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Effect of advanced driver-assistance system trainings on driver workload, knowledge, and trust

Maryam Zahabi [a,*], Ashiq Mohammed Abdul Razak [a], Ranjana K. Mehta [a], Michael Manser [b]

[a] Industrial and Systems Engineering Department, Texas A&M University, College Station, TX, United States
[b] Texas A&M Transportation Institute, College Station, TX, United States

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ABSTRACT

Older adults are more likely to get severely injured or die in vehicle crashes. Advanced driver-assistance systems (ADAS) can reduce their risk of crashes; however, due to the lack of knowledge and training, usage rate of these systems among older drivers is limited. The objective of this study was to evaluate the impact of two ADAS training approaches (i.e., video-based and demonstration-based training) on older drivers' subjective and objective measures of mental workload, knowledge and trust considering drivers' demographic information. Twenty older adults, balanced by gender, participated in a driving simulation study. Results indicated that the video-based training might be more effective for females in reducing their mental workload while driving, whereas the demonstration-based training could be more beneficial for males. There was no significant difference between the video-based and demonstration-based trainings in terms of drivers' trust and knowledge of automation. The findings suggested that ADAS training protocols can potentially be more effective if they are tailored to specific driver demographics.

1. Introduction

Motor vehicle crashes (MVCs) are a major cause of death in the U.S. In 2018, an estimated 40,000 people lost their lives to MVCs and about 4.5 million people were injured in crashes. The estimated cost of MVC related deaths, injuries and property damage in 2018 was $412.8 billion (NSC, 2020). Older drivers (age 60+) make up 19% of all traffic fatalities each year in the U. S. (Tefft, 2017). Previous driving simulation studies have found older adults to have longer secondary task completion times and off-road visual attention to in-vehicle technologies, and poorer driving performance as compared to middle-aged and young drivers (Dingus, Hulse, Antin, & Wierwille, 1989; Edquist, Horberry, Hosking, & Johnston, 2011), which might be due to degradations in sensory, cognitive, and physical capabilities (Horswill et al., 2008). Therefore, older adults are more likely to get severely injured or die in crashes (Koppel, Bohensky, Langford, & Taranto, 2011).

Advanced driver-assistance systems (ADAS) are "*vehicle control systems that improve driving comfort and traffic safety by using vehicle sensors (*e.g. *radar, laser) to help drivers identify and react to potentially hazardous traffic situations*" (Gietelink, Ploeg, De Schutter, & Verhaegen, 2006). Examples of these systems include automatic emergency braking, lane keeping assist system (LKAS), and adaptive cruise control (ACC) (Gietelink et al., 2006). ADAS have the potential to improve the safety and mobility of older adults by providing personal assistance to the driver. ADAS can help older adults if they support drivers'

* Corresponding author at: Industrial and Systems Engineering Department, Texas A&M University, Emerging Technologies Building, College Station, TX 77843-3131, United States.

E-mail address: mzahabi@tamu.edu (M. Zahabi).

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weaknesses (e.g., directing their attention to traffic, assist in blind spots). Some ADAS such as collision warning, LKAS, ACC, and reversing aids have been found to be the most beneficial systems for older drivers (Davidse, 2006). Despite the advantages of ADAS in improving safety, the usage rate of these technologies among older adults is still very low mainly due to the lack of perceived usefulness, functional limitations, lack of system trust, and lack of driver knowledge and experience (Trübswetter & Bengler, 2013). Driver's misunderstanding and misuse of ADAS not only limits the technology acceptance but also increases the risk of MVCs (Eby, Molnar, Liang Zhang, Zanier, & Lidia, 2006).

Without training, drivers may be unaware of the strengths and weaknesses of systems and that systems may respond in some ways that are unanticipated or unintended by the driver (Parasuraman, 2000). Therefore, ADAS training is essential for removing these barriers and improving driver's knowledge, acceptance, and trust in automation (Braun, Gärtner, Trösterer, Akkermans, Seinen, Meschtscherjakov, & Tscheligi, 2019). Prior studies compared drivers' perception and trust of ADAS before and after training or with and without any training. For example, an investigation by Reimer, Mehler, and Coughlin (2010) revealed that prior to training, drivers did not believe that the ADAS (i.e., parallel parking system) would be beneficial in improving their performance and reducing their stress. However, after extensive training and experience with the system, drivers exhibited lower level of stress (as measured by heart rate), reported positive opinions, and were willing to buy the system. In another study comparing driving simulator-based training, reading driver manuals, and no training, it was found that driver familiarization with ADAS in a simulator improved driver-system interactions and trust in the system as compared to reading manuals and no driver training (Koustanaï, Cavallo, Delhomme, & Mas, 2012). ADAS training is especially critical for older adults as they have less familiarity with new technologies as compared to younger drivers (Souders & Charness, 2016). Although providing any kind of training might be beneficial as compared to no ADAS training, previous studies have found that aligned learning preferences for driver education and providing individualized training mechanisms led to higher self-reported driver understanding and use of in-vehicle systems (Abraham, Reimer, & Mehler, 2018).

ADAS training can be provided using online or dealer provided videos, vehicle owner manuals, face-to-face instructions (also called demonstration-based training) by professional trainers such as those in the Driving School Association of the Americas (DSAA) or dealerships, and driving simulations. A survey study showed that older drivers mainly learned about the ADAS features in their vehicle by reading an owner's manual, through on-road practice and experience, or through information from a dealership (Jenness, Lerner, Mazor, Osberg, & Tefft, 2008). Recent studies also compared drivers' use of owner's manuals with interactive support material. For example, Forster, Hergeth, Naujoks, Krems, and Keinath (2019) compared three educational material conditions including an owner's manual, interactive tutorials (i.e., a power point presentation of operating element, driver's view, and quizzes), and a no treatment baseline condition (i.e., generic information) for training on automated driving systems. The findings suggested that both the owner's manual and interactive tutorials led to increase understanding of the system and improved interaction performance. In another study comparing the driving simulation-based training, video-based training, and no training conditions, Ebnali, Hulme, Ebnali-Heidari, and Mazloumi (2019) found that both training methods improved driver takeover performance in conditionally automated driving as compared to no training. However, the interactive training approach where the drivers practiced the automated features in a driving simulator before the actual test led to a more developed mental model of the system. Related to that, Sportillo, Paljic, and Ojeda (2018) found that drivers had better takeover performance if they were trained using head-mounted virtual reality or fixed-based driving simulators compared to reading the owner's manual. Furthermore, drivers had more preference over the virtual reality-based training based on self-reported measures of usefulness and ease of use.

Recent studies also recommend providing interactive ADAS training (i.e., the ability to test ADAS features during the training) for older drivers (Braun et al., 2019). Our previous investigation (Zahabi, Razak, Shortz, Mehta, & Manser, 2020) comparing video-based and demonstration-based training of ADAS, suggested that video-based training improved older drivers' use of ADAS features and reduced off-road visual attention. In addition, we found that video-based training was more effective for female drivers in reducing their cognitive load (as exhibited by the amount of oxygenated hemoglobin (Oxy-Hb) in the prefrontal cortex) and time to activate ADAS features, whereas demonstration-based training was more effective for males. The present study is a follow-up investigation to our prior work (the participants were identical in both studies) that is focused on perceived and physiological measures of cognitive load, knowledge and trust to provide a more holistic evaluation of ADAS training approaches for older adults and to further validate the findings of our previous investigation.

1.1. Impact of training on trust and mental workload

Trust is defined as *'the attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability'* (J. D. Lee & See, 2004). Lack of trust may affect the use of ADAS. Older drivers were found to have concerns regarding ADAS malfunction or failure while driving. Most of these concerns were related to lack of knowledge (Trübswetter & Bengler, 2013). Training and familiarization can improve drivers' trust in ADAS and help in building an appropriate mental model of the system (Kazi, Stanton, Walker, & Young, 2007; Koustanai, Mas, Cavallo, & Delhomme, 2010). Such training can take a variety of forms (e.g., owner manuals, videos, face-to-face instructions, driving simulations). However, there is a lack of research on which training approach is more effective in enhancing older adults' trust in automation.

Effective training is also expected to reduce attentional resources while performing an activity and ultimately reduces mental workload (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). For example, simulation-based training was effective in reducing subjective mental workload of novice drivers in simulated driving tasks (Wang, Zhang, & Salvendy, 2010). In another study, Koustanaï et al. (2012) found that active training of ADAS (i.e., reading the vehicle manual and interacting with ADAS in a driving simulation-based training) decreased mental workload (measured by NASA-TLX) and improved driver-system interactions as compared to drivers who simply read the manual. However, driving simulator-based training can be costly depending on the level of fidelity and might not be as accessible as other training approaches, such as online videos or face-to-face instructions. Our previous investigation (Zahabi et al., 2020) found that the demonstration-based training led to greater activation of the left prefrontal cortex (PFC) and lower activation of the right PFC as compared to the video-based training. As higher workload is associated with increased activation in related brain regions (Herff et al., 2014), it was suggested that demonstration-based training increased drivers' mental workload in subsequent driving scenarios, which included interactions with ADAS as compared to the video-based training. Previous studies have reported that the association between workload and neural activation is not necessarily linear in nature (Bunce et al., 2011), however autonomic responses, such as heart rate variability, have shown strong promise of quantifying mental workload (Heine et al., 2017; Roscoe, 1992). Therefore, the current study compares these two training approaches in terms of perceived and autonomic (physiological) measures of workload to further verify the findings of our prior study and together provide a comprehensive evaluation of ADAS training for older adults.

1.2. Older adult training

Prior studies have assessed the effectiveness of different training approaches with older adults. Some investigations found that training approaches that provide self-paced and unhurried time for practice (e.g., trial and error, online videos) are more effective since older adults tend to be slower and less accurate in performing new tasks. Furthermore, it has been shown that computer-based multimedia training (including pictures and audio narrations) were more effective than traditional computer-based training (using text only or text with pictures) (Van Fleet & Antell, 2002). Related to that, a focus group study examining older adults' preferences toward training methods suggested that there is more preference toward self-training (e.g., reading manuals) rather than getting instructions from professional trainers. However, opposite to the findings of Van Fleet and Antell (2002), online and multimedia instructions were mentioned relatively infrequently as compared to other training methods (Mitzner et al., 2008). One possible explanation for these preferences might be lack of awareness regarding alternative training methods (Mitzner et al., 2008). Other studies comparing different age groups of older adults (i.e., 55–65 yrs., 66–74 yrs., and 75+ yrs.) found that more of the 55–65 age group preferred learning by feeling and doing, 66–74 group preferred learning by feeling and watching, and more in 75+ group preferred learning by thinking and watching. Therefore, the results suggested that as age increases, there is a more tendency toward observational learning methods (i.e., learning and watching) (Truluck, Bradley, & Courtenay, 1999). However, other studies did not find any differences in older adults' performance when trained by passive (e.g., reading from manuals) or animated interactive multimedia training (Echt, Morrell, & Park, 1998). Although the findings of these studies provided valuable insights regarding older adults' preferences toward training methods, they were not conducted in driving training or in-vehicle technology context and therefore might be limited in terms of generalizability to ADAS training methods.

1.3. Problem Statement

ADAS have the potential to reduce older drivers' risk of MVC; however, due to the lack of knowledge and training, usage rate of these systems among older adults is still limited. This barrier can be resolved by providing proper training. ADAS training effectiveness can potentially be impacted by drivers' trust in automation and mental workload associated with the training protocols, and vice versa, which can ultimately influence driver safety. ADAS training can be provided using different approaches such as online videos, vehicle owner manuals, face-to-face instructions, and driving simulations, which may place different workload on the drivers. Previous studies have found advantages of interactive ADAS training approaches as compared to non-interactive methods (e.g., reading manuals). The objective of this study was to evaluate the impact of two potential ADAS training approaches (i.e., demonstration-based and video-based training) on older drivers' subjective and objective measures of mental workload, knowledge, and trust and explore associated gender differences.

1.4. Hypotheses

Three research hypotheses (H) were formulated based on the literature review. Hypotheses 1 and 3 are based on our prior study comparing video-based and demonstration-based training in terms of driver performance, visual attention allocation, and neural efficiency (Zahabi et al., 2020) and are supported by interactivity principle and multi-media instruction which have been found to facilitate training (Arguel & Jamet, 2009; Mayer, 2003). Hypothesis 2 is formulated based on the findings of Hohenberger, Spörrle, and Welpe (2016) and Feldhütter, Gold, Hüger, and Bengler (2016), who reported that female drivers experienced more anxiety and less pleasure and trust in vehicle automation technologies as compared to males. The hypotheses are listed below:

H1) we expected the video-based training to lower cognitive load of drivers, and improve drivers' trust and knowledge of ADAS as compared to the demonstration-based training.

H2) we expected males to experience less cognitive load and to have higher knowledge and trust in ADAS as compared to females.
H3) we expected the video-based training to be more effective for females in reducing their cognitive load and improving their knowledge and trust, whereas the demonstration-based training would be more effective for males.

2. Method

2.1. Participants

Twenty older adults (M = 63.1 yrs., SD = 5.3 yrs.), balanced by gender, participated in the experiment. Participants were recruited through advertisements across campus, retirement groups, churches, and senior living communities in College Station/Bryan area. Each participant was randomly assigned to either demonstration-based or video-based training. All participants had 20/20 vision or corrected vision, did not own a vehicle with ADAS driving technologies, and did not take any medication that would impair driving performance. The Texas A&M University Institutional Review Board (IRB) approved the study protocol and all participants signed an informed consent form before participation.

2.2. Apparatus

A RDS-1000 driving simulator (Realtime Technologies) was used in this study (Fig. 1). The setup included three screens providing 165-degree horizontal field-of-view. A set of full-size driving controls including force feedback steering wheel and pedals provided real-time feedback to the driver. The frequency of data collection was 60 Hz. Heart rate variability (HRV) was captured using Polar V800 GPS sports watch with a heart rate chest strap and monitor at a sampling frequency of 1000 Hz. Level 2 ADAS was provided with ACC and LKAS based on the definition of the society of Automotive Engineers (SAE) which refers to a situation where automation controls both the steering and acceleration/braking of the vehicle while the driver monitors the driving task and is ready to take control with little notice. The ADAS controls were located on the side screen (Fig. 2) and the driver could interact using a touch screen. The ADAS information icons were presented on the information center for drivers (ICD) as shown in Fig. 2.

2.3. Experimental design

The experiment followed a 2 × 2 × 2 within-between subject design in which gender and training type (i.e., demonstration-based training, video-based training) were between subject factors and driving condition (i.e., manual vs. automated) was a within subject variable. The dependent variables included ratings scale of mental effort (RSME) scores, HRV measured by root mean square of successive differences (RMSSD) of consecutive normal-to-normal R-R intervals, ratings of trust in automation, and percentage improvement in knowledge of automated vehicle technologies. RSME score was

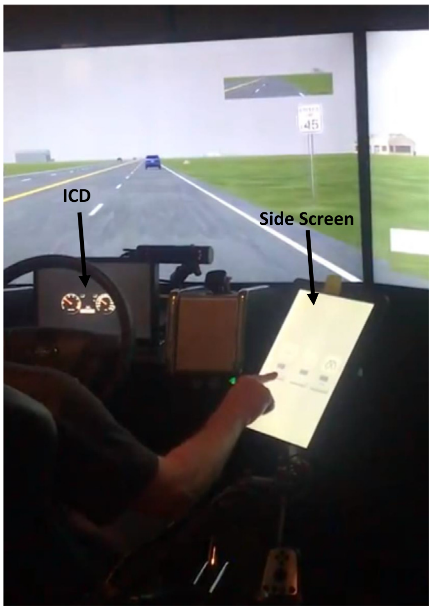

Fig. 1. Driving simulator setup.

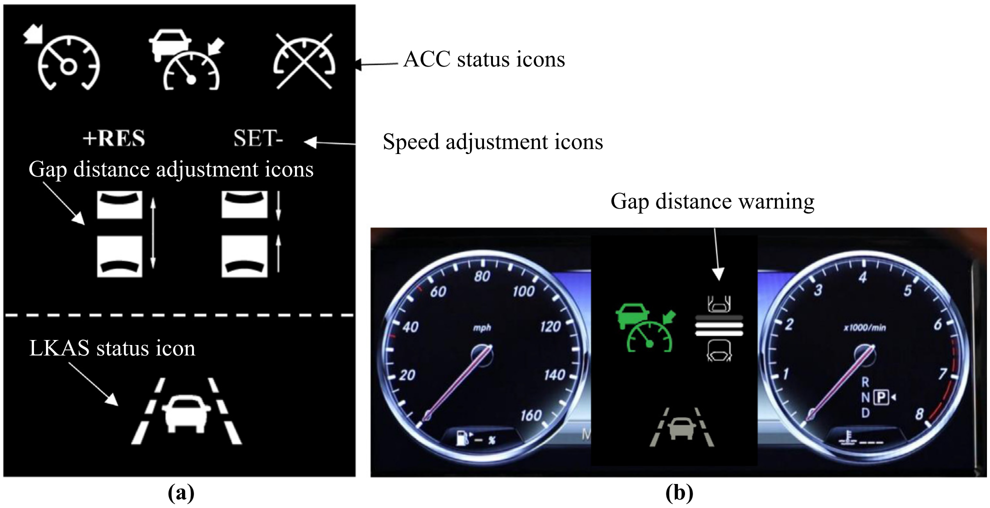

Fig. 2. (a) The ADAS controls on the side screen; (b) The ADAS information icons on the ICD.

measured subjectively using a uni-dimensional scale ranged from 0 to 150 with latter indicating maximum mental effort (Zijlstra, 1993). RMSSD is a time domain HRV index, which is an indicator of parasympathetic function. Lower RMSSD is an indicator of higher mental workload (Mehta, 2015; Orsila et al., 2008). Drivers' level of trust in automation was measured with a subjective rating scale (range: 0–100, higher score indicates more trust in automation) including eight statements as shown in Table 1 (J. Lee & Moray, 1992). Similar subjective measures of trust have been used in prior automated driving studies (Helldin, Falkman, Riveiro, & Davidsson, 2013). However, some of the language and questions were changed to make it easier for our participant sample (i.e., older adults) to comprehend the questions and to be aligned with the topic of our investigation. Participants were provided with a unidimensional visual analog rating scale for each question in the trust survey. They were asked to give a subjective rating by marking a point on a continuous (100 mm) scale with anchors of "strongly disagree" and "strongly agree". The distance from the left anchor to the marking was measured (with millimeter accuracy) and this distance was transformed to a percentage. Drivers' knowledge of automated vehicle technologies was measured using a survey (including 10 questions as shown in Table 2) before and after the experiment. The questions were designed based on the information presented in training (i.e., purpose of using ADAS, understanding ADAS capabilities and limitations, transition between ADAS and manual mode, familiarity with system components and placement). The questions included multiple choice questions and open-ended questions (see Table 2). For the multiple choice questions, the participant needed to select all the correct choices to be counted as a correct response. For the open-ended questions, participant's responses should indicate a correct understanding of a specific functionality (e.g., partial automation refers to a system that takes over longitudinal and lateral control, but the driver must permanently monitor the system and be prepared to take over control at any time). The answer should refer to the characteristics of this system (i.e., longitudinal and lateral control, driver monitoring) to be counted as a correct response or identify the correct definition of an acronym (e.g., ACC stands for adaptive cruise control). The experimenter compared participants' responses to the key and calculated the percentage of correct responses (i.e., $\frac{number\ \ of\ \ correct\ \ responses}{10} \times 100$). The difference between the percentage of correct responses in the post-study survey and pre-study survey was captured as a dependent variable in this study (i.e., knowledge improvement).

2.4. Procedure

Initially, participants were asked to complete a background questionnaire regarding their age, driving experience, and knowledge of automated vehicle technologies. Subsequently, they were randomly assigned to either the demonstration-based or video-based training protocol. The content of both training protocols was similar and followed the knowledge and skill taxonomy of training drivers for ADAS equipped vehicles (Zahabi et al., 2020) including the information regarding the purpose of using ADAS, understanding levels of ADAS and their capabilities and limitations, how to transition between the ADAS and manual mode, and system components and placement of icons. This taxonomy was developed to ensure drivers in both training protocols were provided with a comprehensive and similar information and to remove any potential confounding effect that might have occurred due to the lack of sufficient information in one training protocol vs. the other. Participants in the video-based training were provided with an instructional video describing the ACC and LKAS and how they operate together to create level-2 ADAS (similar to the online training approach). The video was recorded by the same professional trainer that provided the demonstration-based training. Participants could stop or re-play the video at any time during the training. Demonstration-based training included identical instructions to video-based training but the instructions were delivered by a professional trainer. In addition, participants were provided with a demonstration of how the sys-

Table 1
Statements in trust questionnaire.

No.	Statement
1	The performance of the system enhanced my driving safety.
2	I am familiar with the operation of the system.
3	I trust the system.
4	The system is reliable.
5	The system is dependable.
6	The system has integrity.
7	I am comfortable with the intent of the system.
8	I am confident in my ability to drive the vehicle safely without the system.

Table 2
Questions in the knowledge survey.

No.	Question	Question format
1	Define what vehicle automation means to you.	Open-ended
2	What is partial vehicle automation?	Open-ended
3	What does LKAS stand for?	Open-ended
4	What does LKAS do? What is purpose of this technology?	Open-ended
5	When can you use LKAS?	Multiple choice
6	When can you NOT use LKAS?	Multiple choice
7	What does ACC stand for?	Open-ended
8	What does ACC do? What is purpose of this technology?	Open-ended
9	When can you use ACC?	Multiple choice
10	When can you NOT use ACC?	Multiple choice

tems operated in the vehicle (similar to driver training approach). Each training session took approximately 30 min to complete. Participants in demonstration-based training could interact with ADAS features during the training. The video-based training group was also seated in the driving simulator cab and could see the display and icons but did not practice ADAS during training. Participants in both training conditions could ask questions at the end of the training. Upon completion of the training, participants were provided with an introduction to the driving simulator and a training session to become familiar with the setup and controls. Subsequently, participants were asked to drive three simulated driving trials each consisted of eight segments, half were manual and half were automated driving conditions. In manual segments, the driver was responsible for all driving controls. In automated segments, the driver was asked to use the combined ACC and LKAS. Participants reported RMSE scores four times per trial, after the second and fourth ADAS control segments and after the second and fourth manual control segments. Subjective measures of ADAS trust were collected twice in each experiment (after the first and last driving trials) and the knowledge survey was completed again after the experiment. HRV was captured using Polar V800 GPS sports watch with heart rate chest strap and monitor. Participants strapped the monitor to their chests, so that the monitor was positioned high on their ribcage on the sternum. Inter beat interval (IBI) data from the monitor was then employed to obtain the RMSSD of the IBI data for each trial in each condition using the Kubios HRV software (Tarvainen, Niskanen, Lipponen, Ranta-Aho, & Karjalainen, 2014).

2.5. Data analysis procedure

Data post-processing was conducted after data collection to identify any potential outlier due to participants' not following the instructions (e.g., did not complete the surveys) and/or equipment issues (e.g., HR monitor not attached to the skin properly). Diagnostics were performed to ensure analyses of variance (ANOVA) assumptions are met. If there was any violation, data were transformed using Box Cox transformation or ranked in order to perform non-parametric analysis. If non-parametric results were similar to ANOVA results on untransformed measures, analyses on the untransformed responses were considered valid and reported instead (Montgomery, 1991). Trial number was included in the statistical models as a covariate and was removed subsequently if found to be insignificant. A significance level of $\alpha = 0.05$ was set as a criterion for the study. All error bars represent ±1 standard deviations from the mean.

3. Results

3.1. Perceived mental workload

An ANOVA on square root RSME revealed significant main effects of trial number ($F(1,215) = 12.57,\ p = 0.0005,\ \eta_p^2 = 0.05$) and driving condition ($F(1,215) = 16.22,\ p < 0.0001,\ \eta_p^2 = 0.07$) and two-way interactions between gender and training type ($F(1,215) = 61.57,\ p < 0.001,\ \eta_p^2 = 0.22$) and training type and driving condition ($F(1,215) = 4.71,\ p = 0.031,\ \eta_p^2 = 0.021$). There were no main effects of gender ($F(1,215) = 0.29,\ p = 0.59,\ \eta_p^2 = 0.001$) or training type ($F(1,215) = 0.68,\ p = 0.41,\ \eta_p^2 = 0.003$) for RSME. Drivers reported lower perceived workload under automated driving condition (*M* = 55.6, *SD* = 27.2) as compared to manual driving (*M* = 66.6, *SD* = 32.1). In addition, during automated driving segments, drivers who completed the demonstration-based training perceived less cognitive load as compared to drivers who experienced video-based training (Fig. 3). Perceived workload decreased as trial numbers increased. Male drivers perceived lower workload as compared to females under demonstration-based training, whereas female drivers reported lower workload under video-based training (Fig. 4).

3.2. RmSSD

An ANOVA on RMSSD revealed a significant main effects of gender ($F(1,423) = 6.08,\ p = 0.014,\ \eta_p^2 = 0.014$), training type ($F(1,423) = 13.46,\ p < 0.001,\ \eta_p^2 = 0.03$), trial number ($F(1,423) = 5.67,\ p = 0.018,\ \eta_p^2 = 0.013$), and a significant two-way interaction between gender and training type ($F(1,423) = 11.97,\ p < 0.001,\ \eta_p^2 = 0.028$). There was no main effect of driving condition for RMSSD ($F(1,423) = 0.019,\ p = 0.89,\ \eta_p^2 = 0.00$). Male drivers had lower RMSSD (higher workload) as compared to female drivers and this effect was especially significant under video-based training (Fig. 5) (It is important to note that the difference in RMSSD might have been due to gender differences (Koenig & Thayer, 2016; Saleem, Hussain, Majeed, & Khan, 2012). However, we also measured participants' baseline RMSSD and there was no significance difference between males and females in this study). Drivers who completed the video-based training exhibited lower RMSSD (higher workload) as compared to those who completed the demonstration-based training (Fig. 6). In addition, RMSSD increased with an increase in trial number (i.e., drivers experienced less workload as trials increased).

3.3. Trust in automation

An ANOVA on the trust in automation response did not reveal any significant main effects of training type ($F(1,19) = 1.93,\ p = 0.18,\ \eta_p^2 = 0.025$) or gender ($F(1,19) = 0.061,\ p = 0.81,\ \eta_p^2 = 0.003$). The descriptive statistics of the trust survey are shown in Table 3. However, there was a significant effect of trial number ($F(1,19) = 12.71,\ p = 0.002,\ \eta_p^2 = 0.16$) on the response. Drivers trusted the ADAS more as their experience with it increased (Fig. 7).

3.4. Knowledge of automation

An ANOVA on knowledge improvement data did not reveal any significant effect of training type ($F(1,16) = 0.17,\ p = 0.68,\ \eta_p^2 = 0.01$), gender ($F(1,16) = 2.11,\ p = 0.17,\ \eta_p^2 = 0.13$) or any two-way interactions ($F(1,16) = 0.39,\ p = 0.54,\ \eta_p^2 = 0.02$). The descriptive statistics results of knowledge survey are shown in Table 4.

4. Discussion

Hypothesis 1 stated that the video-based training would reduce the cognitive load of drivers, and improve ADAS trust and knowledge as compared to the demonstration-based training. This hypothesis was not supported by the data. The findings of both perceived and physiological workload measures revealed the demonstration-based training to reduce drivers' cognitive load while driving as compared to the video-based training (Figs. 3 and 6). However, these findings should be considered in relation to driver performance and visual attention allocation responses. In our prior study with the same group of drivers

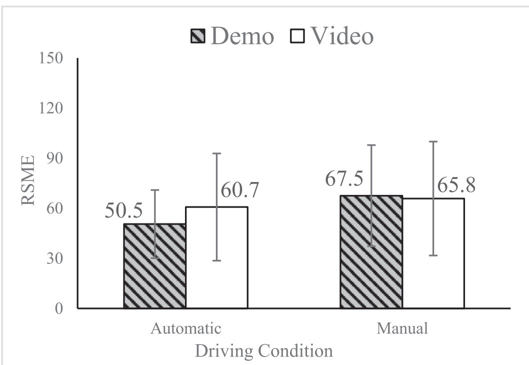

Fig. 3. Interaction effect of training type and driving condition on RSME (error bars indicate one standard deviation from the mean).

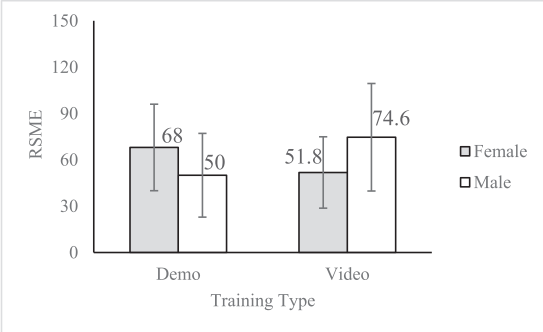

Fig. 4. Interaction effect of gender and training type on RSME (error bars indicate one standard deviation from the mean).

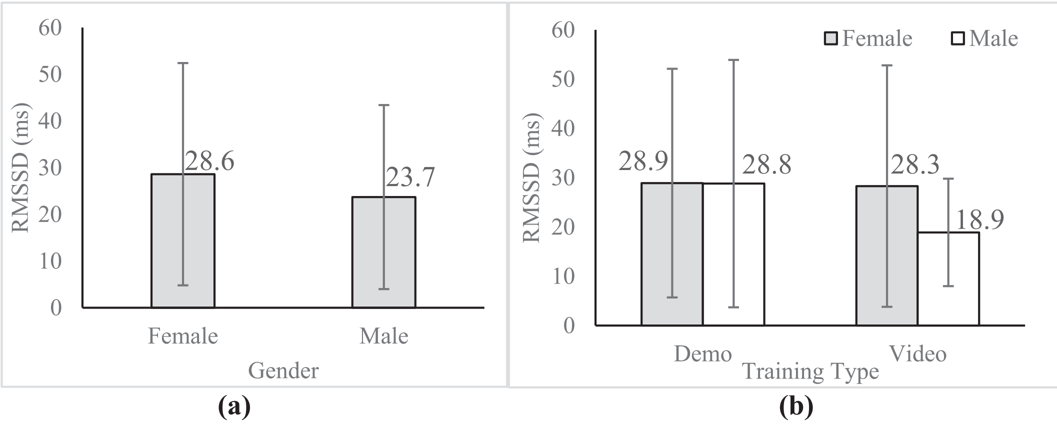

Fig. 5. (a) Effect of gender on RMSSD; (b) Interaction effect of training type and gender on RMSSD (error bars indicate one standard deviation from the mean).

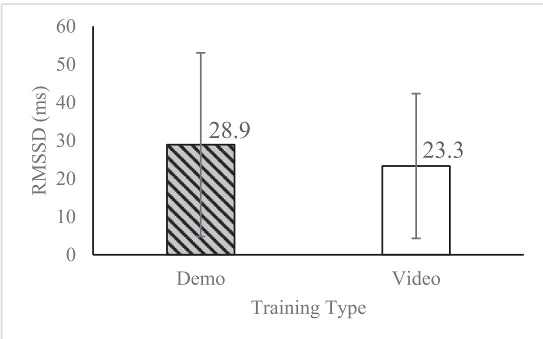

Fig. 6. Effect of training type on RMSSD (error bars indicate one standard deviation from the mean).

(Zahabi et al., 2020), we found that participants who experienced the demonstration-based training did not activate ADAS features such as LKAS as much as the video-based training group. There was a significant effect of training type on the deviation in steering wheel position ($F(1, 200) = 4.13,\ \ p = 0.04,\ \ \eta_p^2 = 0.02$). The LKAS feature, when activated, results in lower steering wheel position deviation than a human driver in manual steering mode. It was found that drivers who received demonstration-based training exhibiting higher deviations in the steering position angle (*M* = 0.19, *SD* = 0.43) as compared to those who completed the video-based training (*M* = 0.18, *SD* = 0.32). Therefore, the lower workload in the demonstration-based training group might have been due to the lack of driver understanding of ADAS features (this issue is also evident based on the knowledge survey descriptive statistics in Table 4), which led to not using these technologies while driving.

Table 3
Descriptive statistics results of trust survey.

Factor	Levels	Mean (%)	SD (%)
Training type	Demonstration	75.06	11.91
	Video	70.14	19.01
Gender	Male	72.16	17.79
	Female	73.04	14.23

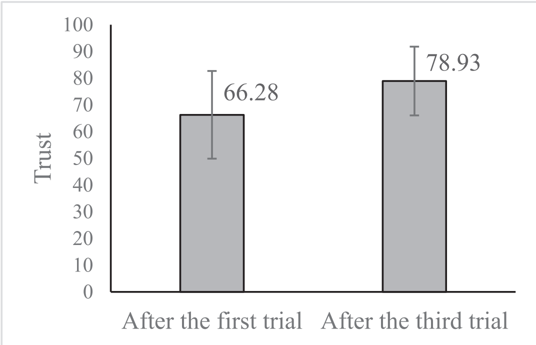

Fig. 7. Effect of trial number on trust (error bars indicate one standard deviation from the mean).

Table 4
Descriptive statistics results of knowledge survey.

Factor	Levels	Baseline knowledge (%)		Knowledge after the training (%)		Knowledge improvement (%)	
		Mean	SD	Mean	SD	Mean	SD
Training type	Demonstration	12	9.19	46	18.38	34	15.05
	Video	13	8.23	51	26.44	38	26.99
Gender	Male	15	8.49	44	23.19	29	17.91
	Female	10	8.16	53	21.63	43	23.12

The findings of visual attention allocation responses in our prior study also confirm this observation. It was found that the drivers who completed demonstration-based training had more off-road glances to the in-vehicle information screens to check the status of ADAS features. On the other hand, the video-based training group used ADAS features more frequently while driving and had fewer off-road glances to the screens. The video-based training group relied more on their memory to remember the conditions to activate ADAS features (e.g., minimum travel speed, presence of both lane lines, and presence of a lead vehicle) and the instruction to activate ACC and LKAS, which led to higher mental workload for this group. Furthermore, the discrepancy between the brain activation versus heart rate variability responses between the two analyses may be due to the diagnosticity of the two measures. fNIRS-based hemodynamic responses are localized brain function changes at the regions monitored (in this case, the PFC) due to task-related events. On the other hand, heart rate based autonomic responses are systemic global responses of sympathetic activation due to an external stressor (in this case the workload associated with the type of ADAS training) and may be impacted by other concurrent psychological experiences, such as anxiety (Sevenster, Hamm, Beckers, & Kindt, 2015). Additionally, while both fNIRS and HRV measures have shown high sensitivity to workload levels, HRV demonstrates little diagnostic power as to the type (e.g., visual or mental) of load induced (Verwey & Veltman, 1996).

The findings of trust survey indicated that although the video-based training group experienced higher mental workload while driving, their level of trust in automation was not significantly different from the demonstration-based group who experienced less cognitive load. Both groups in our study trusted the ADAS (average rating $\geq$ 70%); however, the low ratings might have been due to limited exposure of drivers to ADAS features (i.e., only three driving scenarios). Furthermore, there was no significant effect of training condition on knowledge survey results (although the trend indicated that the video-based training was slightly better in improving drivers' knowledge as compared to the demonstration-based training). The insignificant results might be due to the fact that these responses were collected using self-reported measures. Although subjective ratings have found to be reliable measures of trust in several studies (Brown & Galster, 2004; J. Lee & Moray, 1992), they have some limitations and are not capable of capturing dynamic changes in automation trust. Studies have found significant negative relationship between automation trust and monitoring frequency (Hergeth, Lorenz, Vilimek, & Krems, 2016). Therefore, more direct measures of trust, such as gaze behavior, should be used in future studies to further validate the findings.

Hypothesis 2 predicted that males would experience less cognitive load and have higher trust and knowledge of ADAS as compared to females. This hypothesis was not supported by the data. There was no significant effect of gender on perceived cognitive load. In addition, opposite to our expectation, RMSSD results revealed that males who completed video-based training exhibited higher workload (lower RMSSD) as compared to their female counterparts (Fig. 5). Our findings are not in line with prior study by Hohenberger et al. (2016) that found females to anticipate more anxiety and less pleasure in using automated vehicles as compared to males. However, Hohenberger's study was limited to self-report data collecting through an online questionnaire and the effect of training was not investigated. Our findings suggest that when sufficiently trained, females experience less cognitive workload when using ADAS. Therefore, gender-dependent anxiety associated with using ADAS in Hohenberger et al.'s study might have been due to lack of knowledge and training on ADAS features and can potentially be resolved by training. In addition, findings suggested that to reduce male drivers' cognitive load, demonstration-based training could be provided. Regarding the trust responses, the findings are not in line with the results of Feldhütter et al. (2016) that found female drivers to have less trust in automation as compared to males. However, Feldhütter et al.'s study was focused on young drivers (age range: 21–28 yrs.) and did not assess the impact of training. Both groups in our study trusted the ADAS (average rating $\geq$ 70%). Although there was no significant difference between males and females regarding their knowledge of ADAS, females were found to have slightly better understanding of ADAS after the training which might be the reason for lower workload and comparable trust results with males. Having said this, the insignificant results might also be due to the subjective nature of these responses in the study.

Hypothesis 3 posited that the video-based training would be more effective for females in reducing their cognitive load and improving their trust and knowledge, whereas the demonstration-based training would be more effective for males. This hypothesis was partially supported by the data. Findings of perceived workload and RMSSD revealed video-based training to be more effective for females in reducing their workload while driving, whereas the demonstration-based training was more effective for males (Figs. 4 and 5). To ensure that this finding was not due to the differences between males and females in activating ADAS features, we assessed the effect of gender and the interaction effect of gender and training type on the deviation in steering wheel position response (which is an indicator of LKAS feature activation). However, there was no significant effect of gender ($F(1,200) = 0.40,\ p = 0.53,\ \eta_p^2 = 0.002$) and no significant interaction between gender and training type ($F(1,200) = 0.04,\ p = 0.84,\ \eta_p^2 = 0.00$) on the LKAS activation response.

The results are in line with our prior investigation (Zahabi et al., 2020) comparing driver performance (i.e., time to activate ADAS features) and brain activation in the PFC of male and female drivers who experienced different ADAS training protocols. The literature on learning style differences between males and females is mixed. Some studies found females to learn better in practical settings (Philbin, Meier, Huffman, & Boverie, 1995) and prefer single modal instruction, particularly in the kinesthetic mode (Wehrwein, Lujan, & DiCarlo, 2007), while others did not find any significant differences between the learning style of males and females (Truluck et al., 1999). However, it is important to note that none of these studies was conducted in driving training domain, which limits their generalizability in this application. Combining the findings of this study with the results of our previous investigation (Zahabi et al., 2020), we recommend training male drivers using demonstration-based training and female drivers through video-based training approach to reduce cognitive load and improve older driver's use of ADAS while driving. However, it is also important to note that our findings should be considered preliminary since the study had a limited sample size. We encourage researchers to examine this topic further using a larger sample size. Furthermore, there was no interaction effect between training type and gender on trust and knowledge survey results. As mentioned previously, the insignificant result might be due to the subjective nature of these measures. However, it is important to note that our findings indicated that older adults trusted the ADAS more as their experience with it increased (Fig. 7). Having more exposure to ADAS features can improve the development of drivers' mental model of the technology and therefore impacts their attitude and perceptions regarding the technology (Rajaonah, Anceaux, & Vienne, 2006). The findings are in line with prior investigations on learning and development of trust after having more interactions with ADAS (Beggiato, Pereira, Petzoldt, & Krems, 2015).

This study had some limitations. First, due to the limited sample size (20 drivers), some of the factors did not reveal significant effects on the responses (e.g., automation trust). Second, driver trust in automation was captured through a self-reported measure. Although the survey used was validated and has been used in prior driving studies, it might be biased and might not capture temporary changes in automation trust. Third, the use of open-ended questions in the knowledge survey might impact the classification of results if participants used different or wrong wordings but it was an attempt to get unbiased responses without pre-loading the participants with particular definitions or ideas. Future studies should further validate the findings of this investigation with larger sample size and using more objective measures of trust such as gaze behavior. Finally, future investigations should validate the findings of this study with longer training period and under different driving conditions to see whether more exposure to ADAS features can improve drivers' trust and knowledge.

5. Conclusion

The objective of this study was to evaluate the impact of two training approaches (i.e., demonstration-based and video-based training) on older drivers' cognitive load, trust, and knowledge of ADAS considering gender differences. It was found that drivers who went through the demonstration-based training experienced lower workload while driving. However, based on the findings of our prior study with the same group of drivers (Zahabi et al., 2020), lower workload under demonstration-based training might have been due to the fact that drivers did not activate ADAS features as much as the video-based training group. It was found that training reduced cognitive load of female drivers but there was no significant difference between the perceptions of different genders regarding trust in ADAS. Furthermore, females had slightly better knowledge of ADAS after the training as compared to males. The findings suggested that in order to reduce cognitive load of older drivers, males can benefit from demonstration-based training approach while females can benefit more from video-based training of ADAS. The findings of this study can be beneficial to improve older adults' training of ADAS. Effective training cannot only lead to higher ADAS usage rates, but can also reduce the risk of MVCs for older drivers.

CRediT authorship contribution statement

Maryam Zahabi: Data curation, Formal analysis, Writing - original draft, Writing - review & editing. **Ashiq Mohammed Abdul Razak:** Data curation, Formal analysis. **Ranjana K. Mehta:** Conceptualization, Methodology, Formal analysis, Writing - review & editing. **Michael Manser:** Conceptualization, Funding acquisition, Methodology, Formal analysis, Writing - review & editing, Project administration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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