Modeling Other Road Users' Acceptance to an Automated Shuttle Service

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Abstract. To guarantee a smooth implementation of automated vehicles on the common road, it is essential to have the public acceptance of this technology. Looking to the literature, less is known about the acceptance of the other road users (i.e., conventional drivers, cyclists, or pedestrians). Based on social psychology models of acceptance, we study the determinants of the other road users' acceptance for the implementation of an automated shuttle between Nantes and Carquefou (France). With a sample of 229 participants and using Structural Equation Modeling, we identify the main determinants of the behavioral intention to interact with the automated vehicle. Relying on the findings of the tested model, we propose recommendations for industrials and policymakers to increase public acceptance.

Keywords: automated vehicle · acceptance · SEM · other road users · shuttle service

1 Introduction

With the numerous developments that the automotive industry is seeing, the emergence of semi-automated to fully automated vehicles pledge travelers a new safer, accessible, and more ecologically sustainable transportation alternative. Despite its attractiveness, the public still have concerns about this technology and its adoption is limited [1, 2]. This context justifies the increasing interest of industrials, policymakers, and researchers in better understanding the determinants of the individual acceptance of automated vehicles. Acceptance is defined as the "the attitude towards, or the willingness for use (or non-use), that an individual has of an advanced system" [3].

The growing literature focuses on evaluating the end-user acceptance expressed through their stated intentions to adopt an automated vehicle [4–7]. The recent meta-analyses presenting the defining factors of these intentions, either for using private or shared automated vehicles [3, 8, 9], recognize the significant effects of the socio-demographic characteristics of the respondent (e.g., income, age) or the vehicle attributes

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(e.g., trip duration, cost). Most importantly, these studies emphasize the significant effects of psychological factors (e.g., individual attitudes or perceptions). There is a consensus that these latter should be further considered in the study of automated vehicles' acceptance.

The study of these psychological factors is generally based on theoretical frameworks such as the Technology Acceptance Model (TAM2) [10], the Unified Theory of Acceptance and Use of Technology (UTAUT) [11] or the Theory of Planned Behavior (TPB) [12]. With the increasing interest in the study of automated vehicles we also find the Self-Driving Car Acceptance Scale (SCAS) [13] which is an extension of the factors included in the previously mentioned acceptance models but adapted to the case of studying the technology of automated vehicles (e.g., compatibility, reliability, trust). All these models agree on the idea that the potential user acceptance of the automated vehicle could be expressed in terms of his stated intentions to adopt this mode of transport. Thus, the stronger the stated intentions are, the more accepting the individual is.

We notice that the existing literature focuses mostly on modeling the acceptance of the end-users of automated vehicles giving less interest to studying the acceptance process of another category of individuals who may be impacted by the implementation of an automated vehicle. We refer to the other road users (e.g., conventional drivers, cyclists, or pedestrians) who are external to the automated vehicle but could interact with it. We believe in the importance of considering this category of road users before the introduction of the automated vehicle on the road since they need to accept to cohabitate with it and share a common space. Indeed, the acceptance of this interaction by other road users should facilitate the introduction of these increasingly automated vehicles and therefore reduce the risk of incivility against them [14].

To the best of our knowledge, there are only three previous studies that focus on the other road users sharing the road with an automated vehicle. First, Koustanaï and co-authors [15] studied the influence of perceived safety of conventional drivers on their acceptance of a Level 3 SAE automated vehicle on highways. Based on the SCAS, they showed that perceived safety predicted perceived reliability, which influenced trust, the direct determinant of intention to interact with the automated vehicle. Second, the work of Deb and co-authors [16] focuses on modeling the pedestrian acceptance to cross the road in the presence of an automated vehicle, a concept they call receptivity. Results showed that both safety and interaction scores were the main two determinants of pedestrian acceptance. Third, Pammer and co-authors [17] studied the motorcyclists and cyclists' perceptions of the automated vehicle. Using correlation and regression analyses on Australian data, they found that motorcyclists and cyclists have low trust in both human drivers and automated vehicles. However, the participants think that automated vehicles are safer than human drivers, especially in respecting a safe distance.

These papers offer interesting insights for industrials and policymakers but only consider the acceptance of a private (or individual) automated vehicle. We contribute to this literature by answering the question: *What are the psychological factors that define the acceptance of the other road users toward a shared automated vehicle?*

Answering this question, we identify two main originalities. First, we focus on a shared automated shuttle which presents different challenges and opportunities than a private automated vehicle. For instance, a shared automated vehicle is usually presented as a solution for congestion, a mode that reduces air pollution through the general use of electric energy, and offering new use cases (e.g., first and last kilometer). These elements could influence the perceptions and attitudes of the other road users which need to be investigated. Second, there is no previous psychological model that studies the acceptance of other road users including at the same time conventional drivers, cyclists, and pedestrians. Using original data, collected on the experimental automated shuttle service located between Nantes and Carquefou in France, we test a theoretical model including factors from the TPB and the SCAS. We also take into consideration technophilia and perceived safety as additional factors that were previously demonstrated to be important in the study of new technologies' acceptance [6, 18]. Using Structural Equation Modeling (SEM), we were able to identify the most influencing factors of the other road users' intentions to interact with the automated vehicle.

The remaining of this article is organized as follows: Sect. 2 presents the theoretical model and the tested hypotheses, Sect. 3 introduces the collected data and the used analysis method, Sect. 4 displays the results and their discussion, and Sect. 5 is the conclusion.

2 Theoretical Model and Hypotheses

Based on the literature review of automated driving and acceptance research, we contribute to the understanding of the determining factors of the acceptance of the other road users by testing the theoretical model illustrated in Fig. 1. The present model is an extended version of the TPB assuming that stated intentions are the direct precedent of the real behavior, expressed here as the acceptance of other users of the road to interact with an automated vehicle. We extend this model by introducing influential factors from the SCAS in addition to a couple of factors that have been demonstrated to be determining of the acceptance of new technology such as technophilia and perceived safety. The tested relations in this model are summarized in Table 4.

We suppose that the intentions (i.e., acceptance) are mainly predicted by the level of technophilia (H1d), the individual attitudes toward the automated vehicle (H7b) and the level of perceived behavioral control (H8). These factors are assumed to be positively related to the intentions and these assumptions are grounded in the existing literature. First, previous research has emphasized that a higher degree of technophilia (also called, personal innovativeness) influences positively the acceptance of end-users of the technology expressed as intentions of use, specifically automated vehicles [4, 5, 18]. In this respect, we expect a similar positive relation between technophilia and intentions to interact with the automated vehicle for other road users. Second, positive attitudes have been demonstrated to be a significant determinant of positive intentions of using automated vehicles [4, 5]. Thus, we expect other road users who have positive attitudes to be more willing to accept the circulation of automated vehicles. Third, perceived behavioral control, usually related to concept of self-efficacy [19], has been previously identified as an influential factor of the intentions to adopt new technologies [19–21]. Accordingly, we think that other road users who believe that they have the required resources and opportunities to manage an interaction with the automated vehicle would express higher acceptance of it circulating on the same road.

We also suppose that the intentions to interact with the automated vehicle are determined indirectly by the combination of a number of factors that interact within each other. We specifically test the relationship between subjective norms, reliability, compatibility, trust, and perceived safety assuming that all the factors are positively related between each other and in their prediction of intentions (see Table 4 for details). These assumptions join the results of previous studies on user or non-user of the acceptance of the automated vehicles [4–6, 15].

Lastly, we note that we control for the effects of age and gender[1]. We assume that all the psychological factors included in the model could be influenced by these individual characteristics [21].

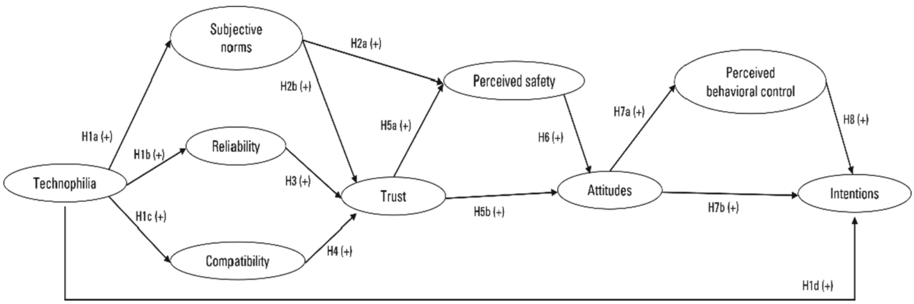

Fig. 1. Proposed research model for investigating the acceptance of automated vehicles by other road users.

3 Data and Methods

3.1 Participants and Procedure

We use original data collected through a twenty-minutes online survey conducted between May and June 2022 as part of the SAM project (Safety and Acceptability of Automated Driving and Mobility). The survey aimed to evaluate the acceptance of inhabitants and users of the Nantes-Carquefou area (France) regarding the introduction of automated vehicles (a shuttle service[2]) using part of the former Nantes-Carquefou railway line (see the red line in the map in Fig. 3). The presented automated vehicle would allow accommodating 6 to 50 people to make 20 min connecting ride from Carquefou to Nantes with an average speed of 20 km/h. The participants had no previous experience with the automated vehicle service deployed at the Nantes-Carquefou site. This allowed us to study their preconceived opinions, attitudes and perceptions influencing their acceptance of the automated shuttle.

[1] We consider the participants regardless of their specific usual mobility practices (being a driver, cyclist or pedestrian) since including this variable did not bring any improvement in the predictive power of intentions to interact with the vehicle. Thus, we opt for the most parsimonious model.

[2] Experimented by SNCF and the Stellantis Group (formerly PSA Peugeot-Citroën).

Each participant received by e-mail an individualized participation link to answer the questionnaire that is composed of three main parts: 1) a presentation of the automated vehicle, 2) the acceptance questionnaire and 3) the socio-demographic questionnaire. The final sample was composed of 445 participants divided into 216 potential users of the automated vehicle and 229 potential other road users who could interact with it. As previously mentioned, in the present paper, we only focus on studying the acceptance of the potential other road users. These participants are equally distributed between males and females. The whole sample's mean age is 51 years old with the majority (60.26%) stating being usual car users. Additionally, the sample is composed of a large share of individuals who declare frequently traveling in the tested area of circulation of the automated vehicle. Thus, these are individuals who are most likely going to be directly impacted by the actual implementation of the connecting shuttle of Nantes-Carquefou.

Table 1. Summary of the socio-demographic characteristics of the sample

Variable	Definition	Proportion (%)
Male	Gender	50.22
Female		49.78
Mode	Mode of transport that is usually used regardless of the trip purpose	
Car (as a driver)		60.26
Public transport		14.85
Bicycle		9.61
Walk (or wheelchair)		3.93
Train		1.31
Motorcycle (or scooter)		0.87
Other		9.17
Potential interaction	Travel frequency in the circulation area of the automated vehicle	
Every day or almost every day		40.17
3 or 4 times a week		16.59
1 or 2 times a week		16.16
2 or 3 times a month		9.61
About once a month		6.55
Less often		7.86
Never		3.06
		Mean (*SD*)
Age	In years	50.58 (0.99)

Notes: SD: Standard Deviation, Sample = 229 participants

3.2 Measures

The studied psychological factors are defined and measured using modified versions of existing instruments and items summarized in Table 2. The measuring items are affirmations that the participant is asked to evaluate and declare on a 6-points Likert scale whether they 1 "totally disagree" to 6 "totally agree".

Table 2. Measuring items of the psychological factors included in the model

Psychological factor	Theory	Definition	Measuring items	Mean (*SD*)
Intentions	TPB	The individual readiness to interact with the automated vehicle and accept its circulation in the same area	When I travel… Whenever possible, I intend to avoid running into automated vehicles I will not avoid places where automated vehicles circulate As far as possible, I will stay away from the automated vehicle	4.10 (1.48)
Attitudes	TPB	Personal favorable or unfavorable evaluation of the automated vehicle	Sharing public space with automated vehicles would be a good idea I think that integrating automated vehicles into public space will improve the quality of life for the residents I will not want to share the street with the automated vehicle I think that the presence of automated vehicles will improve traffic flow I support the presence of the automated vehicle in public space Sharing the public space with the automated vehicle will be pleasant	4.39 (1.24)

(*continued*)

Table 2. (*continued*)

Psychological factor	Theory	Definition	Measuring items	Mean (*SD*)
Perceived behavioral control	TPB	The individual's perception of his capacity (ease or difficulty) to manage the situation when interacting with the automated vehicle	I will travel with ease in places where the automated vehicle is present I will not be afraid to be around the automated vehicle I will not be sure what to do if I run into the automated vehicle	4.46 (1.26)
Subjective norms	TPB	The individual's beliefs about his entourage's attitudes about the automated vehicle	I don't think my relatives would mind being in the same area as the automated vehicle I think the people I care about would advise me to avoid automated vehicles My relatives would not hesitate to go to a place where the automated vehicle is present	4.38 (1.22)
Compatibility	SCAS	The individual's opinion about the readiness of the automated vehicle to circulate without supervision in public spaces	It is essential that a supervisor be on board to retake control of the automated vehicle I think that automated vehicles are not yet advanced enough to drive on public roads I don't think the automated vehicle will be able to handle all driving situations	3.70 (1.31)

(*continued*)

Table 2. (*continued*)

Psychological factor	Theory	Definition	Measuring items	Mean (*SD*)
Reliability	SCAS	The individual's opinion about the risks of failures of the automated vehicle	I don't think automated vehicles will have any failures I think automated vehicles will have failures I think the automated vehicle will be reliable	3.33 (1.16)
Trust	SCAS	The individual's confidence in the maturity of the technology to be able to function correctly	I will have confidence that the automated vehicle correctly detects people and objects around it I will have confidence in the automated vehicle to handle complex traffic situations I will trust the automated vehicle to look out for me	4.26 (1.38)
Perceived safety	Extension	The individual's opinion about the risk of having/not having an accident with the automated vehicle that could harm his personal safety	I think the automated vehicle will be able to avoid me in all circumstances I will not feel safe in a place with the automated vehicle I don't think I will have an accident with the automated vehicle	4.14 (1.26)
Technophilia	Extension	The individual's attraction to testing new technologies	If I hear about a new technology, I try to experiment with it quickly I like to discover new technologies	4.23 (1.34)

Notes: The measuring items are translated from French; The scales of the negatively formulated measuring items were reversed before calculating the means; *SD* = Standard Deviation

3.3 Data Analyses

Confirmatory Factor Analysis (CFA)
The proposed model is based on the previously mentioned literature including psychological factors previously included in the TPB or SCAS. However, we verify the structure of the questionnaire and the robustness of our model by running a CFA. It is a necessary step before running a structural model to assess the relevance of the factors in the tested model compared to the theory (known as the measurement model). This is done by conducting several statistical tests, namely computing the model fit indices, to determine the adequacy of model fit to the data such as the chi-square test, the Root Mean Square Error of Approximation (RMSEA), the Comparative Fit Index (CFI), the Tucke-Lewis index (TLI), the Standardized Root Mean Square Residual (SRMR), etc.

Structural Equation Modeling (SEM)
When studying relationships between psychological factors that are measured using several declarative questions, the most appropriate and widely used method is SEM. The objective of a SEM is to test hypotheses of relationships between several variables of a theoretical model. Actually, it is a combination of a measurement model and several regression models used to understand the paths between the psychological factors. In the present paper we test the way the previously mentioned psychological factors interact in predicting the individual intentions to interact with the automated vehicle as an expression of the acceptance of this mode by the other road users (see the tested model in Fig. 1).

All these analyses have been done on R-4.2.1 using the lavaan package [22].

4 Results and Discussions

4.1 Confirmatory Factor Analysis – Measurement Model

Carrying out the CFA to test the internal consistency of the theoretical model, we use the diagonally Weighted Least Squares method with a Mean and Variance correction (WLSMV) instead of the widely used Maximum Likelihood (ML) estimation method. Our scale is ordinal and our data does not follow a normal distribution based on the results of the Shapiro-Wilk test of normality of data [23]. Actually, WLSMV method has been demonstrated to perform better with ordinal data than the ML method [24] which justifies our choice of estimation method.

The results of the CFA suggest that the model has acceptable adjustment to the data since the model fit indices respect the required thresholds: RMSEA $= 0.070$ (between 0.05 and 0.08 [25, 26]); SRMR $= 0.048$ (< 0.08 [27]); CFI $= 0.970$ and TLI $= 0.964$ (both > 0.95). The factor loading results are all above 0.6 except for two items of the measure of reliability having factor loadings just above 0.5 (See Table 3). Based on the results of the factor analyses, the underlying psychological constructs demonstrate, both, satisfactory validity and reliability (Cronbach's Alpha (CA) coefficients above 0.7 threshold and calculated Average Variance Extracted (AVE) all very close or above the 0.5 threshold). Thus, these factors can be used to calculate a structural equation model.

Table 3. Evaluation of the psychological factors

Psychological factor	Number of used items	Factor loadings range	CA	AVE
Intentions	3	0.653–0.880	0.692	0.543
Attitudes	6	0.643–0.927	0.888	0.658
Perceived behavioral control	3	0.681–0.909	0.804	0.676
Subjective norms	3	0.749–0.840	0.771	0.637
Compatibility	3	0.613–0.769	0.710	0.476
Reliability	3	0.509–0.935	0.748	0.484
Trust	3	0.867–0.919	0.894	0.800
Perceived safety	3	0.688–0.888	0.740	0.593
Technophilia	2	0.861–0.899	0.829	0.774

Notes: CA = Cronbach's Alpha, AVE = Average Variance Extracted

4.2 Structural Equation Model

Figure 2 presents the results of the estimated structural model with solid lines representing the significant relationships and the dotted lines representing the non-significant ones. Table 4 summarizes the supported or rejected tested hypotheses. A total of 68.1% of the variance in the intentions of the other road users to interact with the automated vehicle was accounted for in the model. Besides, the model fit indices are acceptable: RMSEA = 0.065; CFI = 0.970; TLI = 0.969 and SRMR = 0.048.

With a standardized coefficient equal to 1.536 ($p < 0.001$), the perceived behavioral control seems to be the most important direct predictor of the intentions. The analyses reveal a significant positive relationship between attitudes and perceived behavioral control (0.949, $p < 0.001$), trust as a positive predictor of the individual perception of safety of the automated vehicle (0.947, $p < 0.001$) and, in turn, this trust is positively related to the reliability (0.519, $p < 0.01$) and compatibility (0.484, $p < 0.01$). Lastly, positive subjective norms and thinking the automated vehicle is reliable and compatible is more likely for a technophile participant (respectively, 0.932; 1.067; 1.074, $p < 0.001$).

The decomposition of the effects testing the significance of the indirect and total effects (see Table 5) of the psychological factors on intentions (and between each other) identifies the significant indirect effect of the attitudes on intentions which is mediated by the perceived behavioral control (1.458, $p < 0.001$). The results also show that trust (1.403, $p < 0.001$) and technophilia (2.426, $p < 0.001$) indirectly predict the intentions to interact with the automated vehicle.

Controlling for the effects of age and gender (see estimation results in Table 6), the intentions of the participants (i.e., their acceptance) did not significantly vary in function of these individual characteristics. However, we identify several significant effects on other psychological factors in relation to these intentions. Regarding the age factor, we find that younger participants are more likely to be technophile (−0.275, $p < 0.05$)

and to perceive that they have the necessary capacities to handle a situation where the automated vehicle is present (−0.088, $p < 0.05$). On the contrary, older participants are more likely to perceive the automated vehicle as reliable (0.427, $p < 0.001$) and compatible (0.293, $p < 0.05$) as well as being influenced by the attitudes of those around them (0.282, $p < 0.05$). Age did not have significiant effects on perceived safety, trust nor on attitudes. Concerning the gender effect, we find that men are more likely to be technophile (0.414, $p < 0.001$), to be more trusting of the automated vehicle (0.100, $p < 0.05$), and to perceive that they have the capabilities to handle a situation where the automated vehicle is present in their traveling area (0.124, $p < 0.01$). Parallely, women are more likely to perceive the automated vehicle as reliable (−0.516, $p < 0.001$) and compatible (-0.405, $p < 0.01$) as well as being influenced by the attitudes of those around them (−0.444, $p < 0.001$). We identifiy no significant gender effects on the perceived safety nor on the attitudes.

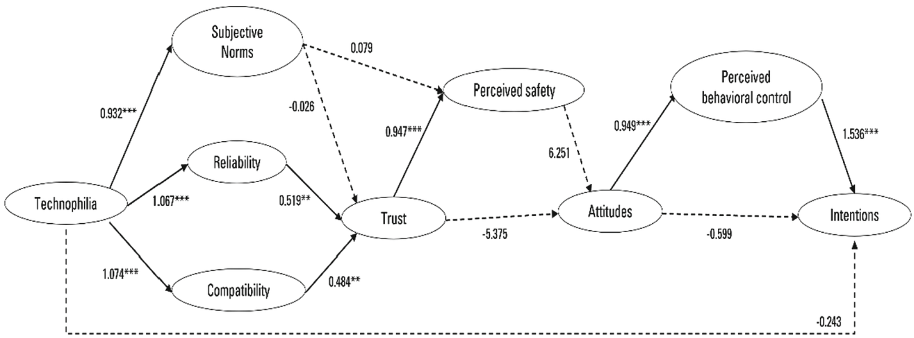

Fig. 2. Standardized regression weights of the model of acceptance of other road users

4.3 Discussion

We contribute to the understanding of the acceptance of automated vehicles by the other road users expressed as stated intentions to interact with it. Relying on the TPB and SCAS, we identify through a SEM that perceived behavioral control is the main predictor of these intentions. Meaning that an individual would be more accepting of the automated vehicle if they believe in their capacity (having the necessary personal or external factors) to handle a situation where they are confronted with this technology. This finding is in line with previous research where perceived behavioral control was found to be a significant predictor of intentions to adopt automated vehicles [7, 29].

The results of the model also showed that the attitudes were not a significant predictor of the intentions which goes against expectations and the previous findings of various acceptance studies of the automated vehicle [4, 5, 7]. This divergence could be explained by the lack of consideration of the role of perceived behavioral control in these previous studies. In our case, this factor has a strong relation with intentions, and it plays the role of a full mediator in the attitudes-intentions relationship.

Table 4. Results of the tested hypotheses

Tested hypothesis		Standardized Estimate	*p*-value	Conclusion
H1a	Technophilia → Subjective norms	0.932	0.000	Supported
H1b	Technophilia → Reliability	1.067	0.000	Supported
H1c	Technophilia → Compatibility	1.074	0.000	Supported
H1d	Technophilia → Intentions	−0.243	0.301	Rejected
H2a	Subjective norms → Perceived safety	0.079	0.179	Rejected
H2b	Subjective norms → Trust	−0.026	0.726	Rejected
H3	Reliability → Trust	0.519	0.004	Supported
H4	Compatibility → Trust	0.484	0.005	Supported
H5a	Trust → Perceived safety	0.947	0.000	Supported
H5b	Trust → Attitudes	−5.375	0.250	Rejected
H6	Perceived safety → Attitudes	6.251	0.177	Rejected
H7a	Attitudes → Perceived behavioral control	0.949	0.000	Supported
H7b	Attitudes → Intentions	−0.599	0.191	Rejected
H8	Perceived behavioral control → Intentions	1.536	0.000	Supported

We additionally found that trust indirectly predicted intentions. This relation is mainly mediated by perceived behavioral control. This means that the trust that an individual has in this technology is internalized in his stated perceived behavioral control which, then, would influence the individual acceptance. A number of previous studies [4–6, 15] confirm the importance of considering the trust-acceptance relationship in the context of the use of automated vehicle. Trust was found to be a direct positive predictor of the use intentions or having an indirect effect on intentions when considering the perceived safety as a mediator of this relation [30].

All these results raise for the industrials and the policymakers the importance of finding ways to reinforce the perceived behavioral control if they want to guarantee a better acceptance of other road users. Based on our model, this could be done either by acting directly on the concerned psychological factor or by programming measures on other influential factors (namely, trust and attitudes) related to the factor of interest.

In the present paper, we defined the perceived behavioral control as the perceived ease of interaction with the automated vehicle. But, since this technology is not available to the public yet, numerous question marks still surround it. To bring answers to the public, and based on the results of the model, industrials and policymakers could increase the individuals' knowledge about automated vehicles through advertising and media campaigns. This would establish a better awareness of the vehicle's features. In turn, it would improve the perceived ease of interaction with the vehicle on the road. Discovering

Table 5. Decomposition of the effects

Dependent variable	Explanatory variable	Direct effects	Indirect effects	Total effects
Subjective norms	Technophilia	0.932***	N/A	N/A
Reliability	Technophilia	1.067***	N/A	N/A
Compatibility	Technophilia	1.074***	N/A	N/A
Trust	Subjective norms	−0.026	N/A	N/A
	Reliability	0.519**	N/A	N/A
	Compatibility	0.484**	N/A	N/A
	Technophilia	N/A	1.048***	1.048***
Perceived safety	Subjective norms	0.079	-0.025	0.054
	Trust	0.947***	N/A	N/A
Attitudes	Trust	−5.375	5.918	0.543***
	Perceived safety	6.251	N/A	N/A
Perceived behavioral control	Attitudes	0.949***	N/A	N/A
	Perceived safety	N/A	5.935	5.935
Intentions	Attitudes	−0.599	1.458***	0.860***
	Perceived behavioral control	1.536***	N/A	N/A
	Trust	N/A	1.403***	1.403***
	Technophilia	−0.243	2.426***	2.504***

Notes: N/A = Not Applicable, * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$, Significance of the indirect and total effects tested using the Sobel test [28]

these facilitating features could also be done through controlled trials where the potential concerned individuals would be put in a realistic setting to interact with the vehicle before its actual introduction on the road and have a better sense of their capacities to manage a situation with its presence. Additionally, individuals need to be reassured about the existence of adequate infrastructures (e.g., a specific color of traffic light to signal the presence of the automated vehicle) to easily accommodate the circulation of the automated vehicle in the presence of the other modes of transport.

Concerning the possible measures to have positive individual attitudes, we recommend industrials and policymakers to emphasize the benefits of introducing an automated vehicle for other road users. This could take the form of communication campaigns highlighting the improved road safety, the better access to mobility (e.g., disabled individuals or elderlies), optimization of traffic flow (e.g., an automated shuttle would allow reaching the destination faster and opting less for the private vehicle) and reducing the greenhouse gas and other pollutant emissions thanks to reduced road traffic.

Lastly, policymakers and industrials should consider programming measures to gain the trust of the other road users by demonstrating the reliability and compatibility of the automated vehicle. The other road users need to be convinced by the maturity of the technology and its readiness to circulate safely in interaction with the random external factors. We advise manufacturers to be transparent about the capabilities of the vehicle, for example by communicating key statistics (e.g., impact of the introduction of the vehicle to accidentology) or the quality control process (e.g., number of vehicle overhauls for a defined period). Besides, policymakers should share the future improvement projects of the infrastructure which would allow to increase the compatibility of the automated vehicle with the existing traffic network.

It would therefore be relevant, for future work, to implement all or part of these proposals in order to confirm their impact on acceptance.

5 Conclusion

We proposed and empirically tested an automated vehicle acceptance model for other road users including psychological factors from the TPB, factors from the SCAS, perceived security and technophilia. Our findings confirmed the important relationship between the individual perceived behavioral control to easily handle a situation in the presence of the vehicle and the intentions to interact with it. Thus, the present paper contributed to clarifying the relationships between the determinants of acceptance and giving new levers that industrials and policymakers should consider before introducing automated vehicles on the common roads.

However, some limitations of this work should be mentioned. First, the used data lacks age representativity of the populations of Nantes and Carquefou[3]. We have a sample with a mean age of 51 years old. Still, most of the participants are directly concerned with the implementation of the automated vehicle since they are frequent users of the studied traffic area. About 57% of the sample declare going in this area at least three times a week. Thus, the sample gives a good representation of the future people that may interact with the automated vehicle.

Second, the proposed model highly depends on the way the psychological factors have been defined and measured. Even though we based our choice of measures on literature and tested their robustness, using other scales could give different results than the ones found here. For instance, when considering the perceived safety, we mainly relate the definition of this factor to the avoidance of collisions. But the safety related to an automated vehicle could also include, for example, aspects of cyber security [33] that were not defined here and should be considered in future studies.

[3] Compared to the age distribution of the population of Nantes and Carquefou in 2019 [31, 32].

Lastly, the proposed model is the first to consider the acceptance of other road users with different mobility practices. Nonetheless, comparative studies should be conducted using data from other experimental automated vehicles (private and shared) to further validate this model. We also believe that this model should be extended by including other potentially influential factors of acceptance. The automated vehicle is expected to have social, environmental and health benefits. Accordingly, factors as the individual environmental awareness [34], level of altruism [35] or health motivations [36] could be included in the acceptance models of other road users.

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Appendices

A. Map of the Nantes-Carquefou Automated Vehicle Implementation

Fig. 3. Map of the automated vehicle's circuit

B. Model Estimation Results

Table 6. Model estimation results

Dependent variable	Explanatory variable	Standardized Estimate	*p*-value
Technophilia	Male	0.414	0.000
	Age	−0.275	0.022
Subjective norms	Technophilia	0.932	0.000
	Male	−0.444	0.000
	Age	0.282	0.014
Reliability	Technophilia	1.067	0.000
	Male	−0.516	0.000
	Age	0.427	0.001
Compatibility	Technophilia	1.074	0.000
	Male	−0.405	0.003
	Age	0.293	0.024
Trust	Subjective norms	−0.026	0.726
	Reliability	0.519	0.004
	Compatibility	0.484	0.005
	Male	0.100	0.052
	Age	0.066	0.176
Perceived safety	Subjective norms	0.079	0.179
	Trust	0.947	0.000
	Male	0.019	0.689
	Age	−0.054	0.220
Attitudes	Perceived safety	6.251	0.177
	Trust	−5.375	0.250
	Male	−0.132	0.668
	Age	0.294	0.479
Perceived behavioral control	Attitudes	0.949	0.000
	Male	0.124	0.004
	Age	−0.088	0.014
Intentions	Technophilia	−0.243	0.301
	Perceived behavioral control	1.536	0.000
	Attitudes	−0.599	0.191
	Male	0.010	0.943
	Age	−0.133	0.295

Notes: The estimated covariances are not included in this table for reasons of parsimony

References

1. Lee, D., Hess, D.J.: Public concerns and connected and automated vehicles: safety, privacy, and data security. Hum. Soc. Sci. Commun. **9**(1), 1–13 (2022)
2. Kaur, K., Rampersad, G.: Trust in driverless cars: Investigating key factors influencing the adoption of driverless cars. J. Eng. Technol. Manage. **48**, 87–96 (2018)
3. Kaye, S.A., Somoray, K., Rodwell, D., Lewis, I.: Users' acceptance of private automated vehicles: a systematic review and meta-analysis. J. Saf. Res. **79**, 352–367 (2021)
4. Nastjuk, I., Herrenkind, B., Marrone, M., Brendel, A.B., Kolbe, L.M.: What drives the acceptance of autonomous driving? An investigation of acceptance factors from an end-user's perspective. Technol. Forecast. Soc. Change **161**, 120319 (2020)
5. Herrenkind, B., Brendel, A.B., Nastjuk, I., Greve, M., Kolbe, L.M.: Investigating end-user acceptance of autonomous electric buses to accelerate diffusion. Transp. Res. Part D: Transp. Environ. **74**, 255–276 (2019)
6. Zhang, T., et al.: Automated vehicle acceptance in China: social influence and initial trust are key determinants. Transp. Res. Part C: Emerg. Technol. **112**, 220–233 (2020)
7. Jing, P., Huang, H., Ran, B., Zhan, F., Shi, Y.: Exploring the factors affecting mode choice intention of autonomous vehicle based on an extended theory of planned behavior—A case study in China. Sustainability **11**(4), 1155 (2019)
8. Lécureux, B., Bonnet, A., Manout, O., Berrada, J., & Bouzouina, L.: Acceptance of shared autonomous vehicles: a literature review of stated choice experiments (2022)
9. Lemonnier, A., Adelé, S., Dionisio, C.: The determinants of acceptability and behavioural intention of automated vehicles–a review. Le travail humain **4**, 297–342 (2020)
10. Venkatesh, V., Davis, F.D.: A theoretical extension of the technology acceptance model: Four longitudinal field studies. Manage. Sci. **46**(2), 186–204 (2000)
11. Venkatesh, V., Morris, M.G., Davis, G.B., Davis, F.D.: User acceptance of information technology: Toward a unified view. MIS Q., 425-478 (2003)
12. Ajzen, I.: The theory of planned behavior. Organ. Behav. Hum. Decis. Process.Behav. Hum. Decis. Process. **50**(2), 179–211 (1991)
13. Nees, M.A.: Acceptance of self-driving cars: an examination of idealized versus realistic portrayals with a self-driving car acceptance scale. In: Proceedings of the Human Factors and Ergonomics Society Annual Meeting, pp. 1449–1453. SAGE Publications Sage CA, Los Angeles (2016)
14. Haué, J.-B., Merlhiot, G., Koustanaï, A., Barré, J., Moneger, F.: Hey Robot, let me the way Automated vehicle and incivility
15. Koustanaï, A., Bel, M., Bordel, S., Metayer, N., Massoulié, J.: Modeling perceived safety and acceptance of AV in traffic. In: ITS European Congress Toulouse, 2022 (2022)
16. Deb, S., Strawderman, L., Carruth, D.W., DuBien, J., Smith, B., Garrison, T.M.: Development and validation of a questionnaire to assess pedestrian receptivity toward fully autonomous vehicles. Transp. Res. Part C: Emerg. Technol. **84**, 178–195 (2017)
17. Pammer, K., Gauld, C., McKerral, A., Reeves, C.: "They have to be better than human drivers!" Motorcyclists' and cyclists' perceptions of autonomous vehicles. Transp. Res. Part F: Traffic Psychol. Behav. **78**, 246–258 (2021)
18. Dastjerdi, A.M., Kaplan, S., e Silva, J.D.A., Nielsen, O.A., Pereira, F.C.: Use intention of mobility-management travel apps: the role of users goals, technophile attitude and community trust. Transp. Res. Part A: Policy Pract. **126**, 114–135 (2019)
19. Luarn, P., Lin, H.H.: Toward an understanding of the behavioral intention to use mobile banking. Comput. Hum. Behav.. Hum. Behav. **21**(6), 873–891 (2005)
20. Ajjan, H., Hartshorne, R.: Investigating faculty decisions to adopt web 2.0 technologies: theory and empirical tests. Internet High. Educ. **11**(2), 71–80 (2008)

21. Venkatesh, V., Morris, M.G., Ackerman, P.L.: A longitudinal field investigation of gender differences in individual technology adoption decision-making processes. Organ. Behav. Hum. Decis. Process.Behav. Hum. Decis. Process. **83**(1), 33–60 (2000)
22. Rosseel, Y.: Lavaan: an R package for structural equation modeling. J. Stat. Softw.Softw. **48**, 1–36 (2012)
23. Shapiro, S.S., Wilk, M.B.: An analysis of variance test for normality (complete samples). Biometrika **52**(3/4), 591–611 (1965)
24. Li, C.-H.: The performance of MLR, USLMV, and WLSMV estimation in structural regression models with ordinal variables. Michigan State University (2014)
25. Kaplan, D.: Structural Equation Modeling: Foundations and Extensions, vol. 10. SAGE publications, New York (2008)
26. Hu, L.T., Bentler, P.M.: Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Struct. Equ. Model.: Multidisc. J. **6**(1), 1–55 (1999)
27. Schreiber, J.B., Nora, A., Stage, F.K., Barlow, E.A., King, J.: Reporting structural equation modeling and confirmatory factor analysis results: a review. J. Educ. Res. **99**(6), 323–338 (2006)
28. Sobel, M.E.: Asymptotic confidence intervals for indirect effects in structural equation models. Sociol. Methodol.. Methodol. **13**, 290–312 (1982)
29. Buckley, L., Kaye, S.A., Pradhan, A.K.: Psychosocial factors associated with intended use of automated vehicles: a simulated driving study. Acc. Anal. Prevent. **115**, 202–208 (2018)
30. Liu, P., Yang, R., Xu, Z.: Public acceptance of fully automated driving: effects of social trust and risk/benefit perceptions. Risk Anal. **39**(2), 326–341 (2019). https://doi.org/10.1111/risa.13143
31. Dossier complet − Commune de Nantes (44109) | Insee. https://www.insee.fr/fr/statistiques/2011101?geo=COM-44109. Consulté 30 Mars 2023
32. Dossier complet − Commune de Carquefou (44026) | Insee. https://www.insee.fr/fr/statistiques/2011101?geo=COM-44026. Consulté 21 Avril 2023
33. Garidis, K., Ulbricht, L., Rossmann, A., Schmäh, M.: Toward a user acceptance model of autonomous driving. In: Proceedings of the 53rd Hawaii International Conference on System Sciences, 7–10 January 2020, pp. 1381–1390. Wailea-Makena, Hawaii, University of Hawai'i at Manoa (2020)
34. Wu, J., Liao, H., Wang, J.W., Chen, T.: The role of environmental concern in the public acceptance of autonomous electric vehicles: a survey from China. Transp. Res. Part F: Traffic Psychol. Behav. **60**, 37–46 (2019)
35. Arısal, İ, Atalar, T.: The exploring relationships between environmental concern, collectivism and ecological purchase intention. Procedia-Soc. Behav. Sci. **235**, 514–521 (2016)
36. Rojas Rueda, D., Nieuwenhuijsen, M.J., Khreis, H., Frumkin, H.: Autonomous vehicles and public health. Ann. Rev. Publ. Health **41**(1), 329–345 (2020)