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Exploring ADAS driver training in driving academies: Perspectives from driving instructors

Soyeon Kim [*] , Simeon Calvert , Marjan Hagenzieker

Department of Transport and Planning, Faculty of Civil Engineering and Geosciences, Delft University of Technology, Stevinweg 1, Delft 2628 CN, the Netherlands

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ABSTRACT

As Advanced Driver Assistance Systems (ADAS) become integrated into vehicles, driver education is important to support the safe and effective use of these technologies. However, structured ADAS educational programs for drivers have not been extensively studied. Moreover, the perspective of driving instructors, key stakeholders in the training process, has been overlooked. To address this gap, this study explores the perspectives of professional driving instructors who have delivered structured ADAS driver training at driving academies across four European countries. Through semi-structured interviews with fourteen instructors, this study examines the impact of the training, training design, implementation challenges, demographic considerations, and institutional roles. Instructors reported that ADAS driver training enhances driver confidence and promotes the appropriate use of the system, particularly by reducing overreliance on automation. They also emphasised the importance of a phased training model, combining theoretical instruction, controlled on-track practice, and on-road driving. In addition, Instructors highlighted the need for tailored approaches for older drivers and for introducing ADAS training after novice drivers have acquired basic driving skills. This study suggests the need for standardised ADAS training and cross-sector collaboration among leasing companies, car dealerships, and regulatory bodies to ensure broad accessibility and effective learning. The findings contribute to developing scalable, inclusive, and safety-oriented frameworks for driver education in emerging vehicle technologies.

1. Introduction

With the integration of Advanced Driver Assistance Systems (ADAS) into vehicles and the approaching uptake of Driver Control Assistance Systems (DCAS), road safety, driving behaviour, and mobility experience are undergoing a transformation. It is estimated that approximately 49 % of global new car sales by 2030 will feature SAE Level 2 driver automation or higher (Goldman Sachs Research, 2024). Despite the increasing prevalence of ADAS in consumer vehicles, it is not guaranteed that all drivers understand and utilise these systems properly. Drivers often misuse ADAS by overreliance or misunderstanding its capabilities (Oviedo-Trespalacios, 2024), or they may fail to use the system effectively or disengage it (Nordhoff, 2024). Such misconceptions and improper use highlight the need for education on ADAS technologies (NHTSA, 2016; Pradhan et al., 2019). ADAS driver training aims to help drivers understand system functions and improve their driving experience and safety. It can address misunderstandings about system interaction, uncertainty regarding when and how ADAS is useful, and a lack of knowledge about system availability or functionality within a given

vehicle (Abraham et al., 2017b; Forster et al., 2019b; Krampell et al., 2020; Manser et al., 2019; Mehler et al., 2023). Previous research on how drivers learn ADAS (Boelhouwer et al., 2020; Kaye et al., 2022; Lubkowski et al., 2021; Nandavar et al., 2023; Viktorová & Sucha, 2019) commonly mentioned car dealerships, owners' manuals, vehicle user interfaces, and trial-and-error as primary learning sources. Relatively few studies have examined ADAS driver training within a driving academy. A driving academy is an institution that provides structured driver education programs, offering both theoretical knowledge and practical training to enhance driving skills and safety. Unlike a driving school, which primarily serves novice drivers (also known as learner drivers), a driving academy offers education for both novice drivers and experienced drivers. It provides foundational training to help new drivers obtain licences and develop safe driving habits, while also offering advanced training for experienced drivers in areas such as defensive driving, eco-driving, and instruction on emerging vehicle technologies. With the increasing integration of ADAS in modern vehicles, driving academies have the potential to serve as an effective platform for ADAS education. In a study exploring drivers' ADAS learning

strategies (Kim et al., Under review), drivers identified education programs in driving academies as a potential ADAS learning channel despite not currently utilising them for ADAS education. Additionally, some driving academies have already begun offering an ADAS driver training program (Autotechtraining, 2025). Despite this potential, ADAS driver training within driving academies remains underexplored. Therefore, research on ADAS driver training in driving academies needs to be added to the research body.

A limited number of studies have explored ADAS driver training in driving academies, particularly from the perspective of driving instructors. Wigum and Sætren (2022) conducted interviews with driving instructors in Norway, revealing that existing driver education programs have not kept pace with technological advancements, highlighting the need for curricula that align with evolving vehicle standards. The instructors also expressed concerns regarding the unclear responsibilities associated with ADAS driver training, the lack of diversity in training vehicles, and time constraints within existing training frameworks (Wigum et al., 2023). However, while these studies provide valuable insights into instructors' perspectives, they are based on anticipated challenges rather than direct experience with systematically implemented ADAS driver training.

The perspective of driving instructors is important for designing and implementing driver training (Watson-Brown et al., 2022). Instructors' experiences and perspectives are important for informing both practice and policy. As experts in driver education, instructors are well-positioned to assess the effectiveness of different training methodologies. They can also provide insights into how drivers engage with technology, common misconceptions, and effective instructional strategies. Moreover, they can offer practical and experience-based feedback, such as instructional methods and time allocation. Given their direct engagement with trainees in the driving training program, instructors can also recognise variations in learning effectiveness across different populations. Understanding their perspectives can help develop more tailored and practical ADAS driver training that accommodates drivers' diverse needs.

1.1. Study aims

Despite growing interest in ADAS education, the role of driving academies, particularly the perspectives of instructors who have delivered ADAS training, remains largely unexplored. Existing research on ADAS training in such settings is limited and has primarily focused on expected outcomes or theoretical predictions (Heikoop et al., 2020; Wigum & Sætren, 2022; Wigum et al., 2023) rather than on evidence from real-world implementation. To address this gap, this study focuses on the perspective of driving academy instructors who have delivered the ADAS driving training program. By providing empirical, practice-based data from instructors who implemented the ADAS driver training in real-world contexts, the study provides insights into training design, instructional challenges, and driver responses that cannot be obtained without hands-on delivery experience.

The driving training program was part of an EU Horizon 2020 Hi-Drive project, involving four mobility clubs affiliated with the Fédération Internationale de l'Automobile (FIA). This initiative implemented a structured training program designed to educate drivers about ADAS and its functionalities. Through semi-structured interviews with instructors, this study aims to explore the impact of training, the challenges instructors face, and the implications for design and practice. By analysing these firsthand accounts, the study provides insights into the practical application of ADAS driver training and its impact on driver behaviour and road safety.

2. Method

The basis of this research is a designed and conducted interview study of professional driving instructors who have delivered the ADAS driver training program. Given the nature of our research objectives, which focus on training implementation, perceived impact, and instructional challenges, an interview method was necessary that allowed participants to elaborate beyond predefined survey options. The qualitative approach enabled us to capture the depth and complexity of instructor feedback, nuanced reflections on training, and contextual challenges that would be difficult to uncover through a quantitative approach, such as a survey.

The instructors who participated in the interviews had delivered the ADAS training program in 2024–2025 through four mobility clubs across Europe (Belgium, Germany, Spain, and Slovenia). According to the predefined protocol, the same ADAS driver training program was delivered across the four mobility clubs. Note that all trainees in the ADAS training were previously licensed drivers, not novice drivers. On average, trainees had over 15 years of driving experience, indicating that the program was implemented with already experienced drivers. The ADAS training program lasted a total of three and a half hours, consisting of a 30-minute theoretical component, 75 min of on-track training, and 90 min of on-road training. During the training, trainees received instruction on several ADAS features, including Blind Spot Monitoring (BSM), Adaptive Cruise Control (ACC), Lane Keeping Assistant (LKA), Emergency Lane Keeping (ELK), Automated Emergency Braking – Front (AEB front), and Rear Automated Braking (AEB rear). Appendix A provides information on each driving academy, trainees' data, and curriculum. Detailed information about the training contents can be described in Beckmann et al. (2025). This study focused on exploring instructors' perspectives on ADAS driver training in driving academies.

2.1. Participants – Professional driving instructors

We interviewed fourteen instructors. All instructors were male, with a mean age of 48.64 (ranging from 33 to 64). The instructors reported an average of 14.5 years of professional experience as a driving instructor, with individual experience ranging from 6 to 28 years. P1 and P2 participated as instructors in the ADAS driver training in Spain; P3 to P9 in Slovenia; P10 to P13 in Germany; and P14 in Belgium. Ten participants were interviewed in English, while four were interviewed in the local language and later translated into English for analysis. All participants received the interview questions in their local language before the interview.

2.2. Procedure

We conducted online semi-structured interviews. At the beginning of each interview, instructors provided informed consent to participate in the study. Following this, they completed a brief demographic questionnaire that included information on the instructor's gender and experience. As outlined in Table 1, the interviews were structured around four key themes: (1) the impact of ADAS driver training based on the instructor's experience, (2) the structure of the training (e.g., duration, method, number of trainees, timing), (3) differences in learning impact based on demographic factors, and (4) challenges encountered during training and suggestions. The interviews had an average duration of 40 min.

2.3. Analysis

An in-depth thematic analysis was conducted following the step-by-step process proposed by Braun and Clarke (2006), which includes familiarisation with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and final analysis. The recorded data were analysed using ATLAS.ti version 23.2.1. All interview transcripts were coded by the first author. While only one coder was responsible for assigning codes, the reliability of the analysis was supported by maintaining an audit trail of coding decisions

Table 1
Questions used to guide the semi-structured interviews.

Theme	Questions
Impact of ADAS driver training	What are your overall impressions of the training sessions and their impact? Do you think training helps trainees to use the ADAS properly? Do you think trainees will use ADAS more?
Training structure	How did trainees respond to learning about ADAS functions? 1. theoretical part, 2. On-track, 3. On-road sessions What specific methods during the training were particularly effective/non-effective? Do you think additional resources or methods (e.g., visual aids, simulations) would improve the training experience? Do you think the time range is well distributed? What do you think about the number of trainees who learn together? Were there any aspects of the training that trainees struggled with most? When is the good time for novice drivers to learn about ADAS in the driving school?
Learning impact among trainees' demographic	Do you think there is a difference in learning impact on trainees' backgrounds (such as age or gender)? Does the difference in experience with ADAS (non-ADAS drivers vs. ADAS drivers) affect the learning experience or learning impact differently? Were there any impacts due to the brand or car model of the training car?
Challenges and suggestions	What challenges did you face as an instructor? How could the training program be improved? Is there anything else you'd like to share about your experience or suggestions for future ADAS driver training programs?

and regular discussions within the research team to review emerging themes and interpretations. This approach ensured consistency and reflexivity throughout the analytic process. During the familiarisation phase, the transcripts were read repeatedly to gain an overall understanding and to note initial observations. Qualitative codes were then systematically generated from the interview data, with relevant excerpts tagged to capture key ideas, actions, or attitudes. These codes were then clustered based on conceptual similarities, forming the foundation for potential themes. Themes were developed based on central organising concepts identified from relevant codes, capturing shared meanings among instructors. The initial clustering of themes corresponded to the interview topics, namely the 'Impact of Training', 'Structure of Training', and 'Challenges in Training'. Within each theme, sub-themes were identified to capture more specific patterns and nuances in the data. As analysis progressed, two new themes were inductively developed: 'Training for Older Drivers', based on age-related insights and 'Introduction of Training', which was initially part of the 'Structure of Training' theme but was separated to reflect its unique role and emphasis in the instructors' responses. Throughout the process, themes were refined iteratively in team discussions to ensure clarity, coherence, and alignment with the research aims. Given that this study focuses on expert interviews, the analysis prioritised the context rather than the frequency of specific topics mentioned.

3. Results

This section presents findings from interviews with instructors. In this section, 'instructors' refer to those who taught the ADAS training program and were interviewed for this study, while 'trainees' refer to the drivers who participated in the program.

3.1. Impact of training

All instructors provided positive evaluations of the training, emphasising its effectiveness in demonstrating how ADAS functions. They highlighted that the training helped drivers understand the practical benefits of ADAS, increased awareness among drivers unfamiliar with these systems, and encouraged more informed and confident use. This section presents the concrete effects of training and examines differences in its impact based on age and prior ADAS experience.

"I think it's important that drivers receive at least some basic training in how these systems work so that they can actually benefit the driver using the vehicle." – P5

"Generally speaking, there is also the fact that many drivers simply do not know about these systems. Through this training, they become familiar with them, and in the end, I would say the impact is quite good because they see that these systems actually work." – P6

There were two main issues trainees faced in understanding ADAS, and training helps address them. Firstly, many trainees did not know they had ADAS functionality or how to use it. Several instructors highlighted a lack of information at a car dealership, leading drivers to deactivate features simply because they did not understand them. Instructors mentioned that training is helpful for drivers who are unfamiliar with ADAS to be aware of the functionalities and gain confidence in the systems, increasing the likelihood of them using the features. Secondly, there were trainees who misunderstood its functions, leading to distrust or over-reliance without understanding its limitations. For example, some trainees complained about the lane departure warning system without understanding the reason behind the alerts, while others misunderstood adaptive cruise control as being capable of handling all driving conditions and became overly reliant on it. Instructors mentioned that training is helpful for drivers to understand ADAS, especially its limitations, to prevent over-reliance. Quotes from instructors are described in Table 2.

Instructors were also asked questions about the training impact depending on differences in trainees' age, gender, and ADAS use experience. Instructors noted that younger drivers adapted to ADAS more quickly, whereas older drivers faced certain challenges. In the next section, we describe in detail the issues and the impact of training on older drivers (Section 3.2). However, instructors mentioned that gender differences did not seem to significantly affect training outcomes. Regarding ADAS experience, while the impact of training varied based on prior ADAS experience, instructors emphasised that training was beneficial regardless of prior exposure, with inexperienced users gaining a basic understanding and experienced users refining their knowledge, as mentioned above.

3.2. Training for older drivers

Instructors shared detailed experiences and opinions regarding older drivers' training and emphasised the need for it. They mentioned that using ADAS can be challenging for older drivers for several reasons, such as a technology gap, misunderstanding, reluctance to use ADAS, and being overwhelmed by new functions and information. The comments below demonstrate these perspectives.

"With ADAS new technologies, elderly people are not so comfortable about the new technologies, and they try to avoid them if they don't understand the system, they don't trust them with it." – P2

"It was funny because many of them (older drivers) didn't even drive automatic cars. You can imagine what everything else in the car was for them. It was science fiction (for the elderly). … I remember just one older guy who said he had everything in his car, all these functionalities, and he went to the service centre and told them to shut down everything because he didn't want anything." – P7

Table 2

Quotes of drivers' issues and the impact of training.

Drivers' issues	Impact of training
Drivers do not know they have ADAS functionalities or do not know how to use them.	The training helped drivers gain confidence in the systems, increasing the likelihood of them using the features in the future.
"The problem is that many people don't even have information about these things. The issue is that people buy cars equipped with all these driver-assistance systems, but no one informs them about how they work. No one demonstrates them, and many drivers don't even dare to explore their own vehicle's features. As a result, they simply don't use these functions, and they remain a complete mystery to them." – P6	*"People who didn't know anything about the systems or that didn't trust on them. After the course, they solved the concerns." – P2*
"It was more people that they didn't know what other functionalities are or they didn't use them it was. They didn't know how to use it or why they would use it … it's a lot of times, people just buy a car and they don't know what they bought. … in our country (Slovenia) when you buy new car, there is nobody to tell you about the functionality or to go with you around. So, a lot of people don't use these systems because they don't know how." – P7	*"The system worked, and that last-second, intense braking was something they rarely experience in real-world conditions. They were very satisfied. Many of them realized firsthand how the system works, something they might never have experienced otherwise." – P5*
"The most useful (of the training) was for more for the people that don't use those systems. Usually or at all because they're scared or something." – P9	*"Some people who come to the training initially do not know about these systems, do not want to use them, and are even afraid of them. But after practical training in a safe environment, they gradually start trusting the system more and begin using it more. By the end, many say that they will now use these systems on the road, which is beneficial for overall traffic safety" – P6*
"The fact that car manufacturers don't really train the buyers of these vehicles properly. That's why offering such training would be a good idea." – P10	*"(There are drivers who think) I would never use it because I'm a good driver. I don't need them, so and all these comments are usually connected with people who never tried it in a safe environment, in on tracks. So they would. They would be able to see how those system are really working." – P8*
	"People are really not aware of positive sides of this of these systems. A lot of people are scared of using systems. And when they see that, it's not that complicated and how they can actually help you, how can they assist you. I think that overall they are quite happy and they are more keen to use them in the future. … Some people were impressed, and they said, "OK, now I will use those systems. I will not be afraid anymore" – P9
Drivers who are aware of ADAS but misunderstand its functions, leading to either disuse or over-reliance. – Disuse	Training corrects misconceptions and ensuring drivers understand both the capabilities and limitations of ADAS. *"I think they understand more how the systems are working, how they can help them. You know while driving when they (ADAS) don't react. And it's more important also that they know that maybe sometimes they cannot react. – P3*
"If you don't know about them (lane detection system) and haven't been explained how they work, they make small corrections, and people get confused. Many times, when drivers want to overtake on a two-way road with multiple lanes and try to shift without signalling, the system prevents them. That creates distrust—like, "What is this car doing?" Especially with the lane-keeping	*"They get to know what they are capable of because also the problem is people use a lot of times don't know what are the limitations of this of this system. They maybe expect too much of them. So, it's really important to know what they are capable of and when, at which point. They cannot intervene anymore so." – P9*

Table 2 (*continued*)

Drivers' issues	Impact of training
assist system. People were like, "What is this? I don't like this. I'm driving, and it won't let me." But in reality, the system is basically telling them that their driving isn't very precise. – P1"	
"During the training sessions, I often find that people complain about systems and such as Adaptive Cruise control or Lane departure warning systems. But I also think that many people misjudge the advance of that systems." – P12	*"The trainees also confirmed that they gained a much better understanding of the driver assistance systems that we demonstrated. Absolutely." – P10*
– Over-reliance	*"The people who are more likely to use the systems are those who are afraid of contact or those who. I believe that trainees are more likely to use the systems after completing such training because it helps them overcome any apprehensions and perhaps also dispels any misconceptions they might have had." – P12*
"They still have to be focused on driving but (they are) not. Doing third −0-things when they think that when using adaptive cruise control, they don't need to worry about the traffic because the car will break itself OK when needed. They didn't know that if the speed difference is big or if car in front brakes hard, that the system will fail." – P3	*"Knowing about the systems knowing which system is in their cars. And the find balance between trusting a system but not over trusting it, I think that's a main point (of the training)". – P13*
"(A trainee said that) when he's in heavy traffic, then he just has Lane assist on and adaptive cruise control on, and then he doesn't need to drive. He can be on a telephone on social media because he thinks the car is driving itself so." – P7	
"About information about those systems (ACC and LKA) are getting wider. So, people are they are informed a bit about that. They just don't know that specifics what or the limits of those systems. So, in that case, in that event it was great to they will be that they were able to try it, especially to try the limit." – P9	

"They have a lot to process just with the driving, and I think that for those people that are overwhelmed with the driving and just looking at the traffic and the signs, and I think for those people, it's actually maybe it's harder to use these (ADAS) systems." – P9

"They don't rely on the functions. They don't know what the functions do, and they say, "Oh, perhaps it's not working properly. I don't know how to handle it, and I'd like to switch it off because. When I switch it off, I'm driving by myself." – P11

During training sessions for older drivers, several challenges were identified. These include differences between training vehicles and personal vehicles, making it difficult to transfer knowledge effectively, as P4 stated, and the overwhelming amount of information presented during training, as P10 stated.

"This is our (driving academy-owned) car, or a different brand that they have. We have to show them (Older drivers) in their car. I mean the trainees because it's easier for them. I just need to push this button, and it's working, but when I show them different brands, it's different because when they go in their own car, it's not there. So, your button is somewhere else, maybe on the screen, or I don't know." – P4

"The presentation was a bit too much for trainees who hadn't dealt much with the topic before.

It went into too much detail, and the older drivers, in particular, found it a bit harder to follow all the explanations, especially in the vehicle." – P10

Some instructors suggested that one-on-one instruction and using an older driver's car during the training might be more suitable for older

drivers to enhance the training effect.

> *"Older people are just afraid of using it because it has something to do with computers. I think that one-to-one Instructions are better because in that case, if you are showing them how to use it" – P8*
>
> *"I think the best would be if they (older drivers) would get to if they have a car with these systems, could be to train with their car, since we do not have the same, you don't have the same buttons and the same (interaction) way how to activate some system. It would be the best if they would learn that they would be able to learn in their cars." –P9*

Despite the difficulties faced by older drivers in using and training for ADAS, one instructor highlighted that the impact of training relies on the willingness to learn rather than age, as P13 stated: *"There will definitely be issues with accepting those systems (depending on age), Issues with trusting the ADAS. But in the end, you can learn, and it doesn't really matter how old you are. It's totally fine.".*

3.3. Structure of training

This section reports instructors' feedback on the training structure, including methods, time allocation, and group sizes.

3.3.1. Method

The training was divided into three parts: theoretical lessons, on-track training, and on-road training. Many instructors emphasised that all three parts complement each other and are essential for effective learning.

> *"Every part of the training had its own needs and advantages."- P3*
> *"Each part of the training is very important. Even theory is definitely necessary because, through theory, trainees learn about the systems.*
> *But that alone is not enough. If someone only hears about a system in theory, it doesn't mean they will trust it.*
> *That's why the second part of the training (on the track) is very useful. And then, of course, continuing the training on actual roads. On the test track, they have the opportunity to safely test." – P6*

Instructors agreed that theoretical lessons are necessary to introduce the concepts and functionalities of the systems. However, one instructor (P10) noted that the information could be overwhelming for older drivers, as mentioned above. While both on-track and on-road training allow trainees to experience the features, they serve different purposes. On-track training provides a safe, controlled environment where trainees can practice without external traffic risks; as P12 stated: *"Trainees are in a secure area and can try the systems without dealing with other vehicles.".* On the other hand, on-road training allows trainees to experience the system in real-world conditions, although it comes with practical limitations, as P9 stated: *"It's good to go on the real road, where you cannot manipulate settings as much. Still, they can use the systems and see that they work in real driving situations.".*

In addition, we asked instructors about their opinions on using driving simulators. While instructors viewed a simulator as a beneficial supplementary tool, they emphasised that the simulator could not fully replace on-road and on-track training, as P14 remarked: *"It doesn't really replace the theoretical, the track and the road (session), but it's something extra that we can add in the in the programme.".* Additionally, some instructors pointed out potential issues with older drivers, particularly motion sickness, as P3 explained: *"Older people get sick on the simulators... they don't like it because it's so far away from real driving, from real experience.".* However, instructors acknowledged that driving simulators could be helpful in demonstrating dangerous scenarios, as P8 stated: *"There are still some dangerous situations we cannot test. But in simulators, we can do that.".* P14, who already had experience using a driving simulator for defensive driving training, mentioned that the simulator could serve as a useful tool for trainees to review and analyse accident scenarios, helping them identify safe driving strategies.

3.3.2. Time allocation

All instructors agreed that the time allocation for training was appropriate. P14 mentioned that while delivering all the theoretical information within 30 min was challenging, this duration was appropriate, as trainees might become disengaged if it exceeded 30 min. Moreover, P3 mentioned that additional time would allow for more knowledge transfer, while P10 noted that as the number of features to be trained increased, more time would be required. P13 suggested incorporating time for instructors and trainees to exchange opinions on what they had learned before moving on to the next part of the training.

3.3.3. Group sizes

The number of trainees per instructor varied by training venue, but typically 2–3 trainees shared a vehicle for on-track and on-road training. Several instructors viewed this group size positively, as it allowed trainees to learn from each other's questions and driving demonstrations, as P9 stated: *"Usually, I had a positive experience if there were three students in the car and then some questions arose, and those questions were usually also meaningful for the other trainees in the car. So, I think it's actually an added value to have more people in the car (instead of 1 to 1).".* However, for older drivers, a one-on-one lesson might be preferable, as previously mentioned in Section 3.2.

3.4. Introduction of training

Effective implementation of ADAS requires more than just a well-structured training program. This section presents the instructors' opinions on the timing and accessibility of the training.

3.4.1. Training outreach

Given that ADAS driver training is currently not mandatory for all drivers, P10 noted that individual training would be too expensive: *"Training programs are not suitable for direct drivers because they require intensive support and are very expensive."* Three instructors suggested that companies renting out vehicles to employees would be suitable target service introduction channels for ADAS driver training (e.g., the company sends employees who received a new car to the driving academy for training). One instructor from Germany mentioned that fleet managers in the company are required to provide vehicle features and safety information when assigning cars to employees in Germany. Additionally, P9 suggested that ADAS driver training could be offered to drivers through car dealerships where customers purchase new vehicles.

3.4.2. Timing for taking training as trainees

Instructors stated that training is beneficial for all drivers, those who have never used ADAS can become familiar with its functionality, while experienced drivers can learn proper usage through training. However, regarding the training for novice drivers (also known as learner drivers), all instructors suggested that novice drivers should first develop basic driving skills before learning ADAS-assisted driving (typically 6 months after starting driving), as P4 stated: *"First, they have to know how to drive because they have to have experience. Then maybe in a couple of months, it's better to have maybe one more course and also discuss these topics or new ideas. Because if you put everything on them when they are learning how to drive, they don't need to know everything.".* They also expressed concerns that introducing ADAS too early could overwhelm novice drivers, as P12 stated: *"It (learning ADAS together with basic driving skills) is too much for them to think about a lot of different things because they have a lot to do... Their driving skills are not good. So, it's too much.".* To ensure effective learning, one instructor proposed an early introduction to ADAS (e.g., during the driving test) but recommended in-depth training only after drivers gained more experience. In addition, one Instructor (P14) highlighted that ADAS driver training is necessary not only for novice drivers but also for drivers replacing their vehicles as technology continues to advance and new features are introduced in cars. Note that all trainees in this study were already licensed drivers, and instructors did

not have direct ADAS training experience with novice trainees. Therefore, instructors provided the recommendations regarding novice drivers' training based on their professional expertise.

3.5. Challenges in training

Instructors identified several practical challenges in ADAS driver training, primarily stemming from the diversity of vehicle models.

"No car has the same systems … Every car is different. The function is different, and how to use it is different. That's what is difficult to implement in our training." – P12

Table 3 describes quotes of challenges as an instructor. One major challenge was the subtle specification differences in features across vehicles. Instructors emphasised that trainees needed to recognise these differences between training vehicles and their own cars. Instructors also had to familiarise themselves with evolving vehicle technologies and different interactions across brands. This confusion extended to trainees as well, especially older drivers who were unfamiliar with such systems. The inconsistency in terminology and interface across brands made it even more challenging. One instructor (P9) suggested that the automotive industry should work towards standardising system interfaces and terminology to improve usability, as follows: *"I think that's one of the things that the industry should go into to make things as similar as possible. I think that we would get better results, and more people would use these systems if we had a unified, let's say, just the naming and then the interface.".* While training with different car brands helped drivers adapt to the various systems encountered on the road, due to the limited available vehicles at the driving academy, it was not always possible to

Table 3
Quotes of training challenge regarding various car brands.

Challenges	Quotes
1. Specification difference	*"The speed range of the systems (for activating) is different between different brands. And the trainees' cars were completely different from ours… They need to realise that there are many differences between the different brands." – P2*
	"The challenge was to learn these functions in this very special car. So to see how it works in this special car and how to adjust it, how to put it on and off. And that was the, I think the challenge to know what's going on in this special car and to answer the questions of the people to this special car." – P11
2. Interaction difference	*"I'm working very much for BMW… Then you talk to some Audi people, and when you get them in a BMW (as a training car), they're completely lost for the moment because they say everything is totally switched. So that's the challenge—to learn how this car functions. How can I adjust it, and how can I put it on and off? Is it a button? Is it a switch? Is it the menu function? That's the big challenge, everything always." – P11*
	"I think the biggest problem is that the difference between the systems. So, they don't operate the same way from one car to another or manufacturer. … (For example) one company has this sound, and another has a different one. And someone who never explored that system doesn't know what's happening… Older drivers didn't use these systems before, and it's difficult for them to understand." – P4
	"I can agree different producers have different names for these systems, but it can be very confusing. Just test a lot of different cars… but (they are confused) what does it mean in the other brand?" – P8
3. Limitation of demonstrating all new functions	*"The problem is that not every car in driving academy has these systems. … We had different cars. Especially for this that so they get different experience because the systems were not the same." – P3*

demonstrate every system variation or new functions.

4. Discussion

This section discusses the effects of ADAS driver training and presents implications for both training program design and practice. The insights are based on the experiences and feedback of driving instructors who implemented the ADAS training program.

4.1. Impact of ADAS driver training in a driving academy

Many drivers hold misconceptions about Advanced Driver Assistance Systems (ADAS), which can lead to misuse or over-reliance. This study suggests that structured training may mitigate these issues by enhancing driver confidence and promoting the appropriate use of ADAS. However, as a qualitative study grounded in instructors' perspectives, we want to note that it does not directly measure drivers' behavioural change.

Instructors reported that trainees who initially exhibited scepticism or fear about ADAS functionalities showed greater trust and a willingness to use these systems after hands-on experience in a controlled environment. Practical exposure seems to reduce the fear of the technology and provides trainees with a clearer understanding of how ADAS can assist them. According to the Technology Acceptance Model (TAM) (Davis, 1989), adoption is primarily driven by perceived usefulness and perceived ease of use. Our findings indicate that the training improved both. Trainees gained trust in the system's safety benefits (usefulness) and learned how to operate it effectively through repeated exposure and instructor guidance (ease of use). As a result, trainees who were initially sceptical or anxious about ADAS reported an increased intention to use it after the training. Therefore, the instructional design of ADAS training can function not only as an educational intervention but also as a behavioural one.

Additionally, instructors noted that the training addressed and corrected misconceptions about ADAS limitations. For example, some trainees mistakenly believed that Adaptive Cruise Control (ACC) and Lane Keeping Assist (LKA) systems could independently handle all driving tasks, leading to overreliance on the systems. Training helps users build accurate mental models (Norman, 1983), which explains how users develop internal representations of how a system operates. Previous experimental studies have shown that training, such as simulator-based (Krampell et al., 2020) or proper information provision before driving (Forster et al., 2019a), can modify and refine drivers' mental models of ADAS. In particular, training provided in a driving academy environment is expected to be especially effective for shaping mental models, as it combines theoretical instruction with practical experience in real or semi-controlled settings. This environment allows drivers to actively test, question, and revise their assumptions under the guidance of expert instructors, which is ideal for developing accurate internal representations of how ADAS functions. Furthermore, such experiential learning opportunities serve as an intervention that fosters automation literacy, which refers to users' ability to understand, appropriately trust, and interact with automated systems (Long & Magerko, 2020). These educational interactions have been shown to help trainees more accurately understand system boundaries, leading to more appropriate and calibrated engagement with the system, and helping them avoid both disuse and overreliance.

Regarding a lack of awareness and misconceptions about ADAS, instructors mentioned that car dealerships often do not provide adequate training on ADAS functionalities, a point supported by Abraham et al. (2017a). Although drivers obtain ADAS-related information from various sources, the most common touchpoint remains the vehicle sales environment. However, as sales interactions prioritise product promotion over education, there is no standardised protocol for ADAS instruction, leading to considerable variability in the information provided. Other channels, such as owner's manuals, in-vehicle infotainment systems, and online resources, are available but require the

driver's active engagement. If drivers do not proactively seek information, they may remain uninformed about ADAS capabilities and limitations. As ADAS technology becomes more widespread, the need for formalised training programs, such as basic driving skill education, has become apparent. In countries such as the Netherlands (CBR, 2023) or the United States (Nowakowski et al., 2015), the implementation of mandatory ADAS driver training has been discussed for several years, including its potential integration into licensing requirements. Establishing standardised ADAS education could bridge existing knowledge gaps and promote safer, more effective use of systems.

4.2. Training for older drivers

There are both benefits and challenges of ADAS driver training for older drivers. Older drivers are known as less accepting and willing to use driving automation systems (Lee et al., 2017; Souders & Charness, 2016). However, Liang et al. (2020), exploring the attitudes of older drivers after experiencing ADAS for six weeks, has reported increases in their perceived safety and adoption. This suggests that while older drivers may face higher initial barriers to ADAS adoption compared to younger drivers, once they understand how to use the systems and recognise their benefits, they are likely to take advantage of ADAS for safer driving assistance. In this study, instructors observed that older drivers frequently struggled with technology adoption due to cognitive overload or initial reluctance. Some older drivers deactivated ADAS functions due to unfamiliarity or distrust. However, structured training sessions in a controlled environment helped mitigate these barriers, gradually increasing their comfort and willingness to use ADAS. Notably, Morris and Venkatesh (2000) suggested that age moderates the relative influence of perceived usefulness and ease of use, thereby shaping technology acceptance based on the TAM. Younger users were found to be more influenced by perceived usefulness, while older users placed greater emphasis on perceived ease of use and supportive learning contexts. In this regard, direct interaction with instructors in driving school environments can provide a more effective learning experience by enhancing perceived ease of use when using systems. Therefore, instructor-led training is expected to improve technology acceptance among older adults.

To enhance the effectiveness of the training, one key suggestion is that personalised, one-on-one training sessions and using trainees' own vehicles may facilitate better learning outcomes for older drivers. Tailored training can reduce cognitive workload and enhance positive attitudes for older users (Pappas et al., 2019). Regarding the cost burden of providing one-on-one training, as discussed in Section 4.4, mandatory ADAS training for older drivers could generate societal benefits. In cases where drivers must bear the cost themselves, however, additional policy support may be required to ensure training efficiency. At the same time, cost savings could be achieved if training is offered in group sessions for specific target populations or if, as such programs become more widespread, they are organised and delivered more efficiently. In addition, since variability in ADAS interface design across different vehicle brands often led to confusion, hands-on training using personal vehicles helped minimise these inconsistencies. Nevertheless, training needs to consider cognitive limitations among older drivers. Instructors noted that the new information presented during training sometimes overwhelmed older drivers. To address this, ADAS driver training for older drivers can be structured into manageable segments, simplify content delivery, and allow for repeated exposure to key concepts. Given ADAS's potential to improve road safety, particularly for older drivers, ensuring its adoption is important. However, due to lower technological acceptance (Acheampong & Cugurullo, 2019; Haghzare et al., 2021) and learning difficulties among older drivers (Holland & Rabbitt, 1994), there is a risk that they may not fully utilise ADAS benefits. Instructor-led ADAS driver training in a driving academy presents a potential positive solution to overcoming these barriers.

We propose that, compared to other learning methods (i.e., owners'

manuals or in-vehicle infotainment systems, instruction at a driving academy is particularly suitable for older adults. Gagnon et al. (2019) showed that individualised on-road driver training reduced the total number of unsafe driving behaviours among urban older drivers by approximately 26 %, compared to in-class education. Given age-related differences in learning speed and cognitive processing, ADAS training at a driving academy can provide a more effective learning environment for older drivers by offering direct feedback and opportunities for repeated practice.

4.3. Implications for ADAS driver training design

This study provides insights into the ADAS driver training program design. First, training is recommended to comprise theoretical instruction, controlled-track exercises, and on-road experiences, as each component has a distinct role in knowledge acquisition and hands-on practice. Theoretical lessons establish foundational knowledge, controlled-track training allows for risk-free experimentation, and on-road training ensures real-world application of learned concepts. Another consideration is integrating driving simulators. The impact of simulator-based training for manual driving (van Leeuwen et al., 2015) and driving with ADAS (Murtaza et al., 2023) has been studied, showing positive outcomes such as increased driving accuracy and reduced reaction time. While simulators can expose trainees to extreme scenarios that cannot be safely replicated in real-life training, instructors noted that the simulator should be used selectively and supplemented with real-world driving training. Thirdly, concerning the optimal number of trainees per session, instructors recommend training groups of two to three trainees, as this allows for interaction, peer learning, and enhanced engagement. However, for older drivers, a one-on-one training approach is advisable, as discussed in Section 4.2, to accommodate individual learning paces and specific needs. Adjusting group sizes according to the target audience can enhance both learning efficiency and training effectiveness. Additionally, training programs address the variability in ADAS implementation across vehicle brands. Differences in system interfaces, interaction methods (e.g., activation buttons), and operational behaviour were identified as challenges for both instructors and trainees. At the same time, unlike basic driver training for license acquisition, ADAS driver training is more likely to target drivers who already own a vehicle. Therefore, grouping participants by similar vehicle models could be effective, as ADAS driver training provided through a dealership or leasing company is likely to involve vehicles from the same brand. Alternatively, tailoring the training to the trainee's specific vehicle model could help reduce learning inefficiencies caused by differences between the training vehicle and the driver's actual vehicle.

4.4. Implications for practice

This study highlights the need for structured ADAS driver training to ensure drivers properly understand and utilise ADAS systems. To facilitate effective implementation of such training, strategies to expand outreach need to be considered. While some drivers voluntarily pursue additional safety training, such as defensive driving courses, most receive training either because their employer mandates it or because regulations require it for certain types of drivers. As instructors in this study pointed out, if ADAS driver training remains optional for individual drivers, unlike basic driver education, its adoption will be limited. Instead, expanding and promoting ADAS driver training through companies or institutions could be a more effective approach. One possible strategy is to provide ADAS driver training through companies that lease vehicles to employees. The vehicle leasing market has been growing (VNA, 2023), and considering the practical barriers individual drivers face in accessing ADAS driver training, such as cost and lack of information about training academies, companies that lease vehicles to employees could integrate ADAS driver training into their

safety policies. Another potential avenue is through insurance companies. It is suggested that ADAS features such as automatic emergency braking and lane departure warnings reduce accident frequency and lower insurance claims(Masello et al., 2022). Since training helps drivers recognise and correctly use these features, insurance companies could incentivise ADAS driver training by partnering with training academies and offering insurance benefits to drivers who complete the program. A third strategy is incorporating ADAS driver training at car dealerships. As discussed earlier in this study, the moment of vehicle purchase presents an opportunity to encourage drivers to undergo training. Car dealerships could offer ADAS driver training to customers purchasing new cars, ensuring that they understand and can effectively use the ADAS features in their vehicles.

ADAS driver training can benefit all drivers. Regarding the timing of training, instructors recommended that drivers undergo ADAS driver training whenever the opportunity arises, regardless of their driving experience, whether they are novice drivers, experienced drivers, or individuals purchasing a new vehicle. However, for novice drivers, instructors suggested introducing ADAS driver training after they have developed basic driving skills, typically six months to two years after obtaining their license. This recommendation is supported by two key reasons. First, acquiring too much information at once can result in cognitive overload (Shrivastav & Hiltz, 2013), reducing the effectiveness of learning. Second, learning advanced technology without a foundation in basic driving skills may increase the likelihood of over-reliance on the system. Such reliance on these features can hinder the improvement of driving skills and reduce the safety of manual driving. For example, Chen et al. (2021) found that the overall stability of evasive manoeuvres after the transition of control from automated driving by novice drivers is considerably worse than that of experienced drivers. Therefore, it seems most appropriate for novice drivers to first establish fundamental driving skills before developing proficiency in ADAS as a supplementary safety aid. However, incorporating ADAS-related topics into theoretical exams can help drivers acquire fundamental knowledge about the system's limitations, capabilities, and basic functions before practical training. For experienced drivers, ADAS driver training is also beneficial to ensure they fully understand system functions and apply them correctly. Even those who have been driving for a long time are likely to encounter unfamiliar ADAS features when switching to a new vehicle. In such cases, training can help them adapt and use these technologies safely and effectively.

Policymakers and industry stakeholders should consider implementing mandatory training modules or incentive programs to improve access to ADAS education for all drivers. For example, an introductory ADAS theory module could be integrated as a mandatory component of initial driver education. Rather than overwhelming novice drivers with extensive technical details, which are often difficult to retain without hands-on practice, this theory module can focus on addressing common public misconceptions about ADAS. These include, for example, the belief that the system allows completely hands-free driving or that it can be safely used in all driving contexts. Clarifying such misunderstandings early is important for building appropriate expectations. An ADAS practical module could then be incorporated into mandatory license renewal processes within the first few months after license issuance. This would reinforce theoretical knowledge through practical experience and allow drivers to use ADAS properly. Extending such requirements to experienced drivers may also be explored, for example, by introducing legal provisions for bundled training at the point of leasing agreements or car dealership sales. On the incentive side, training could be encouraged through insurance discounts, reduced license renewal fees, or extended license validity periods for drivers who complete certified ADAS modules. This approach may be especially effective for older drivers, for whom correct ADAS use is critical given age-related changes for safe driving (Liang, 2023). Since ADAS can enhance safety for this demographic, linking successful completion of ADAS training to renewal incentives could both improve uptake and promote safer driving

practices. Given the rapid advancement of driving automation, continuous learning opportunities will be essential to ensure that all drivers can competently use ADAS-equipped vehicles, ultimately enhancing road safety and driving experiences.

4.5. Limitations and further studies

While this study provided valuable insights from instructors regarding ADAS driver training, several limitations warrant further study. Firstly, the selection bias is inherent in the trainee pool. Many drivers who opted for ADAS driver training were already interested in or had prior experience with these technologies. Moreover, perspectives on novice training should therefore be interpreted as expert opinions rather than empirical observations. Future research should investigate the effectiveness of training among a more diverse driver population, including those with minimal prior exposure to ADAS. Furthermore, all instructors in this study were male, reflecting the broader gender imbalance in the driving instruction profession. Recent industry statistics indicate that female driving instructors account for approximately 15–30 % of the profession across Europe, such as Germany and the UK (Floyd, 2024; Moving, 2023). While this gender ratio partially explains the composition of our sample, it nonetheless limits the diversity of perspectives represented in the findings. Future research should aim to include more gender-balanced samples to explore potential differences in instructional approaches and interactions with trainees. In addition, this study focused solely on the perspectives of instructors. While it provides in-depth insight into training delivery, it does not capture how trainees perceived the training or how it influenced their actual behaviour. We acknowledge that the absence of triangulation using trainee feedback or performance data limits the comprehensiveness and objectivity of the findings. Future research could consider integrating multiple perspectives and data sources to evaluate the effectiveness of ADAS driver training.

5. Conclusion

This study is based on interviews with driving instructors who had delivered ADAS driver training programs, allowing us to capture insights grounded in real implementation. The results found that Advanced Driver Assistance Systems (ADAS) driver training in driving academies mitigates driver misconceptions and disuse, promoting proper system utilisation. In particular, structured training in driving academies is beneficial in encouraging the adoption of ADAS among older drivers. Instructors emphasised the importance of a structured approach that combines theoretical and practical components, as well as the benefits of small groups in enhancing interactive learning. They also suggested introducing ADAS driver training after novice drivers have developed fundamental driving skills, and a vehicle lease company or car dealership as a training introduction channel. This study highlights two key contributions. First, it establishes the role of a driving academy as a viable training source for ADAS education. Second, it provides insights into training effectiveness and design from the perspective of instructors, a key stakeholder group in ADAS education. These findings are expected to support the design and practice of training, ultimately contributing to improved road safety through the proper use of ADAS.

CRediT authorship contribution statement

Soyeon Kim: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation. **Simeon Calvert:** Writing – review & editing. **Marjan Hagenzieker:** Writing – review & editing, Methodology.

Declaration of competing interest

The authors declare the following financial interests/personal

Appendix A. . ADAS driver training

A.1. Mobility club and trainees' data

		Mobility club A	Mobility club B	Mobility club C	Mobility club D
Location		Spain	Slovenia	Germany	Belgium
Total number of instructors		3	7 (on-track and on-road training) + 1 (responsible for theoretical instruction)	4	4
Number of vehicles for ADAS driver training		3 (Seat Cupra Formentor)	7 (2x Škoda Kodiaq, 2x Opel Astra, 2x Hyundai Tucson, and 1x Hyundai Ioniq 6)	4 (BMW)	4 (Peugeot)
Number of trainees in a car for on-track and on-road training		3	3	2	3
Trainees' information	Total number	45	53	14	53
	Gender	Male: 36 / Female: 9	Male: 44 / Female: 9	Male: 11 / Female: 3	Male: 40 / Female: 12
	Average age (SD)	48.58 (10.51)	57.51 (12.30)	40.29 (22.35)	34.49 (19.55)
	Average driving license holding years (SD)	29.93 (11.89)	37.80 (12.20)	22.35 (16.67)	15.52 (19.14)

A.2. Curriculum for the ADAS driver training program

Agenda		Time
Theoretical part	Introduction to training programme agenda, automated driving, and ADAS Driving support systems: Blind spot monitoring (BSM), Advanced cruise control (ACC), Lane keeping assistant (LKA) Emergency Systems: Emergency lane keeping (ELK), Automated emergency braking (AEB front), Rear automated braking (AEB rear)	30Min
On-track training part	In-car preparation Practice: Blind spot monitoring (BSM), Advanced cruise control (ACC), Lane keeping assistant / Emergency lane keeping (LKA/ELK), Rear automated braking (AEB rear)	1H 15Min
On-road training part	Practice: Blind spot monitoring (BSM), Advanced cruise control (ACC), Lane keeping assistant / Emergency lane keeping (LKA/ELK)	1H 30Min
Debrief		15Min

Data availability

Data will be made available on request.

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