



Development and validation of a questionnaire to assess public receptivity toward autonomous vehicles and its relation with the traffic safety climate in China

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ABSTRACT

The advent of autonomous vehicles (AVs) has gained increasing attention in China. Although auto manufacturers and innovators have attempted to confirm that AVs are safe and have introduced them on public roads, it is vital to understand end-users' acceptance of AVs. A total of 1453 participants voluntarily and validly completed a series of questionnaires. The questionnaires included the Autonomous Vehicle Acceptability Scale (AVAS), the Traffic Climate Scale (TCS), and sociodemographic variables. The satisfactory internal consistency reliability and construct validity revealed that the newly developed Chinese version of the AVAS is a suitable tool to measure public acceptance of AVs. Moreover, exploratory factor analysis and confirmatory factor analysis conformed to the four factors of AVAS, including benefits in usefulness (BIU), benefits in situations (BIS), concern scenarios (CS) and system concern (SC). Scores higher on benefits and lower on concerns represent more acceptance of AVs. In addition, we found that the public's perceived local traffic safety climate affected the attitude toward AVs. More specifically, external affective demands (EAD) were found to be a significant predictor of SC, internal requirements (IR) were shown to have an effect on BIS and CS, and functionality was found to be a significant predictor of BIU and SC. Furthermore, the differences between drivers and non-drivers revealed that drivers were concerned significantly less about AVs and regarded AVs as more useful than non-drivers did. To gain more customers for the purchase of AVs, it is necessary for automotive vehicle manufacturers and retailers to introduce and advertise the functions and usability of autonomous driving systems to the public. Gaining acceptance from end users and understanding the factors that affect acceptability will be critical to the widespread deployment of AVs.

1. Introduction

The advent of autonomous vehicles (AVs) has gained increasing attention in China, not only because the Chinese government has encouraged innovation in the manufacturing industry but also because a number of companies have competed to mass produce vehicles with automated driving systems. For example, the “Made in China 2025” strategy proposed by the Chinese government revealed high expectations for AVs to reduce traffic accidents by more than 80% and to reduce traffic fatalities by more than 10% (National Manufacturing Strategic Advisory Committee, 2016). In addition, the Chinese Internet Firm Baidu announced that it would be ready to produce fleets of AVs in 2021 and that it had tested them on public roads. Despite the fact that the government and high-tech companies hold high hopes for automated driving systems, such as increased road safety, reduced human-

caused traffic accidents, increased traffic fluency (Mui and Carroll, 2013; Anderson et al., 2014; Fagnant and Kockelman, 2015), and the ultimate creation of a “safe, efficient comfortable and energy-saving” new type of traffic mode (Kyriakidis et al., 2017; Yunqiang, 2017), it is vital to investigate end users' opinions and expectations of AVs because they are the core of consumption.

Based on technical capability and human participation, the American Society of Automotive Engineers (SAE) divided automated vehicles (AVs) into 6 levels, ranging from level 0 to level 5 in 2014, including no automation (level 0), driver assistance (level 1, DA), partial automation (level 2, PA), conditional automation (level 3, CA), high automation (level 4, HA) and full automation (level 5, FA), different levels of automation have been proposed with different definitions and made further specifications for this classification in 2016 (SAE International, 2014, 2016).

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Efforts have been made to gain more understanding of public expectations and concerns about AVs. Studies focused on this topic frequently used on-line survey to reach people across borders and reduced cost and time, furthermore, most studies recruited only drivers. In general, most studies have indicated that the public has a rather positive attitude toward AVs. The public has expressed interest in adding automated driving systems to personal vehicles and willingness to pay extra money for vehicles with such technology, despite persistent concerns (Fraedrich et al., 2018; Sanbonmatsu et al., 2018). With regard to the perspective of the public on the presumed potential benefits of using an automated driving system, respondents expect AVs to overcome some general issues, such as transportation for the elderly and disabled (e.g., “solve the transport problems of older or disabled people”), parking problems (e.g., “transport me to work or to a meeting without having to care about finding a parking spot”) and road safety issues (e.g., “improved emergency response to crashes”) (Payre et al., 2014; Schoettle and Sivak, 2014; König and Neumayr, 2017). With regard to presumed potential concerns, respondents showed more concerns about legal issues (e.g., “cause legal liability issues for the driver/owner when a crash is caused by the vehicle”), security issues such as hackers (e.g., “may not be secure from hackers”) or the capability of the system (e.g. “safety consequences of equipment/system failure”) (Schoettle and Sivak, 2014; König and Neumayr, 2017). Xu and Fan (2018) investigated public risk perceptions and insurance demand for AVs in the Chinese market and found that 42.35% of respondents believed that AVs could lead to reduced risk and that 45.28% believed AVs could lower insurance rates, all their respondents must own cars and have had experience purchasing automobile insurance. Furthermore, not only the automated driving system itself but also the occasions to which the system is applied raise concerns. Schoettle and Sivak (2014) listed several possible scenarios in which completely self-driving vehicles could be put into use and asked participants to evaluate their concerns about each scenario. Their participants were coming from six countries (China, Japan, India, the United Kingdom, the United States and Australia), 17% of their respondents do not drive, they found that vehicles with no available driver controls or vehicles moving while unoccupied were issues of great concern among the respondents.

Several scales have been developed to measure acceptance. For example, Payre et al. (2014) developed a 7-item a priori acceptability scale, but they focused only on fully automated driving. Verberne et al. (2012) adopted an acceptability scale that included emotional and attitudinal elements of acceptance; however, the items of the scale focused only on adaptive cruise control systems. Nees (2016) created a scale to assess acceptance of AVs that contained eight potential sub-dimensions of acceptance. In addition to these scales, several models have been used to evaluate and predict drivers' intended use of AVs, such as the technology acceptance model and the theory of planned behavior (Hill, 1975; Ajzen, 1991; Buckley et al., 2018). However, no studies have attempted to combine the public's direct anticipations and misgivings with an appraisal of acceptance. We propose that expectations and concerns together may reflect the public's acceptance of AVs and that people who express more good expectations and fewer concerns might be more accepting and more inclined to use AVs.

The factors that influence the acceptance and usage of AVs have been examined. Previous studies have mainly focused on individual variables, such as personality (Migliore, 2013), trust (Buckley et al., 2018; Molnar et al., 2018), and experience with automated driving systems (Payre et al., 2016). Several studies have focused on national variables, such as countries with different incomes (Schoettle and Sivak, 2014; Kyriakidis et al., 2015) or different population densities (Power, 2012; Bansal et al., 2016). Typically, males, younger individuals, urban residents and more highly educated people have more positive attitudes toward AVs (Payre et al., 2014; Haboucha et al., 2017; König and Neumayr, 2017; Hulse et al., 2018; Nielsen and Hausteine, 2018). Hohenberger et al. (2016) found that in comparison to women, men showed more positive emotion (pleasure), less negative

emotion (anxiety) and higher levels of willingness to use AVs. Becker and Axhausen (2017) conducted a literature review and analyzed 16 surveys on public acceptance of AVs. Despite inconsistent results (Silberg et al., 2013; Hartwich et al., 2018), they identified a few trends among these studies. In terms of gender, males were more open to autonomic technology than females were, and in terms of age, young people were more open to the introduction of AVs. On the one hand, few studies have focused on the impact of the current traffic safety climate; on the other hand, most studies have neglected the influence of driving experience and focused only on the attitude of drivers instead of all road users.

The traffic safety climate refers to road users' perceptions of and attitudes toward local traffic environments and traffic conditions (Özkan and Lajunen, 2011; Zhang et al., 2018). The traffic climate scale (TCS) was used to investigate the three components of the traffic safety climate, including external affective demands (EAD, emotional engagement while engaged in traffic, e.g., “stressful”), internal requirements (IR, individual skills and abilities required when participating in traffic, e.g., “demands fast reactions”) and functionality (requirements for a functional traffic system, e.g., “free-flowing”). Reported high scores on external affective demands and internal requirements indicated an unsafe traffic environment requiring participants to have experience, whereas high scores on functionality showed confidence in the traffic system (Gehlert et al., 2014; Zhang et al., 2018; Chu et al., 2019). The policies, practices, routines and infrastructures of local countries may influence the formation of the public's perception of the traffic safety climate; furthermore, this perception may influence the attitudes and behaviors of the public's willingness to participate in traffic. From the perspective of drivers, more perceived external affective demands and less functionality were associated with less risk perception on the road (Gehlert et al., 2014). Similarly, drivers' perceived external affective demands were found to be positively associated with violations, errors, and lapses while driving, while functionality was found to be negatively associated with these driving behaviors (Chu et al., 2019). From the perspective of pedestrians, Xu et al. (2018) found that functionality mediated the effect of the inconveniences pedestrians perceive in city traffic and pedestrians' transgressive behavior, suggesting that infrastructure plays a key role in influencing the behaviors of pedestrians. Parking has become a serious transportation and urban management problem in China (Wang and Yuan, 2013). According to König and Neumayr (2017), the public expects AVs to help address parking problems. Ou et al. (2018) found that home parking availability affects plug-in electric vehicle ownership costs. However, it is unclear whether the public's perceived local traffic safety climate affects attitudes and usage of AVs.

In addition, researchers have found that some characteristics (e.g., age and gender) of the public make people more accepting of AVs. For example, Nielsen and Hausteine (2018) divided respondents into three segments according to their attitudes toward conventional and autonomous vehicles, including skeptics, indifferent stressed drivers and enthusiasts, and compared their socio-demographic profiles. The results revealed that participants who were male, young, and highly educated and those who lived in large urban areas were more passionate about AVs, while participants who were older and car reliant and who lived in less densely populated areas were more critical of AVs. However, most studies have considered the opinions of drivers, while few studies have aimed to investigate the opinions of other road users. Deb et al. (2017) developed and validated a pedestrian receptivity questionnaire for fully autonomous vehicles and found that among pedestrians, males and younger respondents still showed greater receptivity toward fully autonomous vehicles. Nevertheless, it is still unknown whether respondents with different driving experience (e.g., drivers and non-drivers) may hold distinctive expectations of AVs.

As mentioned above, the first purpose of the current study was to develop and validate a questionnaire to assess public receptivity toward AVs. We hypothesized that more benefits and fewer concerns represent

more acceptance of AVs. The second purpose was to explore the relationship between the traffic safety climate and acceptance of AVs. The third purpose was to compare the different expectations and concerns among people with or without driving experience.

2. Methods

2.1. Participants

All participants were recruited through a web-based survey company (<https://www.sojump.com/>) using a convenience sampling technique. Participants were qualified only if they had heard about AVs before the survey. These qualified participants then signed an informed consent form, which told them that the questionnaires they were about to complete aimed to survey their attitudes toward AVs and the current traffic environment. They subsequently completed a series of questionnaires. Participants who completed the survey received 20 CNY (approximately 2.9 USD) as a reward. The study was approved by the Institutional Review Board of the Institute of Psychology, Chinese Academy of Sciences.

A total of 1455 participants (774 drivers and 681 non-drivers) completed the online questionnaires, including the Autonomous Vehicle Acceptability Scale (AVAS), Traffic Climate Scale (TCS) and demographic questionnaire. Two non-drivers were excluded for choosing the same option on the TCS (all selecting “1”). Ultimately, 774 drivers (20–60 years old, $M = 34.55$, $SD = 9.27$) and 679 non-drivers (17–65 years old, $M = 31.65$, $SD = 11.14$) were incorporated into our final analysis. Our data were collected through the Internet, thus, on the one hand, our participants were those who had access to the Internet, on the other hand, they were young (most younger than 50 years old), and highly educated (most above college degree). As for the driver's samples, it consisted of both 33% professional and 67% non-professional drivers, most of them have less than 10 years of driving experiences. Descriptive details of the demographic variables are presented in Table 1.

2.2. Instruments

2.2.1. The autonomous vehicle acceptability scale

The Autonomous Vehicle Acceptability Scale (AVAS) was designed to evaluate public acceptance of AVs. This scale consisted of 20 items from König and Neumayr's (2017) original scale, which measured potential benefits and concerns, and 9 items from Schoettle and Sivak's (2014) study, which included other probable benefits and potential concerns in regard to AVs. Therefore, in our questionnaire, 29 items were included in the initial version of the scale.

A standardized translation/back-translation procedure (Brislin, 1980; Regmi et al., 2010) was utilized to translate the original scale. First, two Chinese versions of the scale were translated from English separately by three psychology students. The accuracy, fluency and adaption of the scale to a Chinese cultural context were then discussed for integration into a complete version by two psychology professors who focused on the study of traffic safety. Once again, this new version was back-translated into English for comparison with the original items by a professional English-Chinese translator. Finally, four drivers were recruited to evaluate whether the new revised items were described lucidly. We finalized the scale after referring to the drivers' comments.

Participants were asked to rate the options that they most agreed with on a 6-point Likert scale from 1 = “absolutely disagree” to 6 = “totally agree” in the benefits dimensions and from 1 = “not at all concerned” to 6 = “very concerned” in the concerns dimensions.

2.2.2. The traffic climate scale

Previously, the TCS has been used to appraise people's attitudes toward the traffic safety climate (Gehlert et al., 2014; Zhang et al., 2018). In this research, the Chinese version of the TCS (revised by

Table 1
Participant demographics (N = 1453).

	Drivers (N = 774)		Non-Drivers (N = 679)	
	N	Percent (%)	N	Percent (%)
Gender groups				
Male	525	67.8	235	34.6
Female	249	32.2	444	65.4
Age groups				
17-29 years old	291	37.6	386	56.8
30-39 years old	260	33.6	107	15.8
40-49 years old	140	18.1	110	16.2
50-65 years old	83	10.7	76	11.2
Education background				
Junior middle school level	77	9.9	18	2.7
High school level	160	20.7	61	9.0
College degree	168	21.7	76	11.2
Bachelor degree	295	38.1	303	44.6
Master degree and above	74	9.6	221	32.5
Driving years				
≤ 5 years	419	54.1	—	—
6-10 years	220	28.4	—	—
11-16 years	78	10.1	—	—
≥ 16 years	57	7.4	—	—
Driver type				
Non-professional	519	67.1	—	—
Professional	255	32.9	—	—
Total mileage (10 thousand km)				
≤ 2	169	21.8	—	—
2-10	353	45.7	—	—
11-50	230	29.7	—	—
> 50	22	2.8	—	—
Annual mileage (km)				
≤ 1000	30	3.9	—	—
1,001-10,000	361	46.6	—	—
10,001-50,000	355	45.9	—	—
> 50,000	28	3.6	—	—
Weekly mileage (km)				
≤ 100	234	30.2	—	—
101-500	431	55.7	—	—
501-1,000	64	8.3	—	—
> 1,000	45	5.8	—	—

Zhang et al. (2018)) was used. Participants were required to choose which degrees of the adjective/phrase they thought best described the traffic climate of the city in which they currently lived on a 6-point Likert scale (1-“does not describe it at all” to 6-“describes it fully”). Three factors were included: the first factor was external affective demands (EAD; including 4 items; e.g., “chaotic”), the second factor was internal requirements (IR; including 4 items; e.g., “requires experience”), and the third factor was functionality (including 5 items; e.g., “harmonious”).

2.2.3. Demographic questionnaire and willingness to use autonomous vehicles

Information about age, gender, and educational background was collected from all participants. Driving years, total mileage (how many kilometers does one drive after getting the drivers' license), annual mileage (the average kilometers one drives per year), weekly mileage, and price of owned car were collected only from drivers. Participants were also asked to what degree they think they are familiar with automated driving system, from 1(not familiar with it at all) to 7(totally familiar with it). Their previous using experiences with automated driving system were collected through a multiple-choice question, they were asked if they have ever used following advanced driver assistance systems: Forward Collision Warning, Lane Departure Warning, Cruise

Control System, Adaptive Cruise Control, Lane Keeping System, Park Assist, Lane Change Assist, Blind Spot Detection.

In addition, three items were used to evaluate participants' willingness to use automated vehicles: "I am willing to drive an automated vehicle", "I am willing to own an automated vehicle" and "I am willing to rent an automated vehicle". Participants were asked to what degree they agreed with these descriptions on a 6-point Likert scale from 1 = "I strongly disagree" to 6 = "I strongly agree". Higher scores on the total of the three items indicated greater willingness to use AVs and hence more positive attitudes toward AVs.

2.3. Statistical analysis

SPSS 19.0 and AMOS 24.0 were used to conduct the data analysis. First, demographic variables and descriptive statistics of each subscale in the AVAS and TCS (mean, standard deviation, range, etc.) were calculated. Next, 901 data points were divided into two parts—half for exploratory factor analysis (EFA) and the other half for confirmatory factor analysis (CFA)—to explore and then confirm the proper structures of AVAS in Chinese samples. In addition, we calculated the internal consistency coefficient for each subscale of the AVAS and the TCS, and the Spearman correlation coefficients between each subscale were also tested. A series of hierarchical regression models was subsequently executed to examine the effect of traffic climate safety on AVs acceptability. Age and gender were also included in the models. Finally, an independent-sample *t*-test was used to compare the differences between the driver group and the non-driver group.

3. Results

3.1. Exploratory factor analysis

A total of 726 participants (340 non-drivers and 386 drivers) were randomly selected from the overall samples. All 29 items were subjected to principal axis factor analysis with varimax rotation using SPSS 22.0. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.912, and Bartlett's test of sphericity was significant ($\chi^2(406) = 9229.549, p < 0.00$), which suggested that the data were satisfactory for factor analysis. Eventually, 18 items that met the following three criteria were retained: (1) factor loading was greater than 0.400, (2) communality value was not less than 0.200, and (3) no cross-loading. Details of the final EFA results are presented in Table 2.

As shown in Table 2, 18 items explained 52.96% of the scale variance, which was divided into four factors. Factor 1 refers to "benefits in usefulness" (BIU); this was a 6-item subscale and explained 29.73% of the variance. This finding indicated that compared with manual driving, individuals believed that AVs can reduce resource consumption and monetary and time expenditures. Factor 2 refers to "concern scenarios" (CS); this 5-item subscale explained 11.74% of the variance. It indicated people's concerns about which scenarios could cause security risks when the automatic driving system was activated. Factor 3 refers to "benefits in situations" (BIS); this was a 3-item subscale that explained 6.54% of the variance. It indicated people's perceptions of the advantages and benefits of AVs in specific situations, such as when impaired or tired. Factor 4 refers to "system concern" (SC), which was a 4-item subscale that explained 4.95% of the variance. It indicated people's concerns about the autonomous driving system itself.

3.2. Confirmatory factor analysis

The remaining 727 cases were selected to conduct the CFA with maximum likelihood estimate (MLE) in AMOS 24.0. The model previously developed by EFA was used to fit 727 Chinese samples. The following several criteria for measuring the fit of the model: (1) the value of the χ^2/df index was lower than 5, (2) the Steiger-Lind root mean square error of approximation (RMSEA) value was lower 0.08, and (3)

the Joreskog-Sorbom goodness-of-fit index (GFI), the Bentler's comparative fit index (CFI) and the Tucker-Lewis Index (TLI) were higher than 0.90. Fig. 1 and Table 3 reveal a good fit of the items in the EFA model for the current Chinese data.

3.3. The reliability of the AVAS and the TCS

Table 4 presents the mean, standard deviation, range and Cronbach's α coefficients of each factor in the AVAS and the TCS. For the AVAS, the reliability of BIU, CS, BIS and SC were 0.832, 0.854, 0.788 and 0.671, respectively. With regard to TCS, the Cronbach's α coefficients of EAD, IR and functionality were 0.868, 0.811 and 0.890, respectively. An internal consistency coefficient greater than 0.7 was considered suitable, and the α values of most subscales fell within the acceptable range, with the exception of SC.

Table 5 presents the means (SD) and distribution of responses to each item in the AVAS scale. The item-total correlations (ITCs) of each item are also reported. The ITCs ranged from 0.627 to 0.878 and reached high levels. According to the mean values, "A self-driving car would lower insurance rates" showed the highest agreement among BIU, and "a self-driving car could solve the transport problems of older or disabled people" was valued the most among BIS. With regard to the concerns, "Riding in a vehicle with no driver controls available" and "a self-driving car could lead to privacy issues caused by steady tracking of exact locations" were the greatest concerns among CS and SC, respectively.

3.4. Correlations among the demographic variables, willingness, AVAS and TCS

Pearson correlations among age, gender, willingness, AVAS and TCS are shown in Table 6. The correlation coefficient for the four factors in the AVAS showed that any two factors were correlated with each other. In terms of the TCS, EAD and IR showed a significantly positive relation, and both had negative relations with functionality.

With regard to age and gender, while CS and SC were both negatively associated with age, BIU had a significant positive correlation with age, and no significant correlation between age and BIS was found. Gender had a negative relation with BIU, indicating that males perceived more usefulness of AVs.

Familiarity and using experiences with automated driving systems were found related with AVAS, for one thing, familiarity was positively correlated with BIU and BIS while negatively correlated with CS and SC; for another, using experience was positively correlated with BIU while negatively correlated with CS. Moreover, the price of owned car was negatively correlated with CS and positively correlated with BIU and BIS.

With regard to the willingness to use AVs, both BIU and BIS were positively correlated with the willingness to use automated vehicles, while CS and SC were negatively correlated with the willingness to use AVs. In addition, IR and Functionality were positively correlated with willingness.

Table 6 shows that there were significant correlations between the TCS and the AVAS; that is, EAD had a positive relation with CS and SC; IR had positive relationships with BIU, CS, BIS and SC; and functionality had a positive relation with BIU and SC and a negative relation with CS.

3.5. Regression analyses among the demographic variables, AVAS and TCS

To examine whether the perceived traffic safety climate was a significant predictor of acceptability, several hierarchical regression models were conducted, and the results are presented in Table 7. As shown in Table 7, the TCS was a strong predictor while controlling for the effect of age, gender and familiarity. Specifically, functionality can predict BIU (perceived ease while using self-driving vehicle); IR can

Table 2
Principal component analysis with varimax rotation (N = 726).

AVAS items	Factors Benefits in usefulness	Commonalities Concern scenarios	Benefits in situations	System concern
1. A self-driving car would lower vehicle emissions.	0.778			0.627
2. A self-driving car would need less fuel.	0.722			0.550
3. A self-driving car would lower insurance rates.	0.671			0.485
4. A self-driving car would yield shorter travel times.	0.640			0.479
5. A self-driving car would lead to fewer traffic jams.	0.626			0.441
6. A self-driving car would give me social recognition (image).	0.483			0.293
7. Public transportation such as buses that are completely self-driving.		0.758		0.656
8. Taxis that are completely self-driving.		0.730		0.613
9. Self-driving commercial vehicles such as heavy trucks or semi-trailer trucks.		0.659		0.472
10. Riding in a vehicle with no driver controls available.		0.599		0.467
11. Self-driving vehicles moving by themselves from one location to another while unoccupied.		0.539		0.422
12. A self-driving car could transport me even when I'm drunk, impaired or under medication.			0.825	0.701
13. A self-driving car can allow me to spend my time on things other than driving (e.g., working, texting, phoning, eating, sleeping, reading, observing the scenery).			0.686	0.494
14. A self-driving car could solve the transport problems of older or disabled people.			0.659	0.470
15. A self-driving car could lead to privacy issues caused by steady tracking of exact locations. ¹				0.619 0.453
16. A self-driving car may require additional learning by the driver to operate it.				0.593 0.380
17. A self-driving car could cause the loss of the pleasing activity of driving manually.				0.466 0.236
18. A self-driving car could lead to job losses.				0.425 0.203
% of variance explained	29.73	11.74	6.54	4.95

predict BIS (people's perception of the advantages and benefits of self-driving in specific situations); EAD and functionality can predict SC (people's concerns about the autopilot system itself); and IR can predict CS (people's concerns about which scenarios can cause security risks when the automatic driving system is activated).

3.6. Differences between drivers and non-drivers on the AVAS

An independent-sample *t*-test was used to compare the differences between the driver and non-driver groups. The results presented in Table 8 reveal that, compared to non-drivers, firstly, drivers scored higher in BIU, this reveals that drivers presumed the AVs as more useful and enhances performance; secondly, drivers rated lower in BIS, this reveals that drivers are less enthusiastic about autonomous driving system be applied to the usage scenarios for people who are not allowed to or improperly drive regular vehicles; in addition, drivers had significantly fewer concerns about not only the automated driving system itself but also the scenarios to which it applied than non-drivers.

4. Discussion

The primary aim of this study was to develop and validate a questionnaire to assess public acceptance of AVs. The results confirmed the acceptable reliability and construct validity of the 16-item AVAS, which contained 4 factors (i.e., BIU, BIS, SC, CS). In addition, the three factors of TCS (i.e., functionality, IR, EAD) significantly predicted AVAS; more specifically, functionality predicted BIU (perceived ease while using self-driving vehicle); IR predicted BIS (people's perception of the advantages and benefits of self-driving in specific situations); EAD and functionality predicted SC (people's concerns about the autopilot system itself); and IR predicted CS (people's concerns about which scenarios could cause security risks when the automatic driving system is activated). Finally, we compared the differences between drivers and non-drivers, and the results indicated that non-drivers generally expressed more concerns about AVs than drivers did.

The newly developed Chinese version of the AVAS showed acceptable reliability and stable structure. After identifying several potential benefits and concerns that people typically hold toward AVs from previous studies (Schoettle and Sivak, 2014; König and Neumayr, 2017;

Buckley et al., 2018), we identified 29 items to measure public acceptance. Factor analysis screened 18 items that met the criteria (such as factor loading greater than 0.400 and no cross-loading) and revealed a four-factor structure of AVAS, including benefits in usefulness (BIU), benefits in situations (BIS), concern scenarios (CS) and system concerns (SC). Two beneficial factors and two anxious factors refer to the public's expectations and perceived concerns toward both the autonomous driving system itself and the situations to which it applied, respectively. With regard to the two beneficial factors, first, the BIU reflects the degree to which the autonomous driving system is perceived as helpful and enhances performance; for example, the autonomous driving system might be considered useful for saving time (i.e., "A self-driving car would yield shorter travel times"). On the other hand, the BIS reflects the degree to which the autonomous driving system can be applied to particular situations, such as the usage scenarios for people who are not allowed to or improperly drive regular vehicles (i.e., "A self-driving car could transport me even when I'm drunk, impaired or under medication"). With regard to the two anxious factors, first, the CS reflects the degree to which the autonomous driving system is worrisome during use in some travel modes, for example, in public transportation (i.e., "Taxis that are completely self-driving"). Next, the SC reflects the degree to which people worried about the problems autonomous driving systems might cause; for example, they may need extra time to learn how to use the system or deprive them of the fun of human driving (i.e., "A self-driving car may require additional learning by the driver to operate it"). In general, the construct validity of the newly developed AVAS was demonstrated by both EFA and CFA. Furthermore, the AVAS showed favorable internal consistency reliability with coefficient values above 0.70 for most factors except for SC.

Correlations were found between the newly developed version of the AVAS and usage intention and self-reported familiarity with AVs. According to the results, both BIU and BIS were positively correlated with the willingness to use AVs, while CS and SC negatively correlated with it. In other words, people who rated higher on the beneficial aspects and lower on the anxious aspects of the potential consequences while using AVs might be more inclined to make use of autonomous driving systems, such as driving or buying vehicles with this system installed. This is consistent with previous findings that respondents who have more positive attitudes toward AVs are more willing to use or

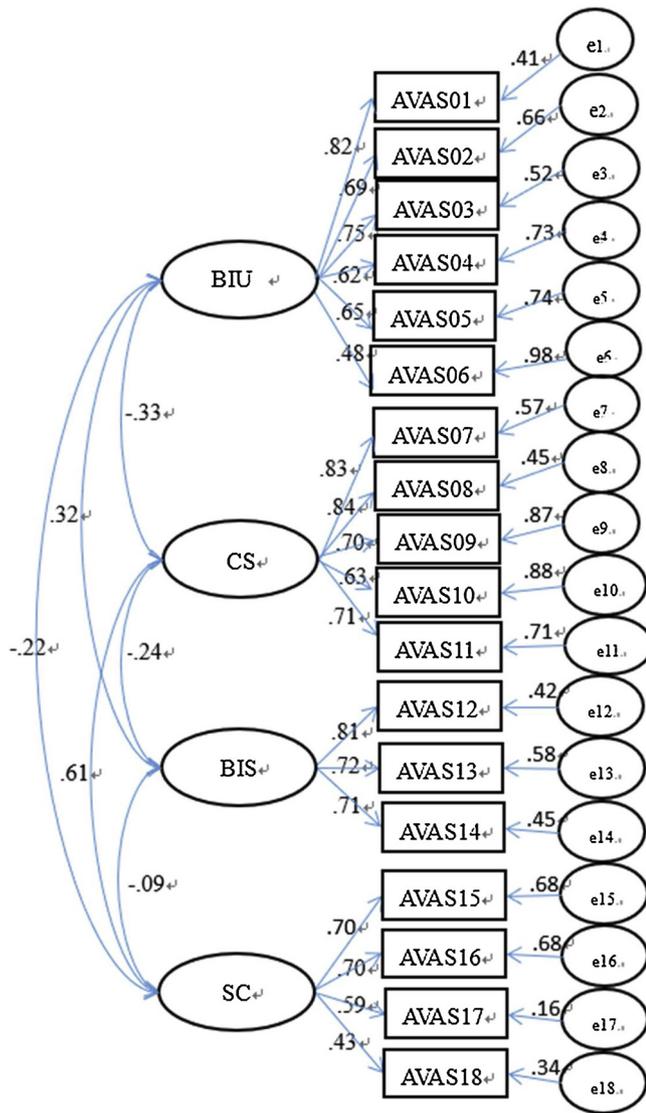


Fig. 1. CFA model of the AVAS (18 items).

purchase AVs (Payre et al., 2014; Nielsen and Haustein, 2018). In addition, self-reported familiarity with AVs was positively correlated with BIU and BIS while negatively correlated with CS and SC. This result is fit previous finding that comprehensive information given in the showroom would help overcome concerns about AVs (König and Neumayr, 2017). Furthermore, among the drivers, the price of owed car was found negatively correlated with CS and positively correlated with BIU and BIS. People with more expensive car perceive AVs as more helpful and less concerned about it been applied in public transportation. People with more expensive car showed more using experiences with advanced assistance systems, we speculated that owing more expensive car represents higher income, this is consistent with previous study (Bansal et al., 2016).

Age and gender were also correlated with AVAS. With respect to

Table 4
The reliability of the AVAS and the TCS (N = 1453).

	Mean	SD	Range	Cronbach's alpha
TCS	–	–	–	–
External affective demands	3.55	1.22	5-30	.868
Internal requirements	4.67	0.82	4-24	.811
Functionality	3.57	1.11	5-30	.890
AVAS	–	–	–	–
Benefits in usefulness	3.84	1.22	6-36	.832
Concern scenarios	4.11	1.51	5-30	.854
Benefits in situations	4.62	1.16	3-18	.788
System concern	3.56	1.45	4-24	.671

age, both CS and SC were negatively associated with it; however, BIU had a significant positive correlation with it, which indicated that the older adults were less worried about AVs and regarded AVs as more useful than younger people did. However, these findings conflicted with typical results that younger people have more positive attitudes (Becker and Axhausen, 2017; König and Neumayr, 2017; Hulse et al., 2018; Nielsen and Haustein, 2018). It is worth noticing that most of our samples were young and highly educated and none of them were older than 65 years old, thus this result should cautiously be generalized to those who are over 65. With respect to gender, the results showed a negative relation with BIU. This result indicated that males perceived more usefulness of AVs than females did, which is consistent with previous findings (Missel, 2014; Payre et al., 2014).

More importantly, to investigate the effect of TCS on AVAS, we conducted several regression analyses. Because age, gender and familiarity were found to correlate with AVAS, their influence was controlled, even though TCS was revealed to be a significant predictor of AVAS. First, EAD was found to be a significant predictor of SC, which indicates that people who considered local traffic with emotional involvement were less likely to be concerned about the problems the system might cause. Next, IR was shown to affect BIS and CS, the perceived benefits and concerns toward the applied scenarios, which means that people who believe that local traffic requires more individual skills expected AVs to be applied to occasions when drivers were forbidden or not recommended to drive manually. However, they worried more about autonomous driving system being applied to public transportation. This finding could be explained by previous studies that found that higher scores on IR revealed perceptions of a risky road environment and thus led to more positive road safety behaviors (Gehlert et al., 2014; Chu et al., 2019), which require self-discipline. However, it is difficult to maintain self-discipline when people are drunk or impaired, so they turn to AVs for help and hope that AVs can help them reach their destination when it is not recommended that they drive manually. On the other hand, the perception of a risky road environment may weaken people's confidence in the application of AVs to public transportation. Lastly, functionality was found to be a significant predictor of BIU and SC; in other words, people who perceived the traffic system as functional were more likely to deem AVs useful but also to show more concerns about the autonomous driving system. This result could be explained by the fact that people who had higher scores on functionality showed more confidence in the traffic system (Gehlert et al., 2014; Xu et al., 2018; Zhang et al., 2018), These people may be more open-minded about the new technology but worried about personal issues, such as learning, or private issues.

Table 3
Goodness-of-fit indices for the model of the AVAS (N = 727).

Model	Bollen-Stine χ^2	P	GFI	CFI	TLI	RMSEA(90% C.I.)	AIC
18 items	460.059	3.566	.000	.932	.930	.059(.054-.065)	342.000

Table 5
The descriptive statistics of the AVAS items and subscales (N = 1453).

AVAS items	M(SD)	ITCs	Response distributions (%)					
			1	2	3	4	5	6
<i>Benefit in usefulness</i>								
1. A self-driving car would need less fuel.	3.66(1.11)	0.753**	3.4	8.5	33	34.3	15.2	5.6
2. A self-driving car would lead to less traffic jams.	3.94(1.13)	0.726**	1.9	6.3	27	34.7	20.9	9.3
3. A self-driving car would yield shorter travel times.	3.86(1.09)	0.736**	2.6	4.3	31.7	35.2	18.6	7.7
4. A self-driving car would lower vehicle emissions.	3.73(1.11)	0.820**	3.2	7.0	31.8	36.4	14.9	6.7
5. A self-driving car would lower insurance rates.	3.95(1.08)	0.761**	2.5	4.7	24.0	40.9	20.2	7.7
6. A self-driving car would give me social recognition (image).	3.93(1.11)	0.627**	3.1	5.0	24.6	38.7	21.1	7.6
<i>Concern Scenarios</i>								
7. Riding in a vehicle with no driver controls available.	4.58(1.18)	0.741**	2.5	2.1	9.6	31.8	27.8	26.1
8. Self-driving commercial vehicles such as heavy trucks or semi-trailer trucks.	4.39(1.27)	0.786**	2.7	4.9	15.1	29.0	25.0	23.3
9. Public transportation such as buses that are completely self-driving.	4.05(1.32)	0.848**	4.4	6.7	21.3	31.0	20.3	16.4
10. Taxis that are completely self-driving.	3.79(1.20)	0.835**	3.8	8.5	27.3	35.0	16.4	9.1
11. Self-driving vehicles moving by themselves from one location to another while unoccupied.	3.72(1.17)	0.763**	4.9	7.0	29.9	34.0	17.8	6.5
<i>Benefit in situations</i>								
12. A self-driving car could allow me to spend my time on things other than driving (e.g., working, texting, phoning, eating, sleeping, reading, observing the scenery).	4.55(1.12)	0.843**	2.3	2.1	9.6	31.2	33.8	21.1
13. A self-driving car could transport me even when I'm drunk, impaired or under medication.	4.57(1.14)	0.878**	2.6	2.5	8.1	30.6	35.1	21.1
14. A self-driving car could solve the transport problems of older or disabled people.	4.74(0.96)	0.793**	0.8	0.7	6.5	30.0	39.4	22.6
<i>System Concerns</i>								
15. A self-driving car may require additional learning by the driver to operate it.	3.41(1.13)	0.723**	6.3	10.4	38.1	29.6	12.3	3.3
16. A self-driving car could lead to privacy issues caused by steady tracking of exact locations.	3.96(1.14)	0.725**	3.3	5.8	21.1	39.8	21.3	8.6
17. A self-driving car could cause the loss of the pleasing activity of driving manually.	3.43(1.27)	0.730**	8.0	12.5	34.3	25.3	13.6	6.3
18. A self-driving car could lead to job losses.	3.44(1.27)	0.667**	7.8	11.6	35.2	27.0	11.1	7.3

Notes.
** p < 0.01.

Finally, the results showed that driving experience impacts people's acceptance of AVs. In general, drivers have more positive attitudes toward AVs; they are significantly less concerned about AVs and regard them as more useful than non-drivers do. This result could complement the finding that drivers with higher mileage are likely to pay more for AVs because of their appreciation of cars (Kyriakidis et al., 2015). In addition, we found that previous using experience with automated driving system was positively correlated with BIU while negatively correlated with CS and SC, this is consistent with previous finding that drivers whose current vehicle with higher level of autonomy express more positive opinion about AVs (Rödel et al., 2014). People with more actual experiences with advanced assisted system perceive AVs as more useful and express less concerns. Nevertheless, drivers expressed less agreement with the usage of AVs for older or disabled persons. This finding may indicate that drivers tend to overrate their driving skills (Goszczyńska and Roslan, 1989; Delhomme, 1991; Williams, 2003) and therefore are reluctant to count on AVs to drive elders home or on other

Table 7
Linear regression analyses for four subscales of AVAS (N = 1453).

Predictors (β)	Dependent variables			
	BIU	BIS	SC	CS
Step 1				
Age	0.132**	0.025	-0.092**	-0.133**
Gender	-0.023	0.092**	-0.053*	-0.019
Familiarity	0.239**	0.128**	-0.175**	-0.269**
Adjusted R ²	0.082**	0.019**	0.038**	0.091**
Step 2				
EAD	0.063	-0.002	0.124**	0.047
IR	0.042	0.121**	-0.008	0.061*
Functionality	0.146**	0.027	0.132**	-0.043
Adjusted R ²	0.018**	0.014**	0.016**	0.013**

Notes.
* p < 0.05.
** p < 0.01.

Table 6
Correlations among the demographic variables AVAS and TCS (N = 1453).

	1	2	3	4	5	6	7	8	9	10	11	12
1 Age	1											
2 Gender	-0.106**	1										
3 BIU	0.167**	-0.112**	1									
4 CS	-0.168**	0.041	-0.304**	1								
5 BIS	-0.016	0.034	0.292**	-0.189**	1							
6 SC	-0.111**	0.019	-0.153**	0.402**	-0.078**	1						
7 EAD	-0.162**	-0.011	-0.042	0.144**	0.051	0.070**	1					
8 IR	-0.150**	-0.003	0.060*	0.121**	0.151**	0.067*	0.477**	1				
9 Functionality	0.079**	-0.036	0.133**	-0.080**	0.001	0.067*	-0.537**	-0.156**	1			
10 Willingness to use	-0.027	-0.050	0.380**	-0.241**	0.415**	-0.174**	0.041	0.182**	0.067*	1		
11 Familiarity	0.114**	-0.274**	0.271**	-0.233**	0.112**	-0.149**	-0.067*	0.044	0.091**	0.227**	1	
12 Using experience ^a	0.087*	-0.081*	0.133**	-0.121**	0.037	-0.063	-0.089*	0.043	0.040	0.131**	0.234**	1
13 Price ^a	0.118**	-0.075*	0.124*	-0.126*	0.077*	-0.070	0.014	0.059	-0.056	0.095**	0.186**	0.219**

Notes: male = 1, female = 2.
^a only drivers were asked, thus N = 774.
* p < 0.05.
** p < 0.01.

Table 8
Means (SD) and statistically significant differences for the two groups in AVAS.

Driving experience	Drivers	Non-drivers	t
BIS	13.631 (2.87)	14.122 (2.486)	−3.471***
BIU	23.822 (5.041)	22.203 (4.557)	6.385***
SC	13.845 (3.510)	14.682 (3.258)	−4.689***
CS	19.997 (5.231)	21.149 (4.392)	−4.508***

Notes.

*** $p < 0.001$.

occasions, such as when they are drunk, impaired or medicated.

Several limitations remain in the present study. First, generalization of the results should be performed with caution because the data were collected through the Internet. This limited our participants to those who had access to the Internet or were highly educated, especially among the non-driver group. In addition, according to China Internet Network Information Center, only 5.1% of internet users are older than 60 years old, so our respondents were lack of older people. Second, to avoid restricting the understanding of AVs for the participants, we did not provide a description of AVs, as in other studies (Payre et al., 2014; Nees, 2016; Körber et al., 2018). This design was intended to reveal the true expectations of the public regarding AV; however, the comprehension of current technology may vary from person to person, thus leading to inconsistent understandings. Third, we measured participants' intention about using AVs in the future, and we found the intention was positively correlated with previous using experiences among the drivers, but, it is still not direct measurement of the truly future purchasing behaviors, and we acknowledged that it was not always consistent between stated intention and actual behavior, however, it is not possible for present study to measure their future actual purchasing behaviors once all levels of AVs were available, this remains an interesting topic.

In conclusion, the newly developed Chinese version of AVAS was proven to be a suitable tool to measure public acceptance of AVs. It showed favorable internal consistency reliability and construct validity. Our hypothesis that more expectations and fewer concerns represent more acceptance of AVs was proven. In addition, we found that the public's perceived local traffic safety climate could affect the attitude toward AVs, and the different aspects of TCS could predict different aspects of attitudes. More specifically, EAD was found to be a significant predictor of SC, IR was shown to have an effect on BIS and CS, and functionality was found to be a significant predictor of BIU and SC. Furthermore, the differences between drivers and non-drivers revealed that drivers were concerned significantly less about AVs and regarded AVs as more useful than non-drivers did. To gain more customers for the purchase of AVs, it is necessary for automotive vehicle manufacturers and retailers to introduce and advertise the functions and usability of autonomous driving systems to the public.

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