Review Article

Effect of conventional driving experience on trust in autonomous vehicles (L2 and 3): A review

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Abstract: One of the main concerns with SAE Level 3 automated vehicles is trust and the factors that influence it. Previous research has identified several factors, including prior experience with driving and similar technology. However, due to the lack of a verified system for measuring influencing factors, the acceptance of automated vehicles is still yet to be ascertained, despite several findings. This article reviews empirical literature examining the effect of prior experience on trust in automated driving. The result suggests that while manual driving skills may no longer be required in AV driving, they will remain essential in certain critical circumstances. The results further indicate that acceptance and trust in technology are affected by different factors depending on age. Older generations may be influenced by their previous experience with traditional driving skills, whereas younger generations may be influenced by their strong familiarity with similar technologies.

Keywords: automated vehicles; trust; driving skills

1. Introduction

Automated vehicles (AVs) are widely anticipated to impact the driving landscape significantly, and understanding how people perceive and trust them has become a critical research area. However, one of the key concerns for AVs is how they interact with human drivers, who may have different driving experiences and perceptions, and how this will influence their trust. According to the National Highway Traffic Safety Administration (NHTSA)[1], drivers will continue to share driving responsibilities, at least for now. They must maintain constant engagement and attention to the driving task and the traffic with available AVs. Manual driving is a mode of transportation that has been around for decades. However, with the advancements in vehicle automation, self-driving vehicles are becoming more pronounced, and people are beginning to wonder what the future of driving will look like, particularly drivers' responses towards the technology and level of involvement, Brandenburg and Skottke[2] noted. Despite the emergence of alternative modes of transportation, manual driving with full human control remains the dominant means of transportation. As of 2019, about 76% of American commuters still engage in manual driving, making it the most popular means of mobility, as reported by the World Economic Forum[3]. Rasmussen[4] highlighted that operating a manual vehicle requires having a driver's license, understanding the rules and regulations, and having some experience driving a car.

On the other hand, self-driving vehicles are designed to use technology such as sensors, cameras, GPS, and artificial intelligence to navigate roads without human help, according to Blanco et al.[5]. Automated vehicles can identify road signs and signals, detect obstacles, and make decisions based on the environment around them. However, there are different levels of self-driving, from driver assistance to fully autonomous, and each level has different capabilities and limitations[6,7]. One benefit of automated vehicles as stated by Endsley[8] is that they can reduce human error-related accidents. Self-driving vehicles can react faster and more accurately to changing road conditions and reduce traffic congestion since they can communicate with one another and other environmental elements-vulnerable and invulnerable. The widespread adoption of self-

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driving vehicles still faces significant challenges, and it will likely take some time before they are accepted as a viable mode of transportation. According to the literature, trust is one of the most relevant psychological factors when assessing the trustworthiness of a system. The widespread adoption of AVs will largely depend on how much people are willing to trust the associated technology, specifically with regard to usability and safety[9,10].

Meanwhile, it is debated that the greatest hindrance to mass acceptance of autonomous driving is more human-related than technical. This makes it more subjective in consolidating the findings on the influencing factors, as studies have shown that humans tend to zone out when their full attention is not needed, which can lead to driver inattention and the associated problem of quickly reengaging to respond[11,12]. Among the different human-related factors mentioned in the AV studies, it is important to consider factors related to human psychology. From a cognitive perspective, trust in technology is the most relevant determinant. Examining trust and previous experiences with AVs is crucial in understanding how people relate to them. Existing research has analyzed trust from three different perspectives, including dispositional trust, initially learned trust, and situational trust, to explain how gradual interaction with self-driving cars plays significant roles in people's adoption of the new technology[13,14], but no specific mention of the impact of prior experience or driving skills on users' trust level. However, a study by Rödel et al.[15] has shown that people's trust in autonomous vehicles can be influenced by other factors such as prior experience with driving, familiarity with the technology, and perceived safety. Research by Hsieh et al.[14] has also shown that trust in autonomous vehicles varies depending on the level of autonomy. For example, individuals are more likely to trust partially autonomous vehicles requiring human input, such as adaptive cruise control or lane departure warning systems, than fully autonomous vehicles requiring no human input. A global automotive consumer study by Deloitte[16] observed that trust in AVs dropped by 9% between 2017 and 2019 across six major countries (such as the US, China, Japan, the UK, India, and South Africa). This could indicate that the higher the level of autonomy, the less trust it attracts. To categorize the layers and features of automated vehicles, the Society of Automotive Engineers (SAE)[7] has developed levels of driving automation (see **Figure 1**). In line with the taxonomy, the lower level of automation usually needs a human driver to guide and monitor the road traffic situation and the activities of the AV systems.

As shown in **Figure 1**, partial driving automation (SAE-L2)[7] still requires the assistive supervision of the driver during driving and taking over control as necessary, this is also confirmed in a study by Lee et al.[17]. As earlier pointed out, driving with limited automation involves the National Highway Traffic Safety Administration (NHTSA)[18] level 3 "limited automation" standard. This means that drivers are responsible for ensuring the vehicle's technical safety functions are in order in specific circumstances while being expected to take control in situations where the conditions change. This stresses the importance of remaining alert while driving with limited automation. The driver should, therefore, still learn proper manual driving skills and respond appropriately to situations while driving. Can a driver/passenger with limited manual driving skills or no previous driving experience with AV handle the task? Participants in a study by Reagan et al.[19] research works were either licensed drivers or highway organization employees with prior experience with partial driving automation. Thus, findings from such experiments may not be generalizable, particularly concerning those who have never experienced such technology or driven before. Through a comprehensive literature review, the study examined the effect of conventional driving skills and prior experience with similar technology on trust development in AVs (L2 and 3). It focuses on the existing research on driving skills and perception in the context of AVs. Three main areas of concern were investigated concerning factors affecting trust and acceptance, and they are related to humans, automation, and the environment. The three dominant areas of discussion in the literature are the driver's perception of the vehicle's capabilities, the driver's level of control, and the driver's previous experience with conventional driving, as explained in section three. After reviewing existing studies, human-related factors, such as age, experience, and familiarity with AV, become obvious in terms of their role in building trust in future drivers of semi-automated vehicles.

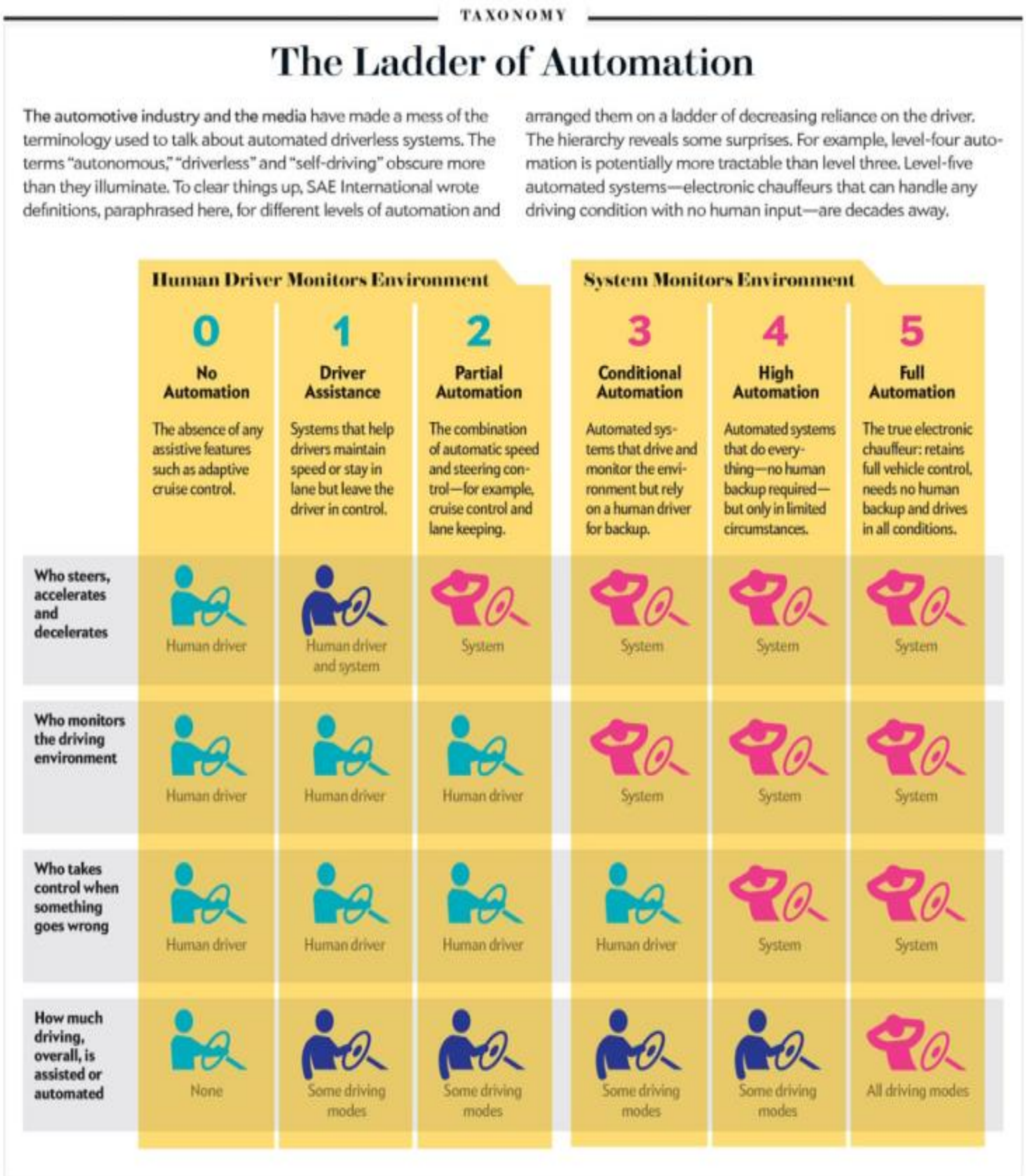

Figure 1. Illustration of the ladder of automation[7].

2. Method

A series of keywords were used to search for relevant papers to achieve this systematic review. The keywords include driving skills, driving experience, trust, and terms related to automated vehicles. A few databases of research articles were searched, including the Association of Computing Machinery (ACM) Digital Library, IEEE, and Google Scholar. Abstracts of papers were examined to sort out those that investigated the topic with respect to the human factors perspective, irrespective of their research methods-surveys, questionnaires, interviews, experimental, observational, simulation, and case studies. An initial relevant 142 papers were identified, among which 90 articles were included in the final review based on the PRISMA framework developed by Moher et al.[20]. The period was not set to a specific date but contained the most relevant papers, as expected from research on AVs.

3. Results

Based on the results of the review, research in three key areas was identified through the analysis of the selected papers: driving experience and skill adaptation, situation awareness and take-over preparedness**,** trust factors in autonomous vehicles, and intention to control. The establishment of trust in autonomous driving and the impact of different factors on trust development are discussed in these areas.

3.1. Driving experience and skill adaptation

Drivers accustomed to manually operating vehicles must adapt their skills to the new automated driving technology. They may need to learn to trust and understand the automated system's limitations. This can be challenging, especially for experienced drivers who are used to being in control. It is very important to note that transitioning from manual to semi-automated driving still requires drivers to apply their skills and previous experience to understand the specific capabilities and limitations of the semi-automated system, as explained by Rasmussen[4]. A user's perceptions and expectations, as well as their capacity to comprehend the features and performance of an automated vehicle, may be influenced by their knowledge before any use or interaction with it (e.g., previous encounters with comparable automation)[21,22]. A survey of 1000 participants by Walch et al.[23] suggested that people's perceptions of autonomous cars varied depending on their perspective as road users. As the user delved deeper into the background information provided by the automated assistance, they began to feel a sense of trust. It was the first time they had relied on automation in this way, and the initial trust they felt was crucial in building a foundation for future interactions. However, the trust was not static and would change based on the user's experience with the automation. Hulse et al.[24] and Atkinson et al.[25] argued that as users utilized the various capabilities of the automated assistance, they would dynamically acquire trust, continually evaluating its capabilities and limitations. The system's performance and design elements will most affect the drivers' skills as they develop their learned trust. On the other hand, research studies have investigated the link between driving skills and trust in AVs. Though there seems to be a correlation between the two, as drivers with higher levels of skills and knowledge in manual driving are more likely to trust automated vehicles, there is little evidence to generalize users' widespread acceptance of automated vehicles[15,26]. One of the major barriers to the widespread adoption of autonomous vehicles is still consumer attitude and distrust. Despite the many advancements in technology and safety measures, people are still hesitant to embrace this new mode of transportation fully. A study of older persons' perception of driving AVs, carried out by Huff et al.[27] showed that they were confident to ride and take over the driving if required. Participants showed high confidence in engaging in self-driving vehicles, partly due to their ability to resume control when required or the fact that an alternative to manual driving is now available; as also noted by similar studies in Marottoli and Richardson[28]. An explanation for this is that manual driving experience can foster the development of good decision-making and judgment skills. In semi-automated driving, these skills are valuable for evaluating the system's actions and determining when to take control. Manual drivers are typically more comfortable making split-second decisions in response to unexpected situations, which can be critical in maintaining safety during semi-automated driving. To further explain, McCall et al.[29] cited a situation where the AV is approaching an area unsuitable for automated driving and needs the driver to take over the control. Questions about participants' ability to take over in compelling situations were asked, and the result also confirmed that participants were confident in taking over. From their responses, participants anticipated some built-in features that enable users to take control if they are physically, mentally, and visually fit to do so[30].

They indicated that such features should be part of every automated vehicle, as shown in participants' responses where 96.2% would want a steering wheel and other basic controls available even in completely self-driving vehicles[31]. Similarly, Puertas-Ramirez et al.[32] identified a Fallback Ready State (FRS) where the user could detect potentially dangerous events and take over the driving. Their study defined Fallback Ready State (FRS) as the minimum awareness required of a user to safely understand and act on takeover requests or system malfunction[7]. In other studies, some authors find traditional driving an important source of pride and fulfillment. Therefore, this perception may negatively impact their trust and readiness to ride AVs[33,34]. Hewitt et al.[26] conducted an extensive survey a8nd found that many people are yet to be educated and persuaded about car automation, though they are excited about the new development. Much research has reported the possibility of changing people's perception of AV through training, increased knowledge, and familiarity with relevant technology[35,36]. However, previous experience will be vital in adapting to the new technology, as age and driving experience significantly impact on on-road behavior[37].

3.2. Situation awareness and take-over preparedness

The contradiction of AV is that while manual skill may not be needed for car driving tasks, it will remain essential under certain critical conditions, especially under lower automation levels, and it is believed that this will place a high demand on drivers who have not been exposed to driving under a high cognitive load, according to Ucińska et al. and Lu et al.[37,38]. As we move towards more advanced automated vehicles, we must consider drivers' situation awareness and take-over preparedness. While the technology is improving, it is still crucial for drivers to be aware of their surroundings and ready to take control if necessary until the implementation of fully automated driving. This means staying focused and alert, even when the vehicle handles most of the driving tasks. It is also important for drivers to be familiar with the capabilities and limitations of the automated system, so they can make informed decisions if they need to take over. By staying aware and prepared, drivers can help ensure automated vehicles' safe and effective use[]39–41]. Studies have investigated the impact of extended supervision of automated vehicles on driver's situation awareness and takeover performance. Brell et al.[36] found that drivers were able to maintain situational awareness during normal automated driving but were less able to do so when the system failed. Endsley[42] also noted that the high level of distraction in manual driving has been a point of concern, as drivers still get carried away with non-driving tasks and other vehicle infotainment systems. Therefore, it becomes difficult to maintain situation awareness, and drivers need more time to take over control of the vehicle following a failure[43–45]. Jarosch and Bengler[46] research looked at the effects of various levels of automation on drivers' ability to take over driving duty. It was found that drivers who were given more information about the status of the automated system were able to take over control of the vehicle more quickly and accurately than those who were given less information. A similar study by Nilsson et al.[47] investigated the relationship between drivers' trust in automated systems and their takeover performance. They found that when drivers trusted the automated system, they were more likely to take longer to respond to a takeover request and had more errors during the takeover process[48–51]. According to Vongvit et al.[52], no significant differences have been found in situation awareness between manual and Automated driving modes. Thus, whatever skills the AV driver has acquired from previous experience with semi-automated vehicles will determine how they handle takeover requests, particularly in extreme situations. In the work of Petersen et al.[53]. and Trösterer et al.[54], it seemed that with capability and readiness, the driver must be able to perform manual takeover in situations where the automated driving features cannot spot potential dangers such as sudden obstruction by an object. Puertas-Ramirez et al.[55] concluded that so long the AV has the potential of committing errors or incorrect behaviors or going beyond the limit of its functionality, the fallback-ready user status must be maintained. However, the implications of not possessing prior knowledge of level 1 driving are sure to be very dramatic, according to participants' responses in a study[26,56].

3.3. Trust factors, control preference, and safety concerns

According to Choi and Ji[57], trust in autonomous vehicles is concerned with the willingness of individuals to rely on the capabilities of the vehicle to perform tasks, make decisions, and operate safely without human intervention. Trust is based on perceptions of the vehicle's reliability, safety, and performance, as well as the degree of control individuals have over the automated vehicle[58]. In an extensive literature review study, Raats et al.[59] used Hoff and Bashir's[39] trust model to summarize the increasing efforts of researchers over the years and analyze aspects of trust investigated, namely learned trust, dispositional trust, and situational trust as seen in **Figure 2**[39]. While existing research in human-computer interaction provides a foundational background for how knowledge about trust in AVs is communicated at a surface level, the overall research summary revealed that little is known about how trust is experienced and perceived when people are using AV technologies, either in realistic driving situations or in test situations. For example, studies by some groups of researchers[60–62] found no major difference in the effect of age on drivers' trust level, even though older drivers demonstrated a more positive inclination toward AV possibly for its mobility benefits, considering the accompanying health challenges with age (**Figure 3**).

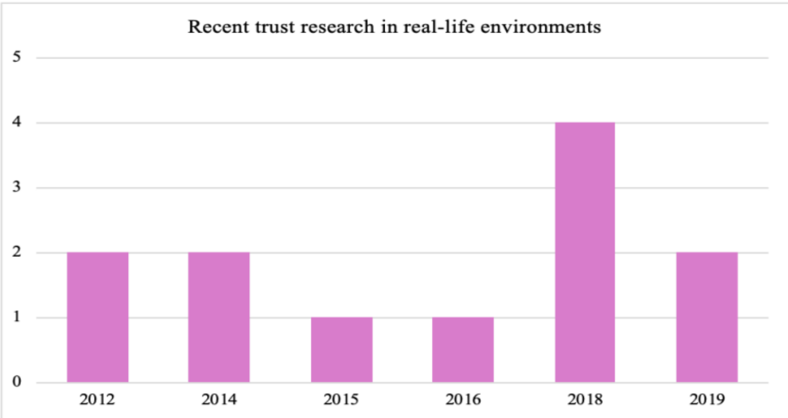

Figure 2. Recent trust research in real-life environments[39].

Method			Trust model								
			General trust	Learned trust	Initial learned	Dynamic learned	Dispositional trust	Situational trust	System performance	Design features	Reliance on system
Method	Study context	Field study	1	1			2	1	2	2	1
		Laboratory study	1		3			1	3	4	2
		Meta-analysis	1								
		Multiple case study research			1						
		On-road study	1			1		1	1	2	
		On-water study							1		
		Online study	2		5	1	7	1	5	4	1
		Test track	3		1	1		1		2	1
		Simulator/Game study	9	2	18	12	14	25	44	50	10
	Data collection	Contextual inquiry				1					
		Day Reconstruction method		1					1		
		Ethnography	1				1	1			
		Eye-tracking	1	1	1		1	1	1		
		Focus group			1					1	
		Interview	4	1	6	4	3	2	4	11	1
		Journaling				1					
		Observation	3		1	1	2	2	2	3	3
		Physiological measurement	1						1	3	
		Questionnaire / User feedback	17	2	29	15	23	28	54	55	14
		Video analysis	3							1	

Figure 3. Summary of research context, data collection methods and how they source[39].

A study by Jin et al.[63] investigated participants based on their driving experience, from novice to experienced drivers, by exposing them to four take-over scenarios. Their result showed that trust level is positively impacted by driving experience. As addressed in relevant studies, several factors have been identified as influencing trust in autonomous vehicles. For example, the result of Vongvit et al.[52]. Among these factors is familiarity with technology[64], initial knowledge, and interaction with lower-level automated cars. Simulator studies by Faltaous et al.[65] introduced awareness (pre-experimental) sessions to boost users' experience with the system's behavior and interaction. Another one noted by Xu et al.[12], is perceptions of safety, which are a critical factor in determining trust. Individuals are more likely to trust automated vehicles if they believe they are safer than human-driven vehicles. Transparency and communication, as in providing clear and transparent information about the capabilities and limitations of autonomous vehicles, can increase trust[66]. User experience is a positive initial impression, including ease of use and comfort, that can increase trust in autonomous vehicles[15]. Personal values[36], such as the importance of environmental sustainability or the desire for personal control, can influence trust in autonomous vehicles[67,68]. Many researchers agree that trust in autonomous vehicles is a complex and multidimensional concept that is influenced by many factors, but as cars start to incorporate more and more autonomous features and people start to get familiar with and have good experiences with those intermediate technologies, it could prove to be a sure path to trusting fully driverless vehicles[69,70].

The safety of AVs is a crucial factor in determining their adoption. Several studies have been conducted on AV safety, focusing primarily on accident rates and causes. According to a study by NHTSA[71], human error is responsible for 94% of all car accidents, and it is believed that automated vehicles promise to reduce it. In many ongoing AV driving tests on public roads, a human driver is always seen, whose job is to follow the traffic and be ready to take control as soon as required. This safety driver potentially has the same legal role as the driver of a manual vehicle, according to Hansson et al.[72]. The challenge involved in relinquishing all control to the technology is a major area of consideration if AVs are to gain global acceptance[73,74]. While more skilled drivers may be less willing to trust AVs, less skilled drivers may benefit from the increased safety features that guarantee the use of AVs[75]. The study suggested that drivers with low trust were more cautious and attentive, leading to better driving performance. However, this finding may not necessarily apply to real-world driving conditions, where high trust in AVs may be required to ensure the safe and smooth operations of the vehicle with high automation.

4. Discussions

Research has shown that driving skills can vary widely among individuals. In the context of AVs, some studies suggest that drivers with higher conventional driving skills may be less willing to trust AVs and may feel uncomfortable with the loss of control that comes with automation. This could cause some fear and reduce the expected acceptance of self-driving vehicles[73,76]. On the other hand, less skilled drivers and persons with disability may be more willing to trust AVs because of the promised features which can compensate for their lack of skills and abilities[68]. One study in a simulated semi-automatic vehicle found that self-confidence in manual controls affects trust and interaction with automation. This is likely true of participants performing better in simulated AV driving tasks[77]. Similarly, other research has shown that driving experience with conventional vehicles and partial driving automation may be more important than education or training, as experienced drivers may be better able to anticipate and react to unexpected situations such as lane deviation, road obstruction, and the sudden appearance of pedestrians, etc.[76]. However, Payre et al.[64] and Ebnali et al.[78] a higher level of declared trust was observed after introducing participants to training and practice sessions in a simulator driving. In addition to driving skills, perception is also a key factor in AV interaction. Research has shown that drivers may have varying perceptions of the safety and reliability of AVs, depending on factors such as age, gender, and prior experience with automation[7]. For example, older drivers may be less comfortable with AVs due to concerns about reliability. In comparison, younger drivers may be more accepting of the technology and see it as an opportunity to explore new technology. Still, trust increases if the system reliably requests a takeover during failure[79]. In Merat et al.[80] and Hegner et al.[81], participants felt more comfortable with SAVs when they had some control over the vehicle's decisions. They preferred being able to intervene in certain situations, such as when the vehicle was about to make a risky maneuver or started malfunctioning.

5. Limitations

Based on the research conducted using the PRISMA framework, it is possible that some important articles were left out due to limited resources. Additionally, the exclusion criteria may not have been as effective as intended, given the small research team involved in the review process. While some articles are reviewed exploring the impact of driving skills and prior knowledge only on conventional driving, most papers focus on other factors influencing the trust and acceptance of AVs. Furthermore, many articles lack a real-track test experimental design, suggesting the need for further validation of the reports in the articles used in this review to determine the effect of driving skills on trust.

6. Conclusions

The interplay of driving skills and trust in AVs is a complex and multifaceted issue affecting these vehicles' acceptance and adoption. While prior experience with AVs and the level of automation can influence trust and driving skills, drivers' confidence in their driving abilities and the reliability and accuracy of the system are also crucial factors. Further investigation and research work are necessary to understand these factors and how they interact to shape drivers' trust in vehicles with various levels of automation, particularly in real-world driving conditions.

Conflict of interest

The authors declare no conflict of interest.

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