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Automated vehicle acceptance in China: Social influence and initial trust are key determinants

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ABSTRACT

Although automated vehicles (AVs) could offer a potentially effective solution to improving road safety, the benefit associated with AVs can be realized only when the public intend to use them. While some efforts have been made to understand why people would use AVs, few of them have investigated the role of social and personal factors in AV acceptance. The present study aimed to fill in this research gap. An AV acceptance model was proposed by extending the Technology Acceptance Model (TAM) with social and personal factors, i.e., initial trust, social influence, and the Big Five personality and sensation seeking traits. The validity of the proposed model was confirmed with a questionnaire survey administrated to 647 drivers in China. Results revealed that at the very beginning of AV commercialization, perception factors (i.e., perceived ease of use and perceived usefulness) from the original TAM showed significant influence on users' intention to use AVs. But more importantly, it was social influence and initial trust that contributed most to explain whether users would accept AVs or not. Some personality traits also played certain roles in AV usage intention. In particular, sensation seekers and those with a higher openness to experience were more likely to trust AVs and had a higher intention to adopt them. In contrast, neurotic people showed a lower level of trust and were less likely to accept AVs. Practically, these findings suggest that promotion of AVs to influential individuals that could help form good social opinions would have significant downstream effects on AV acceptance at the early state of its marketization.

1. Introduction

With advances in sensors, microprocessors, software, telecommunications and related technologies, automated vehicles (AVs) are evolving rapidly (Li et al., 2019; Noy et al., 2018). Current technologies have allowed AVs to be operated in approximately 90% of road conditions (Litman, 2017), and the proportion is expected to increase to 99% in the foreseeable future (Marshall, 2017). A great benefit AVs can bring to us is that they have the potential to dramatically reduce road crashes, as AVs can avoid human shortcomings such as fatigue, distraction and other human errors that account for over 90% of all road crashes (Fagnant and Kockelman, 2015). It is estimated that 50–80% traffic conflicts could be reduced if 50% of vehicles on road are AVs and 90–94% reduction would be achieved

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if all vehicles on road are AVs (Papadoulis et al., 2019).

Although AVs could offer a potentially effective solution to improving road safety, the benefit associated with AVs can be realized only when the public accept them. Recent surveys have shown that people are still more comfortable having humans, instead of automation systems, in control of cars, and that public's intention to use or purchase AVs is generally very low (Abraham et al., 2016; J.D. Power, 2012; Menon et al., 2016; Schoettle and Sivak, 2014). According to IEEE (2014), the basic benefit of AVs such as increased safety and fuel efficiency may not be enough to make drivers hand over control to automated driving system, and the biggest barrier to AV penetration will be public acceptance. It is predicted that decades of years might be needed to socialize this new technology, and this process would be subject to a number of unknown social and personal factors (IEEE, 2014). Therefore, to expedite AV acceptance, it is critical to understand what factors influence public's intention to use AVs.

Efforts have been made to study the influencing factors of AV usage intention. Some studies have focused on how individual's demographics (e.g., age, income and education) were related to opinions towards using AVs. For instance, it has been consistently found that young and male drivers had a more welcome attitude towards AVs and were more willing to purchase one (Abraham et al., 2017; Bansal et al., 2016; Hohenberger et al., 2016; Menon, 2015; Nees, 2016; Payre et al., 2014; Schoettle and Sivak, 2014). Besides, higher income (Bansal et al., 2016; Menon, 2015), living in the urban area (J.D. Power, 2012), tech-savvy (Bansal et al., 2016; Moore et al., 2020), and higher crash record (Bansal et al., 2016) were also related to a higher AV usage intention. Others studies have developed theoretical explanatory models derived from the field of information systems to explain AV usage intention. For instance, the Technology Acceptance Model (TAM) and its extensions have been reported to have good explanation powers of AV usage intention (Buckley et al., 2018; Madigan et al., 2017; Zhang et al., 2019). These models tend to agree that perceived ease of use and perceived usefulness were closely related to users' AV usage intention. Recent evidence showed that trust (Choi and Ji, 2015; Zhang et al., 2019) and perceived risk (May et al., 2017; Xu et al., 2018) also played important roles in shaping public's AV acceptance.

While the above studies have improved our understanding of AV acceptance by users, most of them have only analyzed the effects of cognitive factors in shaping users' acceptance, and impacts from social aspects have not been adequately examined. Klöckner (2014) proposed that people tended to value opinions from those important to them, especially in the early stages of the decision-making process. This notation has been empirically demonstrated by Barth et al. (2016), who reported that social influence had equal or even stronger effects than cost-related factors in the early stages of electrical vehicle adoption. Therefore, it is expected that AV acceptance would be closely related to social influence. Some preliminary efforts have been made on this topic (Distler et al., 2018; Leicht et al., 2018; Panagiotopoulos and Dimitrakopoulos, 2018; Zmud et al., 2016; Zmud and Sener, 2017). However, all of them were carried out in Western culture. It is unknown whether the identified effects of social influence can be generalized to Eastern countries like China. China has a culture that emphasizes collectivism and Chinese people are more likely to be affected by social influence than people in other cultures (Zhou and Li, 2014). Also, all available studies have only investigated the direct effects of social influence and neglected its possible indirect influence through factors such as perceived ease of use and perceived usefulness, although the importance of such indirect effects in new technology acceptance has been well documented in the literature (Schepers and Wetzels, 2007).

Another factor that has been largely ignored in AV acceptance studies is personality traits. To the authors' best knowledge, only three studies were available on this topic. Kyriakidis et al. (2015) investigated how big five personality traits were related to AV acceptance and reported that none of the personality dimensions was correlated with public's general opinion on AVs. Both Payre et al. (2014) and Choi and Ji (2015) examined whether sensation seeking trait was associated with a higher AV acceptance, but they reported different results. Specifically, Payre et al. (2014) found a positive effect while Choi and Ji (2015) found no significant effect of sensation seeking on AV usage intention. The limited number of studies and the inconsistent findings suggested that the effects of personality traits on AV acceptance require more research attention. In the field of information system, there has been evidence suggesting that personality traits could impact technology acceptance, either directly (Amichai-Hamburger and Vinitzky, 2010; Moore and McElroy, 2012) or indirectly through factors such as trust (Wang and Yang, 2005; Zhou and Lu, 2011). Therefore, linking personality traits to variables from the AV acceptance models might enhance the precision of these models.

To sum up, social influence and personality factors have not been adequately studied in terms of their effects on AV acceptance. The number of related studies were limited, the reported conclusions were not unanimous, and their effects in Eastern culture remained largely unknown. By incorporating social influence, personality traits and the important trust factor into TAM, this study aims to investigate that besides TAM factors, whether and how social and personal level factors may affect AV acceptance. The following section offers a review of related work and a detailed description about how the proposed model was developed.

2. Model development

2.1. TAM

TAM is one of the widely recognized models in information systems to understand and predict users' acceptance of technology. The original TAM (Davis, 1989) consists of three factors: perceived ease of use (PEOU), perceived usefulness (PU), and behavioral intention (BI) to use. PEOU is defined as the extent to which a person believes that using a system will be free of effort (Davis, 1989). PU refers to the extent to which a person believes that using the system will enhance his or her job performance (Davis, 1989). BI is defined as a person's subjective probability for performing some behaviors (Davis, 1989). TAM posits that PEOU and PU have direct and positive effects on BI, and additionally PEOU influences PU. These relationships have been proven to be consistent and robust under a broad range of information systems, such as e-commerce and healthcare (Legris et al., 2003; Marangunić and Granić, 2015; Tao et al., 2020; Tao et al., 2018) and can predict approximately 40% of variance in system use.

Table 1
A summary of AV acceptance studies based on TAM and their major findings.

Study	AV introduction method[a]	Automation Level[b]	Sample size	Model(s) (significant factors were emboldened)	R^2/Adj. R^2	Analysis method	Country
1. Zhang et al. (2019)	Verbal description	SAE 3	216	BI = PU + **PEOU** + **Trust**; Trust = PEOU + **PU** + **PSR** + PPR;	0.67;0.56;	SEM	China
2. Xu et al. (2018)	Field experience	SAE 3	300	BI = **PU** + **PEOU** + **PSR** + **Trust**; PU = **Trust**; PEOU = **Trust**; PS = **Trust**;	0.55;0.38;0.29;0.29;	SEM	China
3. Kaur and Rampersad (2018)	Verbal description	SAE 5	101	BI = **PU** + Trust; Trust = **Reliability** + Security + Privacy;	n.r.	SEM	Australia
4. Buckley et al. (2018)	Simulator experience	SAE 3	74	Model 1: BI = **SI** + **PBC** + **Trust**; Model 2: BI = **PU** + PEOU + **Trust**;	0.49; 0.44;	hierarchicallinear regression	U.S.
5. Madigan et al. (2017)	Field experience	SAE 3 (public transportation)	315	BI = **PU** + PEOU + **SI** + **FC** + **HM**;	0.59;	hierarchicallinear regression	Germany
6. May et al. (2017)	Field experience	SAE 1&2	202	BI = **PU** + **PB/PR**;	n.r.	SEM	U.S.
7. Cho, Park, Park, and Jung (2017)	Simulator experience	NHTSA 1-4	68	BI = **PU** + PEOU + **SI** + SE + **PS** + **Anxiety** + **Trust** + **AS**	0.84;	linear regression	Korea
8. Benleulmi and Blecker (2017)	Verbal description	n.r.	313	BI = PU + **PEOU** + **SI** + **HM** + PC + DEC + PIIT + **Trust** Trust = PPR + PSR + PFR + PSPR + PPerR	0.71 0.32;	SEM	Germany
9. Choi and Ji (2015)	Verbal description	NHTSA 3	552	BI = PR + **PU** + **PEOU** + **Trust** + **LOC** + SS; Trust = **system-transparency** + **technical competence** + **situation-management**;	0.68; 0.47;	SEM	Korea

BI: behavioral intention to use AVs; DEC: desirability of control; FC: facilitating conditions; HM: hedonic motivation; LOC: locus-of-control; PB: perceived benefits; PBC: perceived behavioral control; PC: perceived convenience; PEOU: perceived ease of use; PFR: perceived financial risk; PIIT: personal innovativeness in IT; PPR: perceived privacy risk, PPerR: perceived performance risk, safety risk; PR: perceived risk; PSR: perceived safety risk; PSPR: perceived socio-psychological risk; PU: perceived usefulness; SI: social influence; SS: sensation seeking.

[a] : Methods used to help participants get familiar with the AVs they investigated. Verbal description refers to using nonvisual language to convey information. Simulator experience refers to having participants ride AVs in a driving simulator. Field experience refers to having participants riding real AVs on road.

[b] : The level of AV investigated, it can be either SAE (Society of Automotive Engineers [SAE], 2018) or NHTSA Standards (National Highway Traffic Safety Administration [NHTSA], 2013).

TAM has been widely applied and extended in driving contexts to predict drivers' acceptance and usage, such as in-vehicle navigation (Chen and Chen, 2011; Park et al., 2014; Roberts et al., 2012), cruise control (Rahman et al., 2017) and other driver assistance systems (Kervick et al., 2015). Recently, efforts have been made to extend TAM to study influencing factors of AV acceptance and a summary of these studies is shown in Table 1. It can be seen that PU has been consistently found as a significant predictor. In terms of PEOU, 50% of the studies that included PEOU factor have reported a significant effect. Based on this evidence, it was hypothesized that:

H1. PU has a positive effect on BI to use AVs.

H2. PEOU has a positive effect on BI to use AVs

H3. PEOU has a positive effect on PU.

2.2. Trust

Trust is a critical factor in relationships between individuals, and between individuals and organizations (Nyhan, 2000). More recent evidence suggested that trust is also a key element in the development of human-automation relationships. For instance, it has been asserted that rates of usage of automation are directly and proportionally related to the degree of trust expressed (Lee and See, 2004). The well-known principle that "*no trust, no use*" is and will continue to be central to designing automated systems (Schaefer et al., 2016). The role of trust in human-automation relationship also hold true in the context of AVs, which is one type of automation systems. Recent surveys have reported that the lack of trust in AV systems was the most frequently mentioned reason for drivers' unwillingness to use them (Abraham et al., 2016; Zmud et al., 2016). The important role of trust on AV acceptance has also been confirmed by recent empirical studies (Buckley et al., 2018; Choi and Ji, 2015; Kaur and Rampersad, 2018; Liu et al., 2019b, 2019c). For instance, Choi and Ji (2015) surveyed 552 drivers and found that trust was the strongest positive antecedent of AV acceptance. Using a simulated experiment drive, Buckley et al. (2018) concluded that trust accounted for 4% of additional variance in AV acceptance. It should be noted though, that trust towards AVs is more accurately referred to users' *initial trust*, given that the majority of users had no experience in riding an AV yet. Trust research from psychology discipline has demonstrated that initial trust is formed prior to having first-hand experience with another party (Berg et al., 1995; Zhou, 2012) and it is determinate in shaping human-automation relationships (Hoff and Bashir, 2015). Based on the above evidence, we proposed that:

H4. Initial trust has a positive effect on BI to use AVs.

2.3. Social influence

Social influence has been defined as "*a person's perception that most people who are important to him/her think he/she should or should not perform the behavior in question*" (Fishbein and Ajzen, 1975). This means that people may consider a system useful and choose to use it, if their important referents think they should, even though they themselves are not favorable toward the system in their own minds. Therefore, social influence should have a direct effect on PU and BI to use a system. The above relationships have been reflected in some theoretical technology acceptance models such as TAM2 (Venkatesh and Davis, 2000) and UTATU (Venkatesh et al., 2003), and have been validated by many empirical studies (for a review, see Schepers and Wetzels, 2007). The effects of social influence on PEOU were mixed. The majority of previous studies reported a significantly positive relationship (e.g., Svendsen et al., 2013) while others reported a non-significant relationship (e.g., Liébana-Cabanillas et al., 2014). Considering that the majority of the public had no AV usage experience, they might evaluate the ease of operating AVs based on public opinions. Finally, social influence can affect users' level of trust toward a system (Alsajjan and Dennis, 2010; et al., 2008; Liébana-Cabanillas et al., 2014). For instance, Li et al. (2008) reported that social influence was even more pertinent to the development of initial trust compared to cognitive or individual factors. Therefore, one may have a higher level of trust towards AVs if their important referents have a positive attitude toward them. Based on the above evidence, it was hypothesized that:

H5. Social influence has a positive effect on PEOU.

H6. Social influence has a positive effect on PU.

H7. Social influence has a positive effect on BI to use AVs.

H8. Social influence has a positive effect on initial trust.

2.4. Personality traits

Personality traits refer to "*individual differences in characteristic patterns of thinking, feeling and behaving*" (American Psychological Association, 2017). While most theories view personality as relatively stable characteristics of a person, their views about the dimensions of personality diverge greatly. Among all viewpoints, the Big Five is probably the most prevalent and widely accepted paradigm (Goldberg, 1990), which suggests that one's personality traits consists of five dimensions: extraversion, agreeableness, openness to new experience, conscientiousness, and neuroticism. Extraversion is characterized by sociability, talkativeness,

assertiveness, and high amounts of emotional expressions (Mooradian et al., 2006). Agreeableness is concerned with how individuals approach interpersonal relationships, and individuals with a high level of agreeableness are cooperative, trusting, and concerned with the welfare of others (Mooradian et al., 2006). Conscientiousness trait is exemplified by being planful, organized, and to follow norms and rules (Mooradian et al., 2006). Neuroticism refers to degree of emotional stability and impulse control. Neurotic individuals tend to experience negative emotional states such as anxiety, guilt, and fear (Mooradian et al., 2006). Openness is reflected in a strong preference for novelty and variety. Individuals who are high on the openness dimension are not of afraid of new challenges and often display high degree of creativity (Mooradian et al., 2006).

There is a close link between personality traits and trust. Previous research from psychology and sociology has proven that trust between human beings correlates positively with extraversion, agreeableness and openness, and negatively with neuroticism (Evans and Revelle, 2008; Mooradian et al., 2006). Similar effects have been identified in trust toward information systems (Sharif et al., 2014; Zhou and Lu, 2011). For instance, Zhou and Lu (2011) found that users scoring high in extraversion, agreeableness and openness are more likely to trust mobile commerce while those scoring high in neuroticism are less likely to do so. Based on the findings from psychology and information system fields, it was hypothesized that:

H9a. Extraversion has a positive effect on trust.

H9b. Conscientiousness has no effect on trust.

H9c. Agreeableness has a positive effect on trust.

H9d. Neuroticism has a negative effect on trust.

H9e. Openness has a positive effect on trust.

Sensation seeking, according to Zuckerman (1994), is a trait defined by "*the seeking of varied, novel, complex, and intense sensations and experiences and the willingness to take physical, social, legal, and financial risks for the sake of such experiences*" (p. 27). It contributes to a multiple of risky behaviors such as alcohol abuse, gambling and unsafe driving (Zuckerman, 2007). Recent evidence has shown that users with a higher level of sensation seeking are more likely to accept technology such as e-commerce (López-Bonilla and López-Bonilla, 2008) and driving assistance systems (Rudin-Brown and Parker, 2004). Considering that AVs are innovative technologies that provide brand new driving experience, sensation seekers are expected to show a higher intention to use AVs than those who dislike sensation, in order to experience novelty and adventure. Consequently, it was hypothesized that:

H10. Sensation seeking has a positive effect on BI to use AVs.

Finally, there has been much evidence showing that personality traits are moderately correlated with each other (Tao et al., 2017), therefore, correlations within the Big Five personality and sensation seeking traits were added into the model.

The proposed AV acceptance model is shown in Fig. 1.

3. Method

3.1. Questionnaire

A self-administered questionnaire was designed to collect empirical data for this study. The questionnaire consisted of four sections. The first section measured demographic characteristics including age, gender, and education. The second section asked about respondents' driving related information, including active driving experience, accident and citation record within the last three years, and preferred mode of transportation (private vehicle, public transportation, motorcycle, walking/bicycling, or others). The third section was designed to measure personality related traits. First, the Zuckerman's 40 item Sensation Seeking Scale-V Form was

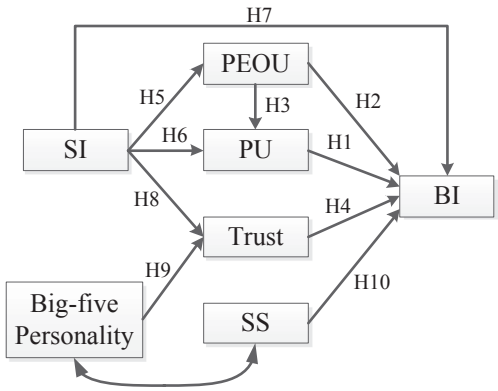

Fig. 1. The AV acceptance model proposed in this study. SI: social influence; PEOU: perceived ease of use; PU: perceived usefulness, SS: sensation seeking; BI: behavioral intention.

used to measure sensation seeking (Zuckerman, 2007). For each item, respondents were required to make a choice between two options, one representing the desire for sensation (e.g., I would like to learn to fly an airplane) and another related to a more cautious preference (e.g., I would not like to learn to fly an airplane). The Chinese Big Five Inventory developed by Wang et al. (2011) was used to measure the big five personality traits. The forth section started with a brief definition of AVs at the SAE Level 3 autonomy, which was read as follows: "*Automated vehicles use advanced techniques such Radar, LiDAR and computer vision to sense the surrounding environment to navigate from origin to destination. Current AVs can perform most of driving tasks such as lane keeping and lane changing. However, drivers need to take over control in situations the system cannot handle (e.g., road construction)*". Following the definition was a question asking respondents whether they had ever heard of AVs prior to this survey and the sources (Internet, TV, newspaper, friends, or other sources) they learned about AVs. Subsequently, items measuring the PEOU, PU, trust and BI to use AVs, adopted from Zhang et al. (2019), were presented in order. Last, three items adopted from Osswald et al. (2012) was used to measure social influence. The order of the questionnaire items was fixed. The items in each scale and the sources where the scales originate from can be found in the Appendix A. All items were measured with a five-point Likert-type scale ranging from "strongly disagree (=1)" to "strongly agree (=5)". Pilot tests showed that all questions were correctly understood and it took 20 min on average to complete the questionnaire.

3.2. Procedure

Web-based questionnaire survey, which has been proven to be a valid tool for assessing driver behaviors in China (Zhang et al., 2018), was applied in this study. The questionnaire was published on Sojump (www.sojump.com), one of the largest online survey platforms in China. To ensure data quality, the study used Sojump's paid sample service, which includes more than 2.6 million members from different cities in China and with diverse demographic backgrounds.

3.3. Participants

A total of 647 drivers completed the questionnaire from November to December 2018. Forty-three were excluded because of completing the questionnaire for less than 5 min, having no actual driving experience, or reporting unrealistic data (age $>$ 100). Of the remaining 604 participants, 259 (42.9%) were female and 345 (57.1%) were male. The average age was 31.38 (SD = 6.47) and the average driving experience was 6.07 (SD = 4.53). On average, the respondents reported to have 1.21 crashes (SD = 2.53) and 2.82 (SD = 3.40) in the last three years. All most all of them (n = 597, 98.8%) have ever heard of AVs. Detailed information about the demographic characteristics of the respondents is presented in Table 2.

3.4. Statistical analysis

The reliability and validity of the measurement scales were first assessed. The internal consistency, which refers to how well related items are designed to measure the same factor, is achieved if both the Cronbach's alpha and the composite reliability (CR) index are higher than 0.7 (Fornell and Larcker, 1981; Kline, 2016; Raykov, 1997). The convergent validity refers to whether items of a specific factor are related to the factor to which it should be related. To guarantee convergent validity, the factor loading of an item on its posited underlying factor in factor analysis should be significant and exceed 0.6 (Fornell and Larcker, 1981). The convergent validity was also assessed with the Average Variance Extracted (AVE) index. An AVE greater than 0.5 is considered adequate.

Table 2
Summary of the demographic and driving related information.

Variable	Mean (SD)	Frequency (Proportion)
Age	31.48 (6.47)	–
Driving experience	6.07 (4.53)	–
Crash	1.21 (2.53)	–
Citation	2.82 (3.40)	–
Gender		
Female	–	259 (42.9%)
Male	–	345 (57.1%)
Transportation mode		
Private car	–	513 (84.9%)
Public transportation	–	73 (12.1%)
Other	–	18 (3.0%)
Driving frequency		
> 7 times a week	–	158 (26.2%)
5–7 times a week	–	230 (38.1%)
2–4 times a week	–	151 (25.0%)
< 2 times a week	–	65 (10.8%)
Heard of AVs		
Yes	–	597 (98.8%)
No	–	7 (1.2%)

Discriminant validity reflects the extent to which the factors differ from one another empirically (Hamid et al., 2017). It is achieved if the loadings of the items on the intended factor are at least 0.20 larger than the cross-loadings (Gaskin, 2016). Another index, the square root of AVE (SAVE), was also calculated to evaluate discriminant validity. To achieve satisfactory discriminant validity, the SAVE for each of the factors should be greater than any of the bivariate correlations involving the factor in the model (Fornell and Larcker, 1981).

It should be noted that for personality related scales, only their internal consistency validity was evaluated and they were included in the model as observed variables (i.e., only their mean values were used in the structure model). This is the common practice to deal with personality related factors (Tao et al., 2017). For other factors, their latent structures were included in the model and all the above mentioned validity and reliability were examined.

The Partial Least Squares SEM (PLS-SEM) was employed to test the relationships in Fig. 1 for two reasons. First, the Shapiro-Wilk tests showed that the distribution of many items in the model (e.g., all items measuring PEOU) was non-normal and PLS-SEM does not require the data to be normally distributed. Second, PLS-SEM can deal with complex models with many observed variables (Ravand and Baghaei, 2016) like what we proposed in our study. Model fits the data if the goodness of fit (GoF) index is greater than 0.36 (Tenenhaus et al., 2005). The R package *plspm* (Sanchez et al., 2013) was used to run the PLS–SEM analysis with a bootstrap procedure of 1000 resamples.

4. Results

4.1. Measurement model

The Cronbach's alpha of personality related traits was: 0.830 for sensation seeking, 0.885 for extraversion, 0.705 for conscientiousness, 0.800 for agreeableness, 0.896 for neuroticism, and 0.835 for openness. All values were greater than the cutoff value of 0.7, suggesting a good internal consistency of the personality traits measurements.

The validity and reliability tests of the other variables can be found in Table 3 and Table 4. It can be seen that all Cronbach's alpha and CR were greater than 0.7 (Table 3), suggesting that the items used to measure each factor had maintained good internal consistency. The factor loadings of all items were all larger than 0.6 and the AVEs of all factors were larger than 0.5 (Table 3), indicating that the measurements had good convergent validity. Finally, the loadings of the items on the factor they were supposed to measure were at least 0.20 larger than the cross-loadings (Table 3) and each of the SAVEs was greater than any of the bivariate correlations involving the factor in the model (Table 4), suggesting the measures have good discriminant validity. To sum up, the measurement model showed a satisfactory reliability and validity, and was appropriate for the analysis of the structure model.

4.2. Associations among major variables

Table 4 shows the descriptive characteristics of the major variables and their correlations. Age was significantly related to all driving-related variables (i.e., driving experience, crash and citation records), four personality traits (i.e., sensation seeking, neuroticism, conscientiousness, and openness), PEOU, and trust. Interestingly, age showed no significant correlation with BI to use AVs. In terms of driving-related variables, only a few significant correlations were identified. In particular, driving experience was significantly related to three personality traits (i.e., neuroticism, conscientiousness, and extraversion) and citation record was significantly related to extraversion and PEOU. Both the Big Five personality traits and sensation seeking were significantly correlated with PEOU, PU, trust of AVs, and BI to use AVs, indicating the importance of personality traits in shaping users' attitude and behaviors.

Table 3
Summary of factor loading, Cronbach's alpha, CR and AVE results.

Factor	Item	PEOU	PU	SI	Trust	BI	Cronbach's alpha	CR	AVE
Perceived ease of use (PEOU)	PEOU1	**0.811**	0.345	0.353	0.315	0.385	0.768	0.852	0.589
	PEOU2	**0.754**	0.381	0.333	0.292	0.348			
	PEOU3	**0.766**	0.334	0.352	0.318	0.307			
	PEOU4	**0.737**	0.425	0.377	0.368	0.399			
Perceived usefulness (PU)	PU1	0.336	**0.715**	0.452	0.399	0.369	0.746	0.840	0.568
	PU2	0.353	**0.763**	0.523	0.504	0.427			
	PU3	0.392	**0.756**	0.460	0.433	0.423			
	PU4	0.386	**0.779**	0.488	0.546	0.502			
Social influence (SI)	SI1	0.355	0.549	**0.847**	0.589	0.504	0.757	0.861	0.674
	SI2	0.359	0.496	**0.844**	0.609	0.502			
	SI3	0.424	0.525	**0.770**	0.539	0.545			
Trust	Trust1	0.350	0.541	0.628	**0.868**	0.567	0.834	0.901	0.751
	Trust2	0.363	0.531	0.595	**0.873**	0.571			
	Trust3	0.389	0.559	0.615	**0.858**	0.616			
Behavioral Intention to Use (BI)	BI1	0.403	0.508	0.523	0.580	**0.866**	0.840	0.904	0.758
	BI2	0.423	0.531	0.561	0.600	**0.880**			
	BI3	0.384	0.459	0.563	0.582	**0.865**			

Table 4
Descriptive characteristics of the major variables and their correlations.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Age	–														
2. Experience	0.68***	–													
3. Crash	0.10*	0.06	–												
4. Citation	0.14***	0.06	0.65***	–											
5. SS	−0.15***	−0.02	0.04	0.00	–										
6. Neuro	−0.22***	−0.18***	−0.07	−0.05	−0.19***	–									
7. Consci	0.15***	0.11**	0.03	−0.01	−0.08*	−0.39***	–								
8. Agree	0.06	0.06	0.05	0.01	0.06	−0.28***	0.43***	–							
9. Open	−0.14***	−0.02	0.02	0.00	0.63***	−0.22***	0.25***	0.32***	–						
10. Extra	0.05	0.10*	0.08	0.14***	0.45***	−0.51***	0.33***	0.33***	0.51***	–					
11. PEOU	0.09**	0.05	0.07	0.12**	0.14***	−0.23***	0.29***	0.18***	0.18***	0.20***	**0.767**				
12. PU	0.07	0.09*	0.01	0.01	0.14***	−0.26***	0.24***	0.23***	0.20***	0.26***	0.47***	**0.754**			
13. SI	0.07	0.04	0.04	0.06	0.21***	−0.24***	0.31***	0.31***	0.31***	0.35***	0.45***	0.62***	**0.821**		
14. Trust	0.11**	0.08*	−0.03	0.00	0.22***	−0.31***	0.31***	0.28***	0.31***	0.35***	0.41***	0.61***	0.70***	**0.867**	
15. BI	0.01	0.04	0.00	0.05	0.27***	−0.23***	0.21***	0.25***	0.32***	0.32***	0.44***	0.56***	0.62***	0.67***	**0.871**
Mean	31.48	6.07	1.21	2.82	0.39	2.39	3.88	3.50	3.60	3.21	3.89	3.82	3.53	3.59	3.90
SD	6.47	4.53	2.53	3.40	0.16	0.82	0.50	0.51	0.62	0.72	0.60	0.69	0.70	0.69	0.73

SS: sensation seeking; Neuro: neuroticism; Consci: conscientiousness; Agree: agreeableness, Open: openness; Extra: extraversion; PEOU: perceived ease of use; PU: perceived usefulness; SI: social influence; BI: behavioral intention.

The values on the diagonal are the squared root of average variance extracted (SAVE).

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.

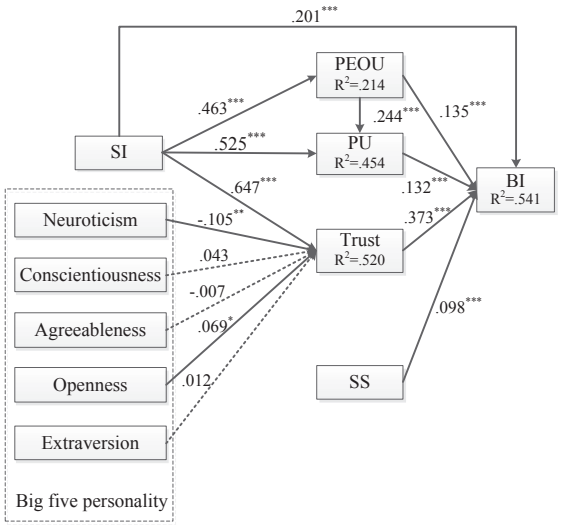

Fig. 2. Results of the structural equation model. Solid lines indicate significant paths and dotted lines indicate non-significant paths. The correlation among the personality traits are all significant but are not shown in the figure. Note: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

4.3. Structural model

The Gof of the structure model was 0.533, which was higher than the cutoff value of 0.36, indicating that the proposed model was a good representation of the hypothesized relationships.

Fig. 2 shows the results of the estimated model, with solid line representing significant relationships and dotted-line representing non-significant relationships. The standardized coefficients of the significant paths are also shown in the figure. A total of 54.1% of variance in BI was accounted for in the model. With a standardized coefficient of 0.373 ($p < 0.001$), trust was identified as the most powerful predictor of BI, followed by PEOU ($\beta = 0.135$, $p < 0.001$), PU ($\beta = 0.132$, $p < 0.001$), and then sensation seeking ($\beta = 0.098$, $p < 0.001$). As high as 52.0% of variance in trust was explained by Big Five personality traits and SI, suggesting that our model represented a good explanation of trust. It should be noted though that not all Big Five personality traits significantly affected trust. Of the five personality traits, neuroticism showed a significantly negative effect ($\beta = -0.105$, $p < 0.01$), openness showed a significantly positive effect ($\beta = 0.069$, $p < 0.05$), while conscientiousness, agreeableness, and extraversion showed no effect on trust. As hypothesized, social influence was a positive predictor of PEOU ($\beta = 0.463$, $p < 0.001$), PU ($\beta = 0.525$, $p < 0.001$) and trust ($\beta = 0.647$, $p < 0.001$) and directly determined BI to use AVs ($\beta = 0.201$, $p < 0.001$). Finally, sensation seeking had a significant effect on BI ($\beta = 0.098$, $p < 0.001$), with sensation seekers having a higher BI to use AVs.

The direct, indirect and total effects of the predictor factors on BI to use AVs are summarized in Table 5. Social influence showed the largest effects, followed by trust and the two cognitive factors from TAM (i.e., PEOU, and PU), and then personality traits.

To check the robustness of the PLS-SEM results, we re-conducted the PLS-SEM analysis by controlling the effects of demographic variables, including age, gender, and driving experience on BI to use AVs. The standard path coefficients of the original model and the model controlling the effects of demographic variables can be found in Table 6. The results showed that none of the demographic variables showed a significant effect on BI and all the relations in the original model remained unchanged after the inclusion of these demographic variables.

5. Discussion

AVs are under fast development but researchers have paid limited attention to public's acceptance towards this emerging

Table 5
The direct, indirect and total effects of factors on BI.

	Direct effects	Indirect effects	Total effects
Sensation seeking → BI	0.098	0	0.098
Neuroticism → BI	0	−0.039	−0.039
Openness → BI	0	0.026	0.026
PEOU → BI	0.135	0.032	0.167
PU → BI	0.132	0	0.132
Trust → BI	0.373	0	0.373
SI → BI	0.201	0.388	0.589

PEOU: Perceived Ease of Use; PU: Perceived Usefulness; SI: Social Influence; BI: Behavioral Intention.

Table 6
Results of the original model and the model controlling for demographic variables.

Hypotheses	Standardized path coefficients Original model	Standardized path coefficients Control demographic variables
PU → BI	0.132***	0.131***
PEOU → BI	0.135***	0.139***
PEOU → PU	0.244***	0.244***
Trust → BI	0.373***	0.378***
SI → PEOU	0.463***	0.543***
SI → PU	0.525***	0.525***
SI → BI	0.201***	0.199***
SI → Trust	0.647***	0.647***
Extraversion → Trust	0.012	0.011
Conscientiousness → Trust	0.043	0.043
Agreeableness → Trust	−0.007	−0.007
Neuroticism → Trust	−0.105**	−0.105**
Openness → Trust	0.079*	0.079*
Sensation seeking → BI	0.098***	0.086**
Age		0.054
Gender		0.007
Driving experience		0.024

PEOU: Perceived Ease of Use; PU: Perceived Usefulness; SI: Social Influence; BI: Behavioral Intention.
*** $p < 0.001$.
** $p < 0.01$.
* $p < 0.05$.

technology. To fill this gap, this study has integrated trust, social factors (i.e., social influence), and personal factors (i.e., personality traits) into the TAM model to explain AV acceptance.

Our results suggested that factors from TAM are important determinants of consumers' BI to use AVs. The significant roles of PEOU and PU in shaping adoption behavior have been emphasized theoretically and have been confirmed in empirically studies in acceptance of a range of technologies such as wearable devices and AVs (Marangunić and Granić, 2014; Yousafzai et al., 2007). Trust, although was not included in the initial TAM, it plays an important role in shaping behaviors in situations with uncertainty, such as the early stage of AVs (Buckley et al., 2018; Choi and Ji, 2015; Liu et al., 2019a; Xu et al., 2018; Zhang et al., 2019). This has also been supported in our study. In together, these results suggest that to be accepted by consumers, AVs must be perceived as easy-to-use, useful and trustworthy.

The important role of social influence in determining technology acceptance has long been confirmed in the field of information systems research (for a review, see Schepers and Wetzels, 2007) and in some AV acceptance studies (Madigan et al., 2017; Panagiotopoulos and Dimitrakopoulos, 2018; Sener et al., 2019). Such relationship has also been replicated in this study. However, what is surprising is that social influence was identified as the most powerful determinant. In particular, it not only had direct effects on BI, but also indirectly influenced BI through PEOU, PU and trust. Two reasons might explain why social influence is such a key factor in shaping AV acceptance, especially in our sample. First, different from commercially available technologies examined in other technology acceptance studies (Rupp et al., 2018; Tao et al., 2018), the AVs examined in our study have not been commercialized yet. Without first-hand usage experience, ones' cognitive evaluation of AVs might be unstable, inaccurate or largely influenced by media reports or opinions from friends, which together might have weakened the effects of cognitive related factors and enhanced influences from social aspects. Second, this study was carried out in China, which is characterized by collectivistic culture. In collectivistic culture, an individual's decision is likely to be influenced by others' opinions because of face saving and group conformity (Zhou and Li, 2014). Therefore, social influence is expected to have a stronger influence on technology acceptance behavior in Chinese culture compared with that in Western culture.

Compared to cognitive and social related factors, the role of personality in trust formation and in technology acceptance has been less empirically investigated, although many researchers have emphasized the necessity to take personality traits into consideration when predicting automation trust and acceptance (Hoff and Bashir, 2015; Svendsen et al., 2013). This gap has been partially filled by our study. Users with an openness to new experience were found to trust AVs more and therefore were more likely to accept AVs. This is expected considering that people who possess this trait have a propensity for spontaneously accepting new ideas (Zhou and Lu, 2011). In contrast, neurotic users presented a distrustful attitude and showed a lower intention to use AV. Such finding is reasonable given that neurotic people are typically troubled by potential loss and risks. In general, our results suggested that the personality of neuroticism and openness to experience could shape one's AV usage intention through trust factor. However, trust did not offer a pathway through which the other three personalities may affect behavioral intention.

Finally, our results showed that those with a higher level of sensation seeking were more likely to use AVs. It is probably due to the fact that the adventure or novelty associated with AVs has enhanced their intention to use them. If this is the case, the novelty seeking would increase intention to use AVs in the first place, but its role may decrease once drivers have used AVs and do not have a feeling of novelty anymore. Another explanation is that AVs free drivers from continuous manipulation work and allow them to engage in some interesting secondary tasks, which might be appealing to sensation seekers. However, Choi and Ji (2015) reported a

non-significant effect of sensation seeking trait on BI. The conflicting findings between Choi and Ji (2015) and our study might due to the difference in the scales used to measure sensation seeking. Choi and Ji (2015) has used three items from the Driving Related Sensation Seeking scale (Taubman et al., 1996) and the three items only measured thrill-related driving behavior like speeding. Driving in automated mode would not provide users with such thrill-seeking driving behavior and therefore those who scored high in their sensation seeking scale might not favor AVs. In our study, the Zuckerman's 40 item Sensation Seeking Scale-V Form (Zuckerman, 2007) was used to measure sensation seeking. It is a non-domain specific scale and measures not only the seeking of thrills, but also the seeking of novel experience. The latter dimension, that is, the seeking of novel experience, should be positively associated with the acceptance of new technologies, such as AVs.

This paper has several limitations. First, whether the surveyed samples were representative of the general Chinese driver population was not checked. Therefore, generalization of our results should be cautioned. Second, our participants, although informed about AVs and their potential applications, did not have direct experience of such a vehicle, which could prevent them from building an appropriate mental model about AVs. Finally, this is cross-sectional study and the relations identified might change over time. Therefore, longitudinal studies are recommended to further clarify how AV acceptance and its influencing factors might evolve with time.

6. Conclusions and practical implications

This study has proposed and empirically tested an AV acceptance model that integrated TAM constructs, trust, social influence and personality traits. Our results showed that social influence and initial trust played the most important role in determining whether users intend to use AVs or not. The original TAM is also valid to explain AV acceptance. That is, people's perception of whether AVs are easy-to-use and useful significantly determine their intention to use AVs. Besides, some personality traits also work in shaping AV usage intention, with sensation seekers and those with a higher openness to experience being more likely while neurotic people being less likely to accept AVs.

Findings from this study have several important implications. First, to increase AV acceptance, efforts should not only be aimed at broadcasting its usefulness and ease-of-use, but also at proposing effective ways to build users' initial trust towards AVs. Second, our results suggested that in the absence of first-hand knowledge or experience, the opinions of a few may have a far-reaching impact on the overall trusting level of a group. Social aspects such as peer opinions are also very important in shaping users' cognitive evaluation and usage intention toward AVs. Therefore, promotion of AVs to influential individuals such as family seniors, group leaders and key members, would have significant downstream effects on AV usage intention. Finally, users with different personality traits can have different AV usage intention. Consequently, AV providers could recognize user groups with distinct personality traits and employ appropriate marketing strategies accordingly. For example, AV promotion can target on users with an openness to experience personality trait first as this group of people that are most likely to trust AVs and become the early batch of AV consumers.

CRediT authorship contribution statement

Tingru Zhang: Conceptualization, Methodology, Formal analysis, Writing - original draft, Funding acquisition. **Da Tao:** Conceptualization, Methodology, Writing - review & editing. **Xingda Qu:** Writing - review & editing, Supervision. **Xiaoyan Zhang:** Writing - review & editing. **Jihong Zeng:** Data curation. **Haoyu Zhu:** Data curation, Formal analysis. **Han Zhu:** Writing - review & editing.

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Appendix A. Items used to measure the factors in the proposed model and the sources of the measurement

Factors	Items	Contents	Sources
Perceived ease of use (PEOU)	PEOU1	1. Learning to use autonomous vehicles will be easy for me.	(Davis et al., 1989)
	PEOU2	2. I will find it easy to get autonomous vehicles to do what I want it to do.	
	PEOU3	3. It will be easy for me to become skillful at using autonomous vehicles.	
	PEOU4	4. I will find autonomous vehicles easy to use.	
Perceived usefulness (PU)	PU1	1. Using autonomous vehicles will be useful in meeting my driving needs.	(Davis et al., 1989)
	PU2	2. Autonomous vehicles will let me do other tasks, such as eating, watch a movie, be on a cell phone on my trip.	
	PU3		
	PU4	3. Using autonomous vehicles will decrease my accident risk	
	PU5	4. Using autonomous vehicles will relieve my stress of driving.	
		5. I find autonomous vehicles to be useful when I'm impaired (e.g., drowsy, drunk, drugs).	
Trust	Trust1	1. Autonomous vehicles are dependable.	(Choi and Ji, 2015)
	Trust2	2. Autonomous vehicles are reliable.	
	Trust3	3. Overall, I can trust autonomous vehicles.	

Social influence (SI)	SI1	1. People whose opinion are important to me would like the autonomous vehicles too.	(Madigan et al., 2017;
	SI2	2. In general, people who I like would encourage me to use the autonomous vehicles.	Osswald et al., 2012)
	SI3	3. I think I am more likely to use the autonomous vehicles if my friends or family used it.	
Neuroticism	Neuro1	1. I'm often worried that something bad would happen.	(Wang et al., 2011)
	Neuro2	2. I often feel worried.	
	Neuro3	3. Sometimes I feel myself worthless.	
	Neuro4	4. I seldomly feel worried or depressed.*	
	Neuro5	5. I tend to link some careless talking from others to myself.	
	Neuro6	6. I tend to have a nervous breakdown when facing pressure.	
	Neuro7	7. I tend to worry something that is unimportant.	
	Neuro8	8. I often feel insecure.	
Conscientiousness	Consci1	1. I only wish to muddle through at work. *	(Wang et al., 2011)
	Consci2	2. I would stay persistent and achieve my goal once it is set.	
	Consci3	3. I tend to make decisions after careful considerations.	
	Consci4	4. People think I am a discreet person.	
	Consci5	5. I tend to do things in logical and organizational ways.	
	Consci6	6. I would like to set up thoughtful plans at the beginning of a task.	
	Consci7	7. I work or study hard.	
	Consci8	8. I'm a person that would act to the best of my ability.	
Agreeableness	Agree1	1. Although there exist some dark things in human society (e.g., wars, crimes, deceptions), I	(Wang et al., 2011)
	Agree2	still believe that human nature is good.	
	Agree3	2. I believe that most people are good-natured.	
	Agree4	3. Although there are some cheaters in society, I think most people are believable.	
	Agree5	4. I don't pay much attention if other people have been unfairly treated. *	
	Agree6	5. I often feel that others' sufferings have nothing to do with me. *	
	Agree7	6. I often feel sorry for those have unfortunate issues.	
	Agree8	7. I'm the kind of person who only takes care of myself and do not worry about others. *	
		8. I often feel sad when others tell me their misfortunes	
Openness	Open1	1. I have rich imagination.	(Wang et al., 2011)
	Open2	2. My mind is often filled with vivid pictures.	
	Open3	3. I have strong curiosity to many things.	
	Open4	4. I like adventures.	
	Open5	5. I'm a person who likes to take risks and break from norms.	
	Open6	6. I have a venturesome spirit that other might not have.	
	Open7	7. I desire to learn new things, even if they are not related to my daily life.	
	Open8	8. I'm receptive to new things, opinions and ideas	
Extraversion	Extra1	1. I like parties.	(Wang et al., 2011)
	Extra2	2. I feel bored of crowded parties. *	
	Extra3	3. I try to avoid parties with a lot of people and noisy environment. *	
	Extra4	4. I tend to play hard in lively and noisy parties.	
	Extra5	5. There are no silences in situations with me.	
	Extra6	6. I hope to be the lead rather than the led.	
	Extra7	7. I hope to be in a leading position in a team.	
	Extra8	8. Most people agree that I'm a passionate and friendly person.	
Sensation seeking (SS)	40 items	The same with those in Zuckerman (2007).	(Zuckerman, 2007)
Attitude (ATT)	ATT1	1. Using autonomous vehicles is a good idea.	(Davis et al.,1989)
	ATT2	2. Using autonomous vehicles is a wise idea.	
	ATT3	3. Using autonomous vehicles is pleasant.	
Behavioral Intention to Use (BI)	BI1	1. I predict I would use autonomous vehicles in the future.	(Gold et al., 2015;
	BI2	2. I plan to use autonomous vehicles in the future.	Venkatesh and Davis, 2003)
	BI3	3. I will purchase autonomous vehicles together with my next car.	

* refers to items need to be reverse scored.

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