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AUTOMATED DRIVING SYSTEMS: COMPARISON OF TRAINING METHODS' EFFECTIVENESS

Summary. The second decade of the 21st century saw the introduction of vehicles equipped with various driver assistance systems. However, the producers' plans go much further. In January 2023, Mercedes-Benz's DRIVE PILOT system was approved for use on public roads in Nevada (United States) as the first and so far only SAE Level 3 series-production solution. Despite increasing automation, the human factor remains important for the safety and efficiency of road transport. In the coming years, and possibly decades, this will mainly be due to the co-existence of vehicles with varying degrees of automation and necessary driver-vehicle interactions in cases where an automated driving system crosses the boundaries of the operational design domain. The latest research reveals the limitations of driving assistance systems, pointing not only to the need for changes in the technological domain but also to the need to pay more attention to the psychological aspects of using assistance systems in cognitive and behavioral areas. Therefore, an additional element of automation implementation should be considered, which is driver training focused on modern technological solutions. Properly arranged and conducted training can be treated as an additional factor facilitating the implementation of automated mobility. The article describes the methods of assessing the effectiveness of training in terms of familiarizing drivers with the functions that automate driving. The authors present the results of tests carried out on a driving simulator with an implemented Level 4 system (according to SAE classification). Three forms of knowledge transfer were analyzed: practical training, e-learning, and training with a short user manual. The results were compared in terms of driver-vehicle interaction effectiveness (e.g., system activation), ensuring that the driver is sufficiently reactive in dangerous situations and understands the limitations of the system. The research was conducted on a group of 81 drivers aged 18–65. Driver training was one of the main pillars of the Trustonomy project, which received funding from the EU research and innovation program Horizon 2020 under grant agreement No. 815003.

1. INTRODUCTION

In 2010, the EU established a goal [9] to reduce the number of road fatalities by half in 10 years, compared to the 2010 level. The report of the European Road Safety Observatory (June 2020 [10]) and the observed trend showed that, despite introduced regulatory changes (technical requirements, stricter laws, etc.), the EU 2020 target was not achieved. In 2021, the number of deaths dropped by 62% compared to 2000 and by 30% compared to 2010.

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The results show that drivers need an additional stimulus to further reduce the number of accidents on European roads. Therefore, consideration should be given to other forms of ensuring road safety than the introduction of additional restrictions. This can be done, inter alia, through the evolution of driver training systems. Innovative training, adapted to the current standards of the automotive market (relating to driving automation systems, various human-machine interfaces, etc.) is an extremely important topic for increasing road safety.

This matter was recently analyzed by the US-sponsored Safe-D project [18, 23], which aimed to develop training protocol guidelines dedicated to the professional trainers of advanced driver-assistance systems. The guidelines were designed using findings from three endeavors: the creation of a taxonomy outlining knowledge and skills, a driving simulator analysis assessing traditional training methods' efficacy, and a test track investigation evaluating the effectiveness of a vehicle-based training approach. The results of this research show that training protocol has a differentiated impact on performance and attention allocation in relation to advanced driver assistance systems (ADASs). The collective findings indicate that a single approach to ADAS training protocols lacks effectiveness. Instead, ADAS training protocols should be customized according to distinct driver demographics. Nonetheless, research has shown that behaviors and attitudes significantly impact one's experience with driving automation systems. However, the newly developed protocol for the trainer was not tested in a driving simulator. Therefore, it was not possible to test potentially dangerous situations. For this reason, it seems reasonable to develop and test full automation-related driver training curricula, including materials dedicated to specific systems and manufacturers.

In March 2020, the Association of Australian and New Zealand Road Transport and Traffic Authorities, Austroads, published a report [3] examining a light and heavy vehicle licensing system in the scope of suitability for L0-L3 automation levels according to Society of Automotive Engineers (SAE) [29]. The authors pinpointed the competencies and understanding necessary for current and future drivers to operate vehicles equipped with driving task-supporting and automating technologies. The research shows that consumers, both nationally and internationally, possess a strong awareness of ADAS technologies. However, their knowledge about the limitations of these systems is deficient. Whilst there are many modes of information delivery for first owners, there is hardly any online information for subsequent vehicle owners to learn about ADASs or automated driving functions (ADFs). According to the survey conducted by Connecting Mobility [6], just 24% of business drivers were given instructions on how to use their ADASs at the car dealership, whereas around half (47%) discovered the functionality of their ADASs through trial and error while driving. This results in an increased number of accident-prone situations.

This, in turn, is one of the early lessons of the Polish Motor Transport Institute’s project AV-PL-ROAD. According to the research, users had no knowledge of modern systems and, therefore, could not react properly. Although the majority of on-road research participants consider themselves good drivers with deep knowledge of assistance systems, only a small number of them were able to properly cooperate with the system to ensure road safety.

Therefore, many national and international organizations have made attempts to raise awareness of the responsibility of driving a featured vehicle [11]. For example, the Dutch Safety Board warns of the need to treat technology and human aspects equally. In February 2020 [8], they provided the United Nations with recommendations to advocate for the initiatives of Euro NCAP to incorporate human factors and consumer information regarding the integration of ADASs into the vehicle safety evaluation (Euro NCAP star system) and to pay more attention to the implementation of human factors and user training-related standards.

The number of crashes involving automated vehicles is also interesting for insurance companies. According to the Insurance Institute for Highway Safety [14], when properly used, forward collision warning systems reduce front-to-rear collisions by 27%. However, the number of such collisions almost doubles if the system incorporates automatic braking functionality. Moreover, rear automatic braking reduces collisions from the back by a substantial 78%. Therefore, Bluedrop [19] states that both dealerships and manufacturers take responsibility for educating fleet managers and drivers, as this is essential for increasing awareness of the proper use of technology.

Also, Japanese scientists Ogitsu and Mizoguchi [24] noted that due to the increasing complexity of driver assistance systems, drivers need a different skill set than before. The greater the complexity of driving interactions that ADASs can handle, the higher the risk the system might create if utilized by drivers lacking adequate understanding of its functionalities. Thus, they decided to build a driving simulator dedicated to ADAS education. However, they put much emphasis on the need to train drivers.

The Motor Transport Institute followed this path and took part in aDrive project, which provided a safe environment for testing driver-vehicle interaction with ADASs and automated driving systems. The simulator can be further developed in order to be compliant with recent advancements in the automotive industry, thus making the tool suitable for driver training purposes.

The National Association of City Transportation Officials reported [22] that virtual reality devices may also be beneficial. These tools support drivers in applying acquired knowledge within simulations replicating the visual, manual, and cognitive demands of driving situations related to Automated Emergency Braking system or other safety technologies. Such training schemes have proven effective, requiring minimal time (an hour or less) to conduct and demonstrating a notable reduction in accidents.

Importantly, a study conducted in the United States [1] revealed that most participants found a test drive with instruction while driving to be the most beneficial form of training.

Of note, driver training programs should not solely target new drivers or individuals purchasing new vehicles from dealerships. Instead, the training should be customized to suit the particular vehicle, support system version, and the participant's level of experience and understanding. The training should be easily accessible and attainable for drivers who have not used modern technology before but want to learn about the method of operation due to the need to replace their vehicle or acquire knowledge. At the same time, it should be noted that training with the use of a modern driving simulator allows for increased immersion and, thus, more effective training. Additionally, only such an environment allows for safe testing of potentially dangerous maneuvers without the need to endanger the trainee or trainer while maintaining the feeling of real driving.

2. HOW TO MEASURE TRAINING EFFECTIVENESS

When delivering training, regardless of its type and content, there are several questions that have to be answered in order to assess its impact on participants:

- How effective was the training in helping trainees gain relevant knowledge and skills?
- Were the trainees able to apply what they learned to improve their performance?
- What other benefits did the training achieve?

The answers to these questions help to determine whether the training was worth the investment, but providing these answers requires measuring the outcomes. This process may sometimes be very complicated, especially when assessing the effectiveness of driver training.

There are two types of measures necessary to provide a good insight into a driver's performance: objective and subjective. The first category includes human- or vehicle-related measures, and their collection requires the use of special equipment (e.g., simulators or dedicated on-board systems in real vehicles). The second category relates to the feelings of the participant and the independent expert, who may also be the experimenter. Both of these methods are presented in the following subsections.

2.1. Objective assessment

The practical part of the driver training or practical skill assessment can be conducted either using a **simulator** or a **real vehicle**. In scientific investigations, simulators offer a distinct advantage, as they allow for the recording of numerous physiological variables in a relatively controlled and safe environment. Among them are ocular, cardiovascular, and skin-galvanic response indicators. Consequently, research conducted on simulators facilitates data definition, acquisition, and management. However, it is worth mentioning that only a few training centers have the financial means to purchase simulators. As a result, only the initial trials of the novel curricula were carried out using a simulator.

In both research and training, simulator sickness is nearly unavoidable when using simulators [4]. This condition arises when information from all senses involved in spatial orientation and movement perception differs from one's prior experiences. When individuals engage in tasks within a new environment, the movement information patterns established previously are said to remain in conflict with those presented in the simulator environment. The incongruity between the current sensory input and the focus of the participant's perception system results in simulator sickness.

Therefore, one's feelings have to be monitored in order to lower the influence of a simulator sickness on a gathered dataset. For the purpose of detecting early symptoms of the disease, a simulator sickness questionnaire (SSQ) was used. This subjective tool assesses the severity of [4] salivation, sweating, nausea and stomach discomfort, tiredness, headache, eye strain, difficulty concentrating, dizziness, feelings of intoxication (with both eyes open and closed), and blurred vision. People identified with SSQ should be excluded from a study. It should be also noted that prior to test drives, it is necessary to conduct an adaptation drive in order to get participants used to the tool itself, which differs from an ordinary vehicle.

There are several methods to assess the driver training impact. Most of them are used to evaluate drivers' performance and may be a part of a decisive algorithm or module (e.g., DIPA module [26]). These objective human- and vehicle-oriented measures are based on time, sight, number of attempts, or intervention accuracy, and they allow evaluations of whether the behavior before and after training is different. For this purpose, the authors of the paper suggest using the following measures in order to assess the impact of driver training on driver performance:

- activation time – the time between system start-up command and full system activation (in this period the driver must perform the appropriate actions to activate the system); these measures can be sub-divided depending on the system operation principle and a sequence of actions required to fully engage the automation mode, for example:
  - response time from the message to clicking the button,
  - response time from clicking the button to taking the feet off the pedals and hands off the steering wheel,
  - total response time from the command to removing the feet from the pedals and hands from the steering wheel (full return of control/full system activation),
- number of attempts to activate the automation feature – how many times the driver tried to engage automation before managing to do it,
- reaction time – a period between a request to intervene (RtI – a command to retake manual control over the vehicle) and driver action leading to system deactivation (e.g., pressing the brake pedal),
- the area of interest (AoI) of the driver's sight in the event of a request to intervene (RtI),
- reaction accuracy in bad weather conditions – how the driver reacted to an unfavorable weather change (possible false sensor readings resulting in the incorrect operation of the driving automation system).

2.2. Subjective assessment

The perceived view of drivers' abilities can influence their behavior. According to research conducted at the University of Alberta (US), a lack of self-confidence in performing a given task or activity seems to result from overestimating the abilities of others. This group, apart from being underconfident in their abilities, had a solid understanding of their performance, expected more from their competitors, and performed better than average. Contrary to this, individuals who tend to overestimate their abilities usually perform worse than average [5]. The study performed by Anna Sundström showed that most drivers perceive themselves as possessing greater skills than the average driver [30]. Additionally, as found by Hassan et al., self-reported proficiency in driving shows a positive correlation with aggressive driving indicators because drivers who have greater confidence in their driving abilities tend to show more aggressive driving behaviors [13].

Therefore, the phenomenon of drivers overestimating their skills often leads to bravado, which is one of the main factors causing road accidents [17]. It occurs most often for young drivers aged 18–24. This group has the highest death rate per 1 million people. Young drivers are most often characterized by high self-confidence, faith in their abilities, the need to impress others, the need to seek sensations, and a lack of experience, which often leads to the incorrect judgment of situations [30, 12, 21, 16]

On the other hand, some drivers underestimate their skills, which makes them drive slowly and unconfidently, which can also cause dangerous situations, especially in heavy traffic. Therefore, it is necessary to assess the driver's skills both by an experienced trainer and by the trainee himself. The subjective assessment of the trainer—a person who, apart from the assessment of human-vehicle cooperation, will be able to assess the driving style and its adaptation to the prevailing conditions. This approach allows a person to get a full picture of the driver's skills and will allow them to pay special attention to mistakes made and elements that need to be repeated. Thanks to this, the training will be more tailored to the needs of a specific user. This approach also allows for a reduction of the need to implement additional research equipment by partially replacing it with qualified coaching staff.

To accurately validate the skills and competencies of the driver, both the trainer and the test person should evaluate the same factors. Among them, the following can be distinguished:

- driver's performance,
- difficulty level of system activation, operating, a proper understanding of system messages (including a request to intervene), control transition, reaction time,
- adaptation time (before the driver feels comfortable)
- overall evaluation of skills and competencies (according to the system's operation).

A scale from 1 to 5, where 1 is the lowest rating and 5 is the maximum rating, may be used. Completion of the surveys should take place right after the drive to ensure the most reliable assessment.

In order to properly match both the training materials and the training form, it is recommended that a trainee evaluate the training. The survey should contain questions about:

- training form, materials, content,
- comprehensibility,
- training duration,
- usefulness, possible impact on road safety,
- overall satisfaction,
- recommendation to others.

3. METHODS

This paper includes a review of the literature in order to identify studies related to the use of automation in driver training and possible ways to transfer automation-related knowledge. With the advancement of vehicles, there has been an increased emphasis on driver training, but no consistent roadway was driven towards fulfilling the gap in driver abilities. Legal regulations are missing to expand curricula to encompass issues related to ADASs. While there are numerous guidelines for teaching electrification, very few efforts have been made to address automation (a comparison of ADAS technologies available during driver's license exams is presented in [27]).

This article is based on a comprehensive analysis conducted by Trustonomy project partners. A group of researchers, professional driving technique trainers, and manufacturers with backgrounds in different driving platforms (passenger cars, trucks, and public buses) analyzed the skills and knowledge necessary to safely drive a modern vehicle.

3.1. Research group

A total of 87 participants selected by the external recruitment entity took part in the research. However, only 81 of them completed the study successfully (six people were excluded due to experiencing simulator sickness or quitting the experiment). Sixty-one of them took part in the first iteration, while 20 additional people were tested in the second round of trials.

Participants were persons who:

- have been issued a category B (passenger cars) driving license,
- have at least six months of experience in driving a motor vehicle,
- regularly drive motor vehicles under their license;
- do not have experience or have little experience (max. two hours) in driving a vehicle with driving assistants, in particular with an active cruise control and lane-keeping system.

The study was conducted on a group of 81 adults who were a representative sample of B-category drivers in Poland. All of them were issued driving license category B (mandatory). Some of them had also category A (motorcycles 4; 4.9%), C (truck of 3500 kg and more with a trailer up to 750 kg maximum authorized mass 3; 3.7%), and D (bus with 8+ passenger seatings with a trailer up to 750 kg maximum authorized mass 1; 1.2%). Note that categories C and D are required to pass the psychomotor reaction test prior to obtaining a license. These categories are for professional drivers. The perticipants represented two age groups: young and middle-aged drivers (27–39 yo) and mature drivers (40–65 yo). Each group consisted of about 40 individuals with a slight predominance of the older group (53%). The mean driver age was 42 years. A gender balance was also ensured, as 41 (50.6%) women and 40 (49.4%) men participated in the research (Fig. 1). When it comes to education level, all of the respondents were high school level (32, 40%) or higher (university degree 43, 53%; university (not finished) 6, 7%).

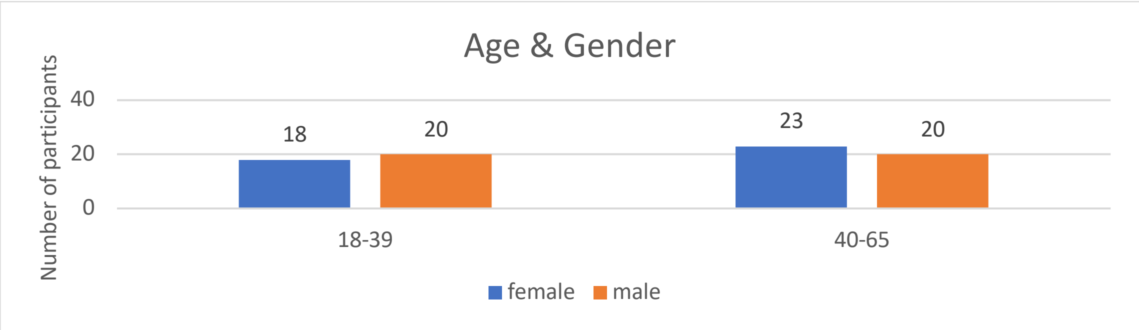

Fig. 1. Gender distribution in age group

Of the participants, 68 (84%) claimed to drive several times a week or every day (Fig. 2). There were only a few respondents who stated that they drive very rarely (several times a year). However, even they claimed to drive around 250 km per month.

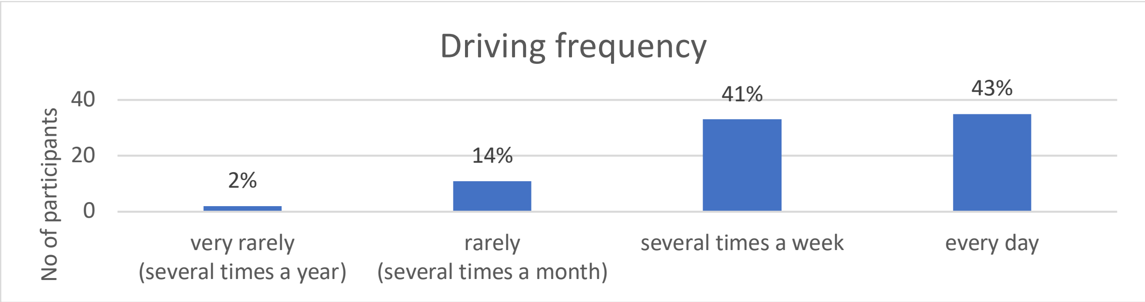

Fig. 2. Participant characteristics: driving frequency

The most frequently given answer to the question about driving hours is one to three hours per day (64%). On this basis and considering the results of the question about the frequency of driving and the distance traveled monthly, it can be concluded that among all respondents, one traveling model dominates: commuting to the place of employment.

Participants were divided into three groups of 27 people each. There were three training types; all of them presented the same information differently, but the scope remained the same.

3.2. Tools

The tests took place in the Institute's laboratory, on a driving simulator owned by ITS. AutoSim AS 1200-6 is a high-class passenger car driving simulator. The extensive software allows for the projection of many different objects and imitating driving in various weather and road conditions, such as rain, wind, snow, road with reduced grip, fog, night or day, in any combination. It is also possible to simulate some types of vehicle breakdown (e.g., a flat tire or a damaged brake system (not used in this research). The simulator is built from a full-size and fully functional Opel Astra IV cabin, visualization system, and 6-DoF motion platform. The simulator is equipped with an automation system called Highway Chauffeur (L4 according to SAE), which controls vehicle speed, position in lane, and gap to other road traffic participants, but it may request the driver to regain control once the system reaches its operational design domain boundaries

The simulator is equipped with Smart Eye Pro, a head and gaze tracking system that measures the subject's head pose and gaze direction in 3D. It also provides information about eyelid opening values and pupil dilation.

3.3. Research procedure

As shown in the figure below (Fig. 3), each participant had to complete preparation activities including consent and the 1st block of questionnaires (pre-training knowledge test, characteristics survey), an adaptation drive, training in the use of automation, then a test drive and the 2nd block of questionnaires. The training could be conducted with the use of an e-learning course (developed in the project) by reading a short one-page user manual or in a practical form on the simulator. In total, one participant had two or three simulator rides and three or four SSQs (proving well-being and the ability to continue simulator research).

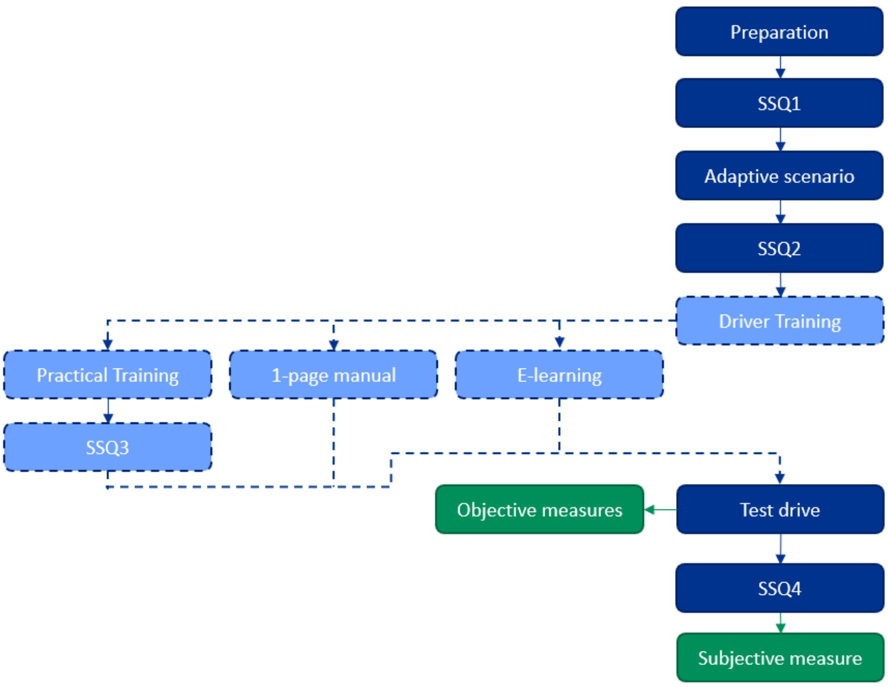

Fig. 3. Diagram describing the research procedure

The test drive scenario was implemented in a simulated environment. It was used to collect data in order to evaluate the results of driver training and validate the training curricula. The scenario concerned a drive on an expressway (motorway) with accompanying traffic, changing weather conditions, occurring events requiring the driver's reactions (both with and without a request to Intervene; RtI), and constant time budget.

Test drive scenario:
1. normal driving – participant asked to turn on automation mode, change to the middle lane, and set the speed to approx. 100 km/h,
2. crash event in front – RtI issued, the participant should regain control and avoid an accident (if no actions are performed the vehicle crashes),
3. normal driving – participant is again asked to turn on automation mode, change to the middle lane, and set the speed to approx. 100 km/h,
4. crash event in front – RtI issued, the participant should regain control and avoid an accident (if no actions are performed, the vehicle crashes),
5. normal driving – participant is again asked to turn on automation mode, change to the middle lane, set speed to approx. 100 km/h,
6. reduced visibility (fog) – no RtI, the participant should retake control due to system limitations (situation discussed during training),
7. normal driving – participant is again asked to turn on automation mode, change to the middle lane, and set speed to approx. 100 km/h.

4. RESULTS

4.1. Activation time

First, the analysis covered the driver's reaction time to a request to turn on the automation system. For this purpose, three parameters were measured:
- **_KLIK:** response time from the request to turn automation on until clicking the green (activation) button,
- **N+R:** response time from clicking the green button until lifting one's feet off the pedals and hands off the steering wheel,
- **_TOTAL:** total activation time from the announcement (request to turn on the automation system) until removing the feet from the pedals and hands from the steering wheel (full control transition from manual to automated mode).

_KLIK results:

Situation 1: According to the results (Kruskal-Wallis test for independent samples with pairwise comparisons due to skewness or elevated kurtosis of distributions for reaction times), there were significant differences in response time from the message to pressing the green button in seconds in groups differentiated based on training type (practical, e-learning, manual), $H(2) = 8.34$, $p = .016$. Tests of pairwise comparisons showed that participants in the practical training group showed faster reaction times in comparison to the "manual" group ($p =.017$). One person was excluded from the analysis (the participant turned on the system before being asked to do so). There were no significant differences for situations 2 and 3.

_N+R results:

According to the results (Kruskal-Wallis test for independent samples with pairwise comparisons due to skewness of distributions for reaction times), in situation 1, there were no significant differences in response time from clicking the green button to taking the feet off the pedals and hands off the steering wheel in seconds in groups differentiated based on training type (practical, e-learning, manual), $H(2) = 4.34$, $p = .109$. Similar results were observed in situations 2 and 3 (no significant differences).

_TOTAL results:

According to the results (Kruskal-Wallis test for independent samples with pairwise comparisons due to skewness of distributions for reaction times), **there were significant differences** in total activation time measured from the announcement to removing feet and hands from the steering tools (full control transition from manual to automatic mode) in seconds in groups differentiated based on training type (practical, e-learning, manual), H(2) = 10.41, p = .005. Tests of pairwise comparisons showed that participants in the practical training group showed faster reaction times in comparison to the "manual" group (p =.010) and e-learning group (p = .023). One person was excluded from further analysis (the participant in the study turned on the system before being asked to do so).

Contrary to this, in situations 2 and 3, **no significant differences** were observed in total activation time in groups differentiated based on training type, (situation 2: H(2) = 0.55, p = .760; situation 3: H(2) = 0.96, p = .620).

In the fourth situation, dedicated to testing drivers' reactions to changing weather conditions, participants again **showed statistically significant differences** in total reaction time from the request to remove the feet from the pedals and hands from the steering wheel in seconds, H(2) = 6.15, p = .046. The practical group showed faster reaction times in comparison to the manual group, p = .044.

Age and gender did not predict driving performance in relation to the training course. According to Spearman's rho correlational coefficients, only higher education coincided with shorter response time and only in situation 3 (_N+R).

4.2. Activation attempts

In situations 1 and 2, **there were significant differences** in the number of attempts to start HC in groups differentiated based on training type (practical, e-learning, manual). In both cases, the lowest number of attempts was characteristic of the "practical" group (Fig. 4). There were no significant differences for situation 3. This may be considered normal because the trainees had been given the opportunity to practice during earlier attempts.

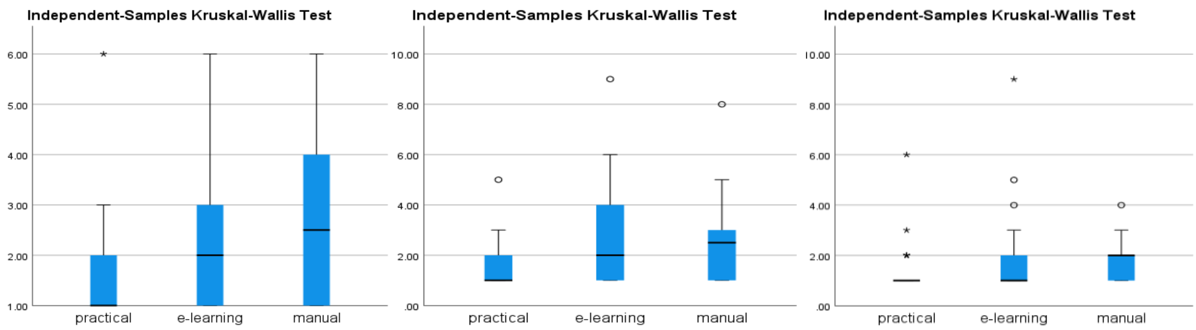

Fig. 4. Number of attempts to activate HC (from left: situations 1, 2, and 3)

4.3. Reaction time

According to the results (Kruskal-Wallis test for independent samples with pairwise comparisons due to the skewness of distributions for the number of attempts), there were significant differences in average reaction times for all three situations taken together in groups differentiated based on training type (practical, e-learning, manual), H(2) = 9.66, p = .008. Reactions in the "practical" group were faster in comparison to the "manual" group, p = .008.

Tab. 1 presents a comparison of mean reaction times in scenario A for all 3 RtI situations. The difference between situations 1 and 2 is 0.853 s, while the difference between situations 2 and 3 is 0.2468 s. This means that the reaction time differs between the first and last RtI by 1.0998 s. Taking into consideration the set speed (approx. 100 km/h), the traveled distance changes by 30 meters.

4.4. Reaction accuracy in bad weather conditions

In the last driving situation, a driver should take control of the vehicle even if there is no request to intervene signal. It has been observed that, even though all three types of training highlighted the issue and suggested taking control in severe weather conditions, the number of correct reactions in foggy conditions was statistically less frequent in comparison to wrong reactions. However, the study showed that training type was a statistically significant predictor of correct reactions. In total, 21 participants reacted and took manual control. Only two of them underwent "manual" training (were asked to read a manual prior to driving). The "practical" and "e-learning" groups had similar results (nine and 10 people, respectively, took manual control) with a slight predominance of e-learning (Fig. 5).

Table 1

Comparison of mean RtI reaction times (three situations)

Descriptive Statistics	Mean value	Std. deviation	Minimum	Maximum
SYT_1_RtI_CR	**3.7645**	1.66159	.60	7.46
SYT_2_RtI_CR	**2.9115**	2.70440	.90	20.85
SYT_3_RtI_CR	**2.6647**	1.52587	.85	8.73

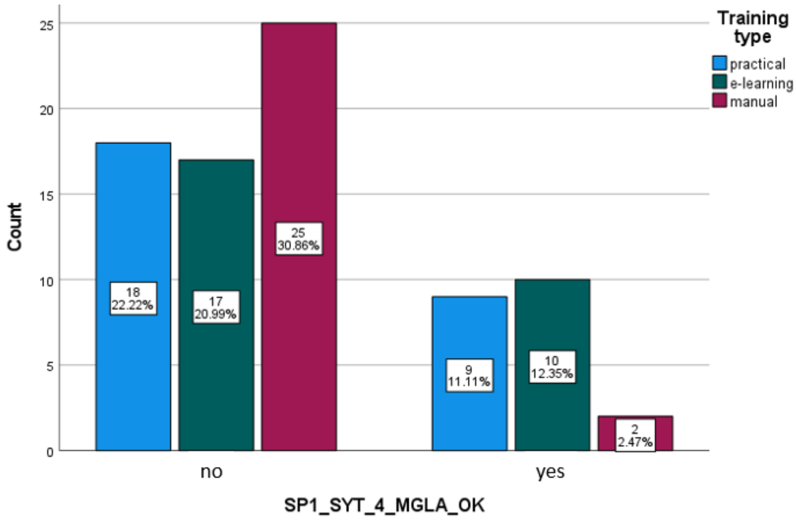

Fig. 5. Relationship with reaction in fog and training type

Age and gender were not statistically significant predictors of correct reactions. Moreover, none of the factors (age, gender, type of training, or taking control of the car) were related to slowing down.

4.5. Driving skills assessment: trainee vs. trainer

After the test drive, both the trainee and trainer were asked to fill out the trainee assessment questionnaire. The factors that were evaluated were training form, training materials, content, briefing, way of presenting information, ease of understanding, adequacy of the duration to the subject matter, adequacy to the time commitment to the subject, broadening the knowledge, usefulness, possible impact of road safety, and overall satisfaction.

Depending on the question, 23-43% of drivers overestimated their skills (depending on the criterion). For some people, these differences were insignificant (1 point). For some drivers, the difference between the trainer's and the participant's assessment was 4 points on a 5-point scale. A situation in which drivers greatly overestimate their capabilities is very dangerous and can lead to many accidents. For each question, 32% to 48% of drivers responded the same as the trainer.

4.6. Training assessment

After completing the training, participants were asked to evaluate the received training. In the first question, participants were asked if the training met their expectations (assessment made on a given scale from 1 to 7, where 1 meant very low and 7 indicated very high). As expected, the practical training received the best scores, obtaining an average grade of 5.81. Overall, 37% of people rated the training at 7, 30% at 6, and 22% at 5. Three people rated the training lower than 5. The second best-rated training was e-learning. It averaged 5.70. The largest group of respondents (33%) rated the compliance of the training with their expectations at 6, 30% gave 7, and 37% of people rated this type at 5 or 4.

Manual was the lowest-rated form of training. The average score was 5.56. The largest group of people (44%) rated this training at 5, while 33% of respondents rated the training at 6. However, it should be noted that the prepared document was a one-page manual containing all the necessary information. It took very little time to read and understand the content, and the training itself was, therefore, very effective. Nevertheless, in the comments, the respondents reported that even though they understood how the system worked after reading the manual, they were very often wrong and needed more time to learn individual activities.

Trainees were also asked how likely they were to recommend this training to others (Fig. 6). Most people (91%) would recommend the training to others (74% would definitely do so, and 17% would rather do so) regardless of its type. Breaking down the results by training type, not surprisingly, it turned out that the practical training was the best-rated.

Overall 73% of the respondents stated that the training they underwent should be compulsory (yes, rather yes). Of the trainees, 20% responded "rather not" or "not," and 7% had no opinion. Breaking the outcomes down by training type, it turned out that most people stated e-learning should be obligatory (21 participants; Fig. 6).

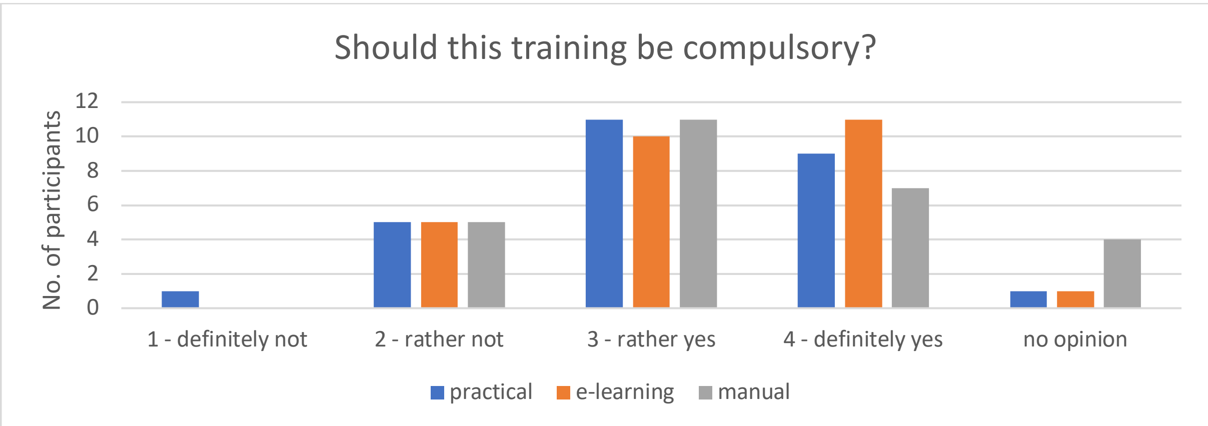

Fig. 6. Necessity to introduce training as compulsory: participants' subjective evaluation (training type)

5. CONCLUSIONS

Rapidly advancing technological changes in the automotive industry, mainly the development of automation, have forced changes in the knowledge and skills required from drivers. As advanced vehicle technologies continue to evolve, so does the unintended potential for mechanical, visual, and cognitive driver distraction, and drivers have to manage different types of risk. Research has been dedicated to assessing training approaches (e.g., limitation-focused and responsibility-focused) [7]. However, they all have one thing in common: the need to teach drivers how to behave in automated vehicles.

Although pilot activities are carried out in individual countries, there is no harmonization of activities and detailed standardized guidelines for ADS-oriented training form, manner, or scope; however, the scientific community has developed recommendations [20]. From the point of view of traffic safety and efficiency, this situation requires urgent changes.

In the automotive industry, the most common educational approaches are practical training with an instructor and reading the vehicle manual. However, according to Ryerson et al. [28], there are driver training deserts (geographic areas of disconnection to behind-the-wheel driver training). Manuals are often poorly composed, long, and difficult to understand. Therefore, the Trustonomy consortium (H2020 program) compared the efficiency of three driver training courses: practical, theoretical, and remote (mixed theory and semi-practical exercise). The materials for L4 (according to SAE) were developed as part of the project. Simulators allow complete repeatability and safety of the tests for multiple repetitions. Therefore, the study used a driving simulator to conduct practical training and to collect data from test drives. However, despite their advantages (they have been proven beneficial for improving human-based road safety [2]), simulators cannot be used by everyone. Some people experience simulator sickness, which excludes their participation in simulator-based training. This, along with its price, means it is not a tool suitable for training centers or driving technique improving centers. The solution to the problem may be e-learning: semi-practical training. The interactive interface allows one to practice almost all activities (including accident-prone situations). It also enables multiple repetitions without generating adverse symptoms. Thus, it can be used by a wide range of recipients.

The article also discusses the methods of assessing the effectiveness of training, both subjective and objective measures. The form and scope of the training should be adapted to the user's preferences, abilities, or experience. The universality of the training was one of the main assumptions of the team creating the training content. The obtained results showed a lack of influence of age and gender on the results of the activation time broken down into different types of training. This may indicate the appropriate composition of the training so that it is understandable for the majority of users. On the other hand, the revealed impact of education may be related to the ability to absorb knowledge in a short time. Usually, people who have obtained higher education have greater cognitive abilities (although, of course, this is not a rule).

According to the obtained results, the most efficient and participant-friendly ADS-related course is practical training. The practical training group showed the best performance results and was the most appreciated by trainees. However, moderate results were obtained by the “e-learning” group. It should be noted that this training type achieved the best results in relation to desirable driver reactions in bad weather conditions. Thanks to the use of semi-interactive video, the trainee can practice driving in dangerous situations or weather conditions that are difficult to predict. It also turned out that most people stated e-learning should be obligatory.

Due to the satisfactory results, the authors suggest further research on the use of semi-interactive e-learning for training purposes. Perhaps the materials (i.e., the animation itself) still need to be refined, and the knowledge should be more condensed.

The results show that despite the use of an extremely short instruction manual (one A4 page), this form of training is characterized by the worst results based on objective measures (i.e., the most important from the point of view of road safety) among the courses under consideration. Unfortunately, it is still the most popular and often the only source of knowledge provided to the user along with the vehicle. It should also be noted that vehicle manuals often consist of several hundred pages, and the language is complicated and sometimes contains linguistic errors (often resulting from incorrect translation). In the study, respondents reported that even though they understood how the system worked after reading the manual, they were very often wrong and needed more time to learn individual activities.

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