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Autonomous Shuttle or Conventional Cab? Investigating Users' Decision to Share a Ride

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ABSTRACT

Shared Autonomous Vehicles (SAV) have the potential to address the major challenges facing road transport in terms of transport efficiency, road safety, and sustainability. As driving and car ownership occupy a special position, especially in Germany, there is a need for research to investigate and better understand people's mode choice, their willingness to switch from private to shared cars, and their attitudes towards novel autonomous mobility services. In an online questionnaire survey (N = 112), we explored people's perceptions and intentions to use conventional cabs versus autonomous shuttle buses. Interest in SAV was high, confirming previous findings. The initial trust of the user makes the difference in the evaluation and usage intention and can be considered as a critical acceptance parameter based on our results.

Keywords: Shared mobility, Shared autonomous vehicle, Autonomous shuttle, Trust in automation

INTRODUCTION

Private motorized transport is a major challenge for transport and the environment. In Germany, the number of cars in households and emissions from private motorized transport are steadily increasing (Nobis and Kuhnimhof 2018, Umweltbundesamt 2022). Shared electric autonomous vehicles offer great benefits and solutions for improving transport efficiency, road safety, and environmental protection (Greenblatt and Shaheen 2015, Zhu et al. 2022). Potential barriers to their use may be related to a lack of willingness to give up a private car and to concerns about the use of autonomous driving. Research is needed on the general willingness to share mobility services, especially those that operate without a human driver on board, i.e., autonomously.

Driving and car ownership occupy a special position, especially in Germany. Although the use of car sharing and alternatives to the car, such as e-bikes, is increasing, it still lags far behind private car use (Umweltbundesamt 2022). It is therefore not surprising that a high need to own a car was identified as a major barrier to the use of new mobility services (Alonso-González et al. 2020). From the driver's point of view, not owning a car may be a drawback because of a perceived lack of flexibility, limited personal

freedom or driving pleasure. Also, sharing a vehicle with strangers may limit the acceptance (Clayton et al. 2020, Dolins et al. 2021). In addition, when the human driver is removed from the vehicle and becomes a passenger, as is the case with autonomous driving, perceived risks and concerns, such as about privacy and fear of loss of control, may limit the willingness to adopt (Biermann et al. 2019, Chen et al. 2020, Schmidt et al. 2015).

Whether and to what extent people are willing to use new mobility services depends on individual factors and is not always the same. For example, it has already been shown that human factors such as socio-demographics, attitudes towards climate change, and car access influence the willingness to use shared mobility options (Mouratidis 2022). Also, personality factors (e.g., propensity to trust) are related to attitudes towards autonomous mobility services (Biermann et al. 2020, Paddeau et al. 2020). Gender differences have been studied in relation to autonomous electric shuttle buses, showing that men tend to be more curious and interested in such a novel service (Philipsen et al. 2018).

The aim of this study was to better understand mobility behaviour and mode choice with a focus on on-demand shared mobility. To assess how different levels of automation might affect attitudes, conventional transportation means (e.g., taxi) and autonomous shuttles were compared. Our research questions and the methodology used to answer them are explained in the following chapter, including a description of our sample.

METHOD

We designed a two-stage empirical exploratory research approach. In a primary interview study (language: German; N = 17), we explored the reasons why people choose to share a ride and identified factors that influence their well-being and trust. Interviews were transcribed verbatim and analyzed using content analysis. The results of the interviews were operationalized and measured in an online questionnaire survey that addressed the following research questions (RQ):

RQ1: What is the mobility behaviour of the participants and what determines their choice of transport?

RQ2: How do participants think and feel about taking a traditional taxi versus an autonomous shuttle?

RQ3: Which mobility service will they choose in the future (conventional or autonomous)?

RQ4: How do user groups differ from each other, e.g., in terms of demographics, personality, mobility attitude, use intention, and trust?

The questionnaire consisted of three parts:

I. First, personal data was collected, including demographics (age, gender, education) and personality traits such as interpersonal trust (Beierlein et al. 2014), technology trust (Jessup et al. 2019, Schneider et al. 2017), and privacy disposition (Xu et al. 2008).
II. Second, mobility behaviour (driving licence ownership, perceived importance of car ownership, experience with semi-automated and

autonomous driving) and mode choice were evaluated, as well as seven items asking about people's attitude towards a taxi ride in terms of safety and reliability (e.g., "A taxi driver obeys the traffic rules"), which were self-developed based on the results of the pre-study (see Figure 2).

III. The third part was introduced by a textual scenario description of a novel on-demand shuttle service using shared autonomous vehicles (SAV). Participants were provided with the following information: The new shuttle service will be used as a complement to existing public transport and is designed for small groups. Passengers can customize their journey, i.e., they can choose the pick-up point and destination, time, route, and equipment. As regards the technical description of the scenario, the participants were informed that the vehicles perform all driving tasks in road traffic autonomously and are connected to their environment (e.g., traffic infrastructure, other vehicles) supported by intelligent systems. Subsequent questions asked about the intention to use (inspired by Davis 1989), trust (Pöhler et al. 2016, Jian et al. 2000), and people's attitude towards riding in an autonomous shuttle (corresponding items were mirrored from the second block on attitudes to taking a conventional taxi). Finally, there was a decision task in which participants were asked to rate which mobility service they would book in the future (conventional or autonomous).

We used different scales, including multiple choice and fully verbalized 6-point Likert scales. Cronbach's alpha (α) was checked for scale reliability, which was good (>.7), except for the self-developed scale measuring attitudes towards riding in a SAV (.669), which was included in the analysis due to the exploratory nature of the overall research design. Descriptive and inferential statistical methods were used to analyze the data. A significance level of .05 was used.

The survey was distributed through a variety of channels, including direct approaches within the research team's social network (e.g., personal text messages), as well as posting the survey link and encouraging participation in topic-specific forums and relevant social media. The response time was estimated at 20 minutes.

Sample

A total of 182 people took part in the survey. After quality control and data cleaning, i.e., elimination of incomplete data sets and speeders (response time less than 50% of the median), N = 112 data sets were included in the analyses. Of these, 59.8% were female and 40.2% were male. Age ranged between 18 and 64 years (M = 30.2; SD = 13.6). The participants were highly educated with 45.5% high school graduates and 39.3% having completed university. On average, the participants were rather trustful towards other people (M = 4.1; SD = 0.8) and technology (M = 4.3; SD = 0.6). The mean privacy disposition score was below the scale mean (M = 3.2; SD = 1.0), indicating that on average participants were not too concerned about data protection and online privacy, for example.

RESULTS

In the following, the results obtained are described in terms of the mobility behaviour and mode choice of the sample, the general attitudes towards conventional cabs and shared autonomous shuttles, and the decision to use either conventional or autonomous mobility services in the future.

Mobility Behaviour and Mode Choice

All of the participants hold a driver's licence. On average, car ownership was perceived as rather important ($M = 4.3$; $SD = 1.5$). Most of the participants had experience of using driver assistance systems (69.6%), 17% had been passengers in a semi-automated car, 12.5% had no experience, and <1% said they did not know whether they had driven in a semi-automated car or not. With regard to self-driving cars, more than half of the respondents (54.5%) had no experience.

In terms of mode choice, private cars were used by the majority (54.5%) on a daily basis. Sharing services (i.e., ride-sharing or car-sharing) were never used by the majority (86.6%). Use of public transport (e.g., bus or train) was varied and relatively evenly distributed (ranging from daily, weekly, monthly to never). Taxis were used by most respondents either less than monthly (43.8%) or never (46.4%).

Figure 1 illustrates the reasons given for the choice of transport mode. In general, there was a broad consensus that aspects such as reliability, flexibility, punctuality, independency, and safety were crucial to the choice of transport mode, whereas prestige and reputation were considered less relevant. A mixed picture of responses emerged with regard to technological readiness and accessibility for people with reduced mobility, the latter possibly due to the relatively young age of the sample.

Attitudes Towards Conventional Cabs vs. Autonomous Shuttles

Figure 2 compares attitudes towards a conventional taxi ride (i.e., with a human driver) and a ride in an autonomous (i.e., driverless) shuttle. On average, the ratings differed only slightly, with a mean for taxi rides of $M = 3.4$ ($SD = 0.8$) and a mean for shuttle rides of $M = 3.5$ ($SD = 0.6$). The differences were in the detail. In particular, compliance with traffic rules was judged differently: Participants were more likely to believe that the autonomous driving service would obey traffic rules than a taxi driver. In turn, they were more likely to assume that a human driver would recognize and react to an emergency than an autonomous shuttle, and that an autonomous shuttle would be more error-prone than a conventional taxi.

User's Decision: Conventional or Autonomous Shared Mobility?

When asked whether they would book a conventional shared mobility service (e.g., taxi, bus, or train) or an autonomous shuttle in the future, 43.8% of the participants said they would use the traditional service, while the majority (56.3%) said they would book the novel shuttle service. This positive basic attitude towards SAV is reflected in the average values of the general

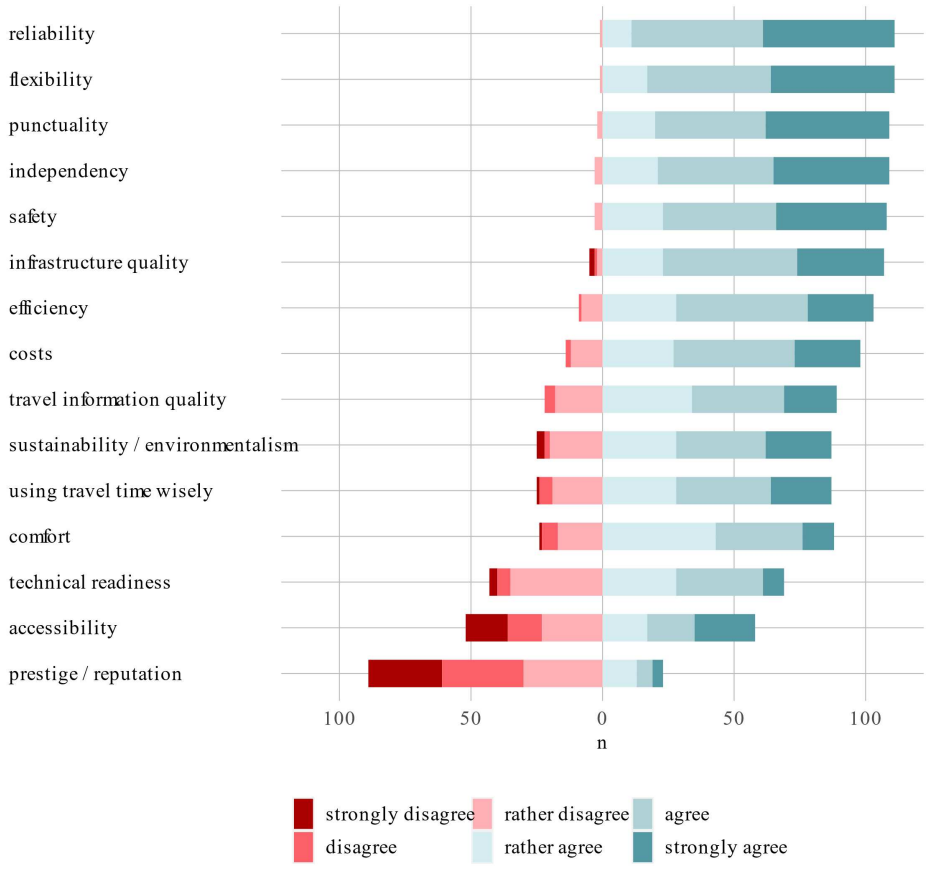

Figure 1: Reasons for mode choice.

usage evaluation (willingness to use, perceived usefulness, etc.) (M = 4.2; SD = 0.9) and the perceived trust in the SAV (M = 4.0; SD = 0.7). Based on the decision task, participants were divided into two groups in order to assess user-specific characteristics in terms of demographics, personality traits, behavioural intention to use and trust in SAV. For simplicity, the traditionalists are referred to as "taxi user" and the pioneers as "shuttle user". An overview of group characteristics is given in Table 1.

Mann-Whitney-U-Tests were calculated to determine if there were gender and education differences between taxi and shuttle users. There was a statistically significant difference in gender distribution between the two groups (U = 1225.000, Z = −2.200, p = 0.028), indicating that taxi users were more likely to be female. Regarding education, no statistically significant difference was found. A one-way MANOVA showed a statistically significant difference between the two groups on the combined dependent variables (i.e., all other user factors), $F(9, 102) = 7.856$, $p < 0.001$, partial $\eta^2 = 0.409$, Wilk's $\wedge = 0.591$. Post-hoc univariate ANOVAs were conducted for every dependent variable. Results show a statistically significant difference between the two groups for technology trust, $F(1, 110) = 16.237$, $p < 0.001$,

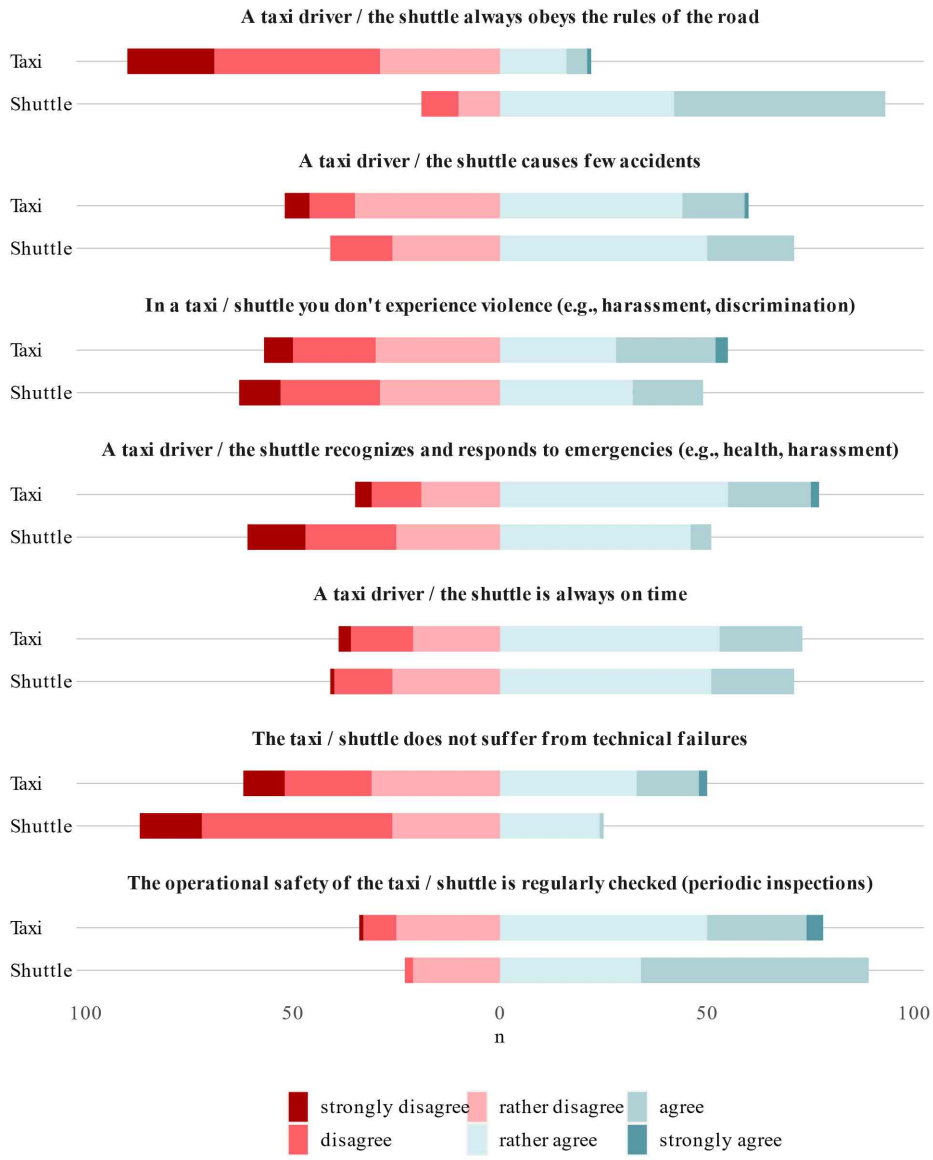

Figure 2: Attitudes towards a ride in a conventional taxi vs. a ride in an autonomous shuttle.

partial $\eta^2 = 0.129$, attitude towards SAV, $F(1, 110) = 8.812$, $p = 0.004$, partial $\eta^2 = 0.074$, intention to use SAV, $F(1, 110) = 53.910$, $p < 0.001$, partial $\eta^2 = 0.329$, and trust in SAV, $F(1, 110) = 17.065$, $p < 0.001$, partial $\eta^2 = 0.303$, but not for age, perceived importance of car ownership, privacy disposition, interpersonal trust, and attitude towards taking a taxi. In summary, the attitude of shuttle users towards the new mobility service was overall more optimistic in terms of safety and reliability. Shuttle users also showed a higher willingness to use SAV and were generally more trusting of technology and the SAV.

Table 1. Taxi user vs. shuttle user: comparison of group characteristics.

User factors	**Taxi user** (N = 49)	**Shuttle user** (N = 63)	p-value
Age	M = 29.2 (SD = 13.2)	M = 31.1 (SD = 14.0)	n.s.
Gender	71.4% female 28.6% male	50.8% female 49.2% male	0.028
Education[1]	51% high school 34% university	41.3% high school 42.8% university	n.s.
Importance of car ownership	M = 4.5 (SD = 1.6)	M = 4.2 (SD = 1.5)	n.s.
Privacy disposition	M = 3.2 (SD = 0.9)	M = 3.3 (SD = 1.0)	n.s.
Interpersonal trust	M = 3.9 (SD = 0.8)	M = 4.2 (SD = 0.8)	n.s.
Technology trust	M = 4.1 (SD = 0.6)	M = 4.5 (SD = 0.6)	<.001
Taxi attitude	M = 3.4 (SD = 0.7)	M = 3.5 (SD = 0.8)	n.s.
SAV attitude	M = 3.3 (SD = 0.5)	M = 3.7 (SD = 0.6)	.004
SAV use intention	M = 3.6 (SD = 0.8)	M = 4.6 (SD = 0.6)	<.001
SAV trust	M = 3.5 (SD = 0.7)	M = 4.3 (SD = 0.5)	<.001

Factors on which the groups differ significantly are shown in bold.

DISCUSSION

The aim of this study was to better understand mobility behaviour and mode choice, as well as attitudes towards conventional and novel autonomous mobility services. The focus was on public and shared transport (not private cars). For reasons of comparability, two on-demand mobility services were compared: conventional cabs (with a human driver on board) and driverless shuttles. The results show a high level of interest in SAV and confirm previous research findings. The initial trust of the user seems to make the difference in the evaluation and willingness to use and can be considered as a critical acceptance parameter based on our results. The results of this study and the methodology used are critically reflected upon below. Input for follow-up studies is derived.

Regarding our first research question (RQ1), the mode choice of the sample was mainly car use. Mobility sharing was hardly used. The majority were experienced in using semi-automated cars, but were inexperienced in autonomous driving. Relevant reasons for mode choice were identified, mainly related to reliability, flexibility, punctuality, independency, and safety. These should certainly be taken into account when designing new mobility services. Relevant questions could be, for example, which aspects of reliability and flexibility play a role. For example, is it the reliability and flexibility of the service and the service provider, or the reliable functioning of the vehicle, and what do potential users want, such as a reliable service centre, flexible booking options, regular maintenance? Follow-up studies should look at the conditions under which car users might consider giving up private transport, and focus more on users of sharing services to understand their reasons for choosing this mode and their attitudes towards traditional and new mobility services. It should also be assessed what knowledge gaps and information

[1]N = 110 (n = 61 shuttle user) due to two missing values.

needs exist in relation to autonomous driving and how information and communication strategies need to be designed accordingly.

In line with previous findings (Biermann et al. 2023, Philipsen et al. 2018), we found a high level of interest and intention to use a novel autonomous shuttle service. Differences in attitudes towards conventional taxis versus autonomous shuttles were in the detail (RQ2). Autonomous shuttles were more likely to be associated with road safety, whereas a human taxi driver was more likely to be associated with the ability to recognize and respond to emergency situations. Follow-up studies should identify the perceived benefits and risks associated with the use of autonomous shuttles (e.g., in terms of human personnel on board and perceived susceptibility to error), as these may be potential barriers and motives for use, i.e., relevant drivers of acceptance.

When asked which mobility service they would like to use in the future (RQ3), the majority of participants expressed a preference for the autonomous shuttle, despite the fact that conventional shared and on-demand services were hardly or rarely used in the sample. This suggests and supports the high level of interest and curiosity of the public in an autonomous and novel mobility service such as the shuttle bus described. However, it also contrasts with usage decisions in other studies (Clayton et al. 2020), possibly due to the selection and presentation of different scenarios. User group differences (RQ4) were found with regard to gender, mobility attitude, use intention, and trust. There were more women than men in both user groups, which can be explained by the overall gender distribution in the sample (proportionally more women). However, the taxi user group was predominantly female, while the shuttle user group was only slightly more female. This is consistent with previous findings that men tend to be more interested in novel mobility solutions than women (Philipsen et al. 2018). As might be expected, the shuttle user group generally showed a more open attitude towards autonomous shuttles and also a higher usage intention. It was interesting to see that the users' perception of trust seemed to make a difference in the evaluation, which supports previous research (Paddeau et al. 2020, Nordhoff et al. 2021). The shuttle user group was more trusting of the technology in general and of the novel autonomous shuttle service. The taxi user group showed a lower level of trust overall. While their reported trust in technology was still high, their initial trust perception towards the autonomous shuttle was towards the middle of the scale (i.e., undecided). This suggests that the taxi users did not have a substantial distrust of technology, but were sceptical of the novel (unfamiliar) shuttle service. Follow-up studies should investigate what drives perceptions of trust and distrust in this context, and which factors and conditions are use-case-related (i.e., related to autonomous driving and the novel shuttle) and which are generic (e.g., explainable by general attitudes towards innovation). Against this background, recommendations for action can then be made for the technical design and implementation of a new driving service, and for innovation management in general.

Issues for discussion and reflection on the results and methods, beyond those already mentioned but relevant to follow-up studies, are as follows: First, the sample was rather small, young, and well educated. Future studies should validate the results obtained in a larger and broader (i.e., more diverse)

sample. Secondly, the data was collected in Germany or in German-speaking countries. As the car has a very special position in Germany and attitudes may be conditioned by cultural influences, it is necessary to mirror our results in a cross-national study in order to identify any cultural differences in the evaluation of novel and autonomous mobility services, mode choice, and people's willingness to switch from private to shared cars. Another point relates to the use case description in our study, which was scenario and text based. As the evaluations are based on the imagination of the individual respondents, it remains essential to interview them again in real-life test situations, such as test drives, as user experience might influence acceptance ratings (Bernhard et al. 2020, Chinen et al. 2020).

CONCLUSION

Car use is high and car ownership is perceived as important. Nevertheless, there is interest in SAV and a willingness to use them for on-demand passenger transport in the future. A crucial factor for acceptance seems to be the users' initial perception of trust, which needs to be further investigated in follow-up studies regarding relevant influencing factors and conditions as well as individual differences in perception and evaluation. From this, recommendations for practical trust building can be derived.

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