Transportation Research Part F: Psychology and Behaviour 99 (2023) 473–484

Contents lists available at ScienceDirect

Transportation Research Part F: Psychology and Behaviour

journal homepage: www.elsevier.com/locate/trf

Does users' experience and evaluation of level 3 automated driving functions predict willingness to use: Results from an on-road study

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ARTICLE INFO

Keywords:
Automated driving
Willingness to use
Acceptance
Experience
Evaluation

ABSTRACT

To ensure the successful deployment of Automated Vehicles (AVs), it is important to understand users' acceptance and willingness to use. The majority of previous studies which have investigated Willingness to Use of automated functionalities in vehicles, have relied on users' imagination of system operational features, without any actual hands-on experience. To close this research gap, we conducted an extensive questionnaire study with participants who had experienced either a Motorway (N = 294) or an Urban (N = 144) Automated Driving Function (ADF) in an on-road study using prototype vehicles, conducted as part of the large-scale European L3Pilot project. We investigated the impact of participants' demographic characteristics, and their evaluation of the ADFs, on their Willingness to Use these ADFs again in the future. Findings revealed that age was a significant predictor but had a small effect, with younger users showing a higher Willingness to Use the Motorway ADF, but not the Urban ADF. Other user characteristics, such as safety drivers versus ordinary drivers, system familiarity, and gender, did not predict Willingness to Use, for either system. Factors related to users' Feelings of Ease (e.g., perceived safety, fun, comfort, trust) and Perceived Usefulness of the system, were the most important predictors, with more positive ratings for these factors leading to a higher Willingness to Use, for both systems. Other factors that showed an effect on Willingness to Use include System Monitoring Requirements (i.e., willingness to engage in other tasks instead of monitoring the system), System Information (i.e., wanting to know more about the system's limitations) and System Expectations being met. This study shows the importance of ensuring that users have a good experience and perceive the system as useful to increase their Willingness to Use the ADF.

1. Introduction

Automated Vehicles (AVs) are expected to bring benefits to society, such as improving road safety, increasing traffic efficiency, and improving energy consumption (Raposo et al., 2017). They are also expected to free drivers from driving tasks (SAE Levels 3–5) (SAE International, 2021), and therefore increase the value of their travel time, by enabling them to spend the time on their preferred tasks instead (Nordhoff et al., 2020). To ensure the successful deployment of AVs, there is a need to establish what factors increase users' acceptance and willingness to use them. Most of the previous research has focused on understanding the acceptability, or a priori

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https://doi.org/10.1016/j.trf.2023.11.004
Received 6 July 2023; Received in revised form 10 October 2023; Accepted 7 November 2023
Available online 10 November 2023
1369-8478/

acceptance, of AVs (e.g., Nordhoff et al., 2017, 2020; Motamedi et al., 2020, Zmud & Sener, 2017, Sener et al., 2019, Kyriakidis et al., 2015). However, these studies mainly rely on drivers' imagination, and their expectations of AVs without experiencing them, and in many cases, participants were not provided with detailed information about the functionality of the AVs they were evaluating.

A small number of studies have explored changes in users perceptions of automated vehicles after experiencing them. Feys et al. (2021) showed that users' attitudes towards, and acceptance of automation improved after experiencing an SAE Level 2 system (SAE, 2021) on a public road in a real traffic situation, compared to their ratings of acceptability before experiencing the system. Similarly, in a field experiment, Xu et al. (2018) found that users who experienced a Level 3 AV as passengers, provided higher ratings of trust, perceived usefulness, and perceived ease of use, than before experiencing the automation, leading to increased acceptance of the system.

Conditionally Automated Cars (CACs) operating at SAE Level 3 and 4 (SAE, 2021) are a step towards fully automated vehicles (SAE Level 5), and will be realised through the implementation of different Automated Driving Functions (ADFs) across specific Operation Design Domains (ODDs; based on SAE J3016, SAE, 2021). ADFs enable the vehicle to perform manoeuvres in a specific scenario, for example on motorways or urban roads, in traffic jams, or in parking lots (see Louw et al., 2021). An investigation of the acceptability of these ADFs in a large-scale online survey found that younger drivers (<39 years), males, and users who had previous experience with Advanced Driver Assistance Systems (ADAS) e.g. lane-keeping assist, generally showed higher intention to use these ADFs, although there were some cross-country differences (Louw et al., 2021). However, it is currently unknown whether similar results will emerge after drivers have actually experienced these ADFs, which may or may not match drivers' expectations.

The current study takes this research a step further by focusing on how drivers' experience of ADFs, and their evaluation of the system affects their willingness to use the ADF in the future. Asking users to provide feedback about the AVs after having a first-hand experience with even a prototype system is likely to provide a more accurate representation of the system's perceived capabilities and limitations. In this study, conducted as part of the EC-funded L3Pilot project, we will evaluate user responses to 12 pilot vehicles which were tested on real roads, operating with either a Motorway (nine vehicles) or Urban (three vehicles) ADF. The Motorway ADF was capable of driving at speeds from 0 to 130 km/h, and could keep in the centre of the lane, change lanes automatically when required, control speed and distancing in car following situations, and handle traffic jams. The Urban ADF was capable of driving within the speed limit of 50 km/h, handling both busy and non-busy multiple-lane urban roads, signalised and non-signalised intersections, and navigating through pedestrian crossings, traffic lights, and roads with bicycle lanes. A key aim of this study is to investigate how factors such as drivers' perceptions of the ADFs, their intended use of time during automation, their takeover experiences, and their demographic characteristics, all impact on their willingness to use ADFs again in the future.

1.1. *Drivers' perception of automated driving*

The terms 'Willingness to Use and 'Intention to Use' have both been commonly used to understand the extent to which a person has formulated conscious plans to use or not to use a system (Warshaw and Davis, 1985, p.214; Kaye et al., 2021; Louw et al., 2021). One of the most widely applied models of acceptance is the Technology Acceptance Model (TAM), which posits that perceived usefulness and perceived ease of use are the two direct predictors of behavioural intention (Davis, 1989; Davis et al., 1989). According to recent *meta*-analyses, perceived behavioural control, perceived benefits/usefulness, perceived ease of use, subjective/social norms, trust and perceived risk are also correlated with Willingness to Use AVs (Kaye et al., 2021; Zhang et al., 2021; Zhang et al., 2019). Therefore, the current study investigates the impact of each of these factors on drivers' willingness to use ADFs in the future.

1.2. *Planned use of time during automated driving*

One of the main benefits of higher-level AVs (SAE Level 3–5) is that drivers can spend their travelling time on their preferred tasks instead. Questionnaire and wizard-of-oz studies have shown that some of the preferred tasks include being idle, talking to fellow travellers, surfing the internet, watching vid***eos or TV shows, observing the landscapes, and working (Detjen et al., 2020; Nordhoff et al., 2020). In a multi-country questionnaire survey, users who responded being likely to engage in other tasks while riding in Fully Automated Vehicles (FAVs) also perceived the time spent in the vehicle to be more useful (Wadud & Huda, 2021). These studies suggest that if users are comfortable engaging in other, non-driving-related tasks during automation, they are more likely to find the system useful, leading to increased willingness to use the system. Thus, this study explores whether drivers felt the need to monitor the system, or were comfortable spending time on other activities while the system was active.

1.3. *Influence of drivers' experiences during takeovers of control from automation*

During Level 3 or Level 4 automation, drivers will be allowed to spend their travelling time doing other tasks. However, they will also need to be able to re-take control of the vehicle, when prompted to do so, at the end of the ODD. To our knowledge, no previous studies have looked at how drivers' experience of taking over control in a real-world setting might effect their willingness to use the system again in the future. Drivers might have overestimated their own capability prior to taking control. Our current study closes this research gap by exploring the impact of drivers' experiences during takeovers of control.

1.4. *Influence of demographic characteristics on willingness to use*

Finally, there is a vast body of research exploring the impact of demographic characteristics e.g. age and gender, on drivers' a priori willingness to use AVs. Previous research has shown mixed results regarding how age affects willingness to use AVs, with some studies showing that younger drivers have a higher willingness to use AVs (e.g. Schoettle & Sivak; 2014; Krueger, et al., 2016; Molin et al., 2016; Becker & Axhausen, 2017; Hulse et al., 2018; Liljamo, Liimatainen, & Pöllänen, 2018), and some concluding the opposite (Delle Site, Filippi, & Giustiniani, 2011; Rödel, Stadler, Meschtscherjakov, & Tscheligi, 2014; Nordhoff et al., 2018a; Zhang, 2020), while a number of other studies failed to find any significant effect of age (Kaye et al., 2021; Yuen et al., 2021). Male drivers generally have higher acceptance of AVs than females (e.g., Payre, Cestac, & Delhomme, 2014; Hulse et al., 2018; Zhang et al., 2019; Zhang, 2020). Louw et al. (2021) found that the effect of age and gender on intention to use specific ADFs is country dependent. Given that there is very little research on the effect of gender and age on post-hoc evaluations of Willingness to Use an ADF, gender and age are also included in the current study (see also Louw et al., 2021).

In addition, there has been little exploration of the differences between safety drivers' and ordinary drivers' evaluations of automated vehicles. A questionnaire found that safety drivers evaluated their experience and the ADFs less positively than ordinary drivers (Weber et al., 2021), but it is not known if this was due to their driving experience or their familiarity with automated systems. Therefore, driver type and system familiarity were also included in the current study, as potential predictors of willingness to use.

2. Method

2.1. Participants

A total of fifty-eight safety drivers and 236 ordinary drivers evaluated the Motorway ADF. Professional safety drivers were present in the vehicle for all studies, apart from the Wizard-of-Oz studies. These drivers were trained to supervise the vehicle and override the system if critical situations became imminent. In the majority of studies, they were seated in the front passenger seat, and their role was to monitor for hazards, prompt the ordinary driver to take-over during critical situations, and in certain situations, to take over control themselves (see Section 2.2.1. However, in some cases, where it was not possible to operate the vehicle with an ordinary driver, these professional safety drivers also acted as participants. For those studies, they were seated in the driver seat where they interacted with the automation as requested during normal operation, and were required to also supervise the vehicle to override the system if critical situations become imminent. Table 1 provides detailed demographic information on both sets of drivers, and Fig. 1 shows their driving experience.

In total, 144 participants evaluated the Urban ADF in three different studies. Table 2 shows the detailed demographic information of the drivers, and Fig. 2 shows the driving experience of drivers.

2.2. ADF, drive descriptions and experimental design

Two ADFs were tested in this study, with nine pilot vehicles used to test the Motorway ADF, and three pilot vehicles used to test the Urban ADF. Pre-experimental briefings were conducted before all studies. Drivers were informed about the organisation of the experiment, the ADF functions and limitations, how to activate and deactivate the ADF, the test route, the role of the safety drivers, and whether they were allowed to perform a non-driving related task. Demographic and background questionnaires were administered before the experimental drive, and all the other questions were administered after participants had experienced the drive. For studies that were conducted during the period of COVID-19, appropriate safety precautions and measures were ensured. All drivers were compensated for taking part in the study, with payment amounts varying across studies depending on the experimental protocol.

Once drivers had completed their drive using the relevant ADF, they were asked to complete a questionnaire (see Section 2.3). The owner of the pilot vehicle was responsible for ensuring that the questionnaire data was uploaded to either the Motorway and Urban Common Data Base (CDB), anonymously. The common format included the list and order of the questionnaire items and the codes for different responses (Bellotti et al., 2020). After all partners had uploaded their data, the data was downloaded for analysis by the

Table 1
Demographic information of safety drivers and ordinary drivers who took part in the motorway ADF evaluation.

	Safety Drivers	Ordinary Drivers
N	58	236
Age	Range = 23–57 years old M = 40.11 (S.D = 11.26) Missing Data from 2 Drivers	Range = 22–70 years old M = 40.72 (S.D. = 11.28) Missing Data from 2 Drivers
Gender	47 Male (81 %) 9 Female (15 %) 1 Other (2 %) 1 Prefer not to say (2 %)	171 Male (72 %) 48 Female (20 %) 1 Other (1 %) 16 Missing Data (7 %)
Driving Experience (Years)	Less than one year (0 %) 1–2 years (0 %) 2–10 years (28 %) More than 10 years (72 %)	Less than one year (0 %) 1–2 years (0 %) 2–10 years (18 %) more than 10 years (82 %)

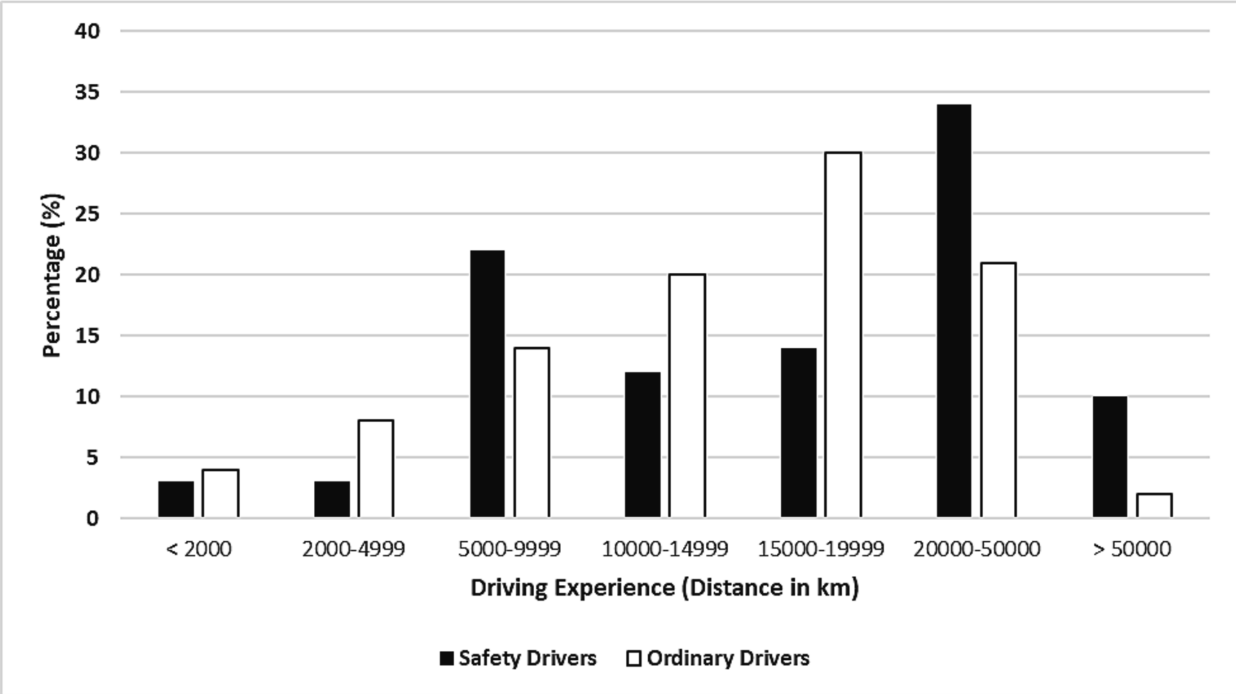

Fig. 1. Driving experience of safety drivers and ordinary drivers who took part in the motorway ADF evaluation.

Table 2
Demographic information of participants who took part in the urban ADF evaluation.

	Participants
Age	Range = 20–68 years old M = 40.30 (S.D = 11.91)
Gender	91 Male (63 %) 53 Female (37 %)
Driving Experience (Years)	Less than one year (0 %) 1–2 years (1 %) 2–10 years (26 %) More than 10 years (73 %)

research team. This process ensured the anonymity of all partners and the locations used for data collection. It also meant that it was impossible to identify the specific study characteristics associated with individual questionnaire responses. Although there were slight differences in the tested systems; the general experimental design, tested route and procedure are described in the following sections.

2.2.1. Motorway ADF

For the Motorway ADF, all nine studies were conducted between May 2019 and September 2021, at various European locations. These included Paris, Cologne, Gothenburg, Sweden, Frankfurt, Munich, Wuppertal, Turin, Novara, Alessandria, Vercelli, and Modena. Most of the studies consisted of a 1 to 1.5 h drive, with distances travelled ranging from 60 to 133 km. However, some drives were as short as 30 min (30 km), and some were as long as 6 h (600 km). Most studies were conducted in daylight in clear, cloudy, or light rain weather conditions. There was no testing in extreme weather conditions, heavy rain, or snow, with limited trials conducted at night time. The prototype Motorway ADF being tested could be activated when the vehicle was travelling between 0 and 130 km/h. It could also drive at speeds from 0 to 130 km/h, change lanes automatically, keep in the centre of the lane, control speed and distance in the car following situations, and handle traffic jams. However, the system could not handle construction sites, which were not included in the testing scenarios. Two studies, conducted using a Wizard-of-Oz method (N = 39), where the vehicle was controlled by an experimenter using hidden controls, were tested on roads with many motorway exits and entrances, while the rest excluded this.

In the studies involving ordinary drivers, safety drivers were present. They usually sat in the front passenger seat. In some cases, a technician was also present and seated in the back seat to monitor the system, using a set of screens positioned in the vehicle. The safety

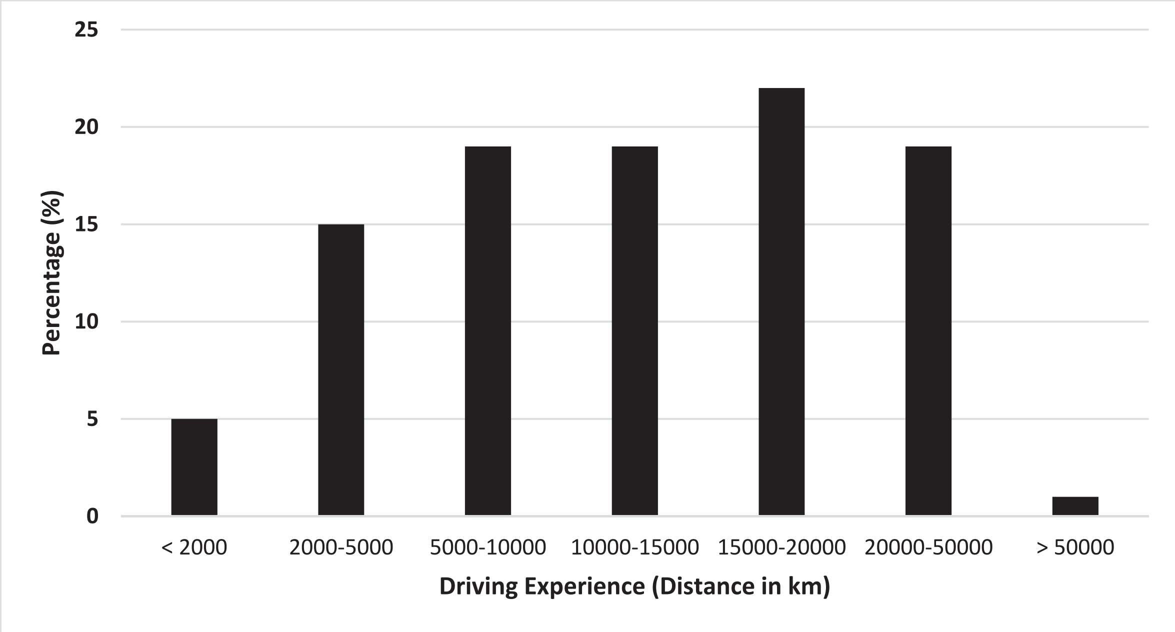

Fig. 2. Driving experience of drivers who took part in the urban ADF evaluation.

drivers were asked to monitor the system and look out for hazards, trigger Level 3 availability, ensure the study's safe and appropriate conduct, and ensure that travel directions were correct. They also prompted the drivers to take over control during critical situations or, in some cases, took control themselves (i.e., when the technician informed the safety driver that the system was no longer working). Otherwise, the safety drivers were asked not to converse with the drivers, to minimise interruptions and distractions. Safety drivers only intervened in dangerous situations or when technical failures arose, in which case participants were told not to touch the driving controls and let the safety driver drive.

All participants were provided with a pre-experimental briefing, during which they were informed about how the experiment would work, the route they would be travelling, and how to activate and deactivate the ADF. The role of the safety driver was also explained, and they were informed about whether or not they could take part in non-driving related tasks while the automation was on. Participants were told they were fully responsible for vehicle control during manual driving. They were also asked to respect the highway code during manual driving and to keep a safe distance from surrounding traffic. Where applicable, drivers were informed about the cameras installed in the vehicles.

In most studies, practice drives were conducted before the experimental drives. In the one exception to this, practice drives were not conducted, but drivers were tested on the activation and deactivation of the ADF while the vehicle was static. The objective of the practice drives was for drivers to familiarise themselves with the vehicle's dynamics, how to activate and deactivate the ADF, the manual driving task, and to understand the capabilities and limitations of the vehicle. Practice drives were typically between 15 and 30 min, some on the motorway and some on the test track.

During the experimental drives, in some studies, participants were allowed to take their eyes, hands, and mind off the road during the Level 3 drive, and engage in a non-driving related task, but not in others. This was mainly due to the road regulations in particular countries, as the tested vehicles were still in the prototyping phase, and, thus, drivers were asked to monitor the road. However, all drivers were required to take control when prompted or reached the end of an ODD (i.e., before exiting / end of the motorway). Unfortunately, due to the anonymised nature of the dataset, it is not possible to separate out the participants (Four studies, 62 participants) who had been allowed to engage in an NDRT from those who had not (Five studies, 232 participants).

To request drivers to take control from the automated system, all of the vehicles provided both auditory and visual HMIs. The HMI designs used and the time at which drivers were informed about the need to take over, varied across studies and vehicles (up to 60 s). Drivers could take over control or deactivate the automated function by pressing a predefined button, providing a steering input, or by using the accelerator/brake pedal. Both visual and auditory cues were also used to inform drivers when the automated function was available. When the vehicle indicated that the ADF was available, drivers were asked to release the pedals and push a button on the steering wheel to engage automation.

2.2.2. Urban ADF

All three Urban ADF studies were conducted between September and November 2020 at various locations in Europe. These included Brussels city centre, Aachen, and urban roads in Hamburg. The tested routes were between 2.4 km and 2.8 km each, and participants experienced one or two laps of the route, with the drives lasting between 10 and 40 mins. All studies were also conducted in daylight, cloudy, sunny, and light rain conditions, but not in extreme weather. The speed limit on urban roads was 50 km/h. Studies were conducted on busy and quiet multiple-lane urban roads, including signalised and non-signalised intersections, pedestrian crossings, traffic lights, and roads with bicycle lanes. The Urban ADF could detect Vulnerable Road Users (VRUs) such as pedestrians and cyclists, but could not detect traffic lights.

For the Urban ADF, participants were mostly passengers seated in the front passenger seat during the experimental drive. In the pre-experiment briefing, participants were given information about the test route, the duration of the study, and the capabilities and limitations of the Urban ADF. Practice drives were not applicable for these drives. Participants were asked to focus on, observe, and experience the Urban ADF during the experimental drives. They were also asked to imagine that they were seated in the driver's seat and pay attention to any takeover request from the vehicle. In one study, participants were allowed to engage in a secondary task because they were passengers, not drivers.

For Urban drives, safety drivers were seated in the driving seat, and their role was similar to the role of the Motorway safety drivers. However, as the participants were passengers, the safety drivers did not have to warn or conduct a takeover control of the vehicle from the participants.

2.3. Pilot-site questionnaire: factors and dependent variable

The main questionnaire discussed in this manuscript was administered after all drives. The questionnaire consisted of 167 items and broadly covered questions about the mode of travel, mobility impact, income, user experiences with the tested ADF, and previous experience with ADAS (see Weber et al., 2021). As the purpose of the current study was to focus on users' subjective experiences of the drives, not all questions were included in the analysis.

The dependent variable used was Willingness to Use, which was calculated as the mean of three questionnaire items: *'I would use this*

Table 3
Grouping questionnaire items into all 12 factors.

FACTOR 1: Feelings of Ease (Cronbach's Alpha = 0.833)	
	I felt safe when driving with the system active.
	Using the system on motorway was fun.
	Driving with the system active was comfortable.
	I trust the system to drive.
FACTOR 2: Workload (Cronbach's Alpha = 0.844)	
	Driving with this system was demanding. (reversed)
	Driving with the system was stressful. (reversed)
	Driving with this system was difficult. (reversed)
FACTOR 3: System Expectation (Cronbach's Alpha = 0.873)	
	Sometimes the system behaved unexpectedly. (reversed)
	The system acted appropriately in all situations.
	The system worked as it should work.
FACTOR 4: System Information (Cronbach's Alpha = 0.51)	
	I would have liked more information about why a takeover request was triggered.
	I would like to know more about the system limits.
FACTOR 5: System Monitoring Requirements (Cronbach's Alpha = 0.5)	
	I would want to monitor the system's performance. (reversed)
	I would use the time the system was active to do other activities.
FACTOR 6: Takeover Experience (Cronbach's Alpha = 0.771)	
	When the system asks me to retake control, I am warned in an appropriate way.
	When the system asks me to retake control, I am warned with sufficient time to do so safely.
	During the takeover I always felt safe.
FACTOR 7: Van Der Laan's Usefulness (Cronbach's Alpha = 0.681)	
	Useful/Useless
	Bad/Good
	Effective/Superfluous
	Assisting/Worthless
	Raising Alertness/Sleep-Inducing
FACTOR 8: Van Der Laan's Satisfying (Cronbach's Alpha = 0.855)	
	Pleasant/Unpleasant
	Nice/Annoying
	Irritating/Likeable
	Undesirable/Desirable
FACTOR 9	Age
FACTOR 10	Gender (coded as male and female)
FACTOR 11	System Familiarity
	Today you will be operating with Motorway ADF. How familiar are you with this type of systems you will be using today.
FACTOR 12	Driver Type (coded as safety driver and ordinary driver)

system if it was in my car', 'I would buy the system' and *'I would use the system during my everyday trips'*. Drivers were asked to rate their level of agreement on the same 6-point scale as the user evaluation and experience items. Any responses rated as 'Don't know', were excluded from the analysis. Cronbach alpha tests were conducted to investigate the reliability of the scales for both Motorway (Cronbach's alpha = 0.845) and Urban ADF (Cronbach's alpha = 0.845), with both showing strong levels of reliability.

2.3.1. Motorway ADF

For the Motorway ADF, 17 newly developed items were analysed, measuring users' evaluation and experience of the system. For each of the 17 questions on user experience, drivers were asked to rate their level of agreement on a 6-point Likert-type scale, ranging from 1 'Strongly Disagree' to 5 'Strongly Agree', where 6 represented 'Don't know'. Any responses given a 'Don't know' rating were excluded from the analysis, and the mean response score was calculated for each factor. The six factors were Feelings of Ease, Workload, System Expectation, System Information, System Monitoring Requirements, and Takeover Experience (Factors 1–6). Table 3 shows that Cronbach's alpha values for Feelings of Ease, Workload, System Expectation, and Takeover Experience were 0.7 or above, indicating good reliability (Nunnally, 1978). However, the reliability values for System Information and System Monitoring Requirements were 0.51 and 0.5, respectively, falling below the recommended cut-off values for factor analysis. This may be because there were only two items in each scale. However, given the clear construct validity of these scales, they were still included in the analysis.

The nine items from Van der Laan et al's (1997) user acceptance scale, which consists of two subscales measuring usability and satisfaction, were included in the analysis as Factors 7 and 8, respectively, using the scoring procedure set out by the authors. Van der Laan's (1997) acceptance scales were rated on a 5-point scale, ranging from −2 to 2. Although Cronbach's alpha value for Usefulness did not reach the 0.7 criteria, this scale has been used across multiple studies and is considered highly reliable and valid.

Along with age (Factor 9), gender (Factor 10) and driver type (Factor 12), system familiarity (Factor 11) was rated on a 6-point scale, ranging from highly familiar to highly unfamiliar, on *'Today you will be operating with Motorway ADF. How familiar are you with the type of system you will be using today'*. Prior to any analysis, any missing data, 'prefer not to say' and 'other' responses were excluded from the data.

2.3.2. Urban ADF

For Urban ADF questionnaire, non-applicable items around retaking control and use of the system on motorways were removed. This led to the inclusion of eleven items relating to users' evaluation and experience. These items were grouped into four factors based

Table 4
Grouping questionnaire items into 9 factors.

FACTOR 1: Feelings of Ease (Cronbach's Alpha = 0.796)	
	Driving with the system active was comfortable. I trust the system to drive. I felt safe when driving with the system active.
FACTOR 2: Workload (Cronbach's Alpha = 0.824)	
	Driving with this system was difficult. (reversed) Driving with this system was demanding. (reversed) Driving with the system was stressful. (reversed)
FACTOR 3: System Expectation (Cronbach's Alpha = 0.858)	
	The system acted appropriately in all situations. The system worked as it should work. Sometimes the system behaved unexpectedly. (reversed)
FACTOR 4: System Monitoring Requirements (Cronbach's Alpha = 0.485)	
	I would want to monitor the system's performance (reversed) I would use the time the system was active to do other activities.
FACTOR 5: Van Der Laan's Usefulness (Cronbach's Alpha = 0.78)	
	Useful/Useless Bad/Good Effective/Superfluous Assisting/Worthless Raising Alertness/Sleep-Inducing
FACTOR 6: Van Der Laan's Satisfying (Cronbach's Alpha = 0.839)	
	Pleasant/Unpleasant Nice/Annoying Irritating/Likeable Undesirable/Desirable
FACTOR 7	Age
FACTOR 8	Gender (coded as male and female
FACTOR 9	System Familiarity
	Today you will be operating with Urban ADF. How familiar are you with this type of systems you will be using today

Table 5
Correlations between factors and their respective mean and standard deviations.

		M	SD	1	2	3	4	5	6	7	8	9	10
1	Feelings of Ease	4.16	0.77	1									
2	Workload	4.33	0.80	0.74***	1								
3	System Expectation	3.56	1.05	0.66***	0.64***	1							
4	System Information	3.36	0.95	−0.21*	−0.24**	−0.35***	1						
5	System Monitoring Requirements	3.32	0.94	0.55***	0.52***	0.43***	−0.21*	1					
6	Takeover Experience	4.23	0.8	0.60***	0.49***	0.44***	−0.18*	0.38***	1				
7	Usefulness	−1.09	0.57	−0.69***	−0.56***	−0.56***	0.10	−0.42***	−0.47***	1			
8	Satisfying	−1.31	0.74	−0.76***	−0.67***	−0.65***	0.23*	−0.47***	−0.48***	0.81***	1		
9	Age	40.60	11.26	−0.10	−0.1	−0.07	−0.004	−0.07	0.11	0.02	0.02	1	
10	System Familiarity	3.26	1.41	0.20***	0.17**	0.18**	−0.02	0.14*	0.24***	−0.15*	−0.19***	0.08	1

* $p \leq 0.05$. ** $p \leq 0.005$. *** $p \leq 0.001$.

on similar constructs (Table 4), Feelings of Ease, Workload, System Expectation, and System Monitoring Requirements (Factors 1 to 4). As in the Motorway analysis, Van Der Laan's (1997) questionnaire was computed into Usefulness (Factor 5) and Satisfying (Factor 6) scales based on the author's recommendations. Reliability tests were conducted to investigate Cronbach's Alpha for each Factor 1 to 6 (see Table 4). Most of Cronbach's alpha values were above 0.70, showing high internal consistency between questionnaire items within each factor (Nunnally, 1978). As with the motorway analysis, the Cronbach's Alpha value for System Monitoring Requirements was 0.485, but was once again included in the analysis due to its strong construct validity. Age, gender and system familiarity were included as Factors 7 to 9.

3. Results

3.1. Motorway ADF

A correlational analysis investigated multicollinearity between factors (see Table 5). Most factors had no strong correlation, as coefficients were less than 0.7. However, Van Der Laan's Usefulness and Satisfying scales had a correlation coefficient of 0.81. This is not surprising, as both scales are designed to tap into the 'Acceptance' construct. Additionally, the Feelings of Ease scale and the Workload scale had a correlation coefficient of 0.74, with a Variance Inflation Factor of 2.2, which is below the acceptable threshold of 2.5 (Johnston et al., 2018).

A hierarchical multiple regression was used to understand the impact of our dependent variables on willingness to use. In order to control for the potential impact of participant demographics and previous experiences on willingness to use, participant demographic characteristics, system familiarity, and driver type were entered in the first step, followed by the experience and evaluation scales, and van der Laan's acceptance scales in the second step. Variables in the first step of the equation accounted for only 8.1 % of the variance in Willingness to Use the ADF (Table 6). Age was the only significant predictor of Willingness to Use (β = -0.20, $p < .05$), whereby younger drivers showed higher Willingness to Use, although the effect was small. None of the other demographic factors had a significant effect, indicating that gender, system familiarity and driver type did not play a significant role in predicting Willingness to Use.

In the second step of the equation, the variables accounted for 68.1 % of the variance in Willingness to Use the ADF, and the R^2 change between Step 1 and Step 2 was significant (R^2 change = 0.601, $F(12, 108) = 19.26$, $p < .001$). Feelings of Ease appeared as the strongest predictor of willingness to use (β = 0.37, $p < .001$), followed by Van Der Laan's Usefulness scale (β = -0.23, $p < .05$) and System Information (β = 0.17, $p < .005$). Age also remained a significant predictor (β = -0.14, $p < .05$). However, Workload, System Expectation, System Monitoring Requirements, Takeover Experience and Van Der Laan's Satisfying scale were not significant predictors of Willingness to Use.

3.2. Urban ADF

For the Urban ADF, a correlational analysis was conducted to investigate any multicollinearity between factors (see Table 7). Most factors had no strong correlation, as coefficients were less than 0.7. However, once again, Van Der Laan's Usefulness and Satisfying scales were highly correlated ($r = 0.81$).

A hierarchical multiple regression was conducted to predict Willingness to Use the Urban ADF, by entering Factors 7 to 9 (Age, Gender, and System Familiarity) in the first step, and Factors 1 to 6 (Feelings of Ease, Workload, System Expectation, System Monitoring Requirements, Usefulness and Satisfying) in the second step. Variables in the first step of the equation accounted for 1 % of the variance in Willingness to Use the ADF (Table 8). None of the variables were significant. In the second step of the equation, the variables added accounted for 67 % of the variance, with a significant R^2 change in the model ($R^2 = 0.664$, $F(9, 122) = 27.98$, $p < .001$).

Table 6
Hierarchical multiple regression results predicting Willingness to Use. Standardised Coefficients Beta were provided.

Step		Step 1 β	p-value	Step 2 β	p-value	R^2	R^2 change
1	Age	−0.20*	0.032			0.081	0.081*
	Gender	−0.10	0.275				
	System Familiarity	0.05	0.661				
	Driver Type	−0.18	0.090				
2	Age			−0.14*	0.014	0.681	0.601***
	Gender			−0.09	0.139		
	System Familiarity			−0.02	0.808		
	Driver Type			0.05	0.445		
	Feelings of Ease			0.37***	0.600		
	Workload			0.05	0.001		
	System Expectation			−0.02	0.816		
	System Information			0.17**	0.005		
	System Monitoring Requirements			0.14	0.056		
	Takeover Experience			0.06	0.446		
	Usefulness			−0.23*	0.017		
	Satisfying			−0.17	0.140		

* $p \leq 0.05$. ** $p \leq 0.005$. *** $p \leq 0.001$.

Table 7
Correlations between factors.

		M	SD	1	2	3	4	5	6	7	8
1	Feelings of Ease	4.00	0.80	1							
2	Workload	4.06	0.86	0.58***	1						
3	System Expectation	3.35	1.11	0.60***	0.49***	1					
4	System Monitoring Requirements	2.83	0.91	0.40***	0.30***	0.16	1				
5	Usefulness	−1.06	0.66	−0.54***	−0.51***	−0.44***	−0.36***	1			
6	Satisfying	−1.11	0.72	−0.63***	−0.57***	−0.52***	−0.42***	0.81***	1		
7	Age	40.30	11.91	0.12	0.05	0.19*	0.02	−0.09	−0.12	1	
8	System Familiarity	3.92	1.34	0.05	0.17	0.20*	−0.11	−0.10	−0.13	0.21*	1

* $p \leq 0.05$. ** $p \leq 0.005$. *** $p \leq 0.001$.

Van Der Laan's Usefulness scale appeared as the strongest predictor (β = -0.33, p <.001), followed by Feelings of Ease (β = 0.29, p <.001) and System Monitoring Requirements (β = 0.24, p <.001). Similar to the Traffic Jam Motorway Hierarchical Model, Workload, System Expectation and Van Der Laan's Satisfying scale did not predict Willingness to Use. None of the demographic factors had a significant effect, which shows that age, gender, and system familiarity did not play a significant role in predicting Willingness to Use the Urban ADF.

4. Discussion and conclusions

To successfully deploy different automated driving functions (ADFs) in vehicles, it is important to understand how users' evaluation of, and their experience with, these systems can predict their Willingness to Use them again in the future. Although some research in this context has focused on understanding how different factors affect the willingness and intention to use a system most were done through online surveys without providing participants hands-on experience with the automated systems (e.g., Nordhoff et al., 2017, 2020; Motamedi et al., 2020, Zmud & Sener, 2017, Sener et al., 2019, Kyriakidis et al., 2015). The current study explored drivers willingness to use motorway and urban ADFs again, after gaining experience with them, providing more detailed insights into how initial experiences of system characteristics can impact future uptake. Results revealed that our models successfully predicted Willingness to Use the Motorway and Urban ADFs, accounting for 68 % and 67 % of the variance in these variables, respectively.

The two most important factors that consistently predicted Willingness to Use for both the Motorway and Urban ADFs, were Feelings of Ease and Van der Laan's Usefulness scale. Our Feelings of Ease factor covered trust, risk/safety and hedonic motivation (i.e. enjoyment and fun) items. The more positively users rated their trust, perceived safety, and enjoyment of the system, the higher their Willingness to Use the ADF. This result aligns with previous research showing that trust (Ghazizaeh et al., 2012), perceived risk/safety (Zhang et al., 2021; Zhang et al., 2019), on-board comfort (Delle, Filippi & Giustiniani, 2011) and hedonic motivation (Venkatesh et al., 2012; Madigan et al., 2017) were linked to Willingness to Use, suggesting that there is strong alignment between the emotional response factors associated with the a priori acceptability of AD, and the factors which are ultimately important for these systems to be accepted and used.

One of the strengths of the current study is that it allows an understanding of how system features and usage affect user acceptance in different contexts. As previously highlighted, one of the proposed benefits of AVs is that users can spend time on other, non-driving related activities while the system is active. As proposed by Wadud & Huda (2021), users who are willing to engage in other tasks while the system is active would consider the system to be more useful, which would increase their Willingness to Use it. Our results revealed that users who were more willing to engage in other tasks and less likely to feel the need to monitor the road and the Urban ADF, had higher Willingness to Use this system. This finding suggests the importance of ensuring users' comfort with the motion while engaging in tasks of their choice while being driven by the ADF (see Weber et al., 2021). However, these factors did not have a significant impact on Willingness to Use the Motorway ADF. This difference between Urban and Motorway ADFs shows that the context within which a system is experienced may influence willingness to use. It is worth noting that the participants were seated in the passenger seat while experiencing the Urban ADF. Although they were asked to monitor the system carefully, the lack of drivers' role could have affected the findings. With the constant evolution and improvement of these systems, future research should investigate the impact of giving participants a more active role in an urban environment.

Due to the design of the prototype systems, System Information and Takeover Control Experience were only evaluated for the Motorway ADF. System Information items related to a desire to understand the reasons for a takeover request, and a desire for information about system limitations. Results showed that users who expressed a higher desire for more information about the system capabilities, also had higher Willingness to Use the ADF in future. Previous research has found links between technology readiness and intentions to use automated vehicles (e.g. O'Hern & St. Louis, 2023), and this result may be a reflection of those who could be deemed as explorers, showing an increased risk in understand this new technology. As this technology becomes more widespread and less innovative, it is possible that this group would benefit from having access to more information about how the technology is evolving. According to results from a recent large-scale survey study (Nordhoff et al., 2021), providing information about the system's limitations, in addition to the system's capabilities, did not affect users' Willingness to Use the system, when compared to those who only received information about the system's capabilities. Therefore, informing users about system limitations may also help to manage these users' expectations, in order to reduce misunderstandings and create a realistic and differentiated image of ADFs (Nordhoff et al.,

Table 8
Hierarchical multiple regression results. standardised coefficients beta were provided.

Step		Step 1 β	p-value	Step 2 β	p-value	R^2	R^2 change
1	Age	0.002	0.986			0.01	0.01
	Gender	−0.03	0.785				
	System Familiarity	−0.09	0.397				
2	Age			−0.07	0.223		
	Gender			−0.06	0.356		
	System Familiarity			−0.09	0.129		
	Feelings of Ease			0.29***	0.000	0.67	0.664***
	Workload			0.13	0.074		
	System Expectation			−0.14	0.057		
	System Monitoring Requirements			0.24***	0.000		
	Usefulness			−0.33***	0.000		
	Satisfying			−0.15	0.130		

* $p \leq 0.05$. ** $p \leq 0.005$. *** $p \leq 0.001$.

2021).

Takeover Control experience was not found to be a significant predictor of Willingness to Use the Motorway ADF. Although users did experience a takeover control during the drive, there was always a safety driver onboard to ensure safety, which may have affected these results. Therefore, as the maturity of these systems progresses, and ordinary drivers are given the opportunity to experience these systems without a safety driver, it will be useful to replicate these questionnaires to provide a more in-depth understanding of how takeover control experience affects Willingness to Use.

In terms of the effect of user demographics on Willingness to Use, we found a small effect of age for the Motorway ADF, whereby the younger the users, the higher their Willingness to Use (in line with Schoettle & Sivak; 2014; Krueger, et al., 2016; Molin et al., 2016; Becker & Axhausen, 2017; Hulse et al., 2018; Liljamo, Liimatainen, & Pöllänen, 2018; Louw et al., 2021). This would suggest that older users may need more targeted campaigns to encourage them to use, and get the maximum benefit out of automated systems. However, other driver demographics, such as gender, system familiarity, and driver type, did not predict Willingness to Use. Although safety drivers appeared less positive in their system evaluations, this did not affect their Willingness to Use the system.

This study is the first large-scale study where European drivers experienced SAE Level 3 Motorway and Urban prototypes on real roads, and, as such, it provides valuable insights on what might predict user Willingness to Use such systems in the future. However, it is acknowledged that due to safety reasons, most of the Motorway studies were conducted in the presence of safety drivers, and for the Urban ADFs, participants only experienced the system as passengers. Therefore, future studies with more mature systems, allowing hands-on user experience, will provide more accurate findings regarding users' Willingness to Use such ADFs. With the rollout of these systems, it is also likely that drivers' will need training in how to safely resume control from automation when required to do so, as there are many studies highlighting the eye-gaze and vehicle control decrements associated with takeover responses in controlled environments (e.g. Louw et al., 2017a, 2017b). In addition, the anonymised nature of the data made it difficult to delve further into some of the contextual elements which might have affected users' responses, e.g. individual system design, or drive duration. Thus, future research is needed to understand whether these factors have an impact on the acceptance of ADFs in different road environments.

CRediT authorship contribution statement

Yee Mun Lee: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization. **Ruth Madigan:** Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Validation, Visualization. **Tyron Louw:** Conceptualization, Data curation, Investigation, Methodology, Project administration, Software. **Esko Lehtonen:** Conceptualization, Data curation, Investigation, Methodology, Project administration, Software, Supervision, Validation. **Natasha Merat:** Conceptualization, Funding acquisition, Investigation, Project administration, Resources, Supervision.

Declaration of Competing Interest

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

Data availability

The authors do not have permission to share data.

Acknowledgements

The research presented in this paper was supported by the project L3Pilot, which received funding from the European Commission Horizon 2020 program (grant agreement: 723051). The information and views set out in this publication are the sole responsibility of the authors. The authors thank all the L3Pilot partners for their cooperation and valuable contribution.

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