Users' Perceptions and Attitudes toward Autonomous Vehicle Technologies after Simulation Exposure – A Study across the Lifespan

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Abstract

The deployment of autonomous vehicles (AV) holds great promise for revolutionizing transportation with the potential to realize traffic safety, mobility, and societal benefits. However, such benefits can materialize only if transportation users are willing to embrace the emerging technologies. This paper reports on a study that quantified Intention to Use, perceived Barriers, and Acceptance of AVs of 101 drivers across the lifespan who have been exposed to "driving" an interactive high-fidelity driving simulator operating in an autonomous mode. Comparison of responses before and after exposure was performed to examine differences within and between age groups (younger, middle-aged, and older adults) and examine gender-related impacts. The statistical analysis revealed that older and middle-aged adults showed statistically significant positive changes in perceptions toward AVs after exposure to the driving simulator in AV mode, as compared to the baseline (pre-exposure). Older drivers showed the greatest improvement in change scores for Intention to Use, Barriers, and Acceptance toward AVs, compared to middle-aged and younger drivers. With respect to gender differences, female drivers showed increased comfort with AVs after exposure to the driving simulator. Moreover, positive changes for Intention to Use, Barriers, and Acceptance were greater for females than males. The study further confirmed that a simulator programmed to run in autonomous mode is a feasible way to expose users to AV technologies in a controlled environment, and can support user acceptance of this emerging technology.

Keywords: Autonomous vehicles; driving simulator; survey; Intention to Use; Barriers; Acceptance.

1 Introduction

The deployment of Autonomous Vehicles (AVs) is expected to have significant impacts on traffic congestion, safety, and the well-being of road users throughout their lifespan, should users accept and adopt these technologies [1]. A number of studies have been conducted to date to capture the drivers' perceptions about autonomous vehicles. Recent reviews [2], [3] suggest that age and gender moderate users' acceptance and willingness to use AVs. A 2019 US-based survey conducted by Lee [4] indicated that among 3,505 adults (16 - 75+ years), older adults (i.e., aged 55+) were less comfortable with higher levels of automation. A survey by Bansal and Kockelman [5] documented attitudes of 1,088 Texans toward AV technology (SAE Level 4) and revealed that older transportation users had a lower interest in accepting all levels of automation. Rovira et al. [6] examined trust in AVs in a survey among 138 participants (86 younger and 52 older adults) and concluded that, in general, there were few age differences in the measure of trust. Similarly, a Texas A&M Transportation Institute online survey (N=3,097) found no correlation between age and acceptance or intent to use AVs [7]. Becker and colleagues [8] conducted a review of 10 studies that examined age effects and AV acceptance and found

that 6 out of 10 studies noted that younger adults were more accepting of AVs than older adults. One out of 10 studies reported a positive correlation with age [9] whereas 3 out of 10 studies found no significant age differences [10], [11], and [12]. Moreover, they concluded that younger adults in urban environments, men, as well as those currently owning a vehicle equipped with technologies, tend to be the most positive about using AV technology [8]. Similar findings were reported by Abraham and colleagues [13] who surveyed roughly 3,000 drivers and found that comfort of AV technology decreased with age and that males are more comfortable with AV technology. Charness et al. surveyed acceptance practices in 441 adults toward AVs and found that gender played a significant role in attitudes towards the concern of AVs, eagerness to adopt AVs, and willingness to relinquish driving control [14]. Specifically, eagerness to adopt was lower in women whereas willingness to relinquish driving control was more prevalent among men.

Based on the studies above, a wide variance in acceptance practices was observed. Some studies suggested that old age is a negative predictor of acceptance practices for AV (e.g., [15], [16]) and others indicated that older adults have the greatest level of acceptance for AVs, even if they will not trade their primary mode of transportation [17]. However, perceptions of drivers about AVs in these studies were solicited via surveys only. Thus, the lack of exposure of study participants to lived experiences with AVs may have had an impact on their understanding of the potential usefulness or ease of use of AVs, which are strong predictors of technology acceptance and adoption.

To address this issue, this study obtained and analyzed information on the perceptions of drivers pertaining to accepting AV technology prior to, and after riding in an autonomous high fidelity driving simulator (Level 4, SAE Guidelines, [18]). Study participants completed an Autonomous Vehicle User Perception Survey (AVUPS) before and after being exposed to an automated driving simulator scenario. The survey was used to quantify young (n= 34), middle-age (n=17), and older (n=50) adults' perceptions of AVs and determine if any differences existed before and after exposure, by age group, and by gender. We hypothesized that participants would demonstrate an increase in *Intention to Use*, reduction in perceived *Barriers*, and increase in *Acceptance* of AV technology after exposure to the technology (vs. pre-exposure). We also hypothesized that older drivers' perceptions would have the greatest magnitude of change (vs. middle-aged and younger adults). Finally, we hypothesized that women participants would demonstrate more positive changes in acceptance of AV technology after exposure to the technology (vs. men).

2 Materials and methods

The University of Florida Institutional Review Board (IRB#201801988; IRB#202000464) provided approval for the study and all participants consented to enroll and participate in the study. Participants of both genders who were 18 years of age or older, had driven in the last 6 months, resided in North Central Florida, and did not show cognitive impairment (< 18 on the Montreal Cognitive Assessment) were eligible to participate.

The study team used pre-visit and post-visit surveys to quantify the perceptions of drivers (N=101) before and after being exposed to "driving" a simulator in autonomous mode, with a scenario specifically designed for this study. Each participant completed a psychometrically sound baseline survey and a post-visit survey (same content as baseline survey) after being exposed to the driving simulator in autonomous mode and was compensated for participation. The study included three different age cohorts, i.e., younger (18-39 years of age; N=34), middle-aged (40-64 years of age; N=17), and older drivers (> 65 years of age; N=50).

The driving simulation scenario for this study introduced a 5-minute acclimation drive to enhance adaptation to the driving simulation environment. The autopilot feature was used next, enabled for a 10-minute automated drive (SAE Level 4) in the driving simulator. Participants sat in the driver's seat and were instructed to ride in the scenario without taking over manual control. The simulator environment represented a low to moderate speed (15-35 mph) residential and suburban area with realistic road infrastructure, buildings, and ambient traffic.

Data collection occurred via capturing participants' demographic data and survey responses. Demographics included age, gender, ethnicity, education, marriage, employment status, and health conditions. The Automated Vehicle User Perception Survey (AVUPS) was administered for the baseline survey and after exposure to the driving simulator in autonomous mode. AVUPS items considered in this analysis represented Intention to Use, Barriers, and the total Acceptance score of AV technology. Additional details about the

The analysis was done in RStudio [19] using R version 4.0.2 [20] and was conducted in three steps: a) analysis of responses from baseline survey (pre-exposure), b) analysis of responses from survey after exposure to the simulator (AV mode), and c) comparison before and after exposure to the simulator. A series of independent t-tests were used to check for differences in responses between males and females across the three AVUPS scores (i.e., Intention to Use, Barriers, and Acceptance). A series of one-way analysis of variance (ANOVAs) or one-way analysis of covariance (ANCOVAs) were performed to evaluate the age effects (young, middle-aged, older drivers) on the three AVUPS scores. Post-hoc tests were deployed to identify the differences among the age groups. A series of paired t-tests were used to explore the differences between the baseline and after exposure to the simulator for both age and gender groups. A series of three-way (age, gender, and time) mixed ANOVAs were conducted to investigate the interactions between gender and age at the baseline and after exposure to the simulator. An alpha level of .05 was set a-priori and was not adjusted for multiple comparisons since the post-hoc tests were only conducted among the age group.

3 Results and discussion

In this study, we examined differences in scores for Intention to Use, Barriers, and Acceptance at a) baseline, and b) after exposure to a driving simulator on AV mode for all study participants combined as well as by age group and gender. We also formulated and tested three hypotheses based on the literature review, and our past and current findings on drivers' acceptance practices of AVs [21], [22], [23], [24].

The first hypothesis postulated that participants would demonstrate an increase in Intention to Use, reduction in perceived Barriers, and increase in Acceptance of AV technology after exposure to the AV technology (vs. pre-exposure). Our hypothesis was validated as the Wilcoxon tests for Intention to Use, t-tests for Barriers, and Wilcoxon tests for Acceptance yielded scores after exposure to the simulator in AV mode that are significantly higher than at the baseline.

Our second hypothesis was that older drivers' perceptions would have the greatest magnitude of change (vs. middle-aged and younger adults) after exposure to driving simulator in AV mode. The results from the analysis confirmed our assumption. We found that older adults have greater acceptance towards AVs when compared to other age groups (young and middle-aged drivers) after exposure to the simulator in AV mode. Moreover, for the older group, the t-tests for Intention to Use revealed that the scores after exposure to the simulator are significantly higher than the baseline, whereas no statistically significant differences were observed for middle-aged and young drivers.

Our third hypothesis postulated that women participants would demonstrate more positive changes in acceptance of AV technology after exposure to the technology (vs. men) and was validated by our study findings. For female participants, the t-tests revealed that the scores after exposure to the simulator were significantly higher than those from the baseline for Intention to Use, Barriers, and Acceptance whereas no statistically significant differences were observed for male participants. Our study also confirmed that gender differences do exist when different age cohorts are exposed to AV technology. We concluded that gender differences in the context of AV technology perceptions vary by age, and the gender-age impacts must be further examined in follow-up studies to better understand their role in predicting AV acceptance.

4 Conclusions

In this work, we used a validated AVUPS to study the perceptions of 101 younger, middle-aged, and older drivers regarding AV before and after being exposed to a driving simulator running in autonomous mode.

Before exposure to AV, older adults had a greater score for Intention to Use and Acceptance compared to middle-aged participants. Other than that, no significant differences were observed between other combinations of age groups or genders. After exposure to the driving simulator operating in autonomous mode, female participants had fewer perceived barriers to accepting the AV technology compared to males. Comparison of scores for Intention to Use, Barriers, and Acceptance before and after the AV technology exposure for all participants combined, revealed that all scores increased after the exposure. Groups that showed greater positive changes in AVUPS scores after exposure to AV included older adults and females.

Compared to the use of questionnaire surveys alone, exposure to AV in combination with surveys can more accurately reveal the perceptions, or hesitations of drivers before and after "driving" the autonomous simulator. As one of the first studies in the US to assess drivers' perceptions of AVs after direct exposure to such technology, the study revealed important foundational information about driver acceptance practices, their intention to use AVs, and barriers to AV technology across the driving lifespan and along gender lines.The findings have important implications for stakeholders of the AV industry as they imply that lived experiences via exposure to "driving" a simulator in autonomous mode can increase user acceptance and reduce perceived barriers pertaining to AV technology.

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