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Naming is framing: The framing effect of technology name on public attitude toward automated vehicles

Peng Liu
Qingqing Fei
Jinting Liu
Tianjin University, P.R. China

Jianqiang Wang
Lanzhou Jiaotong University, P.R. China

Abstract

Vehicles with automated driving systems are called by many names, which are used interchangeably in public discourse, with different and at times misleading meanings. In two studies (total $N = 908$), we examined the naming effects on people's cognitive (perceived benefit and risk), affective (negative and positive affect), and behavioral responses (behavioral intention) to and trust in these vehicles in the Chinese context. Study 1 considered four names (intelligent, automated, autonomous, and driverless vehicles). Study 2 presented an identical description of vehicles with full automation and considered their five names (fully intelligent, fully automated, fully autonomous, fully driverless, and driverless vehicles). We corroborated the naming effects on affective responses and trust. The framing of "driverless vehicle" was less favorable in Study 1 but more favorable in Study 2. Technology names indirectly influenced behavioral intention through certain cognitive and affective responses. Theoretical and practical implications of our results are discussed.

Keywords

attitudinal responses, automated vehicles, driverless vehicles, framing effect, technology name

1. Introduction

Vehicles equipped with automated driving systems that perform part or all of driving tasks on a sustained basis continue to be developed and piloted on public roads, to which an assortment of names is widely used to refer, including automated, autonomous, self-driving, intelligent, and driverless vehicles/cars, and even car-like robots. Gandia et al. (2019) reviewed that "autonomous vehicles/cars" and "intelligent vehicles/cars" are the most mentioned, whereas the term "driverless

Corresponding author:
Peng Liu, College of Management and Economics, Tianjin University, Tianjin 300072, P.R. China.
Email: pengliu@tju.edu.cn

car" is the oldest on record. Terminology around this technology often varies in mass media. However, these names do carry different connotations. "Driverless" and "self-driving" strongly imply a complete replacement of the human driver (Shladover, 2018) and, technically, these two terms are specific to vehicles with full automation. Shladover (2018) pointed out that the word "autonomous" is synonymous with "independence" and "self-sufficiency," and as such, if vehicles need to communicate with the infrastructure or other vehicles to acquire information or to negotiate maneuvers, then they have "cooperative" rather than "autonomous" driving systems, and thus cannot be legitimately called "autonomous" ones. Nevertheless, these terms, without clear definitions, are almost used interchangeably in public discourse (Fraedrich and Lenz, 2016). Misleading and inaccurate terminology has partly caused the serious misunderstanding of automated vehicles (Shladover, 2018).

To avoid multiple definitions with ambiguous meanings, the Society of Automotive Engineers (SAE, 2018) has recommended the term "automated driving systems" to describe vehicles with different automation levels, including No Automation (Level 1; hereafter, L1), Driver Assistance (L2), Partial Automation (L2), Conditional Automation (L3), High Automation (L4), and Full Automation (L5). L3–L5 vehicles can operate in an automated mode. L5 vehicles can drive themselves in any of the same circumstances as a human driver. Nonetheless, lay people might have different understandings of these labels. Nees (2018) found participants did not match "Partial Automation" and "Conditional Automation" with their technical definitions and rated "Partial Automation" as entailing a higher automation level than "Conditional Automation."

The name given to a technology, a central issue for public opinion on and acceptance research on technology, will affect how people perceive the technology (Boersma et al., 2019a; Clarke et al., 2015; Jang and Hart, 2015; Whitmarsh, 2009; Zahry and Besley, 2019) (see section "Framing effect" for more evidence). It has also been identified as one of the key obstacles in science communication (Pilkington, 2019). These common names (e.g. automated and intelligent vehicles) for vehicles equipped with automated driving systems will be continuously used and communicated among the public and mass media. We focused on the framing effect of these names on individuals' attitudinal responses (cognitive, affective, and behavioral), which has been almost ignored.

2. Literature review

Public attitude

Although the definitions of attitude vary, it is usually regarded as a person's summary evaluations (e.g. unfavorable and favorable, dislike and like) of an attitude object (Eagly and Chaiken, 1993). Rosenberg and Hovland (1960) conceptualized it using a tripartite model with cognitive (e.g. beliefs, perceptions, and thoughts attached to the object), affective (e.g. feelings and emotions linked to the object, which could be non-verbal responses or verbal statements), and behavioral (e.g. favorable and supportive behaviors or verbal statements about behavioral intention) components. Behavioral components can be influenced by the other two components of attitude. In research on automated vehicles, these cognitive responses for affecting behavioral components (e.g. behavioral intention) include perceived benefits and risks of automated vehicles (Choi and Ji, 2015; Cunningham et al., 2019; Liu et al., 2019a, 2019b, 2019d, 2019e; Ward et al., 2017), perceived safety (Motamedi et al., 2020; Xu et al., 2018), and perceived ease of use (effort expectancy) and usefulness (performance expectancy) (Madigan et al., 2017; Motamedi et al., 2020; Nordhoff et al., 2018a; Panagiotopoulos and Dimitrakopoulos, 2018; Xu et al., 2018). Affective responses include positive affect and negative affect (Hohenberger et al., 2016; Liu et al., 2019d, 2019e; Myrick et al., 2019). Other influencial factors include social trust in the people and organizations responsible for the technology (Liu et al., 2019d, 2019e) and trust in the technology (Choi and Ji, 2015; Ward et al., 2017; Xu et al., 2018; Zhang et al., 2019).

Framing effect

Framing refers to the process by which particular concepts, beliefs, and attributes are made salient in a communicating text, in such a way as to encourage people to interpret, evaluate, and treat an issue of interest using these accessible concepts, beliefs, and attributes (Chong and Druckman, 2007; Druckman, 2004; Entman, 1993). Framing effects occur when people use frames (e.g. information message, name) to construct meaning, process information, and make evaluations or decisions (Chong and Druckman, 2007). For instance, Vishwanath (2009) examined the influences of intrinsic (perceived ease of use, performance, and utility) and extrinsic cues (non-physical characteristics, such as perceived image and price) on technology adoption. These frames influenced the psychological importance attached by adopters to these specific beliefs, which, in turn, shaped their expectations from the technology and influenced their adoption decision. In the context of automated vehicles, participants were more willing to ride in driverless vehicles after hearing positive information about them and less willing to ride after hearing negative information (Anania et al., 2018). A study that framed self-driving vehicles as producing environmental benefits reported greater trust among participants, leading to their higher risk acceptance of and willingness to ride in the vehicles (Liu et al., 2019c). Hryniewicz and Grzegorczyk (2020) also found that describing AVs with different contents (communal vs agentic) influences AV acceptance.

The name of a technology, usually the first piece of information about the technology, carries much weight and might affect people's responses and evaluations (Boersma et al., 2019a; Clarke et al., 2015). The naming effect has been documented in science communication literature on several controversial issues. For example, the terms "genetic engineering" and "agriculture biotechnology" (vs "genetic modification") have been associated with greater perceived benefits, positive feelings, and purchase intention (Zahry and Besley, 2019). The two terms "global warming" and "climate change" for describing global climate change have different political connotations and elicited different public responses and usage behaviors of these terms. In the United States, "global warming" makes Republican respondents more skeptical about its existence but does not affect Democrat respondents (Schuldt et al., 2011). "Global warming" evokes stronger connotations of human causation, whereas "climate change" evokes stronger connotations of natural causation (Whitmarsh, 2009). Moreover, "global warming" is more used in hoax frames, whereas "climate change" is more mentioned by social media users (Jang and Hart, 2015). Clarke et al. (2015) reported that people are more supportive of the energy extraction process when it is referred to as "shale oil or gas development" (vs "fracking"), and this relation is mediated by greater perceptions of benefit versus risk. Boersma et al. (2019a, 2019b) confirmed that the name alone can influence people's attitudinal responses to a technology and determine the activation of cognitive structures for people's evaluations and interpretations of this technology. In their study of "genomics" and "natural crossing," they suggested that when people have little knowledge about genomics, its name might lead them to associate it with their familiar technology (e.g. genetic manipulation), which forms their less favorable attitude toward genomics. Recently Myrick et al. (2019) found that the name frames (autonomous vehicle, driverless car, and self-driving car) have minimal influence on emotional responses (excitement, anxiety, and curiosity). However, they found that the vehicle product labeled as "self-driving car" decreased excitement, consequently reducing riding intentions. The above empirical evidence shows the non-trivial influence of naming a technology on attitude toward the technology.

Another research line has demonstrated people's misperceptions of the functionality implied by certain terms of vehicle automation (e.g. "Autopilot," "self-driving," and "high automation") and the actual capability of the same (Abraham et al., 2017; Nees, 2018; Teoh, 2020). Particularly, the name Tesla Autopilot, an L2 driver assistance system, induces people to perceive it as equivalent to "high automation" and "autonomous" (Nees, 2018) and to misuse it in unintended situations (Hardman et al., 2019). Banks et al. (2018) explained this misperception as a possible root cause of the fatal accident involving a Tesla Model S (being operated in autopilot mode) that occurred on 7 May 2016 in Williston, Florida. Improper naming would result in people's unrealistic expectations of the capabilities of vehicle technology and, eventually, their improper adoption behaviors. Thus, German's Federal Motor Authority asked Tesla to rename Autopilot and warned its owners that it cannot make their car drive autonomously (Schmitt, 2016). Several organizations (e.g. SAE and the American Automobile Association) united to adopt standardized naming practices for advanced driver assistance systems (L2 vehicles) based on system functionality to reduce confusion and educate consumers (SAE, 2020).

Current research

The public and potential consumers tend to misperceive automated driving technology (Abraham et al., 2017; Nees, 2018; Teoh, 2020), in part because of the misleading and inaccurate terminology applied to it (Shladover, 2018). The term automated driving system and the six automation levels have been recommended to avoid misperception and confusion (SAE, 2018). However, this term is not broadly used (Gandia et al., 2019), and these automation levels still mislead the public (Nees, 2018). Meanwhile, certain names for this technology (e.g. intelligent, automated, autonomous, driverless vehicles) continue to be used in public discourse. The consequences of the use of these names are almost unknown. A name is not only a source of misunderstanding and confusion but also a conceptual label that plays an important role in shaping attitudinal responses (Boersma et al., 2019a). The names given to this technology represent framing choices that might influence public attitude.

Myrick et al. (2019) examined the influence of three names (autonomous vehicle, driverless car, and self-driving car) on affective responses and contributed the most relevant work to the current research. Our Study 1 extended Myrick et al.'s (2019) study by examining the naming effect not only on affective responses but also on cognitive and behavioral responses. The example of the Tesla Autopilot indicated that the naming of an automated driving system influences people's cognitive beliefs (Nees, 2018) and actual usage of the system (Hardman et al., 2019). Previous science communication research (Zahry and Besley, 2019) also indicates the framing effect of technology names on all attitudinal responses. Thus, we focused on participants' attitudinal responses to the advanced vehicle technology labeled by different names and considered two cognitive responses (perceived benefit and risk), two affective responses (positive and negative affect), and one behavioral response (BI). As trust is a key psychological determinant for public acceptance of this technology (Shariff et al., 2017; Xu et al., 2018), we also considered the naming effect on trust. Therefore, Study 1 first addressed the following research question (RQ).

> RQ1: What is the framing effect of vehicle names (i.e. intelligent, automated, autonomous, and driverless vehicles) on trust, perceived benefit, perceived risk, positive affect, negative affect, and behavioral intention?

According to previous work (e.g. Liu et al., 2019d, 2019e; Myrick et al., 2019), trust, perceived benefit, perceived risk, positive affect, and negative affect will influence behavioral intention. The potential naming effect on behavioral intention could be attributed to the direct influence of name frames or its indirect influence through these psychological antecedents. We addressed the following RQ2 in both studies.

RQ2: Do vehicle names directly or indirectly influence behavioral intention through the mediating effects of trust, perceived benefit, perceived risk, positive affect, and negative affect?

Study 2 aimed to detect the influence of vehicle names for SAE L5 vehicles (vehicles with the highest automation) on attitudinal responses to and trust in these vehicles. Study 2 overcomes a research limitation in Myrick et al.'s work (2019) and Study 1: the observed influence of different AV names might be in part due to participants having different prior understanding and cognition about vehicles labeled by these names. To overcome this limitation, in line with Boersma et al.'s (2019a) study on "genomics" and "natural crossing," we framed L5 vehicles with an identical description but different names in Study 2 and ensured that the observed significant influence is due to the framing effect of vehicle names. In Study 2, we expected to witness more robust evidence of the framing effect of vehicle names (if it exists). We addressed the following RQ3 and previous RQ2.

RQ3: What is the framing effect of vehicle names (i.e. fully intelligent, fully automated, fully autonomous, fully driverless, and driverless vehicles) on trust, perceived benefit, perceived risk, positive affect, negative affect, and behavioral intention, given that L5 vehicles are framed with an identical description?

3. Study 1

In Study 1, we aimed to shed light on how participants respond to the following terms that are used interchangeably: intelligent vehicles ("智能驾驶汽车" in Chinese), automated vehicles ("自动驾驶汽车"), autonomous vehicles ("自主驾驶汽车"), and driverless vehicles ("无人驾驶汽车") (Note: "vehicle" and "car" share the same Chinese character). The term "self-driving vehicles" was ignored because its translation is usually the same as that of driverless vehicles in Chinese.

Methodology

Measure design. We designed a questionnaire with 16 items. Take the condition of automated vehicles for example. The three trust items were "I think automated vehicles are dependable" (Trust1), "I think automated vehicles are reliable" (Trust2), and "Overall, I can trust in automated vehicles" (Trust3) (Xu et al., 2018). Positive benefit (PB) was measured with the items "In general, automated vehicles are beneficial to my family and me/to society" (PB1/PB2), whereas perceived risk (PR) was measured with the items "In general, automated vehicles will be threatening to my family and me/to society" (PR1/PR2) (Liu and Xu, 2020). The items for positive affect (PA) were "If I am asked to ride in an automated vehicle, I will feel happy/satisfied/relief" (PA1/PA2/PA3), whereas those for negative affect (NA) were "If I am asked to ride in an automated vehicle, I will feel worried/fear/anxious" (NA1/NA2/NA3), which were adapted from Liu et al. (2019d). Items for behavioral intention (BI) were "I intend to use automated vehicles in the future" (BI1), "I intend to buy automated vehicles in the future" (BI2), and "I will recommend my family members and friends to ride in automated vehicles" (BI3), from Xu et al. (2018). These items were rated on 5-point Likert-type scales (*totally disagree*=1 and *totally agree*=5).

In the exploratory factor analysis (EFA), we first examined the number of factors to extract. Data of Studies 1 and 2 were combined (total $N=908$). The Kaiser–Meyer–Olkin (KMO) factor adequacy index (KMO=.90, > .60) and Bartlett's sphericity tests ($\chi^2=10{,}610.02$, $p<.001$) supported the suitability of the data for EFA. Given that the Kaiser rule (i.e. the eigenvalue-greater-than-one rule) is not the best method for deciding on the number of factors to extract, we used parallel analysis (Horn, 1965). We used the "fa.parallel" function of the R *psych* package (Revelle, 2018), which determined six factors. We set this number in the principal component analysis with varimax rotation. The six factors explained 83.9% of the variance. As shown in Table 1, all items highly loaded

Table 1. Rotated factor patterns (data from Studies 1 and 2).

Item	Rotated factor patterns						Communalities
	I	II	III	IV	V	VI	
Trust1	−.20	.21	**.82**	.24	−.17	.18	.87
Trust2	−.24	.24	**.82**	.20	−.13	.17	.87
Trust3	−.26	.30	**.73**	.20	−.18	.18	.80
PB1	−.12	.26	.24	.18	−.25	**.80**	.87
PB2	−.13	.28	.21	.25	−.18	**.80**	.87
PR1	.17	−.15	−.14	−.06	**.89**	−.16	.89
PR2	.13	−.17	−.17	−.13	**.87**	−.18	.88
PA1	−.14	.19	.22	**.82**	−.11	.13	.81
PA2	−.20	.22	.24	**.83**	−.09	.14	.86
PA3	−.33	.22	.12	**.69**	−.05	.21	.70
NA1	**.84**	−.17	−.20	−.17	.08	−.07	.81
NA2	**.85**	−.15	−.19	−.22	.13	−.09	.86
NA3	**.85**	−.09	−.18	−.18	.16	−.10	.84
BI1	−.10	**.83**	.26	.23	−.14	.17	.86
BI2	−.16	**.83**	.23	.22	−.13	.19	.87
BI3	−.20	**.76**	.19	.20	−.17	.23	.77
Cronbach's α	.90	.90	.91	.85	.87	.85	

PB: Perceived benefit; PR: perceived risk; PA: positive affect; NA: negative affect; BI: behavioral intention.
Corresponding loadings are set in bold (> .60).

on their intended factor (>. 60) and less loaded on other factors (< .40), indicating discriminant validity (Kankanhalli et al., 2005). All Cronbach's α values of the intended factors exceeded .80, indicating internal consistency reliability (Kankanhalli et al., 2005). Thus, the measurement model had acceptable reliability and validity.

Procedure. After given the general introduction of the survey, participants were first asked to rate their agreement or disagreement with the 16 items (see section "Measure design") and then submit their demographic information, including gender (male, female), exact age, education (undergraduate, masters, and doctoral), experience with driver assistance systems, and whether they held a driving license. Considering the potential influence of experience with driver assistance systems on people's benefit and risk judgments of automated driving systems (Brell et al., 2019), we designed a question to measure experience (Brell et al., 2019): Have you ever heard about or used one or more driver assistance systems (e.g. adaptive cruise control system and collision alarm system)? Three options were provided: *Never heard, have theoretical knowledge about the operating principles of driver assistance systems*, and *have used them*. Finally, they were thanked and given a small gift (a pen or a notebook).

Participants. Students in a Chinese university were approached on campus and randomly assigned into one of the four conditions. A total of 440 paper-and-pencil questionnaires were distributed and collected. Three samples were removed because of printing typos, and 12 samples were removed because participants missed several items. In addition, one participant did not provide an age. We used the average age of participants with the same education level as the missing age. Among the final 415 participants, 215 were male and 200 female; their mean age was 21.6 years (standard

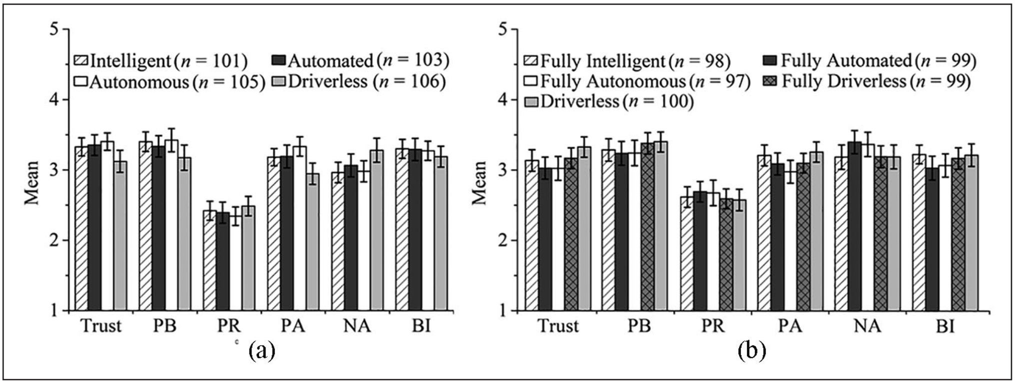

Figure 1. Mean of the six factors in (a) Study 1 and (b) Study 2. Error bar = ± 2 standard error (SE). PB: Perceived benefit; PR: perceived risk; PA: positive affect; NA: negative affect; BI: behavioral intention.

deviation, $SD = 2.9$); 329, 73, and 13 were undergraduate, masters, and doctoral students, respectively; 221 had never heard of driver assistance systems, 175 had theoretical knowledge, and 19 had used them; 213 participants held a driving license and 202 did not.

Results

As shown in Figure 1a, participants seemed to have less favorable attitudinal responses to driverless vehicles compared with three other vehicles. To investigate the framing effect of vehicle name on trust and attitudinal responses (RQ1), we performed analysis of covariance (ANCOVA), a blend of analysis of variance, and regression analysis. In ANCOVA, we examined the significance of the influence of vehicle names on these responses and then looked at the exact differences attributable to vehicle names ("driverless vehicles" as a referent) in the regression analysis. The five demographic factors (gender, age, education, experience, and holder of a driving license) were treated as covariates (see Table 2). We conducted mediation analysis and explored how name frames influence behavioral intention (RQ2).

For addressing RQ1, ANCOVA indicated the significant influence of name frame on trust ($F(3, 406) = 2.98$, $p = .031$, $\eta_p^2 = .022$), negative affect ($F(3, 406) = 3.16$, $p = .025$, $\eta_p^2 = .023$), and positive affect($F(3, 406) = 5.24$, $p = .001$, $\eta_p^2 = .037$), but not on other responses.

Technically, the term "driverless vehicles" is specific to L5 automation (Shladover, 2018), whereas "intelligent," "automated," and "autonomous" can describe L3–L5 vehicles. Here, we used "driverless vehicles" as a referent in the regression analysis. We built a regression model for each psychological factor, with three dummy variables (intelligent, automated, and autonomous) and five demographic factors as potential predictors. We also built an additional model for behavioral intention (Model 2) with these predictors and other five psychological factors as potential determinants of behavioral intention. As shown in Table 2, participants responded differently to driverless vehicles and other vehicles. They placed higher trust in intelligent, automated, and autonomous vehicles compared with driverless vehicles (ps < .05). They perceived (marginally) more benefits of autonomous ($p = .035$) and intelligent vehicles ($p = .053$). Riding in an intelligent, automated, or autonomous vehicle evoked higher positive affect (ps < .05). Accordingly, riding in an intelligent ($p = .004$), automated ($p = .057$), or autonomous vehicle ($p = .015$) evoked (marginally) lower negative affect. Trust, positive affect, and perceived benefit significantly affected behavioral intention in Model 2 (ps < .01). Gender and experience likewise influenced these psychological responses but were not our focus.

Regarding RQ2, mediation analysis was run with trust, perceived benefit and risk, and positive affect and negative affect as five parallel mediators and the five demographic factors as covariates.

Table 2. Unstandardized coefficients in regression models in Study 1 ("driverless vehicle" as a referent).

Predictors	Trust	Perceived benefit	Perceived risk	Positive affect	Negative affect	Behavioral intention	
						Model 1	Model 2
Gender	−0.10	−0.21**	0.06	−0.10	0.17*	−0.14†	−0.01
Age	−0.03†	−0.01	0.02	−0.02	0.02	−0.01	0.01
Education	0.08	0.18	−0.06	0.16	−0.01	0.13	0.03
Experience	0.33***	0.29***	−0.11	0.22**	−0.30***	0.32***	0.10†
Holder of a driving license	0.08	−0.07	0.01	−0.08	−0.05	−0.04	−0.03
Intelligent vehicle	0.22*	0.22†	−0.09	0.26*	−0.32**	0.10	−0.08
Automated vehicle	0.23*	0.18	−0.10	0.27**	−0.21†	0.12	−0.05
Autonomous vehicle	0.26**	0.24*	−0.15	0.40***	−0.27*	0.07	−0.15†
Trust							0.21***
Perceived benefit							0.34***
Perceived risk							−0.03
Positive affect							0.15**
Negative affect							−0.07†

Gender: male = 0, female = 1. Education: undergraduate = 0, other two categories = 1. Experience: never heard = 0, other two categories = 1. Holder of a driving license: no = 0, yes = 1.
†$p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$.

Table 3. Significant indirect effects of vehicle name on behavioral intention in Study 1 and Study 2 ("driverless vehicle" as a referent).

Path	Indirect effect (SE)	95% CI
Study 1		
Intelligent vehicle → Trust → Behavioral intention	0.046 (0.025)	[0.005, 0.104]
Automated vehicle → Trust → Behavioral intention	0.047 (0.026)	[0.003, 0.107]
Autonomous vehicle → Trust → Behavioral intention	0.054 (0.025)	[0.011, 0.110]
Intelligent vehicle → Perceived benefit → Behavioral intention	0.076 (0.040)	[0.001, 0.155]
Autonomous vehicle → Perceived benefit → Behavioral intention	0.082 (0.044)	[0.002, 0.174]
Intelligent vehicle → Positive affect → Behavioral intention	0.038 (0.021)	[0.006, 0.086]
Automated vehicle → Positive affect → Behavioral intention	0.040 (0.023)	[0.006, 0.093]
Autonomous vehicle → Positive affect → Behavioral intention	0.059 (0.027)	[0.016, 0.121]
Study 2		
Fully automated vehicle → Trust → Behavioral intention	−0.116 (0.041)	[−0.201, −0.040]
Fully autonomous vehicle → Trust → Behavioral intention	−0.123 (0.043)	[−0.210, −0.043]
Fully automated vehicle → Positive affect → Behavioral intention	−0.061 (0.034)	[−0.130, −0.001]
Fully autonomous vehicle → Positive affect → Behavioral intention	−0.094 (0.036)	[−0.168, −0.029]

SE: standard error; CI: bootstrap confidence interval.

We used Hayes' (2018) PROCESS Macro (Model 4) with 5000 bootstrapped samples. Although the total effect of vehicle name on behavioral intention was not significant (see Model 1 in Table 2), it had significant indirect effects on behavioral intention through trust, perceived benefit, and positive affect (see Table 3). For instance, participants' higher trust in the three vehicles than driverless vehicles might result in their greater intention to use them.

Discussion

RQ1 asked the framing effect of vehicle name on people's trust and attitudinal responses to advanced vehicles with automated driving systems labeled by different names. Compared with driverless vehicles, the trust, perceived benefit, and positive affect ratings for the other vehicles were (marginally) higher, and the negative affect ratings for others vehicles were (marginally) lower, except that automated and driverless vehicles did not differ in perceived benefit. Myrick et al. (2019) did not find differences between driverless cars and autonomous vehicles in terms of affective responses. The contrast in results could be attributed to the different measures for affective responses or language/cultural differences between Myrick et al.'s (2019) and our Study 1. RQ2 aksed how name frame might affect behavioral intention. Study 1 revealed its indirect effect on behavioral intention through trust, perceived benefit, and positive affect. Myrick et al.'s (2019) also found that an affective response (i.e. excitement) mediated the negative relationship between riding intention and the self-driving car condition (the conditions of autonomous vehicles and driverless cars as the referent).

The observed influence of vehicle name in our Study 1 might be partly due to participants' different prior understanding and cognition of vehicles labeled by these names. In following Study 2, we overcome this limitation and framed L5 vehicles with an identical description but different names, in line with Boersma et al.'s (2019a) study on "genomics" and "natural crossing." Study 2 will demonstrate more robust evidence of the framing effect of vehicle name (if it exists).

4. Study 2

Study 2 aimed to elucidate how participants respond to L5 vehicles labeled by five names: fully intelligent vehicles ("完全智能驾驶汽车"), fully automated vehicles ("完全自动驾驶汽车"), fully autonomous vehicles ("完全自主驾驶汽车"), fully driverless vehicles ("完全无人驾驶汽车"), and driverless vehicles ("无人驾驶汽车"). These L5 vehicles were framed with an identical description but different names.

Methodology

Measure design. The measures of the 16 items were designed exactly as in Study 1, except for two notable differences. First, the four names in Study 1 are for labeling L3–L5 vehicles in public discourse, whereas the five names in Study 2 are specific to technically L5 vehicles. Second, in Study 2, the adverb "fully" was added prior to each of the names examined in Study 1. Given that "driverless" strongly implies a complete replacement of the driver (Shladover, 2018), then technically, the name "driverless vehicles" is specific to L5 vehicles. This name was also in Study 2. For instance, the three trust items in Study 2 were "I think fully automated vehicles are dependable" (Trust1), "I think fully automated vehicles are reliable" (Trust2), and "Overall, I can trust in fully automated vehicles" (Trust3) in the condition of fully automated vehicles.

Procedure. After given the general introduction of the survey, participants in Study 2 were first presented the same description but different names for L5 vehicles. For instance, the description of driverless vehicles was

> The vehicle takes over speed and steering control completely and permanently on all roads and in all situations. The driver or passenger sets a destination via a touchscreen. The driver or passenger cannot drive manually or perform interventions because the vehicle does not have a steering wheel. The driverless vehicle allows drivers (passengers) to perform non-driving activities, such as reading a book, watching a film, surfing the Internet, playing on a phone, dealing with work affairs, and sleeping. (Liu et al., 2019c)

In other conditions, the name "driverless vehicle" was replaced by other names. They were second asked a question (e.g. "Have you already read and understood the description of driverless vehicles?" in the condition of driverless vehicles) to identify inattentive participants or those who did not understand the technology prior to their responses to the vehicles. Then, participants were asked to rate their agreement or disagreement with the 16 items (see section "Measure design") and submit their demographic information, similar to Study 1. Finally, they were thanked and given a small gift (a pen or a notebook).

Participants. A total of 539 participants in a Chinese university were approached and randomly assigned into one of the five conditions. Among them, 8 gave an answer of "No" to the first question, 35 missed certain responses, and 3 made logic errors (i.e. they reported having had actual usage of driver assistance systems but did not have a driving license). Among the final 493 participants, 266 were male and 227 female; their mean age was 21.6 years (SD = 3.5); 409 were undergraduate, 74 were masters, and 10 were doctoral students; 232 had never heard of driver assistance systems, 236 had theoretical knowledge, and 25 had actual usage; 254 held a driving license and 239 did not.

Results

As shown in Figure 1b, participants seemed to have more favorable responses to driverless vehicles compared with fully automated and autonomous vehicles. While investigating the framing effect of L5 vehicle name on trust and attitudinal responses (RQ3), ANCOVA indicated a significant influence of vehicle name on trust ($F(4, 483) = 3.27$, $p = .012$, $\eta_p^2 = .026$) and positive affect ($F(4, 483) = 2.73$, $p = .029$, $\eta_p^2 = .022$) and a marginal influence on negative affect ($F(4, 483) = 1.99$, $p = .095$, $\eta_p^2 = .016$).

Regression analysis with driverless vehicles as a referent in dummy coding indicated that participants had different attitudinal responses to these vehicles (mainly between driverless vehicles and fully automated/autonomous vehicles; see Table 4). Compared with driverless vehicles, fully automated ($p = .003$), fully autonomous ($p = .002$), and fully intelligent vehicles ($p = .062$) were (marginally) less trusted. Participants perceived (marginally) fewer benefits of fully automated ($p = .073$) and fully autonomous vehicles ($p = .044$). Riding in a fully automated ($p = .055$) or fully autonomous vehicle ($p = .003$) evoked (marginally) lower positive affect. Accordingly, riding in a fully automated ($p = .064$) or fully autonomous vehicle ($p = .082$) evoked marginally greater negative affect. Model 1 for Behavioral intention indicated participants' (marginally) lower intention to use fully automated ($p = .047$) and fully autonomous vehicles ($p = .079$). In Model 2, trust, Positive affect, and Perceived benefit were positive predictors of Behavioral intention, whereas and perceived risk and holder of a driving license (no = 0, yes = 1) were negative predictors (ps < .05). As in Study 1, experience and gender influenced one or more psychological responses.

In the mediation analysis for RQ2, vehicle name had significant indirect effects on Behavioral intention through trust and Positive affect (see Table 3). For instance, participants had less trusted in fully automated and autonomous vehicles compared with driverless vehicles, which in turn lowered their intention to use them.

Table 4. Unstandardized coefficients in regression models in Study 2 ("driverless vehicle" as a referent).

Predictors	Trust	Perceived benefit	Perceived risk	Positive affect	Negative affect	Behavioral intention	
						Model 1	Model 2
Gender	−0.02	−0.11	0.06	0.09	0.18*	0.03	0.03
Age	0.01	0.01	0.01	−0.01	0.00	0.01	0.01
Education	−0.10	0.00	0.02	−0.04	0.10	−0.11	−0.06
Experience	0.20**	0.27***	−0.14	0.20**	−0.11	0.23**	0.03
Holder of a driving license	0.03	−0.02	−0.06	0.00	0.05	−0.10	−0.11*
Fully intelligent vehicle	−0.21†	−0.16	0.05	−0.06	−0.02	0.00	0.13†
Fully automated vehicle	−0.33*	−0.20†	0.13	−0.20†	0.22†	−0.22*	0.00
Fully autonomous vehicle	−0.35**	−0.23*	0.13	−0.32**	0.21†	−0.20†	0.07
Fully driverless vehicle	−0.17	−0.03	0.03	−0.17	0.01	−0.05	0.07
Trust							0.35***
Perceived benefit							0.21***
Perceived risk							−0.11**
Positive affect							0.30***
Negative affect							0.05

Gender: male = 0, female = 1. Education: undergraduate = 0, other two categories = 1. Experience: never heard = 0, other two categories = 1. Holder of a driving license: no = 0, yes = 1.
†$p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$.

Discussion

RQ3 asked the framing effect of vehicle name for L5 vehicles. Different from Study 1, Study 2 provided participants with the same description of L5 vehicles, which included information on non-driving activities (i.e. type of benefits related with the use of these vehicles). In this design, participants still had different attitudinal responses to these L5 vehicles with different names. In particular, although the description of these L5 vehicles conveyed the same information on benefits, driverless vehicles led participants to perceive (marginally) more benefits compared with fully automated and autonomous vehicles, probably because these names influenced the interpretation of the benefit information (see also Boersma et al., 2019a) or served as alternative cues. RQ2 aksed how name frame might influence Behavioral intention. Study 2 found its indirect influence on Behavioral intention through trust and Positive affect. Perceived benefit played a mediating role in vehicle name's indirect effect on Behavioral intention in Study 1 but not in Study 2.

5. General discussion

Theoretical implications

Framing effects of technology name. The various names for vehicles with automated driving systems (e.g. intelligent, automated, autonomous, and driverless vehicles), which are frequently and interchangeably used in general discourse, have different meanings (Shladover, 2018) and lead people to mismatch their implied functionality and actual capacity (Nees, 2018). Our focus was on the framing effect of these names on attitudinal responses to these vehicles. Framing effects refer to a phenomenon where (often small) changes in the presentation of an issue produce (sometimes large) changes in opinion and attitude (Chong and Druckman, 2007).

In Study 1, we considered four names for L3–L5 vehicles (i.e. intelligent, automated, autonomous, and driverless vehicles) and found that driverless vehicles were associated with lower trust and less favorable attitude. While providing participants with the same description but five different names for L5 vehicles, Study 2 found that driverless vehicles were associated with higher trust and more favorable attitude than fully automated vehicles and fully autonomous vehicles, offering solid evidence on the framing effect of vehicle name. Therefore, different, albeit logically equivalent, words or phrases can influence individuals' preferences and responses (Druckman, 2004).

We found seemingly "opposite" findings between Study 1 and Study 2: the average evaluations resulting from the name "driverless vehicle" were less favorable in Study 1 but more favorable in Study 2. Study 1's finding may be attributed to the following: (1) the name could be more likely to lead participants to imagine that people have no control of the vehicle; (2) participants had been exposed to more negative and/or less positive information about driverless vehicles compared with other vehicle names that are also used to refer to L3–L5 vehicles in public discourse; (3) some of these participants might have clearly known that driverless vehicles are L5 vehicles and have a lower preference for and more concerns with L5 vehicles compared with other vehicles (see also Schoettle and Sivak, 2014). A notable difference to Study 1 in Study 2 was that participants were given the identical description of L5 vehicles prior to their responses. The description indicated that drivers or passengers cannot intervene with the driving. Thus, the awareness of losing control over the vehicle cannot explain the more favorable evaluations resulting from "driverless vehicles" in Study 2. This name did not have the adverb "fully" compared with the other four names for L5 vehicles. However, this adverb might not be responsible for the significant differences in responses to driverless vehicles and other three vehicles (fully intelligent, fully automated, and fully autonomous vehicles), given the non-significant differences in responses to fully driverless and driverless vehicles (see Table 4). We argue that these names influenced the interpretation of the identical description for L5 vehicles or served as alternative cues, the potential underlying mechanisms of which, however, remain unclear. This point thus merits further investigation.

Our results corroborated the assertion that people use technology names as diagnostic attributes. The naming effect has been studied across several controversial issues, such as "global warming" and "climate change" (Jang and Hart, 2015; Schuldt et al., 2011; Whitmarsh, 2009); "genetic engineering," "genetic modification," and "agriculture biotechnology" (Zahry and Besley, 2019); "fracking" and "shale oil or gas development" (Clarke et al., 2015); and "genomics" and "natural crossing" (Boersma et al., 2019a). Unlike these studies, we examined a relatively non-controversial technology (at least, at present), the names of which are very similar or do not have many differences in the public understanding. Nonetheless, our results still pointed to the framing effect of technology names, even after we controlled for the description of the technology under consideration. Thus, we extend the risk perception and science communication literature on the framing effect of technology names. Technology names yield a non-trivial influence on public attitude.

Regarding behavioral intention in Model 2, name frames did not exert a direct influence but an indirect influence, mainly through trust, Perceived benefit, and positive affect. A similar mechanism underlying the naming effect on acceptance has been revealed (Clarke et al., 2015; Myrick et al., 2019). For instance, in Myrick et al.' (2019) study, although the self-driving car frame (vs the autonomous vehicle/driverless car frames) did not directly influence riding intention, it decreased excitement, a positive affective predictor of riding intention, and thus indirectly decreased riding intention. In Study 1, the indirect effect on behavioral intention was significant even in the absence of a significant total effect (see Model 1 in Table 2), which is possible according to modern thinking about mediation analysis (Zhao et al., 2010). Thus, technology names could indirectly affect public acceptance through their influence on certain cognitive and/or affective determinants of public acceptance.

Determinants of behavioral intention. Certain cognitive and affective responses played a greater role in affecting behavioral intention compared with name frames. In line with several previous studies (e.g. Liu et al., 2019a, 2019b; Xu et al., 2018; Zhang et al., 2019), we found that trust was a robust predictor of behavioral intention in both Studies 1 and 2.

Affect plays an important role in judgments and decisions. Positive affect was a robust predictor of behavioral intention as expected, whereas negative affect did not contribute to behavioral intention ($p > .05$). We found support for this asymmetric impact of positive and negative affect (Merk and Pönitzsch, 2017): Positive affect plays a more important role than negative affect in shaping acceptance of automated vehicles (Liu et al., 2019d, 2019e).

Perceived benefit was another robust predictor in both studies, whereas perceived risk influenced behavioral intention in Study 2 but not in Study 1. Perceived benefit carried more weight in affecting behavioral intention, consistent with previous research (Merk and Pönitzsch, 2017; Midden and Huijts, 2009). Particularly, recent studies (Liu et al., 2019a, 2019d, 2019e; Ward et al., 2017) demonstrated that perceived benefit, rather than perceived risk, is a robust predictor of public acceptance of automated vehicles.

Practical implications

Names of technologies can be a source of misunderstanding and confusion. They also play a role in shaping individuals' evaluations and decisions (Boersma et al., 2019a; Myrick et al., 2019). Several names for vehicles with automated driving systems (e.g. intelligent, automated, autonomous, and driverless vehicles) are used interchangeably. Our results indicate that people have different levels of trust and attitude to these advanced vehicles labeled by these names. Promoters of automated driving technology may choose the name that can simultaneously gain a more favorable public attitude and meet scientific criteria.

The term "driverless vehicle" was found to be more favorable for describing L5 vehicles in Study 2. Technically, this term, which implies a complete replacement of the driver in the driving task, should be specific to L5 vehicles (Shladover, 2018), although it is also widely used for describing L3–L4 vehicles in public discourse. Thus, we suggest the term "driverless vehicle" for L5 vehicles.

Regarding automated vehicles and autonomous vehicles, participants more positively responded to them than to driverless vehicles in Study 1 and they had similar responses to them. The term "automated vehicles" seems to outperform the term "autonomous vehicles," given the strict requirements of vehicles to be deemed "autonomous" (Shladover, 2018). Thus, we suggest the term "automated vehicles" for L3–L4 vehicles.

Limitations and remarks

First, these results are obtained in a single country (i.e. China). Cross-cultural differences exist in public attitude and acceptance of automated vehicles (Moody et al., 2020; Nordhoff et al., 2018b). The name effect might vary between cultures. Thus, replications of our research in other countries and cultures are necessary. Second, the young sample could constrain the generalizability of our results, although the between-subjects design might mitigate the side effect of this sample limitation. Further research can examine these results in the general population. Third, future studies can explore why the selected names elicited different attitudinal responses and whether their influence is due to a deliberate or automatic process. Fourth, since we did not manipulate the psychological mediators, we were unable to detect causal effects (i.e. name frame → psychological mediators → behavioral intention) based on using cross-sectional data. However, in line with previous work (e.g. Clarke et al., 2015; Myrick et al., 2019), we assumed the legitimacy of such causal effects. Fifth, the list of attitudinal responses to automated driving technology was incomplete. Future studies can consider the naming effect on more responses, such as distrust and behavioral avoidance. Sixth, in some policy statements or reports (e.g. National Highway Traffic Safety Administration, 2016), the term "highly automated vehicles" has been used to describe SAE L3–L5 vehicles. We suggest investigating the framing effect (e.g. "highly automated vehicles" vs "fully automated vehicles") and detecting the appropriate term for efficient science communication. Finally, one potential account for the observed framing effect of L5 vehicle name in Study 2 might be that participants might have different understandings of L5 AVs when they saw the identical description but different names. Our limitation is that we did not measure or test how participants thought about L5 AVs, which can be overcome by future studies for an in-depth understanding of the framing effect of vehicle name.

6. Conclusion

Terminology is not neutral. Names carry connotations that can influence the public's attitudinal responses and trust. We examined whether and how the names used to describe vehicles with automated driving systems affected attitudinal responses (cognitive, affective, and behavioral) and trust. Name frames influenced trust, perceived benefit, negative affect, and positive affect. The names for vehicles with full automation influenced attitudinal responses and trust even if supplemented with the same information about the technology. Thus, naming is framing, and terminology should not be used indiscriminately. Names had a minor direct influence on behavioral intention but had an indirect influence through trust, perceived benefit, and positive affect. Trust, perceived benefit, and positive affect were the three consistent predictors of behavioral intention. Our results showed the importance of terminology standardization and the potential benefits of selecting appropriate names, particularly for promoters of this technology. To form a more favorable attitude among the public, promoters of this vehicle technology can use the name "automated vehicles" for L3–L4 vehicles and "driverless vehicles" for L5 vehicles.

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ORCID iDs

Peng Liu https://orcid.org/0000-0003-4929-0531

Qingqing Fei https://orcid.org/0000-0002-9862-4713

Jinting Liu https://orcid.org/0000-0002-1910-2811

References

Abraham H, Seppelt B, Mehler B and Reimer B (2017) What's in a name: Vehicle technology branding & consumer expectations for automation. In: *Proceedings of the 9th international conference on automotive user interfaces and interactive vehicular applications*, Oldenburg, 24–27 September.

Anania EC, Rice S, Walters NW, Pierce M, Winter SR and Milner MN (2018) The effects of positive and negative information on consumers' willingness to ride in a driverless vehicle. *Transport Policy* 72: 218–224.

Banks VA, Plant KL and Stanton NA (2018) Driver error or designer error: Using the Perceptual Cycle Model to explore the circumstances surrounding the fatal Tesla crash on 7th May 2016. *Safety Science* 108: 278–285.

Boersma R, Poortvliet PM and Gremmen B (2019a) The elephant in the room: How a technology's name affects its interpretation. *Public Understanding of Science* 28: 218–233.

Boersma R, Poorvliet PM and Gremmen B (2019b) Naming is framing: The effects of a technological name on the interpretation of a technology. *Journal of Science Communication* 18: A04.

Brell T, Philipsen R and Ziefle M (2019) sCARy! Risk perceptions in autonomous driving: The influence of experience on perceived benefits and barriers. *Risk Analysis* 39: 342–357.

Choi JK and Ji YG (2015) Investigating the importance of trust on adopting an autonomous vehicle. *International Journal of Human-Computer Interaction* 31: 692–702.

Chong D and Druckman JN (2007) Framing theory. *Annual Review of Political Science* 10: 103–126.

Clarke CE, Hart PS, Schuldt JP, Evensen DTN, Boudet HS, Jacquet JB, et al. (2015) Public opinion on energy development: The interplay of issue framing, top-of-mind associations, and political ideology. *Energy Policy* 81: 131–140.

Cunningham ML, Regan MA, Ledger SA and Bennett JM (2019) To buy or not to buy? Predicting willingness to pay for automated vehicles based on public opinion. *Transportation Research Part F: Traffic Psychology and Behaviour* 65: 418–438.

Druckman JN (2004) Political preference formation: Competition, deliberation, and the (ir)relevance of framing effects. *American Political Science Review* 98: 671–686.

Eagly AH and Chaiken S (1993) *The Psychology of Attitudes*. Fort Worth, TX: Harcourt, Brace, & Janovich.

Entman RM (1993) Framing: Toward clarification of a fractured paradigm. *Journal of Communication* 43: 51–58.

Fraedrich E and Lenz B (2016) Societal and individual acceptance of autonomous driving. In: Maurer M, Gerdes JC, Lenz B and Winner H (eds) *Autonomous Driving: Technical, Legal and Social Aspects*. London: Springer, pp. 621–640.

Gandia RM, Antonialli F, Cavazza BH, Neto AM, Lima DAd, Sugano JY, et al. (2019) Autonomous vehicles: Scientometric and bibliometric review. *Transport Reviews* 39: 9–28.

Hardman S, Lee JH and Tal G (2019) How do drivers use automation? Insights from a survey of partially automated vehicle owners in the United States. *Transportation Research Part A: Policy and Practice* 129: 246–256.

Hayes AF (2018) *Introduction to Mediation, Moderation, and Conditional Process Analysis: A Regression-based Approach*. London: The Guilford Press.

Hohenberger C, Spörrle M and Welpe IM (2016) How and why do men and women differ in their willingness to use automated cars? The influence of emotions across different age groups. *Transportation Research Part A: Policy and Practice* 94: 374–385.

Horn JL (1965) A rationale and test for the number of factors in factor analysis. *Psychometrika* 30: 179–185.

Hryniewicz K and Grzegorczyk T (2020) How different autonomous vehicle presentation influences its acceptance: Is a communal car better than agentic one? *PLoS ONE* 15: e0238714.

Jang SM and Hart PS (2015) Polarized frames on "climate change" and "global warming" across countries and states: Evidence from Twitter big data. *Global Environmental Change* 32: 11–17.

Kankanhalli A, Tan BCY and Wei K-K (2005) Contributing knowledge to electronic knowledge repositories: An empirical investigation. *MIS Quarterly* 29: 113–143.

Liu H, Yang R, Wang L and Liu P (2019a) Evaluating initial public acceptance of highly and fully autonomous vehicles. *International Journal of Human-Computer Interaction* 35: 919–931.

Liu P and Xu Z (2020) Public attitude toward self-driving vehicles on public roads: Direct experience changed ambivalent people to be more positive. *Technological Forecasting and Social Change* 151: 119827.

Liu P, Guo Q, Ren F, Wang L and Xu Z (2019b) Willingness to pay for self-driving vehicles: Influences of demographic and psychological factors. *Transportation Research Part C: Emerging Technologies* 100: 306–317.

Liu P, Ma Y and Zuo Y (2019c) Self-driving vehicles: Are people willing to trade risks for environmental benefits? *Transportation Research Part A: Policy and Practice* 125: 139–149.

Liu P, Xu Z and Zhao X (2019d) Road tests of self-driving vehicles: Affective and cognitive pathways in acceptance formation. *Transportation Research Part A: Policy and Practice* 124: 354–369.

Liu P, Yang R and Xu Z (2019e) Public acceptance of fully automated driving: Effects of social trust and risk/benefit perceptions. *Risk Analysis* 39: 326–341.

Madigan R, Louw T, Wilbrink M, Schieben A and Merat N (2017) What influences the decision to use automated public transport? Using UTAUT to understand public acceptance of automated road transport systems. *Transportation Research Part F: Traffic Psychology and Behaviour* 50: 55–64.

Merk C and Pönitzsch G (2017) The role of affect in attitude formation toward new technologies: The case of stratospheric aerosol injection. *Risk Analysis* 37: 2289–2304.

Midden CJH and Huijts NMA (2009) The role of trust in the affective evaluation of novel risks: The case of CO2 storage. *Risk Analysis* 29: 743–751.

Moody J, Bailey N and Zhao J (2020) Public perceptions of autonomous vehicle safety: An international comparison. *Safety Science* 121: 634–650.

Motamedi S, Wang P, Zhang T and Chan C-Y (2020) Acceptance of full driving automation: Personally owned and shared-use concepts. *Human Factors* 62: 288–309.

Myrick JG, Ahern L, Shao R and Conlin J (2019) Technology name and celebrity endorsement effects of autonomous vehicle promotional messages: Mechanisms and moderators. *Science Communication* 41: 38–65.

National Highway Traffic Safety Administration (2016) *Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety*. Washington, DC: National Highway Traffic Safety Administration (NHTSA), U.S. Department of Transportation.

Nees MA (2018) Drivers' perceptions of functionality implied by terms used to describe automation in vehicles. In: *Proceedings of the human factors and ergonomics society annual meeting 2018*, Philadelphia, PA, 1–5 October.

Nordhoff S, de Winte J, Madigan R, Merat N, van Arem B and Happee R (2018a) User acceptance of automated shuttles in Berlin-Schöneberg: A questionnaire study. *Transportation Research Part F: Traffic Psychology and Behaviour* 58: 843–854.

Nordhoff S, de Winter J, Kyriakidis M, van Arem B and Happee1 R (2018b) Acceptance of driverless vehicles: Results from a large cross-national questionnaire study. *Journal of Advanced Transportation* 2018: 5382192.

Panagiotopoulos I and Dimitrakopoulos G (2018) An empirical investigation on consumers' intentions towards autonomous driving. *Transportation Research Part C: Emerging Technologies* 95: 773–784.

Pilkington OA (2019) Definitions of scientific terminology in popular science books: An examination of definitional chains. *Science Communication* 41: 580–601.

Revelle W (2018) How to: Use the psych package for Factor Analysis and data reduction. Available at: http://ww.personality-project.org/r/psych/HowTo/factor.pdf (accessed 16 May 2019).

Rosenberg MJ and Hovland CI (1960) Cognitive, affective, and behavioral components of attitude. In: Rosenberg MJ, Hovland CI, McGuire WJ, Abelson RP and Brehm JW (eds) *Attitude Organization and Change: An Analysis of Consistency Among Attitude Components*. New Haven: Yale University Press, pp. 1–14.

Schmitt B (2016) German government asks Tesla to rename Autopilot, and drivers to read their owner's manual. *Forbes*. Available at: https://www.forbes.com/sites/bertelschmitt/2016/10/14/german-government-asks-tesla-to-rename-autopilot-and-drivers-to-read-their-owners-manual/#592c4cfc51d2 (accessed 26 August 2019).

Schoettle B and Sivak M (2014) *A Survey of Public Opinion About Autonomous and Self-Driving Vehicles in the U.S., the U.K., and Australia*. Ann Arbor, MI: Transportation Research Institute, University of Michigan.

Schuldt JP, Konrath SH and Schwarz N (2011) "Global warming" or "climate change"?: Whether the planet is warming depends on question wording. *Public Opinion Quarterly* 75: 115–124.

Shariff A, Bonnefon J-F and Rahwan I (2017) Psychological roadblocks to the adoption of self-driving vehicles. *Nature Human Behaviour* 1: 694–696.

Shladover SE (2018) Connected and automated vehicle systems: Introduction and overview. *Journal of Intelligent Transportation Systems* 22: 190–200.

Society of Automotive Engineers (SAE) (2018) *Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems*. Washington, DC: SAE International.

Society of Automotive Engineers (SAE) (2020) *Clearing the Confusion: Recommended Common Naming for Advanced Driver Assistance Technologies*. Washington, DC: SAE International.

Teoh ER (2020) What's in a name? Drivers' perceptions of the use of five SAE Level 2 driving automation systems. *Journal of Safety Research* 72: 145–151.

Vishwanath A (2009) From belief-importance to intention: The impact of framing on technology adoption. *Communication Monographs* 76: 177–206.

Ward C, Raue M, Lee C, Ambrosio LD and Coughlin JF (2017) Acceptance of automated driving across generations: The role of risk and benefit perception, knowledge, and trust. In: *19th international conference on human-computer interaction*, Vancouver, BC, Canada, 9–14 July.

Whitmarsh L (2009) What's in a name? Commonalities and differences in public understanding of "climate change" and "global warming." *Public Understanding of Science* 18: 401–420.

Xu Z, Zhang K, Min H, Wang Z, Zhao X and Liu P (2018) What drives people to accept automated vehicles? Findings from a field experiment. *Transportation Research Part C: Emerging Technologies* 95: 320–334.

Zahry NR and Besley JC (2019) Genetic engineering, genetic modification, or agricultural biotechnology: Does the term matter? *Journal of Risk Research* 22: 16–31.

Zhang T, Tao D, Qu X, Zhang X, Lin R and Zhang W (2019) The roles of initial trust and perceived risk in public's acceptance of automated vehicles. *Transportation Research Part C: Emerging Technologies* 98: 207–220.

Zhao X, Lynch JG Jr and Chen Q (2010) Reconsidering Baron and Kenny: Myths and truths about mediation analysis. *Journal of Consumer Research* 37: 197–206.

Author biographies

Peng Liu, corresponding author, is an associate professor at Tianjin University in China. His research focuses on human factors and ergonomics, risk analysis, and risk perception and communication related to complex systems, such as autonomous driving and nuclear power plants.

Qingqing Fei graduated from Tianjin University in China. Her research focuses on risk communication.

Jinting Liu is a graduate student at Tianjin University in China. His research focuses on human factors in autonomous driving.

Jianqiang Wang is an associate professor at Lanzhou Jiaotong University (LZJTU) in China. His research interests include dynamic route planning of autonomous vehicles and traffic flow.