Journal of the Society of Automotive Engineers Malaysia
Volume 6, Issue 3, pp 152-165, September 2022
e-ISSN 2550-2239 & ISSN 2600-8092

A Review on Driving Styles and Non-Driving Related Tasks in Automated Vehicle

M. N. A. M. Norzam[1], **J. Karjanto***[1,2], N. Md Yusof[1,2], M. Z. Hasan[3], A. F. H. Zulkifli[4], S. Sulaiman[4] and A. A. Ab Rashid[5]

[1] Fac. of Mechanical Eng., Universiti Teknikal Malaysia Melaka (UTeM), 76100 Durian Tunggal, Melaka, Malaysia
[2] Centre for Advanced Research on Energy, UTeM, 76100 Durian Tunggal, Melaka, Malaysia
[3] Fac. of Mechanical & Manufacturing Engineering Technology, UTeM, 76100 Durian Tunggal, Melaka, Malaysia
[4] Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, 84500 Pagoh, Johor, Malaysia
[5] Malaysia Institute of Road Safety Research (MIROS), Taman Kajang Sentral, Kajang, Selangor, Malaysia

*Corresponding author: juffrizal@utem.edu.my

REVIEW **Open Access**

Article History:

Received
13 Apr 2022

Accepted
2 Aug 2022

Available online
1 Sep 2022

ABSTRACT – *Until today, most passengers would still feel uncomfortable and experience motion sickness, in the worst case, when doing activities such as reading and using portable devices inside a moving vehicle. Passengers' discomfort occurs because the vehicle is moving in unexpected ways, and it is worse when the passengers are engaged in tasks that take their eyes off the road or known as non-driving-related tasks (NDRTs). In the last two decades, various studies have investigated humans' comfort when riding an Autonomous Vehicle (AV). This review paper summarizes how future AV users will feel comfortable engaging in NDRTs in partial or fully automated driving. Human and AV driving styles have also been reviewed and listed out the range of acceleration and deceleration from different scenarios. The review then focuses on the various NDRTs preferred by users from all over the world and the factors (seating positions and type of trips/journeys) that affect the users when they are engaging in different kinds of NDRTs in the AV. This review would increase the knowledge and awareness that must be considered in the AV's design process to facilitate comfort for the users when performing NDRTs in automated driving.*

KEYWORDS: Ride comfort, driving style, autonomous vehicle, non-driving related tasks (NDRT)

1. INTRODUCTION

Automated Vehicles (AVs) are powered by the latest technology in sensing, computing, tracking, and controlling (Elbanhawi et al., 2015) from the use of computer vision, LiDAR (Light Detection and Ranging), laser, and sonar technologies for obstacle detection and avoidance (Van Brummelen et al., 2018). These technologies make transportation safer, greener, and more fuel-efficient, contributing to accident prevention, especially human errors, which make up many road accidents (Bureau of Infrastructure, 2015). Since vehicles have become increasingly automated, the ultimate goal for driving automation is fully automated driving (Payre et al., 2016). Humans no longer need to focus on fully automated driving since AV will take over the driving task.

The way an AV operates/drives is very critical. However, AV drives use sensors longitudinally and laterally. For example, Adaptive Cruise Control (ACC) helps maintain a safe distance and stay within the speed limit (Hearst Autos Research, 2020). In contrast, humans as drivers might set a different space depending on the size of a preceding vehicle since they drive based on their emotions and motivations (Summala, 2007). In contrast, an AV operates the vehicle based on optimized logic (Yusof et al., 2016). An AV would drive the vehicle precisely according to the systems and programming that are being installed. In recent years, various studies have investigated and formulated an AV driving style that humans prefer in longitudinal, lateral, and vertical acceleration and deceleration.

2. DRIVING STYLES

Driving style is one of the components of driving behavior other than driving skills (Elander et al., 1993). Driving skills concern the attitudes and characters of the driver; therefore, personality traits could be the possible determinants of driving behavior. Driving style refers to how a driver chooses to drive or his driving habits; as a result, each driver has a unique driving style (Chen et al., 2013). Driving style also refers to how a driver chooses to drive and is influenced by the driver's physical and mental state while driving (Eboli et al., 2017). Driving styles of a driver including in accelerating, decelerating, braking, and turning at a junction or intersection.

When a vehicle moves in the longitudinal direction, it consists of two elements: acceleration and deceleration. Wang et al. (2010) found that different driving behaviors affected a vehicle's acceleration and deceleration in longitudinal driving behavior. Part of a skillful driver tends to drive with some risks and step further to the throttle pedal to increase the acceleration. Those who are not skillful become more cautious and prefer a longer distance while following a preceding vehicle. Furthermore, external factors such as different environmental conditions impact the way drivers drive. For example, reduced visibility from weather substantially impacts traffic flow dynamics (Hoogendoorn et al., 2010), while the geometry of the road layouts leads to changes in driving behavior (McLean et al., 1981). Hamdar et al. (2016) investigated the effect of weather conditions and road geometry on longitudinal driving behavior. They found that drivers reduce their acceleration when vision gets blurred from dense fog weather and bad road surfaces like icy surface roads.

On the other hand, lateral acceleration acts transversely to the direction of travel. When a vehicle moves around the corner center, it generates an acceleration known as lateral acceleration (Balkwill et al., 2017). Xu et al. (2015) studied lateral acceleration on a different road and found lateral acceleration increases with curvature. It is well understood that a greater radius accompanies a higher speed, and accidents are much more severe than those at lower rates. Thus, a driver should drive with a slight lateral acceleration and a more significant safety margin for lateral stability. The way drivers drive a vehicle may differ since human have their way of driving in various styles (Taubman et al., 2004).

2.1 Human Driving Style

There are a few types of classification of human driving style. Lv et al. (2018) categorized driving style into three groups: aggressive, defensive, and moderate. Different types of acceleration and deceleration classified driving styles in terms of jerking, the time needed to accelerate or decelerate, and energy consumption. Other findings by Wang et al. (2013) and Xu et al. (2015), drivers behave uniquely when operating the throttle and brake pedals, displaying various driving styles due to their personalities. Aggressive drivers have the most significant use of throttle and brake pedals, followed by moderate and defensive drivers. The different ways of driving would result in different driving styles.

2.1.1 Aggressive Driving Style

Flashing lights, honking, verbal threats to other road users, gestures, inability to maintain proper distances from other vehicles, and more pronounced forms of aggressive behavior such as car-ramming or even physical attacks have all been reported in the context of aggressive driving (Özkan et al., 2010). According to a survey by American Automobile Association Foundation for Traffic Safety (AAAFTS, 2009), between 2003 and 2007, aggressive driving was recognized as the leading cause of 56% of fatal accidents in the United States. Most accidents with fatalities occur from aggressive drivers because of their risky behavior.

Aggressive drivers are also most likely to use the throttle and brake pedal more frequently, consuming more fuel (Gilman et al., 2015; Lv et al., 2017). Furthermore, an aggressive driver is more likely to accelerate until their vehicle and the preceding vehicle is uncomfortably close together (Zhu et al., 2019). Zhang et al. (2017) found that drivers can be categorized as aggressive when the time taken of headway between a vehicle and the preceding vehicle is 2.81 seconds. Therefore, when driving at a higher pace or close to the preceding vehicle, aggressive drivers are more likely to encounter dangerous scenarios that come with reckless driving.

2.1.2 Defensive Driving Style

The drivers with a defensive driving style describe safe, calm, and careful driving in acceleration and deceleration (van Huysduynen et al., 2018; Lai et al., 2018; Shimosaka et al., 2014). Murphey et al. (2009) stated that calm drivers anticipate the actions of other road users, traffic lights, and speed limits. They maintain to stay as passive drivers when driving compared to aggressive drivers.

The defensive driving style is the polar opposite of aggressive driving. Defensive drivers are known for their tiny amplitudes and low-frequency movements on the steering wheel, accelerator, and braking pedal (Lv et al., 2018). Defensive drivers also prefer to decelerate their vehicles early when they stop or approach a junction or intersection (Zhu et al., 2019). Therefore, defensive drivers generate a smaller acceleration when decelerating since they prefer a longer distance when following a preceding vehicle than aggressive drivers.

A defensive driving style has increased drivers’ self-awareness to prevent accidents (Lai et al., 2018). Since defensive driving styles have careful characteristics, drivers' chances of being involved in accidents become much lower. Guruva (2002) found that implementing a defensive driving style effectively prevents traffic light violations and collisions in Zimbabwe. Besides, some drivers become more defensive at an un-signaled intersection with potential risks (Shimosaka et al., 2014).

2.1.3 Moderate Driving Style

Drivers with moderate driving style characteristics are positioned between their aggressive and defensive counterparts. A driver with moderate acceleration and braking has a sensible driving style (Murphey et al., 2009). They do not drive in a way that is too aggressive or too defensive. For example, they drive at a moderate speed that does no harm and would be bullied by other road users. They want to balance various factors, including dynamic vehicle performance, ride comfort, and energy efficiency (Lv et al., 2017).

2.2 Automated Vehicle Driving Style

Three taxonomies are mainly used to define the level of automation in the automotive field. The first is the Society of Automotive Engineers (SAE) taxonomy of automation levels based on the SAE J3016 standard (SAE, 2014, 2016). Secondly, the United States Department of Transportation developed the National Highway Traffic Safety Administration's (NHTSA) taxonomy of automation levels (NTHSA, 2013). Third, Die Bundesanstalt für Straßenwesen (BASt) or the Germany Federal Highway Research Institute’s taxonomy of levels of automation (Gasser & Westhoff, 2012). BASt and NHTSA have five levels of automation, whereas the SAE has six levels. Each automation level determines a human driver's task in an AV, either partially or fully automated. In partially automated driving, human drivers are helped with automated driving systems such as Adaptive Cruise Control (ACC) and Advanced Driving Support System (ADAS). Human drivers no longer need to do driving tasks in fully automated driving since the vehicle is fully equipped with automated driving systems.

Therefore, AVs need a specific driving style similar to humans to secure a smooth and comfortable ride (Oliveira et al., 2019). Light-Rail Transit (LRT) and High-Speed Rail (HSR) are perfect transportation examples to provide passengers with a smooth and comfortable ride. These transportations generate acceleration, deceleration, jerk, and stop that do not generate uncomfortable situations for passengers. Yusof et al. (2016) included LRT’s driving style to explore the preferred driving style for an AV. They discovered that the users preferred all generated accelerations (longitudinal, lateral, and vertical) in the defensive and LRT AV driving style ranges. Since AV should adapt to the user’s driving style, an AV should drive as “exactly” as possible to mirror the human driving style (Bazilinskyy et al., 2021). It can be concluded that an assertive driver wants an assertive or aggressive AV, and a defensive driver wants a defensive AV (Basu et al., 2017; Yusof et al., 2016). If this criterion does not meet, the occupants will feel uncomfortable with AV's driving style. Rapid changes in speed or direction can be unsettling and may result in, at worst, motion sickness (Bellem et al., 2016). When occupants feel uncomfortable with AV’s driving style, they will disengage the AV system and drive the vehicle themselves. This situation should be avoided because the primary goal of automated transportation would not be achieved (Davidson & Spinoulas, 2015; Litman, 2017).

2.3 Human Driving Style vs. Automated Vehicle Driving Style

An AV is a highly intelligent robot that maximizes safety and operates solely on optimum logic (Yusof et al., 2016). As a result, there may be a conflict in the driving style preferences of different AV users, such as accelerations preference at various road profiles. This conflict can be solved when an AV has a specific driving style that matches various humans' driving styles. As cars become more automated, the function of the human in the vehicle evolves from driver to passenger (Detjen et al., 2020).

Several studies were done to determine the range of acceleration of a human driver (Bellem et al., 2016; Bogdanović et al., 2013; De Vlieger et al., 2000; Hugemann & Nickel, 2003; Moon & Yi, 2008) (see Table 1). It was found that human drivers drive vehicles differently since they have specific driving styles. For example, each driver generates acceleration at different rates at a junction or traffic light intersection. Assertive drivers have the highest range of acceleration, followed by moderate and defensive drivers. Aggressive drivers tend to step more on the gas pedal to gain acceleration since they like a thrill and action-driving situation, while defensive drivers are more likely to step on the gas pedal slowly. Assertive drivers tend to drive above the speed limits resulting in the highest fuel consumption and emission (12% - 40%) (De Vlieger et al., 2000).

Besides that, different road types affect the drivers to accelerate at different rates (Bellem et al., 2016; De Vlieger et al., 2000). As expected, human drivers accelerate more on highways, followed by rural or urban roads and city roads. The road situation of the highway is wider; in contrast, drivers have the lowest range of acceleration on city roads since the city is packed with more vehicles. The different conditions (comfort, everyday driving, and dynamic) also give different acceleration rates (Bellem et al., 2016). In everyday driving conditions, drivers drive their vehicles with moderate acceleration, while in dynamic conditions, the drivers can be calm but aggressive to other road users (Murphey et al., 2009). The drivers' acceleration rates in comfort conditions were the lowest compared with everyday driving and dynamic conditions.

Different ranges of decelerations were affected by different gender and age (ElShawarby et al., 2007). Male drivers have a higher deceleration rate and significantly higher speeds since they are more prone to risky driving behavior than female drivers (Liew et al., 2017; Oltedal & Rundmo, 2006). Regarding age differences, older drivers have a lower deceleration rate than younger drivers (below 40 years old). A study done by Hugemann and Nickel (2003) to investigate different lateral accelerations to varying curve radii found that the values of lateral acceleration decreased as the curve radii increased. This was due to the less lateral acceleration force generated when the radii of the curve were big. Table 1 shows the range of accelerations of typical humans in different situations.

Yusof et al. (2016) studied the optimal AV driving style in the Netherlands by simulating automated driving in real-world scenarios. Based on the previous studies, various ranges of accelerations were established, as shown in Table 2. It was found that aggressive and defensive drivers preferred defensive and LRT AV driving styles. On top of that, Haghzare et al. (2021) investigate older adults' acceptance of an AV driving style. A defensive driving style was chosen and set for the simulated AV to run the experiment in this study. It was found that participants aged between 65 to 70 have higher approval than the older-old group (aged 80+) toward AV (Haghzare et al., 2021).

In recent years, many studies investigated AV driving styles from various human driving styles in different situations, such as accelerating, braking, cornering, and overtaking. An AV should have a specific driving style preferred by humans regardless of driving style to make human drivers accept the AV. Therefore, human users would have their free time inside an AV, and they can engage in any activities they want that are not related to driving. During fully automated driving, all the vehicle occupants expect to do productive and joyful activities to fill their journey time. Those activities might depend on the duration and motivation of the journey (Filo & Lubega, 2015; Jorlöv et al., 2017).

TABLE 1: Range of acceleration/velocity with different situations

Situation	Acceleration/Speed		Reference
Accelerate			(Bellem et al.,
Accelerating	0.79 m/s² to 4.86 m/s²		2016; Bogdanović
	City		et al., 2013; De
Aggressive	0.85m/s² to 1.10 m/s²		Vlieger et al.,
Moderate	0.65m/s² to 0.80 m/s²		2000; Hugemann
Defensive	0.45m/s² to 0.65 m/s²		& Nickel, 2003;
Accelerating from non-zero speed	**Rural and urban road**	**Highway**	Moon & Yi, 2008)
Everyday driving	8.7m/s to 16.63 m/s	24.96 m/s to 32.54 m/s	
Comfort	8.61m/s to 15.27 m/s	23.98 m/s to 31.07 m/s	
Dynamic	11.31m/s to 21.37 m/s	25.20 m/s to 32.85 m/s	
Lane changes			
Everyday driving	15.11 m/s	30.63 m/s	
Comfort	13.25 m/s	27.09 m/s	
Dynamic	14.55 m/s	30.56 m/s	
Following at non-varying speed			
Everyday driving	14.04 m/s	27.82 m/s	
Comfort	13.09 m/s	25.29 m/s	
Dynamic	14.37 m/s	27.85 m/s	
Decelerate			
Normal decelerating	-1.51 m/s² to -7.47 m/s²		(El-Shawarby et
Normal braking			al., 2007; Moon &
Low-speed (<40 km/h)	-0.77 m/s² to -2.97 m/s²		Yi, 2008)
High-speed (>70 km/h)	-0.28 m/s² to -1.82 m/s²		
Lateral			
Radius			(Hugemann &
20-40 m	5.3 m/s²		Nickel, 2003)
40-70 m	4.9 m/s²		
70-100 m	3.4 m/s²		
100-200 m	2.7 m/s²		

TABLE 2: Ranges of acceleration in tri-axial directions of AV

Type of acceleration	Acceleration			Reference
Longitudinal	-8.24 m/s² to 3.26 m/s²			
Lateral	-5.59 m/s² to 2.91 m/s²			(Haghzare et al.,
Longitudinal Jerk	-1.34 m/s² to 1.94 m/s²			2021)
Lateral Jerk	-0.67 m/s² to 0.44 m/s²			
	LRT AV	**Defensive AV**	**Assertive AV**	(Yusof et al.,
Longitudinal	-1.37 m/s² to 1.37 m/s²	-3.23 m/s² to 2.45 m/s²	-7.45 m/s² to 4.9 m/s²	2016)
Lateral	0.00 m/s² to 1.47 m/s²	1.47 m/s² to 4.12 m/s²	4.12 m/s² to 5.29 m/s²	
Vertical	-	0.00 m/s² to 1.57 m/s²	1.57 m/s² to 6.47 m/s²	

3. NON-DRIVING RELATED TASKS

The advent of automated vehicles could eliminate the driver from the driving equation, potentially improving safety substantially, time and fuel efficiency, and mobility in general (Beiker, 2012; Douma & Palodichuk, 2012; Silberg et al., 2012). Another significant user benefit is engaging in NDRTs (König & Neumayr, 2017). While the AV is operating in full automation, drivers can do a variety of tasks and can focus entirely on those tasks (Kun et al., 2016; Naujoks et al., 2017). In the SAE level of automation, from Level 3 to Level 5, the automated driving system (when engaged) serves the entire DDT (SAE, 2016). Humans will switch roles from driver to passenger, and their time and space are free since they no longer need to drive.

3.1 Different Methodologies Used When Accessing NDRTs

Different methodologies were used to obtain data from participants, either with or without interaction with an AV during the experiment. An online survey is one of the methods that does not require a physical experiment. For example, Kyriakidis et al. (2015) and Schoettle & Sivak (2014) used an online survey method to get a massive response from different countries worldwide about the preferred NDRT to be done in an AV. In contrast, performing NDRTs and later accessing it during an experiment needs interaction with an AV. For example, participants were asked to complete questionnaires to measure their subjective task load while running the driving simulator (Detjen et al., 2021).

3.2 Synopsis of Preferred NDRT in Different Countries

Various studies from different countries have been conducted about preferred NDRTs by participants in AVs in recent years (refer to Table 3). Germany prefers using the smartphone as their NDRT if an AV is available in the future (Detjen et al., 2020, 2021; Hecht et al., 2020; Naujoks et al., 2016; Pfleging et al., 2016). With an increase in the driving mode from manual, partial, high, and full, the number of people that would engage NDRTs inside a moving vehicle also increased (Kyriakidis et al., 2015). The findings show that people can abandon driving tasks such as controlling the steering or pedals. They can do and enjoy any activities they want inside an AV as automation increases. Besides that, people in Asia countries with high populations, such as Japan, China, and India, prefer texting as their activity in an AV (Schoettle & Sivak, 2014). They use texting in electronic gadgets like smartphones to communicate with other people for reasons such as work-related or daily conversation. Furthermore, people in western countries such as the United States, United Kingdom, and Sweden chose reading as their preferred NDRT in an AV.

3.3 Factors Affecting Engaging Different NDRT

Different types of NDRTs are engaged by an AV's occupants depending on different situations. For example, the occupants would engage in serenity tasks such as reading and doing office work on a peaceful roadway when driving by an AV. But, when the occupants are driven in heavy traffic, they would engage in a suitable task such as watching a movie. Besides that, the design of an AV, such as seating positions, also affects the occupants in engaging different types of NDRTs.

3.3.1 Type of Trip/Journey

Passengers preferred a different type of NDRTs depending on their short or long trips, traveling alone or with other occupants (see Table 4). The purpose of the journey may also play a role because traveling can assist people in preparing for or relaxing before engaging in a necessary activity at their destination (Frei et al., 2015; Keseru et al., 2015; Lyons et al., 2007, 2013, 2016). On shorter trips, users imply passive activities that do not involve much movement. In comparison, users suggest more active vocations on longer trips, making them feel more comfortable on vacation (Keseru & Macharis, 2018). Those who travel alone prefer an activity that can be done by themselves without involving another passenger, such as relaxing, reading, and using a smartphone. They also are less likely to talk or socialize with other passengers (Timmermans & Van Der Waerden, 2008; Van Der Waerden et al., 2009; Zhang & Timmermans, 2010). In Jorlöv et al. (2017), there is a relationship between the type of journey and seating position. During short drives, passengers preferred the seat position with forward-facing and reclining seatback. While for long drives, passengers preferred all oriented towards each other and also seats with the reclining position. Different seating positions provide more comfort to passengers on different types of journeys.

TABLE 3: Overview of different NDRTs found in various studies

Study	Method	Focus	Country	NDRT
(Sun et al., 2021)	Post-experiment (Questionnaire) N=44	Facilitate users' activities and situational awareness while driving.	China	Monitor the driving (55%), listen to music (50%), sleep/rest (43%)
*(Detjen et al., 2021)	Post-experiment (Questionnaire) N=20	Participants freely intervened in the driving process, using either touch, voice, or mid-air gesture interaction.	Germany	Do nothing, eat, smartphone, conversation, music
(Detjen et al., 2020)	Pre- and post-experiment (Questionnaire) N=12	Presenting real-world insights into the attitude towards highly automated driving and NDRTs.	Germany	Use smartphones (75%), eat/drink (50%), and read (43%)
(Hecht et al., 2020)	During experiment (Performed NDRT) N=42	To enhance knowledge about actual activities to allow researchers and developers to properly design future car	Germany	Use phone (75%), read (60%), browse the tablet (50%)
(Malokin et al., 2019)	Without experiment (Online survey) N=2,229	Measure travel multitasking attitudes and behaviors, mode-specific perceptions, and standard socioeconomic traits.	United States	*Driving alone:* Audio (95%), think/plan (76%), eat/drink (50%) *Shared-ride:* Talk to other occupants (83%), think/plan (75%), audio (73%)
(Pfleging et al., 2016)	Without experiment (Online survey) N=300	Investigate which NDRTs while driving highly or fully automated.	Germany	Talk to the passenger (90%), listen to music/radio (88%), watch out of the window (82%)
*(Naujoks et al., 2016)	During experiment (Performed NDRT) N=150	Investigate participants' willingness to engage in a simple and common secondary task while driving with different levels of vehicle automation	Germany	Smartphone
*(Kyriakidis et al., 2015)	Without experiment (Online survey) N=4,886	Investigate user acceptance, concerns, and willingness to buy partially, highly, and fully automated vehicles.	109 countries all over the world	Listen to the radio (57%), eat (49%), passenger (48%)
(Schoettle & Sivak, 2014)	Without experiment (Online survey) N=3,255	Public opinion about self-driving vehicles	United States	Read (11%), text (10%), sleep (7%)
			United Kingdom	Read (8%), sleep (7%), text (6%)
			Japan	Sleep (13%), text (7%), watch television/movies (6%)
			China	Text (21%), watch television/movies (11%), and sleep (11%)
			Australia	Text (8%), sleep (7%), read (7%)
			India	Work (16%), text (15%), watch television/movies (12%)
(Llaneras et al., 2013)	During experiment (Performed NDRT) N=12	Exploring impacts on willingness to engage in secondary NDRTs	United States	Listen to music (92%), talk with passengers (92%), radio interactions (83%)
(Helldin et al., 2013)	During experiment (Performed NDRT) N=59	To investigate the impact of visualizing car uncertainty on drivers' trust during an automated driving scenario	Sweden	Eat (35%), read a newspaper (25%)

NDRTs do not sort in ranking preferred by people/participant

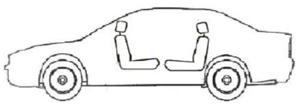
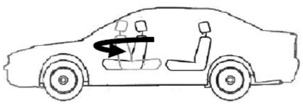
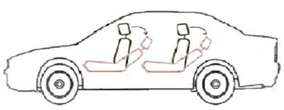
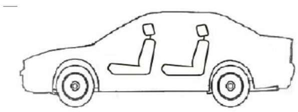
TABLE 4: Overview of preferred NDRT with different types of trips/journeys

Trip/journey	Preferred NDRT	Reference
Short	Looking out the window, sleeping, resting, relaxing, doing nothing, using a smartphone, socializing, watching surroundings.	(Hecht et al., 2019; Jorlöv et al., 2017; Keseru & Macharis, 2018; Krueger et al., 2019)
Long	Playing games, watching movies, socializing, using mobile phones, relaxing, reading, work-related activities, watching the surrounding, listening to music, sleeping.	(Hecht et al., 2019; Jorlöv et al., 2017; Keseru & Macharis, 2018; Kolarova et al., 2019; Krueger et al., 2019; Russell et al., 2011)
Travelling alone	Reading, using a smartphone, work-related activities, relaxing.	(Hecht et al., 2019; Koppel et al., 2019; Krueger et al., 2019)
Travelling with other occupants	Socializing.	(Koppel et al., 2019; Krueger et al., 2019)

3.3.2 Seating Positions

Different seating positions in an AV give the passengers additional comfort when performing various types of NDRT (see Table 5). In Sun et al. (2021), passengers preferred the front seat face backward position because it provides a social setting with better communication and greater space to perform NDRTs. When passengers have a long trip with their family, they prefer the rotatable front seat position to enjoy their trip since they can communicate better (Jorlöv et al., 2017). This seating position allows the passengers to switch between individual and sociable formations. Besides that, the foldable or reclined seat position is designed to increase the passengers' interior room and comfort. They preferred this position to relax or sleep while riding in an AV during the trip or journey.

TABLE 5: Overview of different seating positions in performing NDRT (adapted from Sun et al., 2021)

Seating position	NDRT	Reference
Front seat face backward 	Socializing, communicating	(Jorlöv et al., 2017; Sun et al., 2021; Yang et al., 2019)
Rotatable front seat 	Talking	(Jorlöv et al., 2017; Sun et al., 2021)
Foldable/ recline 	Sleeping, relaxing	(Jorlöv et al., 2017; Sun et al., 2021; Yang et al., 2019)
Forward-facing 	Reading, using a tablet or laptop, watching movies, working/ studying, playing games, using a smartphone, and relaxing/doing nothing	(Jorlöv et al., 2017; Koppel et al., 2019; Yang et al., 2019)

Moreover, passengers prefer different seating positions depending on the kind of trip/journey, whether long or short (Jorlöv et al., 2017). For longer drives, passengers preferred front seat face backward, rotatable front seat, and foldable/reclined seating position when performing NDRT. While in a shorter drive, passengers choose forward-facing and foldable/recline seating positions to gain more comfort when riding an AV. The AV interiors may place a premium on passenger comfort, entertainment, and interactivity, allowing them to participate in various activities (Koppel et al., 2019). Hence, the seating position is one of the main factors contributing to comfort for the occupants besides the driving style of an AV.

4. CONCLUSION

This study reviews how to make human passengers feel comfortable when inside an AV if performing any NDRTs. Firstly, this paper reviews the human and AV driving styles. Generally, there are three types of human driving styles: aggressive, defensive, and moderate. In each type of driving style, human drivers drive their vehicles with different acceleration, deceleration, and cornering. An AV should have a specific driving style that provides comfort to human users. In recent years, various studies have been done to study the AV driving style preferred by human users with different accelerations (longitudinal, lateral, and vertical). Next, several methods were used when accessing NDRTs without or involving interaction with an AV to determine which NDRT that preferred by people from all over the world. Lastly, to engage NDRTs more comfortably, this paper summarizes different seating positions and trips/journeys that impact the passengers performing different NDRTs.

ACKNOWLEDGEMENT

The authors would like to thank the Ministry of Higher Education (MOHE) and Universiti Teknikal Malaysia Melaka (UTeM) for the approved fund and support to make this vital research viable and effective. This research is fully supported by a national grant, FRGS/1/2020/TK02/UTEM/02/1. The authors declare that the contents of this article have not been published previously. All the authors have contributed to the work described, read, and approved the contents for publication in this manuscript. The study was approved by the ethics committee of the UTeM (UTeM.23.01/500-25/4 Jilid 5(30)).

REFERENCES

AAAFTS (2009). Aggressive driving: Research update. AAA Foundation for Traffic Safety. Retrieved from https://safety.fhwa.dot.gov

Balkwill, J. (2017). Performance vehicle dynamics: engineering and applications. Butterworth-Heinemann.

Basu, C., Yang, Q., Hungerman, D., Singhal, M., & Dragan, A. D. (2017). Do you want your autonomous car to drive like you? In Proc. ACM/IEEE Int. Conference on Human-Robot Interaction (pp. 417-425).

Bazilinskyy, P., Sakuma, T., & de Winter, J. (2021). What driving style makes pedestrians think a passing vehicle is driving automatically? Applied Ergonomics, 95, 103428.

Beiker, S. A. (2012). Legal aspects of autonomous driving. Santa Clara L. Rev., 52, 1145.

Bellem, H., Schönenberg, T., Krems, J. F., & Schrauf, M. (2016). Objective metrics of comfort: Developing a driving style for highly automated vehicles. Transportation Research Part F: Traffic Psychology and Behaviour, 41, 45-54.

Bogdanović, V., Ruškić, N., Papić, Z., & Simeunović, M. (2013). The research of vehicle acceleration at signalized intersections. PROMET – Traffic & Transportation, 25(1), 33-42.

Bureau of Infrastructure (2015). Transport and Regional Economics (BITRE), Road Trauma Australia, 2014 statistical summary BITRE, Canberra ACT.

Chen, S. W., Fang, C. Y., & Tien, C. T. (2013). Driving behaviour modelling system based on graph construction. Transportation Research Part C: Emerging Technologies, 26, 314-330.

Davidson, P., & Spinoulas, A. (2015). Autonomous vehicles - What could this mean for the future of transport? In AITPM National Conference, 1-19.

De Vlieger, I., De Keukeleere, D., & Kretzschmar, J. G. (2000). Environmental effects of driving behaviour and congestion related to passenger cars. Atmospheric Environment, 34(27), 4649-4655.

Detjen, H., Geisler, S., & Schneegass, S. (2021). Driving as side task: Exploring intuitive input modalities for multitasking in automated vehicles. Conference on Human Factors in Computing Systems.

Detjen, H., Pfleging, B., & Schneegass, S. (2020). A wizard of Oz field study to understand non-driving-related activities, trust, and acceptance of automated vehicles. Proc. - 12th International ACM Conference on Automotive User Interfaces and Interactive Veh. Applications, AutomotiveUI 2020.

Douma, F., & Palodichuk, S. A. (2012). Criminal liability issues created by autonomous vehicles. Santa Clara L. Rev., 52, 1157.

Eboli, L., Mazzulla, G., & Pungillo, G. (2017). How drivers' characteristics can affect driving style. Transportation Research Procedia, 27, 945–952.

El-Shawarby, I., Rakha, H., Inman, V. W., & Davis, G. W. (2007). Evaluation of driver deceleration behavior at signalized intersections. Transportation Research Record, 2018(1), 29-35.

Elander, J., West, R., & French, D. (1993). Behavioral correlates of individual differences in road traffic crash risk: An examination of methods and findings. Psychological Bulletin, 113(2), 279–294.

Elbanhawi, M., Simic, M., & Jazar, R. (2015). In the passenger seat: Investigating ride comfort measures in autonomous cars. IEEE Intelligent Transportation Systems Magazine, 7(3), 4-17.

Filo, P., & Lubega, I. (2015). Design of interior for a self-driving car propose a conceptual design from a body & trim perspective that can be implemented in future self-driving cars. Chalmers University of Technology, Gothenburg, Sweden.

Frei, C., Mahmassani, H. S., & Frei, A. (2015). Making time count: Traveler activity engagement on urban transit. Transportation Research Part A: Policy and Practice, 76, 58-70.

Gasser, T. M., & Westhoff, D. (2012). BASt-study: Definitions of automation and legal issues in Germany. Proceedings of the 2012 Road Vehicle Automation Workshop, July.

Gilman, E., Keskinarkaus, A., Tamminen, S., Pirttikangas, S., Röning, J., & Riekki, J. (2015). Personalised assistance for fuel-efficient driving. Transportation Research Part C: Emerging Technologies, 58(PD), 681-705.

Guruva, D. (2002). Defensive driving as a preventative strategy for road traffic violations and collisions in Zimbabwe (Doctoral dissertation).

Haghzare, S., Campos, J. L., Bak, K., & Mihailidis, A. (2021). Older adults' acceptance of fully automated vehicles: Effects of exposure, driving style, age, and driving conditions. Accident Analysis and Prevention, 150, 105919.

Hamdar, S. H., Qin, L., & Talebpour, A. (2016). Weather and road geometry impact on longitudinal driving behavior: Exploratory analysis using an empirically supported acceleration modeling framework. Transportation Research Part C: Emerging Technologies, 67, 193-213.

Hearst Autos Research (2020). What is adaptive cruise control? Retrieved from https://www.caranddriver.com/research/a32813983/adaptive-cruise-control/

Hecht, T., Darlagiannis, E., & Bengler, K. (2019). Non-driving related activities in automated driving – An online survey investigating user needs. Advances in Intelligent Systems and Computing, 1026, 182-188.

Hecht, T., Feldhütter, A., Draeger, K., & Bengler, K. (2020). What do you do? An analysis of nondriving related activities during a 60 minutes conditionally automated highway drive. Advances in Intelligent Systems and Computing, 1018, 28-34.

Helldin, T., Falkman, G., Riveiro, M., & Davidsson, S. (2013). Presenting system uncertainty in automotive UIs for supporting trust calibration in autonomous driving. In Proceedings of the 5th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (pp. 210-217).

Hoogendoorn, R. G., Hoogendoorn, S. P., Brookhuis, K. A., & Daamen, W. (2010). Simple and multi-anticipative car-following models: Performance and parameter value effects in case of fog. Proc. of the TRB Traffic Flow Theory & Characteristics Committee Summer Meeting, Annecy, France, 2-16.

Hugemann, W., & Nickel, N. (2003). Longitudinal and lateral accelerations in normal day driving. 6th International Conference of The Institute of Traffic Accident Investigators, 1-8.

Jorlöv, S., Bohman, K., & Larsson, A. (2017). Seating positions and activities in highly automated cars – A qualitative study of future automated driving scenarios. Conference Proceedings International Research Council on the Biomechanics of Injury, IRCOBI, 13-22.

Keseru, I., & Macharis, C. (2018). Travel-based multitasking: Review of the empirical evidence. Transport Reviews, 38(2), 162-183.

Keseru, I., Bulckaen, J., Macharis, C., Minnen, J., Glorieux, I., & Pieter, T. (2015). Is travel time wasted? Evidence from a time-use survey in Flanders, Belgium. In 14th International Conference on Travel Behaviour Research, Old Windsor, UK.

Kolarova, V., Cyganski, R., & Lenz, B. (2019). Activities while travelling? Travel time perception and travel time use in an era of automated driving. Advances in Transport Policy and Planning, 3, 171-206.

König, M., & Neumayr, L. (2017). Users' resistance towards radical innovations: The case of the self-driving car. Transportation Research Part F: Traffic Psychology and Behaviour, 44, 42-52.

Koppel, S., Jiménez Octavio, J., Bohman, K., Logan, D., Raphael, W., Quintana Jimenez, L., & Lopez-Valdes, F. (2019). Seating configuration and position preferences in fully automated vehicles. Traffic Injury Prevention, 20(sup2), S103-S109.

Krueger, R., Rashidi, T. H., & Auld, J. (2019). Preferences for travel-based multitasking: Evidence from a survey among public transit users in the Chicago metropolitan area. Transportation Research Part F: Traffic Psychology and Behaviour, 65, 334-343.

Kun, A. L., Boll, S., & Schmidt, A. (2016). Shifting gears: User interfaces in the age of autonomous driving. IEEE Pervasive Computing, 15(1), 32-38.

Kyriakidis, M., Happee, R., & De Winter, J. C. F. (2015). Public opinion on automated driving: Results of an international questionnaire among 5000 respondents. Transportation Research Part F: Traffic Psychology and Behaviour, 32, 127-140.

Lai, P. Y., Dow, C. R., & Chang, Y. Y. (2018). Rapid-response framework for defensive driving based on internet of vehicles using message-oriented middleware. IEEE Access, 6(c), 18548-18560.

Liew, S., Hamidun, R., & Mohd Soid, N. F. (2017). Differences of driving experience and gender on traffic offences among Malaysian motorists. MATEC Web of Conferences, 103.

Litman, T. (2017). Autonomous vehicle implementation predictions. Victoria Transport Policy Institute.

Llaneras, R. E., Salinger, J., & Green, C. A. (2013). Human factors issues associated with limited ability autonomous driving systems: Drivers' allocation of visual attention to the forward roadway. 92-98.

Lv, C., Hu, X., Sangiovanni-Vincentelli, A., Li, Y., Martinez, C. M., & Cao, D. (2018). Driving style-based codesign optimization of an automated electric vehicle: A cyber-physical system approach. IEEE Transactions on Industrial Electronics, 66(4), 2965-2975.

Lv, C., Wang, H., Zhao, B., Cao, D., Huaji, W., Zhang, J., Li, Y., & Yuan, Y. (2017). Cyber-physical system-based optimization framework for intelligent powertrain control. SAE International Journal of Commercial Vehicles, 10(1), 254-264.

Lyons, G., Jain, J., & Holley, D. (2007). The use of travel time by rail passengers in Great Britain. Transportation Research Part A: Policy and Practice, 41(1), 107-120.

Lyons, G., Jain, J., & Weir, I. (2016). Changing times – A decade of empirical insight into the experience of rail passengers in Great Britain. Journal of Transport Geography, 57, 94-104.

Lyons, G., Jain, J., Susilo, Y., & Atkins, S. (2013). Comparing rail passengers' travel time use in Great Britain between 2004 and 2010. Mobilities, 8(4), 560–579.

Malokin, A., Circella, G., & Mokhtarian, P. L. (2019). How do activities conducted while commuting influence mode choice? Using revealed preference models to inform public transportation advantage and autonomous vehicle scenarios. Transportation Research Part A: Policy and Practice, 124, 82-114.

McLean, J. (1981). Driver speed behaviour and rural road alignment design. Traffic Engineering & Control, 22(HS-032 471).

Moon, S., & Yi, K. (2008). Human driving data-based design of a vehicle adaptive cruise control algorithm. Vehicle System Dynamics, 46(8), 661-690.

Murphey, Y. L., Milton, R., & Kiliaris, L. (2009). Driver's style classification using jerk analysis. 2009 IEEE Workshop on Computational Intelligence in Vehicles and Vehicular Systems, 23-28.

Naujoks, F., Befelein, D., Wiedemann, K., & Neukum, A. (2017). A review of non-driving-related tasks used in studies on automated driving a review of non-driving-related tasks used in studies on automated driving. In International Conference on Applied Human Factors and Ergonomics (pp. 525-537). Springer, Cham.

Naujoks, F., Purucker, C., & Neukum, A. (2016). Secondary task engagement and vehicle automation - Comparing the effects of different automation levels in an on-road experiment. Transportation Research Part F: Traffic Psychology and Behaviour, 38, 67-82.

NTHSA. (2013). National Highway Traffic Safety Administration preliminary statement of policy concerning automated vehicles. Retrieved from http://www.nhtsa.gov

Oliveira, L., Proctor, K., Burns, C. G., & Birrell, S. (2019). Driving style: How should an automated vehicle behave? Information (Switzerland), 10(6), 1-20.

Oltedal, S., & Rundmo, T. (2006). The effects of personality and gender on risky driving behaviour and accident involvement. Safety Science, 44(7), 621-628.

Özkan, T., Taylor, P., Lajunen, T., Parker, D., Sümer, N., & Summala, H. (2010). Symmetric relationship between self and others in aggressive driving across gender and countries symmetric relationship between self and others. 37-41.

Payre, W., Cestac, J., & Delhomme, P. (2016). Fully automated driving: Impact of trust and practice on manual control recovery. Human Factors, 58(2), 229-241.

Pfleging, B., Rang, M., & Broy, N. (2016). Investigating user needs for non-driving-related activities during automated driving. ACM International Conference Proceeding Series, 91-99.

Russell, M., Price, R., Signal, L., Stanley, J., Gerring, Z., & Cumming, J. (2011). What do passengers do during travel time? Structured observations on buses and trains. Journal of Public Transportation, 14(3), 123-146.

SAE (2014). Automated driving: Levels of driving automation are defined in new SAE international standard J3016. Retrieved from https://www.sae.org/misc/pdfs/automated_driving.pdf

SAE (2016). Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles. SAE Int., 3016, 1-12.

Schoettle, B., & Sivak, M. (2014). Public opinion about self-driving vehicles in China, India, Japan, The U.S., The U.K., and Australia. Report No. UMTRI-2014-30.

Shimosaka, M., Kaneko, T., & Nishi, K. (2014). Modeling risk anticipation and defensive driving on residential roads with inverse reinforcement learning. 2014 17th IEEE International Conference on Intelligent Transportation Systems, ITSC 2014, 1694-1700.

Silberg, G., Wallace, R., Matuszak, G., Plessers, J., Brower, C., & Subramanian, D. (2012). Self-driving cars: The next revolution. White Paper, KPMG LLP & Center of Automotive Research, 9(2), 132–146.

Summala, H. (2007). Towards understanding motivational and emotional factors in driver behaviour: Comfort through satisficing. Modelling Driver Behaviour in Automotive Environments: Critical Issues in Driver Interactions with Intelligent Transport Systems, 189-207.

Sun, X., Cao, S., & Tang, P. (2021). Shaping driver-vehicle interaction in autonomous vehicles: How the new in-vehicle systems match the human needs. Applied Ergonomics, 90, 103238.

Taubman-Ben-Ari, O., Mikulincer, M., & Gillath, O. (2004). The multidimensional driving style inventory - Scale construct and validation. Accident Analysis and Prevention, 36(3), 323-332.

Timmermans, H., & Van Der Waerden, P. (2008). Synchronicity of activity engagement and travel in time and space descriptors and correlates of field observations. Transportation Research Record, 2054, 1–9. https://doi.org/10.3141/2054-01

Van Brummelen, J., O'Brien, M., Gruyer, D., & Najjaran, H. (2018). Autonomous vehicle perception: The technology of today and tomorrow. Transportation Research Part C: Emerging Technologies, 89, 384-406.

Van Der Waerden, P., Timmermans, H., & Van Neerven, R. (2009). Extent, nature, and covariates of multitasking of rail passengers in an urban corridor: A Dutch case study. Transportation Research Record, 2110, 106-111.

Van Huysduynen, H. H., Terken, J., & Eggen, B. (2018). The relation between self-reported driving style and driving behaviour. A simulator study. Transportation Research Part F: Traffic Psychology and Behaviour, 56(2018), 245-255.

Wang, J., Lu, M., & Li, K. (2010). Characterization of longitudinal driving behavior by measurable parameters. Transportation Research Record, 2185, 15-23.

Wang, J., Zhang, L., Zhang, D., & Li, K. (2013). An adaptive longitudinal driving assistance system based on driver characteristics. IEEE Transactions on Intelligent Transportation Systems, 14(1), 1-12.

Xu, J., Yang, K., Shao, Y., & Lu, G. (2015). An experimental study on lateral acceleration of cars in different environments in Sichuan, Southwest China. Discrete Dynamics in Nature and Society 2015.

Xu, L., Hu, J., Jiang, H., & Meng, W. (2015). Establishing style-oriented driver models by imitating human driving behaviors. IEEE Transactions on Intelligent Transportation Systems, 16(5), 2522-2530.

Yang, Y., Klinkner, J. N., & Bengler, K. (2019). How Will the driver sit in an automated vehicle? – The qualitative and quantitative descriptions of non-driving postures (NDPs) when non-driving-related-tasks (NDRTs) are conducted. Advances in Intelligent Systems and Computing, 823, 409-420.

Yusof, N. M., Karjanto, J., Terken, J., Delbressine, F., Hassan, M. Z., & Rauterberg, M. (2016). The exploration of autonomous vehicle driving styles: Preferred longitudinal, lateral, and vertical accelerations. AutomotiveUI 2016, 245–252.

Zhang, J., & Timmermans, H. (2010). Scobit-based panel analysis of multitasking behavior of public transport users. Transportation Research Record, 2157, 46-53.

Zhang, Y., Ni, P., Li, M., Liu, H., & Yin, B. (2017). A new car-following model considering driving characteristics and preceding vehicle's acceleration. Journal of Advanced Transportation, 2017.

Zhu, B., Jiang, Y., Zhao, J., He, R., Bian, N., & Deng, W. (2019). Typical-driving-style-oriented Personalized Adaptive Cruise Control design based on human driving data. Transportation Research Part C: Emerging Technologies, 100, 274-288.