User Experience and Behavioural Adaptation Based on Repeated Usage of Vehicle Automation: Online Survey

Naomi Y. Mbelekani, Klaus Bengler
Chair of Ergonomics, School of Engineering and Design, Technical University of Munich, Munich, Germany

***Abstract*—For years, Level 2 vehicle automation systems (VAS) have been commercially available, yet the extent to which users comprehend their capabilities and limitations remains largely unclear. This study aimed to evaluate user knowledge regarding Level 2 VAS and explore the correlation between user experiences (UX), behavioural adaptations, trust, and acceptance. By using an online survey, we sought to deepen understanding of how UX, trust, and acceptance of Level 2 automated vehicles (AVs) evolve with prolonged use in urban traffic. The survey, comprising demographic data and knowledge inquiries (automated driving experience and timeframes, vehicle operation competency, driving skills over long-term use of automation, the learning process, automation-induced effects, trust in automation, and ADS researchers and manufacturers), was completed by various drivers (N=16). This investigation focused on users' long-term experiences with automation in urban traffic. Consequently, we offer user-centric transformative insights into users' experiences with driving automation in urban traffic settings. Results revealed that users' knowledge of automation exhibits their learning patterns, trust and acceptance. Moreover, users' attitudes trust, and acceptance varies across different user profiles. What we have also learned about UX and the changing nature of user behaviours towards automation is that, automated driving changes influence the safety and risk conditions in which users and AVs interact. These findings can inform the development of interaction design strategies and policy aimed at enhancing UX of AV users.**

***Keywords*—Automated vehicles; automation effects; user experience (UX); trust; acceptance; behavioural adaptations**

I. INTRODUCTION

Automation, characterised by its ability to actively select data, transform information, make decisions, or control processes, offers immense potential to enhance human performance and safety [1]. Within the context of driving, automation is described using different levels of task responsibility and human involvement. The International Organization for Standardization (ISO) provides simplified descriptions of what constitutes levels of automation (LOA). However, different original equipment manufacturers (OEMs) develop their vehicle automation systems (VAS) or automated vehicle (AV) systems to suite their brand identity (marketing, brand personality, brand product standards, legal reasons, etc.). They tend to subscribe different names to their systems (for example, as representative Level 2 automation: Tesla Autopilot, Super-Cruise, Blue-Cruise, Pilot Assist, etc.), even though they may fall under the same LOA description under ISO (SAE J3016). With transitional LOA, such as 'partially' as well as 'conditionally' automated, and 'highly automated', which we used to derive a graphical representation, as shown in Fig. 1 and 2. For instance, some OEMs have been known to categorise their VAS based on different marketing strategies. Either with a cool factor, comfort factor, or active safety factor, for example. In a sense, it is quite common for some of these systems to be known by different appellations. Nonetheless, some of the automation systems remain the same as they in effect functions in the same way, for example, driving support systems.

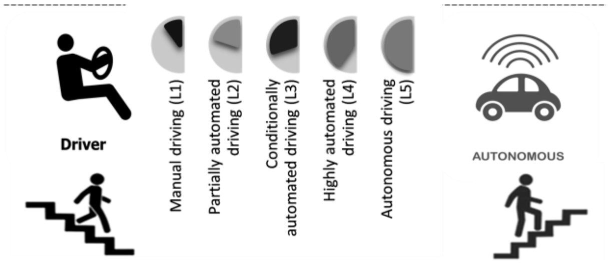
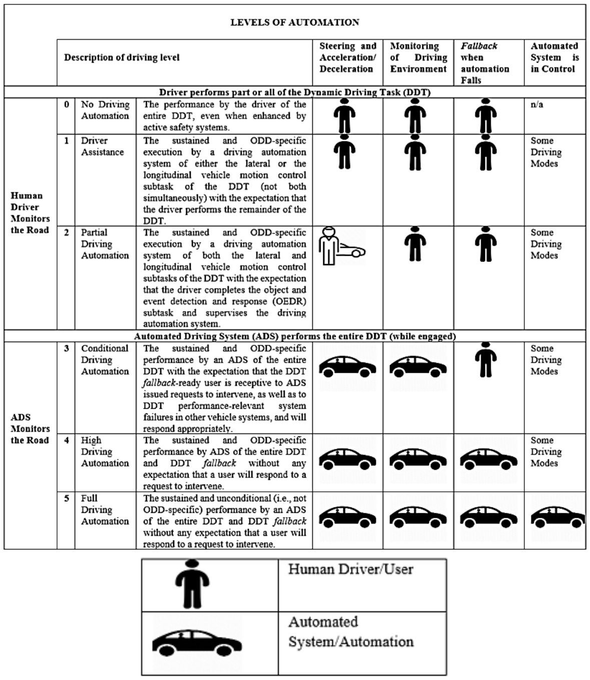


Fig. 1. LOA for AVs, from manual driving to autonomous.



LEVELS OF AUTOMATION

			Description of driving level	Steering and Acceleration/ Deceleration	Monitoring of Driving Environment	*Fallback* when automation Falls	Automated System is in Control
Driver performs part or all of the Dynamic Driving Task (DDT)							
Human Driver Monitors the Road	0	No Driving Automation	The performance by the driver of the entire DDT, even when enhanced by active safety systems.	🧍	🧍	🧍	n/a
	1	Driver Assistance	The sustained and ODD-specific execution by a driving automation system of either the lateral or the longitudinal vehicle motion control subtask of the DDT (not both simultaneously) with the expectation that the driver performs the remainder of the DDT.	🧍	🧍	🧍	Some Driving Modes
	2	Partial Driving Automation	The sustained and ODD-specific execution by a driving automation system of both the lateral and longitudinal vehicle motion control subtasks of the DDT with the expectation that the driver completes the object and event detection and response (OEDR) subtask and supervises the driving automation system.	🧍🚗	🧍	🧍	Some Driving Modes
Automated Driving System (ADS) performs the entire DDT (while engaged)							
ADS Monitors the Road	3	Conditional Driving Automation	The sustained and ODD-specific performance by an ADS of the entire DDT with the expectation that the DDT *fallback*-ready user is receptive to ADS issued requests to intervene, as well as to DDT performance-relevant system failures in other vehicle systems, and will respond appropriately.	🚗	🚗	🧍	Some Driving Modes
	4	High Driving Automation	The sustained and ODD-specific performance by ADS of the entire DDT and DDT *fallback* without any expectation that a user will respond to a request to intervene.	🚗	🚗	🚗	Some Driving Modes
	5	Full Driving Automation	The sustained and unconditional (i.e., not ODD-specific) performance by an ADS of the entire DDT and DDT *fallback* without any expectation that a user will respond to a request to intervene.	🚗	🚗	🚗	🚗

🧍	Human Driver/User
🚗	Automated System/Automation

Fig. 2. VAS spectrum (adapted from SAE J3016).

It is important to discriminate how different AV-LOA have an effect on UX and behaviour towards automation. For instances, different in-vehicle intelligent transport systems (ITS), advanced driver assistance system (ADAS) or automated driving systems (ADS), as well as in-vehicle information and communication systems (IVIS) or in-vehicle information architecture systems (IAS). Additionally, future in-vehicle artificial intelligent (AI) systems and human-machine interfaces (HMIs) or user interfaces (UIs), as well as Adaptive Integrated Driver-vehicle Interface (AIDE). These vehicle computerised systems are designed to support the user in keeping the AV on the road and in avoiding collisions with obstacles, other vehicles and other road users or vulnerable road users (VRUs). However, recent on road risk-based conditions have highlighted that their advantages are not universally guaranteed.

A. Problem Statement and Study Significance

As automated driving technology evolves, it significantly impacts the UX and behaviours of road users, disrupting the environment in which they have traditionally operated. The following are some key insights into the changing dynamics:

1) Change in user behaviour: With the introduction of AV systems, users may become less engaged in the driving task. They may rely more on the AV's capabilities, resulting in changes in their behaviour. For example, such as reduced vigilance and slower response times.

2) BAC: Users may exhibit BAC in response to AVs. This could include changes in driving habits, skills, preferences for AV systems, and changes in risk perception and decision-making processes.

3) Trust and acceptance: As AV technology advances, users' trust in and acceptance of AV systems become critical. In essence, users may exhibit distrust and caution or over trust and incaution towards AV features. However, with positive UX and improved reliability, trust may improve over time.

4) Adaptation to new HMI/UIs: AV systems introduce new HMIs and interaction modalities within AVs. Users need to adapt to these interfaces to effectively control and interact with AVs. In order to avoid mode confusion and induce mode awareness. This adaptation may involve learning new control mechanisms, understanding AV system feedback, and evoking to new ways of interacting with the AVs.

5) Reconsideration of user roles: As AVs take on more driving functions, users' roles and responsibilities in the driving process undergo significant changes. Users may transition from active drivers to passive passengers, requiring them to redefine their roles, participation in NDRT, responsibilities, and expectations concerning AV operation and safety.

6) Impact on road design and environment: The integration of AV technology reshapes the on road experience and driving environment, influencing traffic flow, road infrastructure and design, road users/VRUs, and regulatory frameworks. AV users must adapt to these changes, including new traffic patterns, infrastructure requirements for automated driving operation, and updated regulations governing AVs.

Generally, the changeover to automated driving brings about significant shifts in UX and BA for road users. Understanding these changes is crucial for ensuring safe adoption and assimilation of AVs into the transportation ecosystem.

In this study, we specifically consider levels of UX based on L2 AVs. In order to conceptualise L2 AVs and their usefulness with respect to the user, we consider behavioural adaptation (BA) and change (BC) or BAC based on repeated usage and sequences of effects [2]. Moreover, considering how UX, trust, and acceptance of L2 AV functionalities (e.g. longitudinal and lateral driver support systems) change with long-term repeated usage in urban traffic. Furthermore, it is highly influential to assess usability by emphasising the concept of Learnability in Automated Driving (LiAD) [3], which considers learning effects of automation on user behaviour. Thus, proposes a comparison between users 'learning to misuse' and 'learning to responsibly use' automation, relative to the operation of AV on road traffic. The study explores the relevance of UX, trust and acceptance based on prolonged usage of L2 AVs, by considering users knowledge on the following inquiries, as illustrated by Fig. 3.

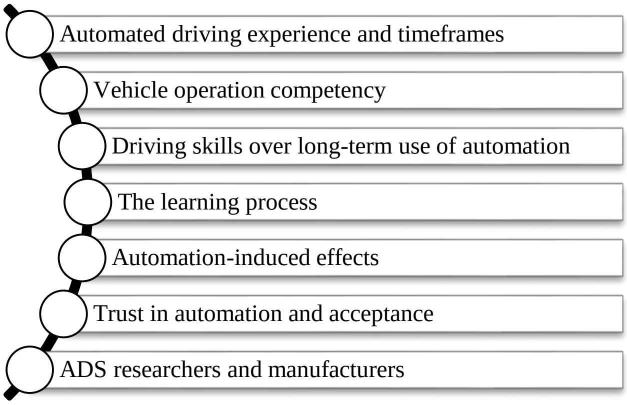


Fig. 3. Study knowledge inquiries.

UX research has become a critical element in creating successful human-automation interactions (HAI) and AVs for future use cases and user journeys. It has become a crucial topic for the future of AV induced quality experiences, particularly with the introduction of super intelligent automation, artificial intelligence (AI) and generative AI. This is because of its direct impact on user behaviour, and as a way of safeguarding in-vehicle AI-UX vision of the future. Thus, it is essential to consider UX that is expedient and self-serving based on human factors and quality-based interaction design strategies. Essentially, developing augmented and super automation intelligence enables AVs that induce safe decisions, as well as active, proactive or reactive (responsive) safety based behaviours in traffic situations also the ability to perform driving actions completely safe in the future.

Depending on user types, context of use, and environmental situation, the knowledge attained from this study opens up the prospect for UX on road that is more efficient, organic/natural, safe and predictive. This opens up a multitude of new research questions based on users experiencing learning, trust, and acceptance over long-term automation exposure. This knowledge helps with formulating resilient interaction design strategies that stand the test of time, and progressive multimodal learning strategies between the user and AV.

II. RELATED WORKS

Numerous researchers have aimed to investigate UX and BA of L2 (see [4-5]) and L3-4 (see [6, 7, 8]) AVs. In an automated highway system, study in [9] investigated the effects driving performance after an extended period of travel. The researchers concluded that human factors play a pivotal role in how AV systems are experienced [9]. The study in [10] emphasised challenges induced by L2 automated driving. This type of research has become a trend, as other researchers aim to identify L3 automated driving [11] due to the L3 AV introduced on public roads. The study in [12] examined the effect of automation use, misuse, disuse, and abuse, which has inspired more research on the topic of BA [2] as automation changes and evolves.

Moreover, researchers have also considered the process of automation acceptance on road traffic, as seen in the lens of the Multi-level model on Automated Vehicle Acceptance (MAVA) [13]. The impact of most of AV features (from fully manual to fully automated) have been discussed by different researchers, as we see with [14, 15, 16]. This also considers a future direction of research and development towards benchmarking Highly Automated Vehicles (HAV) vision boards, considering trust and acceptance. According to some OEMs, we should already have been able to choose to be chauffeured by AVs instead of driving them, the vision for tomorrow where pressing one button will turn AVs into L5 autonomous driving. However, the current reality is that human users are still required to pay attention and be situationally aware during L2-3 automated driving.

In order for users to be able to operate their L2-3 AVs to their fullest capabilities, they are required to familiarise themselves with a myriad of knowledge processes, functionalities, acronyms, controls, and symbols, to name a few. The user-vehicle interfaces (or HMIs) form a significant part on how AV systems are understood and operated. Including the type of information displayed to facilitate mode awareness. Distinguishing, recognising and knowing symbols is, consequently, essential for users to safely operate AVs equipped with different functionalities. It is thus important to explore how HMI/UI design may influence BA over long-term exposure.

The Organisation for Economic Cooperation and Development (OECD) defined BA as “those behaviours which might occur following the introduction of changes to the road-vehicle-user system and which were not intended by the initiators of the change [...]. They create a continuum of effects ranging from a positive increase in safety to a decrease in safety” [2]. As a result, users are able to adapt to the exposed vehicle automation situation (including its limitations and capabilities). Fundamentally, behavioural evolutionism is seen as an applicable theory. In this context, ‘behavioural evolutionism’ pertains to the examination of how user behaviours related to AVs changes over time, incorporating concepts such as learnability, trustability, and acceptability. It considers various factors such as user states, system design, and environmental influences in shaping these behaviours.

As an illustration, the evolution of automated driving (AVs as societal innovations) can be viewed as subject to environmental factors, serving as the mechanisms by which human users adjust to their altered on road traffic circumstances. This adaptation is prompted by both physical alterations in road infrastructure and social changes. Essentially, the process of BAC is considered as the evolution and manifestation of new behaviour towards AV. Users are confronted with changing driving situations that they have to adapt to, constantly. This occurs at changed UXs, resulting in ‘AV user modifications’ due to long-term automation exposure. In a general context, ‘AV user modifications’ is used to depict users experiencing changes or transformations throughout their automated driving experiences. These changes are activated due to users’ interaction with AV systems in various changing situation, and they evolve from the complex interplay of different factors, as illustrated by Fig. 4.

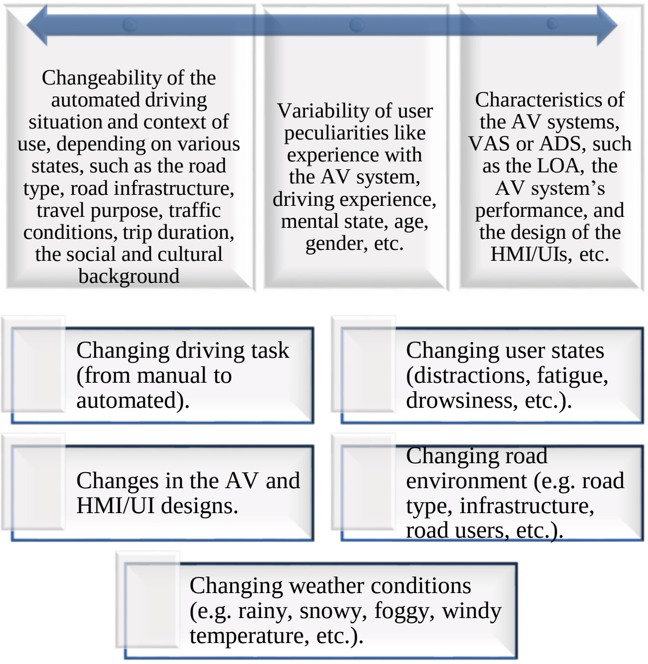


Fig. 4. Changing situations and UX factors.

The ‘power law of learning’ and ‘power law of practice’ is important to consider, as users take possession of the purpose, working principles, and expected performance of the AV over time. This has an indirect and/or direct effect on the usage process; especially, as users are exposed and use the AV system, long-term. Concerning the temporal factors affecting BAC and two main phases, the following have been profoundly argued in literature and are therefore considered.

- Learning and appropriation phase: The user discovers the AV system, learns how it operates, and identifies its capabilities and limitations. This learning process is assumed crucial for the user’s mental model of the AV system, the confidence the user has in it and its optimal use.

- Integration phase: The user, through experienced using the AV system in different road situations, reorganises their activity by integrating the AV system in the management of the overall driving task.

Thorough examination of the ‘learning and appropriation’ phase is essential as the progression and duration of this phase directly influence the evolution of users’ behaviour over time. As the ‘learning and appropriation’ phase unfolds, users may gain crucial elements necessary for constructing mental models pertaining to the AV system. Informed by these mental models, users may make decisions, whether consciously or unconsciously—regarding when to safely operate the AV and when to engage non-driving related tasks (NDRTs). Furthermore, mental models play a crucial role in determining the level of trust to invest in the automation and its incorporation into their daily routines. These decision-making processes have consequences on the manifestation of either positive or negative BA to AVs, and are further explored by study [3]. Thus, when researching BA, it is important to consider mental models. It is essential to discover factors that might cause BA to AV systems (considering longitudinal driver support systems, lateral driver support systems, and driver performance monitoring and support systems). In addition, the users’ mental model in relation to the AV-LOA and the trust in automation should be considered.

Longitudinal Driver Support Systems

- Adaptative Cruise Control (ACC): Similar to traditional cruise control, ACC maintains a predetermined vehicle speed and maintains a safe distance to vehicles in front.
- Forward Collision Warning system (FCW): Detect impending collision with a vehicle in front, notify the driver of the situation.
- Intelligent Speed Adaptation (ISA): A IVIS that inform the driver of their current speed based on the statutory speed limit.
- Reversing and Parking Assistance (R-PA): Low-speed assistance systems designed to reduce collisions between the reversing vehicle and pedestrians, vehicles and other solid objects.
- Adjustable Electronic Stability Control (A-ESC) system: Represent a category of performance-regulated driver support system

Driver Performance, Monitoring Support Systems

- Fatigue Warning Systems (FWS): driver alert systems using eye movement-based measures data and algorithms that aim to predict the trajectory of the vehicle and, for example, steering wheel movements, as well as subtle changes in driving style
- Seatbelt Reminder Systems: Seat pressure sensors and buckle lock to determine the presence of a driver or other occupant.

Lateral Driver Support Systems

- Lane Departure Warning (LDW): Warns driver when vehicle unintentionally begins to move out of its lane.
- Lane Keep Assist System (LKAS): When vehicle moves out of lane, will automatically steer vehicle back into its lane.
- Automatic/Advanced Emergency Braking System (AEBS): Safety feature that automatically prevents a collision
- Blind Spot Information Systems (BLIS): Detects other vehicles located to the driver’s side and rear, gives warning to alert driver.

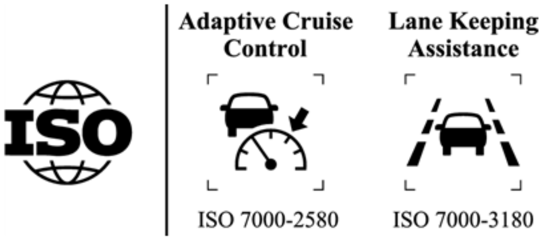


Fig. 5. LOA functionalities and example ISO symbols for ACC/LKA.

Research on BA has primarily cantered around various AV systems. However, there is a need to expand understanding to encompass BA to the context of HMI and UI designs. Adaptive Cruise Control (ACC) and Lane-Keeping Assistance (LKA) systems deal with longitudinal and lateral controls of a vehicle. When referring to AV-HMI induced effects to BA, both ACC and LKA have distinctive symbols. These symbols play a significant role in facilitating users’ comprehension and swift recognition.

- ACC: “a system which accelerates or decelerates the vehicle to automatically maintain a driver pre-set speed and driver pre-set gap distance from the vehicle in front” (ISO 7000-2580).
- LKA: a “system to keep a vehicle between lane markings” (ISO 7000-3128).

The following AV functionalities (see Fig. 5) are able to imitate human driver abilities, such as logical decision-making processes and reasoning on road traffic.

A. *Synergies of effects and BAC perspectives*

Synergies of effects refer to the combined or compounded impacts or benefits that arise from the interaction or coordination of multiple factors or elements due to long-term repeated automation exposure such as trust, reliance, situational awareness (SA), or skills, to name a few. These synergies may result in outcomes that are greater than what would be expected from each individual factor acting alone. For example,

- In trust, synergies of effects may occur when different factors associated with trust in automation influence the AV user to behave in a specific manner. As a result of either over trust, mistrust or distrust.
- In SA, synergies of effects may occur when multiple variables interact to produce a more pronounced or unexpected result. As a result of either distraction, fatigue, drowsiness, concentration (attentiveness), etc.
- In skills, synergies of effects may occur, for example, as a result of deskilling, upskilling, or reskilling.

These effects may result in either constructive (positive) or destructive (negative) impacts, such as increased efficiency or inefficiency, safety or risk, misuse or responsible use, satisfaction or dissatisfaction, acceptance or rejection, etc. Overall, synergies of effects highlight the interconnectedness and potential amplification of HAI and long-term automation exposure outcomes that can arise from the combined influence of different UX factors.

AV-based BA refers to behavioural analysis conducted in the context of repeated AV systems usage or exposure. This involves analysing various aspects such as human behaviour towards the AV system, AV system performance, potential benefits, drawbacks, and impacts on safety and user experience associated with AV technology. This analysis aims to understand how AV systems (see Fig. 6, 7, 8) impact on road traffic and driving dynamics, traffic flow, safety and overall driving experience. As well as, how they align with industry objectives and regulatory requirements.

1) BA perspectives on Longitudinal Driver Support Systems

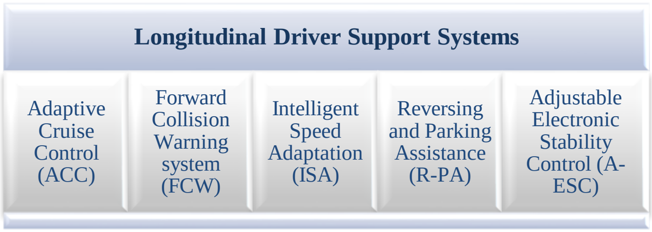


Fig. 6. Myriad of BA for longitudinal driver support systems.

a) ACC-based B: ACC employs sensors such as radar and laser to automatically adjust the distance to the vehicles ahead and provide the driver with road-related information. This includes parameters like the speed and proximity to other vehicles and VRUs. These variables are constantly monitored to maintain safe distances and mitigate risks. The system can assume control of the vehicle’s speed, decelerating or accelerating as needed based on traffic conditions. In cases of emergency, such as a driver failing to respond to visual or auditory warnings, the ACC with emergency braking (EB) system can initiate evasive actions like braking, reducing engine power, or bringing the vehicle to a stop. ACC operates at speeds above 30 km/h, but there are also variants like 'stop and go' ACC or low-speed following (LSF) systems designed for lower speeds [14].

From a BA perspective, among other considerations, studies have considered effects of ACC on BA (see [4, 17]). For example, examine driver behaviour in response to ACC, along with its potential advantages and disadvantages. Studies have delved into driving styles, particularly focusing on speed (driving fast) and attention (the ability to ignore distractions), for example. Findings indicate that ACC-based BA result in higher speeds, smaller minimum time headways, and increased brake force [17]. Furthermore, safety has an impact on BA. While most drivers assess ACC positively, they also note undesirable BA emphasising the need for caution concerning potential safety implications of such systems. Other studies investigated the learning phase of ACC over a month, using various data acquisition methods. For example, [4] noted, “as ACC primarily affects the guidance level, the duration of the learning phase and its impact on driver behaviour might differ.” Moreover, drivers familiarised themselves with the operation of ACC controls and display elements after two weeks [4]. A few drivers felt confident with takeover situations. Ref. [4] revealed significant BC during the initial two weeks. The impact on trust in ACC and acceptance of ACC is important to consider, long-term.

b) FCW-based BA: Collision mitigation systems, like FCW systems, alert drivers, either visually or audibly, about the likelihood of a collision by continuously monitoring the road and nearby vehicles [14]. There are two types of FCW systems: non-adaptive and adaptive. The adaptive FCW adjusts the timing of its alerts based on individual driver reaction times. However, FCW systems do not have the capability to control vehicle speed. They can only warn the driver when entities, such as VRUs, are detected within a predefined threshold based on predicted time to collision (TTC). Many FCW systems rely on the driver to take manual action to control the vehicle and avoid a collision, as they do not initiate automatic actions. The effectiveness of warning algorithms in maintaining drivers’ UX and BA to collision over time is crucial to investigate.

From a BA perspective, research indicates that extended use (>6000 km) of FCW systems can lead to a regression in drivers’ following behaviour to pre-trial levels once the system is deactivated. Additionally, the impact on trust and acceptance of FCW has been highlighted in various studies. The study in [18] evaluated FCW systems based on different driver profiles, distinguishing between non-aggressive drivers (low sensation seeking, long followers) and aggressive drivers (high sensation seeking, short followers). It was noted in [18] that, if the timing of warning presentations is perceived as inaccurate, trust in the system diminishes, leading to reduced likelihood of appropriate driver responses. High-quality FCW design is considered crucial for achieving high acceptance rates and actual usage of the system. The study in [19] explored the likelihood of drivers performing avoidance manoeuvres based on driver characteristics (such as age, gender) and study location. Essentially, in [19] observed that drivers aged 40 years and older were more inclined to use both braking and steering to avoid rear-end collisions, while drivers from coastal urban areas were less likely to solely rely on braking when responding to FCW alerts. Conversely, younger drivers and those in rural settings were more prone to opt for braking alone, potentially due to their familiarity with less congested traffic conditions. These findings shed light on the human factors and environmental factors influencing the adoption of different avoidance strategies by driver types.

The research in [20] investigated how FCW technology impacts driving behaviour and safety, specifically examining how these effects vary across different pre-crash scenarios. They discovered that both the FCW system and the specific scenario influenced driver behaviour leading up to imminent rear-end collisions [20]. The study argued that “various types of drivers experienced different advantages from the FCW in each scenario.” Extensive research has investigated the impact of the FCW system on drivers' adaptability, including their response times in releasing the throttle or initiating braking, as well as its safety benefits, such as reducing collision rates and improving safety metrics like time-to-collision. This comprehensive body of research highlights the effectiveness of the FCW system in enhancing driving safety. These discoveries provide valuable insights for developing next-generation vehicle collision warning systems, especially with the incorporation of augmented reality (AR) and artificial intelligence (AI) technologies.

c) ISA-based BA: ISA systems are largely viewed as IVIS designed to alert drivers about their speed concerning the prescribed speed limit for a given road, thereby enhancing overall road safety. According to study [21], “driver perceptions of ISA systems contribute to the effectiveness of speeding reduction.” This is influenced by several factors, including system capabilities, human factors, user demographics, and trip attributes.

From a BA perspective, ISA systems are generally considered to be well-developed and sufficiently accurate for dependable usage. However, statutory speed limits, such as those set for urban and rural areas, are often established with somewhat rudimentary intervals dictated by lawmakers rather than being based on specific road features, local infrastructure, and relevant parameters like camber, curve radius, and gradient in [14]. Furthermore, researchers have asserted that accidents related to speed persist, particularly on curved road sections. Additionally, it has been argued that simply providing speed limit (PSL) information along vertical and horizontal curves is insufficient to shield drivers from the risks associated with prevailing conditions [22]. The study in [21] investigated driver BA concerning the influence of operating vehicles equipped with ISA systems. The study examined three distinct IVIS-HMI functionalities: informative, warning, and intervening. The researchers explored perceived effects on drivers to discern their attitudes towards the systems and potential connections between anticipated and observed behaviour. The study in [21] concluded that the use of ISA systems led to "the adoption of vehicle speeds that are likely to enhance road safety" and promoted improved driver behaviour. However, it was also uncovered that "drivers may misuse ISA systems, potentially leading to adverse road safety outcomes."

The research in [22] investigated the influence of V-ISA on driving performance, a system with the capability to estimate the dynamic (real-time) speed limit based on current visibility conditions and stopping distance. Additionally, the researchers assessed drivers' acceptance and usability of three V-ISA functionalities. V-ISA operates in three modes: it can (i) provide visual information (V-ISA Information), (ii) alert the driver with a warning sound (V-ISA Warning), and/or (iii) directly intervene to adjust and control vehicle speed (V-ISA Intervening). The study revealed that "V-ISA effectively reduced the risks associated with speeding, with relatively high levels of acceptance and perceived usability" [22]. Moreover, the study found that V-ISA can have positive effects on road safety by aiding drivers in regulating their driving speed.

d) R-PA-based BA: Low-speed driver assistance systems, like reversing or backing systems, are intended to minimize collisions involving the reversing vehicle, VRUs, and entities that might be obscured from the driver's view [14]. These systems typically utilize short-distance radar along with audio feedback (beeps) and/or video feedback (displayed on a screen visible to the driver), providing visual feedback and sometimes audio cues when the vehicle is in reverse. Regardless of the warning medium used (audio or video), reversing systems appear to reduce collisions, with video-based systems demonstrating greater effectiveness. Over time, OEMs have integrated in-vehicle technologies for parking assistance. As an example, Volkswagen offers Park Assist, while Mercedes provides various parking assistance systems such as Parking Assistance System, Active Parking Assist, and Remote Parking Assist, which includes a Digital Extra feature accessible via a smartphone app. BMW offers a range of systems including Self-Parking System, Parking Assist, and Parking Assist Plus. Additionally, Valeo offers the Parking Slot Measurement System, Siemens provides Park-Mate, and Volvo offers the Evolve system for parking assistance.

From a BA perspective, [23] presents a parking assistance system that utilizes dense motion-stereo to generate real-time depth maps of the surrounding environment. This system has various applications, including automatic parking slot detection, collision warnings for door pivoting ranges, augmented parking, and an image-based rendering technique to visualize the area surrounding the host vehicle [23]. The study acknowledges challenges such as shearing effects when utilizing rolling shutter cameras, smearing with global shutter, and misalignments associated with interlaced images. Ref. [24] evaluated the impacts of rear parking sensors, rear-view cameras, and rear automatic braking systems on backing crashes. They used negative binomial regression to compare reported instances of backing crash involvement per insured vehicle among General Motors AV equipped with various combination of systems [24].

Research findings indicate that while rear-view cameras and rear parking sensors are contributing to a decrease in backing crashes, their effectiveness could be constrained by drivers' insufficient use or reaction to the systems. Moreover, revealed that rear automatic braking, as it does not solely depend on drivers' appropriate responses, enhances the efficiency of these safety systems [24]. Ref. [25] stressed the preference among drivers for AVs that can locate suitable parking spots and autonomously manoeuvre into them, minimizing the need for driver intervention and reducing parking stress. The importance of ultrasonic sensors in achieving heightened safety levels was also emphasised. These insights are valuable for informing the design of future automated parking and unparking technologies. The impact of automation in digitalized automatic parking.

e) A-ESC-based BA: The algorithm or model used by the ESC system is determined by the OEM, and its sensitivity varies depending on the vehicle's make, model, and year. For many drivers, the activation of ESC during normal driving is a rare occurrence, which can be considered one of the primary advantages of ESC systems. Equally, A-ESC (Adaptive ESC) systems and S-ESC (Standard ESC) represent a type of support system regulated by performance standards. S-ESC functions to counteract over-steering or under-steering by comparing the actual vertical rotation of the vehicle (measured by the yaw sensor) to the expected rotation based on the steering wheel angle sensor. The relevance of S-ESC or F-ESC (Fixed ESC) is typically low for most drivers in terms of their perceived functionality [14].

A-ESC poses more intriguing considerations from a BA perspective, as it raises questions about system relevance and the potential for BA. The study in [26] examined traffic safety performance concerning active safety systems, with a specific focus on the Antilock Braking System (ABS) and Electronic Stability Control (ESC). This included evaluations of driver behaviour and the impact on traffic safety. In assessing the effect of ESC through physical testing, the researchers identified several test methods. Moreover, estimated driver behaviour effects [26].

2) BA perspective on Lateral Driver Support Systems

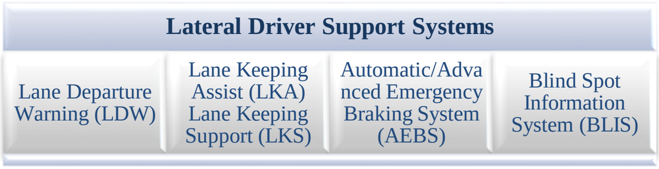


Fig. 7. Myriad of BA for lateral driver support systems.

a) LDW/LKA-based BA: LDW systems are designed to alert drivers when their vehicle unintentionally drifts out of its lane. These systems typically rely on video sensors positioned in the front of the AV or infrared sensors mounted behind the windshield, which process images from the road ahead [14]. They issue warnings to the driver through visual cues, audible alerts, and/or haptic feedback. Similarly, LKA systems operate on the same principles as LDW. However, if the driver fails to heed the warnings, LKA intervenes to ensure the AV avoids unintended lane departures. LKS systems utilise a digital camera mounted on the windshield to identify lane markers and determine the AV's position on the road. These systems provide haptic feedback, often in the form of vibrations in the steering wheel, to alert the driver of lane deviation.

From a BA perspective, for instance, if persistent drifting occurs, indicating driver drowsiness, the system's warning lamps will alert the driver to stop and rest. In cases where the driver is inattentive to the LDW and drifts out of the lane, the steering system will intervene to guide the vehicle back into the lane. The study in [28] observed that "drivers must familiarise themselves with various symbols to correctly identify and activate the system they wish to be using," as OEMs often replace standard graphical symbols with their own preferences. Therefore, it is crucial to consider the learning, trust, and acceptance of AV systems for the continuous development and evaluation of UX and BA over time.

b) BLIS-based BA: Similarly to most in-vehicle ITS or ADAS, BLIS is perceived as an additional safety feature. BLIS comprises a sensor that detects AVs located to the driver's side and rear. When the turn indicator is not activated, it issues alerts (visual or auditory) to drivers. For instance, higher levels of warning intensity indicate an increased potential for hazardous lane changes [14]. BLIS utilises either a camera to visually detect vehicles or side radar for enhanced performance in warning of rapidly approaching vehicles entering the blind spot.

From a BA perspective on BLIS, consist of the possibility of drivers becoming complacent and relying on the system rather than consistently checking their rear-view mirrors over the long term [14]. The study in [29] highlighted that both ACC and BLIS have the capability to reduce driving task discomfort and risks while enhancing driving comfort and promoting safer journeys. However, studies have also cautioned about the potential for users to exhibit negative BA, which could lead to adverse effects on safety. Concerning BA, we consider that, for ACC, research on BA yields conflicting results, particularly regarding lane keeping, following distance, speed adjustment, and reaction to critical events. Consequently, no unanimous conclusions have been reached in this area of study [29]. For BLIS, there is a notable scarcity of studies focused specifically on BA, highlighting a gap in the existing research. Therefore, there is a clear necessity for further investigation and exploration in this area to better understand its implications and effects [29].

3) BA perspective on Driver Performance Monitoring and Support Systems.

Fig. 8. Myriad of BA for driver performance monitoring and support.

a) FWS-based BA: Fatigue can be defined as the subjective sensation of tiredness accompanied by a reluctance or disinclination to continue engaging in a task. Studies examining the impact effects of driver fatigue on driving commonly employ measures such as vehicle control and psychophysiological indicators to assess driver drowsiness. The timing of the day has a more pronounced effect on driver fatigue compared to the duration of the task itself [27]. Driver impairment due to drowsiness is cited as a significant cause of both single and multiple vehicle collisions [27]. It is noted that, "drowsiness and inattention may contribute to approximately one million collisions annually in the U.S., representing one-sixth of reported collisions" [27]. Research indicates that 31% of drivers who experience drowsiness are initially unaware of its onset [27]. FWS are recognized as countermeasures designed to mitigate collisions linked to driver fatigue. They act as countermeasures that help alert drivers that they are drowsy. These driver alert systems utilise eye movement-based measurements and algorithms to anticipate the AV's trajectory. This includes analysing steering wheel movements and subtle changes in driving behaviour, with detection techniques incorporating lane departure, steering wheel activity, and ocular and facial characteristics.

From a BA perspective, the study in [27] noted that, "driver impairment due to fatigue induced drowsiness is a significant cause of vehicle collisions". The study in [27] evaluated driver BA to a FWS, and provided behavioural results on objective and subjective driver fatigue, driving time, number of breaks or on break duration. The research revealed that taking 30-minute breaks is ineffective in countering drowsiness [27]. Moreover, their findings suggest that FWS might not substantially decrease collisions resulting from fatigue [27].

b) Seatbelt reminder systems: Seatbelt Reminder Systems utilize visual and audible reminders, incorporating pressure sensors in the seat and buckle locks to detect vehicle occupants [14]. If an occupant is detected without their seatbelt fastened, the system intensifies signalling, such as flashing lights or audible beeping, to emphasize the urgency of the warning. Certain vehicle models are equipped with systems that monitor all available seats for occupants.

III. METHODS

The study was conducted using lime survey, with a focus on L2 AV usage and UX. As the study was an online study, no control elements were emphasised. The survey instrument was designed using information pertaining the project objectives. From an in-depth industry expert interview study, knowledge obtained from this study was used in deriving the survey instrument. The aim was to gauge a general understanding of UX based on repeated/long-term automation usage in urban traffic streams, specifically from a user-centric perspective.

A. Procedure

Upon opening the survey, participants were informed about the study procedure and what is expected of them. A brief description of what driving automation means was provided. This is because, as non-experts in the field, users are sometimes not able to discriminate the difference between LOA, ITS, ADAS, ADS, as well as IVIS and IAS. This is due to different OEM brand positioning, for example. In addition, they were informed about the length of the survey and each section theme. The survey was a one-time procedure. The average duration between the first and last input was max = 60 days.

B. Sample

The study was conducted with N = 16 drivers. The mean = 2.56, Std. Dev. = 1.031. About half of the sample (50%) was male and another half was female (50%). Concerning the participants age, 16 to 25 (6.3%), 26 to 39 (50.0%), 40 to 59 (18.8%), 60+ (25.0%). In addition, 37.5% held a driving license for less than five (5) years, and 62.5% for more than five (5) years. When asked about their preferences, 25.0% noted they prefer to manually drive their vehicles, while 75.0% noted preference towards driving automation.

Regarding their driving experience (mileage), 37.5% had less than 10000 miles, 18.8% had 10000 to 100000 miles, and 43.8% had 100000 plus miles during the time of the study. When asked, how often do you drive? 43.8% stated 1-3 days per week, 37.5% stated 3-6 days per week, and 18.8% stated 7 days per week. The decision to select the sample of the study, was based on the need to understanding real world users' long-term repeated experiences with L2 automated driving features.

C. Data Analysis

The survey was based on different information themes, for which this paper was derived. To analyse the data, we used descriptive analysis and content analysis for qualitative data. The following themes were analysed: automated driving experience and timeframes, vehicle operation competency, driving skills over long-term use, learning process, automation-induced effects, trust in automation, and remarks. The steps taken to analyse the data, were reviewing and transcription, data familiarisation, theme selection, reviewing, and categorisation, overall data integration, and reporting of results.

IV. RESULTS

A. Automated Driving Experience and Timeframes

Participants where ask to provide their automated driving experience, and timeframe of usage. A period of either "1-13 weeks" was noted by four (4) participants, "3-6 months" was noted by two (2) participants, "6-12 months" was noted by three (3) participants, and "more than 1 ≤ year" was noted by seven (7) participants. When asked about the timeframe of usage, considering short-term or long-term. The participants quantified short-term based on hours to days (with 30 days being the highest timeframe), while long-term was quantified based on months to years (with three years being the highest timeframe).

B. Vehicle Operation Competency

Participants where ask to provide information pertaining to their competence based on long-term automated driving. When asked, "Do you know '*how*' to use all of the driving automation functions installed in the vehicle that you drive?" Ten (10) participants selected 'No' and six (6) participants selected 'Yes', as shown on Fig. 9. Understanding '*how*' to use all the driving automation functions installed in the vehicle that participants drive indicates possessing comprehensive knowledge and proficiency in operating these AV features. This understanding encompasses familiarity with the activation, deactivation, and adjustment of various vehicle automation functions, as well as awareness of their specific functionalities and limitations. This suggests that participants are equipped with the necessary skills and know-how to effectively use these vehicle automation systems to enhance driving safety and convenience.

When asked, "Do you know '*when*' to use all the driving automation functions installed in the vehicle that you drive?" Fourteen (14) participants selected 'No' and two (2) participants selected 'Yes', as shown on Fig. 9. Understanding '*when*' to use all the driving automation functions installed in the vehicle that participants drive involves recognising the appropriate circumstances and conditions for activating these AV systems or features. This comprehension includes awareness of situations (SA) where driving automation functions such as ACC, LKA, and AEB systems can be beneficial and enhance driving safety and efficiency. It also entails understanding the limitations of these AV systems and knowing when manual intervention may be necessary, such as in certain weather conditions, complex driving scenarios, or low visibility situations. Essentially, knowing '*when*' to use driving automation functions involves a nuanced understanding of both the capabilities of AV systems and the context of the driving environment.

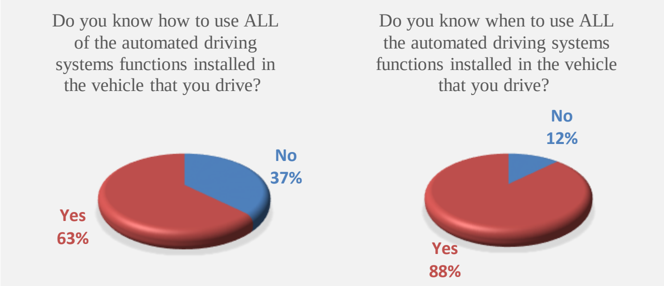


Fig. 9. Use factors: How to use (left) and when to use (right).

When asked, "Are you '*proficient*' in using the driving automation functions installed in the vehicle that you drive during any weather condition?” As shown on Fig. 10, two (2) participants chose ‘No’ and fourteen (14) participants chose ‘Yes’. For participants to state that they are ‘*proficient*’ in using the driving automation functions installed in their L2 AV during any weather condition means that they possess a high level of skill and competence in using AV features, regardless of the weather conditions. This proficiency implies that participants are capable of effectively navigating and controlling the AV’s ADAS/ADS, such as ACC, LKA, AEB, and others, even when faced with challenging weather conditions: rain, snow, fog, or extreme temperatures.

Being proficient in using these L2 AV features suggests that. To some degree, participants understand their capabilities and limitations, know how to activate and deactivate them as needed, and can make informed decisions to ensure safe and efficient driving under various weather scenarios. It also implies that participants are familiar with any specific adjustments or considerations required for optimal performance of the driving automation functions in different weather conditions. Overall, claiming proficiency in using driving automation functions in any weather condition indicates a high level of skill, experience, and confidence in using AV systems to enhance driving safety and convenience across a range of environmental circumstances.

When asked, “Do you feel ‘*comfortable*’ using driving automation functions in your vehicle?” As shown in Fig. 10, one (1) participant selected ‘No’ and fifteen (15) participants selected ‘Yes’. Feeling ‘*comfortable*’ with the driving automation functions in the vehicle indicates a sense of ease, confidence, and familiarity with using these AV features. This level of comfort suggests that participants are at ease with operating the vehicle automation functions and have a good understanding of their capabilities and limitations. It implies that participant feel relaxed and confident while engaging these AV features during their daily driving experiences.

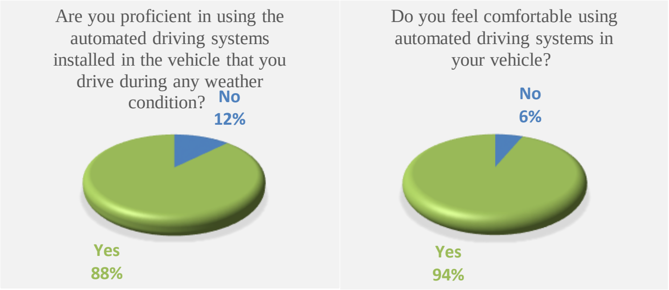


Fig. 10. Proficiency (left) and comfortability (right) factors.

When asked, “Do you know the difference between ‘*hands-off*’ and ‘*hands-on*’ driving automation functions protocols?” Three (3) participants selected ‘No’ and thirteen (13) participants selected ‘Yes’, as shown on Fig. 11 (left figure). The distinction between ‘*hands-off*’ and ‘*hands-on*’ driving automation protocols relates to the degree of manual engagement required from the driver during AV operation:

1) Hands-off driving automation: In this mode, the AV system can manage most driving tasks independently, with minimal or no physical input from the driver. It encompasses advanced automated systems where the AV can steer, accelerate, and brake within pre-set parameters. However, the driver must remain attentive and ready to intervene if necessary.

2) Hands-on driving automation: This protocol necessitates the driver to maintain continuous contact with the steering wheel and be prepared to take control of the AV when required. While automation systems like ACC or LKA may be active, the driver remains responsible for monitoring the driving environment and intervening as needed. Hands-on automation offers assistance but does not fully relieve the driver of their driving responsibilities.

In essence, hands-off automation grants more autonomy to the vehicle, while hands-on automation mandates ongoing driver involvement and supervision, even with automation in operation. When asked, “Do you understand the difference between *automated mode* and *manual mode* in critical situations?” One (1) participant selected ‘No’ and fifteen (15) participants selected ‘Yes’, as shown on Fig. 11 (right figure). Understanding the difference between automated and manual driving modes in critical situations involves drivers grasping how each mode functions and the driver’s role within them. In automated mode, the AV systems primarily handle driving tasks, using sensors and algorithms to make decisions regarding steering, acceleration, and braking. During critical moments such as sudden obstacles or emergencies, the ADS is expected to respond promptly, although driver intervention may be necessary if prompted or if the situation demands it. Conversely, in manual mode, the driver assumes direct control over driving functions, especially in complex or unpredictable scenarios where the ADS may struggle. The driver’s ability to make quick decisions and navigate effectively becomes crucial for ensuring safety. Thus, participants understanding these modes entail recognising the balance between automated assistance and human control in critical driving situations.

When asked, “Do you know in which situations you need to take over control of the vehicle when driving automated?” One (1) participant chose ‘No’ and fifteen (15) participants chose ‘Yes’ as illustrated by Fig. 11 (bottom). Participants understanding the instances necessitating driver intervention to assume control of the AV while driving in automated mode involve identifying various scenarios where human oversight becomes crucial for safety. These include emergencies, such as, sudden obstacles or hazards, AV system technical malfunctions, adverse weather conditions impairing sensor efficacy, navigating complex or ambiguous traffic situations, and adapting to changes in road infrastructure like construction zones. Recognising when to intervene underscores the importance of acknowledging the AV system’s limitations and being prepared to step in when human judgment and decision-making are vital for safe navigation.

When asked, “Where do you usually use automation when driving?” As shown on Fig. 12, for highways: three (3) participants chose ‘No’ and thirteen (13) participants chose ‘Yes’, for inner cities: three (3) participants chose ‘No’ and thirteen (13) participants chose ‘Yes’, and for rural roads: eleven (11) participants chose ‘No’ and five (5) participants chose ‘Yes’. Participants typically use automation features while driving in various scenarios, including highway driving, navigating heavy traffic, and cruising on roads. Driving automation finds its usefulness in a range of contexts, including highway cruising, navigating heavy traffic, and managing long-distance journeys. It is seen as particularly advantageous in scenarios such as highway driving, where traffic patterns are more predictable, as well as during stop-and-go traffic situations, where systems like ACC can alleviate driver fatigue. Moreover, driving automation is seen to prove beneficial during routine commuting, assisting drivers on familiar routes, and in city driving, where systems like AEB enhance safety amidst complex urban environments. Additionally, VAS can support in adverse weather conditions by providing traction control and stability assistance. However, it is crucial for drivers to remain attentive and prepared to take control when necessary, as VASs may not be equipped to handle all driving scenarios effectively.

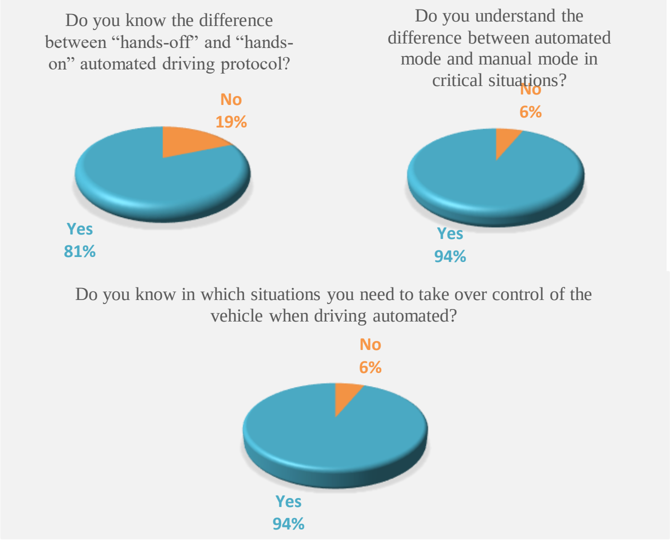


Fig. 11. Hands on/off (left), automated/manual mode (right), and context of use (bottom) factors.

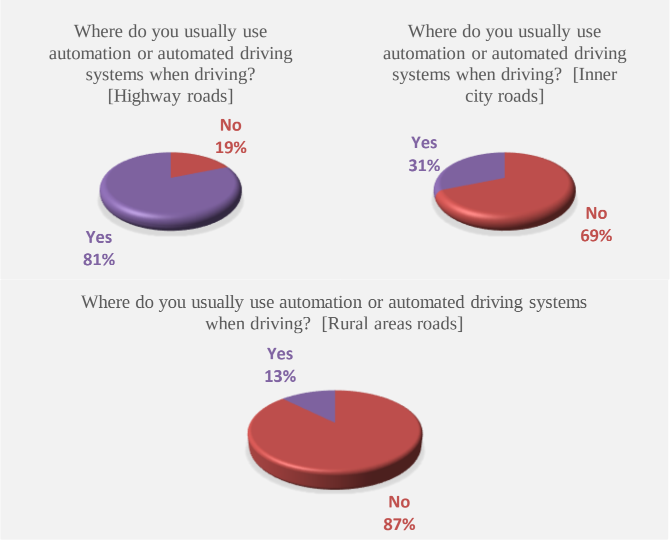


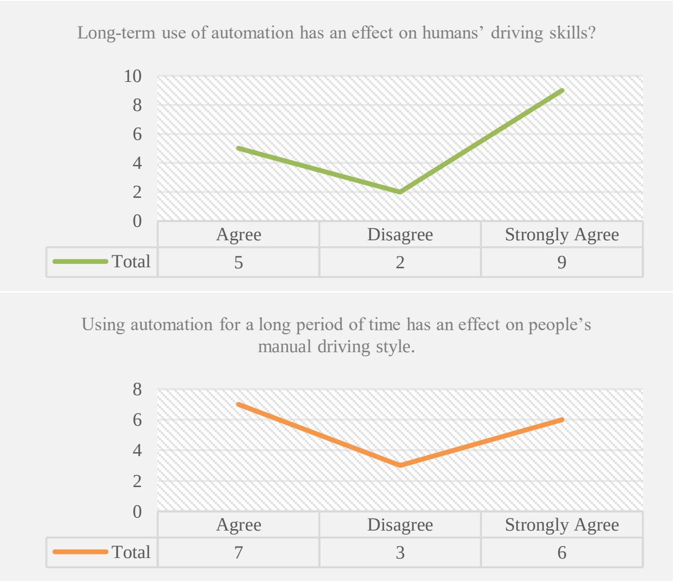
Fig. 12. Where to use factors: Highway (left), inner city (right), and rural roads (bottom).

C. Driving Skills Over Long-Term Use of Automation

Participants where ask to provide information concerning their driving skills based on long-term usage of driving automation features. Proficiency in driving, developed through extensive use of driving automation features, is characterised by a deep understanding of the AV's capabilities and limitations. Over time, drivers become adept at seamlessly incorporating systems like ACC and LKA into their driving routines to enhance safety and convenience. Experienced users of these AV systems demonstrate heightened SA, making informed decisions about when to use VAS based on road conditions and traffic flow. Moreover, these users develop discerning judgment in assessing the reliability of VAS and intervening when necessary to ensure safe driving. Through continuous practice (based on the power law of practice), drivers refine their skills to strike a balance between leveraging automation benefits and maintaining vigilance on the road. With 1 (Strongly Agree), 2 (Agree), 3 (Disagree), 4 (Strongly Disagree). When provided the statements:

1) "Long-term use of automation has an effect on humans' driving skills": As shown on Fig. 13 (top figure), nine (9) participants chose 'Strongly Agree', two (2) participants chose 'Disagree', and five (5) participants chose 'Agree'. This reveals that extended reliance on automation has an impact on human driving abilities.

2) "Using automation for a long period of time has an effect on people's manual driving style": As shown on Fig. 13 (middle figure), six (6) participants chose 'Strongly Agree', three (3) participants chose 'Disagree', and seven (7) participants chose 'Agree'. This shows that prolonged dependence on automation alters individual users' manual driving behaviours.



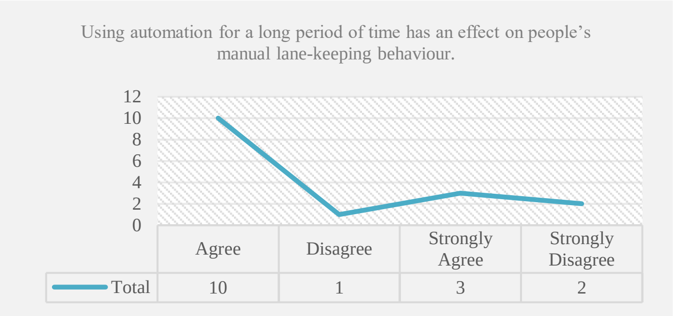


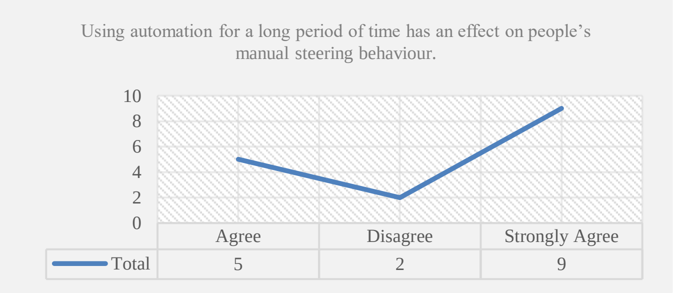
Fig. 13. Effects factors: Driving skills (top Fig), manual skills (middle Fig), and manual lane keeping (bottom Fig).

1) Using automation for a long period of time has an effect on people's manual lane-keeping behaviour": As shown on Fig. 13 (bottom figure), ten (10) participants chose 'Agree', one (1) participants chose 'Disagree', three (3) participants chose 'Strongly Agree', and two (2) participants chose 'Strongly Disagree'. This highlights that extended use of automation influences individual user's manual lane-keeping behaviour over time.

2) "Using automation for a long period of time has an effect on people's manual steering behaviour": As shown on Fig. 14 (top figure), nine (9) participants chose 'Strongly Agree', two (2) participants chose 'Disagree', and five (5) participants chose 'Agree'. This reveals that long-term reliance on automation affects individual users' manual steering behaviour.

3) "Using automation for a long period of time has an effect on people's manual braking behaviour": As shown on Fig. 14 (middle figure), seven (7) participants chose 'Strongly Agree', two (2) participants chose 'Disagree', and seven (7) participants chose 'Agree'. This highlights that extended use of automation has an impact on individual users' manual braking behaviour over time.

4) "Using automation for a long period of time has an effect on peoples' gaze behaviour": As shown on Fig 14 (bottom figure), two (2) participants chose 'Strongly Agree', two (2) participants chose 'Disagree', and twelve (12) participants chose 'Agree'. This shows that extended reliance on automation alters individual users' gaze behavior over time.



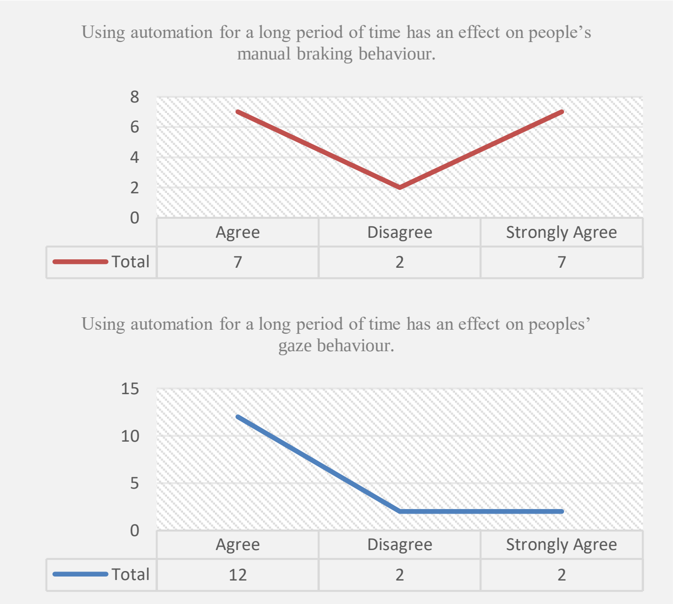
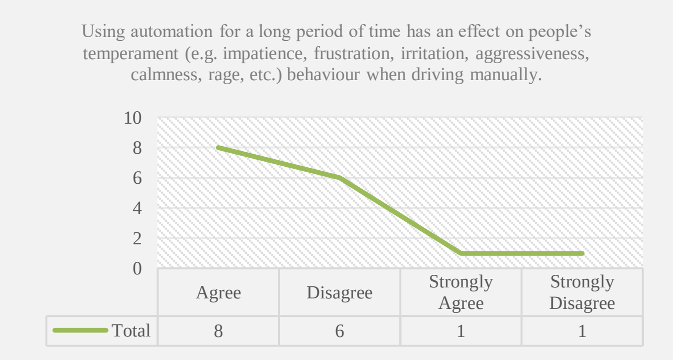


Fig. 14. Effects factors: Manual steering (top Fig), braking (middle Fig), and gaze behaviour (bottom Fig).

5) "Using automation for a long period of time has an effect on people's temperament (e.g. impatience, frustration, irritation, aggressiveness, calmness, rage, etc.) behaviour when driving manually": As shown on Fig. 15 (top figure), eight (8) participants chose 'Agree', six (6) participants chose 'Disagree', one (1) participants chose 'Strongly Agree', and one (1) participants chose 'Strongly Disagree'. This highlights that prolonged use of automation can influence individual users' temperament over time.

6) "Using automation for a long period of time has an effect on people's cognitive reasoning or decision-making process when driving manually": As shown on Fig. 15 (bottom figure), two (2) participants chose 'Strongly Agree', two (2) participants chose 'Disagree', and twelve (12) participants chose 'Agree'. This highlights that extended use of automation can impact individual users' cognitive reasoning or decision-making processes when driving manually.



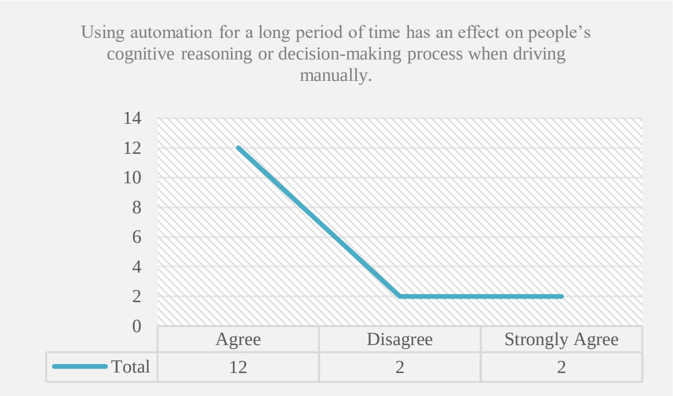


Fig. 15. Effects factors: Temperament (top) and cognitive reasoning (bottom).

D. The Learning Process

Participants were asked to provide information concerning how they learned to use driving automation features in their vehicles. When asked, "Do you think it is important to receive training on how to use driving automation systems?" As shown on Fig 16, Five (5) participants chose 'No' and eleven (11) chose 'Yes'. Thus, this stresses that receiving training on how to use driving automation systems is crucial, especially in different scenarios.

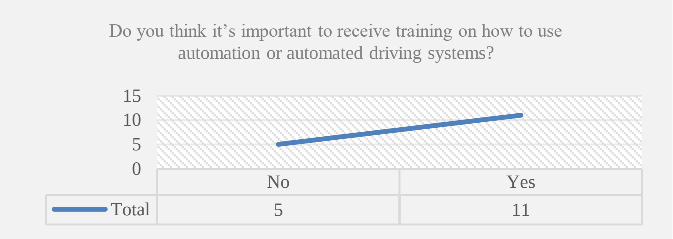


Fig. 16. Learning effects factors.

Participants were thereafter asked to provide a remark for receiving training, at which the following reasons were given:

When asked, "How did you learn to use the automated driving systems in the vehicle(s) that you drive?" with 1 being Social media (YouTube, Facebook, etc.), 2 being Social networks (Family and friends), 3 being Learned by myself, 4 being Driving School, 5 being Vehicle brand website, and 6 being 'Other'. As shown on Fig. 17 (top figure), most participants selected 2, which is 'Social networks (Family and friends)', and only 1 participant selected 1, which is 'Social media (YouTube, Facebook, etc.)'. This shows that participants familiarised themselves with using the AV systems in the vehicles they drive through a combination of reading the user manual, receiving hands-on instruction from dealership staff or certified trainers, and experimenting with the ADSs during their driving experiences. When asked, "How easy was it to learn to use the automated driving features in the vehicle(s) that you drive?" As shown on Fig. 17 (bottom figure), four (4) participants chose 'Challenging', five (5) participants chose 'Easy', one (1) participant chose 'Very challenging', and six (6) participants chose 'Very easy'. This show learning to use AV system depends on individual characteristics, AV system design, as well as context of use and exposure.

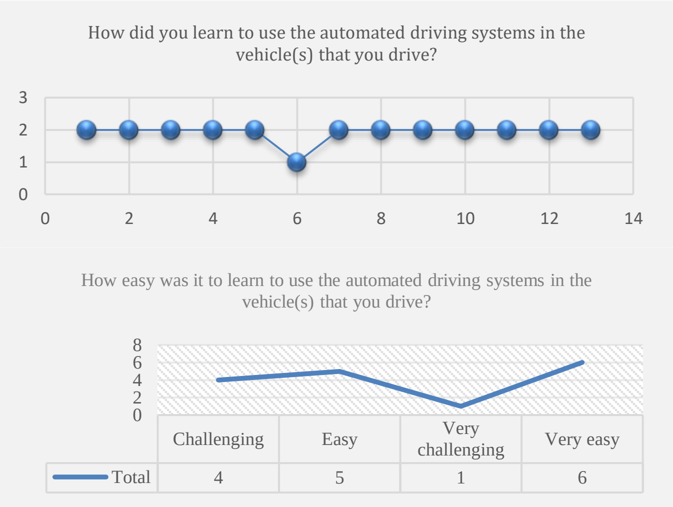


Fig. 17. Learning process (top) and easiness to learning (bottom).

E. Automation-induced Effects

Participants were asked to provide information pertaining to their understanding of automation-induced effects. Information regarding participants' understanding of the effects induced by vehicle automation typically encompasses drivers' awareness of how vehicle automation impacts various aspects of driving behaviour, cognitive processes, and overall driving experience. This understanding may include knowledge about changes in manual driving habits, alterations in attentional focus or gaze behaviour, shifts in decision-making processes, and potential changes in overall driving temperament. Moreover, it may involve awareness of the benefits and limitations of vehicle automation, as well as the importance of maintaining vigilance and readiness to intervene when necessary. Inclusively, an understanding of automation-induced effects is crucial for ensuring safe and effective integration of AV technology into the driving environment. When asked,

- "Do you think there are risks in using driving automation systems long-term?" As shown on Fig. 18 (left figure), eight (8) participants chose 'Yes', five (5) participants chose 'No', and three (3) participants chose not to answer. This shows that using driving automation systems over long term poses certain risks that should be considered.
- "Do you think there are safety benefits in using driving automation systems long-term?" As shown on Fig. 18 (right figure), eleven (11) participants chose 'Yes', two (2) participants chose 'No', and three (3) participants chose not to answer. This shows that there are safety benefits associated with using driving automation systems over long term.

TABLE I. LEARNING EFFECTS REMARKS

Participants	Learning Effects Remarks
	Remarks
"These vehicle automated systems can be complex because every car brand has its own different systems and HMIs. So training especially for first-time users is important."	

“Training and learning by doing is important.”
“Short introduction is needed.”
“You experience it and at first you are a little suspicious or doubt the features. And while monitoring it quite strictly, you get to learn how capable the system really is.”
“Some people don't know how to use automated cars.”
“These automated systems are still new and not a lot of people know exactly how to use them and when to use them, as well as where to use them. So training is important, not necessarily on how to use but also on educating people to know what they are there for.”

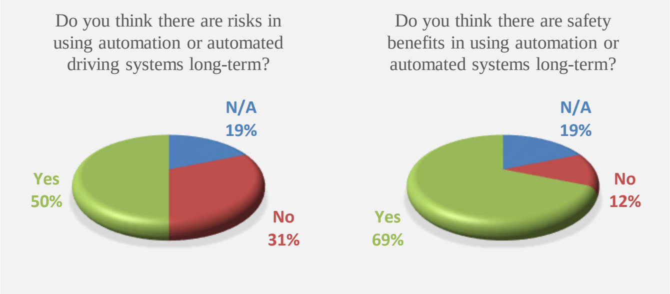


Fig. 18. Risks and safety effects factors.

Participants were further asked to name some risks and safety benefits of using driving automation systems. The following reasons were given (see Table II).

TABLE II. RISKS /BENEFITS OF USING AV

Participants	Risks /Benefits of Using AV	
	Risks	Benefits
	Risks include paying less attention to the road and other vehicles, being overly confident in automation to do all the driving tasks, over trusting the automation in complex situations, loss of driving skills, etc. Inexperienced and insecure drivers pose a hazard.	Safety benefits include automation systems helping with the driving tasks, being able to perform other tasks, more safer driving with automation as my co-driver, the system helping me when I lose control of the car, etc.
	With curvy roads, I sometimes don’t trust in automation; its confusing.	Less congestion, safer on highway.
	Drivers forget how to drive independently and control the vehicle themselves in critical situations.	Safe automatic braking, adjustable distance, automatic speed limitation.
	Rely on systems too much. Forget or stop monitoring surroundings.	As long as used correctly, the system reacts faster and more reliable than a human does.
	You get bored while driving automated, or even tired. You focus on other things you should not.	System applies to the legal limits and regulations.
	You lose skills, need training.	System does not get tired.
	You are out of the loop, if a critical situation comes up.	System might be able to adapt to the user's behaviour.
	Getting the attention back to driving might take longer after a long period of automation.	System is usually safe, instead of a nervous or aggressive driver type.
	Risks when you experience a problem with your car and u cannot fix it because it is an automated car.	System monitors the driver's behaviour and keeps it at a safe level. Faster ROI.
	People become lazy, they forget to drive, they rely heavily on the automation, they neglect their roles, the automation is not 100% safe, and it could fail.	It is good for when you lose control of the car, it can be your co-driver, and it helps with taking off extra stress of driving the car.
	Risks can be system malfunctions. Over trust in automation.	Smaller environmental footprint. Easy integration.
	You cannot change the speed.	

The constraints of AV systems involve their incapacity to completely emulate human decision-making and flexibility in intricate or unforeseeable driving scenarios, as well as their dependence on sensors that could be influenced by adverse weather or environmental conditions. Moreover, these AV systems might encounter challenges in accurately interpreting specific road markings or signage, potentially leading to navigation errors. Additionally, AV systems may not consistently detect all road obstacles or hazards, raising the possibility of accidents or collisions. In essence, while AV systems offer various advantages, it's crucial for users to recognize their limitations and maintain attentiveness during driving. When asked, “Do you understand the limitations of driving automation systems?” As shown on Fig 19 (left figure), eleven (11) participants chose ‘Yes’, two (2) participants chose ‘No’, and three (3) participants chose not to answer.

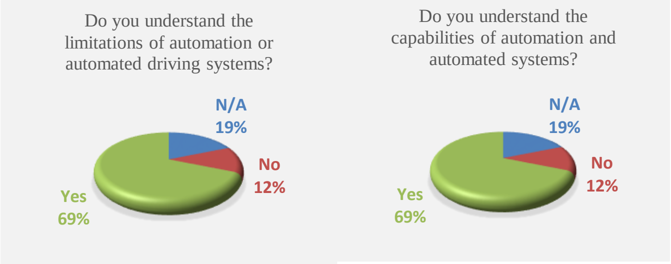


Fig. 19. Limitations and capabilities factors.

The capabilities and functionalities of AV systems include assisting with tasks like maintaining speed and distance from other vehicles, staying within lanes, and offering alerts or interventions in specific driving scenarios. These AV systems can feature advanced elements like ACC, LKA, AEB, and semi-autonomous driving modes. Additionally, certain AV systems provide convenience features like parking assistance and traffic jam assist. Ultimately, these capabilities aim to improve driving safety, comfort, and convenience by lessening the driver’s workload and addressing risks on the road. When asked, “Do you understand the capabilities of driving automation systems?” As shown on Fig. 19 (right figure), eleven (11) participants chose ‘Yes’, two (2) participants chose ‘No’, and three (3) participants chose not to answer.

Participants were further asked to name/list limitations and capabilities of driving automation systems (see Table III).

TABLE III. LIMITATIONS / CAPABILITIES OF AV

Participants	Limitations/Capabilities of AV	
	Limitations	Capabilities
	It is a machine, so it cannot be better than a human.	It is a good co-driver partner
	All limitations are in the manual. May sometimes fail to detect risk situation.	Can handle most of the regular driving scenarios.
	Rush hour traffic is sometimes too much for automation, even on highways.	Shows good performance on well-marked roads, with non-rush hour traffic, at speed range from 50 to 140 km/hr.

In construction areas and on roads without road-marking automation does not work.	Allows relaxed driving. It limits the speed correctly.
Automation is not made for increased speed.	It is good in keeping the selected distance to cars in front.
Limitations during bad weather, and bad road marking.	It is holding the lane exactly. It warns the driver to be alert.
Limits during weather conditions. Sensor blindness and limits/width.	Reproduction of known and common behaviours.
New situations are hard to handle, system is unable to interpret unknown situations.	Driving without changing gears several times.
It has specific speed limit. It is not fully functional yet, it has errors, and it causes people to be negligent when driving.	It is good for driving under the influence, it helps people to not crash.
Limits to using full capabilities or functions due to pre-programming that cannot be over ridded. Limit on ODDs	It keeps people safe, and it helps with driving so that people can do other stuff.

Participants were further asked to list examples of how using driving automation systems over time has negative effects and positive effects on users (see Table IV).

TABLE IV. NEGATIVE / POSITIVE EFFECTS OF USING AV

Participants	**Negative/Positive Effects of Using AV**	
	Negative Effects	**Positive Effects**
	It may be flawed, prone to error, and people can over trust in situations they should not.	People can perform other personal tasks and use their time on the road more usefully like reading, rest, eat, nap and catch up on family time, etc.
	Humans may pay less attention and neglect risks. When the ADS fails, it could be dangerous.	Relaxing during a drive, save time for other things, e.g. reading, working in the car.
	Sometimes driver loses attention. Visual and acoustic warning confuses or frightens driver.	Automated long distance driving is relaxing. Automated driving provides a kind of safety.
	Drivers forget how to park themselves, drivers forget how to assess risks, they forget how to drive smoothly and quickly.	Time while driving for other tasks. Arrive more relaxed. Tendency to drive safer and more relaxed.
	You lose your skills and experience, rely too much on the systems, tend to trust too much, stop monitoring properly.	It makes driving easier for human beings. They are so quick to understand, and you do not get tired.
	You will not know how to manual drive, unable to drive manually.	Reduce workload, consistency, saves time.
	They forget how to drive, they become over trusting on automation, they misjudge it. Less focus.	People can use their time for other things, they can catch up with friends and family, work, can relax, and they can be safe and enjoy travelling.
	You will get into a comfort zone whereby you dependent on it.	It is simple. Less accidents and less road rage.

F. Trust in Automation

Participants were asked to describe the level of trust they have in driving automation systems. When asked, "Do you trust automation to safely drive you to your destination without you constantly supervising it?" As shown on Fig. 20 (left figure), Six (6) participants chose 'Yes', six (6) participants chose 'No', and four (4) participants chose not to answer. Participants in the study express varying levels of confidence in driving automation systems, ranging from complete trust to scepticism or caution.

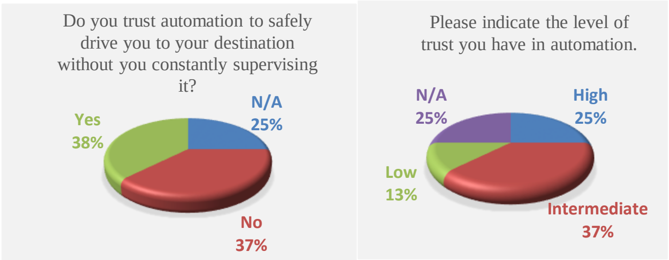


Fig. 20. Trust factors (left) and level of trust factors (right).

Participants were further asked to indicate the level of trust they have in automation, Low, Medium, or High. As shown on Fig. 20 (right figure), Four (4) participants chose 'High', six (6) participants chose 'Medium', two (2) participants chose 'Low', and four (4) participants chose not to answer. They generally indicate their level of trust in automation as low, medium, or high, depending on their experiences and perceptions. Participants provided remarks, such as, "it is not yet error-free", "driver attention is needed", "in the long term, automation for monitoring is needed, traffic violations should be recorded", and "depends entirely on the situation." Participants were asked to list views on trust over long-term use. For example, describe causes to trust, distrust/mistrust, over trust in automation.

Participants were asked to list patterns of trust, which are illustrated by Table V.

TABLE V. CAUSES OF TRUST IN AUTOMATION

Participants	**Table Column Head**	
	Trust in Automation	
Trust	**Mistrust/Distrust**	**Over Trust**
It has disadvantages and advantages. People may overly trust it over time, which can have negative consequences, as these systems are not yet error-free. In situations where people are afraid of technology, its important for it to prove that its trustworthy in order to use it for a longer time.	Because of media that shows that automation can be dangerous, people fear the unknown, fear that machines will overtake human life, etc. No or minimal practice.	Because they believe it is designed to help people, it's more intelligent than humans, it does the job more efficiently, etc.
It depends on the developed type of vehicle automation.	The capability of perception and planning is not developed enough for safe driving.	Don't understand how AV work, and may think it is very safe.
I trust automation if conditions on the road are not crowded and if the road itself is well marked and not too curvy.	Sudden braking on highways or rural roads with speed limits. Automation inaccuracy.	Blind trust in new technology. Not aware of risk circumstances (weather ...).
In the longterm, automation for monitoring is used.	System failure, monitoring of driving behaviour.	Because it is easier to use. Product quality.
Depend on performance - it might get higher. If you do not struggle so much to drive a car, it is much easier to use.	Bad behaviour and false actions (e.g. following falsely detected lanes on highway). Get scared or disappointed by car while driving long distance.	Because of misconceptions that it's more intelligent and skilful than humans.
People trust automation	Because it is a struggle	Lack of education

but not over trust it. Because technology does not always work and cannot replace humans. Maybe over time you get used to the idea of automation, so trust level will increase. This will increase over time.	when it does not function. Because of the sci-fi movies and social media that show how its not good, can become redundant. When not comfortable with automation, a sense of mistrust kicks in.	on what exactly it is and how it's designed. Repeated usage without incidents. Automation accuracy.

It is shown that, causes for trusting vehicle automation include consistent positive experiences, reliable performance, and clear communication of AV system capabilities and limitations. Conversely, causes for distrust or mistrust may arise from instances of system failure, inconsistent performance, or unclear communication about system reliability. Moreover, overtrust in automation may stem from a lack of understanding of its limitations, complacency due to extended periods of successful use, or misplaced confidence in the AV system's abilities.

Concerning examples of automation misuses, participants mentioned the following, which are illustrated by Table VI.

TABLE VI. NDRTS WHILE DRIVING AND MISUSES

<table>
<tr><th rowspan="2">Participants</th><th colspan="2">NDRT and Misuses</th></tr>
<tr><th>NDRTs while driving</th><th>Misuses</th></tr>
<tr><td colspan="2">Phone calls, drinking, texting, sending messages and emails, chatting. Picking up phones, answering text messages. Searching radio channels or music, searching phone numbers, checking the map, calling phone, answering. Answering text messages, emails, checking social media. Text, eat, read papers or books, listening to podcasts, check mails, answer phone calls, get dressed. Texting while driving, making calls. text chatting. checking emails, answering calls, videos calls, and texting, eating, and taking a rest. Google, using social networking. Answering e.g. WhatsApp, Facebook and YouTube. Phone usage, looking outside, talking with other passengers.</td><td>Giving too many responsibilities to the automation to carry out the whole task without their full attention. WhatsApp, e-mails or Mobile phone usage while driving.
Not paying attention to the driving.
Driving or holding the steer wheel with one hand. Stop monitoring, willingly trick the steering detection (not really grabbing the wheel), and ignore warnings. Not putting a seat belt. Making calls while driving. Giving all the driving responsibilities to the car, not being alert on the road, doing other stuff while driving, and drinking alcohol in the car. Answering calls while driving. Using on curvy roads with relatively high speed.</td></tr>
</table>

It is shown that, causes of vehicle automation misuse can stem from various factors, including overreliance on automation, lack of understanding of AV system limitations, complacency due to prolonged successful use, and failure to maintain vigilance and readiness to intervene when necessary. Furthermore, misuses may occur due to misinterpretation of AV system response or information, as well as intentional misuse or disregard for safety guidelines. Furthermore, inadequate training or improper implementation of AV systems can contribute to their misuse.

Participants were further asked to give remarks (see Table VII) concerning ADSs, concerning what researchers and manufacturers should emphasis on.

TABLE VII. RESEARCHERS / OEMS' ADS FOCUS POINTS

<table>
<tr><th rowspan="2">Participants</th><th>ADS Researchers and Manufacturers</th></tr>
<tr><th>Researchers/OEMs ADS Focus Points</th></tr>
<tr><td colspan="2">Researchers/manufacturers should give more focus to designing and developing automated systems that are efficient and safe.</td></tr>
<tr><td colspan="2">The car interfaces should be more efficient, as well as designed for different people, for example, colour blindness, older people with eye issues, etc.</td></tr>
<tr><td colspan="2">The interfaces should not only be in a physical mode but also a nonphysical mode of communication. People do not always want to look at the interface for information; they also want to hear it, feel it or sense its presence.</td></tr>
<tr><td colspan="2">Evaluate the ability of the automated driving while increasing trust of the automated driving. Not only visual und acoustic warning, but also a verbal assistance and warning interface. Easy operation with voice commands.</td></tr>
<tr><td colspan="2">Make clearer when and how the system works. And stress more on when it won't be able to work. Look more into situations that might cause problems. For example, tesla's wrong detection of cycles drawn on tracks, reaction to white tracks or walls, etc.</td></tr>
<tr><td colspan="2">They should make sure that, some parts are easier to use. More physical buttons. AV system affordability, reliability and education.</td></tr>
<tr><td colspan="2">Educational purposes because people sometimes forget. More simplified systems and easy to use functions. Young and old people education.</td></tr>
<tr><td colspan="2">Developer should understand that not everyone has a technical background, so people may not understand it and know how to use it correctly.</td></tr>
</table>

It can be argued that, researchers and manufacturers should prioritise several key areas to ensure the safe and effective use of AVs. These include educating users about AV system capabilities and limitations, improving HAI through intuitive interfaces, enhancing AV system reliability and performance through rigorous testing and repeated measures, implementing continuous monitoring and prolonged evaluation processes, collaborating with regulatory authorities to establish clear standards and policy science, and addressing ethical considerations such as irresponsibleness and accountability. By focusing on human factors aspects, they can promote responsible development and deployment of vehicle automation technologies, fostering trust, safety resilience, and usability among user types.

V. DISCUSSION

Based on the findings, we advocate for further research to gain a comprehensive understanding of the context of automated driving experiences and BA, as well as UX safety architectures over extended periods of automation usage. Although users express satisfaction with AVs, there are concerns stemming from their reactions to safety-critical situations with automation activated, as well as their incomplete understanding of the AV system's functionality, particularly regarding awareness of potential critical situations when automation is engaged. Therefore, it's crucial to investigate BAC over prolonged use or exposure to AV systems. When developing Interaction Design Systems (IxDS) for safety-based use cases, it is essential to consider key parameters related to the human user (see Table VIII), the AV system (see Table IX), and the interaction design factors (see Table X).

TABLE VIII. AUTOMATED DRIVING EXPERIENCE CONSIDERING HUMAN FACTORS

Fundamental Aspects of Human Factors		
Aspects	**Categories**	**Description**
User ability	User ability	Attention allocation, problem recognition, decision making processes, action implementation, skills and competences, etc.
	User variations	Beliefs, emotions, distraction, stress, fatigues, mental state, personality type, drowsy, etc.
	Reasoning efficacy	Mental models, SA, workload distribution, trust, and learning patterns, etc.
	Behaviour adaptation	Changes in use context, use/misuse and abuse automation, trust/distrust, accept/reject, etc.

TABLE IX. AUTOMATED DRIVING EXPERIENCE CONSIDERING AV FACTORS

Fundamental Aspects of AV Factors		
Aspects	**Categories**	**Description**
AV ability	Degree of autonomy	The level at which the automation can operate the vehicle and the degree of autonomy that it is able to make decisions and enforce action, etc.
	AV system morphology	Behavioural components, e.g. anthropomorphic (human-like behaviour), zoomorphic (animal-like), robotic (machine-like), etc.
	HMI/UI	Nature of information, transparency, cleaner design language, terminology and symbols, visually comfortable design, distractive design.
	Adaptation	Automation adaption to user types, etc.
	AV ability	Capabilities and limitations, error-proneness, robustness, awareness, and learning, etc.

TABLE X. AUTOMATED DRIVING EXPERIENCE CONSIDERING INTERACTION DESIGN FACTORS

Fundamental Aspects of Interaction Design Factors		
Aspects	**Categories**	**Description**
IxDS	Suave design	Configurations of humans and AV systems, co-corporative designs, structure of teaming (the interaction can be synchronous or asynchronous), etc.
	Multi-road user	Designed for multi-driver, driver-driver, driver-pedestrian, driver-motorcyclist situations, etc.
	Roles	Supervisor, operator, mechanic/programmer, peer, bystander, mentor, information consumer, synchronous or asynchronous, etc.
	Decision support	Type of info for decision support categorised according to pre-processing, available sensor info, device, type of sensor fusion, etc.
	Design configuration	Homogeneous (singular OEM-based IxD of the same system), heterogeneous (several OEM-based IxD of different systems).
Task ability	Task type	Task specified from an operation classification point of view, performance parameters, task shaping, goal-directed process, analysis, etc.
	Task criticality	Importance of the task to be performed. E.g., an AV could fail to detect human or risky situations
Setting and State context	Environmental	Degree of environmental distractions. E.g. the weather, road type, traffic density, signs, etc.
	Composition	Homogeneous (several vehicles of the same LOA) or heterogeneous (several vehicles of different LOA) operating on the same space.
	Journey pain points	Road design factors that influence user journey, curvy roads, modes of physical proximity to other road users, such as avoiding, passing, following, approaching, and touching, etc.

The findings reveal that when assessing the overall evaluation of vehicle operation competency and driving skills over long-term use, users' understanding of vehicle automation is limited. As automation technology advances, developers must implement improved mechanisms to transparently communicate the purposes of various Vehicle Automation Systems (VAS) and provide guidance on their usage, taking into account the varying levels of difficulty among different user types. Additionally, there should be a focus on enhancing Human-Automation Skilfulness (HAS) to facilitate the development of driving skills, as well as considering future needs for reskilling and upskilling in Human-Automation Interaction (HAI) [30].

Learning is a multifaceted process that can be categorized into three aspects of UX performance: cognitive, affective, and psychomotor, which also includes factors such as acuity (range of vision) [2]. Through repeated exposure to vehicle automation, users undergo continuous development of their mental models and changes in their brain architecture. This occurs due to the various ways in which humans receive, process, connect, categorize, and utilise information, as well as discard it over the long term. With repeated use of automation, there is a notable evolution in UX, trust, and acceptance, driven by users' ongoing learning processes and patterns as they encounter diverse situations.

In regards to automation-induced effects and trust in automation, users often perceive trust as a sense of entrapment. There are observable learning effects stemming from repeated usage, which influence both the levels and patterns of trust over time. As users gain more experience with VAS, they may feel less inclined to monitor the system closely, leading to reduced SA and potentially poorer performance, especially as automation advances to higher levels (e.g., L3). Various NDRTs that users engage in while driving in automated mode are prevalent. While users generally demonstrate a level of trust in automation, they also express safety concerns. Drivers frequently report instances of distrust, along with feelings of risk, discomfort, stress, and encountering demanding situations.

Furthermore, it is essential to recognize that the same user will perceive the same VAS differently depending on various factors such as the situation, setting, weather conditions, and mental state (e.g., fatigue, distraction). Similarly, different users may interpret the same automated driving event in distinct ways and experience trust differently, leading to a context-specific understanding. As UX engineers or researchers, the goal is to strive for a consistent and satisfactory UX based on safety criteria over prolonged use. The results highlight the importance of obtaining a clear understanding of user types for designing AV experiences, particularly as AVs redefine people's lifestyles. Conducting user-centered research helps to gain insights into different user types, their typical behaviours, encountered challenges, and points of discomfort, allowing for the development of IxDS that withstand the test of time. Consequently, this facilitates the creation of AV systems and HMI/UI designs that effectively resonate with diverse users, enhancing driving engagement, pleasure, and satisfaction.

The initial step involves defining various levels of UX and deriving specifications regarding the relationship between UX and BA. These levels of UX encompass novice, advanced beginner, competent, proficient, and expert levels. Additionally, it is crucial to consider how the effects of automation transfer between different levels of knowledge, such as from novice to competent or across various AV designs. This distinction is characterised by the transition from operational explicit knowledge at different levels to more strategic tacit knowledge over time. We can argue that, learned patterns are established through prolonged experiences with automation, resulting in the development of models of information patterns. Models representing different levels of UX should be utilised to shape long-term user behaviour data, providing a comprehensive understanding of both current and future states of in-vehicle UX. The gathered data contributes to a cohesive understanding, which can further inform the determination of the magnitude and type of IxDS required. The following are some lessons learned on inspiring safe adoption of automation and risk-free adaptable user behaviours.

1) *Effective* communication and proactive engagement are essential for influencing user behaviour positively. It is crucial to clearly communicate the effects of automation and provide appealing alternatives.

2) *Bridging* the gap between belief bias, attitude and behaviour requires collaborative efforts from diverse stakeholders, including policymakers, the AV industry, non-governmental organizations, and academia.

3) *Achieving* collaboration among stakeholders necessitates effective transparent communication and mutual understanding. This ensures that all relevant parties are aligned towards promoting safety and responsible behaviour in AV usage, over time.

Additionally, longitudinal data threads are essential for examining various aspects of BA at different levels of UX. Moreover, importance is given towards long-term studies to understand the learning curve, for both learning patterns of incorrect uses (misuses) and correct uses. The research in [4] emphasised the importance of long-term experiments to understand the duration of the learning phase, which necessitates field operational tests. However, field tests are influenced by multiple uncontrollable factors, requiring the integration of various examination methods to obtain reliable information. To advance research in this area, KLEAR (Knowledge discovery on Long-term Exposure of Automation Research) based mixed methods can be employed to assess both negative and positive BA towards AV systems and HMIs. Sequentially, pre-post in-depth interviews (IDI) or focus group discussions, naturalistic Field Operational Tests (nFOT), and/or driving simulator approaches can be conducted with users.

VI. CONCLUSION

The objective of this study was to gather insights into L2 AV features that are currently available in the market and widely used by individuals globally. It is crucial to assess how these AV systems are experienced over prolonged use, considering UX and BA based on real-world automation usage. Our aim was to investigate potential consequences of use in automated driving on road traffic, as well as the synergies of effects on human-automation symbiosis. We examined UX, learning, trust, and acceptance over time to predict the effects of automation and UX aspects on user behaviour. As part of our synthesis in understanding UX, we have identified potential 'user discomfort points' and 'user comfort points' to encompass the diverse nature of topics related to automated driving on road urban traffic scenarios. Furthermore, we have observed a contentious issue surrounding policy science aimed at mitigating risks, as well as considerations about AV design and the approach taken by software developers, OEMs, and various stakeholders in the field, ranging from a 'do not harm' stance to a laissez-faire approach ('let them do'). This issue has been a subject of consideration among scholars for many years.

Furthermore, there is a lack of facilitation of resilient human factors requirements. Additionally, it is crucial to derive specific safety-oriented Interaction Design (IxD) parameters to facilitate the harmonisation of AVs and HMI terminology, levels of difficulty, limitations, capabilities, context of use, and timeframe of exposure. Moreover, consider different user types and variations. Undoubtedly, there exists a delicate balance between unnecessarily constraining innovative designs and ensuring that AV systems remain understandable for average users, thereby sustaining behavioural-based safety over time. It is for this reason that we emphasise the indispensability of long-term data based on automation effects, ranging from short-term to long-term impacts, as well as behaviour and mental models.

ACKNOWLEDGMENT

The project received support from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement No. 860410.

REFERENCES

[1] K.A, Hoff and M. Bashir. Trust in automation: Integrating empirical evidence on factors that influence trust. Human factors, 57(3), 2015:407.

[2] N.Y. Mbelekani, and K. Bengler. Behavioural dynamics towards automation based on deconstructive thinking of sequences of effects: 'As Is – To Be' Automation Effects Change Lifecycle. In International Conference on Human-Computer Interaction. Engineering Psychology and Cognitive Ergonomics. Cham: Springer Nature Switzerland, 2024.

[3] N.Y. Mbelekani, and K. Bengler. Learnability in Automated Driving (LiAD): Concepts for Applying Learnability Engineering (CALE) Based on Long-Term Learning Effects. Information 14, no. 10 (2023): 519.

[4] M. Weinberger, H. Winner and H. Bubb. Adaptive cruise control field operational test—the learning phase. JSAE review, 22(4), 2001: 487-494.

[5] L. Ojeda and F. Nathan. Studying learning phases of an ACC through verbal reports. Driver support and information systems: Experiments on learning, appropriation and effects of adaptiveness. Del, 1 (3), 2006: 47.

[6] D.R. Large, G. Burnett, A. Morris, A. Muthumani, and R. Matthias. A longitudinal simulator study to explore drivers' behaviour during highly-automated driving. In Advances in Human Aspects of Transportation: Proceedings of the AHFE International Conference on Human Factors in Transportation, July 17− 21, 2017, Los Angeles, 2018: 583-594. Springer.

[7] D.R. Large, G. Burnett, D. Salanitri, A. Lawson, and E. Box. A Longitudinal simulator study to explore drivers' behaviour in level 3 automated vehicles. Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, 2019: 222-232.

[8] B. Metz, J. Wörle, M. Hanig, M. Schmitt, A. Lutz, and A. Neukum. Repeated usage of a motorway automated driving function: Automation level and behavioural adaption. Transportation research part F: traffic psychology and behaviour 81, 2021: 82-100.

[9] J.R. Bloomfield, L. Levitan, A.R. Grant, T.L. Brown, and J.M. Hankey. Driving performance after an extended period of travel in an automated highway system. No. FHWA-RD-98-051. United States. Federal Highway Administration, 1998.

[10] S.M. Casner, E.L. Hutchins, and D. Norman. The challenges of partially automated driving. Communications of the ACM 59(5), 2016: 70-77.

[11] A. Feldhütter, T. Hecht, L. Kalb, and K. Bengler. Effect of prolonged periods of conditionally automated driving on the development of fatigue: With and without non-driving-related activities. Cognition, Technology & Work 21, 2019: 33-40.

[12] R. Parasuraman, and V. Riley. Humans and automation: Use, misuse, disuse, abuse. Human factors 39(2), 1997: 230-253.

[13] S. Nordhoff, M. Kyriakidis, B. Van Arem, and R. Happee. A multi-level model on automated vehicle acceptance (MAVA): A review-based study. Theoretical issues in ergonomics science, 20(6), 2019: 682-710.

[14] C.J. Patten. Behavioural adaptation to in-vehicle intelligent transport systems (Chapter 9). Behavioural adaptation and road safety: Theory, evidence and action, edited by Christina Rudin-Brown, Samantha Jamson. 2013:161–176.

[15] F. Flemisch, J. Kelsch, C. Löper, A. Schieben, J. Schindler, and M. Heesen. Cooperative control and active interfaces for vehicle assitsance and automation. 2008.

[16] F. Flemisch, A. Schieben, J. Kelsch, C. Löper. Automation spectrum, inner/outer compatibility and other potentially useful human factors concepts for assistance and automation. Human Factors for assistance and automation. 2008.

[17] M. Hoedemaeker and K.A.Brookhuis. Behavioural adaptation to driving with an adaptive cruise control (ACC). Transportation Research Part F: Traffic Psychology and Behaviour, 1;1(2), 1998:95-106.

[18] A.H. Jamson, F.C. Lai, and O.M. Carsten. Potential benefits of an adaptive forward collision warning system. Transportation research part C: emerging technologies,16(4) 2008:471-84.

[19] X. Wu, L.N. Boyle, and D. Marshall. Drivers' avoidance strategies when using a forward collision warning (FCW) system. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 61(1), 2017: 1939-1943. Sage CA: Los Angeles, CA: SAGE Publications.

[20] L. Yue, M. Abdel-Aty, Y. Wu, J. Ugan, C. Yuan. Effects of forward collision warning technology in different pre-crash scenarios. Transportation research part F: traffic psychology and behaviour, 2021.

[21] I.K. Spyropoulou, M.G. Karlaftis, and N. Reed. Intelligent Speed Adaptation and driving speed: Effects of different system HMI functionalities. Transportation research part F: traffic psychology and behaviour, 1(24), 2014:39-49.

[22] A. Hazoor, A. Terrafino, LL. Di Stasi, and M. Bassani. How to take speed decisions consistent with the available sight distance using an intelligent speed adaptation system. Accident Analysis & Prevention; 2022:106-758.

[23] C. Unger, E, Wahl, and S. Ilic. Parking assistance using dense motion-stereo: Real-time parking slot detection, collision warning and augmented parking. Machine vision and applications, 25, 2014:561-81.

[24] J.B. Cicchino. Real-world effects of rear automatic braking and other backing assistance systems. Journal of safety research, 68, 2019:41-7.

[25] T. Jamil. Design and implementation of a parking helper. Proceedings of World Congress on Engineering and Computer Science, 1, 2009: 20-22.

[26] Linder A, Dukic T, Hjort M, Matstoms Y, Mårdh S, Sundström J, Vadeby A, Wiklund M. Methods for the evaluation of traffic safety effects of Antilock Braking System (ABS) and Electronic Stability Control (ESC). a literature review. 2007.

[27] A. Vincent, I. Noy, and A. Laing. Behavioural adaptation to fatigue warning systems. Proceedings of the 16 th International Technical Conference on the Enhanced Safety of Vehicles., DOTHS808759.

[28] M.J. Perrier, T.L. Louw, and O. Carsten. User-centred design evaluation of symbols for adaptive cruise control (ACC) and lane-keeping assistance (LKA). Cognition, Technology & Work. 2021:1-9.

[29] G.F.B. Piccinini. Driver's behavioural adaptation to the use of Advanced Cruise Control (ACC) and Blind Spot Information System (BLIS). PhD diss., Universidade do Porto (Portugal), 2014.

[30] N.Y. Mbelekani, and K. Bengler. Unequally Yoked [Skilled]: Transformative Views on Human-Automation Skilfulness. International Conference on Electrical, Computer and Energy Technologies (ICECET), Cape Town, South Africa. IEEE. 2023.