

The roles of perceived personal safety and perceived vehicle safety in the choice of fully automated taxis: trust as a mediator

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SHORT SUMMARY

In this paper we aim to investigate the role of perceived safety in the choice of automated taxis (AT) versus normal taxi (NT), focusing on both possible vehicle failures and harmful events, and investigating the causal relation between perceived safety and trust in their impact to the choice of ATs. For this purpose, using data collected in Newcastle and Toronto, hybrid choice models were estimated to capture effects of these three latent psychological factors in the choices of ATs. Results confirm that both Perceived Vehicle Safety (PVS) and Perceived Personal Safety (PPS) have significantly positive effects on trust, which in turn has a significant positive effect on the choice of ATs. This result confirmed the foundation role of perceived safety for building trust on ATs as expected, but PVS is a stronger antecedent of trust than PPS, and this effect is consistent in both datasets, Newcastle and Toronto.

Keywords: Perceived Vehicle Safety, Perceived Personal Safety, Trust, Fully Automated Taxis, Hybrid Choice Model

1. INTRODUCTION

Safety is considered one of the most important factors for autonomous vehicles (AVs). On one side, safety is what motivated the development of this technology, on the other side can potentially hamper its adoption if users do not perceive the current level of safety as sufficient to trust the system. Studies that have measured users' opinions about safety do not report consistent results. For example, Casley et al. (2013) report that 82% of their participants (university students) ranked safety as the most important concerns related to the emergence of AVs. Analogously Kyriakidis et al. (2015) found that around 64% of their respondents were concerned about AVs safety and Lang et al. (2016) that 50% of their participants did not feel safe in a driverless car. On the contrary, Howard and Dai (2014) found that 75% of their respondents regarded safety as the most attractive feature when using automated driving, Schoettle and Sivak (2014) that 84% of their respondents rated safety as the most important benefit, and Smith and Anderson (2017) that only 17% of adults in US rated safety as of primary interest for AVs. These studies refer to a general definition of safety but mostly related to the possibility of an accident with other cars or pedestrians. Studies based on online surveys for public perceptions or opinions have also found a high level of concern on personal safety mostly in the case of autonomous public transport (e.g. Roche-Cerasi, 2019; Salonen, 2018). Despite this, a recent review by Tamakloe and Park (2023) analysed the 20 salient research themes

hidden in the AV-research corpus and reported that safety issues concerning AVs were the least discussed.

The vast majority of the studies on safety focus on opinions or on the role of perceived safety in the intention to adopt (use or buy) an AV, following the Technology Acceptance Model (TAM) or its further developments. On the other hand, while an increasing number of papers are focusing on studying the role of psychological factors into the discrete choice of AVs in general (Haboucha et al., 2017; Kolarova and Cherchi, 2021; Yap et al., 2016) and ATs in particular (Yin and Cherchi, 2022; Yin et al., 2023) only few studies have considered the role of perceived safety in the choice of AVs. Bakioglu et al. (2022) examined how safety concerns influenced decision about owning AVs, where safety perception was indirectly measured by users' liability for road crashes (an attribute in SP experiment, not as a latent psychological variable). Nazari et al. (2018) examined the direct effect of safety concern referred to equipment or system safety and performance to the environment. Jabbari et al. (2022) quantified the direct impact of perceived safety, in terms of overall sense of safety and incidence of traffic accidents, in the context of privately owned cars and ride-hailing services. Finally, Xue et al. (2024) examined the direct effect of perceived safety, in terms of broad safety concern and incidence involving road accidents or vehicle malfunctions when parking, in the context of the joint choice of travel mode and parking for private autonomous vehicles.

Two aspects are worth noting. These studies on the impact of safety on AV choices, primarily focused on the effect of general perceived safety, and/or perceived vehicle or traffic safety (PVS or PTS) (i.e. concerning road accidents or vehicle malfunction that can cause accidents). Additionally, these studies investigated only the direct effect of perceived safety on AVs choice. Psychological literature shows that perceived safety might not affect AV adoption directly, but through the mediator trust, where perceived safety is an antecedent of trust (e.g. Benleulmi and Blecker, 2017; Kaur and Rampersad, 2018). Zhang et al. (2019) found that perceived safety risk and perceived privacy risk, both affect intention to accept AV through the mediating role of trust. A certain amount of perceived safety is probably a prerequisite for trust to be functional. However, other authors have found significant opposite directionality, i.e. that trust is an antecedent of risk in the intention to adopt AVs (e.g. Xu et al., 2018), given that "trusting parties must be vulnerable to some extent for trust to become operational" (Doney and Cannon, 1997) None of these studies deal with the impact of safety and trust on the choice of AVs. Finally, no taxi driver within fully ATs (i.e., lack of supervision) might arise another type of safety concern while traveling or waiting at taxi ranks, i.e., fear of crime, like robbery, violence, harassment, and so forth. No research studied the impact of personal safety (PPS) on AV choices.

Against this background, in this paper we investigate the role of perceived vehicle safety and perceived personal safety and their relationship with trust in the choice of ATs. For this purpose, a Stated Choice (SC) experiment including six attributes was built, along with a set of attitudinal questions for measuring the impact of these three constructs, as well as questions for collecting socioeconomic and travel information. Hybrid choice models were then employed to capture effects of these three latent psychological factors in the choices of ATs.

2. METHODOLOGY

The methodology set up consists of a SC experiment built to elicit preferences for automated taxi (AT) versus normal (i.e., with driver) taxi (NT) and a set of psychological statements identified to measure the impact of safety and trust in the preferences for AT.

The SC experiment built includes six attributes. Three level of service attributes (waiting time, travel time and fixed journey fare, with three levels each), one attribute (only for the alternative

AT) to measure the impact of fuel type (with 2 levels: electric or gasoline) and two attributes to measure the impact of social conformity (number of customers who have used AT or NT, with three levels and customer rating with two levels). A heterogeneous Bayesian D-efficient design was generated using Ngene (ChoiceMetrics, 2012). Three SC experiments were optimised based on travel distances of short trips medium trips and long trips. 16 choice scenarios were generated and randomly divided in 2 blocks. The same SC experiment was used to collect data both in Newcastle and Toronto, the only difference pertains to the values of the levels for the attributes of travel time, travel cost and number of today's customers, which are tailored to suit the respective contexts.

The psychological constructs of interest for this research include perceived vehicle safety (PVS), perceived personal safety (PPS) and trust (T). Statements were presented in random order and some in reversed scale (indicated below with (R)). A 5-point Likert scale was used ranging from 'strongly disagree' to 'strongly agree'.

Perceived Vehicle Safety (PVS):

PVS1(R): I am concerned that the failure or malfunctions of automated taxis may cause accidents (this statement was adapted from (Zhang et al., 2019)).

PVS2: I feel safe having automated taxis sharing the roads with conventional vehicles.

PVS3(R): I am concerned about automated taxis when pedestrians cross the roads.

Perceived Personal Safety (PPS):

PPS1: I believe that the implementation of safety equipment in automated taxis (e.g. surveillance camera and 'SOS' button, etc.) can guarantee my personal safety in case of personal crime (e.g. being physically assaulted/molested).

PPS2(R): I am concerned about my personal safety and personal property safety when using automated taxis since there are no taxi driver inside the taxi.

PPS3: I believe that the implementation of safety equipment in automated taxis (e.g. surveillance camera and 'SOS' button, etc.) can guarantee my personal property safety in case of property crime (e.g. suffering a robbery).

Trust (T) (adapted from Liu et al. (2019)):

T1: I trust the government authorities and the automated taxi company that regulate and supervise automated taxis.

T2: I trust the companies that produce automated taxis.

T3 (R): I do not trust automated taxis are reliable on populated streets.

The samples were collected using a panel provided by Surveyengine¹ and implemented in 2022 in Newcastle, UK, and in 2023 in Toronto (Canada). The final sample consists of 509 valid responses in UK and 544 in Canada. Table 1 reports the key characteristics of the samples. Our samples approximate the gender distribution of the population in Newcastle and Toronto but it underrepresents young people (13.6% against 35% in the Newcastle population in 2021 Census and 13.4% against 34% in the Toronto population, still according to the 2021 Census) and it underrepresents slightly males in Toronto (45% against 48.5% in the 2021 Census).

¹ A software platform designed for conducting stated preference surveys.
<https://surveyengine.com/>

Table 1: Sample Characteristics

		NCL N=509	TOR N=544
		%	%
Gender	Female	47.3	45.0
	Male	52.3	54.2
	Rather not to say	0.4	0.7
Age	<30 years old	13.6	13.4
	≥30 years old	86.4	86.5
Education level	Bachelor degree or below	80.5	72.1
	Master or doctorate degree	19.5	27.9
Current work status	Employed full-time	59.5	69.5
	Non employed full-time	40.5	30.5
Personal monthly disposable income	≤ GBP 1,500 (NCL)	46.0	47.4
	≤ CAD 4,200 (TOR)		
	≥ GBP 1,501 (NCL)	45.6	41.2
	≥ CAD 4,201 (TOR)		
Not reported	8.4	11.4	
Frequency of using taxis	< once a week	76.8	82.5
	≥ once a week	23.2	17.5

3. MODEL ESTIMATION RESULTS

Hybrid choice models (HCM) were employed to elicit preferences for ATs and the role of the latent constructs. The discrete choice component of the HCM is a mixed logit (ML) model to estimate the effect of attributes incorporated in SC experiment and control for intra-individual correlation. The conceptual framework is presented in Figure 1 and model results are reported in Table 2.

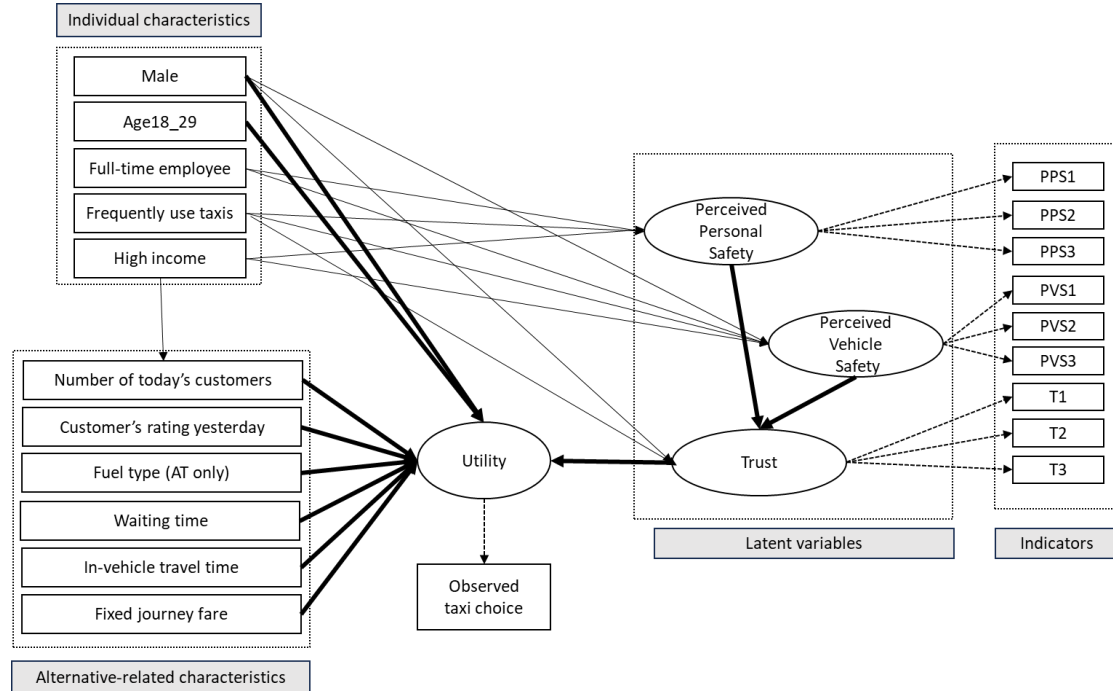


Figure 1 Conceptual framework of hybrid choice model

Regarding the results reported in Table 2, for reason of space we comment only the effect of the latent variables in Table 2 (b). Results confirm that both PVS and PPS have significantly positive effects on trust, which in turn has a significant positive effect on the choice of ATs. This result confirmed the foundation role of perceived safety (both vehicle and personal) for building trust on ATs as expected, but PVS is a stronger antecedent of trust than PPS, and this effect is consistent in both datasets, Newcastle and Toronto.

To identify the right pathway of perceived safety (both vehicle and personal) on the choices of ATs, we tested:

- 1) the direct effects of PVS, PPS and T on the choices of ATs. All three latent variables have significant direct effects on the choices of ATs, however the overall models (BIC and AIC) are inferior to the one showed in Table 2 for both Newcastle and Toronto.
- 2) the directionality between perceived safety and trust in the choice of AT. We tested also trust as antecedent of both PVS and PPS (e.g. Xu et al., 2018). We found that PPS became no longer significant when trust is an antecedent.
- 3) both the direct and indirect (via Trust) effects of PVS and PPS in the utility of AT. Interestingly the direct effects of PVS and PPS became not significant, supporting the hypothesis that the impacts of PVS and PPS on the choices of ATs is primarily channelled through trust, consistent with Kaur and Rampersad (2018); Zhang et al. (2019)

Table 2 (a) Models Estimation Results-Discrete Choice Part

	NCL_HCM		TOR_HCM	
	Estimated Value	Rob. t-test	Estimated Value	Rob. t-test
ASC(AT)	-7.970	-11.69	-7.180	-9.20
SIGMA (AT)	1.270	12.91	1.770	13.55
Level of Services				
Travel cost	-0.446	-11.90	-0.214	-9.97
Travel time	-0.087	-8.02	-0.093	-10.14
Waiting time	-0.108	-9.72	-0.087	-7.96
AT Vehicle Type				
EV (AT)	0.242	2.70	0.262	2.88
Social Conformity				
Number of today's customer/10	-0.300	-2.19	-0.071	-2.63
...*High income (\geq £1501 or \geq \$4201)	0.822	5.83	0.070	2.21
Good review	0.434	6.53	0.483	7.13
Socio-economic characteristics				
Male (AT)	0.292	1.73	0.048	0.21
Age18_29 (AT)	0.696	3.39	0.259	0.97
Latent variable				
Trust (AT)	2.190	10.93	2.120	8.20
Summary of Statistics				
Number of draws	500		500	
Maximum Log-likelihood	-8061.58		-8710.69	
Akaike Information Criterion	16223.16		17521.37	
Bayesian Information Criterion	16538.75		17840.29	
Number of individuals	509		544	
Number of observations	4072		4352	

Table 2 (b) Models estimation results-Latent variable part

		NCL_HCM						TOR_HCM						
		PVS		PPS		T		PVS		PPS		T		
		Value	Rob. t-test	Value	Rob. t-test	Value	Rob. t-test	Value	Rob. t-test	Value	Rob. t-test	Value	Rob. t-test	
Structural model														
Constant		2.070	26.79	2.890	35.45	0.387	1.53	2.220	26.22	2.900	35.28	-0.267	-0.76	
Standard deviation of error term		-0.344	-3.22	-0.160	-2.91	-2.170	-4.29	-0.436	-3.98	-0.086	-1.91	-8.290	-3.33	
Socio-economic characteristics														
Male		0.237	2.73			-0.114	-2.13	0.126	1.71			-0.041	-0.67	
18 years ≤ age ≤ 29 years														
Master or PhD degree														
Full-time employee		0.157	1.86	0.265	2.42			0.016	0.20	0.260	2.64			
High-income (≥ £1501 or \$ ≥4201)		0.232	2.96	0.368	3.50			0.107	1.42	0.089	0.96			
Use taxis at least once a week		0.212	2.10	0.405	3.46	0.128	2.11	0.080	0.86	0.218	1.85	0.024	0.29	
Latent variables														
Perceived Vehicle Safety						0.783	7.65					0.889	5.76	
Perceived Personal Safety						0.296	6.90					0.401	6.56	
Measurement model														
Constant in indicator		N1	0	Fixed	0	Fixed	0	Fixed	0	Fixed	0	Fixed	0	Fixed
		N2	-0.107	-0.32	0.187	0.94	0.187	0.94	0.107	0.25	1.690	8.41	0.056	0.31
		N3	0.347	3.17	-0.880	-2.56	-0.880	-2.56	0.085	0.54	0.380	1.99	0.072	0.23
LV Coefficient in indicator		N1	1	Fixed	1	Fixed	1	Fixed	1	Fixed	1	Fixed	1	Fixed
		N2	1.280	8.70	0.313	4.50	0.935	15.52	1.240	6.60	0.305	4.74	0.965	17.56
		N3	0.856	17.82	0.924	12.39	1.150	10.73	1.010	15.39	0.904	15.64	0.858	8.42
Standard deviation in indicator		N1	-0.143	-2.51	-0.641	-5.50	-0.242	-4.84	-0.173	-2.72	-0.494	-6.52	-0.199	-3.71
		N2	-0.315	-4.35	0.065	2.29	-0.351	-6.30	-0.296	-3.99	0.000	-0.01	-0.329	-6.11
		N3	-0.118	-2.37	-0.531	-6.67	-0.238	-3.68	-0.140	-2.38	-0.414	-5.94	-0.158	-3.14

4. CONCLUSIONS

The paper discussed the impacts from both perceived traffic safety and perceived personal safety on choices of ATs, where trust played a role as mediator. SC experiments, along with a set of statements identified for these three latent psychological factors, were built and implemented in both Newcastle, UK and Toronto, Canada. Hybrid choice models were then estimated to measure the roles of three latent psychological roles and to examine possible pathways in the AT choice process. Results confirmed the significant role of trust as mediator in the impact of both PVS and PPS in the choices of ATs. Interestingly, these effects are significant in both contexts, in Newcastle and in Toronto, and have also similar values, with the exception of PVS, whose impact in the trust in Toronto seems to be larger compared to its impact in Newcastle. Additionally, examining the indirect pathways of perceive safety through trust on choices of ATs was also beneficial for understanding the proper roles of individual characteristics on trust. Their effects on choices of ATs through trust might be partially (e.g., frequent taxi user in Newcastle) or fully (full-time employee and individual with high income in Newcastle) explained by both PVS and PPS.

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