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Attitudes towards privately-owned and shared autonomous vehicles

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ABSTRACT

Research on attitudes towards autonomous vehicles (AVs) shows variation across gender, age, and socio-economic factors. While previous research has emphasized specific features and qualities of AVs, little is known about how attitudinal factors shape AV acceptance across a range of AV "modes" from privately-owned AVs to AV taxis shared with strangers. With an online panel of 834 US-based participants, we examine attitudes towards AVs and sharing. An exploratory factor analysis establishes four attitudinal dimensions: technology acceptance, risk-taking, traffic regulation, and driving enjoyment. We estimate multinomial logistic regression models to examine the impact of these four factors on attitudes toward AVs, willingness to purchase AVs, willingness to use AVs as a taxi service, and willingness to share AV taxis with strangers. We find a complex relationship between psychological factors and AV attitudes. "Early adopters" of technology and those who support stricter traffic regulations are more likely to have a positive attitude about AVs, whereas those who avoid risky behavior were more likely to have a negative attitude instead of a neutral attitude. Similar patterns were found across models of purchasing, using, and sharing AVs. The results imply that people who support traffic regulations may perceive AVs as a safer transport mode than human-driven cars, while those who avoid risk-taking behavior may perceive AVs to be more dangerous. However, we find that a large fraction of the population is not yet ready to use an AV with no driver, and overall reluctance to share a ride in an AV taxi.

1. Introduction

Autonomous vehicles (AVs) hold the promise of transforming how people travel. Large companies, such as Google, Ford, and Baidu, claim that their AVs will be mass produced and commercialized in a few years (Etherington, 2017; Holland, 2018; Muoio, 2016). A range of options for deploying AVs is possible, from privately-owned AVs to AV taxis that pick up multiple customers who share rides. The latter option is seen as a solution to reducing congestion and the environmental impacts associated with motorized vehicles (Sperling, 2018), while privately-owned AVs could lead to empty vehicles traveling city streets after dropping off their owners, exacerbating the many problems associated with motorized vehicles.

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In this research we seek to understand public attitudes towards and perceptions of AVs and in particular shared AVs. Prior research on perceptions and attitudes suggests that views of AVs vary with gender, age, and socio-economic factors (Bansal & Kockelman, 2018; Menon, Barbour, Zhang, Pinjari, & Mannering, 2019). While previous research has examined potential interest in the features of AVs (e.g., design features such as self-driving, auto parking, side collision warning, etc.), little is known about differences between how privately-owned and shared autonomous vehicles will be viewed and accepted by the public, and we examine these questions using data collected in the US via a nationally representative on-line panel.

Evidence indicates that the public is concerned about the operational safety and lack of control of AVs, despite expert claims that they will lead to a dramatic reduction in crashes (American Automobile Association, 2019; Fagnant & Kockelman, 2015). Why do public perceptions about the safety risk of AV technologies differ from those of experts? Laypeople evaluate an emerging technology's benefits and risks based on their knowledge, experience, networks, and the information they can access, which often diverge from expert views (Slovic, 1987). Across a range of attitudinal factors, including risk perception, technology acceptance, and love of driving, we examine attitudes towards AVs, likelihood of purchasing an AV, and attitudes towards shared models of AV deployment. We investigate and disentangle these questions, controlling for our respondents' demographic characteristics. We examine how attitudinal factors shape AV acceptance across various AV "modes" ranging from privately-owned AVs to AV taxis shared with strangers. Our findings provide information to better understand the public's concerns and expectations about autonomous vehicles and how this may affect adoption rates.

2. Literature review

2.1. Attitudes and preferences for AVs

Scholars have begun to explore autonomous vehicles' potential effects on traveler behavior and thereby cities, society, and the environment (Sperling, 2018). Broadly, the literature expects that AVs will have a significant effect on travel behavior, increasing vehicle miles travelled and reducing public transit use and leading to new patterns of urban and exurban lifestyles, and a transformation of urban form (Brown et al., 2014; Martin & Shaheen, 2011; Silberg, Wallace, Matuszak, Plessers, Brower, & Subramanian, 2012; Spieser et al., 2014; Zhang, Guhathakurta, Fang, & Zhang, 2015). Private AVs may lead to a more dispersed urban growth pattern, while shared automated vehicle fleets, conversely, could have positive impacts, including reducing the overall number of vehicles and parking spaces (Soteropoulos, Berger, & Ciari, 2019). Many experts envision adoption of a new passenger transport mode: Shared Autonomous Vehicles (SAVs) (Chen, Kockelman, & Hanna, 2016; Fagnant & Kockelman, 2014; Fagnant, Kockelman, & Bansal, 2015; Loeb, 2016; Shen & Lopes, 2015). Because of automation and enhanced routing capabilities, experts assert that self-driving cars can provide affordable and efficient door-to-door car-sharing services to most people. This includes those who are unable to drive themselves (e.g., elderly, disabled, and those without a license) (Anderson, Kalra, Sorensen, Samaras, & Oluwatola, 2016; Krueger, Rashidi, & Rose, 2016). From this point-of-view, shared self-driving cars may reduce car ownership, encourage the implementation of Dynamic Ride-Sharing (DRS), and replace traditional taxi services, car-sharing services, and even public transit services (Anderson et al., 2016). However, travelers may also retain preferences for private mobility even with AVs, resulting in mobility patterns that may be similar to today's or with increased vehicle activity.

Two recent reviews have sought to summarize the extant literature on attitudes and preferences for autonomous vehicles (Bösch, Becker, Becker, & Axhausen, 2018; Gkartzonikas & Gkritza, 2019). There is a large diversity of studies published, ranging from those focusing on one country to multi-country studies. One study in Finland used a representative mail push-to-web protocol, achieving a 20% response rate (Liljamo, Liimatainen, & Pöllänen, 2018). Many do not use representative data, obtaining data from open on-line surveys (e.g., Krueger et al. (2016), Hulse, Xie, and Galea (2018), Haboucha, Ishaq, and Shiftan (2017), Payre, Cestac, and Delhomme (2014), and Kyriakidis, Happee, and Winter (2015)). Other studies have used on-line panels (e.g. Daziano, Sarrias, and Leard (2017), Hohenberger, Spörrle, and Welpe (2016), Asgari and Jin (2018), Bansal, Kockelman, and Singh (2016), and Bansal and Kockelman (2017)). While on-line panels are paid and can have hidden biases such as a more tech-savvy population that uses the internet, they are structured to obtain a representative demographic sample. We follow a similar approach for our data collection.

Despite the wide variation in survey protocols and locations, there is some consensus in the results on various attitudes and demographic associations with AV perceptions. In general, men, younger people, those who are more tech-savvy, those more aware of AVs, and those living in urban areas are more willing to use and/or purchase AVs. Liljamo et al. (2018) confirmed these demographic associations, but did not base this on a multivariate analysis. They also found a large fraction of their respondents (90%) were not comfortable with full automation with no manual control option. Schoettle and Sivak (2014) had a similar result in a multi-country study.

2.2. Factors in AV acceptance and attitudes

The Technology Acceptance Model (TAM) proposes that users will accept new technologies based on perceived usefulness and ease-of-use, including for AVs (Choi & Ji, 2015; Madigan et al., 2016). However, application to AVs may require additional extensions to the TAM, including trust (Choi & Ji, 2015) and pleasure (Madigan et al., 2016). One of the paradoxes of new technology is that people may not believe the views of experts that it is safe (Slovic, 1987). Many studies report that people have a bifurcated perception of AVs, with some considering them safer than current vehicles and others considering them unsafe. As Slovic (1987) demonstrated, perceptions of risk are associated with new and unknown technologies, and may be based on uncertainty or potentially large consequences of technology failure, regardless of objective levels of risk. Liljamo et al. (2018) suggest that adoption is partly related to concerns over how reliable AVs will be in addition to uncertainty about how AVs will react in dangerous situations. Most respondents expressing these concerns had negative attitudes about AVs.

Many drivers seem unwilling to give up control, and studies have shown that a large fraction report that they enjoy driving. For example, Asgari and Jin (2018) report about 60% of their sample enjoy driving. Using this variable in a multivariate model, they find that those who enjoy driving are less likely to adopt an AV.

Some studies examine the willingness to pay for AVs, using a stated-preference survey. Daziano et al. (2017) found that some consumers were willing to pay up to $10,000 more for an AV. Bansal et al. (2016) and Bansal and Kockelman (2017) found a lower value of about $7000- $7500 based on a survey in Austin, TX, though this was for level 4 automation as opposed to level 5 (the latter is full autonomy (National Highway Traffic Safety Administration)). They also found that over 80% of their respondents did not want to use shared AVs if the costs were higher than using current car-sharing services. About 41% were not interested in shared AVs.

In many studies, a reasonable waiting time has been regarded as critical for the acceptance and use of SAVs (Fagnant et al., 2015; Krueger et al., 2016; Llorca, Moreno, & Moeckel, 2017). In Llorca, Moreno, & Moeckel's simulation, waiting times for SAVs would be reasonable and stable within a dense city center but could be very long in suburban areas, likely reducing the efficiency and popularity of SAVs in low-density areas. This would likely lead to most suburban residents continuing to own their own vehicle.

We are only aware of one study that investigated (via focus groups) the propensity to use a shared AV (Zmud, Sener, & Wagner, 2016). Most of the focus group participants expressed a willingness to try a shared AV, but there was little willingness to make this the sole vehicle that would be used. The study did not investigate attitudes towards shared AV taxis, which is one of our main contributions. Asgari and Jin (2018) report that over 50% of their sample would not trust traveling with strangers.

In Table 1 we list all the factors found in prior studies of AV acceptance. While prior research has shown that attitudes towards AVs and their features vary across demographic groups, scarce research applies a behavioral framework to different AV deployment strategies, such as private AVs and shared AVs. In this analysis, we address this gap in the literature by surveying a representative group of US adults about their attitudes towards AVs and SAVs.

3. Data

Our survey obtained 834 responses via an on-line panel supplied by Qualtrics. The survey was conducted in September 2018 and was balanced to be representative of the US population. After cleaning invalid and incomplete responses, our dataset includes 721 participants. The survey instrument contained 42 questions and took, on average, 8 min to complete. The key dependent variables are attitudes towards AVs, the willingness to purchase an AV, the willingness to use an AV as a taxicab service, and the willingness to share a ride in an AV taxi with strangers. The wording of these questions with the menu of responses is shown in Table 2. Most laypersons may not be familiar with the term "autonomous vehicle" or "automated vehicle." Therefore, we used "self-driving car," which is more widely understood. Respondents that were not familiar with self-driving cars were given a short explanation prior to being presented with the questions in Table 2.

Table 1
Factors found in prior studies of AV acceptance.

	Theoretical Framework	Factor
Autonomous vehicle technologies	Demographic association	Age
		Gender
		Education
		Residential location
	Technology Acceptance Model (TAM)	Perceived usefulness
		Ease-of-use
		Trust
		Pleasure
	Perception of risks	Uncertainty
		Familiarity
		Controllability
	–	Driving enjoyment
	–	Willingness to pay
Shared autonomous vehicles	–	Density
	–	Waiting times
	–	Willingness to pay

Table 2
Questions on views of autonomous vehicles in survey.

Do you have a positive or negative view of self-driving cars?	Positive	Neutral	Negative	N
	304 (36.7%)	343 (41.5%)	180 (21.8%)	827
Would you be likely to purchase a fully self-driving car when these are available?	Yes	Uncertain	No	N
	277 (33.4%)	243 (39.4%)	308 (37.2%)	828
Would you use a taxi service that was self-driving?	Yes	Maybe	No	N
	189 (24.2%)	289 (37.1%)	302 (38.7%)	780
Would you use a self-driving taxi that is shared with someone you do not know?	Yes	Maybe	No	N
	163 (21.1%)	217 (28.1%)	392 (50.8%)	772

The summary statistics in Table 2 show that only about 20% of our sample has a negative view of AVs, with over one-third unlikely to purchase one (the survey does not specify whether AVs would be more costly than conventional vehicles). Only 24% of our sample would use a self-driving taxi and only 21% would share a self-driving taxi with a stranger. In all cases, there are large fractions that provided an uncertain response (neutral, uncertain, and maybe, as shown for the respective questions). Further discussion of our summary results are discussed in the results section. We also collected standard information on demographics (age, race and ethnicity, gender, educational attainment, household income, and household size), geographic location (ZIP code), and current travel behavior (commute mode, commute duration, and car ownership). Our sample has an average age of 45.9 years (Std. Dev. = 16.9), with an average household size of 2.8 people (Std. Dev. = 1.4) and an average commute duration of 18.8 min (Std. Dev. = 17.9).

Our questionnaire queried respondents for their home Zip code. Using this information we classified respondents living in urban areas using the National Center for Education Statistics (NCES) location code (National Center for Education Statistics, 2017). The code has four basic types: city, suburban, town, and rural. We defined ZIP codes in "city," "suburban," "town," and "rural fringe" as urban areas, and those "distant rural" and "remote rural" ZIP codes as rural areas. Our data was not collected to be representative of urban and rural splits, but using the NCES definition, the split between urban and rural respondents in the survey was 80.8/19.2, which was close to the US urbanization rate of 80.7% (US Census Bureau, 2012).

We included a set of questions to assess attitudes towards new technologies (smartphone, wearable devices, and smart home devices), traffic regulations, risky behavior, and driving. These were measured using a 5-level Likert scale from "strongly disagree" to "strongly agree". These questions are shown in Table 3. Our questions on attitudes to regulation and freedom to test AVs on city streets are modeled on the work of Kahan, Braman, Gastil, Slovic, and Mertz (2007). Iversen (2004) analyzed risk-taking and driver behavior, and we base our questions on speed limits, fines for speeding and safety concerns when driven by others on variants of questions in Iversen's survey. Questions on risk-taking and not knowing what will happen were derived from Meertens and Lion (2008). Our question on vehicle choice fitting the consumer's personality is from Moon (2002). Finally, Handy, Weston, and Mokhtarian (2005) provide questions on preferring to drive and loving to drive. The questions on frequency of using ridesharing and new technologies are our own. The full survey is available at: https://doi.org/doi:10.7282/t3-9d68-0k53.

4. Methods

4.1. Exploratory factor analysis

We performed an exploratory factor analysis on 12 attitudinal and behavioral questions. Results from a varimax rotation are shown in Table 3. The scree plot of eigenvalues suggested either three or four factors were appropriate. Our subjective interpretation of the factor loadings suggested that four factors better captured the underlying latent constructs. We defined these as "pro-technology", "driving enjoyment", "regulating traffic", and "risk avoidance". The loadings for each are shown in Table 3, with shaded areas identifying the largest loadings for each variable. In general, the loadings are as we might expect, with related attitudinal measures contributing to each of our four factors. However, the measure "I believe that the government should develop regulations for self-driving cars," falls into Factor 4-Risk Avoidance rather than in Factor 3-Traffic Regulation. Put another way, support for regulation of self-driving cars is more associated with a personal sense of risk than generalized support for better traffic regulation.

4.2. Multinomial logit models

We estimated multinomial logit models to examine the impact of these four factors on (a) attitudes toward AVs, (b) willingness to purchase AVs, (c) willingness to use AVs as a taxi service, and (d) willingness to share a ride in an AV taxi with strangers. Our reference variable in each case was the negative (or "no") response (see Table 2). Control variables include demographic, socioeconomic, and travel characteristics. In addition to our latent variables, we included other independent variables in our models. These included a dummy variable for interest in or owning a smart device (e.g. an Apple iWatch) and level of familiarity with AVs, coded as a dummy variable (very or somewhat familiar vs. less familiarity). Demographic

Table 3
Factor loadings for attitudinal variables.

	Factor 1 Pro-technology	Factor 2 Driving enjoyment	Factor 3 Regulating traffic	Factor 4 Risk avoidance
How often do you use Uber, Lyft, or another ridesharing service?	0.8920	0.1505	0.1158	0.1355
When did you first use a smartphone app-based ridesharing service?	0.8869	0.1505	0.0795	0.1020
I believe that the government should develop regulations for self-driving cars.	0.1060	0.1515	0.0779	0.4068
I believe that the technology companies developing self-driving cars should have the freedom to test their vehicles on city streets.	0.4534	0.1399	0.2171	0.0631
When I am driven by someone I do not know (such as a cab driver, limo driver, or Uber or Lyft driver) I am not concerned about my safety.	0.4481	0.1045	0.2609	0.0803
I think speed limits are too high	0.2658	0.0846	0.8051	0.1579
Fines for speeding should be higher.	0.2065	0.1129	0.5104	0.3288
I prefer to avoid risky activities.	-0.0105	-0.0057	0.1774	0.7167
I really dislike not knowing what is going to happen.	0.1109	0.1506	0.0590	0.4477
I chose my vehicle because it fits my personality and represents who I am as a person.	0.2882	0.3719	0.1667	0.1830
I prefer to drive when I am in a motor vehicle.	0.1231	0.6786	0.0740	0.1763
I love to drive and driving seems fun.	0.1525	0.7997	0.0482	0.0885
Note: N=721				

control variables included: age, sex, Hispanic, non-Hispanic black, children in the household, and household income (coded as three categories: "under $50 k," "$50 k to under $150 k," and "greater than $150 k").

5. Results

In Table 4 summary statistics for demographic variables are shown, showing the number of observations in each category and each groups perception of AVs. In general, younger, male, and wealthier respondents are more likely to have positive perceptions of AVs, relative to older, female, and poorer respondents. Urban and rural respondents do not have much difference in their perceptions with this summary data showing that rural residents have a slightly higher likelihood of positive perceptions than urban residents; this conflicts with the results of most studies that concluded urban residents have more positive perceptions (e.g. Liljamo et al. (2018), Schoettle and Sivak (2014)).

We further examine the general attitude towards AVs shown in Table 2 by examining whether those reporting a positive view of AVs also have positive views about purchasing AVs, using an AV taxi, and sharing with a stranger. Some 74.2% of

Table 4
Summary statistics for demographic variables versus positive and negative perceptions of AVs (omitting neutral perceptions).

	N	Positive perceptions of AVs	Negative perceptions of AVs
Year born			
Born 1925 – 1945	45	20.0%	32.5%
Born 1946 – 1964	257	25.3%	32.7%
Born 1965 – 1979	217	44.2%	19.8%
Born 1980 – 2000	313	43.1%	12.8%
Sex			
Female	423	24.6%	25.3%
Male	397	49.9%	17.4%
Household Income			
Under $25,000	146	26.0%	24.0%
$25,000 – under $50,000	188	29.8%	21.8%
$50,000 – under $100,000	257	33.5%	23.3%
$100,000 – under $150,000	106	50.9%	17.9%
$150,000 – under $200,000	50	60.0%	20.0%
$200,000 or greater	43	76.7%	7.0%
Respondent residence location			
Urban	660	35.6%	22.6%
Rural	155	39.4%	19.4%

Note: The sum of observations for each variable is based on respondent totals for that variable which may exceed 721, the response total for fully completed surveys.

Table 5
Multinomial logit model of positive and neutral attitudes towards AVs versus negative attitudes.

Variable	Positive Attitude (vs. Negative Attitude)				Neutral Attitude (vs. Negative Attitude)			
	Model 1 Coef.	Model 2 Coef.	Model 3 Coef.	Model 4 Coef.	Model 1 Coef.	Model 2 Coef.	Model 3 Coef.	Model 4 Coef.
F1: Pro-technology	1.54***	1.06***	1.01***	1.03***	0.63***	0.45**	0.49**	0.55***
F2: Driving enjoyment	0.28**	0.13	0.01	−0.01	−0.03	−0.08	−0.24	−0.22
F3: Regulating traffic	0.36***	0.30**	0.46***	0.46***	0.20	0.23*	0.22	0.24
F4: Risk avoidance		−0.14	−0.11	−0.24	−0.67***	−0.68***	−0.68***	−0.68***
Own/be interested in smart devices		0.88***	−0.23	1.10***	1.10***	0.05	−0.03	−0.02
Be familiar with AVs		0.79***	0.89***	0.88***		−0.07	−0.19	−0.20
Live in an urban area		−0.34	−0.32	−0.31		−0.15	−0.22	−0.17
Age		−0.03***	−0.02*	−0.02*		−0.01	−0.003	−0.002
Female		−0.96***	−1.06***	−1.03***		0.05	−0.14	−0.20
Hispanic		0.17	0.09	0.08		0.66*	0.66*	0.63*
Non-Hispanic Black		−0.56	−0.56	−0.57		−0.30	−0.14	−0.19
Have a child		0.22	0.35	0.36		0.44*	0.39	0.45
Income (*ref: <50 k*)								
50 k-150 k (median)				0.11				−0.17
>150 k (high)				−0.13				−1.04**
Constant	0.75***	1.46**	0.65	0.61	0.86***	1.30**	1.06*	1.20*
N	*721*	*701*	*516*	*516*	*721*	*701*	*516*	*516*
Pseudo R2	*0.15*	*0.21*	*0.22*	*0.23*	*0.15*	*0.21*	*0.22*	*0.23*

Note: Model 3 has the same variables as Model 2 but with the same number of observations as Model 4; Significance level: * p < .10, **p < .05, ***p < .01.

Table 6
Multinomial logit model of willingness to purchase an AV versus not purchasing.

Variable	Will purchase (vs. Will not purchase)				Uncertain (vs. Will not purchase)			
	Model 1 Coef.	Model 2 Coef.	Model 3 Coef.	Model 4 Coef.	Model 1 Coef.	Model 2 Coef.	Model 3 Coef.	Model 4 Coef.
F1: Pro-technology	1.67***	1.06***	1.11***	1.10***	0.46***	0.21	0.32*	0.33*
F2: Driving enjoyment	0.37***	0.18	0.03	0.004	0.17	0.12	0.13	0.14
F3: Regulating traffic	0.37***	0.28*	0.49***	0.49***	−0.09	−0.09	0.07	0.09
F4: Risk avoidance	0.17	0.17	0.22	0.20	−0.19	−0.22*	−0.22	−0.21
Own/be interested in smart devices		1.29***	1.23***	1.18***	0.54**	0.60**	0.60**	
Be familiar with AVs		1.25***	1.00***	0.96***	0.14	−0.07	−0.08	
Live in an urban area		−0.22		−0.41	−0.49	0.09	0.15	0.16
Age		−0.03***	−0.02**	−0.03***	−0.01*	−0.01	−0.01	
Female		−0.80***	−0.97***	−0.81**	−0.21	−0.16	−0.16	
Hispanic		−0.02	−0.49	−0.46	0.22	0.10	0.09	
Non-Hispanic Black		0.48	0.35	0.39	−0.24	−0.36	−0.37	
Have a child		0.68**	0.83***	0.78**	0.31	0.23	0.23	
Income (*ref: <50 k*)								
50 k-150 k (median)			0.71*				0.04	
>150 k (high)		1.00*					−0.18	
Constant	−0.08	−0.47	−0.08	−0.49	−0.03	0.004	−0.05	−0.06
N	*720*	*700*	*516*	*516*	*720*	*700*	*516*	*516*
Pseudo R2	*0.18*	*0.25*	*0.26*	*0.26*	*0.18*	*0.25*	*0.26*	*0.26*

Note: Model 3 has the same variables as Model 2 but with the same number of observations as Model 4; Significance level: * p < .10, **p < .05, ***p < .01.

those expressing a positive view of AVs, report that they would purchase one. About 52.5% report that they would use an AV taxi and 40.7% answered "maybe". Surprisingly, of those with a positive view 23.6% are unlikely to share, however a large plurality of 44.7% reports that they would share.

To more fully explore these effects, we estimate four models, one for each dependent variable, as shown in Tables 5–8. Key variables of interest are our latent attitudinal variables derived from our factor analysis, "pro-technology", "driving enjoyment", "regulating traffic", and "risk avoidance". Model 1 in each table is a simple model that only includes attitudinal variables. Model 2 adds additional control variables. Model 4 includes an income variable, but we lose almost 200 respondents who did not provide income information; therefore, we include Model 3 omitting the income variable, but estimated with only those who provided income (i.e, with the same number of observations as Model 4), to determine whether any difference in estimates are due to the inclusion of income or the reduction in sample size.

Table 5 displays the models for attitudes towards AVs. Coefficients are relative to the reference case, negative attitudes. The left part of the table displays the coefficients and significance level for having a positive attitude, and the right shows the coefficients and significance level for having a neutral position. Among the four latent variables generated by our factor anal-

Table 7
Multinomial logit model of willingness to use an AV taxi service versus not using.

Variable	Will use AV taxis (vs. Will not use AV taxis)			Maybe (vs. Will not use AV taxis)				
	Model 1 Coef.	Model 2 Coef.	Model 3 Coef.	Model 4 Coef.	Model 1 Coef.	Model 2 Coef.	Model 3 Coef.	Model 4 Coef.
F1: Pro-technology	1.92***	1.38***	1.43***	1.42***	0.93***	0.61***	0.63***	0.65***
F2: Driving enjoyment	0.34**	0.11	0.11	0.10	0.24**	0.12	0.11	0.12
F3: Regulating traffic	0.53***	0.39**	0.53***	0.52***	0.25**	0.27**	0.29**	0.29*
F4: Risk avoidance	−0.02	0.03	0.03	0.02	−0.39***	−0.42***	−0.47***	−0.47***
Own/be interested in smart devices		1.34***	1.25**	1.24**	0.52**	0.58**	0.63**	
Be familiar with AVs		1.02***	0.83**	0.81**	0.46**	0.49**	0.50**	
Live in an urban area		−0.38	−0.51	−0.55	0.31	0.14	0.18	
Age		−0.03***	−0.03**	−0.03***	−0.02**	−0.01	−0.01	
Female		−1.18***	−1.20***	−1.12***	−0.73***	−0.65**	−0.72**	
Hispanic		−0.29	−0.13	−0.12	−0.07	0.04	0.03	
Non-Hispanic Black		−0.56	−0.51	−0.48	−0.44	−0.21	−0.24	
Have a child		0.11	0.27	0.25	0.23	0.43	0.45	
Income (*ref: <50 k*)								
50 k-150 k (median)				0.30			−0.27	
>150 k (high)				0.35			−0.51	
Constant	−0.53***	0.23	0.20	0.03	0.27**	0.51	0.01	0.16
N	*680*	*660*	*490*	*490*	*680*	*660*	*490*	*490*
Pseudo R2	*0.19*	*0.24*	*0.25*	*0.25*	*0.19*	*0.24*	*0.25*	*0.25*

Note: Model 3 has the same variables as Model 2 but with the same number of observations as Model 4; Significance level: * p < .10, **p < .05, ***p < .01.

Table 8
Multinomial logit model of willingness to share an AV taxi with a stranger versus not sharing.

Variable	Will share (vs. Will not share)			Maybe (vs. Will not share)				
	Model 1 Coef.	Model 2 Coef.	Model 3 Coef.	Model 4 Coef.	Model 1 Coef.	Model 2 Coef.	Model 3 Coef.	Model 4 Coef.
F1: Pro-technology	2.01***	1.49***	1.61***	1.63***	0.89***	0.63***	0.62***	0.66***
F2: Driving enjoyment	0.52***	0.27	0.25	0.25	0.17	0.03	0.07	0.09
F3: Regulating traffic	0.71***	0.63***	0.77***	0.74***	0.25**	0.22*	0.17	0.17
F4: Risk avoidance	0.25	0.32	0.22	0.22	−0.04	−0.01	−0.05	−0.04
Own/be interested in smart devices			1.65**	1.78**	1.85**	0.52**	0.31	0.40
Be familiar with AVs			1.27***	1.45***	1.52***	0.31	0.16	0.20
Live in an urban area			−0.84**	−0.61	−0.55	−0.44	−0.25	−0.19
Age			−0.02*	−0.01	−0.01	−0.01*	−0.01	−0.01
Female			−1.17***	−1.07***	−1.20***	−0.93***	−0.85***	−0.98***
Hispanic			0.57	0.92**	0.95**	0.05	0.04	0.05
Non-Hispanic Black			0.63	0.76	0.74	0.51	0.43	0.41
Have a child			0.15	0.18	0.17	0.27	0.59**	0.62**
Income (*ref: <50 k*)								
50 k-150 k (median)			−0.82*				−0.58*	
>150 k (high)			−0.74				−0.86*	
Constant	−1.28***	−1.68*	−2.54**	−2.08*	−0.35***	0.28	0.06	0.38
N	*668*	*653*	*485*	*485*	*668*	*653*	*485*	*485*
Pseudo R2	*0.22*	*0.28*	*0.30*	*0.31*	*0.22*	*0.28*	*0.30*	*0.31*

Note: Model 3 has the same variables as Model 2 but with the same number of observations as Model 4; Significance level: * p < .10, **p < .05, ***p < .01.

ysis, *Pro-Technology* and *Regulating Traffic* consistently have positive associations with having a positive attitude towards AVs. Coefficients for both are smaller for neutral versus negative attitudes, with *Regulating Traffic* not being significant. There is no statistically significant association with *Driving enjoyment*. *Risk Avoidance* attitudes are associated with negative attitudes towards AVs. Not surprisingly, owning or being interested in smart devices has a positive association with positive attitudes towards AVs as does familiarity with AVs. We do not find any effect associated with living in an urban versus a rural location. Women are less likely to have a positive view of AVs and those who are older tend be less positive. Ethnicity and race, controlling for other factors, do not seem to have a significant effect on attitudes. Likewise, income generally does not have a statistically significant association with attitudes, though there is a small negative association for those with income greater than $150,000 for neutral vs. negative attitudes.

As we had a relatively large non-response to our income question, we tested whether the reduction in sample size affects the models (comparing model 2 and model 3). Coefficients are very similar in magnitude as is statistical significance. The introduction of our income variables (model 4) also does not affect model results.

Table 6 has models of the willingness to purchase an AV versus being unwilling to purchase one. The question in the survey did not indicate how much more an AV would cost compared to a conventional vehicle, so these answers likely also represent attitudes towards AVs. Results on our attitudinal factors are similar to those of Table 5, with positive associations for those with *Pro-Technology* and *Regulating Traffic* attitudes, though less so for those uncertain about purchasing an AV. Control variables are also similar, the one exception being that those with children are more likely to state that they would purchase an AV. Those with higher incomes also seem a bit more likely to be willing to purchase an AV, suggesting respondents may be thinking about relative prices in how they answered this question.

Table 7 presents models evaluating associations with the willingness to use AV taxis. Again, having *Pro-Technology* and *Regulating Traffic* attitudes were positively associated with willingness to use AV taxis. Those who avoid risky behavior, i.e., having a high score on *Risk Avoidance*, are more likely to have a negative attitude instead of a neutral attitude towards using AV taxis. Control variables generally follow the same pattern as in other models, although there is no statistical significance with income or having children. Women have a large negative willingness to use an AV taxi, relative to their perceptions of AVs.

Table 8 examines the willingness to share an AV taxi with a stranger. The results of these models were generally similar to our other results on the attitudinal factors. In particular, women are very unwilling to share with strangers, but those of Hispanic background are slightly more willing to share, consistent with the previous models. There is a small effect for those who have more income being less willing to share.

6. Discussion

In this study, we examine the relationship of psychological, behavioral, and demographic factors on attitudes towards privately-owned and shared AVs. We find that latent psychological factors play an important role in the attitudes and preferences towards views and perceptions of autonomous vehicles and their usage. Specifically, across all models, respondents who tend to be early adopters of technology i.e., a high score on *Pro-Technology*, are more likely to be willing to use or purchase an AV, as well as to use an AV taxi, including with strangers. On the other hand, we find that driving enjoyment, once we control for demographics, has no significant relationship with attitudes towards AVs, either positive or negative. This suggests that even when an individual reports that they enjoy driving, the affective benefits of being "behind the wheel" do not outweigh the substantive perceived benefits of AVs.

Intriguingly, we find that those who support rigid traffic regulations (i.e., a high score on *Regulating Traffic*) are more likely to have a positive attitude toward AVs. Similar patterns were found across all of our models. Support for traffic regulation and enforcement may imply a comfort with system-level control of personal mobility that AVs would reinforce. On the other hand, those who avoid risky behavior (i.e., a high score on *Risk Avoidance*) are more likely to have a negative attitude instead of a neutral attitude. As Table 3 shows, the factor analysis situates support for AV regulation within the risk avoidance factor, implying that respondents overall continue to see AVs as something closer to a personal risk rather than a system to be regulated. These results suggest that risk avoidance and support for regulation should not be conflated, and AVs are not yet perceived as a normal, relatively non-risky part of the transportation system. This is not unusual for new technologies that consumers and the public are unfamiliar with (Slovic, 1987). Governments and AV companies may find that overall acceptance of AVs increases if more people understand AVs as part of a well-managed mobility system. The congruence between those who have positive views of AVs and positive views of purchasing, using taxis, and sharing likewise supports this finding.

This research demonstrates that although most people hold an open-minded attitude towards self-driving technologies, a large fraction of the population is not yet ready to use an AV without a driver and also reluctant to share a ride in an AV taxi. Psychological factors, such as the level of technology acceptance, driving enjoyment, and risk-taking, play important roles in people's attitudes towards privately-owned and shared AVs. Age, gender, and costs of AVs also consistently influence people's attitudes, willingness to purchase AVs, and willingness to share a ride; these demographic associations are found in most other studies (Liljamo et al., 2018). A human's ability to take back control from a self-driving car is one of the essential concerns that consumers have at present. The AV industry and policymakers should consider these factors when they deal with these emerging technologies and transportation modes.

The use and sharing of AV taxis may play a vital role in sustainable transportation systems (Fagnant et al., 2015). We observed a significant swing in people's choices when they were asked about sharing an AV ride with strangers. While a plurality of over 40% those with positive attitudes towards AVs are willing to share, this could still be a large obstacle against the adoption and use of SAVs. Our models suggest that those with high scores on our *Pro-Technology* and *Regulating Traffic* factors have positive associations with the willingness to share an AV ride. The former factor implies familiarity with the ride-sharing technology, which may affect the perceived risk for this transportation mode. In contrast, the latter indicates that people who will share AV taxis may think of ride-sharing as a solution to transportation problems. Younger adults and males are more likely to share an AV ride, although women are not. These findings echo previous studies (see Krueger et al. (2016)). Clearly there are concerns about sharing a closed space with strangers. This may suggest that shared AVs need to include private spaces for customers; this may, of course, result in major redesigns of vehicles.

While household income was not associated with the general attitudes towards AVs and the willingness to use AV taxis, it had a significantly positive association with the willingness to purchase an AV and a significantly negative association with sharing an AV taxi with strangers. This finding suggests a clear income effect. Those with more income demand a private space and their own vehicle. While we did not examine relative prices associated with different usage modes, there is a clear need to understand the relative effects, especially if policy makers seek to make sharing more widespread.

Surprisingly, we found no statistically significant effects associated with geographic location (based on urban vs. rural). Our measure of this is not precise, and future research could examine more fine-grained elements of location, especially the availability of parking at or near residences, which could affect the propensity to share rather than own a vehicle.

7. Conclusions

In conclusion, we find results similar to many other attitudinal studies of AV perceptions, in particular on the demographic associations. Younger people and males have the most positive attitudes, as do those who are more familiar with the technology. Most other studies have not directly examined the range of possible outcomes, from private ownership to sharing an AV taxi with strangers. Prior work also did not generally analyze representative samples. Our main limitation is the use of an on-line panel, which may be a slightly more "tech-savvy" sample than the general public. Our primary finding is that those with more pro-technology attitudes and who have a desire for more regulated traffic have the most positive attitudes across all our models. The contrast in overall support for AVs between pro-regulation and risk-avoiding respondents is also notable, suggesting an ongoing tension in how individuals perceive AVs. Findings were consistent across AV options, with similar attitudinal factors explaining both owning an AV or willingness to share an AV, either alone or with a stranger in the vehicle.

Our analysis opens up directions for future research. We did not find that living in an urban area or a rural area was a determinant for attitudes, willingness to purchase, and willingness to use AV taxis. However, future research should explore the effects of more specifically-defined variability in the built environment, assessing factors such as population density, road density, degree of congestion, land use patterns, and parking availability. In addition, it would be beneficial to survey the attitudes and opinions of the same panel again in a few years. Attitudes towards AVs remain based on what people see on the news or in conversation, and as AVs become more of a reality, researchers can track how attitudes towards AVs shift alongside their acceptance of technology, enjoyment of driving, support for regulation, and sense of personal risk. Sensational news about fatal crashes or technological incidents involving AVs or other automation technologies may lead to changes in perceptions and attitudes over time.

Our research did not investigate issues associated with privacy, security, or the distributional consequences of AV technology. How will these technologies change relative access to transportation? Will those more fearful of technology and those who wish to be in control be disadvantaged? These are all clearly questions for more detailed research. We hope our investigation of some of the underlying latent psychological factors are a starting point for additional studies.

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