Age Differences in Acceptance of Self-driving Cars: A Survey of Perceptions and Attitudes

Chaiwoo Lee(✉), Carley Ward, Martina Raue, Lisa D'Ambrosio, and Joseph F. Coughlin

Massachusetts Institute of Technology AgeLab, Cambridge, MA, USA
chaiwoo@mit.edu

Abstract. As self-driving cars begin to make their way on to the road, there is a growing need for research to understand acceptance of the technology among potential users. This study looked at responses from a national sample of 1,765 adults in the United States to uncover key determinants of the acceptance of self-driving cars and to understand how age and other characteristics relate to perceptions of and attitudes toward self-driving cars. Data from the online survey showed that perceived usefulness, affordability, social support, lifestyle fit and conceptual compatibility are key predictors of acceptance of self-driving cars across ages. A comparison across generational cohorts (i.e., Millennials, Generation X, Baby Boomers and the Silent Generation) found that age negatively affects perceptions of a self-driving car, interest in using it, and behavioral intentions to use one when it becomes available. Furthermore, experiential characteristics associated with age, including experiences with, knowledge of and trust toward technology in general, were found to have significant influence on how people felt about self-driving cars.

Keywords: Technology adoption · Automotive technology · Automated driving · Traffic safety · Technology experience

1 Introduction

A growing number of companies and organizations are working to bring self-driving cars – vehicles that can sense the surrounding environment and operate in it without requiring control, navigation or monitoring from a driver – to the road. Prototypes of self-driving cars and related technologies are continuously being tested for their functionality. Little is known, however, about how self-driving cars and their features are perceived and accepted by potential consumers and users.

There is a significant body of research around technology acceptance across various domains. Numerous studies have built on to earlier models such as the Technology Acceptance Model (TAM) [1] and the Diffusion of Innovations Theory [2]. In TAM, perceived usefulness and perceived ease-of-use are main factors that affect a user's attitudes toward using technology, which then influences the user's behavioral intentions and actual usage, as illustrated in Fig. 1. In the Diffusion of Innovations Theory, five characteristics – relative advantage, compatibility, complexity, trialability and observability – are the key factors that underlie adoption. Research stemming from

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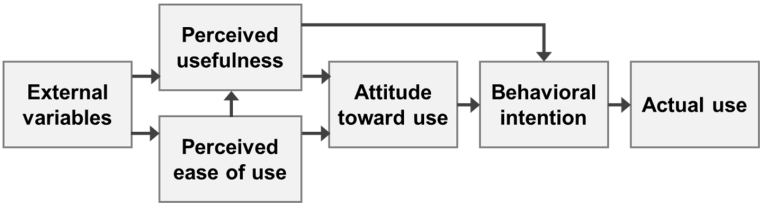

Fig. 1. Technology acceptance model [1]

these early models has described how perceived usefulness, ease-of-use, social influence, personal characteristics, cost and other factors also affect the adoption and use of technologies [3–8].

Recently, studies have begun to explore user perceptions and attitudes in relation to the acceptance of automotive technologies. In a study on automotive telematics, vehicle technologies that combine wireless communications technology and location-based services, Chen and Chen [9] tested different technology acceptance frameworks to understand the determinants of adoption and found perceived ease of use to be a key factor. Effects of individual characteristics on adoption have gained interest as well. For example, Son et al. [10] studied advanced driver assistance systems including forward collision warning and lane departure warning, and found differences by gender and age, with women and younger drivers showing lower acceptance. Efforts to understand user acceptance of automotive technologies are also beginning to focus on automated vehicles that do not require a human operator. For example, Madigan et al. [11] studied user acceptance of an automated public transport service for short-haul travel and found performance expectancy, effort expectancy and social influence to be key predictors. Abraham et al. [12] conducted a large-scale survey to understand acceptance of varying levels of automation in vehicles, and found that younger adults were more comfortable with the fully autonomous, or self-driving, mode compared to older adults.

Self-driving cars promise benefits for a diversity of road users, including drivers of various ages and abilities. With the aging of the population, the number of older drivers is expected to increase rapidly. The number of licensed drivers 70 years of age and older increased by 38% between 1997 and 2014 [13], and the trend is projected to continue. Age-related changes in physical and cognitive capabilities, however, can lead to declines in mobility and driving abilities [14, 15], leading many older adults to stop driving altogether. For this reason, they may be the primary beneficiaries of self-driving cars. Older adults, however, have knowledge of and experiences with technology that may differ from younger generations, which may cause them to perceive and accept self-driving cars differently [10, 12].

While research on technology adoption and transportation safety has begun to explore determinants of acceptance and age effects with regards to new automotive technologies, how different generations perceive and accept self-driving cars is not yet fully understood. In this study, a large-scale survey was conducted to investigate older adults' perceptions of and attitudes toward self-driving cars, and how their perspectives differ from other generations.

2 Data Collection

2.1 Questionnaire Design

A questionnaire was designed to gather people's attitudes toward and perceptions of self-driving cars, as well as interest in use and adoption. Questions explored various factors that contribute to technology acceptance and adoption identified in previous research [1, 8], as described in Table 1. In order to learn about other characteristics that may affect acceptance of a self-driving car, questions were also asked around experiences with technology in general, driving behavior and history, and demographics.

The questionnaire also included the following short description of a self-driving car: "For the purpose of this study, we define self-driving cars as those in which operation of the vehicle occurs without the driver controlling the steering, acceleration, and braking; the driver is not expected to constantly monitor the roadway. A self-driving car uses advanced sensors and software to navigate itself to your destination, understand the road environment, and react to various changes in the driving situation from traffic congestion to a pedestrian crossing the street. Some of the anticipated benefits from these vehicles include: more opportunity for people to use their time productively, increased safety on the road, and greater efficiency." Participants were shown the description before the questions displayed in Table 1 were asked, in order to establish a basic baseline knowledge.

Table 1. Technology adoption factors asked in the survey (adapted from [1, 8])

Category	Factor	Question statement	Response scale
Perceptions	Usefulness	How effective do you think that self-driving cars will be at preventing accidents?	1: Not effective at all–5: very effective
	Ease of use	Self-driving cars would be easy to use	1: Strongly disagree–5: strongly agree
	Affordability	Self-driving cars would be affordable for me	
	Accessibility	I will know where to find self-driving cars when they become available	
	Technical support	I will know where to go for technical support if something went wrong with a self-driving car	
	Emotional benefits	Self-driving cars would provide emotional benefits to users	
	Social support	My family and friends will approve of me using a self-driving car	
	Reliability	Self-driving cars will work reliably over time	

(*continued*)

Table 1. (*continued*)

Category	Factor	Question statement	Response scale
	Interoperability	Self-driving cars will work well with other smart technologies	
	Lifestyle fit	Using a self-driving car will fit into my lifestyle	
	Conceptual compatibility/fit	Self-driving cars will work in ways that make sense to me	
Attitudes toward use	Overall interest	How interested are you in using a self-driving car?	1: Not at all–5: very interested
Behavioral intention to use	Likelihood of adoption - general	How likely would you be to purchase a self-driving car?	1: Not at all–5: very likely
	Likelihood of adoption - conditional	How likely would you be to use a self-driving car if you were no longer capable of driving?	
External variables	Age (year of birth)	What is your year of birth?	n/a
	Technology experience	How would you rate your level of experience with technology in general?	1: Not experienced at all–5: very experienced
	Technology confidence	How confident are you generally in your ability to learn and use new technologies?	1: Not very confident–5: extremely confident
	Technology trust	How would you rate your overall level of trust toward technology?	1: No trust at all–5: very high trust
	Knowledge of new technologies	Select the technologies that you know about: smart glasses, smart watches, smart thermostats, smart TVs, drones, 3-D printers, tablets, smartphones, GPS navigation systems, fitness bands, cloud data storage, ridesharing services and mobile payment services.	0 (none checked)–13 (all checked)
	Driving experience	Do you have a current, valid driver's license?	Yes or no

2.2 Sample Profile

The survey was conducted in the United States, and responses were collected from a national sample of 1,765 adults. Data collection was completed online with a panel service provided by Qualtrics (http://qualtrics.com). The sample represented a wide age distribution and various demographic traits as summarized in Table 2.

Table 2. Participant profile (n = 1,765)

Characteristics	Descriptive statistics
Age (year of birth)	Silent Generation (born on or before 1945): 241 (13.7%)
	Older Baby Boomers (born 1946–1954): 303 (17.2%)
	Younger Baby Boomers (born 1955–1964): 341 (19.3%)
	Generation X (born 1965–1980): 332 (18.8%)
	Older Millennials (born 1981–1989): 307 (17.4%)
	Younger Millennials (born 1990–1998): 241 (13.7%)
Gender	Male: 933 (52.9%)
	Female: 815 (46.2%)
	Other or no answer: 17 (1.0%)
Education	Some high school or less: 36 (2.0%)
	High school diploma: 354 (20.1%)
	Some college: 442 (25.0%)
	Trade/technical/vocational school or associate's degree: 210 (11.9%)
	College degree: 449 (25.4%)
	Some post-graduate work: 75 (4.2%)
	Post-graduate degree: 199 (11.3%)
Marital status	Single, never married: 509 (28.8%)
	Married or living with a partner: 926 (52.5%)
	Divorced or separated: 230 (13.0%)
	Widowed: 99 (5.6%)
	Other: 1 (0.1%)
Ethnicity	White: 1411 (79.9%)
	Black or African-American: 147 (8.3%)
	Hispanic or Latino: 56 (3.2%)
	Asian or Asian-American: 77 (4.4%)
	Other or multiracial: 74 (4.2%)
Employment	Employed full-time: 526 (29.8%)
	Employed part-time: 172 (9.7%)
	Not employed: 197 (11.2%)
	Self-employed: 123 (7.0%)
	Retired: 501 (28.4%)
	Student: 80 (4.5%)
	Homemaker: 143 (8.1%)
Annual household income	Less than 25,000 USD: 451 (25.6%)
	25,000 USD or more but less than 50,000 USD: 529 (30.0%)
	50,000 USD or more but less than 75,000 USD: 365 (20.7%)
	75,000 USD or more but less than 100,000 USD: 237 (13.4%)
	100,000 USD or more but less than 150,000 USD: 133 (7.5%)
	150,000 USD or more: 50 (2.8%)

The majority of the participants had a valid driver's license at the time of data collection (89.2%). Most of them self-reported as frequent and safe drivers, with 57.2% driving at least five days per week; 69.8% reported they had never been stopped by a police officer for a moving violation, and 51.4% reported they had never been in a traffic accident.

3 Results

Statistical analysis was done to describe how perceptions of self-driving cars influence attitudes toward use and behavioral intentions to use them. Effects of age were analyzed to understand how potential users of different generations feel about self-driving cars and if they differ in terms of their willingness to use. Possible effects of past experiences with technology and driving behavior were also analyzed. The overall research model, which includes factors and measures described in Table 1, is illustrated in Fig. 2.

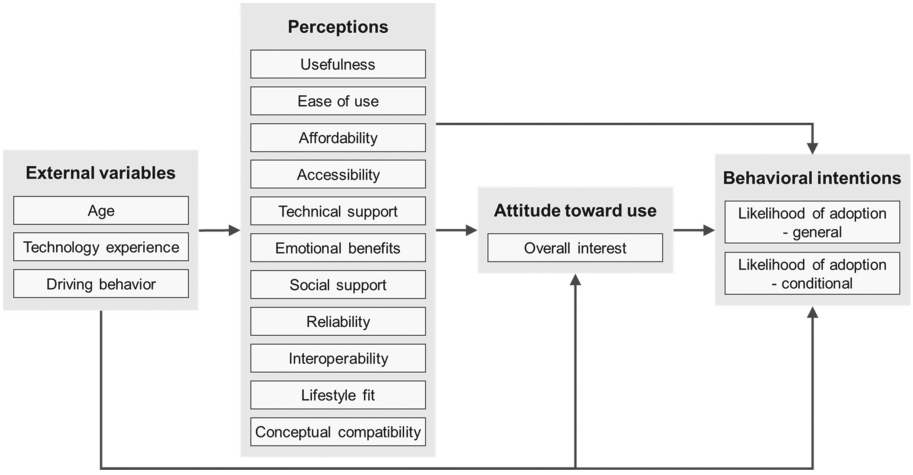

Fig. 2. Conceptual research model

3.1 Determinants of Self-driving Car Acceptance

The results of a regression analysis of acceptance measures on adoption factors are summarized in Table 3. The following factors were significant predictors of self-driving car acceptance: perceived usefulness, affordability, social support, lifestyle fit and conceptual compatibility. Across ages, those who perceived self-driving cars to be more practical, affordable, accepted by peers, and compatible with their lifestyles and conceptual mental models were more interested in getting and using them. Furthermore, attitudinal interest in self-driving cars strongly predicted behavioral intentions to use them.

Table 3. Regression results: effects of adoption factors (standardized β coefficients)

Independent measures		Dependent measures		
		Attitude	Behavioral intentions	
		Overall interest	General	Conditional
Perceptions	Usefulness	.294**	.274**	.219**
	Ease of use	.036	.101	.086**
	Affordability	.060**	.209**	–.053*
	Accessibility	–.017	.025	.004
	Technical support	.006	.024	–.050
	Emotional benefits	.028	.020	.090**
	Social support	.053*	.058*	.055*
	Reliability	.010	–.032	.046
	Interoperability	.001	–.032	.033
	Lifestyle fit	.389**	.336**	.265**
	Conceptual fit	.103**	.052	.132**
	R^2 (perceptions → attitude and behavioral intentions)	.721	.648	.549
Attitude	Overall interest	–	.891**	.775**
	R^2 (attitude → behavioral intentions)	–	.794	.600

* $p < 0.05$, ** $p < 0.01$.

3.2 Age Differences

Age was negatively associated with perceptions, attitudes and behavioral intentions toward the acceptance and use of self-driving cars. As summarized in Table 4, a comparison of average ratings across generations with analysis of variance (ANOVA) showed that older participants perceived self-driving cars as significantly less useful ($F = 33.033$, $p = .000$) and more difficult to use ($F = 26.965$, $p = .000$) compared to younger participants. Older adults were also more likely to think that self-driving cars would be more expensive ($F = 45.233$, $p = .000$) and more difficult to find where to purchase or access ($F = 8.025$, $p = .000$). Older adults indicated that they believed self-driving cars were less likely to be backed up with technical support ($F = 21.406$, $p = .000$), less likely to provide emotional benefits ($F = 20.853$, $p = .000$), less likely to be approved by their peers ($F = 27.341$, $p = .000$), less reliable ($F = 14.530$, $p = .000$), less likely to work with other technologies they have ($F = 21.637$, $p = .000$), and less likely to fit with their lifestyles ($F = 44.268$, $p = .000$) and mental models ($F = 21.483$, $p = .000$), compared to younger participants.

Strong inverse relationships with age were also found for overall level of interest in using a self-driving car ($F = 90.529$, $p = .000$) and likelihood of purchasing one in the future (general: $F = 82.792$, $p = .000$, if no longer able to drive: $F = 41.170$, $p = .000$), indicating that older adults are currently less interested in self-driving cars and less likely to use one when it becomes available. Millennials, those born between

Table 4. Age differences: mean comparisons (all measured on a 5-point scale, ANOVA results significant at $\alpha = 0.01$ for all factors)

		Silent generation (~1945)	Baby Boomers (1946–1964)	Generation X (1965–1980)	Millennials (1981–1998)
Perceptions	Usefulness	2.93	3.01	3.30	3.58
	Ease of use	3.15	3.28	3.58	3.78
	Affordability	2.12	2.18	2.55	2.95
	Accessibility	2.92	2.95	2.99	3.30
	Technical support	2.61	2.73	2.97	3.27
	Emotional benefits	2.89	2.99	3.19	3.50
	Social support	2.71	2.92	3.18	3.45
	Reliability	3.33	3.32	3.55	3.75
	Interoperability	3.30	3.39	3.58	3.87
	Lifestyle fit	2.47	2.77	3.17	3.49
	Conceptual fit	3.05	3.16	3.39	3.67
Attitude	Overall interest	2.15	2.48	3.10	3.57
Behavioral intention	General	1.92	2.11	2.77	3.14
	Conditional	2.85	2.97	3.48	3.77

1981 and 1998, were most favorable toward the use of self-driving cars. They indicated interest in using a self-driving car ($M = 3.57$ out of 5), and said they would consider getting one in the future generally ($M = 3.14$ out of 5) or if they were no longer able to drive ($M = 3.77$ out of 5). On the opposite end, the Silent Generation, those born in or before 1945, displayed low overall interest ($M = 2.15$ out of 5) and said that they are not likely to consider using a self-driving car in any case ($M = 1.92$ out of 5). Across ages, however, participants indicated that they would be more likely to use a self-driving car if they were no longer able to drive and less likely to use one if they were capable of driving.

3.3 Effects of Experience with Technology in General and Driving

In addition to age, experience with technology in general was strongly associated with self-driving car acceptance. Regression analyses showed that, across ages, participants who self-reported greater experience with technology in general and higher confidence in use of new technologies were significantly more interested in self-driving cars and more likely to purchase one in the future, as summarized in Table 5. Those who self-reported being more knowledgeable of new technologies were significantly more likely to purchase a self-driving car in the future if they were no longer able to drive. Trust toward technology in general had the strongest effect on self-driving car

Table 5. Effects of external variables on acceptance (standardized β coefficients)

Dependent measures		Independent measures – external variables					
		Year of birth	General technology experience and perceptions				R^2
			Experience	Confidence	Trust	Knowledge	
Perceptions	Usefulness	.004	.013	.031	.440**	.016	.217
	Ease of use	.013	–.011	.116**	.395**	.038	.219
	Affordability	.023	.178**	–.006	.308**	–.096**	.168
	Accessibility	–.023	.116**	.077*	.264**	.013	.152
	Technical support	–.015	.152**	.035	.313**	–.022	.181
	Emotional benefits	.012	.030	–.014	.397**	–.011	.162
	Social support	.025	.054	.020	.377**	.000	.175
	Reliability	–.005	–.006	–.002	.478**	.043	.233
	Interoperability	.029	–.013	.024	.430**	.096**	.215
	Lifestyle fit	.039	.043	.032	.409**	.007	.206
	Conceptual fit	.022	–.010	.082**	.414**	.035	.216
Attitude	Overall interest	.032	.117**	.071*	.396**	.020	.266
Behavioral intention	General	.017	.131**	.067*	.379**	–.008	.249
	Conditional	.029	.023	.071*	.354**	.054*	.180

* $p < 0.05$, ** $p < 0.01$.

acceptance. Among all technology experience measures, overall trust toward technology had the strongest effect on self-driving car acceptance as shown in Table 5.

As shown in Table 5, technology experience, confidence, trust and knowledge also had significant effects on self-driving car acceptance. These technology measures were not independent of age, however. The ages of participants, measured as year of birth, were correlated with self-rated level of experience with technology in general (Spearman's rank correlation $\rho = .390$, $p = .000$), confidence in ability to learn and use new technologies ($\rho = .325$, $p = .000$), overall level of trust in technology ($\rho = .196$, $p = .000$), and knowledge of new technologies ($\rho = .139$, $p = .000$). The findings suggest that while self-driving car acceptance varies across generations, as shown in Table 4, age may have an indirect effect on acceptance through experience with technology in general.

Additionally, current drivers and non-drivers showed minor differences in their attitudes toward using self-driving cars. Participants who did not have a valid driver's license were significantly ($p = .025$) more likely to be interested in using a self-driving car ($M = 3.12$ out of 5) than those who currently had a valid driver's license ($M = 2.86$ out of 5). No significant interaction effects were observed between age and possession of a driver's license.

4 Discussion and Conclusion

Self-driving cars have the potential to make transportation safer and more convenient for all users. Older adults, who are more likely than younger generations to experience difficulties with driving, are uniquely positioned to benefit from the enhanced mobility such technology could provide them.

In this study, a large-scale national survey was conducted to understand people's perceptions of and attitudes toward acceptance of self-driving cars, and to describe how age and other characteristics influence their thoughts. An online questionnaire was used to gather responses on evaluations of various technology adoption factors, overall interest in using a self-driving car, behavioral intentions to use, driving behavior, experience with technology in general, and demographics.

Across ages, perceived usefulness, affordability, social support, lifestyle fit and conceptual compatibility were significant determinants of self-driving car acceptance. The results from this study, however, suggest that older generations may not yet be ready to take their hands off the wheel and hop into a self-driving car. Age was inversely correlated with all predictors of self-driving car acceptance, as well as overall interest and behavioral intentions to use. While younger generations reported greater interest, older respondents thought of self-driving cars as less beneficial and were less interested in using them. An analysis with the effects of experience with technology in general further revealed that people who self-reported greater experience with technology in general, higher confidence in use of new technologies, higher overall trust toward technology, and greater knowledge of new technologies were more accepting of self-driving cars. These technology experience variables, which were all negatively associated with age, also showed significant effects on acceptance in addition to chronological age.

The findings indicate a need for further research on generational differences in relation to past experiences, perceived benefits of, and trust in adopting self-driving cars. While the results from this study found older adults to be less accepting of fully-automated self-driving cars, a few studies on advanced driver assistance systems suggest that older drivers were more likely to accept new in-vehicle technologies [10, 16]. Future studies can explore age differences around the acceptance of varying levels of vehicular automation. Additionally, research is needed to further explain potential links among age, technology experiences, trust and risk perceptions, and to describe how these relationships may affect acceptance of future systems.

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