator takes on several important tasks for the passengers and other road users. On the one hand, people will become used to technology. On the other hand, the design of the shuttle buses should support users in the transition phase to enable a smooth adoption and conversion to fully automated modes. Currently, human operators handle the majority of communication with the outside world. As a result, other road users rely more on the human driver than the actual signals from the automated shuttle bus. This is an obstacle to the futuristic vision of a fully automated shuttle bus. Since the goal of automated shuttle buses is to operate without a human driver in the future, external communication needs to be enhanced. Thus, the exterior design of the automated shuttle bus indicates future driving maneuvers and reduces the uncertainty of all involved. In the interaction between automated vehicles and other road users, there are already some approaches by other researchers and designers for external human-machine interfaces (eHMI) for vehicles. In this context, a solid taxonomy on current eHMI concepts was created by Dey et al. [52], which both ranked existing eHMI designs and identified research gaps. This way, the current eHMI concepts can be divided into 12 design patterns, including projection on the road, 1D/2D abstract light bar, tracking light, audio, and many more. However, it should also be emphasized that some attractive approaches should be viewed with caution, as they were mostly laboratory studies that only marginally examined poor conditions or represented a small sample.

Despite the proven benefits that eHMI offers, legislation in Germany is a significant obstacle for many eHMI approaches. An example is the regulation regarding externally mounted light sources, which states that "only the prescribed lighting equipment and that which has been declared permissible are allowed to be mounted on motor vehicles and their trailers (Cf. § 49a Para. 1 StVZO [53])". This also includes light bars or rear windscreen displays, also used in some eHMI concepts. These regulations ensure that other road users are not distracted from what is happening on the road. Still, there are major constraints in the eHMI development process, without proper adaption.

4.5.3. Operators and Digital Companions

Our results show that people consider informant and supervisor as the operators' main roles. Through our observations and the interviews with the operators, we found that they actually have large tasks and responsibilities, particularly those that address emotions such as trust and feeling comfortable. We already discussed that operators' presence was perceived as necessary but at the same, time it irritated people as they had the expectations of the vehicle driving in fully automated mode with no personnel on board. Most of our participants stated they would use automated shuttle buses without them. Nevertheless, the abundance of duties on board leads us to conclude that it is indispensable to account for all roles, particularly the ones that have an emotional flavor. One solution of how the system could cover this is the concept of a digital companion, which we evaluated during our study. Previous work demonstrated that the driver in PT is considered a "guardian" [40], and we, therefore, hypothesized that a concept that includes a human, such as the human tele-assistant, would be favored by participants. While our interview and questionnaire results confirm this, to our surprise, the concept of a hologram was nearly well accepted by our study sample. Our hologram was presented as an anthropomorphized, meaning human-like [54] version. This could be one explanation for its reception by our participants as several prior works confirm that human-like appearances, behavior, and voices foster acceptance of technologies, robots, or digital assistants [55–57]. The concept is not sufficiently realistic to run into an *Uncanny Valley* trap [58]. On the other hand, more recent work disproves the hypothesis that suggests we should no longer hold back the development of highly realistic androids [59]. Our interviewees stated that the hologram, as it is located inside the vehicle, radiates a certain presence that is essential for a digital companion. We hypothesize that a more embodied concept than a voice-based assistant, as in [37], is more appropriate for substituting a human on board. Nevertheless, the robot concept was mainly rejected because it was in the way or took too much space. Human-like looks and comportment are not as important as human-like communication [60]. We suggest future studies consider this finding and explore whether the presence or level of anthropomorphism is more crucial in the context of shared automated shuttle buses. The participants of our questionnaire expected the digital companion to be friendly and human-like- which goes in line with it being an anthropomorphic version. From our participants' point of view and from what the operators have reported from their experience, the role of a supervisor on board was similarly important. In the context of design spaces for companions in video games, power dynamics have been identified as essential category [47]. With the abundant roles of operators that have been identified in our studies, we argue that power dynamics become important for a digital companion in automated shuttle buses. While we hypothesize that a friendly informant or psychologist might take a role at eye level or hierarchically inferior to the passenger, a superior hierarchical role might be more appropriate for the supervisor, traffic educator, or when handling, e.g., inappropriate behavior of passengers. While more than half of our participants indicated a neutral position towards whether a digital companion in automated shuttle buses should be male or female. This conflicts with previous work in the field of assistance robots claiming that people identify more with digital assistants that represent the same gender [61]. Although we hypothesize that gender might not be important to our participants, and personalized digital companions to allow for high identification might not be feasible if we want to keep the role of one operator for all passengers, representing a neutral gender might be challenging on the one hand, and innovative and future-oriented on the other one.

5. Limitations and Future Work

We have conducted on-site studies visiting two current pilot projects of automated shuttle buses in two cities in Germany. All passengers that we interviewed were first-time passengers. Thus, we can assume that our results are not generalizable for long-term usage as we could not consider familiarizing or learning effects. Furthermore, our results apply specifically to Germany, where, due to legal restrictions, an operator has to be on board the SAVs by law. These effects might differ in areas where these vehicles are already on the roads for a longer time with no operator on board. Moreover, in countries facing various mobility challenges, such as, Latin America, where personal safety and gender-based violence are among the most critical issues in PT [62–64], the results may vary. The operator's role is very important as they communicate with other road users, inform passengers about the system's behavior and foster trust. However, they might become less relevant as passengers, and other traffic participants become used to automated shuttle buses. The locations where our study took part were two smaller cities with low traffic density and high urbanization, and user needs might be different in other (traffic) contexts or different cultures or locations. Further research is needed as well as the speed of these vehicles increases. While we found that their low speed is one of the most significant downsides of these pilot projects, safety and security concerns might increase with the vehicle's velocity.

6. Conclusions

In this paper, we presented a mixed-method user study including in-depth interviews with operators and with passengers, questionnaires, and in-the-field observations to investigate the current opinion on automated shuttle buses and the roles of the operators on board the buses. While the idea of automated shuttle buses is being sold as fully automated vehicles that do not require the presence of a human fallback on board, in today's pilot projects, the buses circulate with operators. We introduce findings on current acceptance hurdles of automated shuttle buses from the perspective of passengers, operators, and other road users, and dismantle the abundant and heterogeneous roles of the operators. As these roles have to be overtaken by the system in the future, we presented the evaluation of proposed concepts for digital companions for automated shuttle buses. We identified the human tele-assistant and the hologram as the preferred solutions and proposed further (design) requirements for such companions and ideas for further work. To summarize, there is still a wide range of issues that urgently need to be resolved before automated road vehicles become a well-established part of the transport infrastructure. Besides the technical challenges and legal regulations, there are still several problems in individual and social acceptance. These must be thoroughly investigated in early development phases and further pilot projects to avoid initial negative associations with the innovative technology. A technology that is accepted and used by society could greatly benefit the population in the upcoming years, especially in the area of public transport.

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