Attitudes Toward Autonomous on Demand Mobility System: The Case of Self-Driving Taxi

Iis P. Tussyadiah, Florian J. Zach and Jianxi Wang

Abstract Self-driving cars are ready to serve customers, but previous studies found that the general public is still cautious to ride in autonomous vehicles. This study investigated the influence of attitude and trust in technology on intention to use self-driving taxi. Based on a survey with 325 residents in the United States (US), this research found low level of negative attitude towards technology (computers and robots) and high level of trust in autonomous vehicles. The likelihood of using self-driving taxi at home (as residents) and for travel (as tourists) is negatively influenced by perception that technology is dehumanizing and positively by expectations of reliability, functionality, and helpfulness of self-driving taxi. The analysis also revealed the effects of current patterns of mobility and innovativeness on intention to use self-driving taxi.

Keywords Technophobia · Self-driving car · Autonomous vehicle · Smart travel · On demand mobility · Uber

1 Introduction

Recent years have been witnessing a race to bring intelligent self-driving vehicles on the roads, with Google's self-driving car project being a prime example. Equipped with artificial intelligence and robotic technology, self-driving cars are

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designed to efficiently and safely navigate through city streets, sensing and processing relevant information from the surroundings to mitigate traffic delays and accidents without human assistance (Sanchez, 2015; Thrun, 2010). As a result, the use of self-driving cars is said to reduce traffic congestion and critically enhance passenger safety (Ross, 2014). Adding autonomous vehicles to city streets implies changes in infrastructure (e.g., internet-of-things, smart systems) and personal travel behaviour (Fagnant & Kockelman, 2015; Hars, 2015; Lenz & Fraedrich, 2016; Pavone, 2016), bringing us closer to the realisation of smart cities/smart destinations (Guo, Liu, & Chai, 2014; Xiang, Tussyadiah, & Buhalis, 2015).

The use of autonomous vehicles is not only beneficial for its sustainability through reduced ecological footprints of mobility (i.e., commuting and tourism), but also for its efficiency in resource utilization as it provides new opportunities for car sharing models by decoupling two resources: drivers and vehicles (Beiker, 2016; Hars, 2015; Lenz & Fraedrich, 2016; Pavone, 2016). Uber added self-driving cars to serve its customers in Pittsburgh in August 2016 (Mitchell & Lien, 2016), marking the first move to the implementation of autonomous on demand mobility system. Customers requesting a ride via Uber app will be paired with self-driving cars at random. These cars are equipped with self-driving kits and will be supervised by humans in the driver's seat for the time being, satisfying the category of autonomy level 3 according to the National Highway Traffic Safety Agency (NHTSA), but are expected to be fully autonomous (level 4) by 2021 (Chafkin, 2016).

With on-demand self-driving taxi service coming to operation, adoption rate by residents and tourists remains a critical issue to assess its success and shape its future. Despite the benefits, concerns about autonomous technology continue to intensify amongst the general public, causing resistance to autonomous vehicles (Schoettle & Sivak, 2014, 2015). These concerns are oftentimes rooted in fear of technology following its own course, independent of human direction (Dietterich & Horvitz, 2015) and hesitation to give up autonomy and control of an important aspect of human life to a machine (Glancy, 2012). The use of autonomous vehicles also implies diminishing demand for professional drivers (Ross, 2014), resulting in technology being perceived as dehumanizing. In order to identify a priori acceptance of self-driving taxi service, this research examines consumers' general attitudes toward technology and how it influences the likelihood of using self-driving taxi at home (as residents) and while traveling (as tourists). The findings will lay a foundation to better understand consumer behaviour with regards to the use of autonomous vehicles for personal travel, which will assist policymakers, including tourism destinations, and relevant travel businesses in strategic implementation of autonomous on demand mobility system.

2 Attitudes Toward Self-Driving Cars: Concept and Measurement

Autonomous technology paves the ways for the future of transportation and mobility. However, the general public are still very cautious about it. Pew Internet found that 48% internet users in the US indicated interest in self-driving cars (Smith, 2014), while American Automobile Association (AAA) reported that 75% US drivers feel afraid to ride in self-driving cars (Hsu, 2016). Surveying consumers in China, India, Japan, the US, the United Kingdom (UK), and Australia, Schoettle and Sivak (2014) found that while consumers showed high levels of interest and expectations about the benefits of self-driving vehicles, they also expressed high levels of concern about autonomous cars not driving as well as human drivers. More recently, Schoettle and Sivak (2015) revealed that full-autonomous mode of transportation is the least preferred by US motorists. As the success of autonomous on demand mobility system depends on the widespread adoption of autonomous vehicles on the road, it is important to advocate the public to learn to trust such robotic vehicles (Hsu, 2016). In order to predict the adoption rate of self-driving taxi, a better understanding of the general attitude toward and trust in autonomous vehicles is essential.

Negative attitudes toward technology. Studies confirm that some consumers demonstrate resistance to technology, resulting in avoidance of new technological innovation. A large body of literature conceptualizes the term technophobia (i.e., fear of technology) to explain the negative affective and attitudinal response to new technology (e.g., Brosnan, 1998; Rosen & Weil, 1990). While it has been applied mainly for computers, the concept is relevant to explain aversion to current technological trends, such as fear of artificial intelligence, robotics, drones, and self-driving cars (Dietterich & Horvitz, 2015). Rosen and Weil (1990) define technophobia to include one or more of the following: (1) anxiety about current or future interactions with technology, (2) negative global attitude toward computing technology, including the societal impacts of its operation (e.g., fear that technology will steal human jobs and destabilize society), and (3) specific negative cognition while interacting with or thinking about technology. Technophobia has been found to have adverse effects on acceptance of and performance with computer technology (Brosnan, 1998). Therefore, it is proposed that general aversion to technology (i.e., negative attitude) is a detriment to technology adoption in the case of self-driving cars.

Hypothesis 1 Negative attitude toward technology has a negative effect on intention to use self-driving taxi.

Various scales have been developed to measure technophobia as general attitude toward technology, including Computer Attitude Scale (CAS) (Nickell & Pinto, 1986) and Negative Attitudes toward Robots Scale (NARS) (Nomura, Kanda, & Suzuki, 2006). While researchers refer to self-driving cars as robotic cars or robocars (Ross, 2014; Thrun, 2010), it is largely unknown whether people associate autonomous cars as robots or as computers and if they would respond differently to different terms (i.e., if fear of robots is higher than that of computers). As suggested by Sanchez (2015), language plays a role in instilling perception of technology. To that end, this study measures aversion to computers and compares it with that to robots.

Trust in Technology. Trust has been identified to have strategic importance in understanding consumer acceptance of automated technology (Tay, Jung, & Park, 2014). Similar to trust within inter-personal exchanges (e.g., trust in suppliers), consumers place a significant level of trust in technological artefacts during human-technology exchanges, such as in online recommendation agents (Wang & Benbasat, 2005). This is called "trust in technology" (Lankton, McKnight, & Thatcher, 2014; Wang & Benbasat, 2005). In exchanges with autonomous agents, which involve transferring the decision making role from humans to technological agents, trust in technology becomes ever more critical to adoption (Glancy, 2012; Tay, Jung, & Park, 2014). It is proposed that for consumers to use self-driving taxi, they need to trust that the cars will work as designed.

Hypothesis 2 Trust in technology has a positive effect on intention to use self-driving taxi.

Lankton, McKnight, and Thatcher (2014) conceptualize system-like technology trusting expectations, which include reliability (i.e., continuously operating properly and in a flawless manner), functionality (i.e., having the functions and features to accomplish tasks), and helpfulness (i.e., providing adequate and responsive aid). They argue that these attributes are appropriate for less human-like technology artefacts (Lankton, McKnight, & Thatcher, 2014) as opposed to, for example, social robots that are designed to have human-like characteristics. Thus, it is expected that these attributes can capture trust in self-driving cars.

3 Method

In order to test the hypotheses, an online questionnaire was developed to capture attitudes toward technology, trust in technology, and intention to use self-driving taxi. To compare general attitudes toward computers and robots, respondents were randomly assigned into two groups: one responded to the original 20 items in CAS scale (Nickell & Pinto, 1986) (computer group) and the other to modified items where the word "computer" was replaced by "robot" (robot group). Respondents were given a scenario of a ride-hailing service with self-driving cars and asked if they agree to associate self-driving cars with computers or with robots, respective of their group. Trust in technology was measured by Lankton, McKnight, and Thatcher's (2014) scale with nine items measuring three constructs: reliability, functionality, and helpfulness, adapted to fit the self-driving taxi context. To measure a priori acceptance, respondents were asked to state the likelihood of using self-driving taxi in two different contexts: at home (as a resident) and while traveling (as a tourist). The questionnaire also includes demographic characteristics, travel behaviour, frequency of using taxi, use of ride-hailing services, and personal innovativeness, which is measured using domain specific innovativeness (DSI) scale (Goldsmith & Hofacker, 1991).

The questionnaire was distributed through Amazon Mechanical Turk, a marketplace for work that requires human intelligence, in July 2016. In order to obtain quality data from relevant respondents, the survey was only made available to users with approval rate above 98%. This effort resulted in 325 responses. Respondents are 60% male, mostly younger (58% under 35 years old), mostly college-educated (43% have at least a Bachelor Degree), and with household income less than US$ 40,000 (about 46%). Data were analysed using factor analysis, analysis of variance (ANOVA), and hierarchical regression analysis.

4 Findings

Negative Attitude toward Technology. Principal Component Analyses (PCA) were conducted separately for computer and robot groups, each revealed four dimensions, accounting for 63% of variance in computer group and 66% in robot group. Thus, PCA was conducted with aggregate data and the resulting four factors, accounting for 63% of variance, were used for subsequent analyses (see Table 1). *(Un)Beneficial* explains perception on the benefits of computers or robots to humans and society (all in reversed scale). *Dehumanizing* contains perceived harm and damages caused by the use of computers and robots on human beings and society (e.g., loss of jobs and human values). *Intimidating* reflects perceived complexity of computers/robots that is beyond people's comprehension. *Controlling* explains concerns over computers/robots gaining more power and, thus, control human's life.

As illustrated in Fig. 1, negative attitudes toward computers/robots are relatively low. Comparing the two groups using one-way ANOVA, there are significant differences between computers and robots in terms of (Un)Beneficial (F (1,324) = 27.100, p = 0.000) and Intimidating (F (1,324) = 31.397, p = 0.000) factors, with robots being viewed as more intimidating and less beneficial than computers. This suggests that language use can influence perception of technology among the general public. No differences were found across respondent characteristics.

Responding to the scenario about self-driving taxi service, respondents in the computer group demonstrated high level of agreement to associating self-driving taxis as (being driven by) computers (*Mean* = 4.64, *s.d.* = 0.64), while those in the robot group were slightly less (*Mean* = 3.76, *s.d.* = 1.14) in associating self-driving taxis with (being driven by) robots (ANOVA: F (1,324) = 76.766, p = 0.000).

Table 1 Attitude toward computers/robots

Attitude toward computers/robots (ACR)	Factor loading	Eigen-value	Cum. %	Alpha
Factor 1: (Un)Beneficial		3.52	17.60	0.84
Computers (robots) are responsible for many of the good things we enjoy[a]	0.72			
The use of computers (robots) is enhancing our standard of living[a]	0.71			
Computers (robots) are a fast and efficient means of gaining information[a]	0.71			
Computers (robots) can eliminate a lot of tedious work for people[a]	0.70			
Computers (robots) are bringing us to a bright new era[a]	0.66			
There are unlimited possibilities of computer (robotic) applications that haven't even been thought of yet[a]	0.66			
Life will be easier and faster with computers (robots)[a]	0.57			
Factor 2: Dehumanizing		3.43	34.73	0.84
Computers (robots) are dehumanizing the society	0.84			
The overuse of computers (robots) maybe harmful and damaging to humans	0.78			
Computers (robots) are lessening the importance of too many jobs now done by humans	0.77			
People are becoming slaves to computers (robots)	0.63			
Computers (robots) turn people into just another number	0.63			
Factor 3: Intimidating		3.08	50.11	0.89
Computers (robots) intimidate me because they seem so complex	0.86			
Computers (robots) make me uncomfortable because I don't understand them	0.79			
Computers (robots) are difficult to understand and frustrating to work with	0.77			
I feel intimidated by computers (robots)	0.74			
Factor 4: Controlling		2.51	62.68	0.77
Soon our world will be completely run by computers (robots)	0.79			
Computers (robots) will never replace human life[a]	0.78			
Soon our lives will be controlled by computers (robots)	0.75			
Computers (robots) will replace the need for working human beings	0.70			

Note[a]reversed scale; Alpha = Cronbach's alpha

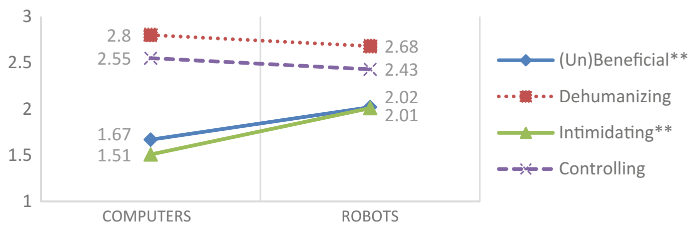

Fig. 1 Attitude toward computers versus robots (mean values). *Note* ** significant at $p < 0.01$

Trust in Technology. Consistent with Lankton, McKnight, and Thatcher (2014), three factors emerged from factor analysis for trust in self-driving taxi: reliability, functionality, and helpfulness (Table 2). As illustrated in Fig. 2, the mean values for trust factors indicate medium to high level of trust in self-driving taxi. Comparing mean values of trust factors between computer and robot groups showed a significant difference in Helpfulness (F (1,324) = 4.010, p = 0.046), with computer group scoring higher (see Fig. 2). Mean differences in trust were also tested across different user factors. A significant difference was found only in terms of gender, with male rating higher on Reliability (F (1,322) = 8.840, p = 0.003), Functionality (F (1,322) = 5.519, p = 0.019) and Helpfulness (F (1,322) = 11.507, p = 0.001). Therefore, gender was included as an explanatory variable in regression analyses.

Intention to Use Self-Driving Taxi. Respondents indicated a higher level of intention to use self-driving taxi as tourists (*Mean* = 3.38, *s.d.* = 1.23) than as

Table 2 Trust in self-driving taxi

Trust in self-driving taxi	Factor loading	Eigen-value	Cum. %	Alpha
Factor 1: Reliability		2.75	30.58	0.95
…will not malfunction on me	0.92			
…will provide error-free ride	0.91			
…will not fail on me	0.86			
Factor 2: Functionality		2.74	61.04	0.95
…will have the features required to get me to where I need to go	0.89			
…will have the overall capabilities to get me to where I need to go	0.88			
…will have the functionalities to get me to where I need to go	0.88			
Factor 3: Helpfulness		2.38	87.53	0.87
…will provide me the help I need during a ride	0.91			
…will supply my need for help during a ride	0.78			
…will provide competent guidance during a ride	0.76			

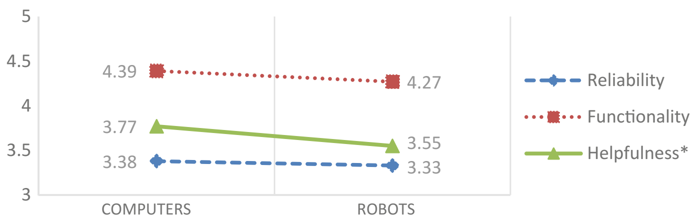

Fig. 2 Trust in Self-Driving Taxi: computers versus robots. *Note* * significant at $p < 0.05$

Table 3 Correlation matrix

Variables	Correlation						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) (Un)Beneficial	1						
(2) Dehumanizing	0.40**	1					
(3) Intimidating	0.45**	0.42**	1				
(4) Controlling	0.13**	0.50**	0.29**	1			
(5) Reliable	−0.36**	−0.34**	−0.20**	−0.06ns	1		
(6) Functional	−0.52**	−0.22**	−0.31**	−0.06ns	0.51**	1	
(7) Helpful	−0.39**	−0.28**	−0.21**	−0.02ns	0.54**	0.60**	1
(8) Innovativeness	−0.26**	−0.18**	−0.19**	0.09ns	0.21**	0.13*	0.25**

Note *significant at $p < 0.01$; ** significant at $p < 0.001$; ns = not significant

residents (*Mean* = 2.85, *s.d.* = 1.32), suggesting the potential impacts of this service for the tourism industry. Prior to conducting regression analyses, correlations between explanatory variables in the model were assessed (see Table 3). While factors of attitudes have significant correlations with factors of trust (except Controlling), the correlation coefficients are not too high to warrant concerns for multicollinearity in regression analyses.

Next, hierarchical regression analyses were conducted for the intention to use self-driving taxi at home and for travel. Model 1 assesses the effects of attitude and trust factors; then the control variables were integrated into Model 2 to assist in isolating the effects of independent variables. Dehumanizing and Reliability significantly affect intention to use self-driving taxi at home in Model 1 (Table 4). Integrating the control variables significantly improved the model (R^2 change = 0.212), with Reliability, Functionality, prior experience with ride-hailing services, and frequent use of taxi at home and for travel as significant predictors of intention. Intention to use self-driving taxi for travel is significantly explained by Dehumanizing, Reliability, Functionality, and Helpfulness in Model 1. The explanatory power in Model 2 improved only slightly (R^2 change = 0.091), indicating weak effects of the control variables. Dehumanizing, Reliability, Functionality, Helpfulness, frequent use

Table 4 Results of regression analyses

	Intention—at home		Intention—for travel	
	Model 1	Model 2	Model 1	Model 2
R^2	0.210	0.422	0.349	0.440
R^2 Change	0.210	0.212	0.349	0.091
F	12.008	16.098	24.192	17.364
F Change	12.008	16.157	24.192	7.208
Sig. of *F* Change	0.000	0.000	0.000	0.000
Independent Variables				
ACR: (Un)Beneficial	-0.055^{ns}	-0.063^{ns}	-0.014^{ns}	0.019^{ns}
ACR: Dehumanizing	-0.132^{*}	-0.099^{ns}	-0.248^{**}	-0.204^{**}
ACR: Intimidating	-0.043^{ns}	-0.082^{ns}	-0.063^{ns}	-0.054^{ns}
ACR: Controlling	0.078^{ns}	0.037^{ns}	0.093^{ns}	0.041^{ns}
Trust: Reliability	0.247^{***}	0.173^{**}	0.219^{***}	0.184^{***}
Trust: Functionality	0.087^{ns}	0.175^{**}	0.155^{**}	0.194^{**}
Trust: Helpfulness	0.080^{ns}	-0.012^{ns}	0.149^{**}	0.114^{*}
Control Variables				
Took Trip (Dummy)		0.025^{ns}		0.027^{ns}
Took Uber (Dummy)		0.134^{**}		0.023^{ns}
Taxi Use at Home		0.463^{***}		0.075^{ns}
Taxi Use for Travel		-0.173^{**}		0.181^{***}
Gender (Dummy)		-0.023^{ns}		-0.029^{ns}
Innovativeness		0.057^{ns}		0.130^{**}
Computer Group (Dummy)		0.013^{ns}		0.038^{ns}

Note * significant at $p < 0.05$; ** significant at $p < 0.01$; *** significant at $p < 0.001$; ns = not significant

of taxi for travel and personal innovativeness are significant predictors of intention to use self-driving taxi for travel.

Of the attitude factors, only Dehumanizing was found to negatively influence intention to use self-driving taxi at home and for travel (partial support for Hypothesis 1). This indicates that consumers' perception of technology taking away human values is still a hurdle for adoption of autonomous cars. Factors of trust positively influence intention to use self-driving taxi, except for Helpfulness in at home context (partial support for Hypothesis 2). In particular, Reliability consistently showed significance and higher beta values in predicting intention. It is important to note that travellers who use taxi more frequently in tourism destinations are more likely to use self-driving taxi for travel. Also, the positive effect of personal innovativeness on intention to use self-driving taxi for travel confirms the role of innovativeness in adoption of a novel technology (self-driving cars) in less familiar places (i.e., tourism destinations).

5 Conclusion and Recommendation

The introduction of self-driving cars for ride-hailing services marks the start of a new era of smart travel. This new development signifies research needs on consumers' response to the opportunity to use autonomous vehicles for personal travel (i.e., commuting and tourism). This study investigates consumers' a priori acceptance of self-driving taxi at home and while traveling and assesses the influences of attitudes toward and trust in technology. Respondents demonstrated low negative attitudes toward technology and high trust in self-driving taxi. The perception that technology can be dehumanizing was found to negatively influence use intention, while expectations of reliability, functionality, and helpfulness of self-driving taxi contribute to use intention. It can be suggested that in order to remove the roadblock to adoption of autonomous on demand mobility system, it is imperative for developers to communicate to the general public that the use of autonomous vehicles would not lessen people's roles (e.g., human drivers are no longer needed, reduced value of driving skills), but provide opportunities for new roles (e.g., new types of employment). Building trust in self-driving cars amongst consumers, especially with regards to their reliability, will also guarantee a higher adoption rate. While found insignificant to influence intention, language use in communicating new technology also plays a role in shaping consumers' perception. Referring to autonomous vehicles as robot cars, for example, may result in consumers perceiving them as more complex (thus, intimidating) and less helpful.

This study also found that use intention was caused by current patterns of mobility. Frequent taxi use and prior experience with Uber positively affect use intention at home, while personal innovativeness and frequent use of taxi for travel positively affect use intention while traveling. The higher level of intention to use self-driving taxi for travel (compared to at home) indicates a major impact of this development on tourism. For tourism destinations, it is expected that innovative tourists (those who are eager to try out new things) and heavy users of taxi services (i.e., personal transportation) to be more likely to adopt self-driving taxi. Therefore, portraying self-driving taxi service as a novel experience in marketing materials would appeal to these types of tourists and drive adoption. This study is among the first attempts to investigate autonomous on demand mobility system in tourism. As autonomous technology (including the subject areas of robotics and artificial intelligence) is an emerging topic in tourism research, future research should focus on ethics, privacy, values, and other issues beyond system-like expectations that are relevant to consumers' attitudes toward self-driving vehicles and likelihood for adoption in various tourism settings.

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