Diversity and Anticipated Acceptance of Automated Driving: The Impact of the Living Environment and Gender in Germany - Establishing Convergent and Discriminant Validity of the QAAD

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Abstract

Human diversity will have an essential impact on the acceptance of fully automated vehicles (AVs). However, there has been scant research on the validity of the anticipated acceptance of AVs and on the influence of gender and living environment. Therefore, we conducted a cross-sectional, empirical questionnaire study in Germany and queried 141 participants (65 female, 74 male, one diverse, one non-binary; age: 18 to 81 years) from different living environments (Big City, City, Rural). The results indicated consistent findings of convergent and discriminant validity of technology acceptance (TA). Furthermore, stable gender effects were identified, with women reporting lower values on TA than men. Interestingly, the results on living environment only partly indicated that residents living in big cities assign greater values to TA than in smaller cities or in rural environments. While the living environment may be less influential, gender remains a significant factor in achieving public acceptance of AVs.

CCS Concepts

• **General and reference → Empirical studies**; **Measurement**; **Validation**; • **Applied computing → Psychology**; • **Social and professional topics → Gender**.

Keywords

Fully Automated Driving, SAE Level 5, Anticipated Acceptance, Living Environment, Gender, Diversity, Convergent and Discriminant Validity, QAAD

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1 Introduction

Modern technologies have become an essential part of our daily lives, with possibilities expanding rapidly in many fields, like in the mobility sector, where automated driving (AD) is predicted to be the future of transportation systems [2, 5, 34]. The capabilities of AD systems can vary depending on which of the 6 Levels of Automation, defined by the Society of Automotive Engineers [40], from Level 0 – No Automation, to Level 5 (L5) – Full Automation, has been realised. While a driver is still required up to level 4, who intervenes to a diminishing extent as the level progresses, there is no longer a driver needed in L5 vehicles. Nonetheless, self-driving cars promise benefits at all levels, including improved traffic flow and safety through fewer road accidents [2, 13, 14, 17], as well as reduced fuel consumption [14] resulting in a significant decrease in CO_2 emissions [29] ultimately leading to lower global carbon emissions and thereby mitigating climate change [13]. In Germany, a study on the anticipated acceptance of AD has shown that AVs at level 3 could be first accepted by the public around 2030 (or a bit later) and at level 5 by about 2040 [52]. This outlines the necessity to learn more about the underlying psychological phenomena if AVs are intended to be accepted by the public. Moreover, the ongoing ageing of the population and increase in older drivers [26] will boost the demand for AD, particularly for those that cannot drive a car themselves anymore, as it can provide more mobility [11, 13] and alleviates social isolation, especially in rural areas [51]. Another benefit is the productive use of time [2, 14], referring to performing Non-Driving-Related-Tasks (NDRTs) while driving, such as transforming the car into a mobile workspace [13, 34] or using the travel time to chat with others [36]. Many of these benefits are most effective in L5 vehicles, for example, NDRTs could be dangerous in L3 vehicles, as the driver is still required to monitor the car and intervene if necessary [25]. Contrary to this, Rödel et al. [39] discovered that both user experience and acceptance decrease continuously with higher levels of automation. One reason for this could be the numerous concerns that hinder people from ultimately accepting AD. Such concerns focus on expected costs [10, 18, 48], ultimately leading to social exclusion [19] as AD vehicles are likely to be purchased initially by wealthy people [7]. Other fears relate to potential job losses as artificial intelligence (AI) replaces humans [19, 31] as well as concerns about data privacy and software hacking [6, 23]. In terms of technical anxieties Schoettle and Sivak [41] identify concerns about equipment failure and fear of accidents due to technical outage [22]. Although the biggest problem in achieving "Vision Zero", the goal of no more people dying in road accidents, is human error, since 93 % of total crashes in the U.S. were human error induced [17], and insufficient distance, inappropriate speed, and alcohol consumption are the leading causes of road accidents in Germany [46], many people are still concerned about giving away the control over the vehicle and being in the hands of technology [34, 45]. In conclusion, the biggest obstacle to the widespread adoption of AD is psychological and not technical in nature [45]. But this acceptance is crucial, as, according to Nordhoff et al. [32] it is one of the most essential prerequisites for the success of automated vehicles, and a lack of it could prevent the introduction of such vehicles on public roads [55]. To better understand and evaluate such psychological factors, many questionnaires based on different technology acceptance models have emerged. The best-known and often extended model is the Technology Acceptance Model (TAM) [15] that posits that perceived usefulness and perceived ease of use influence the attitude toward use, which in turn influences the behavioural intention, ultimately leading to actual usage. Another frequently cited model that emerged from the TAM is the Unified Theory of Acceptance and Use of Technology (UTAUT) [49], which integrates eight psychological models and aims to explain users' intentions to use an information system, resulting in usage behaviour. This requires four key constructs, namely performance expectancy, effort expectancy, social influence and facilitating conditions. The first three key constructs directly determine intention to use and usage behaviour, while the fourth is only a determinant of the latter. Venkatesh et al. [49] also found that experience, voluntariness, gender, and age are relevant moderators that influence the four key constructs.

1.1 Related Work

Many studies have aimed to find such correlations with demographic variables influencing such key determinants and found correlations with education [28, 33], technical savvy and income [6].

Overall, gender and age differences mentioned by Venkatesh et al. [49] are best pronounced in existing literature. Men are more optimistic towards automated vehicles (AV) [33], have more positive attitudes towards AVs [28], and are more willing to use and inclined to purchase an AV [21, 35]. Women, on the other hand, express more concerns about self-driving cars [24] and are less intrigued by the possibilities of NDRTs [54], although they indicate a lower desire for control than men [53]. In line, Weigl et al. [55, 56] showed that women and older people express less acceptance towards AV. In addition, there are robust findings that older drivers show less interest in AVs and are less willing to purchase one [6, 21, 26, 41]. They rate AVs as less trustworthy, and their interest declines as the level of automation increases [1]. Also, similar to women, older people indicate lower interest in NDRTs [55, 56] and are more worried about self-driving cars [24]. In comparison, younger people are more optimistic towards AVs [33] and regard self-driving cars as more beneficial [26]. Although these effects have been widely demonstrated, the results may not be generalisable, as many of the studies were often conducted in a single country, like France [29, 35], Australia [14], China [51], and Germany [34]. Studies comparing acceptance between countries have produced mixed results. On the one hand, Weigl et al. [53] compared acceptance in the U.S.A. and Germany with even slight methodological differences, but still acquired the same consistent results. On the other hand, a comparison of people from Israel and North America showed that Israelis express greater acceptance than North Americans [20]. Furthermore, Schoettle and Sivak [41] also identified significant differences between respondents from Australia and respondents from the USA and the UK.

Besides this, what has been reported more clearly is a significant correlation with living environment, suggesting that people living in densely populated areas [28] or urban areas [44] show higher acceptance, even when explicitly measured for L5 [55]. Interestingly, among college students, living environment has not been found to have an impact on the adoption of digital technologies [47]. Consistently, rural respondents appear to value self-driving cars less than urban respondents [24].

1.2 Present Study

Because of these national differences, we decided to conduct a survey of the anticipated acceptance of fully automated vehicles (SAE level 5) in Germany. As there has been scant research, we were particularly interested in the two primary goals: First, applying different questionnaires measuring technology acceptance with a special focus on automated driving to study whether there might be convergent and discriminant validity among those. Second, we put a special emphasis on the investigation of any gender differences and of differences between varying types of living environment, such as Big City (+100,000 inhabitants), City (100,000 and 5,000), and Rural (less than 5,000), as well as any interaction between gender and living environment. In this regard, we applied the following three questionnaires: (1) the Questionnaire on the Acceptance of Automated Driving (QAAD) [55], (2) the Questionnaire on the Acceptance of Self-Driving Cars (AS) [26], and (3) the Technology Readiness (TR) questionnaire (as a kind of control with no special focus on automated driving) [30]. Therefore, we investigated the following research questions (RQs):

(1) RQ1: How could convergent and discriminant validity of the anticipated technology acceptance within the context of automated driving be identified using the QAAD, the AS, and the TR questionnaire for validation?

(2) RQ2: How is the influence of gender and living environment (Big City, City, Rural) on the factor scores of the QAAD, the AS, and the TR questionnaire?

2 Method

2.1 Participants

In total, the sample consisted of 144 participants, of whom three were excluded because they did not complete the assessment and one additionally because of an incorrect code. Finally, 141 participants (74 males, 65 females, one diverse, one non-binary) with an age range from 18 to 81 (M = 43.45, SD = 18.12 years; female: M = 43.34, SD = 18.14; male: M = 44.20, SD = 18.24) were included in the analysis. The sample consisted mainly of Germans (N = 121), as intended, whilst the second largest nationality were Belgians (N = 16), who were partially assisted to address language misunderstandings. Ninety-five participants were in a relationship (36 dating, 55 married, 4 in a registered civil partnership), while 41 participants were not in a relationship (31 single, two widowed, eight divorced). Of all participants, 132 (i.e., 93.62%) had a valid driving licence, and 29 participants (i.e., 20.57%) reported never having been in an accident, regardless of severity. The frequencies and the cell sample sizes of living environment and gender are depicted in Table 1.

Table 1: Cell sample sizes as function of living environment and gender

	Big City	City	Rural	$\sum$
female	25	22	18	65
male	27	28	19	74
diverse	1	0	0	1
non-binary	1	0	0	1
$\sum$	54	50	37	141

Note. $N = 141$.

2.2 Study Design

We applied an exploratory, cross-sectional online questionnaire study in Germany and collected data with three main questionnaires such as the "Questionnaire on the Acceptance of Automated Driving" (QAAD) [55], the "Questionnaire on the Acceptance of Self-Driving Cars" (AS) [26], and the "Technology Readiness" (TR) questionnaire [30] with no special focus on automated driving (for comparative reasons). Furthermore, two short additional questionnaires were applied, which are beyond the scope of the present study. Besides the investigation of convergent and discriminant validity of the QAAD, for the second primary analyses, the factor scores of the three questionnaires, the QAAD, the AS, and the TR, constituted the dependent variables (DVs). Gender (female, male) and living environment (Big City, City, Rural) were the categorical variables yielding 2 x 3 between-subjects-design.

The three categories of living environment were defined as follows: *Big City* = +100,000 inhabitants; *City* = between 100,000 and 5,000 inhabitants; *Rural* = a small village in the countryside or near a city with less than 5,000 inhabitants.

The categorisation into big city ($\geq 100,000$ inhabitants), city (5,000 to $< 100,000$ inhabitants), and rural ($< 5,000$ inhabitants) is based on official German statistical classifications. These define large cities (big cities) as municipalities with $\geq 100,000$ inhabitants, medium-sized cities as 20,000 to $< 100,000$ inhabitants, small towns as 5,000 to $< 20,000$ inhabitants, and rural municipalities as those with $< 5,000$ or no central functions [8, 42]. While widely used in urban and regional research and policy, this approach has been criticised as overly simplistic. Arcaute et al. [3] argue that population size alone fails to capture functional urban systems and spatial dynamics. Commuting patterns and population density are proposed as more robust indicators. Furthermore, Wandl et al. [50] the growing relevance of *in-between* territories (i.e., areas that do not fit neatly into urban or rural categories). These hybrid spaces are increasingly common across Europe and call for a more nuanced spatial understanding that incorporates networks, functions, and socio-spatial characteristics. Nevertheless, the simplified categorisation by population draws on standards set by the Federal Agency for Civic Education (Bundeszentrale für politische Bildung, bpb) and the Federal Institute for Research on Building, Urban Affairs and Spatial Development (Bundesinstitut für Bau-, Stadt- und Raumforschung, BBSR) and therefore provides an institutionally recognised, transparent, and context-sensitive framework that supports both analytical clarity and practical implementation within the survey.

2.3 Materials

To directly assess the acceptance of AD Level 5, we decided on the "Questionnaire on the Acceptance of Automated Driving" (QAAD) [55] and the "Questionnaire on the Acceptance of Self-Driving Cars" (AS) [26]. For the QAAD, the factor PRO summarised items pertaining to safety, trust, ease of use and usage intentions as well as benefits for disabled and older people. In contrast, the factor CON summarised items pertaining to driving enjoyment, personal freedom, safety, stress, and estimation of future success. The Factor NDRTs queries activities like working, relaxing and entertainment, and, reversely coded, observing driving functions. AS perceptions (Per) items pertained to usefulness, ease of use, affordability, accessibility, technical support, emotional benefits, social support, reliability, interoperability, lifestyle fit and conceptual compatibility. Furthermore, the AS attention towards use (AtU) item queried overall interest, while behavioural intentions (BI) were measured with two items relating to the likelihood of adoption, one in general and one conditional (i.e., one is no longer able to drive a car). We decided on the two questionnaires because both questionnaires' underlying theories stem from the TAM and UTAUT, but each questionnaire further built on different models of acceptance, resulting in different conceptual research models, as the distinct factors and items indicate. Also, the QAAD has already been conducted in Germany [55] while the AS was only published in English and conducted in the U.S.A. Thus, we sought to replicate the results from Weigl et al. [55] concerning L5 and further to see to what extent these results emerge in the AS. Since the AS was published in English by Lee and colleagues, we translated each item to German, which was then checked by a native English speaker with proficiency in German. To assess the construct of technology acceptance, we used the "Kurzskala Technikbereitschaft", "Short Scale on Technology Readiness (TR)" [30] that measures the human-centered openness and readiness for technology (and not for the readiness of the technology itself) with its' facets Technology Acceptance (TA), Technology Competence Beliefs (TCom), and Technology Control Beliefs (TCon).

To target attitudes towards self-driving cars specifically for SAE level L5, a brief introduction was presented on top of each page for the QAAD and the AS, introducing the participants to the SAE levels of AD and AVs, especially fully automated vehicles. Although the original AS included an introductory section, it was decided that a variation of the explanation used in the QAAD would be more appropriate to avoid confusion amongst participants. The original introduction to the topic in the AS was rather general and not level-specific, which could have been misleading.

We share the data set and additional results with the scientific community via the repository of the Open Science Framework (OSF): https://osf.io/vjx7k/ .

2.4 Procedure

We conducted an online questionnaire survey in Germany using the research tool SoSci Survey [27]. Recruitment was conducted by students of the course "Empirical Practice" who invited participants personally or via email. The quality of the recruitment was determined by two codes to link attendants to their recruiters and to counteract unwanted link users. Participation was anonymous and voluntary, and participants were given a brief introduction to the study as well as a detailed explanation of data protection and data use before giving their consent, also indicating that they were over 18 years of age. It was possible to omit some demographic items, but all items in each of the main questionnaires were mandatory. Consequently, all participants included in the final analysis provided a complete data set for each of the five questionnaires. Finally, participants were thanked for their participation, and contact information was provided in case of any questions. The mean completion time for the survey was 24.53 minutes (SD = 9.11), with a maximum of 47.65 minutes and a minimum of 9.07 minutes.

2.5 Statistical Analyses

The statistical significance level was set to α = .05. For the correlational analyses, the α-level was Bonferroni-corrected because of multiple testing. Results with $p < \alpha$ are reported as statistically significant.

After the primary steps of data management was done (e.g., exclusion of fakers or incomplete data), reverse-coded items were recoded to meet the requirements stated in the respective manual (e.g., items on the QAAD were measured from 1-101 due to the programming of the SoSci Survey slider scale and therefore transformed to a scale from 0-10). Then, values for each factor were computed for the factor mean scores of the QAAD, the AS, and the sum score for the TR questionnaire, as stated in each manual.

Initially, the statistical prerequisites were examined. Thereby, the descriptive statistics of the DVs and the frequency distributions of the IVs were examined (cf. Table 1). Furthermore, they were also graphically investigated. Moreover, skewness and kurtosis were assessed separately for all combinations of gender and living environment (2 x 3 = 6) on all the QAAD, the AS, and the TR questionnaire DVs (QAAD: 3 factors, AS: 3, TR: 3; 9 in total). Almost all values are within the interval $[-1.96; 1.96]$ or close to it. The detailed results are provided via OSF (cf. 2.3).

When those results are taken together, most statistical assumptions are met. Hence, for the two primary objectives, the investigation of (I) convergent and discriminant validity of the QAAD and (II) any differences between the subgroups of gender and living environment, parametric statistical analyses were applied. However, since not all cell sample sizes were almost equal (cf. Table 1) and not all prerequisites were ideally given, especially the MANOVA results have to be interpreted with caution. In this regard, the test statistic *Pillai's trace* was applied to all MANOVA analyses [37]. It is considered relatively robust and powerful in the context of small samples and uneven cell sizes (i.e., unequal/unbalanced groups) and for departures from the statistical assumptions such as homogeneity of variance-covariances [4, 43].

The statistical analyses were performed with IBM® SPSS® Statistics, version 29.0.2.0 [12].

3 Results

After the examination of the statistical prerequisites, two primary statistical analyses were applied to study our research questions. First, the convergent and discriminant validity of the QAAD were investigated (cf. section 3.1). Second, MANOVAs were applied to the factor scores (DVs) of three questionnaires (QAAD, AS, TR) to investigate any differences between the subgroups of gender and living environment (cf. section 3.2).

3.1 RQ1: Validation: Convergent and Discriminant Validity of the QAAD

After the computation of the mean scores for all factors of the QAAD, the AS, and the TR questionnaire, the parametric Pearson product-moment correlation coefficient was applied to obtain the correlational main findings (cf. Table 2). It was expected that if the QAAD measures almost the same factorial constructs as the two other questionnaires on technology acceptance, namely the AS and the TR, for convergent validity, there would be substantial correlations of the PRO and the NDRTs factor with all the other factors of the AS and the TR questionnaires (RQ1). For discriminant validity, it is assumed that there are substantial negative correlations between the CON factor of the QAAD with all the other factors of the AS and the TR questionnaire. As depicted in Table 2, both the convergent and discriminant validity investigations show consistent correlational findings (positive coefficients for convergent factors and negative among the discriminant factors). Interestingly, but also reasonably because of more similar latent constructs, the correlations between the QAAD and the AS are greater. In contrast, the correlations are lower between the QAAD and the TR questionnaire, indicating that the QAAD and the AS share and explain more of the same variance, whereas the QAAD and the TR share less of the common variance (cf. Table 2).

Table 2: Bivariate correlations (parametric, Pearson) of the three QAAD factor mean scores PRO, CON, NDRTs with the three factor scores of the AS (Per, AtU, BI) and the three factor scores (TA, Com, TCon) of the TR questionnaire, respectively.

	AS			TR		
QAAD	Per	AtU	BI	TA	TCom	TCon
PRO	.72*	.69*	.66*	.39*	.39*	.33*
CON	-.62*	-.56*	-.59*	-.32*	-.33*	-.32*
NDRTs	.65*	.57*	.55*	.49*	.48*	.44*

Note. $N = 141$. (cf. detailed and additional correlation tables uploaded on OSF); *Significant at the Bonferroni-corr. $\alpha = .0024$ (two-sided).

3.2 RQ2: Living environment, Gender, Anticipated Acceptance of Automated Driving

To examine RQ2, we applied a two-factorial MANOVA to the factor scores of the three questionnaires, the QAAD, the AS, and the TR, with gender (female, male) and living environment (Big City, City, Rural) as categorical variables, yielding a 2 x 3 between-subjects design.

First, we investigated the QAAD and applied the MANOVA to the three factor mean scores PRO, CON, and NDRTs (DVs). The first MANOVA analyses revealed a gender effect and an effect of living environment, but no interaction effect between gender and living environment (cf. Table 3).

Further univariate analyses showed that men reported substantially larger values than women for the mean factor scores PRO and NDRTs (cf. Table 4 and Figure 1 for the means (M) and the standard error of the means (SEM)). In contrast, for the CON factor, there was an opposite gender effect with women articulating more concerns than men (cf. Table 4 and Figure 1 with the M and SEM). Additionally, there was a substantial effect for the living environment for the PRO and the CON factors, but none for NDRTs. People living in a *Big City* reported greater values on the PRO and smaller ones on the CON factor when compared with residents living in *Cities* and in *Rural* areas. However, post-hoc tests did not reveal a difference between people living in cities and in rural areas on both the PRO and the CON factor (those supplementary results of the post-hoc tests are shared via the OSF repository; cf. above). It has to be noted that in all Figures, on the y-axis, 0 = "I fully disagree" and 10 = "I fully agree".

Second, we applied the MANOVA to the three factor mean scores, Per, AtU, and BI (DVs) of the AS questionnaire. These MANOVA analyses uncovered again a gender effect but no effect of living environment and no interaction effect between gender and living environment on those factors (cf. Table 5).

Further univariate analyses showed that men assigned substantially larger values than women to the mean factor scores Per and BI (cf. Table 6 and Figure 2 for Ms and SEMs). However, there was no gender effect observed on the AtU mean factor score.

Third, we examined the TR questionnaire and applied the MANOVA to the three factor scores TA, TCom, and TCon (DVs). The MANOVA analyses revealed a further gender effect and an effect of living environment, but no interaction effect between gender and living environment on those three factors (cf. Table 7).

Additional univariate analyses uncovered that men reported larger values than women on the mean factor scores TA and TCom (cf. Table 8 and Figure 3 for Ms and SEMs). However, no gender effect was found on the TCon factor score. Moreover, there was an effect of living environment, but only for the TCom factor score. Supplementary post-hoc tests showed that residents living in a *Big*

Table 3: MANOVA: Two-factorial multivariate analyses of variances of the factor scores PRO, CON, and NDRTs of the QAAD as a function of gender and living environment.

	Pillai	F^a	df_1	df_2	p	$\eta^2_{p.}$
Gender	.115	5.67	3	131	.001	.115
Living env.	.114	3.41	6	264	.003	.072
Gender * Living env.	.028	0.62	6	264	.714	.014

Note. $N = 139$. Pillai = Pillai's Trace; [a]Exact F statistic computed by SPSS; df_1 = hypothesis df, df_2 = error df; $\eta^2_{p.}$ = effect size partial η^2.

Table 4: MANOVA: Corresponding univariate tests of the factor mean scores PRO, CON, and NDRTs of the QAAD for gender (G), living environment (LE), and the interaction of gender and living environment.

	DV[a]	SumSq.	df	M.S.	F	p	$\eta^2_{p.}$
Gender	PRO	50.96	1	50.96	12.03	<.001	.083
	CON	25.51	1	25.51	5.47	.021	.039
	NDRTs	116.12	1	116.12	14.47	<.001	.098
LE	PRO	54.28	2	27.14	6.40	.002	.086
	CON	87.47	2	43.73	9.34	<.001	.123
	NDRTs	43.85	2	21.93	2.73	.069	.039
G * LE	PRO	7.41	2	3.70	0.87	.420	.013
	CON	10.81	2	5.40	1.15	.319	.017
	NDRTs	3.17	2	1.59	0.20	.821	.003
Res.	PRO	563.62	133	4.24			
	CON	623.03	133	4.68			
	NDRTs	1067.52	133	8.03			

Note. $N = 139$. $df_{total} = 139$. SumSq. = Sum of Squares; M.S. = Mean Squares; Res. = Residuals; [a]Dependent variable: Factor mean scores: PRO, CON, and NDRTs; $\eta^2_{partial}$ = effect size partial η^2.

Table 5: MANOVA: Two-factorial multivariate analyses of variances of the factor scores Per, AtU, and BI of the AS as a function of gender and living environment.

	Pillai	F^a	df_1	df_2	p	$\eta^2_{p.}$
Gender	.069	3.23	3	131	.024	.069
Living env.	.048	1.07	6	264	.379	.024
Gender * Living env.	.028	0.63	6	264	.704	.014

Note. $N = 139$. Pillai = Pillai's Trace; [a]Exact F statistic computed by SPSS; df_1 = hypothesis df, df_2 = error df; $\eta^2_{p.}$ = effect size partial η^2.

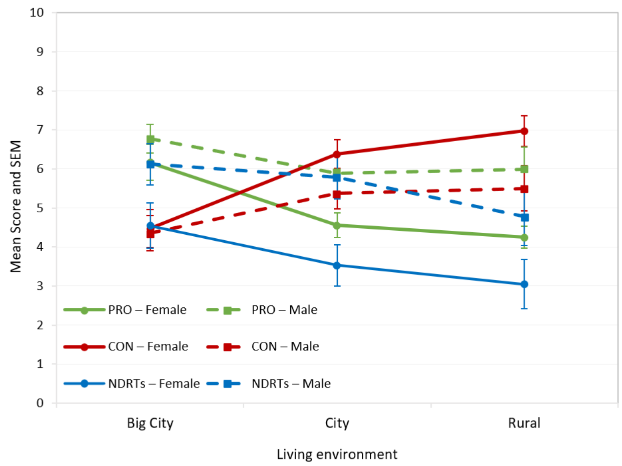

Figure 1: Mean scores and standard errors of the mean (SEM) for the mean factor scores PRO (green line), CON (red), and NDRTs (blue) of the QAAD. Women: solid line; Men: dashed line.

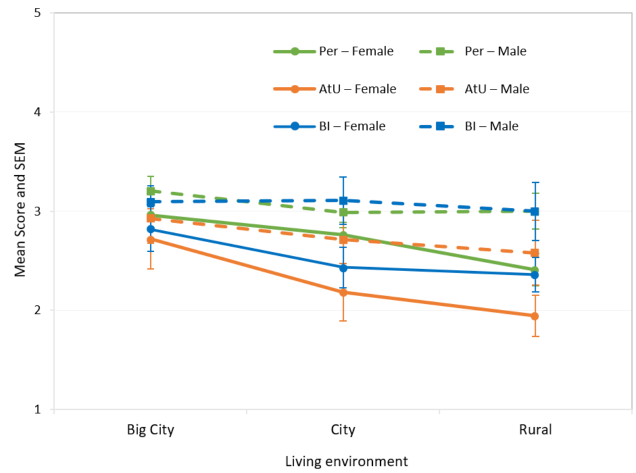

Figure 2: Mean scores and standard errors of the mean (SEM) for the mean factor scores Per (green line), AtU (orange), and BI (blue) of the AS. Women: solid line; Men: dashed line.

Table 6: MANOVA: Corresponding univariate tests of the factor mean scores Per, AtU, and BI of the AS for gender, living environment (LE), and the interaction of gender and living environment.

	DV[a]	SumSq.	df	M.S.	F	p	$\eta^2_{p.}$
	Per	4.16	1	4.16	7.58	.007	.054
Gender	AtU	7.08	1	7.08	3.87	.051	.028
	BI	9.45	1	9.45	8.32	.005	.059
	Per	3.14	2	1.57	2.87	.060	.041
Living Env.	AtU	7.44	2	3.72	2.03	.135	.030
	BI	1.81	2	0.90	0.80	.454	.012
	Per	0.88	2	0.44	0.80	.450	.012
Gender * LE	AtU	1.17	2	0.58	0.32	.728	.005
	BI	1.22	2	0.61	0.54	.586	.008
	Per	72.90	133	0.55			
Residuals	AtU	243.46	133	1.83			
	BI	151.19	133	1.14			

Note. N = 139. df_{total} = 139. SumSq. = Sum of Squares; M.S. = Mean Squares; [a]Dependent variable: Factor mean scores: Per, AtU, and BI; $\eta^2_{partial}$ = effect size partial η^2.

Table 7: MANOVA: Two-factorial multivariate analyses of variances of the factor scores TA, TCom, and TCon of the TR questionnaire as a function of gender and living environment.

	Pillai	F^a	df_1	df_2	p	$\eta^2_{p.}$
Gender	.114	5.62	3	131	.001	.114
Living env.	.132	3.11	6	264	.006	.066
Gender * Living env.	.046	1.03	6	264	.405	.023

Note. N = 139. Pillai = Pillai's Trace; [a]Exact F statistic computed by SPSS; df_1 = hypothesis df, df_2 = error df; $\eta^2_{p.}$ = effect size partial η^2.

City assigned larger values when compared with residents living in *Cities* and in *Rural* areas, whereas there was no difference between people living in cities and in rural areas (those supplementary results of the post-hoc tests are shared via the OSF repository; cf. above).

4 Discussion

The objectives of the present study were twofold: First, to assess the convergent and discriminant validity of the anticipated acceptance of automated driving QAAD, the AS, and the TR questionnaire (RQ1). Second, to shed more light on the, as yet, scantily researched effects of the interplay of gender *and* living environment (Big City, City, Rural) on the anticipated acceptance of AD, specifically for SAE level L5 AVs, and technology acceptance in general (RQ2).

4.1 RQ1: Validation of the QAAD

Hence, as expected, both the convergent and discriminant validity investigations have shown consistent correlational findings with positive coefficients for the convergent factors and negative coefficients among the discriminant factors. Therefore, the QAAD seems to measure and share common variance with both questionnaires, but more with the AS than with the TR. These findings make sense from a content perspective because of the more closely related latent constructs of the QAAD and the AS questionnaire.

Particularly, the correlation coefficients between QAAD and AS ranged from r = .55 to r = .72 across all (3 × 3 = 9) combinations (cf. Table 2), supporting convergent validity and the success of our translation into German. This alignment is theoretically consistent, as both instruments assess attitudes toward automated driving. Still, they operate at different levels of specificity, thereby emphasising

Table 8: MANOVA: Corresponding univariate tests of the factor mean scores TA, TCom, and TCon of the TR questionnaire for gender (G), living environment (LE), and the interaction of gender and living environment.

	DV^a	SumSq.	df	M.S.	F	p	$\eta^2_{p.}$
Gender	TA	117.86	1	117.86	11.04	.001	.077
	TCom	119.66	1	119.66	11.77	<.001	.081
	TCon	15.95	1	15.95	2.09	.151	.015
LE	TA	35.91	2	17.95	1.68	.190	.025
	TCom	200.17	2	100.09	9.84	<.001	.129
	TCon	34.04	2	17.02	2.23	.112	.032
G * LE	TA	44.17	2	22.09	2.07	.130	.030
	TCom	17.06	2	8.53	0.84	.434	.012
	TCon	1.53	2	0.76	0.10	.905	.001
Res.	TA	1419.51	133	10.67			
	TCom	1352.41	133	10.17			
	TCon	1017.12	133	7.65			

Note. N = 139. df_{total} = 139. SumSq. = Sum of Squares; M.S. = Mean Squares; Res. = Residuals; ^{a}Dependent variable: Factor mean scores: TA, TCom, and TCon; $\eta^2_{partial}$ = effect size partial η^2.

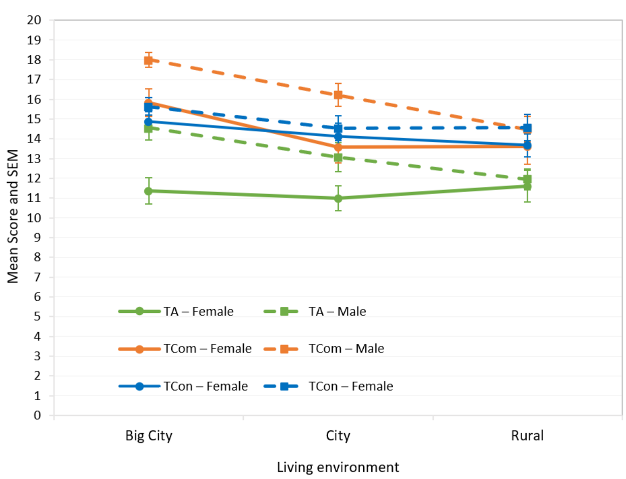

Figure 3: Mean scores and standard errors of the mean (SEM) for the mean factor scores TA (green line), TCom (orange), and TCon (blue) of the TR questionnaire. Women: solid line; Men: dashed line.

distinct facets of user perception. While the QAAD focuses explicitly on fully automated (L5) vehicles, the AS adopts a more general, level-independent perspective. This conceptual distinction likely accounts for the observed correlation patterns. For instance, the QAAD factor PRO exhibits stronger correlations with AS constructs due to shared thematic focus. In contrast, the NDRTs factor (highly relevant in the context of L5 vehicles) shows comparatively weaker associations, presumably because the AS lacks L5-specific framing. Consequently, the QAAD captures functional and experiential aspects of automation (e.g., non-driving-related tasks) more comprehensively. Furthermore, with regard to theoretical underpinnings, the QAAD follows a valence- and content-driven structure, without explicitly distinguishing cognitive, affective, or intentional dimensions. In contrast, the AS adheres to a linear structure, as proposed in theoretical frameworks such as TAM and UTAUT, which differentiate between sequential components (e.g., Perceptions, Attitudes toward Use, and Behavioral Intentions). This structural divergence likely accounts for the stronger correlations of QAAD factors with the AS factor Per and the relatively weaker correlations with AtU and BI. In contrast, the TR, which represents general technology acceptance, showed lower correlations with the QAAD. The correlation coefficients ranged from $r = |.32|$ to $r = .49$, again across all ($3 \times 3 = 9$) combinations (cf. Table 2). This suggests the influence of additional variables when assessing technology acceptance in the specific context of automated driving. It is conceivable that general inquiries regarding technology acceptance are too abstract, prompting respondents to engage with reduced emotional involvement. This interpretation is further supported by the finding that domain-specific instruments, such as the QAAD and AS, which incorporate visual and contextual cues, may elicit stronger cognitive and emotional engagement. This effect was not observed in the TR. Taking the findings of convergent and discriminant validity together, RQ1 is satisfactorily investigated and answered.

4.2 RQ2: Living environment, Gender, and Anticipated Acceptance

Another objective of this study was to gain preliminary insights into the interrelationship between gender and living environment and their effects on the anticipated acceptance of AVs. Men demonstrated more positive perceptions and higher usage intentions regarding L5 AVs compared to women, consistent with Weigl et al. [56]. Women showed less interest in NDRTs and expressed greater concerns about L5 vehicles, consistent with previous research König and Neumayr [24], Liljamo et al. [28], Othman [33], Venkatesh et al. [49], Weigl et al. [53, 54, 55, 56]. However, gender differences can also be likely due to variations in affective responses towards AVs, as noted by Hohenberger et al. [21], and technology in general, which could be influenced by societal norms and gender roles. Women are often socialised to prioritise safety and exhibit cautious behaviour [9] and may therefore have greater risk perception associated with AVs or technology in general. Nevertheless, these effects were only minor to medium in size, and the average level of acceptance remained moderate to low, indicating that there is still considerable room for improvement in acceptance across both genders. Interestingly, an effect of living environment was only partly observed, especially on the two mean factor scores, PRO and CON, of the QAAD, but not on the third, namely NDRTs. For the AS questionnaire for all three mean factor scores, no effect of living environment was found. Furthermore, for the TR questionnaire, only for the TCom factor (technology competence beliefs) an effect of living environment was observed. However, there were no effects for the general technology acceptance (TA) and the technology control beliefs (TCon) factors. Hence, in summary, the effects of living environment were only observed on three (out of nine) factor scores measured with the QAAD, the AS, and the TR questionnaire.

Nevertheless, it is remarkable that those effects of the three different factors portray the same findings: People residing in big cities report more openness on the anticipated acceptance of AVs (PRO) and a bit fewer concerns (CON), as well as more technology competence beliefs (TCom), than those living in smaller cities or in rural areas. There was no substantial difference between smaller cities and rural areas. A reason might be that those residing in smaller urban or especially in rural areas often rely more on private cars for transportation. Thus, this might result in a bit lower appreciation. In summary, the results of the potential effects of gender and living environment offer more insight and answer our RQ2.

4.3 Limitations and Future Research

Overall, the results should be interpreted with caution because of the relatively small sample size, especially the cell sample sizes (cf. Table 1). Furthermore, a (quasi-)experiment, for example, a vignette or a driving simulator study, could also address specific test scenarios or settings (whilst often lacking a general perspective when such a study is limited to specific scenarios or settings). As it is with all questionnaire studies, they are limited by their real-world exposure to such AVs. However, from a scientific and probabilistic point of view, it is also possible that the same participants would report more or less the same opinions, preferences, and attitudes on AVs, even when exposed to them. Hence, sole exposure might not necessarily change their ratings. Nevertheless, in future studies, also addressing gender and living environment could be pretty interesting. Finally, these findings are only partially generalisable. Conducted in Germany, the results may differ in other countries. While outcomes are likely influenced by national wealth and income, meaning that countries with similar wealth may show comparable results, the conclusions drawn here are primarily applicable to the German context and should serve only as a guide for studies in other regions. Future longitudinal studies on AD acceptance could be valuable to observe whether ongoing digitalisation and the public use of AI technologies might influence gender-related differences in acceptance as people grow older or if their opinions are rather imperturbable.

We applied convenience sampling to collect the data for our exploratory cross-sectional study. Although this method is considered time-efficient, practical, and cost-effective, it has to be noted that this rather subjective data sampling approach can yield biased results, which may have a significant influence on the representativeness and validity of the findings [16]. Hence, it would be interesting to apply those questionnaires in VR as well as in real-world quasi-experimental outdoor studies with AVs. Nevertheless, it cannot be ruled out that similar findings could also emerge in these different settings as identified in the present study. Furthermore, we assessed additional demographic variables such as income and education. Income was not compulsory, so only 112 respondents completed them (27 missing). Nevertheless, there were no substantial associations (correlations) with the DVs for both variables, income and education. Moreover, media consumption could also confound the results. Therefore, in future studies, it would be interesting to also include this factor.

Another limitation of the findings in the present study is the slight under-representation of citizens residing in rural areas (n = 37 vs. 54 in a big city and 50 in a city; cf. definitions in section 2.2). Hence, the findings for rural citizens, when compared to citizens living in a big city or city, have to be treated with caution. Future studies could put a special emphasis on sampling not only larger sample sizes but also ones with more similar cell sample sizes. However, in this regard, it has to be noted that the very small subgroups of diverse and non-binary participants, which would also be very interesting to be analysed in future gender studies, seem to be representing a fairly realistic sample size with n = 2 in our sample of 141 respondents in total, yielding 1.4%, when compared to estimated numbers of, for example, 0.6% [38].

5 Conclusion

In conclusion, only gender has a consistent significant impact on AD acceptance, indicating that interventions should be carefully tailored to address the specific concerns of each gender, particularly women. Informational events, particularly targeted at women, could be beneficial to counteract these challenges. For example, information campaigns in schools could raise awareness and understanding. Additionally, government policies that support the purchase of AD vehicles or their introduction in public transport could provide people with positive experiences. Implementing AVs in limited areas with fixed routes could alleviate concerns, as people would perceive the situation as less error-prone. Such campaigns could be most effective when offered during major social events, where public transport demand is high and the overall mood is positive, with people being open to changes. This could encourage acceptance and should be tested in different cities to alter public perception in different areas across Germany. Furthermore, car manufacturers could offer test rides in a similar manner to offer a low-threshold entry to the topic. Such strategies are crucial to make AVs more familiar to people. Moreover, to ultimately realise AD acceptance, effective communication about AD systems must prioritise transparency to build trust since AD systems are new and subject to intense scrutiny, where media coverage is more likely to focus on accidents and failures, which reinforces availability heuristics. This skewed portrayal may hinder public acceptance by amplifying fears and concerns, despite the fact that human error remains the leading cause of car crashes, making manual driving inherently riskier. Therefore, not even the most sophisticated AVs will be perfect for all users, addressing the different human-centered inter- and intra-individual physiological and psychological needs of all genders across their lifespans, with varying profiles of personality and user preferences. Hence, understanding the psychological phenomena that influence the anticipated acceptance of technology will remain essential in the coming years.

6 Highlights

- Convergent and discriminant validity confirmed for the QAAD, especially with the AS.
- Women reported more concerns and lower ratings on the anticipated acceptance of AVs than men.
- Men expressed a greater willingness to engage with and utilise AVs than women.
- People residing in big cities seem to be a bit more open to AVs than those living in smaller cities or rural areas.

- No impact of living environment (Big City, City, Rural) on general technology acceptance.

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