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ORIGINAL ARTICLE

Teaching advanced technology (ADAS) and use of touch screens in driver training in Norway

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Abstract

As many as 4,601 people were injured or killed on the roads in Norway in 2022. This number is too high and highlights the necessity of putting road safety on the agenda. The car industry today is represented by a vast increase in advanced technology for drivers to interact with, and knowing how and when to use this technology is crucial for safe driving. Thus, our research question was: *Does the Norwegian driver training industry teach advanced driver assistance technology (ADAS) and touch screens in their driver training?*

A survey was distributed to 1,058 driving schools in Norway, resulting in 333 responses. The results showed that driving instructors spend considerably more effort on teaching inbuilt driving assist technologies that enhance driving safety than on those that are designed to enhance safety but that, if not understood well, could lead to hazardous outcomes. Suggestions on how to improve driver training and driving instructor education are made. Research and practical implications are presented to make sure that driving education is updated and aligned with technological advancements in the automobile industry and to ensure traffic safety for all road users.

Keywords ADAS · Driver training · ACC · Rane assist · Road safety · Driver training · Automated technology · Human factors

1 Introduction

In 2022, 116 people were killed and 4,485 were injured in car accidents in Norway. Of these number, 86 were males who died and 30 females. Severely injured were 362 male and 216 female, and slightly injured were 2273 male and 1557 female (SN, 2022a). This means that even though Norway is one of the safest countries in the world regarding road traffic (OECD, 2020), there is still a need to decrease the number of accidents. New technology has been making its way into the car industry and attracting increasing attention over the past few years. This technology is becoming more and more complex and less and less transparent, and it is increasingly taking over tasks for the driver. However, the driver is still in charge and must be able to regain control at all times, which provides new tasks for driving instructors and the driver training industry.

Driver training is essential for road safety. Thus, driver training must keep up with the technological solutions that are entering the car industry. Advanced driver assistance systems are predicted to reduce energy consumption and road traffic emissions and increase road safety (e.g. Schoettle & Sivak, 2014; Choi & Ji, 2015; Nordhoff et al., 2018; Greenblatt & Shaeheen, 2015). Additionally, as of 2022, new EU regulations make it mandatory in the EU for new cars to have a set of Automated Driving Systems (ADS) to increase road safety (EC, 2018). This suggests that technological development will continue with automation and semi-automation in cars. As partially automated driving is found to increase the driver's workload (Kim et al., 2023)

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and bring conflicts of human-machine shared control (Vanderhaege, 2021), it is crucial to learn about the interaction between the technology and the driver's use of it. Research shows that, for instance, touch screens are responsible for accidents and unwanted incidents, as they take time to operate, during which the driver's attention is focused off the road rather than on it (Kopač and Pušavec 2019). In addition, adaptive cruise control is found to decrease attention and increase reaction time (Lee et al. 2007; Stanton et al. 1997). Therefore, the driver training industry must know how to teach the use or non-use of this technology.

Thus, our research question is: *Does the Norwegian driver training industry teach advanced driver assistance technology (ADAS) and touch screens in their driver training?*

In this project, we chose to explore technologies that are a significant part of the technological curriculum for driving instructor education in Norway: the anti-lock braking system (ABS) (Bandhari et al., 2012) and the electronic stability program (ESP) (Ferguson, 2007; Lie et al., 2004), which are safety systems built into the car that the driver does not turn on and off. We also narrowed the licences down into private cars requiring a licence B. Further, we looked into common technologies in cars that are not a mandatory part of the curriculum of driving instructor education: the lane keeping assistant (LKA), adaptive cruise control (ACC), and touch screens, which are technologies that the driver can choose to use or not and that could be used in high-speed and high-risk contexts, thus having the potential to be involved in serious accidents.

Furthermore, we present the theoretical framework regarding human interaction with semi-automated technology, driving and advanced technology, and teaching ADAS and advanced technology before the method section. The results are presented prior to a discussion, and a conclusion finalises the article.

2 Theoretical framework

2.1 Human interaction with semi-automated technology

Interactive systems span from automation to autonomous systems. Automated systems perform what they are programmed to do, while autonomous systems, through machine learning, are capable of expanding on their autonomy and independence from human operators in a wider range of situations. In other words, autonomous systems are the evolved version of automated systems: better adaptable to a wider variety of conditions (Hancock 2016; U.S. Air Force 2015).

Most automation systems are still brittle, and thus they are still far from full, safe autonomy. According to Woods and Cook (2006), automation brittleness refers to automation handling a range of situations it is designed to address, but for out-of-design-domain situations, automation still requires human intervention (Endsley 2017). In order to reap the benefits of increased automation, it is important to address those challenges and to ensure that people have an accurate understanding of automated assistance features, how they work and their capabilities and limitations. An accurate mental model develops through ongoing interaction with the technology and training. This is essential to develop a calibrated level of trust in automation technology and to understand when to take over from automation. This is especially crucial in the context of driving, where drivers only have a few seconds to take over from automation to avoid accidents.

2.2 Supervisory role of humans and implications for situational awareness and workload

Automation is designed to relieve humans of extra workload and assist them in task performance. However, as mentioned in the previous section, increased automation comes with challenges. With an increased level of autonomy, the role of the human transitions into a more supervisory role. This transition from performing manual operations to monitoring has repercussions for human vigilance and the maintaining of situation awareness. This is referred to as the automation conundrum (Endsley 2017). When humans are not fully engaged in manual operation, it is possible that they lose situation awareness by falling out of the loop (OOTL). This is a serious challenge characterised by lack of attention, loss of situational awareness and deskilling (Di Flumeri et al. 2019). When humans are OOTL, they require more time to notice potential dangers and to intervene or take over from automation. Automation brittleness makes it more difficult for humans to notice if automation is acting incorrectly or to understand the reasoning behind automation's behaviour. Furthermore, automation may suddenly pass control to the human operator when it faces an out-of-design-domain issue. In such situations, the human operator may not be ready to take over. To mitigate the adverse effects of OOTL, it is important to help the human understand the automation system's behaviour. Too much transparency and increased situational awareness can, however, lead to an excessive workload for humans. This is also unsafe, as the cognitive overload can reduce humans' processing power and performance. Too heavy and too light a workload are both potentially dangerous. An intermediate workload is the optimal and safest range to aim for (Yerkes and Dodson 1908; Park et al. 2018). However, interaction over time with automated systems and training can also help with developing a better understanding of various situations and the limitations of the automation, and through familiarity and predictability, the human's sudden changes in workload may be mitigated. An important notion here is the development of a mental model based on training with the system.

People try to make sense of their experiences and develop mental models of the systems they interact with (Johnson-Laird, 1988). A mental model consists of mapping the key components in the system, figuring out the relationships between the key components and figuring out techniques for interacting with the system (Westbrook 2006). However, in developing mental models, it is important to understand that individuals differ in their knowledge, experience, cognitive abilities and sense-making approaches. All of these factors could impact how a person perceives and engages with automation.

Once the human operator develops a mental model of the key components and their functioning and develops techniques to engage with the system, the operator gains a sense of control. The human operator gains a sense of control through their own actions and can control the consequent outcomes, referred to as the sense of agency (Le Goff et al., 2018).

When human operators gain a sense of agency and control, it is important to be realistic about to what extent one can consistently get the same result from the same action across situations. This is key in developing an appropriate level of trust in automation and knowing when one should take over. An appropriate level of trust knowing the capabilities and limitations of the system through prolonged engagement with it.

According to Lee et al. (2021), most drivers today are not familiar with automation functions, and they tend to use manual control when in doubt about automation functions. Others have found that ACC and lane keeping systems are underused (Harms et al. 2020). Therefore, drivers lose trust in automation and underuse it, simply due to not being familiar with it and not understanding it. Literature is not consistent in when and how automation functions should be taught to drivers for best results in regard to gaining an optimal level of trust. The study by Victor et al. (2018) showed that if drivers receive a detailed description of an automated driving system, they tend to overtrust it. However, Hergeth et al. (2016) reported that if automation functions and their limitations are presented early on, drivers tend to develop lower trust levels than drivers who did not get this information in the early stage (Lee et al. 2021). Although this research is more focused on the level of trust in automated systems, it shows important implications for the timing, amount and content of information that should be presented to (potential) drivers about automation assist functions. Some design has further been developed to hinder over trust, such as for instance forcing the driver to touch the steering wheel during driving.

2.3 Driving and advanced technology

There is an increase in different levels of automated vehicles (Calvert et al., 2023), and people generally seem to accept cars' technology. Driver acceptance of a combination of technologies, such as adaptive cruise control, lane assist, and collision avoidance has been found to be high for those using it (Eichelberger and McCartt 2016). However, in real-life driving, the conditions are relevant in regard to how and if ADAS should be used. These are conditions such as road markings, signs, curves and weather. For instance, in the Nordic countries, where there is snow on many roads during wintertime, road markings will not be visible or detectable. If a car transfers from a context where the systems are in control to one where the vehicle's systems deteriorate or stop functioning due to such a setting, the car will then leave control to the driver, which could increase risk, as the driving conditions are even more difficult than on roads with optimal conditions.

Furthermore, users who were aware of specific limitations regarding ACC reported less willingness to use ACC in such settings (Dickie & Boyle, 2009). Krake et al. (2020) found that participants who were taught about the limitations of ACC were more likely to hit the brake sooner and take over control of the vehicle in situations where ACC might not work. The use of ACC was also found to be pleasing to the driver, especially in high-speed, low-density driving conditions (de Winter et al. 2017). However, ACC is also found to increase reaction time, and there are several examples of drivers failing to intervene in time when action was required (Lee et al. 2007; Rudin-Brown and Parker 2004; Stanton et al. 1997). Vanderhaegen (2021) found that confusions from the driver of how this technology worked resulted in unwanted incidents. In addition, when the systems, such as ACC and lane assist system technology, are used at the same time, the car is closer to self-driving, which might affect the driver's attention.

Lane assist system technology supports the driver in the lateral control of a vehicle and is found to have the potential to prevent one out of five fatal crashes (Jermakian 2011). This is one of the most varied technologies, where the driver does not necessarily know whether the lane assist will give a warning sign that is haptic (e.g. steering wheel vibration) or audible or visual, or if it will actually keep the car in the lane for the driver. In addition, it has great variation in how it works based on the curves of the road, road markings and so forth. Factors such as these contribute to a confusion between the reasoning of a driver and the technology which sometimes resulted in dangerous situations (Vanderhaege, 2021).

Another technical solution invented to give the driver access to more information while driving is the touch screen. However, touch screens do not seem to increase road safety to the extent that other technological solutions do. A touch screen makes a driver take their eyes off the primary task of keeping their eyes, and thus attention, on the road. Rather, it forces the driver to take their eyes off the road while manoeuvring programmes without tactical cues (Beruscha et al. 2017). A survey conducted by one of Norway's largest insurance companies found that 43% of respondents said it took their attention away from the traffic, and of these 46% reported that it resulted in an accident (Gjensidige, 2022). As many as 100,000 accidents were reported due to inattention caused by the use of touch screens in Norway (NRK, 2022). One reason for this could be that touch screens are found to be less effective than buttons (van Zon et al. 2020), and thus more time is spent navigating through a touch screen without tactile cues.

There are challenges regarding increasing automation in cars, as this changes the driver's tasks from manually driving to monitoring (Carsten et al., 2012). Changing the tasks to monitoring is well known for being challenging in regard to keeping the attention of humans (Bainbridge 1983), as their vigilance drops (Casner & Hutchins, 2019).

2.4 Teaching ADAS and touch screens

Over the past five years, there has been a slight increase in scientific literature on how to deal with the new technological solutions in the driver-training industry (e.g. Forster et al., 2019; Lubkowski et al., 2021; Merriman et al. 2021; Sætren et al. 2018a). Technology that is developed to increase safety will not be able to reach its potential if it is not used in an appropriate manner. Thus, knowing how to teach this is essential for driving instructors.

The SAE levels of automation (Society of Automotive Engineers International, 2018) are often referred to and used as a guideline. Here, at levels 0 and 1, the driver has full control of the car, and all the skills for driving must be held by the driver. The technologies ABS and ESP are this level. At levels 2–4, the driver supervises and takes control when needed. Thus, the same basic skills are necessary in addition to understanding when to take over or not and how the technology works. This is further where the technology of ACC and LKA are. At level 5, the car is fully driving itself, and there is no need for a driver to be in control. Levels 2–4 are particularly difficult for a driver (Banks et al. 2018).

According to Fan et al. (2018), ADAS, designed to enhance drivers' perception of the road, relies on effective Human-Machine Interfaces (HMI) to timely present driving environment information and warn about potential hazards. Visual, audio, and haptic feedback are common modalities considered. Visual displays, such as dashboards and head-up displays, enable efficient task performance and maintain driver focus. Visual warnings use different colors, content, or symbols to signify urgency. Auditory displays offer quick responses and are classified into tones, icons, earcons, and speech. Careful volume design avoids startling drivers. Haptic feedback, delivered through steering wheels, seats, pedals, or seatbelts, alerts drivers to critical situations. Interactivity, necessary for certain ADAS, can be facilitated through physical controls, voice commands, or air gestures, ensuring drivers' continued engagement with safety systems. Lilis et al. (2019) emphasize that visual feedback, provided by Heads Up Display or HUDs, helps drivers maintain focus on the road, while acoustic and haptic feedback offer alternative notification methods. Visual HMI elements in ADAS are integral for improving driver awareness and interaction with safety systems, thus enhancing driving experiences. Langlois (2013) explored the efficacy of luminous signals designed for peripheral vision, which not only improve driving performance but also increase driver comfort. These signals, cheaper than HUDs, offer reassurance by activating only when necessary but they still require further research when it comes to their long term influence on driver's attention (Langlois 2013).

The research regarding what to teach is far from unanimous. For instance, recent research indicates that teaching limitations in ADAS is less effective than teaching responsibility when teaching reflection on when and in which situations one should take over control from ADAS-controlled cars. Thus, teaching learner drivers a number of limitations to remember may not be a good approach for teaching ADAS (DeGuzman & Donmez, 2022). Another reason for this is that technology advances very rapidly and there is a vast variation in cars' technological solutions, so teaching and learning all limitations could be impossible. Others have found that focusing on the limitations of the technology shows a safer human–technology interaction. For instance, users who were aware of specific limitations took over control of the car sooner when they encountered that limitation (Bianchi-Piccini et al. 2015).

In a literature review regarding training for levels 0–3, Merriman et al. (2021) found 26 driver training studies. In the majority of these studies, the learner drivers had a combination of theoretical and practical training in regard to the technology and its capabilities and limitations, as well as how to activate and deactivate the technology when a takeover is to be conducted (Boelhouwer et al. 2020; Hergeth et al. 2017; Krampell et al. 2020; Payre et al. 2017; Sportillo, Palijc, Ojeda, Fuchs et al., 2018a; Sportillo, Paljic, & Ojeda, 2018b).

In a report on driver-training guidelines for automated vehicle technology in the United States, Manser et al. (2019) identified five levels of educational requirements for skills and knowledge drivers should be trained on when using ADAS:

1. Purpose of using ADAS, including risks and benefits.
2. Understanding levels of ADAS, including capabilities and the driver's level of responsibility.
3. Transition between ADAS and manual mode and handling critical situations, including system malfunctions.
4. Familiarity with system components and placement, including sensor and radar camera.
5. Understanding the limitations of ADAS, including adaptive cruise control, lane keeping assistance systems, and emergency brake assist.

2.5 Legal aspects of advanced technology in driver education

There are few legal directions in regard to the laws and regulations concerning the technological development in driver systems. In Norway, all motor vehicle traffic, as well as other road traffic, is regulated by the Road Traffic Act, with associated regulations (Lovdata, 1965). Some of the law's provisions make explicit demands on the driver's competence and behaviour. According to § 6, the driver must adjust the speed according to the traffic conditions and always 'have full control over the vehicle'. In Sect. 10, drivers are ordered to stop for traffic control, and in Sect. 12, specific duties are laid out for drivers in the event of a traffic accident. Furthermore, according to § 23, the driver is responsible for ensuring that the vehicle is in a safe and compliant condition, which is of importance when knowing that by combining ADAS technologies, such as ACC and LKA, the car could have tendencies toward being self-driving. Other provisions have a more general duty subject could be of importance, such as the general rule of care in § 3, the duty to obey signals, signs and markings in § 5 and to obey police instructions in § 9. Certain duties in the event of a traffic accident according to § 12 apply to 'anyone'.

The Road Traffic Act, with its assumption of traditional driver responsibility among other things, sets restrictions for the use and testing of autonomous and self-driving vehicles. As an increasing number of cars are being delivered with complex advanced driver assistance systems, new and 'unfamiliar' systems can appear disturbing. For both experienced and inexperienced drivers, it is important to understand how the car's driver support systems work in different situations and, according to the law, the driver must control the vehicle at all times (Lovdata, 1965).

Today, driving licences are differentiated by which training the candidate underwent concerning technology for only one aspect. That is, whether it was a manual gearing system or an automatic one. This is also the chosen gearing system for the driving test. You are not allowed to take the test in an automatic car if you are obtaining a licence for a manual one. Regarding what other technology is legal to use during a driving test in Norway, vehicles for driving tests can have a driver assistance system. The candidate can use this as long as the system, or the use of it, does not hinder the assessment of basic technical driving skills. The examiner must make a judgment when it comes to what is permitted and the candidate's skill in using the systems. The only system that the candidate is not allowed to use is a parking assistant that assesses the opening and carries out part or all of the parking operation for the driver (Helde 2019).

2.6 The cars in Norway

According to Statistics Norway, (SN, 2023b), there were approximately 2.9 million passenger cars in Norway in 2022: 1.9 million cars that run on petrol and diesel, 600,000 electric cars, and the rest hybrid or using other fuel. There is also a tendency towards an increase in newer cars and a decrease in older ones, as in 2022 there were approximately 500,000 cars under 4 years of age and 490,000 that were over 15 years old. Compare this to 2018 numbers, where 475,000 cars were under 4 years of age and 515,000 over 15 years old. The average age for cars in Norway in 2022 was 11.5 years, which is in line with the rest of Europe, where the average car age is 11.8 (ACEA 2023). In addition, of all private cars, almost a quarter were electric cars in July 2023, and of new cars sold from January to July 2023, 82% were electric (NPRA, 2023).

These numbers indicate that the cars in Norway have increasingly advanced technological solutions as the cars get newer, and additionally, most new and all electric cars have automatic transmission rather than manual gearing. June 2022 was the first month in which more learner drivers obtained driving licence B with automatic transmission (51%) than with manual gearing (49%), which is a rather rapid increase from 2018, when the number for automatic gearing was only 18% (NPRA, 2022).

3 Method

3.1 Design and sample

For this study, we chose a cross-sectional design based on a questionnaire investigating the use of advanced technology in driver teaching. Data sampling was done through two different methods. First, invitations to participate in the study were sent to 1058 driving schools by email in two

Table 1 Demographics, information about the respondents ($n=333$) and systems installed in instructor vehicles

Variable	Frequency	Variable	Frequency
Age groups	*n*(%)	Years of teaching experience	*n*(%)
Under 30	40 (12.0)	0–3 years	34 (10.2)
31–40	85 (25.5)	4–6 years	37 (11.1)
41–50	74 (22.2)	7–9 years	39 (11.7)
51–60	80 (24.0)	Over 10 years	223 (67)
Over 60	54 (16.2)		
Location of teaching school	***n*(%)**	**Educational institution**	***n*(%)**
Region south	45 (13.5)	Nord University	275 (82.6)
Region east	116 (34.8)	OsloMET	10 (3.0)
Region west	86 (25.8)	Swedish institution	18 (5.4)
Region mid	44 (13.2)	Danish institution	10 (3.0)
Region north	42 (12.6)		
Information about the car you use most in teaching			
Car energy source and transmission	***n*(%)**	**Anti-lock braking system (ABS)**	***n*(%)**
Fossil manual	149 (44.7)	Yes	332 (99.7)
Fossil automatic	68 (20.4)	No	0 (0.0)
Hybrid	16 (4.8)	Don't know	1 (0.3)
Electric	100 (30.0)		
Electronic Stability Programme (ESP)	***n*(%)**	**Lane Keeping Assist (LKA)**	***n*(%)**
Yes	331 (99.4)	Yes	237 (71.2)
No	1 (0.3)	No	91 (27.3)
Don't know	1 (0.3)	Don't know	5 (1.5)
Adaptive Cruise Control (ACC)	***n*(%)**	**Touch screen**	***n*(%)**
Yes	254 (76.3)	Yes	242 (72.7)
No	74 (22.2)	No	89 (26.7)
Don't know	5 (1.5)	Don't know	1 (0.3)

rounds two weeks apart in March 2023. These two rounds of invitations resulted in 267 responses. After reviewing the demographics, we found that instructors in the under 30 age group seemed to be underrepresented. In order to adjust for this, we chose to do an additional round of invitations through two Facebook pages for driving instructors in Norway in April 2023, which resulted in a total sample of 333 participants in this study.

3.2 Questionnaire

Our questionnaire was carefully designed to investigate the use of ADAS in all parts of driver education in Norway. Here is a list of variables that we included.

Table 2 Instruction about technology provided by the instructors ($n=333$) outside the car prior to driving

Technology	Not at all *n*(%)	Some degree *n*(%)	High degree *n*(%)
Anti-lock braking system	60 (18.0)	137 (41.1)	136 (40.8)
Electronic stability programme	64 (19.2)	148 (44.4)	121 (36.3)
Lane keeping assist	148 /44.4)	148 (44.4)	37 (11.1)
Adaptive cruise control	135 (40.5)	142 (42.6)	56 (16.8)
Touch screen[1]	135 (40.4)	143 (42.9)	50 (15.0)

[1] $n=5$ missing respondents on this variable

3.3 Demographics

Included demographics (Table 1) were age (under 30, 31–40, 41–50, 51–60, over 60), years of driver teaching experience (0–3, 4–6, 7–9, over 10 years), location of driver teaching school (region west, region east, region south, region mid, region north), as well as the institution where participants' teaching education came from (Nord University, OsloMET, Swedish institution, Danish institution, other).

3.4 Information about cars used in teaching

We included information about the vehicles used in teaching. This included the energy source (fossil fuel manual, fossil fuel automatic, hybrid, electric), ABS (yes or no), ESP (yes or no), LKA (yes or no), ACC (yes or no) and touch screen (yes or no).

3.5 Information about instruction provided with regard to ADAS

Information about instruction given on the use of ADAS was collected and divided into theoretical instruction given outside the car and practical instruction provided inside the car, both prior to driving. We divided it into the following technologies: ABS (yes or no), ESP (yes or no), LKA (yes or no), ACC (yes or no) and touch screen (yes or no).

4 Results

In this section, an overview of the driving instructors' information, the types of cars that are being used for driving lessons and the driving assist technologies and usage is presented.

The respondents were fairly evenly distributed with regard to age groups, with a majority within the 30s, 40s and 50s, and a slightly less representation under 30 and over 60 years of age (Table 1). We also saw a fairly even distribution of instructors throughout regions, with the highest representation in the most populated areas such as region east and west. With regard to years of experience. We obtained the most answers from driving instructors having over ten years of experience, but instructors with less experience were also represented in our sample.

There was some variety in car energy source and transmission. Hybrid and electric cars all have automatic gearing, and these two made together up for 34.8%, The use of fossil fuel, combined with manual gearing, was most represented. With regard to technology integrated into the car, ABS and ESP were reported to be present in almost every car, while lane keeping assist, adaptive cruise control, and touch screen were present in over 70% of the cars.

Most of the instructors reported that they either to some or to a high degree taught the students about ABS and ESP in theoretical classroom instructions prior to driving (Table 2), while they to a lesser degree did the same for LKA, ACC and touch screen. After moving instruction inside the car, still prior to driving (Table 3), there were a high degree of instructors not choosing to introduce the student to the technology of the car within that setting.

With regard to the use of technology during driving instruction (Table 4), especially ABS and ESP were used by a majority of instructors, while LKA, ACC and touch screen were used to some degree or not at all for the most part of instructors.

Looking at the instructors who reported to use specific technology during driving, there were some of them that did not provide students with prior instruction (Table 5). Although this group constitute a minority of instructors.

Table 3 Instruction about technology provided by the instructors ($n=333$) inside the car prior to driving

Technology	Not at all *n*(%)	Some degree *n*(%)	High degree *n*(%)
Anti-lock braking system	113 (33.8)	150 (45.2)	70 (21.0)
Electronic stability programme	120 (35.9)	148 (44.3)	66 (19.8)
Lane keeping assist	169 (50.6)	132 (39.8)	32 (9.6)
Adaptive cruise control	158 (47.3)	130 (39.2)	45 (13.5)
Touch screen	126 (38.3)	141 (42.9)	62 (18.8)

Table 4 Use of technology during driving instruction (in car during driving)[1]

Technology	Not at all *n*(%)	Some degree *n*(%)	High degree *n*(%)
Anti-lock braking system	40 (12.0)	185 (55.4)	105 (31.4)
Electronic stability programme	61 (18.3)	179 (53.6)	88 (26.3)
Lane keeping assist	142 (42.5)	130 (38.9)	52 (15.6)
Adaptive cruise control	130 (38.9)	145 (43.4)	54 (16.2)
Touch screen	131 (39.6)	143 (43.2)	25 (7.6)

[1] Due to some respondents answering "unsure", the percentages on each category does not equal 100 on these variables

Table 5 Use of included car-technology during driving without having been given prior instruction

Technology	No use *n*(%)	Some use *n*(%)	High use *n*(%)
Anti-lock braking system	13 (3.9)	9 (2.7)	4 (1.2)
Electronic stability programme	11 (3.3)	12 (3.6)	4 (1.2)
Lane keeping assist	29 (8.7)	12 (3.6)	4 (1.2)
Adaptive cruise control	36 (10.8)	10 (3.0)	1 (0.3)
Touch screen	19 (5.7)	3 (0.9)	0

5 Discussion

This paper presented the status quo of driving instruction and use of the driving assist technologies ABS, ESP, LKA and ACC, in addition to touch screens. This overview further shows the variation in the types of cars that are being used in driving schools and the variations in how instructors present driving assist technologies to their students, if at all. The research question was: *Does the Norwegian driver training industry teach advanced driver assistant technology (ADAS) and touch screens in their driver training?* The results showed that there were several areas that need closer attention, and ultimately change, to ensure safer traffic conditions on Norwegian roads.

As for the driving assist technologies, it is worth differentiating between the ones that must be included in the learner drivers' theoretical and practical training as opposed to the ones that suffice to be part of the theoretical training. One way to approach this is to consider features that are automatically in use in the cars, such as ABS and ESP, that are activated. Other features, such as ACC and LKA, are ones that can be activated or deactivated and require human intervention. According to our results, a large percentage of driving instructors in Norway do not teach interaction with ACC and LKA or only do it to a small degree. This will increase the chance that the learner driver is out of the loop regarding awareness of the situation (Endsley 2017; Di Flumeri et al. 2019).

The results showed that instructors give instruction about the technologies outside the car prior to driving, which is mainly theoretical in a classroom setting (see Table 2). Here, 40.8% and 41.1% gave instruction on ABS to a high and to some degree, respectively. High degree percentages were 36.3% for ESP, 11.1% for LKA, 16.8% for ACC, and 15% for touch screens. Some degree percentages were 44.4% for ESP, 44.4% for LKA, 42.6% for ACC and 42.9% for touch screens. There was also a gap in technologies that are not taught at all prior to driving, with ABS and

ESP both under 20% and ACC, LKA and touch screens all over 40%. In regard to a more practical approach, which is seen in Table 3, where the instructors teach technology inside the car prior to driving, and in Table 4, which is concerned with the use of technology while driving, the results showed the same tendency with a higher focus on ABS and ESP and less on LKA, ACC and touch screens. According to research on human technology interaction, it is very important that humans have exposure to technologies that are more demanding in cognitive load so that they develop more accurate mental models and gain control (Le Goff et al., 2018; Westbrook 2006). At high speed, ACC, LKA and touch screens are more taxing on cognitive resources as they may not be aligned with drivers' expectations, while ABS and ESP require less human intervention and attention. Thus, the fact that the main focus of instruction is devoted to ABS and ESP rather than ACC, LKA and touch screens points to a potential safety gap in driver training.

According to Table 5, ABS and ESP were used during driving without the instructor teaching about prior to driving. This indicates that the learner driver needs these technological solutions in order to prevent unwanted incidents and potentially accidents, as these are technological solutions that are activated when the car's behaviour is out of the safe range. Another aspect in regard to this table is that learner drivers seem not to be taught about critical technologies such as LKA, ACC and touch screens, and the majority of these learner drivers do not use them during driving either. This means that learner drivers probably lack knowledge of these technologies when obtaining their licence.

5.1 How to make driver training safer

5.1.1 Update driver training

The technologies that were taught most thoroughly (see Tables 2, 3 and 4) by the instructors were ABS and ESP, which is probably due to the fact that these two have long been a significant part of the educational system at the largest driving instructor educational institution in Norway (Nord, 2023). However, learning how a car moves with or without inbuilt systems, rather than technology a driver chooses to use, may not be optimal knowledge for learner drivers. According to research on human–machine interaction, learning how to interact with semi-automated technology (Bianchi-Piccini et al. 2015; Manser et al., 2019), build good mental models (Endsley 2017; Westbrook 2006) and optimal levels of trust (Ma et al. 2020; Sætren et al., 2015), bears important safety consequences. Yet ACC, LKA and touch screens reportedly had less focus. With an increase in newer cars (SN, 2023b), there is likely to be more updated technology in the cars on the roads, and thus it is increasingly important to know how to interact with this technology as safely as possible. Our first suggestion is thus to focus more on automatic technology used at high speeds that the driver interacts with.

Even though there is a large number of cars with automatic transmission in Norway, 44% of driving instructors reported (Table 1) that they teach manual gearing as they mostly use manual cars. Manual gearing takes cognitive and motoric workload from the driver that is not necessary. Thus, it is questionable as to why this is so common in the driver training industry. If one obtains a licence for a manual car, one is allowed to drive both manual and automatic, and if one obtains a licence for an automatic car, one can only drive an automatic. Further, since increasing numbers of cars in Norway are becoming automatic, and the tendency is that young people prefer automatic, the driver training industry might adapt to this trend. It does, however, require fewer lessons to teach automatic compared to manual, which might be a reason the industry still uses manual – they make more money from manual licences than from automatic ones. However, this can be compensated by investing in teaching learner drivers about technology use and its limits. Competition and economy play a part in this industry (Sætren et al. 2020). Our second suggestion is thus for the industry to focus more on automatic gearing and its benefits, rather than on manually geared cars.

The driver training system seems to make it necessary to bring about changes and adaptations in the regulations in order to meet new competency requirements for car drivers (Helde 2019). Driver training that gives future drivers sufficient knowledge of driver support systems is important, so that every motorist can drive carefully and minimise the risk of injuries and fatalities. Thus, our third suggestion is that the law and regulations should be updated.

In Norway, it is the Norwegian Public Roads Administration (NPRA) that is responsible for the curriculum in regard to driver training (NPRA, 2017). This curriculum is rather vague when it comes to the teaching and training of technology, as instructors have reported in previous research (Wigum and Sætren 2022). Incorporating education of these features into formal theoretical and practical training seems beneficial. For this reason, our fourth suggestion would be for the NPRA to make the necessary adaptions to the curriculum, which is the tool driving instructors use for their teaching.

The workload increases with lack of knowledge and experience with semi-automated technology (Banks and Stanton 2017), and there should be research conducted as to how a driver training system should expand in order to include sufficient training (Sætren et al. 2018a).

5.1.2 Update education and training for driving instructors

A question that needs to be considered is whether the educational institutions for driving instructors have the optimal educational system for automated technology. Instructors need updated knowledge and skills regarding how to teach new features and technology, but there are no places where such knowledge is accessible to instructors so they can get such updated training themselves (Nord, 2023; Wigum et al. 2023). Thus, the first suggestion is for the educational system to provide courses to update knowledge and skills.

Further, an authorised driving instructor in Norway is not obliged to take any courses after completing their education. Thus, it is not mandatory to keep skills and knowledge updated within the driver training industry. A second suggestion could thus be to make changes in the educational system for driving instructors to receive mandatory training within a certain time period in order to keep their authorisation.

Another aspect is that the vast majority of driving instructors in Norway are educated at the same educational institution (see Table 1). This is because this institution has been the main source of education for driving instructors in Norway since 1973. This institution developed first as a high school, then from 2004 as a college and from 2016 as a university. This means that driving instructors educated prior to 2004 had a three-year high school education, between 2004 and 2016 had a two-year college education, and from 2016 onwards, a two-year university education. Additionally, such a monopoly of educating driving instructors has both downfalls and benefits; in this case, however, it might seem that if the competence is lacking there, it will potentially also lack throughout large parts of the Norwegian driver training industry. Furthermore, at Nord University, there is a strong focus on educating future driver instructors on how to teach manual gearing. A suggestion is thus to assess whether some of this effort could be transferred to educate how to teach new technology and automatic gearing. Driving instructors could perhaps have the same differentiation in their authorisation as in the licences regarding authorisation to drive manual or automatic gearing.

It seems of importance to train driving instructors on understanding the benefits of using updated automated technological features (Manser et al., 2019; Bianchi-Piccinini et al., 2015). If instructors project a negative view towards the use of driving assist systems, learner drivers might feel discouraged from even exploring these features, thinking they are a sign of weakness.

A way of incorporating ACC, LKA and touch screens into formal, safe training could be to use simulator training where drivers have a chance to familiarise themselves with these features in a safe context. Benefits of using simulator training are inclusion of different technological solutions for various scenarios, resource efficiency, and the fact that it is an environmentally sustainable way of training and iteration (Sætren et al. 2018a; Sætren, Birkeland et al., 2019a; Sætren, Lindheim et al., 2019b; Sætren, Wigum et al., 2019c; Sætren et al. 2020a, b, 2021). A suggestion is thus to use simulators as a training method both for learner drivers and driving instructors.

5.1.3 Testing, instructing and design

It is important that the NPRA establishes clear guidelines for the use of driver support systems during driving tests, as the test makes directions for the training (Sætren et al. 2019; Sætren et al. 2020a; Sætren, Bogfjellmo, et al. 2020b). In addition, having differentiated licences by codes that indicate which knowledge and skills the driver has in regard to which technology they should be allowed to drive could be another suggestion.

Further, driving instructors buy their cars from manufacturers, and one idea is that training requirements directly from the manufacturers and car dealers could be regulated (Sætren et al. 2018a). As technology today is far from standardised, there is vast variation for the driver trainer industry to cope with. Car suppliers and dealers could be held responsible for training their particular driver support systems. A useful development in road traffic safety could be to create a database where it would be possible to enter a car model and get information and online introductory video trainings on which driving assist features are available in that specific car model, where to locate them and how to use them safely.

Car design is also up for discussion. As of now, according to § 6 in the Road Traffic Act, with associated regulations (Lovdata, 1965), the driver must always 'have full control over the vehicle'. This is subject to interpretation. Furthermore, technologies that partly take over control of the vehicle, such as ACC and LKA, or technologies that take attention away from the traffic situation, such as touch screens, are not mentioned. It is a paradox that the law states that the driver must always be in control of the vehicle, but the design of modern vehicles forces the driver to attend to devices inside the car without tactical cues, thus taking their eyes off the road. The laws need to take technological advancements into account and be updated accordingly.

In Norway, learner drivers receive formal training on safety and what could cause an accident. Distraction by gadgets for example, and overtrust in one's illusion of control are among the most common causes of accidents. However, distraction caused by touch screens is not emphasised enough. There is a context in which the use of a touch screen during driving is inevitable. The safe use of the touch screen and being cognisant about not losing situation awareness while navigating the touch screen should be brought further into the light. This is not just crucial for driving training but also has significant design implications for car manufacturers. It is not necessary to compete over the aesthetic design of touch screens with features that are not necessary or that could even cause distractions and accidents. It is crucial, however, to design these interfaces in a way that facilitates safe navigation with minimum need to process information and being 'away' from the primary task of driving.

6 Conclusion

Regarding the answer to the research question '*Does the Norwegian driver training industry teach advanced driver assistant technology (ADAS) and touch screens in their driver training'*, the Norwegian driving instructor industry does teach technology, but it seems that it is more eager to teach inbuilt technology that the driver does not need cognitive workload for, such as ESP and ABS, rather than technology that increases the risk of accidents if it is not understood well, such as LKA, ACC and touch screens. With more advanced cars and technological features, we must make a shift from traditional approaches to driving and adapt to evolving trends. Trainings should adapt and evolve at the same time. The more training and exposure learner drivers have with the use of human–technology interactive systems, the more accurate their mental models will be, leading to better control of the vehicle and safer driving manoeuvres. Therefore, the incorporation of technology use into formal driving education is the way forward.

6.1 Implications and further research

The areas that need closer inspection include the driving assist technologies, the safe use of touch screens while driving, incorporation of technology assist features in the formal training of driving students and the legal implications for car manufacturers, dealers, driving schools and driving instructors.

From the scientific research perspective, there is a huge amount of research that focuses on automation and autonomous systems, especially on autonomous vehicles. This research is, however, mostly focused on the design of technology and the design of transparency for the driver, passengers and pedestrians. However, there is a clear gap in the literature regarding training programmes for new drivers both prior to and during driving lessons. Education on driving is not aligned with technological advances for driving. Furthermore, most technological advancements are tested on users that have expertise and can provide feedback. There is not a clear overview, however, on the extent to which novices are being used as test users for human–automation interactive systems. Research can shed light on the necessity of using novice test users for such systems as well as expert ones to see if there is a need to expand test users' range. In addition, more research is needed to evaluate driving training practices and to investigate the alternatives and alterations that can make such training even more effective with regard to technological advancements.

From the practical perspective, it is important to collect statistics on the number of accidents that might have been caused by technology assist malfunction or misuse. If the numbers meet a certain threshold, action must be taken to incorporate these formal trainings on technology assist features in the broader education programme of driving schools. From the legal perspective, it is crucial that the regulatory bodies and the car industry collaborate to determine the best way to offer trainings to drivers before they can be held accountable for technological malfunctions or unintentional misuse. In addition, initiatives must be taken by driving schools to evaluate the best way they can prepare their learners for technology use while driving. As important as a top-down approach by regulatory bodies is, it is also important to take an immediate bottom-up approach and investigate what learner drivers and their instructors think is the best way to learn about and use these features safely. Therefore, research and practice must join forces to create a safer driving experience for all road users.

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Declarations

Competing interests The authors declare no competing interests.

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