

Research Article

As Long as I Don't Have to Drive Myself

The Influence of Trait Anxiety in the Context of Fear of Giving Up Control on the Acceptance of Autonomous Shuttle Buses

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As a new, highly complex, and far-reaching technology, autonomous driving can be associated with various fears and uncertainties. However, recent findings show that high trait anxiety can positively contribute to the intention to use (ITU) autonomous vehicles (AVs). An explanation for this is that the possibility of handing over one's driving control to artificial intelligence (AI) is even more relieving for more anxious people. Our study aimed to test whether this explanation can be supported by investigating to what extent this relationship can be applied to buses in which control is handed over per se—in the conventional bus to a driver, and in the autonomous bus to the AI. We also analyzed how the fear of giving up control mediates the relationship between trait anxiety and ITU. In a quasi-experimental study, 253 subjects were surveyed while riding an autonomous or conventional electric bus. The results confirmed a positive association between trait anxiety and ITU in the overall sample but not in the autonomous and conventional subsamples. Contrary to our assumptions, fear of giving up control served as a slightly suppressive but not significant mediator. The results were independent of whether control was handed over to a human driver in the conventional electric bus or to AI in the autonomous bus. Our study thus provides fundamental new insights into the acceptance of AVs and buses in general and opens the door for subsequent research based on these findings.

Keywords: anxiety; artificial intelligence; autonomous driving; autonomous vehicle acceptance; public transport; trait anxiety

1. Introduction

Autonomous driving has gained increasing attention in recent years and is already beginning to take its first steps into our daily road traffic [1, 2]. In pilot projects worldwide, artificial intelligence (AI) replaces humans as drivers. In just a few years, autonomous vehicles (AVs) are expected to account for 50% of new vehicles [3]. In this context, a huge research field has opened around autonomous driving. In recent years, in addition to technical feasibility, the focus has increasingly been on factors that contribute to humans' successful adoption of AVs.

2. Literature Review and Research Framework

People differ in the extent to which they accept AVs. Factors such as individual perception, attitude and personality can have an influence on AV acceptance [4, 5]. Taking the user's personality into account is therefore a decisive approach for the successful implementation of AVs. In this context, potential uncertainties and worries regarding new, largely unknown technologies such as AVs also play an important role [6]. Autonomous driving in general seems to be associated with various fears and anxieties [6]. Fear of machine movement and concerns about the predictability and

reliability of autonomous systems still prevent users from trusting autonomous driving technology [7, 8]. In addition, there are fears regarding data security and driving safety [6, 9]. Overall, AVs are still perceived as riskier compared to conventional vehicles, although they even promise to improve road safety [10, 11].

The worries, fears, and perceived risks can unsettle users [6, 9]. While perceptions of safety decrease with a higher level of automation, the perceived anxiety increases [12]. Access to AVs in public transportation is currently severely limited, so corrective experiences are still rare [6]. Prior experience with AVs may favor the adoption [13]. In a simulation study, Park, Iagnemma, and Reimer [14] showed that subjects experienced less anxiety the longer they drove an AV. Regarding autonomous technologies, anxiety lowers the intention to use (ITU) AVs, preventing positive experiences [15]. On the other hand, anxiety and concerns are also compensated by positive expectations regarding driving safety and the risk of accidents, which in turn can reduce the anxiety of potential users [6]. Although various fears burden the acceptance of AVs, contrary study findings also demonstrate a positive effect of anxiety. Qu, Sun, and Ge [16] found in a study among drivers of self-driving cars in China that individuals with higher trait anxiety attributed higher reliability to autonomous driving systems and were more willing to adopt AVs. The authors explained their unexpected positive effect by suggesting that more anxious individuals may be less afraid of the errors of an autonomous driving system than of their own human errors. According to their conjecture, the subjects' anxiety was less about losing control and more about "taking back control from a self-driving car" [16].

The issue of control has been addressed many times in the AV context. It is a key issue for many decision-makers and interest groups in several respects regarding the successful implementation of AVs [17–19]. While developers and manufacturers are responsible for producing vehicles in a technical way that enables them to take over driving control reliably and as comfortably as possible, legislators and policymakers focus on the questions of who carries the responsibility when driving control is handed over and which regulations are required to ensure the protection and safety of all parties involved [19]. Ensuring the willingness to give up control actively and thereby encouraging the broad public use of AVs is a central concern of operators and providers [19]. Other road users (e.g., pedestrians) are indirectly affected by the delivery of control to AVs if they have to rely on the technology to interact with them reliably and safely in an encounter. However, AV users are probably the most central starting point for relinquishing control to AVs. In other words, the successful use of AVs depends on the passengers' active willingness to give up control. Accordingly, a great focus of research in this context has been on this target group [20]. Previous findings show that people differ in terms of their need for control and that this impacts AV acceptance [21]. A high need for control has a negative effect on the ITU of AVs [21]. In contrast, an external locus of control, i.e., the belief that events are not self-caused but are caused by external factors [22], leads to higher ITU [23].

It is possible that giving up control is easier for individuals when they see the control in external influences rather than having a higher internal locus of control [23]. Hegner, Beldad, and Brunswick [24] specially examined the fear of giving up control in the context of AV acceptance and found that a low fear of giving up control, along with trust in AVs, positively affects acceptance.

If the possibility of handing over control is indeed decisive for the direction of the correlation between trait anxiety and the acceptance of autonomous cars, as hypothesized by Qu, Sun, and Ge [16], the question arises as to what extent this effect can also be shown for buses. In contrast to autonomous cars, the main question for autonomous buses is not whether one's control is handed over, but to whom: the human driver or the autonomous technology. Strauch et al. showed that subjects report lower confidence when they are driven in a simulator by an autonomous system instead of a male or female driver [25]. Results like this might suggest that people generally prefer riding a conventional bus to riding an autonomous bus. Therefore, if anxious people generally prefer to use buses because they can hand over driving control, we assume that they nevertheless choose to hand over control to a human driver rather than to the AI in AVs. According to this reasoning, individuals with high anxiety would prefer riding in conventional buses with human drivers to riding in autonomous buses. We would like to point out that the term autonomous can currently only be interpreted with restrictions. AVs cannot yet handle the complexity of every traffic situation completely and at all times [26]. Rather, we are in an interim phase in which AVs drive autonomously in standard traffic situations but rely on so-called teleoperation in dangerous situations. In this case, human operators perform monitoring and driving in control centers until the vehicle has left the dangerous situation [26]. Psychological research does not yet differentiate between AVs with and without the use of teleoperation. We, therefore, also use the term autonomous with the restriction that an operator takes over driving control in critical situations.

2.1. Research Hypotheses. The studies demonstrate the relevance of trait anxiety for the development of AV acceptance. Understanding the impact of trait anxiety in this context can allow developers and providers to design and promote AVs with a greater focus on people who have a high level of anxiety, e.g., by specifically highlighting the control transfer option for this target group. Nevertheless, the previous research findings in this context still show substantial gaps and unexplained aspects. It currently remains to be answered how the somewhat contradictory results can be explained. This study aims to understand the role of anxiety and, in this context, the prerequisites for the acceptance and ITU of autonomous shuttle buses in more detail to derive implications for the successful establishment of autonomous buses.

To this end, we examine the relationship between trait anxiety and ITU. Qu, Sun, and Ge [16] suggested that more anxious individuals are more willing to hand over control. Accordingly, this willingness in turn has a positive effect on the ITU of AVs in which driving control can be surrendered to the AV technology. We, therefore, examine the extent to

which the relationship between trait anxiety and ITU is mediated by fear of giving up control, which, to the best of our knowledge, has not been investigated so far.

Buses present a particular case in this context because the passenger on the bus (unlike in a car) cedes control as standard, either to the AI in the AV or to a human driver on the conventional bus. Therefore, we examine to what extent the relationship between fear of giving up control and ITU, as well as the relationship between trait anxiety and ITU, depends on the so-called bus modality (autonomous vs. conventional). This study is, to the best of our knowledge, the first to compare the acceptance of autonomous and conventional buses in terms of the influence of trait anxiety and fear of giving up control. This comparison helps us to determine the role of autonomous technology in this context and to differentiate the effects from the conventional bus modality. Based on the above considerations, we derive the following hypotheses (Figure 1).

- H1. Trait anxiety is positively related to ITU of (a) autonomous and (b) conventional buses.
- H2. The relationship between trait anxiety and ITU of (a) autonomous buses and (b) conventional buses is mediated by the fear of giving up control.
- H3. The mediation models for autonomous buses and conventional buses differ, with a stronger relationship between fear of giving up control and ITU (path b) and a stronger relationship between trait anxiety and ITU (path c) for AVs.

3. Method

3.1. Design and Procedure. We conducted a quasi-experimental questionnaire study with two between-subject conditions (autonomous vs. conventional) to investigate the effect of trait anxiety on ITU through fear of giving up control. In the autonomous condition, we collected data from subjects on-site while driving an autonomous bus; in the conventional condition, we collected data from subjects while driving a conventional (electric) bus. We attached importance to the fact that the buses in the conventional condition drove with electric drive to grant better comparability to the (anyway electrically driving) autonomous buses. The survey was carried out in Regensburg between October 2022 and July 2023. In this period, autonomous buses were piloted on a ring route in the industrial park. The subjects were surveyed exclusively during their journey with the respective bus to ensure that the sample only included persons who had used the bus. Data were collected via the online service SosciSurvey. Beforehand, the subjects were informed about the purpose of the study, their rights, and data protection. All participants gave their informed consent digitally by clicking a checkbox. They then answered questions about their sociodemographics, personality, mobility behavior, and their perception and experience with autonomous buses or conventional buses, depending on which bus they were using at the time of the survey. The data were stored anonymously and are available in the OSF repository (<https://osf.io/7e9vc>) [27]. A preprint

has previously been published (<https://osf.io/preprints/osf/r2ug5>) [28]. The study was approved by the Regensburg Ethics Committee (# 22-3088-101).

3.2. Sample. A minimum sample size of $N=214$ was determined a priori using the software G^* Power, version 3.1.9.4, to ensure an overall power of 0.80 ($f^2=0.15$, $\alpha=0.05$). The sample ($N=253$, of which 106 were male, 144 were female; age: $M=26.68$, $SD=11.18$ with a range of 16–76 years) was recruited via personal approach in the buses and student subject platforms. It comprises 127 subjects (50.20%) surveyed while driving with an autonomous bus and 126 subjects (49.80%) surveyed while driving with a conventional bus. Three subjects under 16 years of age were excluded from study participation beforehand. Participation in the study was voluntary and was not financially remunerated. Psychology students received credit for their participation as part of their coursework.

3.3. Instruments. In our study, we used a set of questionnaires to collect information on sociodemographics, personality, mobility behavior, and perceptions and experiences with autonomous or conventional buses. Permission was obtained in advance for all instruments used in the study for which it was required. The sociodemographic variables included gender, age, education level, occupation, and income. The mobility behavior scale included two questions on frequently used means of transportation and two items on liking car or public transportation use.

For the survey of trait anxiety, we used the German short form of the trait scale of the State-Trait Anxiety Inventory [29]. The eight-point Likert scale (1 = *almost never* to 8 = *almost always*) assessed 10 statements about personal indicators (e.g., I get tired quickly.) Cronbach's α was high at $\alpha=0.85$ [30]. For fear of giving up control, we developed five items, rated on a five-point Likert scale (1 = *do not agree at all* to 5 = *strongly agree*) following Hegner, Beldad, and Brunswick [24] (e.g., I am concerned that I have no control over the [autonomous] bus.). Cronbach's α reached $\alpha=0.86$, indicating high reliability [30]. We also surveyed the ITU with four items according to Korkmaz et al. [31] on a five-point Likert scale ranging from *do not agree at all* (1) to *strongly agree* (5, e.g., I plan to use (autonomous)-electric public buses frequently in the future.). The reliability of this scale was high (Cronbach's $\alpha=0.85$) [30].

All bus-related items were adapted in their wording to the respective bus modality (autonomous vs. conventional). The study was conducted as part of a large research project on autonomous driving. Therefore, in addition to the scales relevant to our study, the following were also collected: Technology Readiness Index 2 [32]; perceived safety adapted from Xu et al. [33]; environmental concerns [34]; perceived sustainability, self-developed; environmental self-efficacy [35]; knowledge about AVs, self-developed; previous experience with AVs, self-developed; and General Self-Efficacy Short Scale (German: Allgemeine Selbstwirksamkeit Kurzskaala) [36]. These variables are not considered in our study.

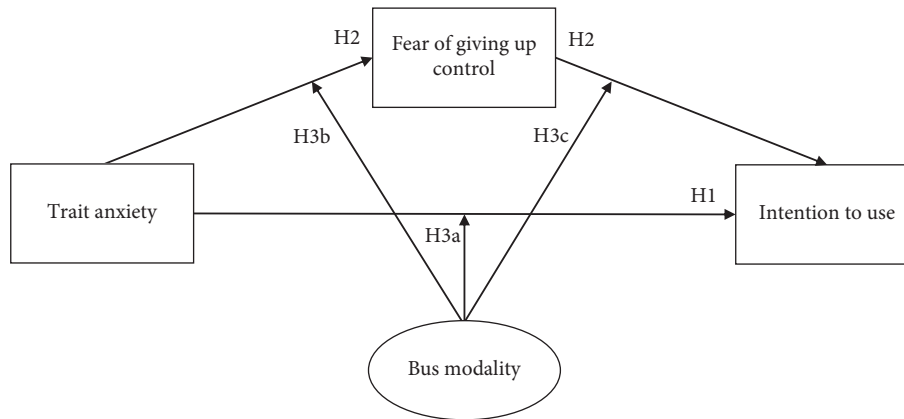


FIGURE 1: Hypothesis model.

An overview of all items and scales used is available as a codebook at <https://osf.io/7e9vc> [27].

3.4. Statistical Analysis. Data were analyzed using R statistical software (version 2023.12.0) with the lavaan and semTools package [37, 38]. As the examination of the outliers through boxplots showed, all of the conspicuous data values were within the plausible range. So, we did not exclude them [39, 40]. We then reviewed the requirements for the mediation analysis [41]. Our data were collected independently. Therefore, we assume independence of the error terms (no autocorrelation). We confirmed the linearity of the correlations graphically using a scatter plot with a fitting curve. To check for possible multicollinearity, we considered the Pearson correlation coefficient of the predictors, which was not significant and unremarkable at $r = 0.05$. Furthermore, the normal distribution and homoscedasticity requirements were not met in our data. We, therefore, additionally calculated the mediation analyses using bootstrapping with 1000 iterations. This procedure is considered robust to violations of the normal distribution and homoscedasticity [42, 43]. We first examined the relationship between trait anxiety and ITU in terms of mediation by fear of giving up control. We performed a mediation analysis for the total sample, the autonomous condition, and the conventional condition (H1, H2). We then compared the mediation models of the two conditions using a multigroup analysis (H3). This procedure is used to uncover possible differences in the mediation models between the autonomous and conventional conditions [44]. A significant result indicates significant differences between the groups [44]. The used dataset and analysis code are available in the OSF repository <https://osf.io/7e9vc> [27].

4. Results

4.1. Descriptive Statistical Analysis. Table 1 shows the descriptive statistics of the relevant study variables. ITU was left-skewed in both the autonomous and conventional conditions, suggesting that the sample generally showed an open attitude toward bus use. Overall, ITU was lower for AVs than for conventional vehicles. The mean value of trait

anxiety was similar to the results of Qu, Sun, and Ge [16]. On a four-point scale, they found a mean trait anxiety value of $M = 1.94$. This is similar to our value of $M = 3.74$ on the eight-point scale. Noticeably, the autonomous and the conventional samples differed significantly in trait anxiety and fear of giving up control, with lower trait anxiety and higher fear of giving up control in the autonomous condition. To further explore this result pattern, we decided to plot the fear of giving up control as a function of trait anxiety and bus modality using a scatterplot (Figure 2). The graph shows a relatively low fear of giving up control for conventional buses across all trait anxiety values. For autonomous buses, the fear of giving up control varied more, with higher values as trait anxiety increased.

4.2. Inferential Statistical Analysis. We examined the association between anxiety and the ITU with fear of giving up control as a mediator. The analysis was conducted in the total sample and separately for the autonomous and the conventional condition. The sample size ($N = 253$) ensured an overall power of 0.99 ($f^2 = 0.15$, $\alpha = 0.05$). The results are shown in Table 2. We found a positive total effect of trait anxiety on ITU for the total sample. This positive relationship was evident in both conditions, being stronger for conventional buses than for autonomous buses. However, the association in both conditions did not reach significance (H1 a and b rejected). These results of the total effect were also found using bootstrapping, total sample: $b = 0.09$, $p = 0.018$; autonomous sample: $b = 0.01$, $p = 0.890$; and conventional sample: $b = 0.10$, $p = 0.082$. Trait anxiety overall contributed to the variance resolution with a small effect of $\Delta R^2 = 0.02$ [45]. When the mediator was included, this direct effect slightly increased for the total sample as well as for both subsamples, with significant direct effects for the total sample and the conventional subsample. A similar pattern was evident with the use of bootstrapping, total sample: $b = 0.09$, $p = 0.008$; autonomous sample: $b = 0.03$, $p = 0.620$; and conventional sample: $b = 0.10$, $p = 0.050$. This phenomenon is known as suppression and indicates that the mediator damps down, rather than strengthens, the positive association between trait anxiety and ITU [41]. This

TABLE 1: Descriptive statistics: mean values, mean value comparisons, and correlations.

Variable	M (SD)			t	1.	2.	3.	4.	5.
	Total	Autonomous	Conventional						
1. Gender	0.59 (0.52)	0.54 (0.50)	0.65 (0.53)	-1.79	—	—	—	—	—
2. Age	26.68 (11.18)	29.54 (13.00)	23.79 (8.06)	4.24**	-0.07	—	—	—	—
3. ITU	4.27 (0.78)	4.10 (0.79)	4.45 (0.73)	-3.60**	0.05	-0.03	—	—	—
4. Trait anxiety	3.74 (1.23)	3.41 (1.18)	4.08 (1.20)	-4.47**	0.25**	-0.12	0.14*	—	—
5. FGC	1.65 (0.77)	1.84 (0.82)	1.46 (0.66)	4.08**	-0.01	-0.03	-0.23**	0.05	—
6. Bus modality	0.50 (0.50)	—	—	—	-0.10	-0.01	0.09	-0.39**	0.00

Note: *t* = *t*-test to compare the two conditions (autonomous vs. conventional). Gender: 0 = male, 1 = female. Bus modality: 0 = autonomous bus, 1 = conventional bus. *N* = 253, autonomous condition: *n* = 127, conventional condition: *n* = 126. Abbreviations: FGC = fear of giving up control, ITU = intention to use.

* *p* < 0.05.
 ** *p* < 0.01.

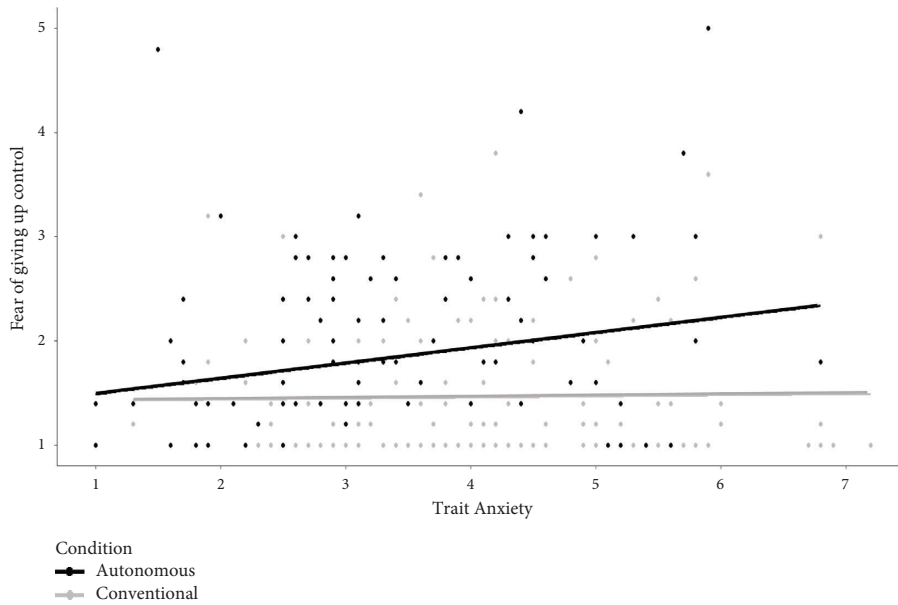


FIGURE 2: Scatter plot representing the relationship between trait anxiety and fear of giving up control.

TABLE 2: Mediation analysis: coefficients of the investigated paths and correlations.

Sample	Predictor	Criterion									
		FGC				ITU					
		<i>b</i>	SE	<i>p</i>	95%-CI		<i>b</i>	SE	<i>p</i>	95%-CI	
			UL	LL				UL	LL		
Total	TA (total effect)	—	—	—	—	—	0.09	0.04	0.026	0.01	0.17
	TA (direct effect)	0.03	0.04	0.444	-0.05	0.11	0.10	0.04	0.013	0.02	0.17
	Indirect effect	—	—	—	—	—	-0.01	0.01	0.452	-0.03	0.01
	FGC	—	—	—	—	—	-0.24	0.06	< 0.001	-0.36	-0.13
<i>R</i> ² = 0.07, <i>F</i> (2, 250) = 10.13, <i>p</i> < 0.001											
Autonomous	TA (total effect)	—	—	—	—	—	0.01	0.06	0.905	-0.11	0.12
	TA (direct effect)	0.15	0.06	0.015	0.03	0.26	0.03	0.06	0.649	-0.09	0.15
	Indirect effect	—	—	—	—	—	-0.02	0.02	0.183	-0.05	0.01
	FGC	—	—	—	—	—	-0.14	0.09	0.112	-0.31	0.03
<i>R</i> ² = 0.02, <i>F</i> (2, 124) = 1.24, <i>p</i> = 0.29											
Conventional	TA (total effect)	—	—	—	—	—	0.10	0.05	0.066	-0.01	0.20
	TA (direct effect)	0.01	0.05	0.831	-0.09	0.10	0.10	0.05	0.050	0.00	0.20
	Indirect effect	—	—	—	—	—	-0.00	0.01	0.831	-0.03	0.02
	FGC	—	—	—	—	—	-0.28	0.09	0.003	-0.47	-0.10
<i>R</i> ² = 0.09, <i>F</i> (2, 123) = 6.18, <i>p</i> = 0.003											

Note: *N* = 253, autonomous sample: *n* = 127, conventional sample: *n* = 126.

Abbreviations: CI = confidence interval, FGC = fear of giving up control, ITU = intention to use, LL = lower limit, TA = trait anxiety, UL = upper limit.

was confirmed when analyzing each mediation pathway in more detail. Contrary to our prior hypotheses, trait anxiety positively predicted fear of giving up control not only in the total sample but also in both subsamples. However, the relationship only reached significance in the autonomous condition. Fear of giving up control had a negative effect on ITU, which was significant for the total sample and the conventional subsample but not for the autonomous subsample. Overall, the indirect effect on ITU was negative. Nevertheless, the indirect effect of fear of giving up control did not reach significance, neither for the total sample nor for autonomous buses and conventional buses. This result for the indirect effect was also found using bootstrapping, total sample: $ab = -0.01$, $p = 0.506$; autonomous sample: $ab = -0.02$, $p = 0.130$; conventional sample: $ab = -0.00$, $p = 0.859$. Therefore, we reject H2 a and b.

The multigroup analysis revealed no significant difference in the models between the autonomous and the conventional conditions. This implies that the proposed mediation model was independent of bus modality, $t(3) = 4.96$, $p = 0.175$. Therefore, H3 is not confirmed.

5. Discussion

5.1. Summary and Practical Implications. Our study aimed to investigate whether trait anxiety is associated with the ITU of autonomous buses and to what extent this relationship is mediated by fear of giving up control and dependent on the bus modality. Before discussing the results, we would like to emphasize again that the term autonomous in this context means that the vehicle drives autonomously in standard situations. In critical situations, operators take over the monitoring and driving via teleoperation (see Introduction section). In total, three main findings emerge from our study:

First, we found a positive influence of trait anxiety on the ITU across both conditions. This result was also evident for the subsamples, although not significantly, but on a descriptive level. These findings are of special interest. They show that although autonomous driving may be associated with various fears according to some studies [46, 47], this does not mean that more anxious individuals are generally more skeptical about AVs. The contrary is observed here. We can conclude from the above results that autonomous and conventional buses seem particularly attractive to more anxious individuals. Our study thus extends the results of Qu, Sun, and Ge [16] first, by the perspective of real AV users, and second, by the context of autonomous and conventional buses. This shows that the positive association is not only evident in autonomous cars but also in autonomous buses and conventional buses. In practical terms, this means that anxious people are not at all the more critical target group when it comes to AVs. Rather, this target group seems to see an advantage in AVs. The results also suggest that more anxious individuals may even see an advantage in autonomous cars, autonomous buses, and conventional buses [16]. In terms of successful practical implementation, this means that this target group does not necessarily require extraordinary attention, e.g., in terms of design or

a particular familiarization with AVs. Rather, it is now an important next step to identify why people with higher trait anxiety are more open to AVs. By understanding the underlying mechanisms, conclusions can be drawn to further address more anxious users and possibly even win them over as promoters or initiators, e.g., in AV marketing. With regard to policy regulations, the results of this study might suggest that this target group does not initially need to be specifically considered or protected. At this point, however, we would like to emphasize that the current state of research shows that fears and insecurities, which are highly associated with trait anxiety, nevertheless have an impairing effect on AV acceptance [6, 17, 46, 48]. Therefore, we advise being careful in inferring that trait anxiety or anxiety in general does not need any consideration in policy regulations. Further research is needed to test and replicate the results of this study to allow for practical derivations for policymakers. Although the correlation between trait anxiety and AV acceptance was significant for the overall sample, this effect did not reach significance for the subsamples (autonomous and conventional, H1 not supported). Our results are, therefore, not fully consistent with the findings of Qu, Sun, and Ge [16]. One reason could be the reduced sample size and thus reduced power in the subsamples [49]. Qu, Sun, and Ge [16] collected their data among the general population, regardless of their previous AV use. The authors thus achieved a sample size of $N = 527$. However, no experience with autonomous driving technology can currently be expected. To ensure the validity of the results, we therefore decided to conduct an on-site survey among users of autonomous and conventional buses. Within the research project, we only had access to autonomous buses for a defined period in which the data could be collected. A further increase in the sample size was therefore not possible in this time span, particularly for the autonomous bus. It is possible that (unlike in the study by [16]) existing smaller effects were therefore not revealed. Another reason for the non-significant effect could be that Qu, Sun, and Ge [16] focused on autonomous cars, not autonomous buses. It is possible that using a car is more attractive to anxious people than using a bus, e.g., because the person is not sitting in a car with strangers, unlike on a bus. This might increase the influence of trait anxiety on the ITU of private vehicles and thus make it more evident. The relationship may also be influenced by other variables, such as unconsidered moderators, due to which the effect of trait anxiety on ITU is not fully revealed. A variable that may have influenced the mode of action of trait anxiety is dispositional trust. Previous research shows that trust is an important determinant of ITU [20, 50, 51]. Thus, it is possible that trait anxiety has a lower effect on ITU when confidence is high because autonomous technology may be perceived as less threatening. Conversely, a low level of trust could lead to trait anxiety having a stronger effect on the ITU. An interaction of trait anxiety with another variable (e.g., trust) cannot be ruled out and could (possibly in combination with the smaller sample size) explain why the effect on ITU was limited in our study. We recommend further investigating possible previously not considered moderators, particularly

trust, in future studies to clarify this. However, the positive, although not significant, relationship between trait anxiety and ITU AVs in our study already indicates that trait anxiety may also have an affirmative role in the use of autonomous buses.

Second, we found that the opportunity to hand over driving control is not the crucial factor/aspect that promotes the ITU of anxious people. We investigated the relevance of fear of giving up control as a potential underlying mechanism of this relationship. Here, we were able to show that, contrary to our assumptions, fear of giving up control does not account for the positive relationship between trait anxiety and ITU (H2 not supported). Based on the assumption made by Qu, Sun, and Ge [16] discussing their results, we supposed that more anxious individuals would prefer to hand over control to other entities (in our study, the AI vs. the human driver) rather than taking driving control themselves. Accordingly, a high fear of giving up control would in turn have a negative effect on the ITU of autonomous and conventional buses. However, our results do not support this assumption. In our study, there was no significant mediation by fear of giving up control.

In this context, it is noteworthy that trait anxiety and fear of giving up control showed significant differences between the subsamples. In particular, the fear of giving up control showed little variance in the conventional condition, with lower values (see Figure 2). This is surprising because we expected the two variables and their association to be independent of bus modality. It is possible that the fear of giving up control is particularly stimulated when control is handed over to an abstract autonomous technology. Previous research has already shown that people have greater trust in a human driver than an autonomous driving technology [25]. The fear of giving up control would therefore also be dependent on bus modality. Nevertheless, our results also show that trait anxiety has a significant influence on the fear of giving up control, however, only among users of autonomous buses. Some studies suggest that anxiety is particularly strong in situations that are associated with uncertainty or threat [52, 53]. Possibly, the use of autonomous driving technology represents a comparable situation because the technology is still difficult to grasp and hardly accessible [6, 10, 54]. This could explain why the influence of trait anxiety on fear of giving up control is only evident in the autonomous condition. To validate this assumption with our data, we subsequently examined how the bus modality affects the relationship between trait anxiety and fear of giving up control. For transparency of the calculation and results of this subsequent analysis, the corresponding R code is available in the OSF repository: <https://osf.io/7e9vc> [27]. The results of the moderation analysis confirmed the previously revealed significant positive influence of trait anxiety but not of bus modality, $b = 0.07$, $p = 0.808$, on fear of giving up control. The moderation by the bus modality missed significance, $ab = 0.052$, $p = 0.083$, possibly due to the previously discussed sample size. Future studies can take this finding as a starting point to investigate these relationships in more detail and in larger samples. This may help to understand whether trait anxiety exerts a greater

influence on fear of giving up control in autonomous buses than in conventional buses. However, it remains open as to why trait anxiety in the autonomous condition does not also have a more substantial effect on the ITU.

Furthermore, contrary to our expectations, more anxious individuals descriptively also showed a higher fear of giving up control to buses, which had a negative effect on ITU. Thus, our model includes a positive direct effect and a (nonsignificant) negative indirect effect in both conditions (autonomous vs. conventional). Accordingly, although trait anxiety has a positive direct effect on ITU in the total sample, it has a nonsignificant negative indirect effect on ITU via the mediator. This seemingly contradictory phenomenon is known in the mediation analysis literature as the “suppression effect” [41]. The actual effect of trait anxiety on ITU is thus underestimated because it is dampened by fear of giving up control [41]. In our study, however, the effect of this suppression is negligible because it only has a slight effect on the relationships. The opportunity to give up control by Qu, Sun, and Ge [16] is thus not an explanation for the positive association between trait anxiety and ITU, neither for autonomous nor for conventional buses.

Nevertheless, it remains open why more anxious individuals reported a higher ITU for buses. A possible explanation for this is that concerns about the autonomous driving technology have meanwhile been reduced by the higher availability, e.g., of autonomous assistance systems, and autonomous as well as conventional buses may even be perceived as safer than, e.g., driving a vehicle oneself. Cunningham, Ledger, and Regan [48] showed that autonomous driving is associated with higher road safety by more than one-third of people. It may be that anxious people in particular value the new technology, e.g., because of the higher safety. It might also be possible that the positive association is due to another common feature of the buses that has nothing to do with either autonomous technology or control delivery. The buses in which we surveyed ran on electric propulsion in both conditions. We consciously decided to have electric buses in the conventional comparison group to ensure comparability with electric-driving autonomous buses. Some studies provide evidence that higher trait anxiety is associated with higher concern about climate change [55]. It is possible that, therefore, more anxious individuals are more likely to prefer public transit, which is inherently more environmentally friendly than private driving [56]. The electric drive of our buses may also be perceived more positively in this regard, conditioning the positive relationship between trait anxiety and ITU. Future work can address our findings and further examine these and other possible explanations for the positive association between trait anxiety and ITU. According to our results, the fear of giving up control does not explain the positive association. However, it decreased ITU for conventional buses in a direct way. Manufacturers and providers of buses can use this as an opportunity to specifically strengthen the perceived control while riding the bus, e.g., by installing emergency buttons that are highly visible and that passengers can use to intervene if necessary [57]. In the buses, posters could provide information about the training path to

becoming a bus driver or about the functioning of the AI to strengthen the trust in its reliability and take away users' fear of giving up driving control. The challenge of giving up control in AVs could also be explicitly addressed in the marketing of AVs. Commercials showing people who are quickly convinced of the benefits of AVs (e.g., driving safety) despite their initial fear of giving up control after their first experiences could be a promising avenue. Initial fears or uncertainties about giving up control could thus be normalized, while potential users are encouraged to use AVs at the same time [58]. Another approach may be to give people the feeling that they have control over the bus route, e.g., by requesting a bus via an app. These on-demand services are currently being simulated and tested for several cities, e.g., Hamburg, Germany [59], and Fuyang, China [60], and they might have a positive impact on the perceived control. Providers should also emphasize the benefits of buses and inform passengers specifically, e.g., opportunities related to driving safety or optimizing traffic flow [11, 61]. It may be the task of future work to determine which measures are best suited to counteract the fear of giving up control in buses.

Third, according to the multigroup analysis results, the effects of our mediation model appeared to be independent of whether control was handed over to the AI (with the assistance of human operators in critical situations through teleoperation) or a human driver (H3 not supported). Contrary to earlier assumptions, AV technology did not further increase the impact of fear of giving up control significantly. This bodes well for the widespread adoption of autonomous buses, as in our study it seemed irrelevant for ITU whether control was handed over to the AI or a human bus driver. Overall, however, the willingness to use autonomous buses was still lower than for conventional buses. This result may be due to disadvantages of autonomous buses that were not considered in this study but have a negative impact on ITU, e.g., the unfamiliar driving situation or possibly higher infrastructure costs [3, 62]. For the implementation of AVs, this implies that work still needs to be done to ensure that autonomous buses are accepted as an alternative or even a substitute for conventional buses. We need to point out again for the interpretability of this finding that the term autonomous in our study means that in critical situations, driving control is taken over by an operator via teleoperation. Fully AVs cannot be investigated in real road traffic at the current state of technological development. There is evidence that fully autonomous buses, which will be able to drive without teleoperation in the indefinite future, will be seen even more skeptically because control will be handed over fully to AI [54]. Assuming this, the focus should be even more on making AVs more attractive to users. Autonomous buses could, for example, be designed similarly to conventional buses, for which acceptance is higher, to minimize the first apparent difference. In the marketing of autonomous buses, more attention should be drawn to the advantages of autonomous buses over conventional buses. Feedback from potential users should be obtained to find out why they still show a lower ITU toward autonomous buses, e.g., through surveys among bus users. This would help to take appropriate precautions and make adjustments with

regard to regulations, guidelines, the implementation process, and the provision of autonomous buses.

5.2. Limitations and Future Work. To evaluate the results of our study in a well-founded manner, we would like to point out some limitations. First, the limited generalizability of our study results based on the selected sample should be noted. Due to the limited availability of autonomous buses, we could only collect test subjects for the autonomous bus condition on one autonomous bus route in the city of Regensburg. However, we would not have been able to meet our pre-specified sample size if we had recruited only natural users of the autonomous bus in Regensburg because the driving schedule and passenger numbers of these buses were very limited. Therefore, the sample of the autonomous condition consisted mainly of students from the University of Regensburg, who were specifically recruited through a university platform. This made the sample less variant and limited in representativeness in terms of age and education level, but it also achieved a larger sample size. In addition, the sample was not balanced with respect to gender, resulting in a higher proportion of women in our study. There were significant differences in trait anxiety and fear of giving up control that could possibly be related to gender or age effects [63–65]. This made it difficult for us to compare the two conditions with regard to the influence of trait anxiety. Furthermore, sociodemographic factors, e.g., gender, age, education, or socioeconomic status, may directly influence the ITU of AVs [57, 66, 67]. In our study, ITU was largely independent of gender and age. Nevertheless, we recommend that the sociodemographic generalizability of our findings be tested at a later point in time when autonomous buses are widely available and that the study also be replicated with a focus on other (e.g., older) populations. Under these conditions, the results should also be examined within a larger sample. Within the project period, it was not possible to expand the sample due to the limited availability of autonomous buses. Future studies may address our findings and replicate them in larger samples once autonomous buses are widely implemented. This could reveal effects that may not have been evident in our study due to the limited sample size [49].

Furthermore, we need to consider the limitations of our survey situation. The autonomous buses in which the study data of the autonomous condition were collected are currently plying in the industrial park of Regensburg on a ring-shaped route. The autonomous bus reaches a maximum speed of 18 km/h and is thus slower than the conventional buses in the comparison condition. This could potentially lead to a perception of the trip being less time efficient, which could negatively affect ITU. Furthermore, autonomous buses are not yet technically capable of driving fully autonomously on public roads. For critical situations, so-called operators are needed via teleoperation who take over driving monitoring systematically. One limitation of our study is that we do not know whether the participants thought they were handing over driving control completely to the AI or whether they were aware that an operator could take over driving control in a critical situation. This might have influenced their attitude

toward giving up control. The possibility of the control transfer to the operator in an emergency may be one reason why the mediation model in the autonomous condition did not differ from that in the conventional condition. In case future studies cannot be conducted in fully autonomous buses, it should at least be monitored whether the users were aware of the human operator taking over control in an emergency or perceived the vehicle as fully autonomous. Another limitation is the inconsistent reference framework of different anxiety questionnaires. For better comparability, we surveyed trait anxiety with the same inventory already used by Qu, Sun, and Ge [16]: the State-Trait Anxiety Inventory [68]. The inventory is established worldwide, and its psychometric quality and validity were confirmed many times [69, 70]. However, as noted by Qu, Sun, and Ge [16], the results depend on what the anxiety refers to in the wording of the items. Qu, Sun, and Ge [16] cite as an example a study by Hohenberger, Spörrle, and Welpé [15], in which anxiety negatively affected the ITU of AVs. In this study, the anxiety items were primarily related to anxiety about making mistakes when interacting with AVs (e.g., I would be afraid that I could cause (e.g., by pushing a button) a malfunction (e.g., emergency brake) by using an [semi-] automated car, [15]). In contrast, the items of the State-Trait Anxiety Inventory used by Qu, Sun, and Ge [16] refer more to general inadequacies of oneself in the context of trait anxiety (e.g., I don't have self-confidence., translated from German, [29]). Thus, while the items of Hohenberger, Spörrle, and Welpé [15] directed the focus to anxiety in dealing with AVs, we possibly addressed general self-related anxiety in our study [16]. According to Qu, Sun, and Ge [16], this may be one reason why anxiety (focusing on AVs) negatively affected ITU in the study of Hohenberger, Spörrle, and Welpé [15]. In contrast, in the study of Qu, Sun, and Ge [16] as well as in our study, individuals with high (self-focused) anxiety were more open to AVs. Among other reasons, this may be because potential risks and dangers related to AVs (unlike in the study of Hohenberger, Spörrle, and Welpé [15]) were not explicitly addressed and thus less anxiety was raised among the subjects.

Furthermore, the general characteristics of mediation analysis must be considered. We found in our study that the effect of trait anxiety on ITU was slightly partially suppressed by fear of giving up control. The actual magnitude of the influence was revealed only when the mediator variable was included. However, it is unlikely that the fear of giving up control is the only mediator of this relationship. Thus, other mediators may exist that mediate the association between trait anxiety and ITU, both reinforcing and suppressing [41]. For example, as discussed in the section "Summary and practical implications" above, higher trait anxiety could lead to higher climate change anxiety, thereby increasing the propensity to use public, electric, and efficient vehicles. Therefore, it cannot be ruled out that the actual association is even stronger than we currently found [41]. This is a well-known general limitation of mediation analysis [41]. We can only progressively confirm the true role of our mediator by further understanding the relationship between trait anxiety

and ITU, thereby ruling out the influence of possible confounding mediators. This may be the task of future research in this field.

6. Conclusion

The present study on the acceptance of AVs aimed to understand the influence of trait anxiety on ITU in greater detail by focusing on the fear of giving up control. Trait anxiety positively affected ITU in general, but the association only reached significance when the total sample was considered. The mediation by fear of giving up control was in our study not the positive direction of the relationship. Surprisingly, these results appeared independent of whether control was given to AI in the autonomous bus or a human driver in the conventional bus in a direct statistical model comparison. The finding that AVs and public transport are attractive transport concepts, particularly for anxious people, suggests that there may already be widespread awareness in the population of the benefits of autonomous, sustainable, and efficient transport concepts. It may be the task of future research to further investigate the underlying mechanisms of action that condition the relationship between trait anxiety and ITU.

Data Availability Statement

The original dataset, the syntax for statistical analysis, and an overview of all items used in the study are available in the OSF repository, <https://osf.io/7e9vc>.

Disclosure

A preprint has previously been published (<https://osf.io/preprints/osf/r2ug5>) [28].

Conflicts of Interest

The authors declare no conflicts of interest.

Author Contributions

F.S. and M.H. contributed to conception and design, performed analysis and interpretation of data, drafted and/or revised the article, and approved the submitted version for publication. F.S. contributed to the acquisition of data.

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