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User acceptance of automated public transport

Valence of an autonomous minibus experience

Christoph Bernhard [a,*], Daniel Oberfeld [a], Christian Hoffmann [b], Dirk Weismüller [b], Heiko Hecht [a]

[a] Experimental Psychology, Johannes Gutenberg-Universität Mainz, Mainz, Germany
[b] Mainzer Mobilität, Mainz, Germany

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ABSTRACT

Autonomous driving is receiving increasing attention in the automotive industry as well as in public transport. However, it is still unclear whether users are willing to use automated public transportation at all. In order to answer this and other questions, the transport company of the city of Mainz, Germany, tested the autonomous minibus EMMA (Elektro-Mobilität Mainz Autonom) on a 600-meter-long test track in public space. The study presented here was conducted with the aim of exploring crucial determinants for the use of an autonomous minibus. On the basis of established acceptance models, a questionnaire was developed, which was completed in a field survey by a total of 942 participants before or after their journey with the minibus. Autonomous vehicles in public transport in general and the minibus in particular were evaluated positively by the majority of respondents. Above all, participants judged safety and environmental friendliness of the minibus as important. Participants who completed the questionnaire after their first trip with EMMA provided higher ratings of acceptance than those who had not travelled on the bus. Performance expectancy was the most important predictor for both acceptance of automated public transport in general and acceptance of the minibus EMMA. However, the experienced valence of the ride, in terms of how pleasant or unpleasant passengers experienced the first trip with the minibus, also affected acceptance of the minibus. This suggests a role of valence on intention-to-use, which has hardly been considered in previous theories and studies.

1. Introduction

Automated driving has received much attention in recent years. When speaking of automated driving, different degrees of automation have to be distinguished. According to the established classification of the Society of Automotive Engineers (SAE), a distinction can be made between partial and conditional automation (levels 1, 2, and 3), high automation (level 4) and full automation, henceforth called autonomous driving (level 5) (SAE, 2014). In this context, partial and conditional automation describe a system that only supports the driver in selective, clearly defined situations. Highly and fully automated systems perform all driving and monitoring tasks autonomously, but only autonomous driving no longer requires a human monitor.

* Corresponding author at: Experimental Psychology, Johannes Gutenberg-Universität Mainz, Wallstraße 3, 55128 Mainz, Germany.
E-mail address: christoph.bernhard@uni-mainz.de (C. Bernhard).

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Several work groups and simulation studies exist that argue for and try to quantify the potential benefits of autonomous driving, especially in on-demand mobility and ride-sharing (e.g. Chan, 2017; Fagnant & Kockelman, 2015; Milakis, van Arem, & van Wee, 2017). One advantage is the significant reduction of accident risks. A report of the National Highway Traffic Safety Administration (NHTSA) shows that critical traffic situations are largely caused by the human driver and that distraction and erroneous decisions are most strongly associated with accident numbers (NHTSA, 2008). Furthermore, autonomous public transport could meet rising demands in urban areas through flexible mobility services, such as ride-sharing. This would also decrease the number of personal vehicles and thus global CO_2 emissions (Chan, 2017; Merlin, 2017; Milakis et al., 2017). The higher energy efficiency of autonomous driving could increase this effect, which in turn would have a positive impact on consumption, travel time and costs (Fagnant & Kockelman, 2015; Hoogendoorn, van Arem, & Hoogendoom, 2014). Specifically, in a simulated case study with taxi data from Singapore, Spieser et al. (2014) demonstrated that automated ride-sharing services could cover current mobility needs with one third of the vehicles.

Research on acceptance of this mobility concept in public transport has just begun (e.g. Nordhoff et al., 2018). Acceptance could be a decisive factor for the success of autonomous systems (Saffarian, de Winter, & Happee, 2012). In the following, we first give a general overview of the conceptualization of user acceptance and subsequently present recent findings regarding the acceptance of autonomous public transport in more detail.

1.1. User acceptance of automated systems

Dillon and Morris (1996) define user acceptance as "*the demonstrable willingness within a user group to employ information technology for the tasks it is designed to support*" (p. 7). According to this definition, acceptance usually is conceptualized as the intention to use a new system. A well-known model that follows this definition is the Unified Theory of Acceptance and Use of Technology (UTAUT, Venkatesh, Morris, Davis, & Davis, 2003; Venkatesh, Thong, & Xu, 2012). UTAUT integrates existing acceptance models in order to formulate a uniform theory of user acceptance. The model includes three key predictors of intention-to-use: performance expectancy, effort expectancy, and social influence. UTAUT also includes facilitating conditions as a direct predictor for use behavior. The relationship between effort expectancy, social influence, and intention-to-use - as well as between facilitating conditions and use behavior - is moderated by gender, age, and experience. In contrast, the influence of performance expectancy should only be moderated by age and gender (Venkatesh et al., 2003; Venkatesh et al., 2012). In an extension of the original model, UTAUT2 includes the constructs hedonic motivation, price value, and habit as predictors for intention-to-use and use behavior. Moreover, it excludes voluntariness of use, which had been included in UTAUT (Venkatesh et al., 2012). Performance expectancy originally describes the expectation of a user that the use of the system will improve his or her job performance. On the other hand, effort expectancy is defined as the "degree of ease associated with the use of the system" (Venkatesh et al., 2003, p. 450). UTAUT formed the basis for our conceptualization of user acceptance. We decided for UTAUT for three major reasons. First, UTAUT integrates constructs from eight different acceptance models into one model and thus can be expected to include the most important determinants of usage intention. Moreover, it adds potentially important moderators, namely age, gender, and experience to the model. Finally, UTAUT also reduces complexity in comparison with newer conceptualizations of the Technology Acceptance Model (TAM, Venkatesh & Bala, 2008), by incorporating fewer constructs. In adopting UTAUT, we also follow other researchers who used and adopted UTAUT to conceptualize user acceptance towards autonomous driving (Adell, 2010; Ghazizadeh, Lee, & Boyle, 2012; Madigan, Louw, & Dziennus, 2016; Madigan, Louw, Wilbrink, Schieben, & Merat, 2017; Nordhoff et al., 2018). However, we also decided to incorporate additional factors not included in UTAUT to predict usage intentions of potential users. This will be outlined in Section 1.3.

1.2. Acceptance of automated public transport systems

Although the potential of automated mobility concepts in road-based public transport has been recognized for many years, their implementation started only a few years ago. The earliest projects, CityMobil and CityMobil 2, were initiated by the European Union (Alessandrini, Cattivera, Holguin, & Stam, 2014). Recently, numerous other projects, mostly involving small buses, have been launched. For example, the CAST project (Christie, Koymans, Chanard, Lasgouttes, & Kaufmann, 2016), Drive Sweden (https://www.drivesweden.net/en/organization), or the EUREF project in Berlin (Nordhoff et al., 2018). In the following, we will outline the findings of these and other projects in more detail.

Christie et al. (2016) showed that the majority of users perceive automated minibuses positively. During a test on a public road in Switzerland, residents and pedestrians also evaluated an automated minibus mostly positively (Eden, Nanchen, Ramseyer, & Evéquoz, 2017). In this study, however, participants criticized the slow velocity of the minibus (20 km/h) and expressed uncertainty with respect to the predictability of the minibus's driving behavior. In the CityMobil2 project, (Madigan, Louw, & Dziennus, 2016, Madigan, Louw, & Wilbrink, 2017) examined the relationship between expectations and intention-to-use with respect to an autonomous minibus. Overall, subjects expressed a high intention-to-use, which was predicted by performance expectancy and social influence. Effort expectancy predicted intention-to-use only in the first study, but not in the second study, where additional predictors were added into the regression model (Madigan, Louw, & Wilbrink, 2017). Most recently, Nordhoff et al. (2018) investigated user acceptance of an autonomous minibus in Berlin. Again, participants seemed to accept the minibus, rating it as useful and the ride as pleasant. Interestingly, Nordhoff et al.

included several characteristics of the minibus, such as design or spaciousness, into their questionnaire. These characteristics were highly correlated with intention-to-use. These results are similar to those of Krueger et al. (2016), who conducted a survey about automated ride-sharing services and found that service attributes such as costs, travel time, and waiting time were key determinants of acceptance.

Thus, participants seem to perceive autonomous minibuses positively. However, it should be noted that the above-mentioned studies were mere demonstrations of future mobility concepts, which might limit the generalizability of the results. Quantitative results from internet-based surveys with large, representative samples do not support the predominantly positive attitude towards autonomous driving. Although these studies found a general willingness to use autonomous vehicles (Payre, Cestac, & Delhomme, 2014), manual driving seems to be the preferred option (Kyriakidis, Happee, & de Winter, 2015). Regarding autonomous minibuses, people seem to have idealized expectations regarding the technical capacities of autonomous vehicles (Nordhoff, de Winter, Payre, Van Arem, & Happee, 2019). In addition, a large proportion of respondents expressed negative attitudes, in particular with respect to the reliability of the automated system, data security, as well as political and legal regulations (Bazilinskyy, Kyriakidis, & de Winter, 2015; Kyriakidis et al., 2015).

1.3. Research scope

Our research directly expands on the above studies. It was conducted in the course of a project that was partially funded by the local public transport provider of the city of Mainz, Germany. In the project, an autonomous minibus called EMMA (Elektro-Mobilität Mainz Autonom) was presented to the public and tested for a period of one month. One main goal of our study was to explore the potential users' acceptance of and intention to use automated mobility concepts. Our approach differs from the above-mentioned studies in several ways. First, only two main determinants of UTAUT, performance and effort expectancy, together with the moderators age, gender, and experience were used to conceptualize user acceptance. Even if the demographic variables had not been identified as moderators in previous studies for autonomous public transport (Madigan, Louw, & Dziennus, 2016; Madigan, Louw, & Wilbrink, 2017), they still are integral features of UTAUT and UTAUT2 (Venkatesh et al., 2003; Venkatesh et al., 2012). Therefore, we considered it important to reexamine their role in modelling the acceptance of autonomous public transport.

We are aware that UTAUT and its revised version, UTAUT2, include additional constructs to predict the intention to use new technologies. Regarding autonomous vehicles, Nordhoff, Kyriakidis, Van Arem, and Happee (2019) formulated a comprehensive multi-level model of acceptance of automated vehicles, which includes many constructs on two different levels. We acknowledge the importance of all these constructs to predict the use of autonomous vehicles. However, it was our goal to achieve as valid as possible a conceptualization of acceptance with the shortest and most efficient possible questionnaire. Thus, we decided against including all UTAUT constructs in our questionnaire and instead only focused on performance and effort expectancy, which we considered as most important, as well as on their moderators age, gender, and experience. Similar constructs have been acknowledged as key determinants of usage intention in the original TAM (Davis, 1989; Davis, Bagozzi & Warshaw, 1989), and their importance has been repeatedly demonstrated (see King & He, 2006; Schepers & Wetzels, 2007; Turner, Kitchenham, Brereton, Charters, & Budgen, 2010), also in autonomous driving (Buckley, Kaye, & Pradhan, 2018; Ghazizadeh et al., 2012; Madigan, Louw, & Dziennus, 2016). Performance expectancy in particular has been identified as the strongest predictor of usage intention in these studies. Regarding effort expectancy, findings from studies on autonomous public transport and driver support systems suggest that this construct might not be a key predictor of intention-to-use (Adell, 2010; Madigan, Louw, & Wilbrink, 2017). However, since it has typically been and still is included as a key determinant in models of user acceptance (e.g. Nordhoff, Kyriakidis, et al., 2019), we decided to include effort expectancy in our model, thus putting the concept to an additional test.

An additional goal of our project was to explore the importance of factors other than those included in UTAUT in predicting users' intention to use automated public transport. More specifically, we considered user opinions towards safety and other characteristics of the minibus as important, as did Nordhoff et al. (2018). Perceived safety in particular seems to be a decisive factor for the acceptance of new vehicle technologies (Osswald, Wurhofer, Trösterer, Beck, & Tscheligi, 2012) and might improve the prediction of intention-to-use. We also assessed the valence of the passengers' experience with the minibus. Valence is a classical part of dimensional emotion concepts (e.g., Schlosberg, 1954). It describes the evaluation of an object, situation, or event on two polar opposites, which are typically referred to as "good-bad", "positive-negative", or "pleasant-unpleasant". In our case, valence describes the global evaluation of the trip with the minibus as pleasant or unpleasant. Moreover, our study differs from Nordhoff et al. (2018) in two crucial aspects. First, we use regression models and dominance analysis to quantify the importance of each factor for the prediction of intention-to-use, instead of focusing solely on the correlation structure of previously extracted factors. Second, we interviewed subjects either before or immediately after their trip with the minibus. Thus, participants who completed the questionnaire after the ride with the minibus were different from those who completed the questionnaire prior to their ride with the minibus. To the best of our knowledge, a pre-post comparison has not been conducted by any other study so far and enabled us to examine how one trip with an autonomous minibus can change the perception of autonomous public transport in general.

2. Methods

2.1. Questionnaire

In our study, we used two different questionnaire versions. The first version, hereafter called the pre-questionnaire, assessed user acceptance of autonomous driving in public transport prior to a drive with the minibus EMMA. It consisted of items to assess key constructs of UTAUT, namely intention-to-use, performance expectancy, and effort expectancy in relation to autonomous driving in public transport. The second version, hereafter termed the post-questionnaire, was completed after a ride with EMMA. It contained the same items as the pre-questionnaire, as well as items assessing opinions on the safety and other characteristics of the minibus. All items measuring acceptance were inspired by Venkatesh et al. (2003), adapted to the context of autonomous public transport and translated into German. Both questionnaires can be found in the supplementary material.

Pre-questionnaire. In the first part, participants gave their consent and were then asked to indicate their age and gender. Also, participants indicated whether they had previously ridden the minibus. Next, five items assessed performance expectancy, effort expectancy, and intention-to-use (see Table 1). As recommended by Davis et al. (1989), all items were rated on 7-point Likert scales ranging from *1 (strongly disagree)* to *7 (strongly agree)*. Effort expectancy and intention-to-use were measured by one item only. Whereas one-item-measures for intention-to-use have been used in other studies before (Madigan, Louw, & Dziennus, 2016), we are aware that the use of only one item might represent a limitation of our questionnaire, especially regarding effort expectancy. We will return to this issue in the discussion section. In the last part of the questionnaire, two control items asked participants whether they had answered all questions seriously and honestly, as well as whether they had completed a similar questionnaire before.

Post-questionnaire. In the first part, a rating scale with five levels assessed how frequently participants use public transport. The five levels were described with the anchors *never*, *infrequently (once in a months or less)*, *several times a month*, *several times a week* and *every day*. Then, the items from Table 1 followed. The second part focused on the evaluation of the minibus EMMA (see Table 2). All items in Table 2 were measured on 7-point rating scales. One additional item assessed the willingness to use the minibus with dichotomous response format, followed by a question with open response format. Finally, participants could answer three open questions, namely what they had liked best, what they missed, and what had surprised them during the test drive.

2.2. Test track and minibus

The field test took place on a public riverside road in Mainz from August 07 to 25, 2018. Fig. 1 depicts the test track. It was 600 m long and mostly straight. One end-point was located in a pedestrian area. Interested persons could drive from one end point of the track to the other for free. If the demand was high, a drive back to the starting position was not possible. One drive with the minibus took five to ten minutes.

An autonomous minibus of the manufacturer Navya (https://navya.tech/en/autonom-shuttle/) was used during the whole demonstration phase (see Fig. 2 for a visual impression). The bus drove electrically for a maximum time period of nine hours and with a maximum speed of 15 km per hour (kph). The minibus provided enough space for a maximum number of eleven passengers. During each test drive, an operator was on board who monitored the minibus and who could take over control, if necessary, by using a video controller. The operator was seated on a normal passenger seat, but was recognizable by a shirt of the transport company and by the controller in his hands. The minibus used GPS, radar, and LIDAR (Light Detection and Ranging) data to localize itself in the previously encoded environment. Thus, it drove autonomously on a predefined track, comparable to virtual rails. Additionally, the minibus was equipped with camera systems to identify surrounding road users. In case of an imminent collision, the minibus initiated an emergency brake automatically and communicated with other road users and passengers via visual signals and auditory alerts. As soon as the obstacle disappeared, the minibus drove on. The operator's task was to initiate a turning maneuver at the end of the test track as well as to open and close the doors. Other forms of intervention by the operator were not observed during the test period.

Table 1
Items from the pre-questionnaire to assess UTAUT constructs performance expectancy, effort expectancy, and intention-to-use.

Constructs	Questionnaire item
Performance expectancy	Autonomous driving will become an important part of public transport
	Autonomous driving will help me to reach my destinations better than conventional forms of public transport.
	Autonomous driving is safer than conventional forms of public transport.
Effort expectancy	It is easy to understand how to use an autonomously driving minibus.
Intention-to-use	If available, I would use autonomous vehicles in public transport.

Note. Since the study took place in Germany, all items rated in the questionnaires were German. English translations of the items are shown here. For the German version of the questionnaire, please refer to the supplementary material.

Table 2
Items from the post-questionnaire to asses willingness-to-use, perceived safety, valence, minibus characteristics and environmental friendliness.

Constructs	Questionnaire item
Willingness to use EMMA	If the autonomous minibus EMMA was available on a route, I would use it. *strongly disagree* / *strongly agree*
Perceived safety	I feel just as safe in the autonomous minibus as in a normal vehicle. *strongly disagree* / *strongly agree*
	I trust the autonomous minibus to take me safely to my destination. *strongly disagree* / *strongly agree*
	The autonomous minibus must be monitored by an operator on board so that it is safe and reliable. *strongly disagree* / *strongly agree*
Valence	I found the trip with the autonomous minibus to be… *unpleasant* / *neutral* / *pleasant*
Minibus characteristics	The speed of the minibus was… *too slow* / *just right* / *too fast*
	The breaking of the minibus was… *too weak* / *just right* / *too strong*
	The space available in the minibus was… *very uncomfortable* / *neutral* / *very comfortable*
Environmental friendliness	How important is the minibus's environmental friendliness to you? *not important at all* / *neutral* / *very important*

Note. Since the study took place in Germany, all items rated in the questionnaires were in German. Words in italics represent the anchors and, if applicable, the middle categories of the rating scales.

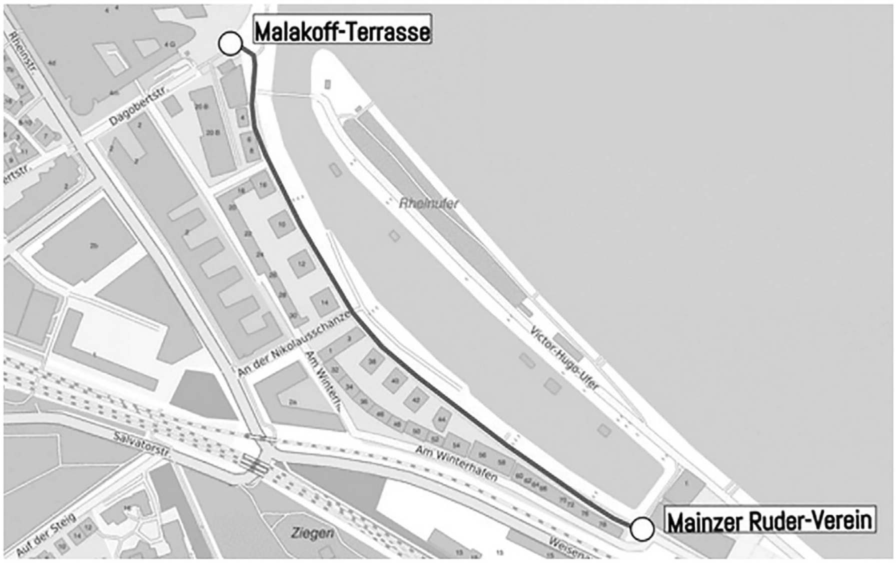

Fig. 1. Test track of the minibus EMMA in Mainz. Copyright © 2018 Mainzer Mobilität.

2.3. Recruiting and procedure

A total of $N = 942$ participants took part in the survey. Of those, $n = 371$ were female and $n = 522$ male, $n = 49$ did not provide gender information. The average age of the interviewees was 45.2 years (SD = 19.3 years, range 4–89 years). Of the total sample, $n = 578$ completed the pre-questionnaire and $n = 364$ the post-questionnaire. The two groups did not differ in their mean age ($t\,(765.99) = 0.78$, $p = .437$) or gender distribution ($\chi^2\,(1) = 0.34$, $p = .528$). In the post-questionnaire, 54.7% of the participants indicated that they never or rarely use public transport, 14.3% several times a month, 12.6% several times a week and only 16.8% on a daily basis. Six people did not provide any information about usage frequency.

The survey took place from Mondays to Saturdays, between 10 am to 1 pm and 2 pm to 5 pm, in the pedestrian area at one of the end-points of the test track. Subjects were recruited directly in the pedestrian area. If they agreed to participate in the survey, participants received the questionnaire. All participants who had not yet used EMMA received the pre-questionnaire and all others the post-questionnaire. If possible, the post-questionnaire was handed to the passengers immediately after leaving the minibus. People could only participate once in the survey. Completion of the questionnaires took about 5 min for the pre-questionnaire and about 10 min for the post-questionnaire. The questionnaires were completed directly at the test side. In addition to the print questionnaires, onlookers also had the opportunity to access the questionnaires online

Fig. 2. The autonomous minibus EMMA. Copyright © 2018 Mainzer Mobilität.

via a QR code. QR codes were available both in the minibus and at the bus stops. We used the software LimeSurvey for online questionnaires. However, only four respondents used this option.

2.4. Data analysis

The analysis was carried out in three steps. First, questions on the general acceptance of autonomous public transport were analyzed descriptively, which were identical in both questionnaires. Subsequently, ratings for safety and vehicle dynamics from the post-questionnaire were examined in more detail. We report relevant descriptive statistics for both questionnaires. Furthermore, we provide figures with means and 95% confidence intervals in order to examine significant differences between independent groups. Note that in our between-subjects design, two conditions with non-overlapping 95% confidence intervals show a significant difference in means on an α-level of 0.05. Regarding age, participants were grouped into four age groups, ranging from 1 to 20, 21 to 40, 41 to 60 and 61 to 90 years. In the last step, two multiple linear regressions were calculated. The first regression tested whether the two UTAUT variables performance and effort expectation predicted participants' intention to use autonomous public transport and whether, in accordance with Venkatesh et al. (2003), age, gender, and experience moderated this relationship. The second regression analysis tested whether ratings of safety and vehicle dynamics as well as the UTAUT variables predicted participants' willingness to use the minibus. In both regressions, reported β values correspond to the standardized regression coefficients. The residual Q-Q plots showed no systematic deviation from normal distribution. The results were evaluated at a significance level of $\alpha = 0.05$. All calculations were performed with the software SPSS Statistics 23.

3. Results

3.1. General acceptance of autonomous public transport

Table 3 gives an overview of means and standard deviations of the items collected in both the pre- and post-questionnaire. In addition, Fig. 3 illustrates means and 95% confidence intervals of the ratings. On average, participants evaluated the minibus positively, with ratings between 4.40 and 5.86 on the 7-point rating scale and thus above the mid-point (4). Ratings in the post-questionnaire were slightly higher than those in the pre-questionnaire. Participants in both questionnaires preferred the middle category for the last two items of performance expectancy, indicating no preference for either autonomous or conventional public transport regarding travel quality or safety. However, participants in the pre-questionnaire seemed to be significantly less confident about the ease associated with the use of an autonomous minibus in the pre-questionnaire than in the post-questionnaire, as shown by Fig. 3, left upper panel. In terms of gender, men consistently gave higher ratings than women, as illustrated in Fig. 3, upper right panel. Finally, the participants in the age groups

Table 3
Means and standard deviation of the questionnaire items measuring acceptance of autonomous driving in public transport.

	Overall	Questionnaire		Gender		Age groups			
		Pre	Post	Male	Female	1–20	21–40	41–60	61–90
N	942	578	364	522	371	102	295	289	242
PE1	5.45 (1.49)	5.42 (1.50)	5.49 (1.47)	5.62 (1.47)	5.26 (1.46)	5.67 (1.43)	5.51 (1.41)	5.41 (1.53)	5.34 (1.55)
PE2	4.40 (1.41)	4.36 (1.42)	4.48 (1.41)	4.54 (1.46)	4.24 (1.31)	4.59 (1.39)	4.39 (1.42)	4.36 (1.45)	4.39 (1.39)
PE3	4.41 (1.44)	4.29 (1.46)	4.61 (1.39)	4.50 (1.46)	4.29 (1.40)	4.40 (1.63)	4.43 (1.43)	4.35 (1.44)	4.47 (1.37)
EE	5.54 (1.35)	5.27 (1.38)	5.95 (1.19)	5.70 (1.28)	5.34 (1.38)	5.53 (1.37)	5.65 (1.38)	5.55 (1.35)	5.39 (1.28)
BI	5.86 (1.39)	5.81 (1.38)	5.93 (1.39)	5.97 (1.36)	5.74 (1.39)	6.00 (1.42)	6.08 (1.26)	5.73 (1.39)	5.69 (1.48)

Note. N = number of participants. Standard deviations are in parentheses. PE = performance expectancy. EE = effort expectancy. BI = behavioral intention.

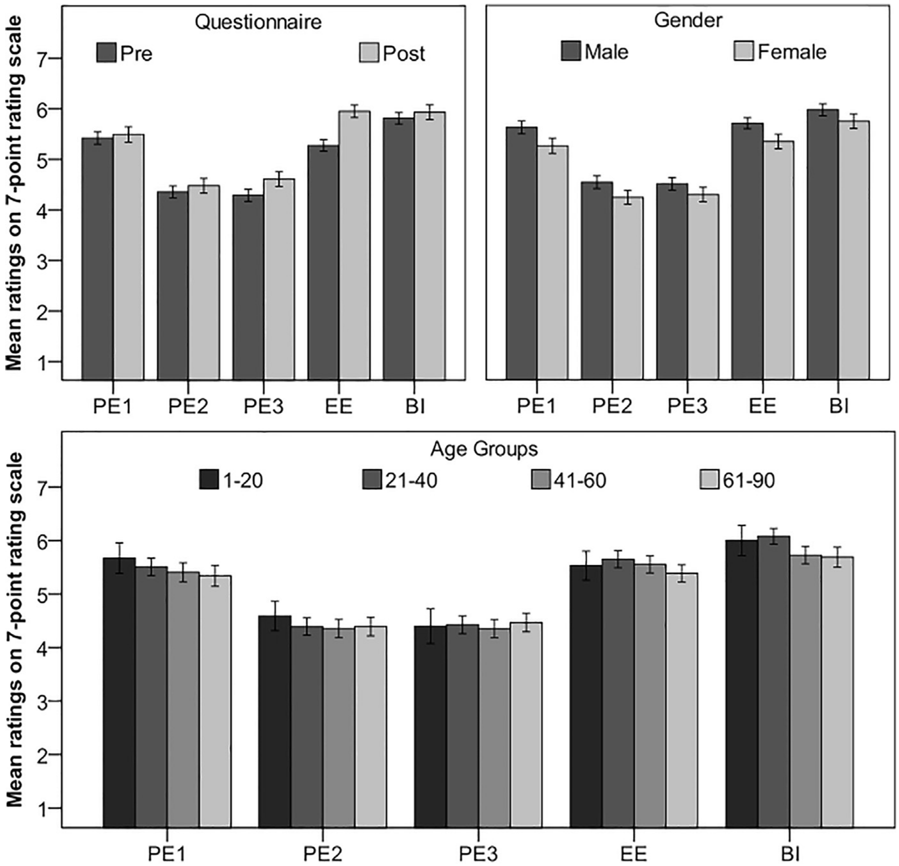

Fig. 3. Mean ratings on questionnaire items measuring acceptance of autonomous driving in public transport, separated by questionnaire type, gender, and age. Error bars show 95% confidence intervals. PE = performance expectancy. EE = effort expectancy. BI = behavioral intention.

rated autonomous driving in public transport similarly. However, younger participants tended towards higher ratings regarding their intention to use autonomous public transport.

3.2. Acceptance of the autonomous minibus EMMA

Table 4 shows the means and standard deviations of the items assessed in the post-questionnaire and Fig. 4 depicts the means and 95% confidence intervals for the ratings separately for gender and age group. Most ratings were higher than the middle category 4 on the 7-point rating scale, except for the item related to the velocity of the minibus. The items *valence* and *environmental friendliness* received the highest ratings. Again, ratings differed between genders. On average, women gave significantly higher ratings for the items *need for an operator*, *spaciousness of the minibus* and *environmental friendliness*, as shown in Fig. 4, left panel. Finally, older differed from younger participants most strongly regarding the velocity of the mini-

Table 4
Means and standard deviations of the items assessing acceptance of EMMA.

	Overall	Gender		Age groups (in years)			
		Male	Female	1–20	21–40	41–60	61–90
N	364	200	151	44	113	115	88
WU	6.06 (1.31)	5.98 (1.40)	6.13 (1.20)	6.05 (1.35)	6.10 (1.36)	6.02 (1.33)	6.06 (1.23)
PS1	5.71 (1.47)	5.82 (1.46)	5.52 (1.48)	5.76 (1.66)	5.86 (1.38)	5.55 (1.57)	5.72 (1.34)
PS2	5.82 (1.29)	5.90 (1.28)	5.67 (1.31)	5.97 (1.38)	5.88 (1.22)	5.64 (1.44)	5.90 (1.09)
NO	4.65 (1.78)	4.44 (1.86)	4.92 (1.62)	4.84 (1.82)	4.40 (1.87)	4.72 (1.78)	4.80 (1.63)
Va	6.32 (1.56)	6.19 (1.25)	6.49 (1.02)	6.24 (1.32)	6.17 (1.18)	6.36 (1.17)	6.51 (1.03)
Ve	2.82 (1.56)	2.69 (1.14)	2.99 (1.15)	2.49 (1.19)	2.48 (1.05)	3.04 (1.19)	3.12 (1.09)
Br	4.58 (1.00)	4.60 (0.98)	4.55 (1.04)	4.46 (0.77)	4.77 (1.05)	4.62 (1.06)	4.35 (0.91)
Sp	4.37 (1.53)	4.17 (1.51)	4.69 (1.51)	4.73 (1.48)	4.09 (1.56)	4.38 (1.57)	4.55 (1.41)
EF	6.22 (1.28)	6.01 (1.46)	6.49 (0.92)	5.97 (1.34)	6.15 (1.31)	6.31 (1.26)	6.28 (1.23)

Note. N = number of participants. Standard deviations are in parentheses. WU = willingness to use EMMA. WU = willingness to use EMMA. PS = perceived safety. NO = need for an operator. Va = valence. Ve = velocity. Br = braking. Sp = spaciousness. EF = environmental friendliness.

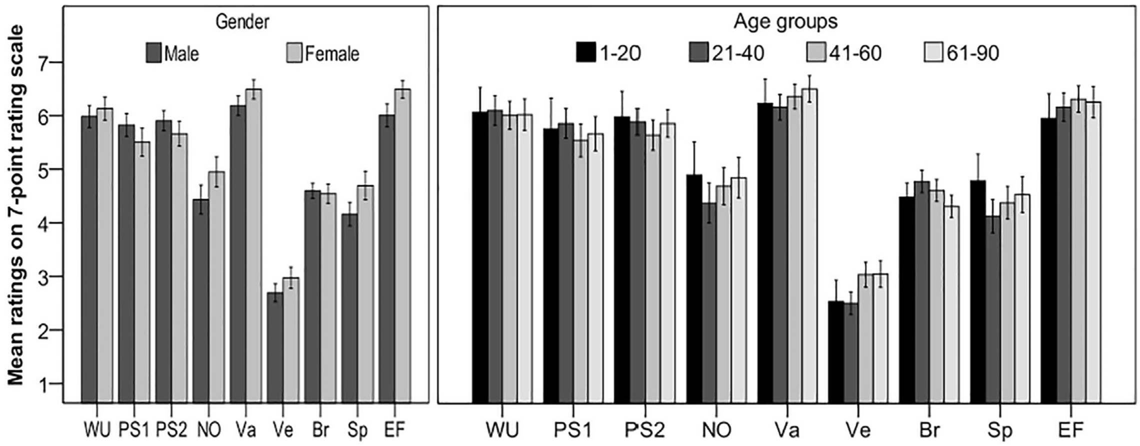

Fig. 4. Mean ratings on questionnaire items assessing acceptance and driving characteristics of the autonomous minibus EMMA, separated by gender and age. Error bars show 95% confidence intervals. WU = willingness to use EMMA. PS = perceived safety. NO = need for an operator. Va = valence. Ve = velocity. Br = braking. Sp = spaciousness. EF = environmental friendliness.

bus. Older participants perceived the velocity of the minibus as being just right, in contrast to younger participants, who gave lower ratings (Fig. 4, right panel).

3.3. Prediction of intention-to-use and willingness-to-use

In accordance with previous studies (Madigan, Louw, & Dziennus, 2016; Nordhoff et al., 2018), we tested whether participants' intention to use autonomous public transport can be predicted by performance expectancy, effort expectancy, and their moderators. We also tested whether the ratings on the characteristics of the minibus EMMA could predict the retrospective willingness to use the minibus.

In accordance with the high internal consistency of the three items measuring performance expectancy (Cronbachs $\alpha = 0.78$), we first aggregated them into one factor. Thus, the linear model included the predictors *performance expectancy*, *effort expectancy*, as well as the demographic variables *age* and *gender* and *questionnaire type*, as an indicator for the experience with the minibus. Fig. 5 shows a graphical representation of our regression model. In contrast to UTAUT, we tested the main effects of the moderator variables, as was done in Madigan, Louw, & Wilbrink (2017). We also tested for a moderator effect of experience on performance expectancy, which we expected to be absent, based on UTAUT (Venkatesh et al., 2003; Venkatesh et al., 2012). Age was a continuous predictor, whereas the two categorical predictors gender and questionnaire type were dummy-coded. Gender was dummy coded with males and questionnaire type with the pre-questionnaire as reference groups. All predictors entered the analysis simultaneously. Table 5 shows the correlation structure of the predictors and the criterion (intention-to-use).

Table 5 shows that some of the predictors were significantly correlated. In such a case, it can be misleading to derive the relative importance of the predictors from the size of their squared standardized regression coefficients, since these predictors do not appropriately partition variance because of their collinearity (Tonidandel & LeBreton, 2011). For this reason, we used dominance analysis to assess the relative importance (Azen & Budescu, 2003; Budescu, 1993). This approach has

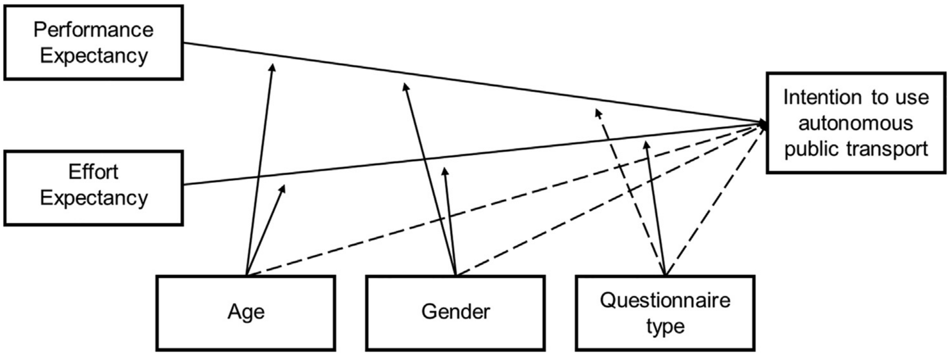

Fig. 5. Regression model for the criterion (intention to use autonomous public transport). Solid lines represent the effects expected by UTAUT (Venkatesh et al., 2003).

Table 5
Correlation structure of the predictors and the criterion (intention to use autonomous public transport).

		BI	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1.	Performance expectancy	**0.63**										
2.	Effort expectancy	**0.46**	**0.04**									
3.	Age	**−0.09**	0.02	−0.05								
4.	Gender	**−0.08**	**−0.12**	**−0.13**	0.04							
5.	Questionnaire type	0.02	**0.07**	**0.24**	−0.02	0.02						
6.	Performance expectancy × Age	0.03	0.00	0.02	0.04	**0.08**	0.00					
7.	Performance expectancy × Gender	−0.03	**−0.09**	0.05	**0.08**	0.02	−0.02	−0.01				
8.	Performance expectancy × Questionnaire type	0.01	0.00	0.00	0.00	−0.02	0.05	−0.03	0.05			
9.	Effort expectancy × Age	0.03	0.02	**−0.09**	−0.05	0.03	−0.02	**0.43**	−0.03	−0.04		
10.	Effort expectancy × Gender	**0.07**	0.05	**0.08**	0.03	−0.03	0.05	−0.03	**0.41**	−0.04	−0.03	
11.	Effort expectancy × Questionnaire type	−0.01	0.00	**−0.09**	−0.02	0.05	**0.13**	−0.04	−0.02	**0.41**	0.01	0.04

Note. N = 862. BI = Behavioral intention (criterion). Gender was dummy coded with 0 = male and 1 = female. Experience = questionnaire type. Questionnaire type was dummy coded with 0 = pre and 1 = post. Correlation coefficients in bold show significance at $p < .05$.

already been applied by other researchers to determine the relative importance of predictors in multiple linear regression analyses (e.g. LeBreton, Ployhart, & Ladd, 2004; Oberfeld & Klöckner-Nowotny, 2016; Thomas et al., 2014; Tonidandel & LeBreton, 2011). In dominance analysis, the importance of each predictor is determined by creating regression models containing every possible subset of the remaining predictors, including one model containing only the intercept term. Then, the changes in the variance accounted-for (ΔR^2) that result from adding the predictor of interested to all possible regression models are calculated. The General Dominance Weight (GDW) is the mean of these squared semipartial correlations ΔR^2. Table 6 presents the results of the multiple linear regression and dominance analysis.

The regression model showed an acceptable fit, R^2 = 0.459. According to the dominance weights, the most important predictor of intention-to-use was performance expectancy, followed by effort expectancy. The regression coefficients for age

Table 6
Results of the linear regression and the dominance analysis for the criterion (intention to use autonomous public transport).

Predictors	β	*SE*	*t*	*p*	GDW
Performance expectancy	**0.52**	**0.03**	**18.96**	**<0.001**	**0.304**
Effort expectancy	**0.28**	**0.03**	**9.49**	**<0.001**	**0.135**
Age	**−0.07**	**0.03**	**2.86**	**0.004**	**0.006**
Gender	−0.02	0.03	0.99	0.323	0.002
Questionnaire type	**−0.09**	**0.03**	**3.13**	**0.002**	**0.004**
Performance expectancy × Age	0.01	0.03	0.34	0.737	0.001
Performance expectancy × Gender	−0.01	0.03	0.40	0.686	0.002
Performance expectancy × Questionnaire type	0.01	0.03	0.36	0.717	0.000
Effort expectancy × Age	0.04	0.03	1.31	0.189	0.002
Effort expectancy × Gender	0.04	0.03	1.39	0.164	0.003
Effort expectancy × Questionnaire type	0.02	0.03	0.78	0.439	0.000
R^2 = 0.459, $p < .001$					

Note. N = 862. β = standardized ordinary least-squares (OLS) regression coefficient. *SE* = standard error of the regression coefficients. R^2 corresponds to the coefficient of determination, as calculated by SPSS. GDW = General Dominance Weight. Gender was dummy coded with 0 = male and 1 = female. Experience = questionnaire type. Questionnaire type was dummy coded with 0 = pre and 1 = post.

and experience were significant, but their small dominance weights indicate that they accounted only for a small amount of variance in the criterion. All other effects were not significant.

Next, we analyzed how the ratings on safety and driving dynamics of the autonomous minibus as well as the UTAUT variables predicted participants' willingness to use the minibus. This analysis was only performed for the post-questionnaire. Since the items measuring perceived safety and performance expectancy were in part similar and highly correlated (r = 0.379 - r = 0.795), we decided to calculate a PCA in order to test whether those items loaded on the same factor. One factor with eigenvalue greater than one was extracted, based on the Scree-plot. Because of its small factor loading of a = 0.27, the item *need for an operator* was removed and we calculated a second PCA. This resulted in one factor, with loadings between a = 0.73 und a = 0.82. Thus, the items were aggregated into one factor called performance expectancy, the internal consistency was high (Cronbach's α = 0.84). We then performed a multiple linear regression including the items about valence and the minibus characteristics, the UTAUT variables *performance* and *effort expectancy*, *age* as continuous predictors, *gender* and *usage frequency* as categorical predictors, and the interaction terms of the UTAUT variables and the demographic variables. Fig. 6 illustrates the regression model. The solid lines show the effects expected by UTAUT (Venkatesh et al., 2003). Gender was again coded with males as reference group. The dummy coding for usage frequency resulted in four dummy predictors with the fifth level (*every day*) as reference group. Table 7 shows the correlation structure between the predictors and the criterion willingness to use the autonomous minibus. Interactions are not shown for sake of simplicity.

Since predictors were again correlated, we calculated general dominance weights for each predictor. Table 8 shows the results of the multiple linear regression and the dominance analysis. For the sake of simplicity, non-significant interaction terms are not shown. The model showed an acceptable fit, R^2 = 0.456. According to the GDWs, performance expectancy was the most important predictor of willingness-to-use, followed by valence, spaciousness, and effort expectancy. The regression coefficient for effort expectancy was not significant. The regression coefficients for the demographic variables age, gender, and usage frequency also did not reach significance. Finally, the dummy predictor for the usage frequency category *monthly used* as well as the interaction between the category *never used* and performance expectancy reached significance.

3.4. Comments of passengers

At the end of the post-questionnaire, three open questions invited participants to write down their opinions regarding the test drive. The three questions asked what the participants had liked the most, what they had missed, and what had surprised them the most. The written comments of test passengers were categorized inductively. 51 participants explicitly stated they did appreciate that the minibus drove autonomously. The low noise level (n = 39) and the environmental friendliness of the minibus (n = 36) was also perceived positively. 21 users described the driving style of the minibus as pleasant and calm. However, 43 users also wished to have more seats or space available in the minibus. Furthermore, 39 participants evaluated the speed of the minibus as too slow. 19 passengers wished they could use the minibus on other test

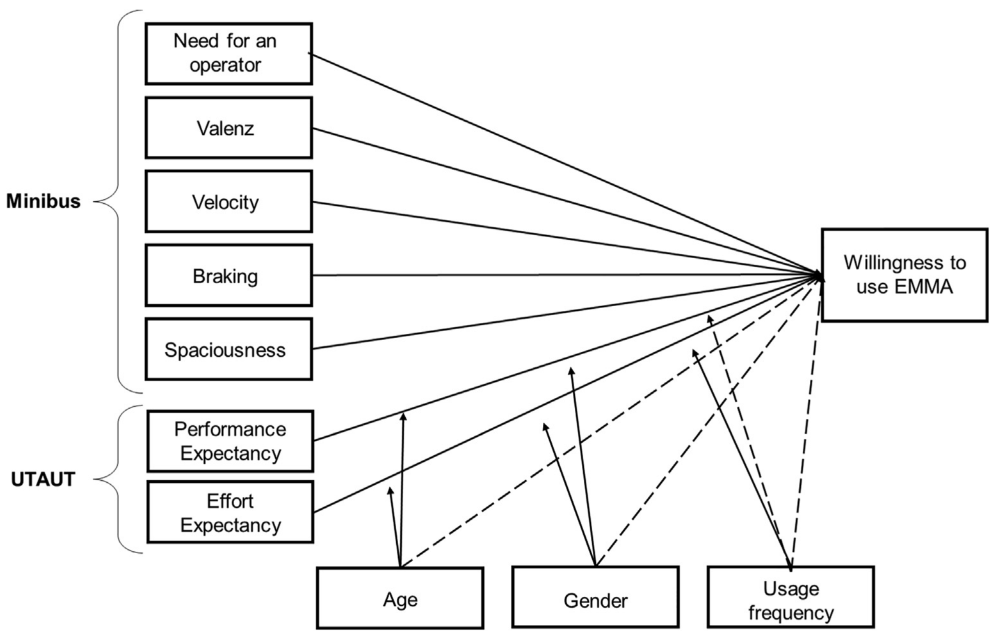

Fig. 6. Regression model for the criterion (willingness to use EMMA). Solid lines represent the effects expected by UTAUT (Venkatesh et al., 2003).

Table 7
Correlation matrix of the predictors and the criterion (willingness to use EMMA).

		WU	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1.	Need for an operator	**0.12**												
2.	Valence	**0.43**	0.07											
3.	Velocity	0.07	−**0.28**	**0.21**										
4.	Braking	−**0.17**	0.03	−**0.25**	−**0.18**									
5.	Spaciousness	**0.33**	-0.06	**0.32**	0.11	−**0.20**								
6.	Performance expectancy	**0.57**	**0.18**	**0.42**	−0.01	−**0.15**	**0.24**							
7.	Effort expectancy	**0.34**	**0.13**	**0.26**	−0.05	−0.00	**0.17**	**0.49**						
8.	Age	0.02	−0.06	0.10	**0.21**	−**0.14**	0.02	−0.04	−0.11					
9.	Gender	0.06	−**0.14**	**0.13**	**0.12**	−0.03	**0.17**	−**0.13**	−0.08	0.02				
10.	Never used	−**0.16**	−0.01	−0.07	**0.12**	0.08	−0.05	−**0.12**	−0.05	−0.03	0.07			
11.	Infrequently used	0.07	−0.05	−0.02	−0.02	−0.07	−0.04	0.06	−0.04	**0.16**	−0.03	−**0.36**		
12.	Monthly used	0.09	0.06	0.10	−0.02	−0.02	0.04	−0.00	−0.01	**0.16**	0.08	−**0.21**	−**0.29**	
13.	Weekly used	−0.00	0.03	0.04	0.03	0.06	−0.06	−**0.0**4	0.04	−0.09	−0.08	−**0.20**	−**0.27**	−**0.16**

Note. N = 311. WU = Willingness-to-use (criterion). Gender was dummy coded with 0 = male and 1 = female. Usage frequently was dummy coded, resulting in four predictors with the fifth level (*every day*) as reference group. Correlation coefficients in bold show significance at $p < .05$.

Table 8
Results of the linear regression and the dominance analysis for the criterion (willingness to use EMMA).

Predictors	β	*SE*	*t*	*p*	GDW
Need for an operator	0.06	0.05	1.32	0.188	0.008
Valence	**0.16**	**0.05**	**2.90**	**0.004**	**0.076**
Velocity	0.06	0.05	1.14	0.255	0.003
Braking	−0.02	0.05	0.49	0.627	0.009
Spaciousness	**0.13**	**0.05**	**2.55**	**0.011**	**0.045**
Performance expectancy	**0.44**	**0.06**	**7.63**	**<0.001**	**0.192**
Effort expectancy	0.06	0.05	1.13	0.261	0.044
Age	−0.07	0.05	1.41	0.161	0.002
Gender	0.08	0.05	1.61	0.110	0.005
Never used	−0.03	0.06	0.44	0.662	0.011
Infrequently used	0.12	0.06	1.91	0.058	0.006
Monthly used	**0.11**	**0.06**	**2.00**	**0.046**	**0.006**
Weekly used	0.09	0.06	1.61	0.108	0.002
Performance expectancy × Never used	**−0.15**	**0.06**	**2.09**	**0.038**	**0.011**
R^2 = 0.456, $p < .001$					

Note. N = 311. β = standardized ordinary least-squares (OLS) regression coefficient. *SE* = standard error of the regression coefficients. R^2 corresponds to the coefficient of determination, as calculated by SPSS. GDW = General Dominance Weight. Gender was dummy coded with 0 = male and 1 = female. Usage frequently was dummy coded, resulting in four predictors with the fifth level (*every day*) as reference group.

tracks as well. Finally, 44 passengers were surprised and impressed by the ability of EMMA to brake autonomously and by the overall safety of the minibus.

4. Discussion

4.1. Summary of results

Overall, autonomous public transport and the autonomous minibus EMMA were perceived predominantly positively. The largest difference between participants with and without test drive was observable for effort expectancy. Before a drive with the minibus, participatns were rather skeptical about the ease-of-use of the minibus, but those who had been in the bus provided much higher ratings. Apparently, one drive with the minibus was sufficient to resolve concerns about autonomous public transport in general. EMMA was perceived as safe, and not all participants perceived the necessity for an operator on board. They also perceived the minibus's braking behavior as comfortable, although some participants perceived it as too strong. The spaciousness was rated as neutral or comfortable. However, the majority rated the travel speed of 15 kph as too slow, with large differences between the age groups. Finally, the environmental friendliness of the minibus seems to be important, especially for female users.

We calculated two linear regressions on intention-to-use and willingness-to-use. Performance expectancy and effort expectancy together with age, gender, and experience explained 45.9% of the variance of the intention to use autonomous public transport. Dominance analysis indicated that performance expectancy was the most important predictor, followed by effort expectancy. Regarding participants' willingness to use EMMA, all predictors together accounted for 45.6% of its variance. Performance expectancy was again the most important predictor, but effort expectancy did not explain a significant proportion of variance. The dominance weight of effort expectancy nevertheless indicated that this factor might contribute to the prediction of willingness-to-use. The two predictors valence and spaciousness also reached significance. Valence was the second most important predictor, followed by spaciousness.

The results of our analyses are in part consistent with research on autonomous public transport and UTAUT (Christie et al., 2016; Eden et. al., 2017; Madigan, Louw, & Dziennus, 2016; Madigan, Louw, & Wilbrink, 2017; Nordhoff et al., 2018; Portouli et al., 2017; Venkatesh et al., 2003). As expected, performance expectancy was the most important predictor for intention-to-use. Thus, as a first implication, research as well as providers of public transport need to identify effective ways to improve the performance expectancy of potential users in order to increase acceptance. In contrast to UTAUT, we could not replicate moderation effects of age, gender, and, at least for the first regression, experience. This result is in line with other studies (Madigan, Louw, & Dziennus 2016; Madigan, Louw, & Wilbrink 2017) and might be attributable to the technology of interest. UTAUT was originally developed for information technology, not autonomous driving. Ghazizadeh et al. (2012) developed an acceptance model for autonomous driving based on UTAUT and did not include any moderators. Using this instrument, it might be possible to assess the acceptance of autonomous public transport more efficiently and reliably. More specifically, it might be appropriate to reconsider the role of age and gender as moderators for acceptance of autonomous public transportation. Excluding these variables would reduce the complexity of the rather extensive existing models. Finally, by comparing participants before and after a ride with the minibus in a between-subjects design, we were able to test how the opinions of passengers change after the first encounter with an autonomous minibus. Most importantly, there was a difference between the two groups regarding effort expectancy. Participants before a drive with the minibus were rather skeptical about the ease-of-use of autonomous public transport, but participants who had been on the bus provided much higher ratings. This might explain the results of our regression analysis as well as those from Madigan, Louw, & Wilbrink (2017) and Adell (2010). As Adell suggested, the autonomous system does not require the user to act continuously. Since this makes it rather easy to learn how to use an autonomous minibus, effort expectancy might be more important in predicting whether people are willing to use the minibus before their first trip (i.e. predictive acceptance), but becomes less important after the first encounter. Our results support this suggestion.

Another major difference is that previous research did not include the valence or vehicle characteristics into their regression models (e.g. Madigan, Louw, & Dziennus 2016; Adell, 2010). Especially the overall valence of an experience with new technologies had not been included in classic theories of user acceptance (Davis, 1989; Venkatesh et al., 2003). Venkatesh et al. (2012) added a similar variable, hedonic motivation, to the second version of UTAUT. After Madigan, Louw, & Wilbrink (2017) had included this factor, they obtained results comparable to those presented here. However, hedonic motivation represents the tendency of people to approach situations where they experience pleasure or enjoyment. In terms of system use, a user uses a system in order to experience fun or enjoyment. This is different from our definition of valence. Our results indicate that the overall valence of an experience with a new technology can be an important predictor for the willingness to use this technology. Furthermore, the importance of specific vehicle characteristics, such as spaciousness, as well as the driving style of a vehicle for acceptance have been mostly neglected in theory and research. Only recently, Oliveira, Proctor, Burns, and Birrell (2019) showed that the driving style of an autonomous vehicle can affect both trust and acceptance of users. The only model that takes vehicle characteristics into account is the one recently developed by Nordhoff, Kyriakidis, et al. (2019). Our results support the role of vehicle characteristics as determinants of acceptance. More specifically, the spaciousness of the minibus seems to affect user acceptance. Thus, in order to improve acceptance, manufacturers should ensure that autonomous minibuses provide enough space for the passengers.

4.2. Limitations

Some aspects that could limit the interpretation of the results should be discussed. First, the positive feedback of participants might have been caused in part by the context of use. EMMA was a prototype that will not be part of public transport in the near future. Moreover, the whole project was promoted in the local news as an innovation in public transport. The promotion, EMMA's prototypical state and the free use surely made participants more permissive regarding technical problems and highlighted the positive aspects of automation. Also, we cannot rule out that people who partake in a demo of an autonomous vehicle are more positive about this technology in general. All this could explain differences between our results and more critical evaluations found in internet-based surveys (Bazilinskyy et al., 2015; Kyriakidis et al., 2015). Furthermore, it should be noted that the minibus was never fully occupied, which might explain the high ratings on spaciousness. Moreover, we measured experience with conventional public transport, but not with automated systems in general. The latter could be a more important factor for the acceptance of autonomous driving and thus could explain the missing moderation effect of experience. However, Madigan, Louw, & Dziennus (2016) measured participants' experience with autonomous minibuses and still found no moderation effect.

In addition, we excluded social influence from our research model, which has been identified as an important predictor in many studies, also in the domain of autonomous public transportation (e.g. Adell, 2010; Madigan, Louw, & Dziennus, 2016; Madigan, Louw, & Wilbrink, 2017). The exclusion of social influence might have limited the explanatory power of our model. We recommend including social influence in future models, since it has repeatedly been shown to be an important predictor of behavioral intention. Finally, we used one-item-measures to conceptualize behavioral intention and effort expectancy. Especially for effort expectancy, the use of a one-item-measure represents a potential weakness, since one item might not adequately measure all aspects of this construct. This might limit the interpretability of our results regarding effort expectancy. The same might be true for behavioral intentions. However, there is evidence that behavioral intention can be assessed using just one item (Madigan, Louw, & Dziennus 2016). Future research should use scales with more items to reliably measure these two constructs.

5. Conclusion

Our study investigated user acceptance of an autonomous minibus. The results indicate that users are generally open-minded towards autonomous public transportation. A test drive with EMMA also produced mainly positive results. In contrast to previous studies, we investigated both the general acceptance of autonomous public transport and the acceptance of a prototypical system. The distinction between these two types of acceptance, namely predictive and retrospective acceptance, enabled us to investigate whether and how a single drive with an autonomous minibus changes the general acceptance of autonomous public transport systems, which was not possible in previous studies. Moreover, dominance analysis enabled us to make inferences about the relative contribution of each predictor to usage intention. Apparently, performance expectancy plays a major role in this prediction and thus in both predictive and retrospective acceptance. Effort expectancy, in contrast, seems to be more important for predictive acceptance, but less important for retrospective acceptance. Another important predictor for retrospective acceptance was the experienced valence of users. It seems plausible that the global evaluation of a drive, in terms of pleasant or unpleasant, affects users' willingness to use an automated system, but it has nevertheless been neglected in acceptance theory and research. UTAUT2 is the first model that includes a similar factor, hedonic motivation (Venkatesh et al., 2012), but this factor focuses solely on the pleasure experienced during a drive. The results presented here provide support for the importance of valence for retrospective user acceptance. Finally, the positive opinions regarding EMMA should not simply be generalized to acceptance and use of autonomous mobility concepts in realistic road traffic. Conceivably, other aspects are important, such as the vehicle's propulsion method. Environmental friendliness was important to our participants. Operators of public transport or manufacturers of autonomous vehicles should take this into account and promote green propulsion systems to increase user acceptance.

CRediT authorship contribution statement

Christoph Bernhard: Conceptualization, Methodology, Formal analysis, Data curation, Writing - original draft, Writing - review & editing, Visualization, Project administration. **Daniel Oberfeld:** Conceptualization, Methodology, Validation, Writing - review & editing, Supervision. **Christian Hoffmann:** Conceptualization, Resources, Supervision, Project administration. **Dirk Weismüller:** Conceptualization, Resources, Project administration. **Heiko Hecht:** Conceptualization, Methodology, Validation, Writing - review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trf.2020.02.008.

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