



Drivers trust, acceptance, and takeover behaviors in fully automated vehicles: Effects of automated driving styles and driver's driving styles

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ABSTRACT

Automated Vehicle (AV) technology has the potential to significantly improve driver safety. Unfortunately, drivers could be reluctant to ride with AVs due to their lack of trust and acceptance of AVs' driving styles. The present study investigated the effects of the designed driving style of AV (aggressive/defensive) and driver's driving style (aggressive/defensive) on driver's trust, acceptance, and take-over behavior in a fully AV. Thirty-two participants were classified into two groups based on their driving styles using the Aggressive Driving Scale and experienced twelve driving scenarios in either an aggressive AV or a defensive AV. Results revealed that driver's trust, acceptance, and takeover frequency were significantly influenced by the interaction effects between AV's driving style and driver's driving style. General estimating equations were conducted to analyze the relationships between driver's trust, acceptance, and take over frequency. The results showed that the effect of driver's trust in AVs on takeover frequency was mediated by driver's acceptance of AVs. These findings implied that driver's trust and acceptance of AVs could be enhanced when the designed AV's driving style aligned with driver's own driving style, which in turn, reduce undesired take over behavior. However, the "aggressive" AV driving style should be designed carefully considering driver safety.

1. Introduction

Automated Vehicles (AV) technology has been developed to reduce injuries, improve mobility, and release drivers from driving tasks (Favarò et al., 2017). However, these benefits may not be achieved until AVs are accepted by the public (Körber et al., 2018). A recent survey by the American Automobile Association (2019) reported that 71% of drivers in the U.S. were afraid of riding with fully AVs. Another study that investigated drivers' attitudes towards AVs suggested that concerns of safety, software hacking, and legal issues affected driver's trust and acceptance of AV technology (Kyriakidis et al., 2015). Therefore, it is important to understand these two constructs, driver's trust and acceptance, before the implementation of AVs in road traffic.

Trust in automation was defined as "an attitude that a user is willing to be vulnerable to an action from an automated system." (Körber et al., 2018). In automated systems, trust was found to be an important construct that can influence users' reliance and intention to use these systems (Carter and Bélanger, 2005; Gefen et al., 2003; Lee and See, 2004; Parasuraman et al., 2008; Pavlou, 2003). Another associated construct in automated systems is acceptance of technology, which is defined as a

human's direct attitude towards the technology and systems, including pleasantness, comfort, usefulness, and easy to use (Van der Laan et al., 1997). The Technology Acceptance Model (TAM) was a widely used theory that describes how an individual accepts and uses an information system (Davis et al., 1989). TAM demonstrates that a user's intention to use a system is determined by perceived usefulness and perceived ease of use. Previous studies on automation systems have suggested that users will not be willing to use or purchase a system without enough level of acceptance (Adell, 2010; Labeye et al., 2014; Martens and Jenssen, 2012; Van der Laan et al., 1997; Venkatesh et al., 2003). Both of trust and acceptance are important concepts to be studied in the field of driver-AV interaction. Previous studies have suggested that the lack of trust and acceptance of AV might affect the extent of a driver's use of automated vehicles (König and Neumayr, 2017; Kyriakidis et al., 2015; Schoettle and Sivak, 2014).

Existing studies focused on various interface design factors that have effects on a driver's trust and acceptance of AVs, such as anthropomorphic and conversational displays (Large et al., 2019; Ruijten et al., 2018), and informative interfaces for surrounding environment (Morra et al., 2019). However, the discussions on driving styles of AVs have not

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received attention until recently. In conventional vehicles, a passenger's feeling of comfort depends primarily on the driver's manual driving style (Ellinghaus and Schlag, 2001). This finding could be applied to the occupants (as drivers) of fully AVs. Previous research on this topic has shown that AV's driving style could influence driver's comfort, preference, trust, and acceptance (Bellem et al., 2018; Basu et al., 2017; Hartwich et al., 2018; Lee et al., 2019; Yusof et al., 2016) with one exception that found the AV's driving styles does not influence driver trust significantly (Oliveira et al., 2019).

Driving style has long been studied in conventional vehicles and is defined as a person's preferred way of driving that develops into driving habits over time (Kleisen, 2011; Elander et al., 1993). 'Driving habits' in this definition include automated skills and more consistent controlled behavior across different driving scenarios for a given driver (Sagberg et al., 2015). Sagberg et al. (2015) proposed a conceptual framework of driving styles that defined global driving styles (e.g., aggressive driving styles) and specific driving styles with behavior indicators (e.g., high traveling speed in longitudinal control). Based on this framework, a global driving style is composed of a set of specific behavioral indicators, which might be related to the same underlying motivation from drivers.

Various terms and concepts have been used to represent different global driving styles (such as *aggressive, deviant and risky, defensive, and concentrated and focused driving*), however, the precise definition of each global driving style was not provided and varied across different studies. Dula and Geller (2003) proposed the definition of aggressive driving with three dimensions, intentional acts of aggression toward others, negative emotions experienced while driving, and risk-taking behavior. While some researchers stated that aggressive driving and risky driving are both associated with negative safety impact (e.g., Constantinou et al., 2011; Dula and Ballard, 2003), other researchers argued the definition aggressive driving emphasized more on the motivation and intention to cause a negative physical or psychological impact in order to achieve the travel goal (e.g., Soole et al., 2011). Sagberg et al. (2015) provided a systematic review on manual driving styles and discussed the way to distinguish aggressive and defensive global driving styles. The authors argued that a consensus was reached that aggressive driving styles could be clearly distinguished from defensive driving styles based on different motives at a general level. To be more specific, the aggressive driving style refers to habitual driving with excitatory motives focusing on accomplishing travel goals, whereas defensive driving refers to habitual driving with inhibitory motives focusing on avoiding risks.

In terms of the operationalization of the driving styles, the settings of specific behavior indicators were usually investigated. These indicators include a driver's preference of longitudinal control (e.g., speed, acceleration and time headway), lateral control (e.g., steering angle and lateral acceleration), gap acceptance (e.g., left turn gap acceptance), and errors and violations (e.g., how strictly drivers obey the traffic laws) (Sagberg et al., 2015). For example, the indicators of an aggressive driving style include over-speeding, intentionally tailgating, jerky driving, inappropriate flashing high beams, and honking (Soole et al., 2011). The indicators of defensive driving styles focus on traffic safety, implemented by lower speed, smoother acceleration, earlier deceleration, earlier lane changing, larger gap to other road objects (Dettmann et al., 2021; Ekman et al., 2019; Feng et al., 2019; Hartwich et al., 2019; Roßner and Bullinger, 2019, 2020; Beggiato et al., 2020; Sun et al., 2020).

In terms of the impact of driving styles of AVs, a few studies have investigated how automated driving styles influence the driver's comfort, preference and trust. Bellem et al. (2016) analyzed drivers' maneuvers metrics in the manual driving and found drivers could perceive the differences in driving styles based on the maneuver metrics (e.g., acceleration, jerk, quickness). In a follow-up study that investigated the effect of automated driving styles on driver comfort and preference by using a

motion-based simulator, researchers found that drivers preferred a smooth driving style, including a symmetrical acceleration profile with small acceleration rate and a lane change profile with low jerks and early motion feedback (Bellem et al., 2018). Lee et al. (2019) examined three driving styles of AVs (e.g., aggressive, moderate, and conservative) on driver's trust in intersection negotiations by using a fixed-based simulator. In their study, drivers press either the gas pedal or the brake pedal to indicate their higher or lower trust in AVs. The study revealed that most moderate drivers have higher trust in moderate AVs than that in defensive AVs or an aggressive AVs. Oliveira et al. (2019) examined two driving styles of AVs, human-like behavior and machine-like behavior by using a motion-based simulator, and the results showed that there was no significant difference between these two driving styles on driver's trust.

To date, little research has been done to investigate how driver's individual difference influence their trust and acceptance of AV's driving styles in human-AV interaction. One of the exceptions is the study done by Hartwich et al. (2018) that investigated the effects of driver age and the familiarity of AV's driving style on driver's acceptance and comfort by asking participants evaluating different driving styles in the recorded videos by using a fixed-based simulator. The findings showed that younger drivers had higher comfort, enjoyment and acceptance with a familiar AV's driving style, but elder drivers had higher acceptance of the unfamiliar driving style.

However, it is still unclear how driver's own driving styles (e.g., aggressive and defensive) influence their trust, acceptance, and propensity to take over control of AVs, especially when an AV drives in a different driving style from their own. Automated driving styles might align or disagree with drivers' driving styles. The discrepancy between the driver's driving styles and AV's driving styles may impair driver's trust and acceptance toward an AV's driving behavior, which in turn negatively affect driver's takeover behavior frequency and the use of AVs. To be more specific, aggressive drivers prefer a higher speed, a smaller time headway and gap, larger longitudinal and lateral accelerations, and are more likely to disapprove of other's driving behavior, whereas drivers with a defensive driving style may be the opposite (Sagberg et al., 2015). Therefore, aggressive drivers may not accept AVs with a defensive driving style and take over vehicles more frequently than desired. In comparison, defensive drivers may not trust or accept AVs with an aggressive automated driving style and give up the automation functions entirely. This suggests a need to understand the interaction between driver's driving style and AV's driving styles on driver's trust, acceptance, and takeover behavior, to promote driver trust and improve driver safety.

Moreover, most of the existing studies that investigated AV's driving styles focused more on driver's subjective evaluation of AVs without investigating its influence on drivers' take over behavior in AVs (Bellem et al., 2018; Hartwich et al., 2018; Lee et al., 2019; Oliveira et al., 2019). Providing drivers with the possibility to takeover AVs might also influence their trust, acceptance, and behavior in AVs, especially for aggressive drivers who have high locus of control. Furthermore, existing studies focused on vehicle maneuvers in simple scenarios, such as accelerations on straight road segments, lane changes, and straightly crossing intersections without interactions with traffic lights or traffic signs. The current study aimed to investigate more complex scenarios (e.g., responses to traffic light, turning behavior at intersections) and hazardous scenarios (e.g., interaction with other vehicles and pedestrians) by systematically manipulating the abovementioned set of specific indicators to reflect two global driving styles of AVs on the aggressive-defensive dimension.

In summary, the present study aims to investigate the impact of driver's driving styles and AV's driving styles on driver's trust, acceptance, and takeover behaviors in normal and hazardous scenarios when riding with a fully AV. It is hypothesized that drivers have higher trust and ac-

ceptance of AVs and take back control less frequently when the AV's driving style aligns with their own driving style.

2. Method

2.1. Participants

Thirty-two participants (16 males and 16 females) participated in this study. Participants were required to be native English speakers and have held a driver's license for at least 2 years. Their ages ranged from 18 to 39 with an average age of 23.38 years ($SD = 4.65$) with the average annual driving mileage ($M = 7656$ miles, $SD = 5195$). The number of aggressive drivers and defensive drivers are balanced with a pre-screening procedure to classify driver's driving styles with the Aggressive Driving Scale (ADS) (Krahé and Fenske, 2002). Out of the participants who completed the ADS, there were 30 (33.71%) aggressive drivers, 27 (30.34%) moderate drivers, and 32 (35.96%) defensive drivers. The participants who were classified as aggressive drivers or defensive drivers were then contacted to participate in the formal experiment. The participants were consecutively selected in order of appearance according to their convenient accessibility. The sampling process comes to an end when the total amount of participants for each driver group was reached. All participants were recruited from the general public via Penn State's StudyFinder website and compensated \$10/hour for this study. The study was approved by the Institutional Review Board at Pennsylvania State University.

2.2. Apparatus

A driving simulator (STISIM Drive® M300WS-Console system) was used in this study. It comprises a Logitech Momo® steering wheel with force feedback (Logitech Inc., Fremont, CA), a throttle pedal, and a brake pedal. The STISIM simulator is installed on a Dell Workstation (Precision 490, Dual Core Intel Xeon Processor 5130 2 GHz). Driving scenarios were presented on a 27-inch LCD with 1920×1200 -pixel resolution. The automated driving system was implemented by STISIM Drive Open Module (OM) programming. As shown in Fig. 1, participants could push the red button beside the steering wheel to switch the AV between automation mode and manual-driven mode freely. There was a graphic bar on the top of the middle screen. When vehicle was in the automation mode, the color of the bar would be green. When vehicle was in the manual-driven mode, the color of the bar would be yellow.

2.3. Materials

Aggressive Driving Scale (ADS). This 24-item scale was developed by Krahé and Fenske (2002) and validated by Zhang et al. (2016) to assess

aggressive driving behaviors. Participants were asked to report the frequency of the aggressive behaviors they engaged in by rating each statement on a 5-point scale ("0" = never to "4" = very often). An example item is "How often do you overtake a slow driver on the inside?". Participants were pre-screened with the ADS to determine their driving styles, and those who were identified as aggressive and defensive drivers were recruited in the formal experiment. Drivers were classified as aggressive drivers when $ADS \geq 30$ for male drivers and $ADS \geq 21$ for female drivers, and defensive drivers when $ADS \leq 23$ for male drivers and $ADS \leq 13$ for female drivers (Krahé and Fenske, 2002; Krahé, 2005).

Checklist for Trust between People and Automation (Jian et al., 2000). This questionnaire was used to evaluate 12 potential factors of trust between people and automated system, including 'deception', 'underhanded manner', 'suspicion', 'beware', 'harm', 'security', 'integrity', 'dependable', 'reliability', 'entrust', 'familiarity' on a 7-point scale ('1' = not at all to '7' = extremely).

Propensity to Trust Questionnaire. This questionnaire was a six-item self-report scale developed by Sinha et al. (2008) to assess individual propensity to trust machines. The item responses were on a 7-point scale ranging from 1 (strongly disagree) to 7 (strongly agree). An example item is, "I am likely to trust a machine even when I have little knowledge about it." The scale reliability was reported with an α of 0.86.

System Acceptance Questionnaire (Van Der Laan et al., 1997). This nine-item questionnaire was designed to measure human's acceptance of new technology with two dimensions, usefulness, and satisfaction. Participants were required to evaluate systems by rating on a 5-point scale from -2 to +2 (e.g., '-2' = useful to '2' = useless). Followed by the procedure of Beggiato et al. (2015) and Hartwich et al. (2018), a total of nine items were produced to one acceptance dimension, which was calculated from the mean value of all nine items.

Evaluation of AV driving indicators. This survey was developed by authors to measure participant's evaluation of the AV's specific driving indicators that were manipulated to create two automated driving styles, such as speed, deceleration, turning angle, and time headway to lead vehicle. It was used to indicate driver's perception of the AV's driving styles to be either defensive (e.g., '0' = extremely slow speed) or aggressive (e.g., '8' = extremely fast speed) on a 9-point scale. Participants were also required to assess their trust, acceptance, and safety during each AV drive on a 9-point scale ('0' = extremely distrust/unaccepted/unsafe to '8' = extremely trust/accept/safe). The reasons for their take over behaviors were recorded if there were any during the drive.

Subjective evaluation of comfort, preference and safety. This survey was developed by authors to measure participant's subjective evaluation of automated driving styles after finishing all AV driving tasks, including comfort, preference, similar with me, and safety, on a 9-point scale ('0' = strongly disagree to '8' = strongly agree). At the end of the questionnaire, an open-ended question was designed to collect the participants' opinions on how the design of the AVs should be improved to increase their trust in AVs.

2.4. Experiment design and scenarios

The experiment adopted a 2×2 between-subjects design with the participant's driving style (aggressive vs. defensive) and the AV's driving style (aggressive vs. defensive) as independent variables. Each participant only experienced one of automated driving styles. As shown in Table 1, specific driving indicators were manipulated to create a more aggressive and a more defensive automated driving style for eight normal scenarios and four hazardous scenarios. The values of the indicators were adopted from several research studies that investigated driver's driving styles on the aggressive-defensive dimension in the same or similar scenarios (Deffenbacher et al., 2003; Hong et al., 2014; Hill et

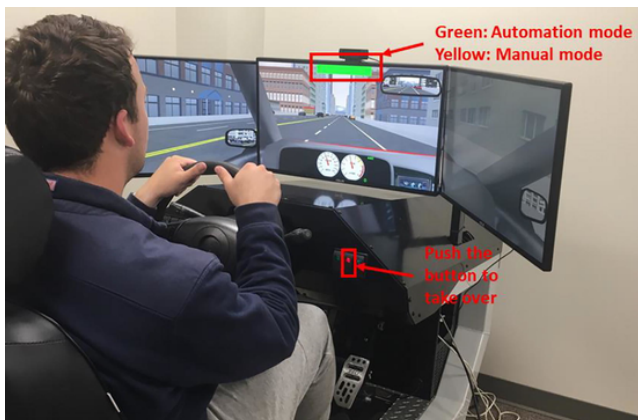


Fig. 1. The STISIM Driving Simulator.

Table 1
Values of driving indicators for AVs.

	Aggressive AV	Defensive AV
Average speed (ft/s)	76.31	66
Acceleration (ft/s ²)	6.379	5.468
Deceleration – approaching intersection (ft/s ²)	–7.143	–3.712
Turning speed – Right (ft/s)	16.126	10.625
Turning angle – Right (rad/s)	0.664	0.438
Turning speed – Left (ft/s)	21.813	19.192
Turning angle – Left (rad/s)	0.385	0.339
Lane change angle (rad/s)	1.326	1.182
Time to collision to lead vehicle – Hazard 1 (s)	2.5	4.5
Deceleration– Hazard 1 (ft/s ²)	20	10.393
Deceleration– Hazard 2 (ft/s ²)	24.13	24.13
Deceleration/Acceleration-Hazard 3	6.379	–3.712
Deceleration- Hazard 4 (ft/s ²)	–7.143	–3.712
Distance to collision – Hazard 4 (ft)	32.43	81.33

al., 2015; Yan et al., 2007). An urban environment was simulated with two lanes in each direction of the roadways, moderate traffic density (13 vehicles/ mile /lane), dense buildings, and pedestrians walking along the roads. The posted speed limits were 45 mph.

There were two driving tasks in this experiment, including driving conventional and AVs. The AV driving task contained eight normal driving scenarios and four hazard scenarios, as shown in Table 2. The hazard scenarios were selected and redesigned based on the existing accidents reports with AVs, as shown in Table 3 (Favarò et al., 2017, 2018). All 12 scenarios were divided into 4 blocks with the sequence of being balanced with a Latin Square design across four experimental conditions. Since we expected participants might take over AVs more frequently in the hazard scenarios, the hazard scenarios were designed at the end of each block so that they could easily recall and report the reasons for their takeover behaviors after each block. For the conventional vehicle driving task, participants were asked to experience the same 8 normal driving scenarios. To avoid the order effect of scenario sequence, a Latin square design was used to balance the sequence of scenarios.

2.5. Dependent variables

There were three sets of dependent variables that were collected in the study, including subjective data collected with questionnaires described in the material subsection, manual driving performance in conventional vehicles, and take-over driving performance in AVs. As shown in Table 4, the subjective data included trust propensity, trust, acceptance, safety, comfort, preference, and subjective evaluation of AV. The take-over driving data and manual driving data were both

Table 2
Scenarios in the AV driving task.

Block	Scenarios
1	Drive straightly 1. Turn right after a red light changed to a green light 2. Stop in front of the stop sign Hazard 1: Slow lead vehicle brakes down
2	Drive straightly 3. Turn right on a green light 4. Cross the intersection on a green light Hazard 2: Pedestrian runs into the road
3	Drive straightly 5. Turn left after a red light changed to a green light 6. Cross the intersection on a yellow light Hazard 3: Vehicle on the adjacent lane cuts in
4	Drive straightly 7. Turn left on a green light with oncoming traffic 8. Go straight and stop at a red light Hazard 4: Jam traffic

recorded by STISIM. During the AV driving task, participant's *takeover frequency* was recorded along with their take over performance depending on the scenarios. If participants took over AV when driving on an open road, their *average acceleration from the start*, *average speed*, *speed standard deviation*, and *lateral position standard deviation* were measured. If they took over AV when approaching intersections, the *position where they began to decelerate*, *stop distance*, *stop time*, *average deceleration* and *maximum deceleration* were measured. If they took over AV to make turns at intersections, their *average turning speed* and *average turning angle* were calculated. If they took over AV when following a lead vehicle, their *speed standard deviation*, *minimum time-to-collision (TTC)*, and *minimum distance to lead vehicle* were measured. For the driving tasks with a conventional vehicle, the types of manual driving data recorded were the same as driving data after takeover in AVs.

2.6. Procedure

Participants who responded to advertisements were pre-screened to classify their driving styles with Aggressive Driving Scale (ADS) after provided verbal consents. Participants who were identified as either aggressive drivers or defensive drivers were recruited to participate in the experiment. Upon arriving, participants gave their written consent and then filled out the *Demographic Questionnaire* and *Propensity of Trust*, as well as the pre-test trust scale, “*Checklist for Trust between People and Automation*”. Before the formal testing, they received an introduction to the experiment and the automated driving system. They were then given a 15-minute practice session to familiarize themselves with driving simulator manually. After the practice, participants were instructed to complete a conventional vehicle driving task, including driving on an open road, following a slow lead vehicle, and turning at intersections.

Afterward, participants were instructed to complete an AV driving task on the simulator. They were trained with a 5-minute practical session to learn about how to switch between automation modes and manual-driving modes. The AV was design as a fully AV that it could handle all scenarios including hazard scenarios, and no crash would have occurred if no takeover behavior. In the formal experiment, participants were asked to drive the AV with the assigned driving style in an urban environment, and experience four blocks of the driving scenarios in a balanced order. During the drive, they could push the button to switch between automation mode and manual-driven mode freely. The count of pushing the button was recorded as takeover frequency. Even though the AV was designed as a fully AV, drivers were asked to always monitor the road environment so that their trust, acceptance and evaluation of the designed automated driving styles could be investigated. To further ensure drivers to experience the AV's driving style for all designed scenarios, the vehicle would switch back from manual-driven mode to automation mode after 2500 feet of manual driving if a driver took over the vehicle. After each block, participants were asked to evaluate the designed driving indicators of AVs and explain the reasons why they took over control of the AVs if there were any.

After the entire experiment, participants filled out several questionnaires, including *Subjective Evaluation of AV*, *Post-Test Checklist for Trust between People and Automation*, and *System Acceptance Questionnaire*. Finally, they were interviewed with several questions to explore the reasons for any change in their trust in AVs and the factors that could improve their trust in the designed automated driving style. The total experiment time is 75–90 min.

2.7. Data analysis

The aim of this study was to investigate the impact of driver's driving style and AV's driving style on driver's trust, acceptance, and takeover behavior when riding with a fully AV. A two-way MANCOVA was firstly conducted to analyze the effects of AV's and driver's driving

Table 3
Diagrams of hazard scenarios.

Hazard 1-2		
Description	There was a slow lead vehicle (34 mph) in front of AV. After AV slows down, HV would suddenly brake and AV would brake to stop.	A pedestrian suddenly crosses the road and AV would brake to stop.
Hazard 3-4		
Description	A vehicle from adjacent lane intended to cut into the AV's lane. Aggressive AV would accelerate, and defensive AV would decelerate.	AV drove into a traffic jam. The AV followed a slow driving vehicle (15 mph) and the AV would slow down.
Legend		

style on drivers' trust and acceptance of AVs with driver's trust propensity as a covariate. Because trust propensity and pre-test trust were significantly correlated ($r = 0.48$, $p = .006$), only trust propensity was added in this model as a covariate. The follow-up two-way ANCOVAs were conducted with the covariate of trust propensity to analyze the effects of AV's and driver's driving style on driver's trust and acceptance, respectively. Driver's subjective evaluation of their comfort, preference, and safety were analyzed with two-way ANOVAs. Then, a quasi-Poisson Regression Model was conducted to analyze the effect of AV's and driver's driving style on driver's takeover frequency during the driving task.

Afterwards, the general estimating equations (GEEs) were used to quantify the relationships among drivers' trust, acceptance, safety, and takeover frequency with the data collected in each driving block while considering the impact of AV's and driver's driving styles.

Lastly, the reasons behind the takeover behavior were explored. Takeover behavior was divided into four groups based on the scenarios in which takeover behavior occurs, including decelerating when approaching an intersection, decelerating when following a slow lead vehicle, going straight, and others. For behavior of decelerating when approaching intersection, Welch's ANOVAs were conducted to analyze the effect of AV's and drivers' driving style on drivers' takeover behav-

ior due to lack of homogeneity of variance. The takeover behavior indicators include distance from takeover to stop line, time to stop line when takeover, distance from initial position to stop line, and average deceleration. For behavior of decelerating when following a slow lead vehicle and going straight, descriptive analysis was performed to interpret the results.

3. Results

Thirty-two participants were assigned into four groups based on their own driving style and AV's driving style. In each group, gender was balanced and there were four males and four females. The information of age and annual driving mileage for each group was shown in Table 5. There were no significant differences among each group on their age ($F(3, 28) = 1.00$, $p = .41$), annual driving mileage ($F(3, 28) = 0.78$, $p = .51$), and driver license age ($F(3, 28) = 0.64$, $p = .59$).

As shown in Table 6, descriptive data analysis was conducted to summarize the results of all the dependent variables.

Table 4
Measurement of each dependent variable in this experiment.

Dependent Variable	Time to Measure	Instrument to Measure
Trust Propensity	Before the experiment	Propensity to Trust Questionnaire (Sinha et al., 2008)
Pre-test Trust	Before the experiment	Checklist for Trust between People and Automation (Jian et al., 2000)
Manual Driving Data in a Conventional Vehicle	First Session	STISIM Drive® Simulator
Takeover Frequency in an AV	Second Session	STISIM Drive® Simulator
Takeover Driving Data in an AV	Second Session	STISIM Drive® Simulator
Subjective Evaluation of AV driving indicators (e.g., average speed, deceleration, stop distance) (during the specific block)	Second Session – after each block	Evaluation of AV driving indicators
Trust, Acceptance, Safety (during the specific block)	Second Session – after each block	Evaluation of AV driving indicators
Comfort, Preference, Safety (during the entire experiment)	After Entire Experiment	Subjective evaluation of comfort, preference and safety
Post-test Trust (during the entire experiment)	After Entire Experiment	Checklist for Trust between People and Automation (Jian et al., 2000)
Acceptance (during the entire experiment)	After Entire Experiment	System Acceptance Questionnaire (Van Der Laan et al., 1997)

Table 5
Participants information for each group (Mean $\pm$ SD).

	Aggressive Drivers		Defensive Drivers	
	Aggressive AVs	Defensive AVs	Aggressive AVs	Defensive AVs
Age (years)	24.25 $\pm$ 7.03	22.13 $\pm$ 2.36	21.88 $\pm$ 2.75	25.25 $\pm$ 4.89
Annual Driving Mileage (miles)	6250 $\pm$ 4432	9353 $\pm$ 3953	8750 $\pm$ 7071	6250 $\pm$ 5000
Driver License Age (year)	7.75 $\pm$ 7.15	5.75 $\pm$ 2.66	5.75 $\pm$ 2.82	8.44 $\pm$ 5.39
Type of cars	50% SUV, 37.5% Sedan or Wagon, 25% Van or Minivan	37.5% SUV, 62.5% Sedan or Wagon	25% SUV, 75% Sedan or Wagon	25% SUV, 75% Sedan or Wagon
Moving Violations	50%	37.5%	25%	25%

Table 6
Summary of all the dependent variables (Mean $\pm$ SE).

	Aggressive Drivers		Defensive Drivers	
	Aggressive AVs	Defensive AVs	Aggressive AVs	Defensive AVs
Trust	5.88 $\pm$ 0.35	5.00 $\pm$ 0.53	4.75 $\pm$ 0.45	6.13 $\pm$ 0.30
Acceptance	1.17 $\pm$ 0.13	0.78 $\pm$ 0.25	0.57 $\pm$ 0.20	1.11 $\pm$ 0.17
Comfort	6.50 $\pm$ 0.71	5.75 $\pm$ 0.49	4.00 $\pm$ 0.80	6.63 $\pm$ 0.63
Preference	6.38 $\pm$ 0.68	5.50 $\pm$ 0.73	4.13 $\pm$ 0.69	6.00 $\pm$ 0.53
Safety	5.88 $\pm$ 0.79	5.88 $\pm$ 0.52	3.88 $\pm$ 0.72	7.00 $\pm$ 0.42
Takeover Frequency	2.00 $\pm$ 0.76	2.75 $\pm$ 1.15	3.00 $\pm$ 1.28	1.00 $\pm$ 0.50

3.1. Drivers' trust and acceptance toward AVs

The results of MANCOVA showed that a significant interaction effect between AV's and driver's driving style on their post-test trust and acceptance (Wilks' lambda: $\Lambda = 0.77$, $F(2, 26) = 3.97$, $p = .03$, $\eta_p^2 = 0.24$) and a significant effect of driver's trust propensity on their post-test trust and acceptance (Wilks' lambda: $\Lambda = 0.78$, $F(2, 26) = 3.77$, $p = .04$, $\eta_p^2 = 0.23$) were found. No significant main effects for AV's (Wilks' lambda: $\Lambda = 0.99$, $F(2, 26) = 0.05$, $p = .95$) or driver's driving style (Wilks' lambda: $\Lambda = 0.99$, $F(2, 26) = 0.20$, $p = .82$) on driver's post-test trust and acceptance were found.

As shown in Fig. 2, results indicated a significant interaction effect between AV's and driver's driving style on their post-test trust in AVs ($F(1, 27) = 7.67$, $p = .01$, $\eta_p^2 = 0.22$). For simple effect, aggressive drivers trusted aggressive AVs significantly more than defensive drivers ($F(1, 27) = 6.85$, $p = .02$, $\eta_p^2 = 0.21$), whereas defensive drivers trusted defensive AVs significantly more than aggressive AVs ($F(1, 27) = 4.72$, $p = .04$, $\eta_p^2 = 0.15$). Besides, a significant effect of driver's trust propensity on their post-test trust in AVs was found ($F(1, 27) = 5.97$, $p = .02$, $\eta_p^2 = 0.18$), such as drivers with a higher trust propensity trusted more on AVs. No significant main effects for AV's ($F(1, 27) = 0.10$, $p = .75$) or driver's driving style ($F(1, 27) = 0.27$, $p = .61$) on driver's post-test trust in AVs were found.

As shown in Fig. 3, the significant interaction effects between AV's and driver's driving style were found on their acceptance of AVs ($F(1, 27) = 4.92$, $p = .03$, $\eta_p^2 = 0.16$). An analysis of simple effects showed that aggressive drivers have marginally significant higher acceptance of aggressive AVs than defensive drivers, $F(1, 27) = 4.00$, $p = .056$, $\eta_p^2 = 0.13$. Meanwhile, defensive drivers have numerically higher acceptance of defensive AVs than that of aggressive AVs, however, the difference is not significant ($F(1, 27) = 2.98$, $p = .09$, $\eta_p^2 = 0.10$). No significant main effects of either AV's driving styles ($F(1, 27) = 0.06$, $p = .81$) or driver's driving styles ($F(1, 27) = 0.37$, $p = .55$) were found. Besides, no significant of driver's trust propensity on their acceptance in AVs was found ($F(1, 27) = 0.08$, $p = .78$).

As shown in Fig. 4, when analyzing acceptance with two dimensions (usefulness and satisfaction), the results indicated that drivers perceived both designs of AVs to be useful regardless of their own driving

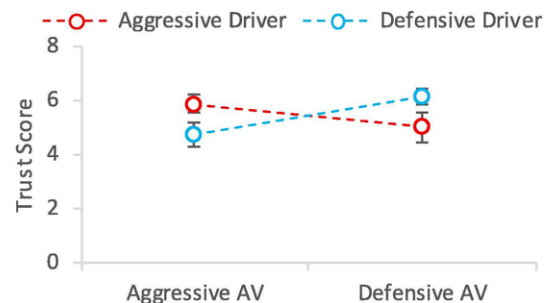


Fig. 2. Effects of AV's and driver's driving style on trust (error bars: ± 1 SE).

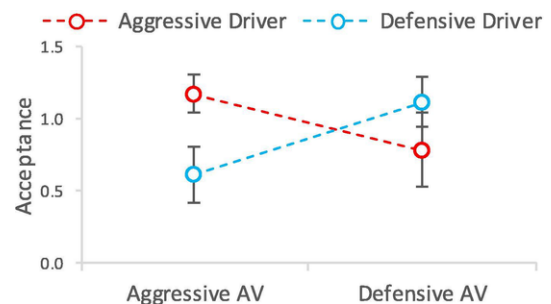


Fig. 3. Effects of AV's and driver's driving style on acceptance (error bars: ± 1 SE).

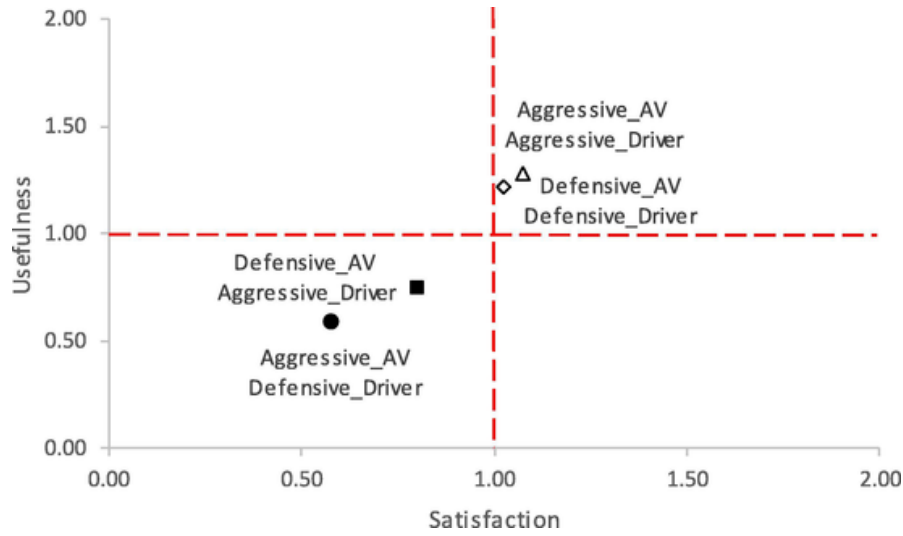


Fig. 4. Average usefulness and satisfaction scores for each experiment.

styles since the usefulness scores in all four experiment conditions are above zero (neutral). However, drivers showed better satisfaction with AVs when the designed AV's driving styles aligned with their own driving styles than when AV's driving styles differed from driver's driving styles.

3.2. Drivers' subjective evaluation of comfort, preference and safety

3.2.1. Comfort

As shown in Fig. 5(a), results showed that the significant interaction effect between AV's and driver's driving style was found on their comfort ($F(1, 28) = 6.42, p = .02, \eta_p^2 = 0.19$). For simple effect, when driving aggressive AVs, aggressive drivers felt significantly more comfortable than defensive drivers ($F(1, 28) = 7.04, p = .01, \eta_p^2 = 0.20$). Moreover, defensive drivers felt significantly more comfortable when driving defensive AVs than aggressive AVs ($F(1, 28) = 7.77, p = .01,$

$\eta_p^2 = 0.22$). Results did not find any significant main effects for AV and driver's driving style on driver's comfort when driving AV ($F(1, 28) = 1.98, p = .17; F(1, 28) = 1.49, p = .23$).

3.2.2. Preference

As shown in Fig. 5(b), results showed that the significant interaction effect between AV's and driver's driving style was found on their preference ($F(1, 28) = 4.29, p = .048, \eta_p^2 = 0.13$). For simple effect, aggressive drivers preferred aggressive AV significantly more than defensive drivers ($F(1, 28) = 5.74, p = .02, \eta_p^2 = 0.17$). Defensive drivers preferred defensive AV marginally significantly more than aggressive AV ($F(1, 28) = 3.99, p = .056, \eta_p^2 = 0.13$). No significant main effects for AV and driver's driving style on driver's preference to AV was found ($F(1, 28) = 0.57, p = .46; F(1, 28) = 1.74, p = .20$).

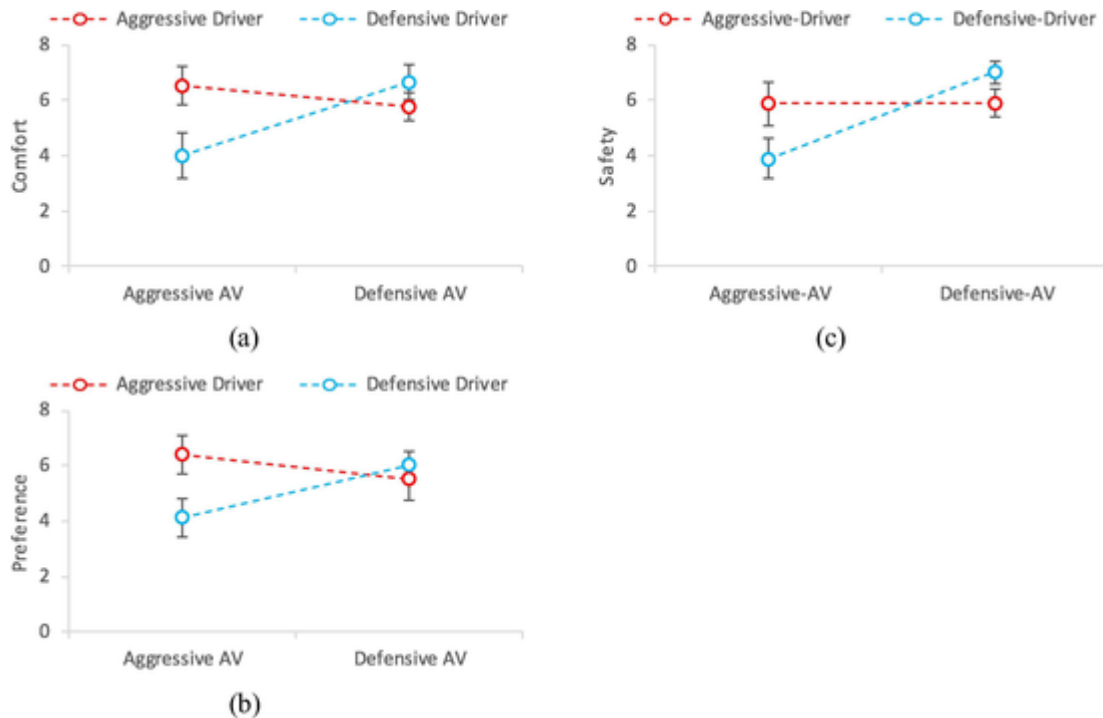


Fig. 5. Effects of AV's and driver's driving style on comfort, preference, and safety (error bars: ± 1 SE).

3.2.3. Safety

As shown in Fig. 5(c), results showed the significant interaction effect between AV's and driver's driving style was found on their subjective safety ($F(1, 28) = 6.17, p = .02, \eta_p^2 = 0.18$). For simple effect, when driving aggressive AVs, aggressive drivers felt significantly safer than defensive drivers ($F(1, 28) = 5.06, p = .03, \eta_p^2 = 0.15$). Defensive drivers felt significantly safer when driving defensive AVs than aggressive AVs ($F(1, 28) = 12.34, p = .002, \eta_p^2 = 0.31$). The significant effect of AV's driving style on how drivers felt safe during AV driving was found ($F(1, 28) = 6.17, p = .02, \eta_p^2 = 0.18$). However, due to the significant interaction effect, this can only be assumed for defensive drivers. The main effect of driver's driving style on safety was not significant ($F(1, 28) = 0.48, p = .49$).

3.3. Takeover frequency

The fitted quasi Poisson Regression Model showed that driver's takeover frequency was predicted by the interaction effect between AV's and driver's driving style ($t(124) = 2.18, p = .03$), as shown in Fig. 6. For the simple effect, aggressive drivers took over AVs significantly more frequently than defensive drivers when driving defensive AVs ($t(124) = 0.94, p < .05$), and defensive drivers took over significantly more frequently when driving aggressive AVs compared with driving defensive AVs ($t(124) = 2.17, p = .03$).

GEEs were conducted to test the relationship between takeover frequency and their trust, acceptance, safety in each block. As shown in Fig. 7, the results showed that driver's subjective safety when driving an AV was predicted by AV's driving style ($\beta = 0.68, p < .001$), and the interaction effect between AV's and driver's driving style ($\beta = 0.50, p = .003$) in a linear relationship. Driver's trust in an AV was predicted by driver's trust propensity to machines ($\beta = 0.08, p < .001$), safety ($\beta = 0.44, p < .001$), and the interaction effect between AV's and driver's driving style ($\beta = 0.34, p = .01$) in a linear re-

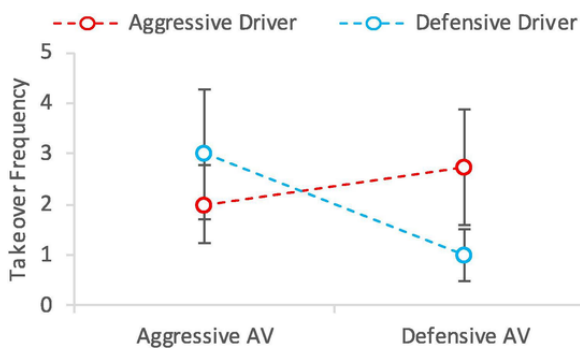


Fig. 6. Effects of AV's and driver's driving style on takeover frequency (error bars: ± 1 SE).

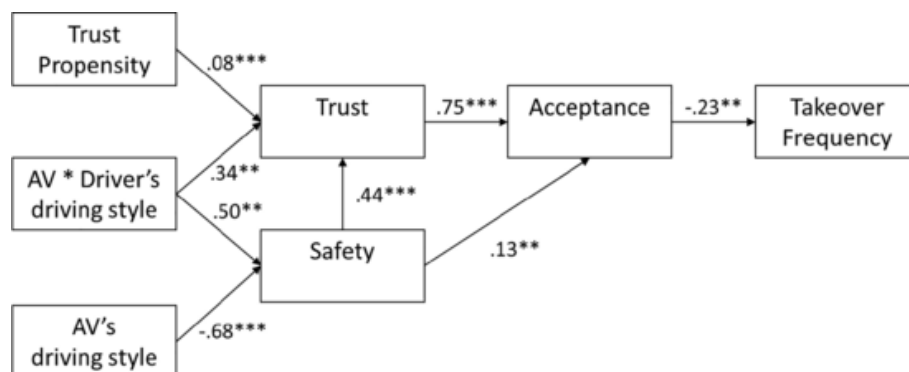


Fig. 7. GEE models for the relationships between AV's and driver's driving styles, trust, acceptance and takeover frequency in each block (* $p < .05$; ** $p < .01$; *** $p < .001$).

lationship. Driver's acceptance toward an AV was predicted by driver's trust ($\beta = 0.75, p < .001$) and safety ($\beta = 0.13, p = .003$) in a linear relationship. Driver's takeover frequency was predicted by driver's acceptance ($\beta = -0.23, p = .006$) in a Poisson relationship.

3.4. Takeover performance

All of the takeover behavior was divided into four groups based on the scenarios in which takeover behavior occurs (e.g., straight road segments vs. intersection, free flow vs. car-following). The first group was labeled "approaching intersections" representing conditions in which drivers took over AVs when the AV approaches an intersection. The second group was labeled "driving straight" representing the conditions in which drivers took over the AV when it drove on straight road segments without the interaction with other road users. At the beginning of each scenario, drivers were required to drive AVs straightly on an open road. Some drivers took over AVs at this time to accelerate the vehicles. The third group, labeled "slow moving vehicles", represented the scenarios when AV follows a slow lead vehicle on straight road segments. The fourth group represented the rest of takeover scenarios due to their rare occurrences, such as lane changing and speeding up after AV stop. Fig. 8 showed the takeover frequency in each group under each experiment condition. Due to the limited data of takeover behavior in other scenarios, statistical analysis was only performed for the approaching intersection scenarios in the following section.

3.4.1. Approaching intersection

To analyze the effect of AV's and drivers' driving style on drivers' takeover performance, Welch's ANOVAs were conducted for each driving indicator due to lack of homogeneity of variance, including distance from takeover to stop line, time to stop line when takeover, distance from beginning to decelerate to stop line, and average deceleration.

3.4.2. Distance from takeover to stop line

As shown in Fig. 9, the results showed that when driving aggressive AVs, there was a significant effect between driver's driving style on the distance from takeover to stop line ($F(1, 14.82) = 8.20, p = .01$), such that the distance from takeover to stop line for aggressive drivers ($M = 335.84$ ft) were significant smaller than defensive drivers ($M = 508.35$ ft). When driving defensive AVs, there was no significant effect between driver's driving style on the distance from takeover to stop line ($F(1, 3.21) = 7.89, p = .06$). There was no significant effect between AV's driving style on the distance from takeover to stop line for aggressive drivers ($F(1, 1.14) = 35.45, p = .09$) or defensive drivers ($F(1, 11.03) = 0.16, p = .70$).

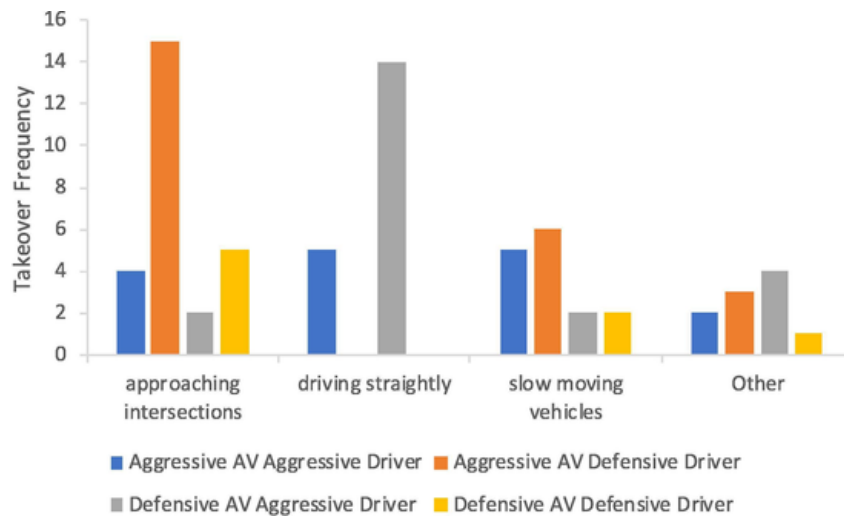


Fig. 8. The frequency of takeover behaviors in classified scenario groups.

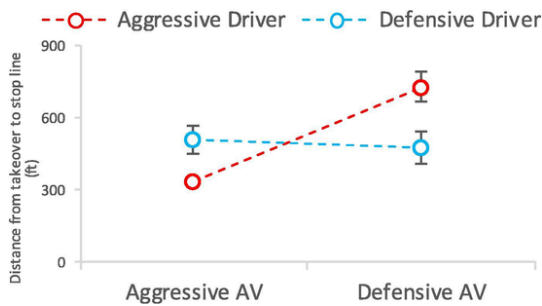


Fig. 9. Effects of AV's and driver's driving style on distance from takeover to stop line (error bars: ± 1 SE).

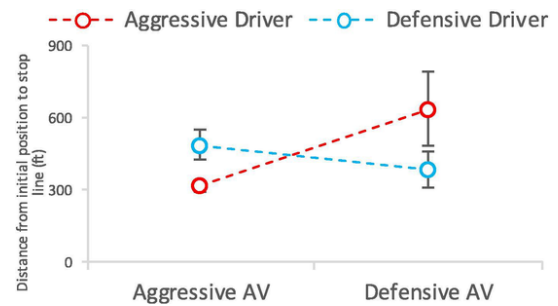


Fig. 11. Effects of AV's and driver's driving style on distance from beginning to decelerate to stop line (error bars: ± 1 SE).

3.4.3. Time to stop line when takeover

As shown in Fig. 10, the results showed that when driving aggressive AVs, there was a significant effect between driver's driving style on the time to stop line when takeover ($F(1, 14.75) = 9.61, p = .01$), such that the time to stop line when takeover for aggressive drivers ($M = 4.44$ s) were significant shorter than that for defensive drivers ($M = 6.76$ s). When driving defensive AVs, there was no significant effect between driver's driving style on the time to stop line when takeover ($F(1, 2.90) = 7.48, p = .07$). There was no significant effect between AV's driving style on the time to stop line when takeover for aggressive drivers ($F(1, 1.09) = 44.69, p = .08$) or defensive drivers ($F(1, 9.73) = 0.34, p = .57$).

3.4.4. Distance from initial position to stop line

As shown in Fig. 11, the results showed that when driving aggressive AVs, there was a significant effect between driver's driving style on

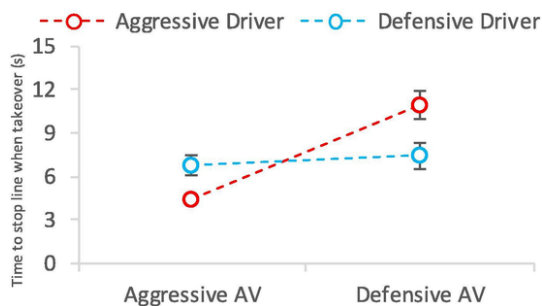


Fig. 10. Effects of AV's and driver's driving style on time to stop line when takeover (error bars: ± 1 SE).

the distance from initial position to stop line ($F(1, 15.26) = 6.66, p = .02$), such that the distance for aggressive drivers ($M = 314.48$ ft) were significant smaller than that for defensive drivers ($M = 485.76$ ft). When driving defensive AVs, there was no significant effect between driver's driving style on the distance from beginning to decelerate to stop line ($F(1, 1.56) = 2.13, p = .31$). There was no significant effect between AV's driving style on the distance from beginning to decelerate to stop line for aggressive drivers ($F(1, 1.04) = 4.23, p = .28$) or defensive drivers ($F(1, 9.54) = 1.05, p = .33$).

3.4.5. Average deceleration

As shown in Fig. 12, the results showed that among aggressive drivers, there was a significant effect between AV's driving style on the average deceleration ($F(1, 3.52) = 54.19, p = .003$), such that the average deceleration for driving aggressive AV ($M = 7.92$ ft/s²) were significantly larger than driving defensive AV ($M = 2.37$ ft/s²). No such

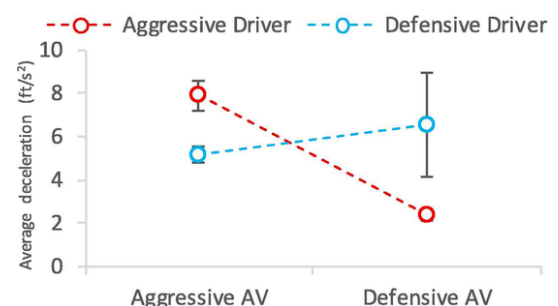


Fig. 12. Effects of AV's and driver's driving style on average deceleration (error bars: ± 1 SE).

significant effect was found for defensive drivers ($F(1, 4.19) = 0.31$, $p = .61$). When driving aggressive AVs, there was a significant effect between driver's driving style on the average deceleration ($F(1, 4.73) = 11.36$, $p = .02$), such that the average deceleration for aggressive drivers ($M = 7.92 \text{ ft/s}^2$) were significantly larger than defensive drivers ($M = 5.20 \text{ ft/s}^2$). When driving defensive AVs, there was no significant effect of driver's driving style on the average deceleration ($F(1, 4.07) = 2.97$, $p = .16$).

In summary, when riding with an aggressive AV, aggressive drivers were more likely to takeover and decelerate later than defensive drivers when approaching intersections. The average deceleration of aggressive drivers was also larger than that of defensive driver when driving an aggressive AV. However, there was no significant difference on takeover performance between aggressive drivers and defensive drivers when riding with a defensive AV. Additionally, among aggressive drivers, the average deceleration for driving aggressive AV was significantly larger than driving defensive AV.

3.4.6. Driving straightly

There were 3 participants in this study taking over AVs 16 times when it was driving straightly. All of them were aggressive drivers. One drove an aggressive AV and took over 4 times. The other two drove defensive AVs and took over 12 times (Driver 1 took over 3 times and Driver 2 took over 9 times). To explore their purpose of taking over AVs when going straight, drivers' 85th percentile manual driving speed after the takeover was compared with the initial average speed of AV. The descriptive results showed that in the thirteen out of sixteen takeovers (81.25%), driver's 85th percentile speed after takeover was higher than the AV's initial speed. This result suggested that drivers taking over AVs on straight road segments might mainly be due to their desire to drive faster. In the remaining three takeovers, drivers 85th percentile speed were lower than AV's initial speed but with less than 3 ft/s differences. It suggested that drivers taking over AVs in this situation may be satisfied with the AV's speed, but they may seek taking control of the vehicles by themselves. Only one takeover occurs during the acceleration

process, whereas the rest of takeover all occurs after the AV had reached its average speed.

3.4.7. Slow moving vehicles

There were two hazardous scenarios in which the AV was required to slow down when following slow lead vehicles. In Hazard 1 (slow lead vehicle brakes down), only 6 participants who drove aggressive AVs took over to slow down the vehicles, including 2 aggressive drivers and 4 defensive drivers. Due to the limited number of takeover data, only descriptive analysis was conducted to compare the takeover performance between aggressive drivers and defensive drivers. The descriptive results showed that both of average and max deceleration obtained from aggressive drivers ($M_{\text{average deceleration}} = 3.65 \text{ ft/s}^2$, $M_{\text{max deceleration}} = 9.95 \text{ ft/s}^2$) were smaller than data obtained from defensive drivers ($M_{\text{average deceleration}} = 6.87 \text{ ft/s}^2$, $M_{\text{max deceleration}} = 11.99 \text{ ft/s}^2$). In addition, both of minimum TTC and minimum distance obtained from aggressive drivers ($M_{\text{TTC}} = 0.41 \text{ s}$, $M_{\text{min dist}} = 4.98 \text{ ft}$) were smaller than data obtained from defensive drivers ($M_{\text{TTC}} = 2.05 \text{ s}$, $M_{\text{min dist}} = 24.74 \text{ ft}$). Therefore, when driving an aggressive AV, defensive drivers were more likely to keep a longer distance from the lead vehicle and preferred larger decelerations in responses to keep larger distance with the ahead vehicles compared with aggressive drivers.

In the other hazard with jammed traffic, there were 5 participants (3 aggressive drivers and 2 defensive drivers) who drove aggressive AVs took over to slow down the vehicle, and 3 participants (1 aggressive drivers and 2 defensive drivers) who drove defensive AV took over to slow down the vehicle. The descriptive results showed that both of the average and max deceleration obtained from aggressive drivers were larger than data obtained from defensive drivers when driving the AV with same driving style, as shown in Fig. 13(a) and (b), respectively. As shown in Fig. 13 (c), the minimum TTC obtained from aggressive drivers was shorter than data obtained from defensive drivers when driving a defensive AV, but no such difference was observed when they drive an aggressive AV. The minimum distance obtained from aggressive drivers was smaller than data obtained from defensive drivers when driving the AV with the same style, as shown in Fig. 13(d).

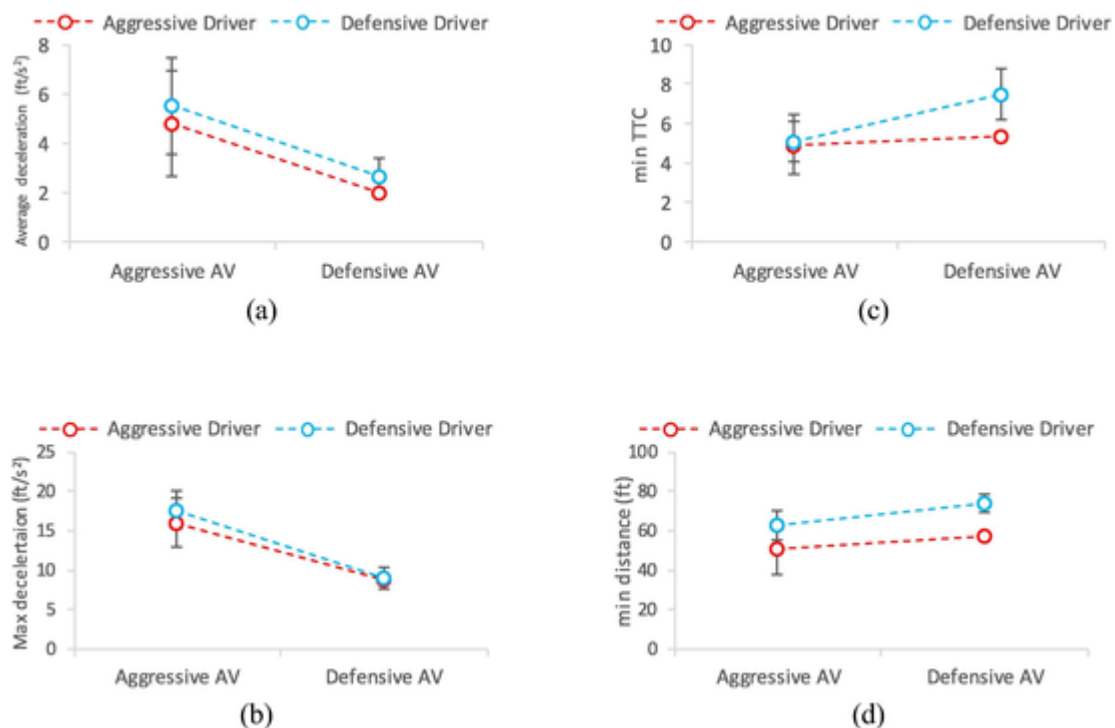


Fig. 13. Effects of AV's and driver's driving style on average deceleration, max deceleration, minimum TTC, and minimum distance in hazard with jam traffic (Error bars: $\pm 1 \text{ SE}$).

4. Discussion

To date, a few studies have found the impact of automated driving styles on drivers' comfort and trust (Bellem et al., 2018; Basu et al., 2017; Hartwich et al., 2018; Lee et al., 2019; Oliveira et al., 2019; Yusof et al., 2016). However, it is unclear how drivers' own driving styles influence their trust, acceptance, and propensity to take over control of AVs when interacting with AVs with different driving styles. The present study investigated the effects of driver's driving styles and AV's driving styles on driver's trust, acceptance, and takeover behaviors in normal and hazardous scenarios when riding with a fully AV. The results suggested the significant interaction effects between AV's driving style and driver's driving style on driver's trust, acceptance, and takeover behavior. When AV's driving styles align with drivers' driving styles, it promoted driver's trust, acceptance, subjective evaluation of the AVs (i.e., comfort, safety, preference), and decreased driver's takeover frequency during the driving tasks. Although the simple effects of AV's driving style were not significant for aggressive drivers, it was found aggressive drivers have significant higher trust and acceptance of aggressive AVs and took over defensive AVs more frequently than defensive drivers. These findings highlight the importance to design the AV's driving styles by considering driver's driving style to improve driver's trust, acceptance, and reduce takeover frequency.

For driver's trust in AV, there was a significant interaction effect between AV's driving style and driver's driving style. It showed that drivers whose driving styles were compatible with the AV's driving style trusted significantly more on the AV systems. This result supported Hoff & Bashir's (2015) trust model for automation, which proposes that the extent to how consistent the performance of automation is with the operator's expectation could influence their trust in the system. When a defensive driver rides with an AV, driver's trust could be affected by how AV's driving behaviors fit the driver's expectation. For aggressive drivers, their trust in AVs also increased when AV's driving style were similar to theirs but without achieving significance, indicating AV's driving style having a larger impact on defensive drivers' trust than aggressive drivers. This result is supplement to previous literature in which it found moderate drivers have higher trust in moderate AVs, compared with aggressive AVs and defensive AVs (Lee et al., 2019). Although drivers' driving styles were not classified in Lee's study, the least differences between drivers' driving styles and the moderate AV's driving style compared with either aggressive or defensive AV driving style suggested that most of drivers in their study were moderate drivers. In comparison, the present study focused on defensive drivers and aggressive drivers on the defensive-aggressive dimension. Comparison of the findings with Lee et al.'s study suggests that drivers have higher trust in AVs with driving styles that are compatible with their own driving styles. Since AV's driving styles were only classified into two categories in the present study, future research should be undertaken to investigate if similar results could be found for aggressive and defensive drivers when they interact with AVs with a moderate driving style.

Previous research had investigated several individual factors that could influence the acceptance of AV, including gender (Hohenberger et al., 2017; Kyriakidis et al., 2015), age (Bansal and Kockelman, 2017), and income (Kyriakidis et al., 2015). The present study found that drivers' driving style was also a determinant for driver's acceptance of AVs. Similar to trust, the study also found a significant interaction effect between AV's driving style and driver's driving style on driver's acceptance, which suggested that drivers accept AVs better when AV's driving styles align with drivers' driving styles. This result is partially consistent with Hartwich et al.'s study that found younger drivers showed higher acceptance of AV with familiar driving styles compared with unfamiliar driving styles, whereas older drivers showed higher acceptance of unfamiliar driving styles (Hartwich et al., 2018). In Hartwich's study, participants experienced the replay of their own drive as a familiar AV driving style and other drivers' manual driving style as unfamiliar

AV driving styles. The results of the young drivers are consistent with the findings from the present paper, but not the elder drivers. One of the reasons might be that the participants of the present study have an average age of 23.38 years ($SD = 4.65$) with a range of 18 to 39 years. This is similar to the young age group (25–35 years) collected in Hartwich et al.'s study with an average age of 28 years ($SD = 2.1$), whereas it is different to the older driver group (65–84) with an average age of 69 years ($SD = 6.0$). Future study is needed to examine how changes of the AV's driving style on the aggressive-defensive dimension influence older drivers' trust, acceptance, and takeover behavior in AVs.

Compared with previous research focusing on the driving styles of AVs, the present study provides drivers with the capability to switch between automation mode and manual-driven mode freely to investigate how drivers make decisions on whether to take over control of the vehicles under different AV's driving styles. The findings of the study suggested that drivers took over AVs more frequently when the AV showed a different driving style from their own. Specifically, aggressive drivers took over defensive AVs significantly more frequently than defensive drivers, and defensive drivers took over aggressive AVs significantly more frequently than defensive AVs. By further analyzing their takeover reasons, it revealed that defensive drivers took over aggressive AVs more frequently because they felt uncomfortable, unsafe, or anxious, as the driving styles of aggressive AVs exceed their safety margin (Summala, 2007). In comparison, aggressive drivers took over defensive AVs more frequently than defensive drivers because they wanted to drive at a faster speed, a higher acceleration rate, or preferred to control vehicles by themselves (Adnan et al., 2018). Therefore, the design of AV's driving styles could be improved to be compatible with driver's driving styles to reduce drivers' take over frequency and increase driver's uses of AVs. The present study revealed the need for future research to explore techniques to mitigate the potential aggressive behaviors in AVs since most of the AVs on the market has been designed with a more defensive driving style.

In addition, the current study quantified the relationships between driver's trust, acceptance, and takeover frequency when driving AVs. The effect of driver's trust on their takeover frequency in AVs is mediated via drivers' acceptance of AVs. This finding supports the application of the Technology Acceptance Model (TAM) that investigates users' acceptance of technology and automation systems in explaining driver's acceptance and behavior in automated vehicles (Belanche et al., 2012; Davis, 1989). Belanche et al. (2012) extended the original TAM by integrating trust as the third component that influences user's acceptance into the TAM model for an online service system. Choi and Ji (2015) demonstrated that trust was a major factor in the acceptance of an AV based on the results from questionnaires. All these findings support that trust is a crucial contributor to an individual's acceptance of an AV. In previous studies, the acceptance of an AV was mainly measured as the intention of users to use and purchase the AV (Choi and Ji, 2015; Adnan et al., 2018). The present study suggested that drivers' acceptance of AVs might be a critical subjective construct to predict drivers' takeover frequency. It is, therefore, important to evaluate and improve driver's acceptance of AVs when designing AV's driving styles to reduce undesired takeover behaviors and improve driver safety.

In terms of driver takeover performance, the results revealed that aggressive drivers showed different takeover performance compared with defensive drivers when driving aggressive AVs and showed different takeover performance under different AV's driving styles in the intersection approaching scenarios. Aggressive drivers prefer to decelerate late with larger deceleration after takeovers, whereas defensive prefer to decelerate early with smaller deceleration when driving aggressive AVs. However, no such difference was found when drivers driving defensive AVs. The findings suggested defensive drivers' takeover performance was more stable and consistent regardless which type of AVs with which they are interacting. This could help to explain the reason

why defensive driver's trust, acceptance, and takeover frequency changed significantly when AV's driving styles aligned with or against their driving styles. They could only trust and accept the AV that has the similar driving style to them. In comparison, aggressive drivers' takeover driving performance was more flexible and adjustable based on the AV's driving style. The reason might be that aggressive drivers need to obey the traffic laws and control and regulate their behavior in the real-life. Their acceptable range of AV's driving style might be wider compared with defensive drivers. As the results, aggressive drivers showed higher trust and acceptance and less takeover behavior when driving aggressive AVs compared with defensive drivers. However, the effects of AV's driving styles on trust and acceptance for aggressive drivers are not significant. It illustrates that the AV's driving style might not be the most important factor that affects aggressive driver's trust, acceptance, and takeover frequency, but it could influence their takeover performance during AV driving. The present study suggested the aggressive driving behavior might not be directly addressed when automated driving is available as long as drivers were given access to take over AVs. With most AVs designed in a defensive style today, it is necessary to explore how to mitigate aggressive driving behavior in AVs and reduce aggressive driver's takeover behavior.

Although this study was carefully prepared, there are still several limitations. In this experiment, drivers could take over a fully AV freely throughout the driving tasks, which could improve external validity and effectively investigate driver's subjective evaluation and takeover behavior when driving a fully AV. Drivers who are satisfied with the AV's driving styles might not take over the AV during the entire experiment. However, as a result, the sample size of takeover performance might be limited. Therefore, more empirical evidence is needed to confirm driver's takeover behavior with different AV's driving styles.

Firstly, AV's driving styles were classified into two categories in the present study, a more defensive driving style and a more aggressive driving style. From the design perspective, AV's driving styles on the dimension that varies from defensive-aggressive might change on a continuous scale. However, it's fairly easy and reasonable to start with two levels of the driving styles since this is one of the early attempts to investigate the design of AV's driving styles with various scenarios and multiple categories of driving indicators. In order to create more levels of AV's driving styles, further empirical evidence is needed to investigate if drivers could perceive the differences among the multiple levels of driving styles with the designed driving indicators and the determine potential cut-off criteria of AV's driving styles.

Secondly, only aggressive drivers and defensive drivers were investigated in the present study. The rationale of the present design that focused on the defensive and aggressive drivers is that the authors hypothesized most hazards occurred in the intra-vehicle interaction are caused by the differences between drivers' own driving styles and the driving styles of the AVs they interact with. When AV takes a moderate driving style similar to the driving style of moderate drivers, the safety issues could be much less problematic. However, even if aggressive and defensive drivers account for only a portion of the driver population, they could create more problems for the deployment of AVs and introduce significant risk for road safety. That being said, future studies are needed to examine if similar effects of AV's driving styles on drivers' trust, acceptance, and takeover behavior could be found for moderate drivers.

Thirdly, in this study, the determination of the values of each indicator was arbitrary, which was adopted from several studies in the literature that investigated aggressive/defensive driving styles in manual driving (Deffenbacher et al., 2003; Hong et al., 2014; Hill et al., 2015; Yan et al., 2007). However, as long as the drivers could perceived the differences between the designed aggressive/defensive automated driving styles at the global driving style level, the results could provide insights on the pattern changes of driver trust, acceptance and behavior. From the practical perspective, the design of driving style indicators should

be deliberately studied in the future to create a safe AV driving style in the meantime promote driver trust and acceptance of AVs. Fourthly, the present study tested driver's trust, acceptance, and takeover behavior in urban environment with moderate traffic density, however, drivers could prefer different AV driving style or certain driving indicators differently in different road environment. For example, when approaching hazards or driving on the road with high traffic density, drivers might prefer more defensive driving styles compared with that when driving on an open road. Future study could investigate whether the driving styles of AVs should be adjusted based on different traffic environment to promote drivers' trust, acceptance, and decrease their takeover frequency. In addition, participants were required to use a fixed-based driving simulator in this study. Future study could investigate AV's driving style with more motion cues.

In summary, this study brought insights into the design of AV's driving style to promote drivers' trust and acceptance of AVs and reduce undesired takeover behaviors. It is recommended to design the AV's driving styles that are aligned with the drivers' driving style to help drivers obtain more benefits. However, automated driving styles should be carefully designed on the defensive-aggressive dimension to avoid creating an extremely aggressive AV driving style that could potentially lead to risks to AV drivers or other road users just to promote aggressive drivers' trust. The findings from the study suggest that it is feasible to gradually adjust certain driving indicators of AV driving styles to make it slightly more aggressive or more defensive in order to enhance driver's trust and acceptance and reduce unnecessary takeover behaviors. In the meantime, such adjustment should be done under the consideration of driving safety by setting the driving indicators within a range of a safe driving style. The optimal design of each driving style indicator needs to be addressed by considering drivers' driving style and investigating its importance in various driving scenarios in future studies.

Uncited references

Constantinou et al., 2011; Roßner and Bullinger, 2019.

CRediT authorship contribution statement

Zheng Ma: Methodology, Software, Investigation, Formal analysis, Writing - original draft, Visualization. **Yiqi Zhang:** Conceptualization, Methodology, Writing - review & editing, Supervision, Funding acquisition.

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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