ICT-INEX Project

Deliverable 8 (IO4) version EN Guidelines for the integration of advanced 3D visualization technologies & gamification mechanisms with other professional driver candidate training methods

Deliverable Type:	**PU**
Nature of the Deliverable:	**P**
Date:	**30.08.2019**
Distribution:	
Editors:	**Instytut Transportu Samochodowego**
Contributors:	**Arkadiusz Matysiak (ITS)**
	Kamila Gąsiorek (ITS)
	Jacek Skalny (Cargo)
	Bernard Kosiński (Cargo)
	Pirita Niemi (TTS)
	Teemu Lähde (TTS)
	Sabine Schwenk (3s)

Funded by the European Union

***Deliverable Type:**	*PU= Public, RE= Restricted to a group specified by the Consortium, PP= Restricted to other program participants (including the Commission services), CO= Confidential, only for members of the Consortium (including the Commission services)*
***** Nature of the Deliverable:***	*P= Prototype, R= Report, S= Specification, T= Tool, O= Other*

Abstract: This report provides the summary of all the activities covered in Intellectual Output 4. The deliverable is divided into three distinct parts. The first part introduces the theoretical description of VR technology, its vocational implementations and the potential for its implementation in professional driver training. The second part presents the results of the piloting activities conducted in Poland and Finland throughout the project. The third part presents the final recommendations for the implementation and combining VR-based training with other ICT-based training tools and methods.

Disclaimer

List of Authors

Partner	Author
ITS	Kamila Gąsiorek, Arkadiusz Matysiak
TTS	Teemu Lähde, Pirita Niemi
Cargo	Jacek Skalny, Bernard Kosiński
3s	Sabine Schwenk

Table of Contents

Executive Summary

The output is result in developing structured guidelines for the implementation and integration of advanced 3D visualization technology and gamification mechanisms for the professional drivers training system.
The technological and social innovations (such as augmented reality, virtual reality, gamification) were assessed in scope of their applicability and usability in training future PDs. The increase of the training attractiveness was also examined in this output. The first driver training-targeted implementations of these innovations indicate their major preventive impact. This conclusion was thoroughly analyzed and summarized along with other results of this output in a from of structured guidelines.
The intellectual outcome was designed & executed according to the following plan:

- Analysis of the currently undertaken, virtual reality, augmented reality and gamification-based activities in the field of PD candidate training
- Analysis of the usefulness and effectiveness of each technologies and tools in the context of professional driver training
- Analysis of the physiological drawbacks associated with the use of 3D visualization techniques in the context of professional driver training
- Analysis of the applicability for low-cost, innovative ICT-based, on-site training
- Development and verification of virtual reality, augmented reality and gamification-based training concepts combined with other training techniques
- Analysis of the pilot training results and the evaluation of innovative training tools in the context of training process quality and the economic efficiency of the training company.
- Development of virtual reality, augmented reality and gamification-based training programs
- Development of the competency profile for the instructor of 3D visualization and gamification-based training combined with other training techniques
- Development of legal and organizational recommendations enabling the use of innovative professional driver training methods based on the use of 3D visualization techniques and gamification and their integration with the currently identified training programmes.

1. Introduction

1.1 The ICT-INEX project

The ICT-INEX project pursued the goal to increase the accessibility and effectiveness of professional driver (PD) training with the use of ICT-based tools taking into account the needs of three disadvantaged groups on the labour market. These specific disadvantaged groups were defined as young unemployed persons (up to the age of 29 years) described with the term "NEET" (Not in Education, Employment or Training), older unemployed persons facing periods of long-term unemployment (50+ group) and migrants stemming from outside the EU (28) countries.

For the ICT-INEX study, a special focus was put on innovative training methods, for example simulator-based training (SBT), virtual reality (VR) learning or the application of augmented reality (AR) and gamification (also named 'serious games'). During the project, the specific needs, obstacles and available learning solutions for the three disadvantaged groups were analysed for developing a coherent model of training for professional drivers for the transport industry using innovative ICT solutions. At the same time, recommendations for changes in the European and national PD legislation of the participating ICT-INEX project partner countries Poland, Finland and Austria were developed. The target groups who are supposed to benefit from the project results are mostly driver training companies and European and national decision makers who are responsible for the laws on PD training. At the same time, transport companies and the three disadvantaged target groups (NEETs, 50+ , migrants).

The work package of Intellectual Output (IO) 4 was to develop guidelines for the implementation and integration of advanced 3D visualisation technologies and gamification mechanisms in the scope of the PD training system. For this deliverable, technological and social innovations such as VR, AR and gamification were assessed in the scope of their applicability and usability in the training of future professional drivers. IO4 consisted of the following work packages:

An analysis of the currently undertaken VR, AR and gamification-based activities in the field of PD candidate training. An analysis of the usefulness and effectiveness of technologies and tools in the context of PD training. A research on the physiological drawbacks associated with the use of 3D visualisation techniques in the context of PD training and a research on the applicability for low-cost, innovative ICT-based and on-site training. Another goal of IO4 was the development and verification of VR, AR and gamification-based training concepts combined with other training techniques. Pilot trainings were to be undertaken by the Finish and Polish project partners followed by the evaluation of innovative training tools in the context of training process quality and the economic efficiency of the training company. Another IO4 goal was the development of a competency profile for instructors of 3D visualisation and gamification-based training combined with other training techniques. Finally, legal and organisational recommendations enabling the use of innovative PD training methods based on the use of 3D visualisation techniques and gamification had to be developed in combinations with their integration with the currently applied training programmed.

1.2 Workpackage description

The final result of this task is the development of structured guidelines for the implementation and integration of advanced 3D visualization technologies and gamification mechanisms into the professional driver training system.

Assumed, among others assessment of the suitability of technological and social innovations (e.g. augmented reality, virtual reality, gamification) for the training of future PMs. The possibility of increasing the attractiveness of this process will also be part of the result. The first implementations in trainings in transport indicate their high preventive impact on trainees

1.3 Deliverable structure

Chapter 2 of the following IO4 report starts with a description of the attitude of trainees and PD stakeholders when it comes to VR-based professional driver training.

Chapter 3 presents an analysis on the usefulness and efficiency of VR, AR and gamification in PD candidate training, e.g. the different VR devices/headsets and how VR devices are used in driver training. This is followed by scientific research results from a 2017 study on a VR-based programme for training awareness and risks in passenger cars.

Chapter 4 analyses physiological barriers connected with the use of 3D visualisation techniques in driver training. The analysis includes the role of immersion in VR, VR usage in driver research & training and the topic of simulation sickness (e.g. sickness factors, theoretical models of simulation sickness, reasons behind simulation sickness and preventive methods).

Chapter 5 concentrates on the applicability of low-cost and VR-based professional driver candidate training methods. This includes an introduction and description of a pilot training on spherical videos in vocational PD training followed by a presentation of the test methods and an analysis of the test results combined with recommendations.

Chapter 6 deals with a pilot research on the applicability of gamification techniques to e-learning platforms (with descriptions on the research tools, the test procedures, the testes gamification elements and personality traits measured in the research followed by the research results).

Chapter 7 presents three pilot studies on three use cases of the potential of VR implementation into PD training curricula. For all three pilot tests, the pilot participants, the used training tools, the testing/training procedure and the pilot results are described.

Chapter 8 contains all kinds of recommendations, i.e. on training management, on the transfer of knowledge, on skills maximisation, on stakeholders' cost minimisation, on instructor competences, on instructor profiles, on training tools specifications, on the support of the training management systems and on combining VR, AR and gamification with other ICT-based training tools.

The final chapter 9 presents national conclusions from the Polish, Finnish and Austrian perspective.

2. Trainee and stakeholder attitude towards VR-based professional driver training

2.1 Motivation and attitude of the transport and driver training industry

In order to analyze the subjective comparative assessment and the attitudes of two age groups - NEET and 50+ - towards two models of VR goggles and a low-class simulator during the implementation of the actual study a survey was conducted on a group of 30 people (15 people - NEET, 15 people - 50+). The survey's questions were of the open character and read as follows:

- Describe the most noticeable differences between driving using each device (VR vs 2D).
- What did you like during the drive in VR goggles?
- What did you dislike during the drive in VR goggles?

Answers were classified in the form of "for" and "against" arguments, assigned to categories, and then their quantities for VR and 2D were compared.

The analysis of the answers given in the survey indicates that young people have more experience with virtual reality than older people - their answers indicate higher requirements for this technology (more negative comments were noted), but at the same time they are people aware of the benefits of using it. The effect of freshness is noticeable in people aged 50+, these people often encountered virtual reality for the first time during this study. This may be the reason for their enthusiastic attitude.

One of the biggest problems when using the virtual reality, experienced by the respondents, were the greater symptoms of simulation sickness than in the case of screen projection. Symptoms of simulation sickness were more often declared by older people 50+. Therefore, these persons may require the implementation of additional measures in this respect.

Detailed survey results are presented in sub-chapter below.

2.2 Trainee attitude – survey

Analyzes showed that 23 out of 30 subjects preferred simulation presented in HTC Vive and Oculus Rift goggles over 2D projection. They were mainly young people (14 people). Older people also equally often preferred traditional 2D projection (6 people). Detailed results are presented in Fig. 1.

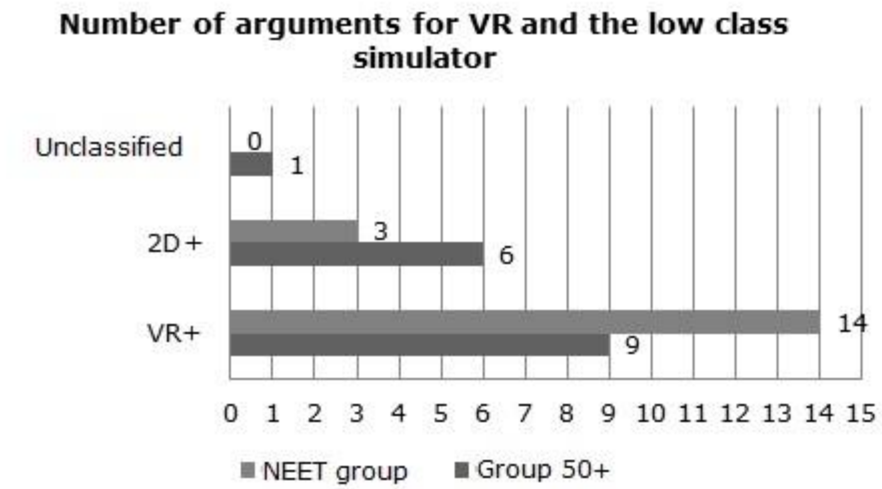


Fig. 1. Preferences of the older and younger people against two models of VR goggles and a low-class simulator

Among the reasons for their choices, participants most often mentioned realism. This means that VR simulation better reflects real road conditions than 2D simulation. 8 people from the NEET group and 6 people from the 50+ group drew attention to this aspect. In addition, analyzes have shown that VR goggles increase the sense of immersion in virtual reality. This was an important aspect especially for young people. 7 people emphasized this property in their statements. Respondents also mentioned among the arguments for VR: wider viewing angle, better image quality and greater driving comfort.

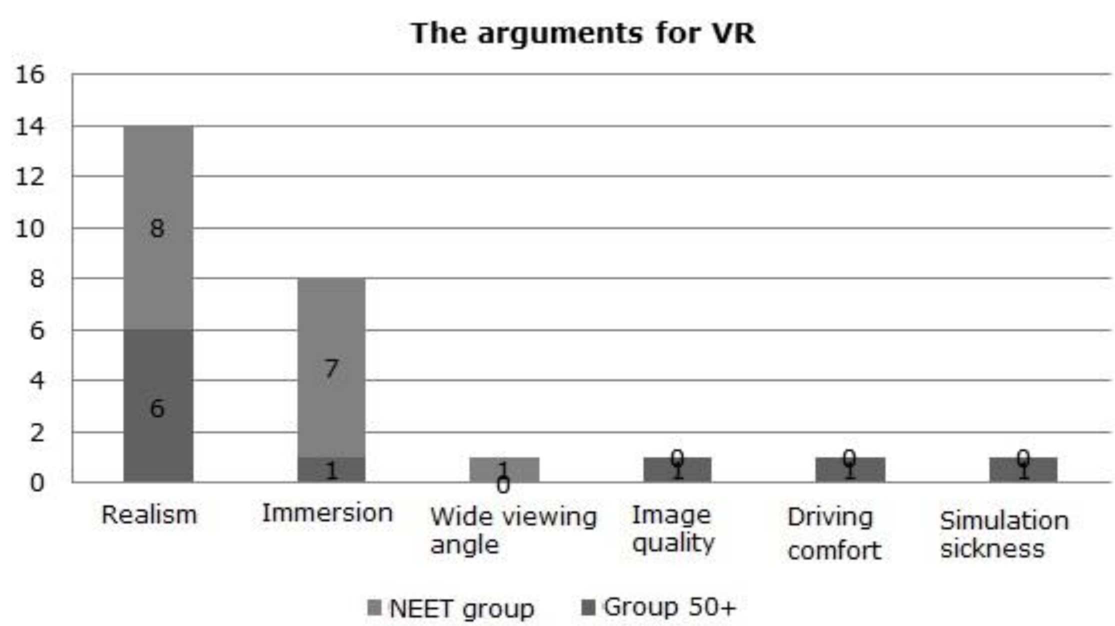


Fig. 2. Arguments of the respondents for choosing virtual reality, broken down into age groups.

As the main argument in favour of 2D projection and the use of a low-class simulator, the respondents mentioned a smaller simulation sickness. Three people drew attention to this aspect. In addition, the surveyed drivers in their answers emphasized image quality, realism, immersion, driving comfort and interaction with the controls (pedals, steering wheel).

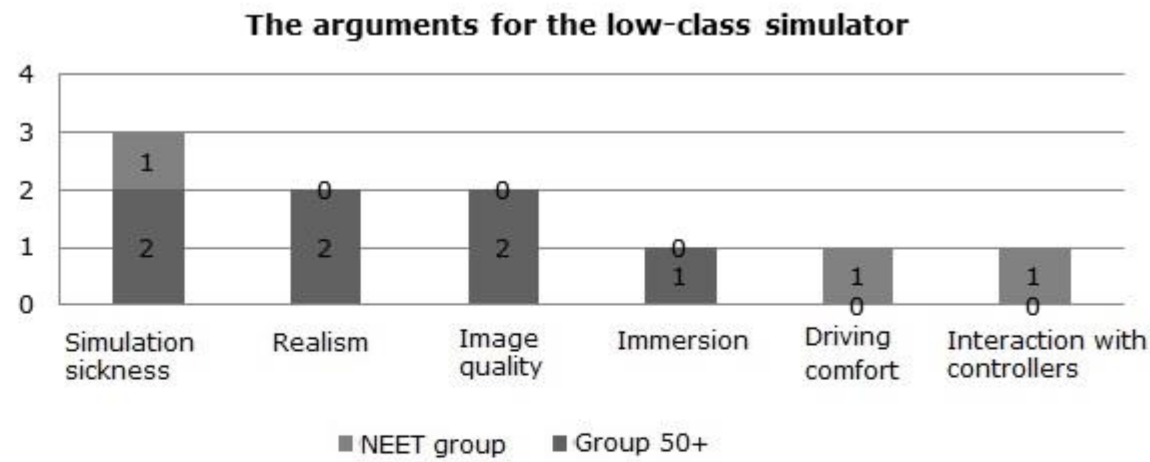


Fig. 3. Arguments of the respondents in favour of choosing 2D projection, broken down into age groups.

Analyzes of the answer to the question "What did you like during the drive in VR goggles?" showed similar results. The most common answer to this question was "simulation realism". This answer was given by 8 people from the 50+ group. The respondents also declared that during these simulations they experienced control over the road situation and had no problem with controlling the vehicle. The advantages of this method of simulation also mentioned the high level of immersion and the amount of fun.

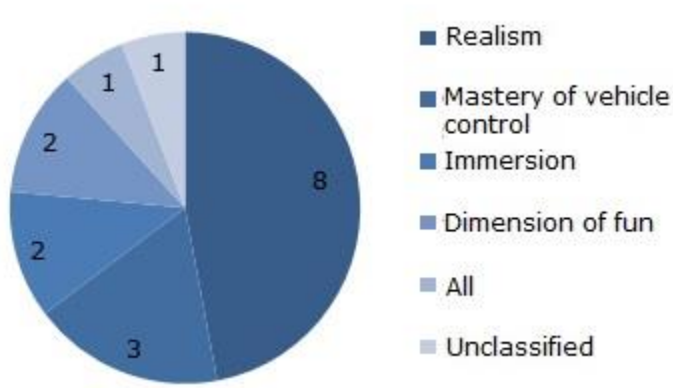


Fig. 4. Answers to the question: What did you like during the drive in VR goggles? In the 50+ age group.

In the group of young people (NEET), the respondents highlighted two important properties - realism and simulation immersion. The answers given in this group of respondents are presented in Fig. 5.

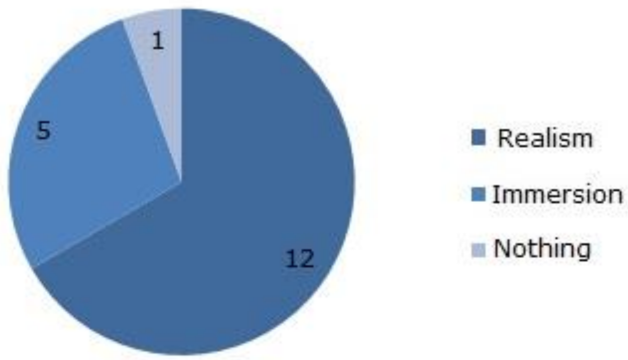


Fig. 5. Answers to the question: What did you like during the drive in VR goggles? In the NEET age group.

The older people mentioned the occurrence of simulation sickness symptoms as the main disadvantage of virtual reality goggles - this was the answer given by 4 people. Respondents also reported problems regarding image quality, physical characteristics of the goggles and the driver environment elements. On the other hand, for the young people who were less likely to experience the symptoms of the sickness, the biggest difficulty was the image quality - too low image resolution and its graininess. The answers given in this group of respondents are presented in Fig. 7.

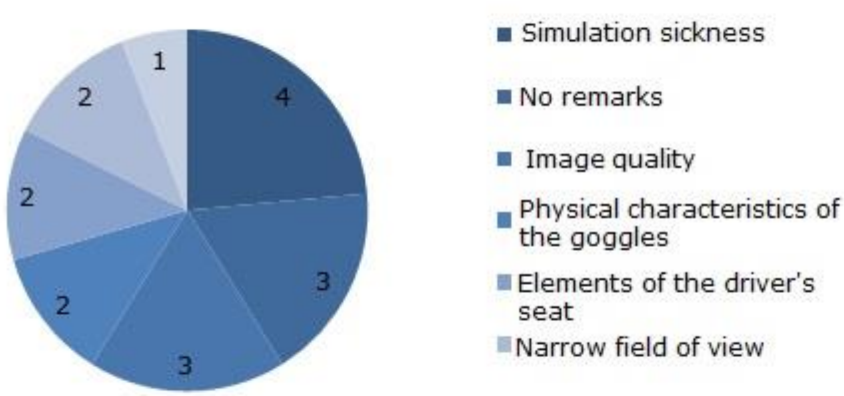


Fig. 6. Answers to the question: What did you dislike during the drive in VR goggles? In the 50+ age group.

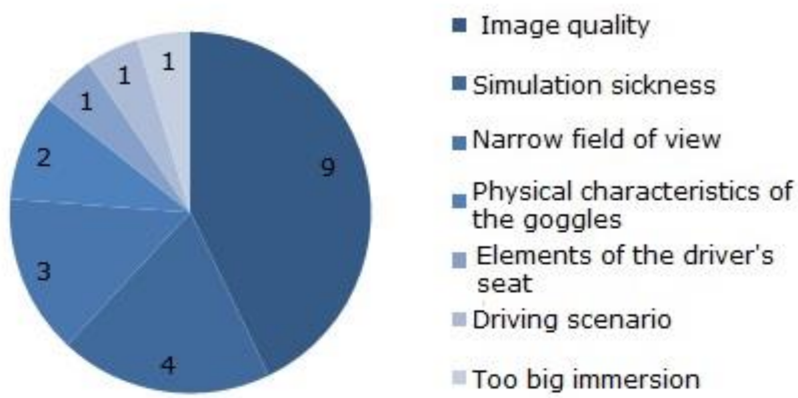


Fig. 7. Answers to the question: What did you dislike during the drive in VR goggles? In the NEET age group.

3. Usefulness and efficiency analysis of VR, AR and gamification in PD candidate training

3.1 Virtual reality

As things stand today, a complete transfer to the virtual world is possible even using compact devices, for example HMD (Head Mounted Device) goggles. Some of the most popular devices on the market are Samsung Gear VR, Oculus Rift, HTC Vive and Sony PlayStation VR[1]. There are also many new solutions available: HTC Vive Pro, HTC Vive Focus, Oculus Quest, Oculus Go, Lenovo Mirage Solo, Pimax 8K, Fove 0, or Razer OSVR HDK 2.

3.1.1 VR devices for consoles and PCs

Nowadays, commercially available advanced virtual reality systems used for education purposes cooperate mostly with PCs. Taking Oculus Rift headset as an example, it consists of goggles, a camera tracking user's position, touch controllers and sensors. It also provides sound effects, which are very important for achieving the immersion effect, i.e. they generate 360º surround sound. It generates image recreating a 110º field of view, while also tracking the user's head movements for the full 360° angle. It uses OLED displays with a resolution of 1080 x 1200 for one eye or higher, of the effective resolution of 2160 x 1200 with a 90 Hz refreshing rate. The images are transmitted to each eye separately. The set controllers are designed to track hand movements.

The other PC-destined HMD model besides Oculus Rift is HTC Vive as well as its newer version, HTC VivePro. The Vive Pro has a resolution of 2880 x 1600 on the dual-OLED display, while the Vive's resolution is 2160 x 1200, which gives a pixel increase of 78%, and also 37% of the number of pixels per inch of the display. In the newer goggles, the SDE effect ("Screen-door effect"), i.e. the visibility of individual pixels has been reduced.

The goggles use a new, improved version of lenses called Fresnel. The disadvantage of the lenses used in the HTC goggles is the so-called "godrays" that is the rays of light overlapping the image at the time of displaying elements with high contrast, e.g. bright letters on a black background. The image in the new goggles is said to be more transparent than in the standard Vive. The refreshing rate and field of view in both models are the same, i.e. - 90 Hz and 110°, respectively. A significant difference in a newer version of the goggles are the integrated headphones and a supporting strap. A special VIVE Wireless Adapter and

[1] Leswing K., 'Here are the top 5 most popular VR headsets – and what they cost', an online article available under: https://www.businessinsider.com/vr-headsets-comparison-popularity-price-features-details-2017-6?IR=T

Intel WiGig Wireless technology provides the opportunity to use the new HTC Vive Pro without having to connect the headset to the computer.

Another wide-scale sold HMD model is Sony Playstation VR. So far, it has been used solely for gaming purposes. It is equipped with 5.7-inch OLED display which provides a resolution of 1920 x 1080. The screen is additionally covered with a diffusion mesh with hexagonal eyelets, which minimizes the SDE effect. The goggles have 120 Hz refresh rate. The device cooperates only with the PlayStation 4 console. It requires less space for the operation than the HTC Vive, and one can use the virtual reality while sitting or standing up in a zone with dimensions of approx. 2 × 3 meters.

3.1.2 Standalone VR sets

Oculus Go goggles are a new version of the Oculus Rift. In contrast, this model does not require connection to a computer. It is also a much cheaper tool. It is based on the 5.5-inch 2560 x 1440 LCD display, which can operate at 60 Hz or 72 Hz refreshing rate. Compared to Oculus Rift, the Oculus Go headset is less advanced in tracking the movements of user's head. The Oculus Go goggles do not have external sensors, therefore they do not register the user's position in the room. It is based on 3 degrees of freedom.

Another solution of this kind are the Lenovo Mirage Solo goggles which are equipped with the "WorldSense" technology - an inside-out tracking system ensuring tracking in six degrees of freedom (6DoF) without the need for external sensors. However, the motion controller is already tracked like in other models in three degrees of freedom (3DoF). The device cooperates with the Google Daydream VR mobile platform and does not require a smartphone to work. The display is a 5.5-inch QHD (2560 x 1440) LCD screen displaying the image at 75 Hz resolution. The device is equipped with Fresnel lenses with a viewing angle of 110 degrees.

3.1.3 Mobile VR sets

Mobile virtual reality headsets are based on smartphones and are generally wireless. Samsung Gear VR goggles are an example of such solution. The resolution, density of pixels and the field of view depend on the phone that will be used as the display. When using Samsung Galaxy S8 model (a dedicated model for these goggles), the pixel density reaches 568 ppi. The main element of the Gear VR are 42-millimeter lenses with a field of view of 101°. It is narrower than the field in devices connected to the computer, discussed in chapter 1.1. Due to smartphone’s hardware limitations such headset also ensures lower image refreshing rate.

3.1.4 Emerging VR headsets

One of the latest market-available solutions is the HTC Vive Focus headset. These glasses do not require pairing with any other device (e.g. a computer, like a standard version of the Vive model or a telephone). Goggles provide a resolution of

2880 × 1600 pixels. The field of view is the same as in other HTC devices - 110°. The goggles provide a refreshing rate of 75 Hz. Dedicated motion controllers with six degrees of freedom provide an important element of the headset. The Goggles can also be operated without any controllers by using hand gestures. According to the creators' idea, the device has been conceived for educational purposes. With the help of a special software, it is possible to connect the device wirelessly with a personal computer via WiFi 5 GHz and stream the VR applications from online platforms.

Another emerging market solution is the Pimax 8K headset. Its producer was said to have paid special attention to designing mechanisms for decreasing the simulation sickness occurring during a VR experience. The device has a wide field of view of 200 °, while the human angle of view is about 220 °. The refresh rate is about 80 - 85 Hz, which gives about 15 ms delay. It is also based on two displays with a resolution of 3840 x 2160. The device is to be compatible with applications available on Steam VR platform. Pimax 8k has been recently released to the market.

Another device is called FOVE 0 VR. This headset uses eyetracking technology. This means that no controllers are needed for these glasses, the interaction is based on the user's view. The goggles consist of a 5.7 inch OLED display with WQHD 2560 × 1440 resolution with a pixel density of 506ppi. The screen allows a field of view in the range of 90 - 100 °, with a refreshing rate from 60Hz to 90Hz. On average the system refreshing is 70Hz. The goggles provide a technology called "foveated rendering". It allows to render only those objects that the goggles’ user is looking at. According to the developer, this version of a headset is intended for developers and enthusiasts of new technologies.

Razer OSVR HDK 2 is a headset which is comparable with its functionality to widely sold Oculus Rift and HTC Vive goggles. Razer goggles have a dual OLED display with a resolution of 2160 x 1200 pixels, with a refreshing rate of 90 Hz. Provided field of view is 110°. It is an open source virtual reality system. This means that the device is open to creating applications for VR equipment, without any technical limitations (software and hardware). Just like the Oculus Rift, it allows to track your position in 360°. Razer, like HTC devices, works with the Steam VR environment.

3.2 VR devices in driver training

Due to the very rapid development of virtual reality technology, the use of VR headsets for training the drivers (including professional driver training) seemed a matter of time. One of the first implementations took place in 2015 as part of the Toyota -TeenDrive365 initiative [15]. The aim of the project was to create tools that would allow modelling habits of safe driving among young drivers. The company designed a driver distraction simulator consisting of a fully functional

Toyota car cab and an Oculus Rift device. Designed training scenarios were based on the most common distraction factors such as talking on a mobile phone while driving or talking to a passenger. Thanks to them, it was possible to examine and improve the behaviour of young people against these factors.

City Car Driving is a PC application which is also worth mentioning as an example [14]. It is a car driving simulator allowing to operate in various, realistic street traffic conditions, in which the real-life Highway Code rules apply. The software is available for PCs, which enables participation in remote training sessions under the supervision of a driving instructor from anywhere with an access to the network. Due to a high fidelity of recreated virtual environment as well as software's accessibility, it might be possible to provide elements of practical driver training through a distant learning, VR-based scheme.

The use of virtual reality technology for driver training is a promising way of teaching due to the ability to create and practice driver behaviour in specific and/or risky situations that cannot be replicated in real-life conditions. VR training can help the driving instructor to assess whether the driver will be able to react adequately in an unforeseen situation, including not only driving-related activities. Virtual reality can also be used in trainings which are not directly related to vehicle driving, i.e. training in practical skills such as proper cargo securing. The use of virtual environment also allows to check the effects of driver's fatigue and distraction.

The implementation of VR will increase training availability. At the same time, it will increase the training attractiveness. It should also be noted that these technologies are much cheaper than the technologies currently used, so they will reduce the company's expenditures, which is an additional advantage. The important fact is, however, that only the low-end simulators could be replaced with VR-based training solutions. It will be ineffective in the training situations which require the reproduction of sensations (e.g. vibrations, wind effect) that can only be generated using high-end driving simulators.

3.3 Scientific research

In 2017, a VR-based program for training awareness and risk was developed and evaluated during a research made in a passenger car. The researchers used Oculus Rift headset [2] The program was addressed to young, novice drivers with an accident rate of at least eight times higher than the experienced drivers. Six driving scenarios were designed, in which 24 participants were divided into three research groups. Each person took part in one of the three training programmes conducted in a driving simulator - VRAPT (training with the use of VR), RAPT (training without VR) and a control group. The results showed that young drivers participating in the V-RAPT program anticipated a much larger percentage (86.25%) of potential hidden hazards compared to young drivers participating in the RAPT program

(62.36%) and the control group (30.97%). The VR-based training programme was effective in improving the ability of young drivers to predict hidden road hazards.

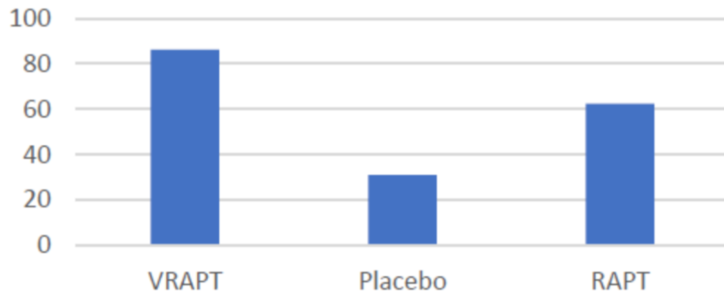
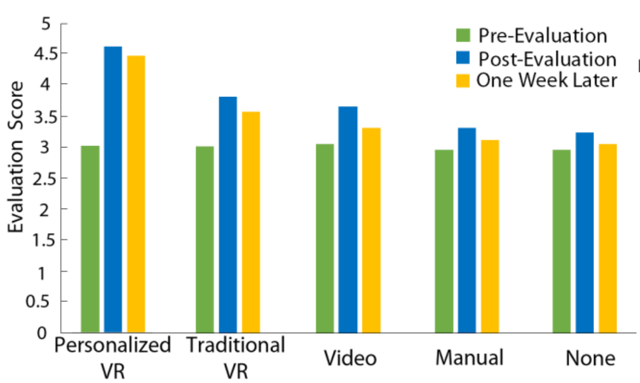


Figure 8. Anticipation of hidden road hazards in 3 trainee groups

Source: [2]

The VR-based program for training awareness and behaviour in the risky & sudden road situations was also implemented by Kopciak et al. [5]. The project investigated the possibilities of using VR-based driving simulator prototype to teach driving in a safe, virtual environment using cognitive learning and gamification methods. The simulator was equipped with Oculus Rift goggles. While driving, young drivers had to reach a specific location and complete the given tasks. They might have encountered various road situations, such as fog or an unexpected meeting with a speeding vehicle. They had to quickly assess the situation and react in an appropriate way. During driving, the participants were assisted by Movado – a built-in sound system. The system acted as an assistant, commented the driving behaviour, gave information about training's aims and supported the user, e.g. by navigating in a virtual city. Three user tests were carried out. In the first scenario, 55 trainees made a 2-3 minute drive through a virtual car park, during which they collected tokens, had to avoid a sudden cloud of smoke, drive in a slalom between pylons and then manoeuvre into the right space in the parking lot. After driving, each participant was asked to describe his/her experiences. 93% were very positive about driving in VR goggles, and 67% would like to use the program during real driving lessons. 9% of people declared that they felt nauseous, and 18% felt slight discomfort. 67% of drivers had no problem with navigating or steering the vehicle, and 64% actively scanned the virtual environment. The 2nd scenario used a driving school car park replica. Trainees' task was to drive in a slalom, drive through a narrow spot, manoeuvre into and out of a parking space while looking at other cars. Then, they had to park in the garage, perform a turning manoeuvre and accelerate to 40 km/h, and finally stop in front of the designated line. 96% were positive about the driving experience, and 74% would like to use the program while driving. Only 4% had nausea and 11% had slight discomfort. 72% had no problem with steering the virtual car or moving around the track. The third scenario took place in the virtual model of the city of Sankt Pölten in Austria. After completing the specially designed scenario, the trainees re-evaluated their experience. 100% of participants were positive about the program, and 78% would like to use it while learning to drive. 3% felt nauseous, and 16% experienced slight discomfort. The VR-based driving simulator proved to be helpful in teaching young drivers and preparing to move in the real traffic.

Lang et al. [19] aimed at using VR technology to improve driving habits. In the training program, the user's wrong driving habits were first identified, then the appropriate training, aimed at improving specific driving skills, was selected. Having gone through the initial habit recognition test, a trainee went through a personalized route which included various road events. This aimed at helping him/her to improve specific habits. FOVE 0 VR headset was used in this research. In order to confirm the effectiveness of the VR-based training program, a comparison with methods of training was conducted. A total of 50 trainees were assigned to one of five research groups. First group covered "personalized VR". Trainees drove through a route where they encountered several types of significant traffic events characteristic for their driving habits identified during the initial test. When passing the event, the trainees received an appropriate warning message. In the second "traditional VR" group, the participants also received warning messages, but in this scenario they drove a non-personalized route. The third "video" group was asked to watch a movie about driving and road safety. In the fourth group, each participant was asked to read a vehicle driving guide. The manual contained details and illustrations about proper and safe driving habits. Each research scenario lasted 15 minutes. The fifth group was a control group which did not undergo the training. After the drive, each participant was asked to perform two post-evaluation tests, in which he was driving a vehicle in a city traffic using a VR device. The first one was done just after the experiment, the second a week later. During the tests, the trainees had the response time to crisis situations measured. The results showed that the trainees who were trained using personalized VR achieve better average results than the people trained with the other methods. This was noticed in their reaction times as well as in the permanence of the improvement.



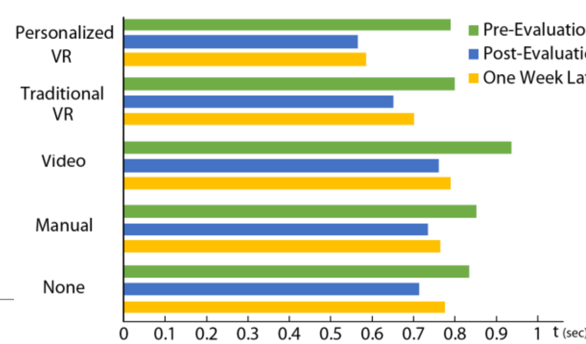


Fig. 9. Results of post-evaluation tests and reaction times of drivers before, just after and a week after the experiment against the type of training

Source: [19]

A VR-based driving simulator was developed and has been currently tested also in Switzerland [10]. The simulator cabin was placed on a 6-degree motion platform, and the HTC Vive headset was used for display the virtual environment. In the simulation based on a pre-defined, driving-related list of activities, the quality of driving was constantly evaluated and the optimal city route for a given driver was suggested in order to improve driving skills. The research was carried out to determine whether the quality of the simulator was satisfactory. It showed that the majority of drivers experienced the presence (subjective feeling of being in a virtual environment) during driving. They also felt that steering a virtual vehicle was not a problem. The study was conducted on 17 drivers. Trainees' task was to cover 15-minute drive through the city. After the drive they filled out two questionnaires on simulation sickness and presence. The questionnaire on presence consisted of 22 questions. The participants had to answer how strongly they experienced the presence in the simulator on a scale from 1 (completely not) to 7 (completely). The results show that the overall level of presence was at a satisfactory level, while the lowest result was indicated for the sound effect quality. A relatively high result on the "possibility to act" scale suggests that the simulated vehicle movement was similar to real traffic at the level enabling the trainees to steer the vehicle without much difficulty. Results of the simulation sickness questionnaire suggest that in order to improve driving skills in a virtual reality environment, training should consist of a series of many shorter training sessions. The highest result was recorded on the "nausea" scale, which indicates that with the used hardware configuration does not allow to experience real acceleration.

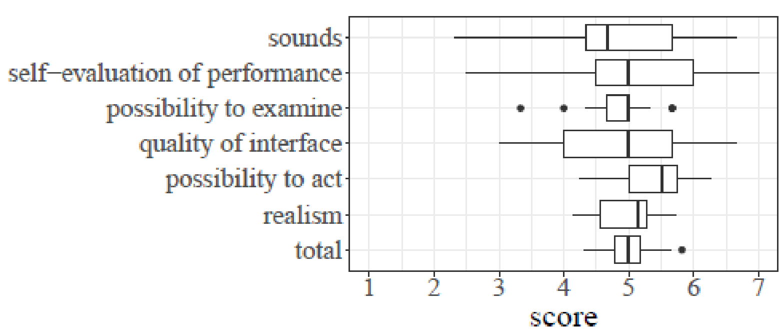


Fig. 10. Results of the Questionnaire regarding presence

Source: [10]

According to Blissing et al. virtual reality can be a good, complementary solution for driving simulators. [3]. Researchers made a comparative analysis of the driver's behaviour when using different modes of virtual reality. Two configurations based on HMDs were tested - video transparency (VST) and pure virtual reality (VR). Oculus Rift headset was used for the experiment. 22 drivers participated in the study. Participants had to drive through a slalom course at their own pace in 4 different virtualy reality modes: VST-RR - using a transparent, head-mounted display, in which no overlays were used and real slalom cones were used; VST-MR – using a transparent display in which virtual cones were imposed on the video stream; VR - using a non-transparent image of fully virtual world in the VR goggles; DV - using the direct view of the environment, i.e. driving without any display mounted on the head. The acceleration changes made during driving, i.e. jerking, vehicle braking, time to complete the course, as well as well as maximal curvature were examined.

A distinct effect of the VR goggles was detected. It affected all measured parameters. There were visible changes in the driver's behaviour in terms of acceleration and braking when driving in goggles compared to driving without them. The drivers while wearing HMD drove on average 35% slower. Fewer differences were visible between the different modes of virtual reality. Only the mixed reality mode (VST-MR) differed significantly with a lower average speed compared to other modes. Similar differences were noted in the maximum curvature index and lateral position deviation. Lower indicators were recorded for driving without goggles. The authors of the study noticed that the mixed reality mode is perceived as the most difficult one. This is probably due to a narrower field of view, as well as noticeable registration errors. Currently, the VR mode is considered better than the VST mode.

	Acceleration changes		Time to completion		Maximum curvature		Lateral deviation		Difficulty		Performance	
VR-mode												
VST-RR	8.94	A	21.0	A	7.77	A	10.9	A	3.92	A	4.27	A
VST-MR	9.64	A	25.4	B	9.96	B	12.1	A	5.16	B	3.68	A
VR	8.82	A	22.0	A	9.52	B	12.2	A	4.13	A	4.19	A
DV	6.52	B	14.7	C	6.78	C	8.3	B	1.51	C	6.25	B
Run												
1	8.70	A	21.7	A	8.47	A	11.1	A	3.87	A	4.32	A
2	8.39	A	20.7	B	8.59	A	11.0	A	3.68	AB	4.66	B
3	8.35	A	19.9	C	8.47	A	10.5	B	3.49	B	4.82	B

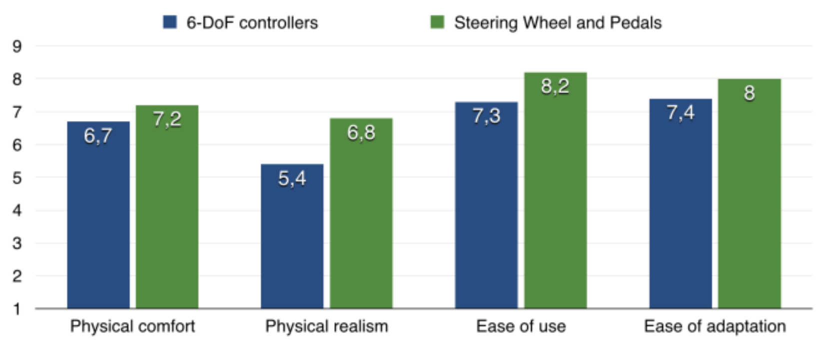
Fig. 11. The influence of particular VR modes on the behaviour of the driver

Source: [3]

Weidner et al. [18] compared displaying 2D images, stereoscopic 3D images, and VR-based images and checked their impact on the physiological responses of a driver, simulation sickness severity and overall behaviour while driving in a driving simulator. 94 participants took part in the research. Their objective was to perform the task of a lane change. The results indicate that the use of VR-HMD leads to similar results like stereoscopic 3D or 2D screens. There was no significant difference in physiological responses or behaviour during lane change. However, a much more severe simulation sickness for VR-HMD was shown in comparison with the stereoscopic 3D image.

VR-based systems also seem to be a promising tool for training and teaching drivers in transferring the control in autonomous vehicles. It is generally estimated that the trucking industry will be the first area in which the driving automation systems will be deployed. As soon as partially automated vehicles are implemented, they will require to take over the control in certain difficult road situations in which the in-vehicle systems will not be able to make decisions independently. Sportillo et al. [13] compared three different training systems. The first of them was user's manual which consisted of a presentation of 8 slides displayed on the 13.3" screen of a laptop. Slides contained text and images showing the actions to be taken during manual driving, automated driving mode and when requesting a control transfer. The second system was a driving simulator, consisting of an actual vehicle cabin and a 65-inch screen in front of the cockpit at a distance of 1.5 m from the driver. The third system was a VR-based system comprising of the goggles and a steering wheel. After the training session, the actual test session took place. 60 participants had a secondary task to perform on the tablet placed next to it. During autonomous driving, participants were asked to engage in one of 9 secondary activities. Three requests to take over the control were issued during the drive: (A) 10-second transfer due to the narrowing of the road because of the stationary car on the right lane; (B) 10-second transfer due to the loss of the area marking; (C) 5-second transfer due to sensor failure. The participants' reaction time equalling the time of taking over the control was recorded. A significant difference was observed between the training group using the user's manual (rt = 5.15 s) and the other two systems. However, no differences were observed between the stationary simulator (rt = 3.17 s) and the VR system - HMD (rt = 3.16 s). After the test, the participants assessed the training systems using a questionnaire. The VR-based system was given a highest rate.

In another simulation, Sportillo et al. [12] compared different virtual reality interfaces, namely manual controllers in a low-end simulator (consisting of the steering wheel and pedals). In the study, like in the one abovementioned, the control takeover in an autonomous vehicle was used as a test situation. The research scenarios were displayed on HTC Vive goggles. The interaction with the simulator was not limited to taking over control and driving. The driver also had to perform a second activity while driving to distract him/her from the main driving task. The task was displayed on a tablet which was placed on the line of sight to the right. It was a task of memorizing and recreating the pattern. 10 drivers took part in the experiment. The response time was measured, i.e. the time needed to take control of the vehicle after the displaying system warning and of the driving stability after regaining control in terms of changes in steering wheel position. This had to be done while avoiding the obstacle on the road. Additionally, the drivers completed the questionnaire regarding comfort, realism, ease of use and the adaptation. The results suggest that subjective comfort, ease of use and adaptability assessments show a significant difference in favour of a low-level driving simulator (realistic interface). The number of steering wheel position changes suggests that it is easier for the drivers to control the vehicle in the simulator. It has been noted, however, that drivers reacted faster with the use of handheld controllers.



Variable	6-DoF	Realistic
Reaction time (mean, [s])	2.17	2.67
Num. of steering turns (median)	8.5	5

Fig. 12. Subjective and objective measurement results and the interface type

Source: [12]

Virtual reality can also be used for traffic psychology purposes. This area is very much related to professional driver's occupation due to the fact that each candidate needs to go through regular psychology tests in order to maintain the professional qualifications.

Agrawal and Vemuri [1] used VR technology to study the frustration, anger and behaviour of drivers when driving in adverse conditions. The experiment used Oculus Rift goggles. The focus was put on examining the driver's reaction when being forced to follow a slowly moving vehicle. The task of 30 participants was to overtake a vehicle which was blocking road traffic. Three research scenarios were created: a) lack of ordinated road lanes b) change of the lane possible only on some sections of the road, and c) lines designated concrete lane separators. In the first scenario a three-wheeled vehicle was in front of participant's car. Both were in the same middle lane. Two lorries were driving on the left lane, and the right one was taken by the passenger cars. The researches could overtake a three-wheeler from either side, using gaps between the vehicles in adjacent lanes. In the 2nd scenario, participants could overtake or change lanes only on designated sections. Physical barricades were placed on the road to indicate where to change the lane. The driver could overtake the vehicle, but changing the lanes required quick reactions and the ability to predict the vehicle’s speed on two adjacent lanes. In the last scenario, the drivers were forced to follow a slowly moving vehicle for the entire trip due to the presence of concrete lane separators. After driving, the participants estimated the immersion of the designed solutions and the level of frustration. The evaluations indicate the correctness of using VR to study drivers' behaviour. Based on the results, it can be concluded that the virtual reality configuration developed for this experiment was effective in testing behaviours, as well as in understanding the traffic flow. Heavy traffic, its noise, the need to follow slowly moving vehicle and the inability to change lanes caused a high level of annoyance and anger in 73% of participants (score> = 3).

Fig. 13. The subjective immersion level of the virtual environment and the level of drivers' frustration

Source: [1]

Another study [16] shows the usefulness of virtual reality to assess the ethical behaviour of people in autonomous vehicles. Virtual reality (HMD Oculus Rift goggles) was used to assess ethical behaviour in the simulated traffic scenarios and the collected data was used to train and evaluate a number of decision models. In this study, participants drove the virtual car on a foggy day and had to choose one of the two obstacles which they sacrificed to save the other. Obstacles which resembled various inanimate objects, animals and people were chosen randomly. The drivers had either 4 seconds or 1 second to react. 105 participants took part in the experiment. The results indicate that human moral behaviours can be properly described using algorithms that can also be used by vehicles. It has been found that time pressure reduces the consistency of decision patterns, thus providing an argument for algorithmic decision making in traffic. This study confirms the usefulness of virtual reality to assess ethical behaviour in humans, providing consistent results for different people.

Research confirms that the use of VR technology does not enable to replace a high-end driving simulator. The full substitutability can only be discussed in the context of low-end simulators. Filio et al. [4] compared the reactions of 29 drivers to the dangerous traffic situations. The trainees took part in two research scenarios. In the first one, a high-end simulator was used, while the second one relied on the use of a widely availabe HMD - Oculus Rift goggles. In each scenario, the participants encountered two pedestrian crossings on their route. On each of them there was a virtual pedestrian who suddenly ran onto it. The driver's reaction time (perception), braking time, speed and standard deviation of the lateral position were measured. People with the goggles had noticeably longer times of noticing pedestrians entering the road than when driving a high-end simulator and presenting the image on a cylindrical screen. Slight differences in the vehicle speed and braking time in reaction to a dangerous event between display modalities have also been shown. Lower speeds were noticed while driving in the simulator, which the authors attribute to the features of cylindrical screens. They are said to be more comfortable to use and during such driving, it is easier to control the vehicle. There were also differences in terms of standard deviation from the lateral position of the vehicle. The higher indicator was noticed while driving in HMD goggles, not only when approaching a pedestrian crossing, but also on straight sections of the road. This can be explained by the narrowed field of view and higher vehicle speed. Drivers felt more comfortable at higher speeds but experienced greater cognitive load due to the reduced field of view.

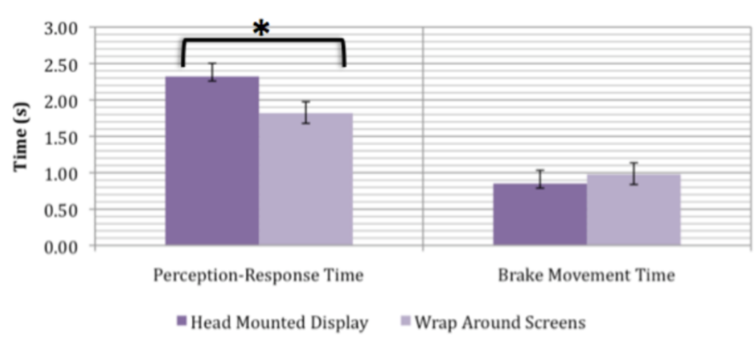


Fig. 14. Comparing average times of danger perception and braking time using HMD goggles or a high-end simulator (cylindrical screens)

Source: [4]

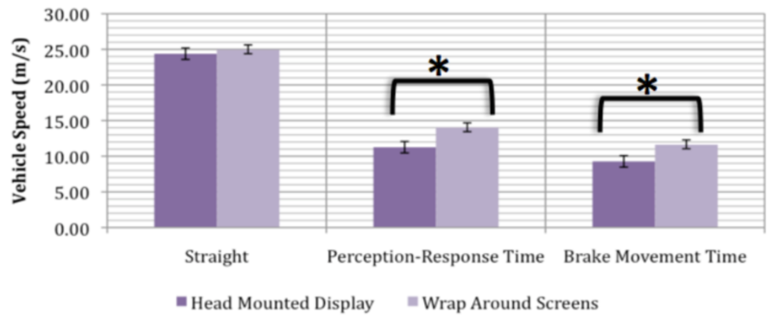


Fig. 15. Comparing average speeds using HMD goggles or high-end simulator (cylindrical screens)

Source: [4]

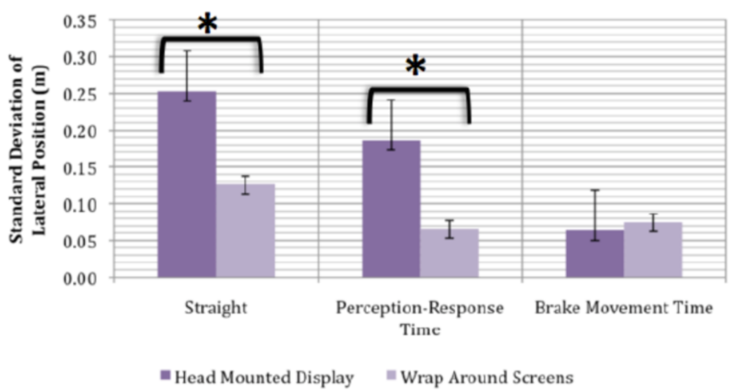


Fig. 16. Comparing standard deviation from lateral position using HMD goggles or high-end simulator (cylindrical screens)

Source: [4]

Walch et al. [17] conducted a study on 20 drivers, in which they compared the subjective, VR goggles-based driving experience with driving in a low-fidelity driving simulator. The simulation was displayed either using three 40-inch screens or HTC Vive goggles with 110° field of view and a resolution of 2160 x 1200 pixels. A racing game was used for the simulation. In both cases, participants had to drive the same 20.64km stretch of winding road and the same vehicle with an automatic transmission. Participants were instructed to cover the circuit as fast as possible, but also with the least possible damage to the vehicle. The drivers after the experimental run completed the questionnaires on simulation sickness, discomfort, immersion level and presence. The results of the study indicate that the use of VR goggles can potentially separate the participants to a greater extent from the real world than the use of flat screens of a low-end simulator. Admittedly, no statistically significant differences were found in the level of perceived presence between the examined conditions. No significant influence on the immersion result was noticed either. However, based on the second questionnaire, a tendency can be observed that participants felt more immersed (involved) when using VR goggles

(M = 37:29 vs. M = 29:11). The analysis of the simulation sickness questionnaire did not show any significant differences between the conditions. However, as the driving comfort questionnaire showed the participants experienced greater discomfort with VR HMD (M = 1 vs. M = 0.5) . Despite that, participants preferred the use of virtual reality technology.

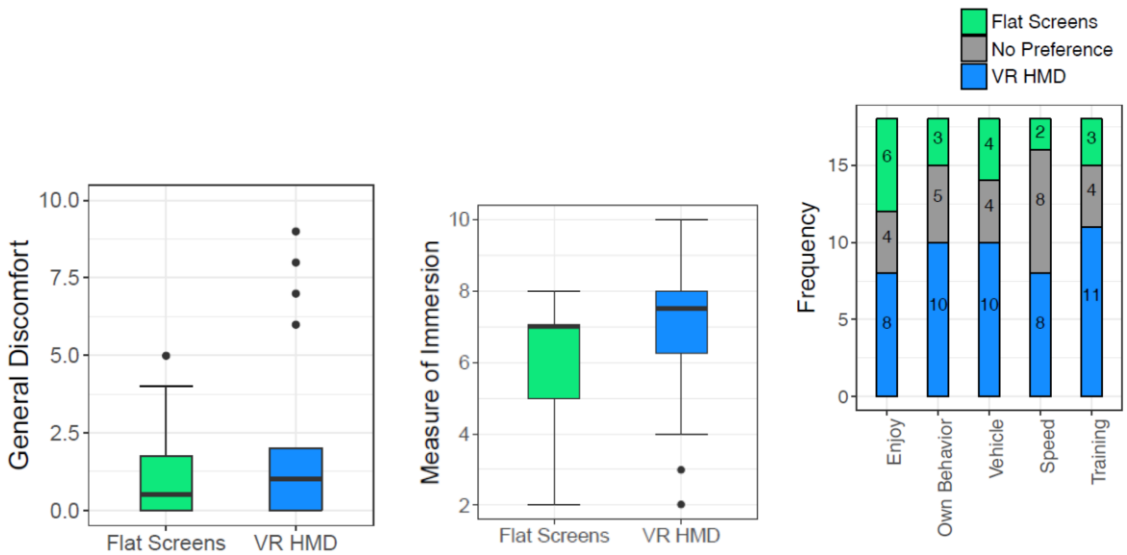


Fig. 17. The feeling of discomfort, immersion experience and drivers' preferences while using HMD goggles or a low-end simulator (flat screens)

Source: [17]

These results were confirmed by Ricaud et al. [9]. The simulation presented with Oculus Rift goggles was compared with a low-end simulator consisting of a PC computer, a steering wheel and a joystick. 44 participants had four tasks to perform. The first one was driving along the road with many bends, requiring complex manoeuvres. The drivers had limited visibility during the driving. The second task was to drive on the platform about 5 m above the ground. Unlike the first task, the participants did not have limited visibility here and it was necessary for them to observe the surroundings so as to perform precise manoeuvres. The third exercise was to find hidden road signs. The fourth was a slalom drive across the square at high speed. The time of the exercise coverage, head movement frequency and joystick steering, penalty for colliding with objects in a virtual environment, improper road signs or falling from the platform were measured. The results showed that HMD goggles are a good alternative to the low-end simulator. However, the authors draw attention to the disturbing phenomenon of simulation sickness that occurred in nearly 50% of the surveyed drivers. The average duration of all exercises was similar in both study groups. Significant differences were found during the analysis of individual tasks. While driving with HMD goggles in the first exercise, the participants had much more control over the vehicle and less difficulty in making sharp corners without damaging the vehicle. The lap time was also shorter by 13%. In the second exercise, 44% of people coped better when using the Oculus Rift goggles. The average driving time was longer when using the goggles (1min 49s), than when using a low-end simulator (1min 35s). In the third and fourth task, similarly to the first one, most of the participants who wore google, achieved better results. The lap and tasks performing times were respectively 3 and 8% shorter. When the drivers with goggles did not have enough time to assess the traffic situation and prepare to perform the manoeuvre, they drove more precisely and less frequently collided with the virtual objects.

Read and Saleem [8]. checked whether and how exactly the VR goggles reflect reality while driving. A total of 15 drivers took part in the experiment. The researchers measured the task execution time, maximum speed, number of collisions and situational awareness during parking of the vehicle in the real environment and in a virtual environment. The virtual environment was displayed either with the use of HMD - Oculus Rift goggles or using computer screens. The analysis of situational awareness data showed no significant differences between the three research groups. Slightly lower results were noted for the group which had a scenario displayed on the computer screen. This confirms that virtual reality does not create lower level of awareness than in a real road situation. There were significant differences in the task completion time - the shortest time (M = 39.51) occurred while driving in real conditions, the longest (M = 84.06) while having the image displayed on the screen. The time of task completion while driving with VR goggles was twice as long as in real conditions (M = 64.43). The analysis also showed that the speed and amount of risky behaviour in virtual reality increases compared to real driving. However, in the case of VR goggles, there are much fewer of them than during the simulation on a computer monitor (M = vs. M = 5). While using the goggles, fewer accidents were also observed compared to the simulation displayed on the computer screen (M = 0.45 vs. M = 0.78).

Descriptive Statistics	Real-World	VR	Flat Screen
Average	18.12	18.10	17.45
Minimum	11.00	10.50	12.00
Maximum	32.00	30.00	29.50
Range	21.00	19.50	17.50
Std. Dev.	5.40	4.90	4.58

Figure 18. Situational awareness in a real and virtual environment while performing a parking task

Source: [8]

Descriptive Statistics	Real-World	VR	Flat Screen
Average	39.51	64.43	84.06
Minimum	23.81	27.14	27.54
Maximum	58.98	174.42	199.06
Range	35.16	147.28	171.52
Std. Dev.	11.97	42.73	51.55

Fig. 19. Time of completing the parking task in a real and virtual environment

Source: [8]

Risk Level	Reality Frequency	VR Frequency	Flat Screen Frequency
Cautious	6	5	3
Confident	9	9	7
Risky	0	1	5

Fig. 20. Risky behaviour in a real and virtual environment during the parking task

Source: [8]

Virtual reality is also used for training in other professions. Hupont et al. [5] used VR to train forklift drivers. Two different types of image display were compared - conventional 2D computer screens and HMD Oculus Rift goggles. Training's aim was to acquire basic skills of driving a forklift before stepping into a real vehicle, which is why the simulation consisted of several exercises, starting from the most basic ones (such as the procedure of starting the vehicle) to more advanced ones (e.g. moving loads from shelves to a truck). 22 individuals took part in the survey. After conducting the simulation scenarios trainees filled out a questionnaire on presence, usefulness and emotions felt. The results show that Oculus Rift increases the sense of immersion in the 3D world and is rated as more useful, easier and suitable for the exam from the computer screen projection. A worrying aspect though is the high percentage of people reporting nausea after using goggles.

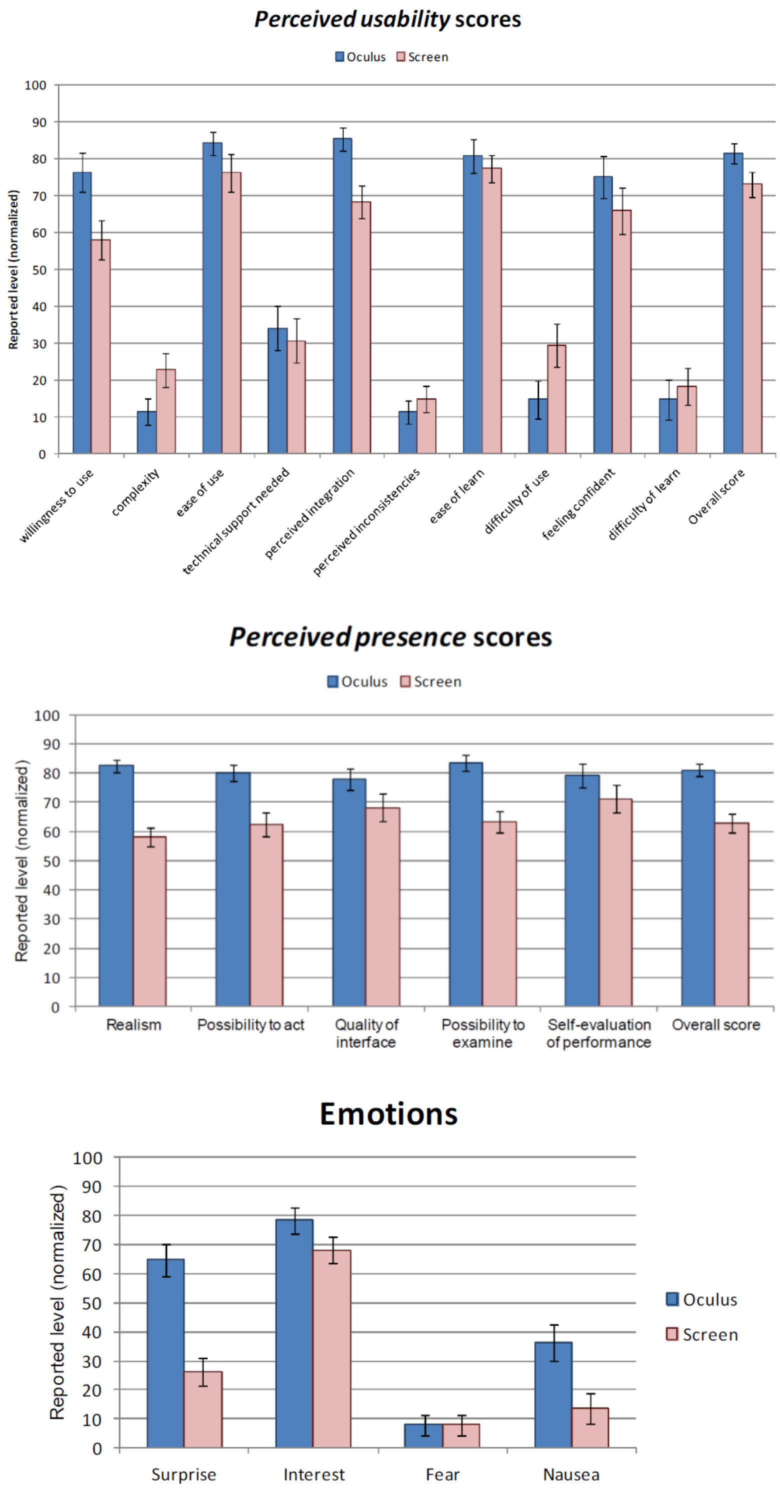


Fig. 21. The subjective level of presence, usefulness and emotions felt and the method of the simulation

Source: [5]

One of the latest researches shows that virtual reality technologies can be also used to analyze the behaviour of other road users, including pedestrians [11]. Sobhani and Farooq examined the impact of VR technology on the behaviour of pedestrians at the crossings. In this study Oculus Rift goggles were used. A total of 42 participants were assigned to one of three research conditions: a) no distraction, b) pedestrian distracted by a smartphone, c) pedestrian distracted by a smartphone, but warned by a special message. Trainees' task, besides checking traffic for safe passage through the crossing, was simultaneous coverage of going through labyrinths using a smartphone. The warning message in the third test condition were flashes and colour-changing LED diodes. All these conditions were provided in the virtual reality-based environment. The variable parameters were: the time of passing through the crossing, the crossing speed, the initial speed, the waiting time at the crossing as well % of the time during which the head was directed towards the smartphone while waiting and during the passage. The results showed that women show more dangerous behaviours at the pedestrian crossings, especially when their attention is distracted, but warning messages in the form of LEDs have reduced this negative impact. Men are more cautious, but their distraction has a more negative impact in comparison to women (a 28% decrease in attention compared to 12%).

3.4 Summary

The analysis of scientific research on using virtual reality in driver training shows that the most commonly used tool at the moment are the HMD Oculus Rift goggles. The decision as to which device to use in the teaching curriculum, however, is unclear. PC-based devices are more costly, while smartphone based goggles are not capable of producing high quality images due to the limited computing power.

Moro et al [7] have compared two types of Oculus VR goggles, one PC-based and the other smartphone-based. A total of 20 participants were presented a lecture on a specific topic which was followed with a knowledge test. The results of the tests were compared, taking into account the effect of goggles on the subject perception, including negative health effects resulting from their use. There were no statistically significant differences in the test results, both groups correctly answered 60% of the questions. However, for 40% of participants when using a Gear VR device, much more often disorientation and blurred vision were observed ($P < 0.05$). There were no significant differences in the perception of educational activities between the two groups. However, the results in terms of comfort of use, ease of use, clarity of instructions were more advantageous for the PC-based goggles.

General Symptoms	Oculus Rift	Gear VR	*p* value
General discomfort	0%	20%	0.146
Fatigue	10%	10%	1.000
Boredom	10%	20%	0.542
Drowsiness	30%	20%	0.615
Headache	10%	10%	1.000
Dizziness	0%	10%	0.317
Difficulty concentrating	10%	30%	0.255
Nausea	10%	10%	1.000
Disorientation	0%	40%	0.029*
Eye-related symptoms			
Tired eyes	20%	20%	1.000
Sore/aching eyes	0%	30%	0.067
Eyestrain	0%	20%	0.146
Blurred vision	0%	40%	0.029*
Difficulty focusing	10%	40%	0.121
Double-vision	0%	20%	0.146

Mann–Whitney U test: *$p < 0.05$

Fig. 22. The effect of goggles on the perception of the subjects and health effects

Source: [7]

HTC Vive is also used for research and educational purposes. These goggles cooperate with a wide range of software and have large movement tracking capabilities. Fully-fledged VR sets such as HTC Vice or Oculus Rift are more technologically advanced than mobile VR sets, therefore they are recommended for research purposes. Virtual reality in the mobile models is associated with a narrower field of view, depending on the specific goggles and the screen size of the phone that will be inserted inside, as well as with a lower refreshing rate. Due to these features, the user may have the impression of viewing the virtual world through binoculars. This effect also reduces immersion. However, the advantage is that you do not have to connect such device to a computer. Additionally, some research state that fully-fledged VR sets will result in fewer symptoms of simulation sickness.

The analysis of the conducted research proves that state-of-the-art virtual reality technologies are used primarily for modelling safe driving habits, especially for young drivers. VR-based training programs are effective in improving the capabilities of inexperienced drivers to anticipate hidden dangers and prepare for driving in real traffic. They are also useful for training of professional drivers. Special software allows drivers to participate in remote training sessions under the supervision of a driving instructor from anywhere and gives the opportunity to undergo part of practical training, including driving in special conditions and additional training sessions.

VR technology can also be used to teach behavioural modelling during control transfer in autonomous vehicles and conduct research in the field of transport psychology. Results of taking over control of a vehicle in VR-based conditions are similar to the results observed in a stationary simulator. The research also confirmed the usefulness of using VR to study the frustration, anger and behaviour of the driver when driving in adverse conditions. Virtual reality is an effective tool for studying the behaviour of other road users, such as cyclists and pedestrians, as well as for training drivers of other professions, for example of forklift drivers.

It should be remembered though that the full substitutability of the driving simulator with the VR-based solutions can only be applied with regard to low-end simulators. The substitutability is ineffective in the implementation of tasks requiring the reproduction of sensations that can be generated only using high-end driving simulators.

3.5 Bibliography

1. Agrawal M., Vemuri K. (2018). *A Heterogeneous Traffic Virtual-Reality Simulator to Study Irritation/Anger and Driving Behavior under Adverse Conditions.* Published by BCS Learning and Development Ltd. Proceedings of British HCI 2018. Belfast, UK.
2. Agrawal, R., Knodler, M., Fisher, D., & Samuel, S. (2017). *Advanced Virtual Reality Based Training to Improve Young Drivers' Latent Hazard Anticipation Ability.* In Proceedings of the Human Factors and Ergonomics Society Annual Meeting. SAGE Publications
3. Blissing, B., Bruzelius, F., & Eriksson, O. (2017). *Driver behavior in mixed and virtual reality - A comparative study.* Transportation Research Part F: Traffic Psychology and Behaviour.
4. Filio D., Dony, L., Gonzalez D., Oliver M. (2017). *Comparison of Wrap Around Screens and HMDs on a Driver's Response to an Unexpected Pedestrian Crossing Using Simulator Vehicle Parameters*. In: Proceedings of the Ninth International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, June 26-29, 2017, Manchester Village, Vermont. Iowa City, IA: Public Policy Center, University of Iowa: 172-178. https://symulatorjazdysamochodem.pl/
5. Hupont, I., Gracia, J., Sanagustín, L., Gracia, M.A. (2015). How do new visual immersive systems influence gaming QoE? A use case of serious gaming with oculus rift. In 2015 Seventh International Workshop on Quality of Multimedia Experience (QoMEX).
6. Kopciak PA., Klar P., Hellmann D., El Aeraky S., Dullfuss M. (2016). V*irtual Reality Driving Simulator Prototype for Teaching Situational Awareness in Traffic.* 103-Recent Advances in Multimedia Processing, Organization and Visualization beyond Domains and Disciplines.
7. Moro C., Stromberga Z., Stirling A. (2017). *Virtualisation devices for student learning: Comparison between desktop-based (Oculus Rift) and mobile-based*

(Gear VR) virtual reality in medical and health science education. Australasian Journal of Educational Technology, 2017, 33(6).

8. Read, J. and Saleem, J. (2017). *Task Performance and Situation Awareness with a Virtual Reality Head-Mounted Display.* Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 61(1), pp.2105-2109.
9. Ricaud B., Lietar B., Joly C. (2015). Are Virtual Reality headsets efficient for remote driving?. Conference on Road Safety Simulation 2015 (RSS 2015), Oct 2015, Orlando, United States. Proceedings of the International Conference on Road Safety.
10. Ropelato S., Zünd F., Magnenat S., Menozzi M., Sumner B. (2018). A*daptive Tutoring on a Virtual Reality Driving Simulator.* In 1st Workshop on Artificial Intelligence Meets Virtual and Augmented Worlds (AIVRAR) in conjunction with SIGGRAPH Asia 2017. ETH Zurich.
11. Sobhani, A., Farooq, B. (2018) *Impact of Smartphone Distraction on Pedestrians' Crossing Behaviour: An Application of Head-Mounted Immersive Virtual Reality.* Journal of Transportation Research Part F: Traffic Psychology and Behaviour, Accepted: 17-06-2018.
12. Sportillo D., Paljic A., Boukhris M., Ojeda L., Fuchs P., Roussarie V. (2017). *An immersive virtual reality system for semiautonomous driving simulation: a comparison between realistic and 6-DoF controller-based interaction.* Proceedings of the 9th International Conference on Computer and Automation Engineering2017ACM.
13. Sportillo D., Paljic A., Ojeda L., Fuchs P., Roussarie V. (2018). *Light Virtual Reality systems for the training of conditionally automated vehicle drivers.* IEEE Virtual Reality, Mar 2018, Reutlingen, Germany.
14. Strona internetowa narzędzia City Car Driving: http://citycardriving.com
15. Strona internetowa projektu Toyota TeenDrive365: http://www.teendrive365inschool.com/
16. Sütfeld, L. R.; Gast, R.; König, P.; Pipa, G.(2018). *Using virtual reality to assess ethical decisions in road traffic scenarios: Applicability of value-of-life-based models and influences of time pressure.* Frontiers in Behavioral Neuroscience 2018
17. Walch, M., Frommel J., Rogers K., Schüssel F., Hock P., Dobbelstein D., Weber M. (2017): *Evaluating VR driving simulation from a player experience perspective*, pp. 17–25.
18. Weidner F. , Hoesch A., Poeschl S., Broll W. (2017). *Comparing VR and non-VR driving simulations: An experimental user study.* In Virtual Reality (VR), 2017 IEEE, pp. 281–282. IEEE.
19. Yining Lang, Wei Liang, Fang Xu, Yibiao Zhao, Lap-Fai Yu (2018). Synthesizing Personalized Training Programs for Improving Driving Habits via Virtual Reality. IEEE Virtual Reality (VR 2018)

4. The analysis of physiological barriers connected with using 3D visualization techniques in driver training

4.1 Role of immersion in virtual reality

Highly immersive technology VR is recognized as the key technology of virtual reality, because it relies on almost complete isolation of a subject from sensory impressions coming from the outside world. Instead, visual and auditory stimuli are presented, which are a reflection of the simulated space. The stimuli is presented using devices called HMD - Head-Mounted Display, as well as other types of special goggles, placed on the subject's head. The glasses are equipped with headphones and two displays that allow 3D spatial vision and sound reception. The displays installed in goggles are located always in front of subject’s eyes, regardless of head movements. In such way, the impression of "immersion" is provided.

A tracking system enables to navigate through the virtual environment. The system consists of an antenna and sensors placed in a HMD and allows its exact positioning. Movements (e.g., HMD rotation) are constantly registered in order to allow appropriate changes to the displayed image as the head moves. The sensors can also be used in other places, such as on the upper, lower limbs or back. Sensors mounted on the hands or legs enable their movements to be mapped and to interact with objects in virtual environment. [16, 32].

4.2 VR usage in driver research & training

Immersive virtual reality is used today i.e. in the vehicle driving simulations. It is used as one of the display methods. Additionally, the screens placed in front of the simulator cabin and projectors can be used. However, in this case, the image of the simulated environment is limited to the size of the screen and visible only from the front of the simulator, while the HMD uses a high-quality stereoscopic image. User has the opportunity to look around while the head movement is taken into account in the perspective of the image displayed in the mirrors. Youngblut et al. [50] determined that the binocular field of view in the human reaches, in the horizontal plane, 180 degrees and 120 degrees in the vertical axis. However, during the rotation of the head, the field of view in the horizontal plane can reach as much as 270 degrees. Youngblut also stated that a 90 - 110-degree field of view would suffice to create an immersive virtual environment. Research on virtual reality technologies by Anthes et al. [2] shows that the state-of-the-art market-available systems are within the above limits and can reach up to 200 degrees.

Additionally, using HMD allows to use a less complicated cockpit that takes up less space. This is a cheaper solution than a high-fidelity simulator. Still, it has its drawbacks, which until recently included e.g. the need to use the tracking system. Poor tracking accuracy used in older HMD devices and the possibility of encountering relatively high latency may prevent the user from reading some of the depth hints. Currently, in tracking systems of modern displays, inertial measurement units (IMUs) are used to accurately track the orientation of the object, as well as other objects in the room. They are equipped with a gyroscope, accelerometer and cameras [27]. Before, the technology has been limited due to its low capabilities when not being equipped with eye tracking. Currently, advanced devices are equipped with an eye-tracking system, which increases display efficiency and influences interaction in a virtual environment [49].

A high-fidelity driving simulator with a full-size and fully equipped cabin is a more expensive solution than an HMD device. Participation in the simulation does not require the tested to introduce additional devices, however, obtaining a stereoscopic image in it is difficult, and the image in the mirrors does not take into account the head positioning [16].

Despite the highly developed technology of both HMD devices and driving simulators, there are negative effects observed. Their use is associated with the possibility of simulation sickness occurrence. This can be an important factor affecting the quality of data obtained in the research, and sometimes even prevent participants from taking part in the experiments.

Chapter 4.3 provides an in-depth analysis of the simulation sickness in the virtual reality. It presents selected research and scientific theories, which explain why people experience sickness, what are its symptoms and causes, and how the VR-based simulation sickness differs from the simulator sickness. Chapter 4.3.4 deals with adapting the human perceptual-motor system to virtual environment conditions and preventing negative aspects of adaptation to the virtual reality.

4.3 Simulation sickness

Simulation sickness is sometimes referred to as visually induced motion sickness [48]. It is a condition occurring either during or after the exposure to a virtual environment during which the subject experiences unpleasant symptoms such as headaches or dizziness, eye strain, confusion, sweating, nausea, and even vomiting [28]. It is estimated that the symptoms of this sickness are experienced by from 30% to as much as 80% of the population [40].

Although simulation, simulator and motion sickness cause the same symptoms, it is not the same ailment. Simulator sickness occurs as a result of discrepancies between the signals felt by the equilibrium organ (the vestibular apparatus, which is part of the inner ear) and signals obtained by the visual channel [4,28]. In the case of motion sickness, vestibular stimulation alone may be sufficient to cause the sickness, although sight may also be a contributing factor. Simulation sickness, however, occurs without vestibular stimulation. It is believed that there is no single specific cause of simulation sickness, and it is considered a polygenic sickness [28].

Stannley [45] noted that in simulation sickness the disorientation symptoms are greater, and the oculomotor disorders are smaller compared to simulator sickness. In the simulator sickness, the opposite condition is noticed, disorientation symptoms are less visible, and oculomotor disorders are more strongly felt. Author of the study believes that simulation sickness is 3 times stronger than the sickness caused by a driving simulator. However, this has not been confirmed by some of the latest studies by Davis et al. [9]. The researchers have found that motion sickness, simulator and simulation sickness are induced in different situations, but give similar symptoms.

4.3.1 Simulation sickness factors

There are many symptoms that may occur due to simulation sickness. The analyzes carried out by Bruck and Watters [5] indicate the existence of four main factors that make up the sickness phenomenon:

- general factor of simulation sickness,
- visual factor,
- arousal,
- fatigue.

These factors explain 78.27% of the sickness phenomenon variances. The general factor of simulation sickness includes most of the variables associated with the condition. These variables are: nausea, stomach problems, fatigue, dizziness, a feeling of head’s heaviness, cardiovascular activity, discomfort, salivation, concentration problems, increased sweating and anxiety. These symptoms are the result of physiological processes and are mainly associated with reduced well-being. Particular attention should be paid to anxiety. This factor increases along with the number of moving stimuli presented during the tasks in a simulated environment. It is expressed by the increase in individual sickness symptoms. [3, 5].

The second factor is a visual factor. It comprises three symptoms: respiratory function, headache and eye fatigue. People exposed to a large number of mobile stimuli presented during tasks in a virtual environment reported eye fatigue and headaches. The authors claim that the tendency to headaches may be associated with an increase in the excitability of the visual areas of the cerebral cortex. However, they do not provide reasons for including respiratory function in this factor.

The third component is the stimulation factor. The authors consider a respiratory function to be the most important component of this factor. They also include in it the difficulty in concentration, dizziness, blurred vision and stomach discomfort. Breathing is a key role in the functioning of the autonomic nervous system, as evidenced by changes in the level of blood saturation with carbon monoxide arising from exercise or as a result of psychological stress. As the research shows, there is a relationship between the level of anxiety disorders and changes in the level of carbon monoxide [3 for: 15]. In people with anxiety disorders, there is a tendency to hyperventilate and breathing disorders in the periods when the panic phase does not occur. Hyperventilation causes a reduction in blood flow through the brain, which in turn may cause a decrease in concentration and dizziness.

The last factor distinguished by Bruck and Watters [5] is the fatigue factor. It consists of: a feeling of head heaviness, sight tiredness and subjectively perceived fatigue. Simulation sickness, as well as simulator sickness, may be the effect of over-stimulating the muscles controlling the vision organ, which may lead to inefficient ocular processes during exposure to visual stimuli in the virtual environment, and as a result, lead to headaches and eye strain [3].

4.3.2 Theoretical models of simulation sickness

Currently, there are several theories explaining the origin of motion sickness and simulator sickness, which also explains the simulation sickness. However, the researchers do not agree which one is the most appropriate. Sensory Conflict Theory and Postural Instability Theory are considered to be the most common [40].

The Theory of Sensory Conflict is also called the Theory of information mismatch which flow from various senses or the Tip Conflict Theory. This is the oldest and the most acceptable concept explaining simulation sickness. It is also most often referred to by scientists in their research. The theory is based on the assumption that the sickness occurs in a situation when there is a discrepancy of information from all the senses, which provide data about body orientation and movement perception. It causes a perceptual conflict which the body does not know how to deal with. Information received by the visual system and the vestibular system is inconsistent or some of the sensory systems do not receive stimuli (information). In other words, when a subject performs a task in virtual environment, the pattern of movement information is inconsistent with what is presented in a virtual environment. Virtual environments can cause inadequate stimulation because delays, image resolution, colours, lighting may not correspond to the real world and to what the perceptual system is normally used to [48].

According to the theory, the condition for the occurrence of the simulation sickness symptoms is the occurrence of disorders at the level of vestibular receptors. The vestibular system, responsible for the balance, coordination and perception of the whole body movement may not receive any stimuli, even if the information about the movement is perceived by the visual system, which may cause a conflict situation and bring about the sickness. Strongly associated with this mismatch is the illusion of spontaneous movement (sensation of illusory self-motion), during which the subject has the impression of moving, although no movement is performed. This phenomenon is called "vection" and is considered to be the primary cause of simulation sickness. In the case of motion sickness and simulator sickness, the mismatch of information from different senses is reversed, the subject may feel motion while not seeing it [27, 48].

Additionally, an important conclusion that can be drawn from the Sensory Conflict Theory is the fact that the human perceptual system is flexible. It easily adapts to new conditions depending on individual properties and the time of exposure to the virtual environment. Adaptation improves response and well-being in new environmental conditions, but it also can contribute to the disturbance of functioning in the real environment and affect the safety level of performed activities after the simulation [3].

Although the theory explains the reasons behind simulation sickness, it has little predictive power in determining whether the sickness will occur in a particular situation. Also, the theory does not take into account individual differences and does not explain why, in some of the respondents the sickness occurs with different set of stimuli than in the others. The Alternative Model and criticism of the Sensory Conflict Theory is the Postural Instability Theory. Its representatives stated that the lack of similarity between the experienced and the expected sensory information is impossible to measure because it is impossible to determine the starting point. The size of the difference can therefore be estimated only based on the observed symptoms. The greater the difference, the more severe are the symptoms.

According to this theory simulator sickness is a result of prolonged postural instability. This means that a person exposed to simulation conditions does not implement the right strategies to limit the body movements caused by the virtual environment. Postural stability in this theoretical model is not only a variable that changes with the exposure to the virtual environment, but it is also treated as a conducive aspect to the occurrence of simulation sickness symptoms. Owen et al. [36] and Stoffregen et al. [47] found out that relying on the level of postural stability or instability, one could predict whether or not the symptoms of simulator sickness would occur. This theory, like the Sensory Conflict Theory, has been criticized because it has been proven that there are no standardized methods to effectively measure instability [8] and there is a delay between symptoms and instability. This means that instability is a result of simulation sickness [1].

An interesting theory is also the Rest Frame Theory, according to which the frame is any construction that the observer takes for a motionless one. The nervous system has access to many such frames, and one of them is chosen by the system as a reference point when making judgments and perceptions of spatial relations. In some cases, the nervous system is unable to choose a single frame. In a virtual environment, the subject may receive conflicting information about what is immobile and what is not, which may make it difficult to choose a particular frame. Eventually, this may cause a simulation sickness. Prothero [20] in his study discovered that creating an independent visual background in a virtual environment which is compatible with inertial cues can reduce the symptoms of simulation sickness. Rebenitsch and Owen [40] and Chang et al. [6] reached the same conclusion - field of vision and navigation are strongly correlated with the sickness. Chang [6] in his experiment examined the ride in a virtual rollercoaster where he placed two vertical and two horizontal lines, forming an external reference frame and providing a sense of direction. The results revealed that the inclusion of these frames resulted in fewer symptoms of simulation sickness. According to the authors, the reference frame may delay or reduce the appearance of the sickness. The results are in line with the results of Duh, Parker and Furness [12], where the grid was imposed on the visual stage. The grid caused lesser symptoms of the sickness than the situation with the lack of a net.

The Theory of Poisoning is more controversial and less popular. The theory attempts to explain the occurrence of simulation and motion sickness from an evolutionary standpoint. Inadequate stimulation of the virtual environment affects the visual and vestibular system of the subject, in such a way that his body misreads the incoming information. The participant has the feeling that he has ingested some kind of toxic substance that causes disturbing symptoms leading to vomiting reactions [28, 48].

4.3.3 Reasons behind simulation sickness

We can additionally distinguish factors that are not directly related to the theories discussed in section 3.2, and which are indicated as the causes behind simulation sickness. These causes can be divided into those related to technology and devices, individual differences and the causes resulting from inadequate application design. Along with the development of virtual reality technology, the role of human factors in sickness occurrence has been increasingly underlined [40].

4.3.3.1 Technological reasons

One of the primary reasons associated with the device and its optimization are: tracking delay, poor detection of changes in eyeball positioning and the user's head position in real time [10,28]. A low refreshing rate may be associated with dizziness and nausea. Eye pain and visual fatigue can also be caused by the flickering of the display. Kolasinski [25] found that flickering increases along with increasing the field of view. This particularly puts a strain on peripheral vision, which is even more sensitive to flickering than the rest of the eye.

The field of view plays a key role in a virtual reality technology. It is strongly associated with simulation sickness. Research shows that larger field of view increases symptoms [41]. Lin, Duh, Parker, Abi-Rached and Furness and [51] have found out that as the field of view expands, in particular between 60, 100 and 140 degrees, the sickness level is growing. The effect of the field of view can be noticeable regardless of whether we are taking into account an HMD device, head mounting or an external projector [17]. Reducing the field of view reduces the tendency for simulation sickness to occur, but it can cause user disorientation as soon as he moves fast from a standstill while experiencing virtual environment. The field of view is correlated with the presence in the virtual world, i.e. the reduction of the field causes a decrease in the sense of presence [17,14].

In one of the recent studies Fernandes and Feiner [14] have developed a dynamic field of view, which narrowed down to match the user’s acceleration or rotation in virtual environment. They eventually noticed a reduction in symptoms of the simulation sickness in comparison with the static field of view. Reducing the degree of virtual reality perceived by the participants helps them to adapt to the virtual environment without diminishing their subjective level of presence. Similar results were obtained by Budhirajai et al. [37]. By adding a blur effect to the sides of the screens, the onset of the sickness was delayed and the symptoms decreased.

Another cause of the simulation sickness is a mismatch of an HMD to the distance between user’s pupils and the so-called "net effect" that can be visible between the subpixels in a close up. The reason behind this effect is the insufficient resolution of the screen. As evidenced by the research on the onset of the simulation sickness, the weight of the device does not affect it [10]. However, the user's position is important. Depending on the HMD device and application, the user may stand or sit. Symptoms of simulation sickness appear more often when using HMD devices in a standing position because it is associated with postural instability.

4.3.3.2 Reasons related to the human factor

An important issue regarding the reason behind simulation sickness is the role of individual differences in the severity of this phenomenon. It turns out that the factors such as gender and age affect the susceptibility to the sickness symptoms. Women generally appear to be more susceptible than men. A higher rate of nausea is explained by differences in sex hormones and a wider field of vision in women. The wide field of view increases the likelihood of flicker perception, as earlier mentioned (25, 28). It is worth noting that there is a lack of new studies confirming relationship between the gender and the occurrence of simulation sickness, and the existing ones are not unequivocal. Also the age affects the susceptibility to the simulation sickness. The highest sensitivity occurs at the age of 2 to 12 years, it drops significantly between 12 and 21 years of age, and then gradually decreases with age [39].

Other sicknesses or complaints, such as influenza, colds, ear or upper respiratory tract inflammation, migraine, and upset stomach may also contribute to the increase of susceptibility to simulation sickness. Symptoms can also be triggered through fatigue, alcohol poisoning or sleep deprivation [7, 28].

The studies demonstrate that a regular exposure to the virtual environment helps to adapt to it [24]. The studies conducted on military pilots indicate that they are less susceptible to the sickness than others due to excessive exposure to training and simulators. It was also shown that pilots with a higher number of hours flown experience a greater severity of simulation sickness symptoms than the pilots with short aeronautical background. This is an evidence that the pilot's perceptual system is getting more adapted to the real-life flight conditions as his/her experience grows. This eventually causes greater susceptibility to differences between simulated and real conditions [23, 31].

People who have already experienced motion sickness under real conditions are also more susceptible to the symptoms of simulation sickness [40]. Thus, the occurrence of motion sickness may be a natural contraindication to the use of virtual reality devices.

4.3.3.3 Application and design

Scientific research proves that the software application and its design may also contribute to the emergence of the sickness. High rates of rotational acceleration, lack of movement predictability and lack of full control of the situation may cause simulation sickness. The influence of participant’s motion control has been checked by Stanney et al. [44]. Different degrees of freedom were compared and it was noted that six degrees of freedom caused more sickness symptoms than three degrees. However, the researchers suggest that providing the users with full control allows an effective operation and task performance, i.e. under six degrees of freedom greater efficiency and user presence were noted.

Lloarch, Evans and Blat [30] proved that the navigation system also affects the sickness symptomps. In a study conducted in 2014 two systems were compared: a conventional game controller-based navigation and an IMU(inertial measurement unit)-based positioning system. The results showed that a traditional controller caused a worse subjects’s mood than the system using IMU.

Dorado and Figueroa [11] compared the impact of using ramps and stairs in a virtual environment on subject’s discomfort. They noticed that the ramps caused smoother movement, more control and fewer symptoms of the sickness than stairs.

So, Ho and Lo [42] showed that there is a relationship between spatial velocity and the simulation sickness occurrence. During the 30 minute, HMD device-based simulation the effects of the eight speeds: 3, 4, 6, 8, 10, 24, 30 and 59 m/s were checked. It turned out that both nausea and indicators of visually induced sense of own motion (vection ratings) increased significantly with the increase of speed from 3 m/s to 10 m/s. At speeds above 10 m/s, the assessments stabilized. It was found that the movement pace significantly affect the sickness symptoms at the initial stage, but did not affect their growth rate along with the exposure time. The results confirm the results of the Nooji et al. study. [35] In a study conducted in 2017, the role of visually evoked sense of one's movement (vection), optokinetic nystagmus (OKN) and uncoordinated head movements in the formation of simulation sickness caused by rotation of the visual environment were examined. The results showed an increase in sickness symptoms along with the increase in strength and intensity of the visually induced sense of one's movement (vection strength). There were no significant relationships between indicators related to head and eye movements and the occurrence of the sickness.

Scientific research indicate that the sickness can be also caused by the graphics and the picture’s detail level [9, 19, 21]. Davis et al. [9] in the aforementioned study compared high and low realism in two roller coasters. The simulation of the roller coaster with the greater level of detail and realism caused nausea much more frequently than the simulation with lesser graphic realism.

This study confirms the experiment carried out in 2005 on pilots of jet aircraft [21]. In this study, flights at higher altitudes in simulators caused less sickness symptoms than low altitude flights due to the graphic fidelity. Similar results were obtained by Jaeger and Mourant [19]. The researchers compared two simulations with two different image structures. Simulation with a higher level of detail caused an increase in simulation sickness symptoms.

Besides the realism and detail level, the depth of the image is also significant. Images with a lower depth level cause more oculomotor mismatches. The influence of different types of monitors and graphic styles in 3D and 2D models on the user presence and simulation sickness was examined by Liu and Uang. The results show that 3D models with better depth guidance cause fewer sickness symptoms than flat 2D images [29].

Although sickness occurrence is influenced by such factors as: graphics, level of detail of the image, its resolution or depth, as of today the effect of colour and contrast on simulation sickness has not been demonstrated, especially in modern HMD devices.

4.3.4 Prevention methods

Virtual reality (VR) is one of the most modern computer technologies and has been increasingly used not only for games, but also for research, education and training.

Virtual reality-based training programmes should take into account the possibility of simulation sickness symptoms in the participants. The training should be preceded by an interview about previous experiences, susceptability to travel sickness and health problems that may affect the sickness occurrence. Additionally, participant should undergo the process of VR adaptation before the training, during which his/her perceptive and motor system will adapt to the conditions of the virtual environment. According to Piaget's theory [38 for: 26], the adaptation of cognitive structures to the requirements of a given environment takes place through two processes: assimilation and accommodation of schemes and operations to the requirements of the given environment. During the assimilation process, new perceptual contents change to already known schemes and experiences under the influence of similarity However, in the accommodation process, the participant can change established patterns or create new ones based on new experiences. These processes are triggered by the technological aspects of the virtual environment related to the construction of the immersive virtual environment, such as proper tracking of the person's movements, fast rendering, stability and high image quality, as well as by factors related to the emergence of a presence experience (subjective feeling of being in a virtual environment), i.e. the level of control of the environment, its predictability [26]. These factors related to both the technological and psychological side can trigger and facilitate the adaptation process, but they can also make it difficult and cause simulation . Therefore, they require further scientific research and should be improved.

Both at the beginning and during the training process, simulation sickness can be assessed based on the observational indicators and through subjective and objective measures. The observation is based mainly on the physiological indicators which can be observed at a given moment by the observer, such as sweating, facial blushing, increased respiratory activity. The key subjective method used in the simulator sickness evaluation is the Simulator Sickness Questionnaire (SSQ) by Kennedy [22]. By means of a questionnaire, the participant can assess the intensity of certain sickness symptoms. The questionnaire lists 16 symptoms characteristic to the simulation and simulator sickness. The participant determines the significance of a particular symptom on a 4-point scale. Another scale, is the Motion Sickness Questionnaire (MSQ), yet it is less frequently used in scientific research, Objective measures are understood as indicators of emotional arousal, being a result of the exposure to environmental stimuli. These include respiratory parameters, skin-galvanic reaction, posturographic and oculographic methods and cardiovascular indicators. The intensity changes of psychological indicators in comparison to the changes in the physiological indicators are delayed. Therefore, the use of physiological indicators, such as skin-galvanic reaction or EEG, allows the detection of the sickness at much earlier stage [33].

The frequency of heart contractions is a physiological indicator, which can also be analyzed to assess simulation sickness. However, this method is used quite rarely because cardiovascular parameters are considered to be less sensitive to the sickness [3].

Posturographic methods are considered a good indicator of ataxia, which is also a symptom of simulation sickness. The participant must adapt to the simulation conditions at the visual and vestibular level, and after simulation it is necessary to adapt to the natural conditions again. The conflict between visual and vestibular stimuli can cause postural instability as well as simulation sickness symptoms. Therefore, when assessing the sickness possibility, it is good to take into account three components of the equilibrium system: visual, vestibular and proprioceptive. They play a major role in the process of maintaining the balance in a standing position. Reflex reactions, for which postural muscles are responsible, show a lower threshold of excitability than oculomotor reactions, have greater sensitivity and last longer [3].

Research on the relation between posturographic indicators and simulation or simulator sickness is unfortunately not unambiguous. Kennedy showed that the level of variables measured by posturographic methods correlates significantly with the disorientation scale of the SSQ questionnaire. The study found that the higher the level of disorientation, the worse results were obtained in posturographic tests. The relationship occurred regardless of the conditions (static vs. dynamic) [22]. Stoffregen et al. [46, 47] proved that the differentiation in the posturographic indices, as well as the posture deflection acceleration, are good indicators of the sickness. In addition, the probability of symptom occurrence may increase due to the severity of head movements.

However, some research experiments indicate a lack of correlation between posturographic factors and subjective assessment of the sickness. This is explained by the fact that changes in the indicators are visible only after prolonged exposure to the simulation conditions. Therefore, when using them, the duration of the study should be considered. According to the researchers, gender differences may also be important here. Erhrlich showed that women are more susceptible to the sickness. The experiment compared the condition of a fast pace of action (60 mph) with a slow pace (25 mph). For women, a greater postural instability was observed than for men. They declared discomfort associated with the operation of oculomotor mechanisms more often. [13, 34]. Additionally, there are experiments showing that posturographic indicators are not sensitive to the range of field of view [18].

Testing/training conditions of HMD applications are extremely important in the prevention of simulation sickness. So is the exposure to the virtual environment. The studies indicate that prolonged exposure exacerbates symptoms [33, 43]. The influence of study duration on the severity of the sickness symptoms was checked by Stanney et al. 1,000 people took part in the study, and it lasted 15, 30, 45 or 60 minutes in the independent measurement scheme. 80% of the participants experienced nausea, oculomotor disorders and disorientation. The feeling of disorientation lasted up to 24 hours after the test. 12.9% of people did not complete the study due to feeling poorly, in 9.2% of them there was an emetic reflex, and in 1.2% vomiting. It can be assumed that exposure to a virtual environment should not exceed 2 hours. It is also recommended to use breaks between simulation sessions. One session should not last longer than 1 hour [3].

Comfort should be also provided when training doing research using immersive virtual reality. Controlling the level of anxiety and mood is as important as observing the level of symptoms associated with simulation sickness.

4.4 Summary

The phenomenon of simulation sickness is important both from a scientific and practical perspective. The most important training and research goal is to build such simulator working conditions using VR, which will be optimal for the training process, but also for the participating drivers. Minimizing the simulation sickness symptoms will be an indicator of achieving this goal.

As far as the simulation sickness is considered, one should remember that its symptoms may vary depending on the type of device used, its parameters, as well as on the individual characteristics of every participant. The phenomenon is multidimensional, therefore the severity of symptoms is very diverse. Individual factors include age, sex and the level of static spatial capabilities. The highest sensitivity occurs between 2 and 12 years of age, drops significantly between 12 and 21 years of age, and then gradually decreases with age. Women appear to be more susceptible to its occurrence than men. More frequent nausea is explained by differences in sex hormones and a wider field of vision in women. However, there are no recent studies confirming the age aspect. The anxiety level and individual susceptibility to simulation sickness may also have an influence. Increased susceptibility to the sickness is noticed in people suffering from another ailment, e.g. flu, cold, otitis or upper respiratory tract inflammation, migraine, upset stomach, fatigue, and sleep deprivation. These persons should not take part in the training process. The contraindication to using virtual reality devices should also be the occurrence of real-life motion sickness. These persons are more susceptible to simulation sickness.

Before starting the training process, it is extremely important to choose the right virtual reality device. One of the primary causes of simulation sickness is tracking delay and poor detection of real-time changes of both eyeball position and head position. A low refreshing rate may be associated with dizziness and nausea. Among the factors related to virtual reality technology, a display's flickering is also important because it causes eye pain and visual fatigue. Flicker increases with an increasing field of view. This puts pressure particularly on the peripheral vision, which is even more sensitive to flickering than the rest of the eye. The field of view is also strongly associated with simulation sickness. Larger field of view increases the symptoms, smaller in turn - may cause disorientation. In addition, the field is correlated with the presence in virtual reality, i.e. the reduction of the field of view causes a decrease in the sense of presence. Delaying the sickness symptoms and their reduction without losing the subjective level of presence can be provided by the devices enriched with a dynamic field of view. Adding a blur effect to the sides of screens in HMD goggles can also help. The weight of the device does not affect the onset of the simulation sickness.

When designing virtual reality scenarios, one should pay specific attention to elements such as graphics and the image detail. The simulation with a greater level of detail and realism may cause a much more frequent occurrence of nausea than a simulation with less graphic realism. Images with a lower depth level cause more oculomotor mismatches. The 3D images with better depth guides cause fewer sickness symptoms than flat 2D images. As of today, the effect of colours and contrast on the simulation sickness has not been proven, especially in modern HMD devices.

The user’s physical position is also important. Symptoms of the sickness appear more often when using HMD devices in a standing position because it is associated with postural instability.

Before the virtual classroom training, one should conduct an interview about previous experiences, susceptibility to the motion sickness and health problems that could cause sickness. The participant should also undergo the process of adaptation to VR. During the training, the trainer should evaluate observational (mainly physiological) indicators and subjective measures (Symptom Sickness Questionnaire) and objective measures (emotional arousal indicators). It is also strongly recommended to control the anxiety and mood of the training participant. The exposure to the virtual environment should not exceed 2 hours, and one session should not last longer than 1 hour. It is also recommended to provide breaks between simulation sessions.

4.5 Bibliography

1. Akiduki, H., Nishiike, S., Watanabe, H., Matsuoka, K., Kubo, T., Takeda, N. (2003). *Visual-vestibular conflict induced by virtual reality in humans.* Neuroscience Letters 340(2003), 197-200.
2. Anthes, C., Garciá-Hernández, R., Wiedemann, M., Kranzmüller, D. (2016). *State of the Art of Virtual reality Technology.* IEEE Aerospace Conference, 1-19.
3. Biernacki, M., Dziuda, Ł. (2012). *Choroba symulatorowa jako realny problem badań na symulatorach*, Medycyna Pracy, 63(3), 377 - 388.
4. Brooks, J.O., Goodenougha, R.R., Crisler, M.C., Kleina, N.D., Alleya, R.L., Koona, B.L., Logan, W.C., Ogleb, J.H., Tyrrell, R.A., Willsa, R.S. (2010). *Simulator sickness during driving simulation studies.* Accident Analysis and Prevention, 42, 788 – 796.
5. Bruck S., Watters P.A. (2011). *The factor structure of cybersickness.*Displays 2011;32(4):153–158.
6. Chang, E., Hwang, I., Jeon, H., Chun, Y., Kim, H., Park, C. (2013*). Effects of Rest Frames on Cybersickness and oscillatory Brain Activity.* International Winter Workshop of Brain-Computer Interface, Gangwo, South Korea. 62-64.
7. Chowdhury TI, Mohammad S., Ferdous S., Quarles J. (2017).*Information recall in a virtual reality disability simulation*. VRST '17 Proceedings of the 23rd ACM Symposium on Virtual Reality Software and Technology.
8. Cobb, S., (1999). *Measurement of postural stability before and after immersion in a virtual environment.* Applied Ergonomics 20(1999), 47-57.
9. Davis, S., Nesbitt, K., Nalivaiko, E. (2015). *Comparing the onset of cybersickness using the Oculus Rift and two virtual roller coasters.* Proceedings of the 11th Australasian Conference on Interactive Entertainment, 3-14.
10. DiZio, P., Lackner, J. (1997). *Circumventing Side Effects of Immersive Virtual Environments.* Design of Computing Systems: Social and Ergonomic Considerations, Proceedings of the Seventh International Conference on Human-Computer Interaction (2), 893-896.
11. Dorado, J., Figuerora, P. (2014). *Ramps are Better than Stairs to Reduce Cybersickness in Applications based on a HMD and a Gamepad*. IEEE Symposium on 3D User Interfaces 2014, 47-50.
12. Duh, H., Parker, D., Furness, T. (2001). *An "Independent Visual Background" Reduced Balance Disturbance Evoked by Visual scene Motion: Implication for Alleviating Simulator Sickness.* CHI '01 Proceedings of the SIGHCI Conference on Human Factors in Computing Systems, 85-89.

13. Ehrlich J.A., Singer M.J. (1996): *Simulator sickness in stereoscopic vs. monoscopic helmet mounted DISPLAYS.* Proceedingsof the Human Factors and Ergonomics Society 40th Annual Meeting, Philadelphia, USA. Human Factors and Ergonomics Society, Santa Monica1996, ss. 1299–1299.
14. Fernandes, A., Feiner, S. (2016). *Combating VE Sickness through Subtle Dynamic Field-Of-View Modification.* IEEE Symposium on 3D User Interfaces 2016, 201-210.
15. Giardino N.D., Friedman S.D., Dager S.R.: Anxiety, respiration,and cerebral blood flow: implications for functionalbrain imaging. Compr. Psychiatry 2007;48(2):103–112.
16. Grabowski A. (2012). *Wykorzystanie współczesnych technik rzeczywistości wirtualnej i rozszerzonej do szkolenia pracowników (Virtual and augmentedrealitycontemporarytechniques in trainingworkers)*, Bezpieczeństwo Pracy, nr 4/2012, s. 18-21.
17. Harvey, C., Howarth, P. (2007). *The Effect of Display Size on Visually-Induced Motion Sickness (VIMS) and Skin Temperature*. Proceedings of VIMS2017, 96-103.
18. Ijsselsteijn W., Ridder H., Freeman J., Avons S., BouwhuisD. (2001): Effects of stereoscopic presentation, image motion,and screen size on subjective and objective corroborative measures of presence. Presence 2001;10(3):298–311.
19. Jaeger, B., &Mourant, R. (2001). *Comparison of simulator sickness using static and dynamic walking simulators.* Proceedings from the Human Factors and Ergonomics Society 45th Annual Meeting.
20. Jerrold D. Prothero (1998). *The Role of Rest Frames in Vection, Presence and Motion Sickness*', Ph.D Thesis, Universityof Washington, 1998.
21. Johnson, D. (2005). Introduction to and Review of Simulator Sickness Research. U.S. Army Research Institute for the Behavioral and Social Sciences 1832.
22. Kennedy R.S., Fowlkes J.E. (1992): *Simulator sickness is polygenic and polysymptomatic: Implications for research.* Int. J. Aviat. Psychol. 1992;2(1):23–38
23. Kennedy R.S., Lilienthal M.G., Berbaum K.S., Baltzley D.R., McCauley M.E. (1989).*Simulatorsickness in U.S. Navy flight simulators.*Aviat. Space Environ.Med. 1989;60(1):10–16.
24. Keshavarz, B. (2016). Exploring Behavioral Methods to reduce Visually Induced Motion Sickness in Virtual Environments. VAMR 2016: Virtual, Augmented and Mixed reality, 147-155.
25. Kolasinski, E. (1995). *Simulator Sickness in Virtual Environment*. U.S. Army Research Institute for the Behavioral and Social Sciences 4(1027).
26. Koziński, M. (2016). *Proces adaptacji jednostki do rzeczywistości wirtualnej i środowiska 3D.* Rocznik Kognitywistyczny, 9, 1–11.

27. LaValle, S. (2017). *Virtual Reality*. Cambridge University Press.
28. LaViola Jr., J. (2000). *A Discussion of Cybersickness in Virtual Environments.* SIGCHI Bulletin 32(1), 47-56.
29. Liu, C., Uang, S. (2015). *Effects of depth-perception cues and display types on presence and cybersickness in the elderly within a 3D virtual store.* Journal of Ambient Intelligence Humanized Computing 7(6), 763-755.
30. Lloarch, G., Evans, A., Blat, E. (2014). *Simulator sickness and Presence using HMDs: comparing use of a game controller and a position estimation system.* VRST'14 Proceedings of the 20th ACM Symposium on Virtual Reality Software. 137-140.
31. McCauley, M., Sharkey, T. (1992). *Cybersickness: Perception of Self-Motion in Virtual Environments*. Presence 1 (3), 311-318.
32. Milanowicz M. (2013).*Koncepcja wykorzystania technik rzeczywistości wirtualnej do prowadzenia badań nad utratą równowagi człowieka*, Mechanik, 7, s. 433-442.
33. Min B.C., Chung S.C., Min Y.K., Sakamoto K. (2004):*Psychophysiological evaluation of simulator sickness evoked by a graphic simulator*. Appl. Ergon. 2004;35(6):549–556.
34. Murata A. (2004): *Effects of Duration of Immersion in a Virtual Reality Environment on Postural Stability.* Int. J. Hum.Comput. Interact. 2004;17(4):463–477.
35. Nooji, S., Pretto, P., Oberfeld, D., Hecht, H., Bülthoff, H. (2017). *Vection is the main contributor to motion sickness induced by yaw rotation: Implications for conflict and eye theories.*PLoS ONE 12(4), 1-19.
36. Owen N., Leadbetter A.G., Yardley L.: *Relationship between postural control and motion sickness in healthy subjects.* Brain Res. Bull. 1998;47(5):471–474.
37. P. Budhiraja, M. R. Miller, A. K. Modi, and D. Forsyth (2017).*Rotation Blurring: Use of Artificial Blurring to Reduce Cybersickness in Virtual Reality First Person Shooters.* Oct. 2017.
38. Piaget, J. (1981). *Równoważenie struktur poznawczych*. Warszawa: PWN.
39. Reason J. T. and Brand J. J. (1975). *Motion Sickness*, London: Academic press.
40. Rebenitsch, L., & Owen, C. (2016). *Review on cybersickness in applications and visual displays.* Virtual Reality, 20(2), 101-125.
41. Seay, F., Krum, D., Hodges, L., Ribarsky, W. (2002). *Simulator Sickness and Presence in a High Field-Of-View Virtual Environment.* CHI EA '02 Extended Abstracts on Human Factors in Computing Systems, 784-785.
42. So, R., Lo, W., Ho, A. (2001). *Effects of Navigation Speed on Motion Sickness Caused by an Immersive Virtual Environment.* Human Factors, 43(3), 452-461.

43. Stanney K.M., Kingdon K.S., Nahmens I., Kennedy R.S. (2003): *What to expect from immersive virtual environment exposure: influences of age, gender, body mass index, and past experience*. Hum. Factors 2003;45(3):504–520.
44. Stanney, K. M., Kingdon, K., Graeber, D., & Kennedy, R. S. (2002). *Human performance in immersive virtual environments: Effects of duration, user control, and scene complexity.* Human Performance 15 (4), 339–366.
45. Stanney, K., Kennedy, R., Drexler, J. (1997). *Cybersickness is Not Simulator Sickness.* Proceedings of the Human Factors and Ergonomics Society Annual Meeting 41(2), 1138-1142.
46. Stoffregen T.A., Hettinger L.J., Haas M.W., Roe M.M.,Smart L.J. (2000): *Postural instability and motion sickness in a fixed-base flight simulator*. Hum. Factors 2000;42(3):458–469.
47. Stoffregen T.A., Smart L.J. Jr: *Postural instability precedes motion sickness.* Brain Res. Bull. 1998;47(5):437–448.
48. Tiiro, A. (2018). *Effect of visual realism on cybersickness in virtual reality.*University of Oulu.
49. Varjo Technologies. (2017). Bionic Display. Retrieved May, 2018, from https://varjo.com/bionic-display/.
50. Youngblut, C., Johnston, R., Nash, S., Wienclaw, R., Will, C. (1996). *Review of Virtual Environment Interface Technology.* Institute for Defense Analyses.
51. Lin, J., Duh, H., Parker, D., Abi-Rached, H., Furness, T. (2002). *Effects of Field of View on Presence, Enjoyment, Memory and Simulator Sickness in a Virtual Environment.* Proceedings of the IEEE Virtual reality. 164-172.

5. Applicability of low-cost, VR-based professional driver candidate training methods

5.1 Spherical videos in vocational training – introduction and aim of the pilot

The last few years have brought a significant increase in interest in the use of spherical films (also known as 360° films) not only as an innovative form of communication, but also using its educational potential. This situation was significantly helped by the growing interest in virtual reality technology, which is a related technology - spherical films are included in the broadly understood VR. This increase contributed not only to lower prices of new image display devices, but also to conducting many studies showing that solutions using virtual reality are willingly chosen by students/trainees [1]. Research also indicates that the use of VR in training may have more impact on the trainee than the traditional media used so far, and thus increase the probability of creating attitudes and behaviours.

Despite these advantages, VR has not been widely implemented so far for applications in education. This results, to a large extent, from the cost limitations that most educational institutions have - designing and creating a virtual environment is associated with the commissioning of a specialized IT company or learning complicated and time-consuming methods of programming and creating three-dimensional graphics [3].

The use of spherical films allows an alternative approach to creating educational content - it can be recorded using a 360° camera, which is much cheaper to buy and use [2]. It should be noted, however, that spherical films have limitations related to the scope of their use. Due to the fact that they do not allow interaction with elements/devices found in the film, their use is recommended in the first place as an addition to the theoretical part of the courses. In the case of learning to drive a truck, it may be, for example, raising awareness related to the dangers of using a mobile phone or laptop while driving or learning about the dangers of interacting with unprotected road users - pedestrians and cyclists. What's more, spherical films allow even to increase empathy for other road users, allowing the future truck driver to experience the feeling, for example, of being a cyclist overtaken by a multi-ton vehicle, which at the same time enables to visually become aware of the need for behaving adequately in its vicinity.

In the research conducted as part of the project, a comparative analysis was made, among the subjects from two age groups, of the impact of two methods of spherical film projection - using a VR helmet and a tablet - on the phenomenon of immersion and simulation sickness. The benefits and inconveniences related to the properties of two methods for the presentation of spherical films as well as the subjective assessment of the usefulness of each of them in the driver training were also assessed.

5.2 Pilot participants

The study involved 30 drivers, including 15 men aged 20 - 29 years and 15 men aged 50 - 65 years. All participants of the study were active drivers, had a driving license for a minimum of 3 years and travelled around 3,000 km per year during this period. The selection for research groups and the characteristics of the subjects are described in detail in Chapter 7.1.2.

5.3 Training tools

The study used two methods of virtual environment presentation, i.e. using virtual reality goggles - Samsung Gear with a Samsung S8+ phone and a tablet with a diagonal of approx. 10 inches.

Samsung Gear VR

The dimensions of the goggles are 98.60 × 120.70 × 207.10 mm and are characterized by precise tracking of the head movements due to the high signal refresh rate (sampling rate) of 1000 Hz thanks to the built-in Gear VR sensors. The screen has a resolution of 2560 x1440; and the refreshing factor is 60 Hz. The field of view according to the manufacturer's information is 101°.

Tablet

The Samsung Galaxy Tab tablet with a 9.7-inch screen size was used to play spherical films. It displays up to 16 million colours in Super AMOLED technology and has a resolution of 1536 x 2048 pixels. The tablet is also equipped with a gyroscope, which allows to freely change the angle of view on the reproduced spherical recording.

5.4 Testing procedure

The study was carried out in accordance with the research methodology developed at the Motor Transport Institute with the use of virtual reality. The research scheme is shown in Fig. 15.

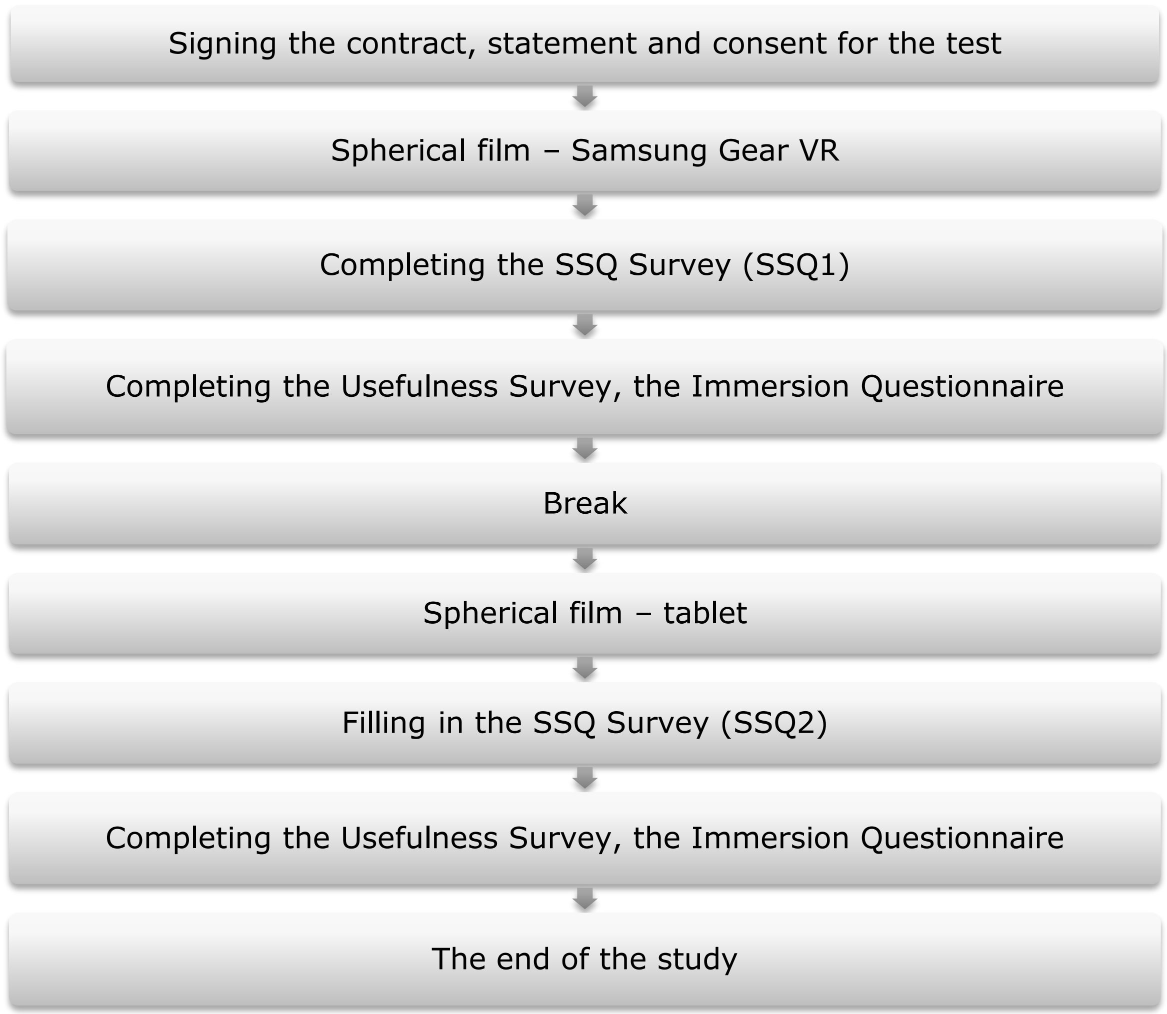


Fig. 23. Diagram of the research procedure used in the spherical film research conducted

5.5 Measured values and test methods

5.5.1 Usefulness measurement method

To evaluate the perceived usefulness, a questionnaire was created for the needs of the survey. The respondents were asked to assess the difficulty level of using a given projection method, the degree of realism of simulation, the level of comfort of particular aspects of simulation and the ease of operation, i.e. comfort of use, visual comfort (smoothness of looking around the scene), level of contrast and depth, image focus and frame of mind during the trip. The questions were based on a 6-point Likert scale. In addition, the respondents were asked about the usefulness of using particular tools for the driver training. The questionnaire was completed after each of the two research drives. The surveys used represent Annexes to this report.

5.5.2 Immersion measurement method

To assess the level of immersion during the experiment, the Immersion Questionnaire was used, which is the Polish adaptation of The Immersion Questionnaire, Strojny and Strojny 2014. The questionnaire is described in detail in Chapter 7.1.5.2.

5.6 Analysis of the results

5.6.1 Descriptive statistics

Participants of the research were recruited divided into two groups of drivers: young and older. 15 men were qualified for both groups. Surveys carried out before the actual tests allowed to determine the characteristic features of both groups of drivers. The results of the surveys have been presented in chapter 7.1.6.1.

5.6.2 Subjective assessment of the immersion level

Analyses have shown that Samsung Gear goggles increase the sense of immersion in the virtual reality. There were statistically significant differences in the level of immersion between Samsung Gear (M = 85.8 points) and tablet (M = 66 points). There were no significant differences in the level of immersion between younger and older people after the film presented in the Samsung Gear goggles. Differences were noticed between individual age groups after the film presentation on the tablet. Younger people rated the tablet immersion much lower (M = 54.9 points) than the older ones (M = 77.2 points).

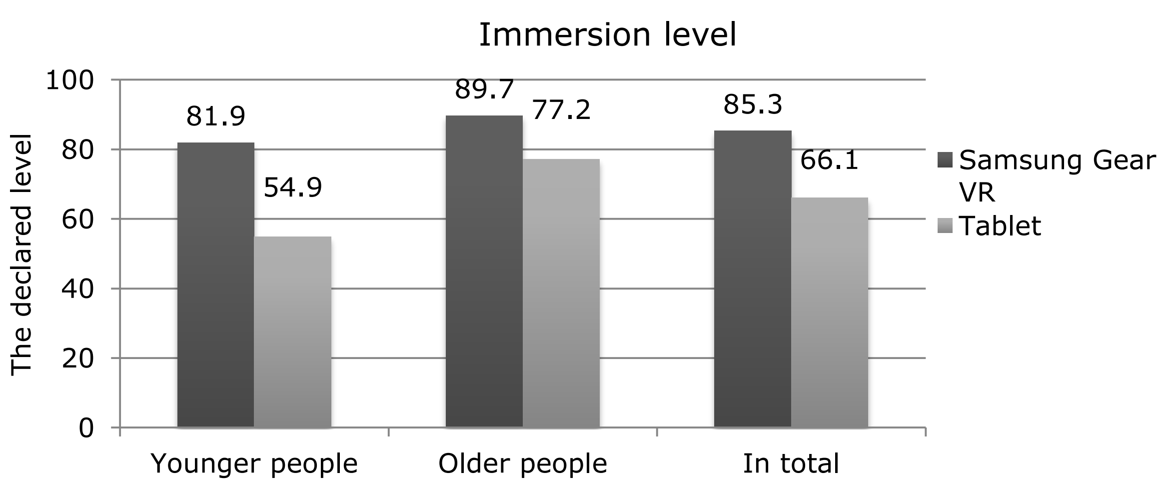


Fig. 24. Immersion experience in the group of young people, older and in total observed during the presentation of spherical film in goggles and on the tablet.

5.6.3 Subjective evaluation of the usefulness of individual simulation methods

Analyses of the questionnaire data showed that there are statistical differences in the level of declared comfort of vision. The respondents rated the Samsung Gear goggles (M = 5.4) better than the tablet (M = 3.8). In addition, Samsung was rated higher in terms of realism (M = 5.03 for SG and M = 3.3 for tablet respectively). There were no significant differences in other aspects - the level of detail of the image, the sharpness of the image or the declared well-being in virtual reality.

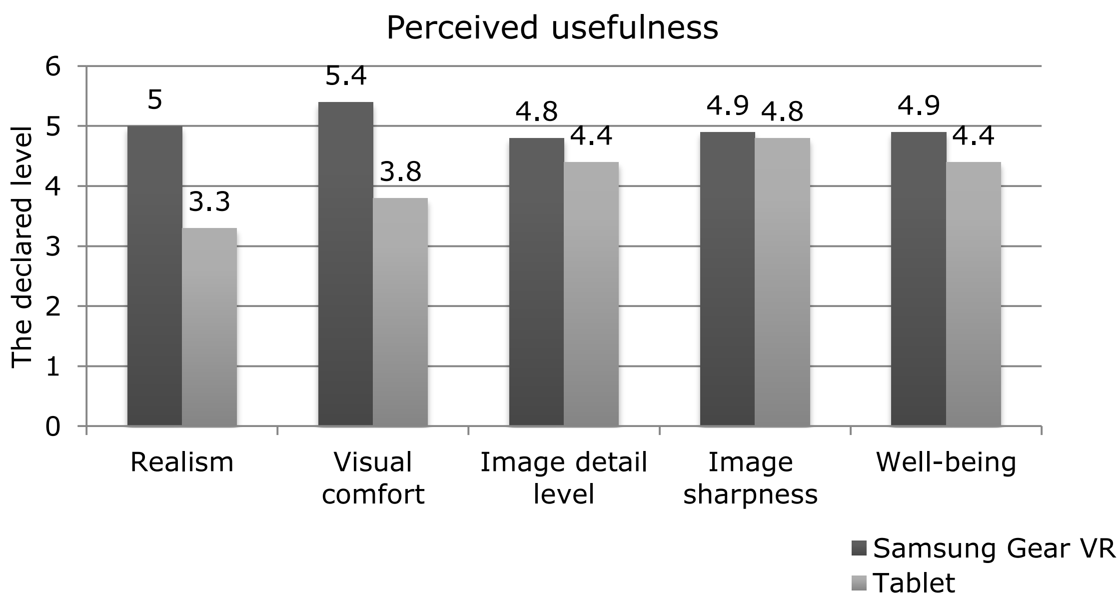


Fig. 25. Perceived usefulness of the virtual reality goggles and projections on the tablet.

93% (28 people) of respondents found the level of difficulty using VR goggles as easy. The film presented on the tablet was similarly rated. 86% (26 people) of drivers thought that the use was easy.

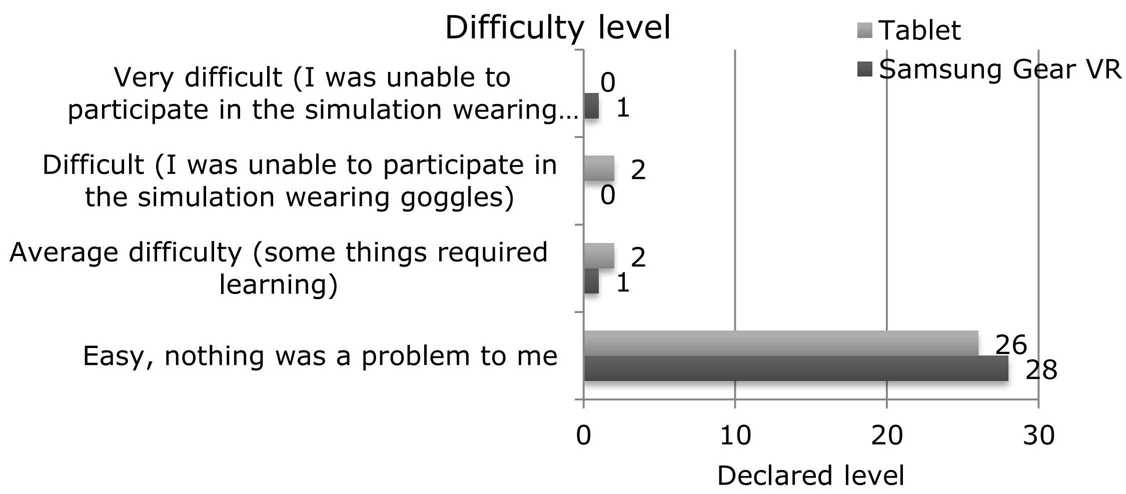


Fig. 26. Perceived difficulty level of using virtual reality goggles and tablet.

For 96% (29 people), nothing made it difficult to use goggles. 3% declared problems with looking around. In the case of a tablet, 90% (27 people) of drivers had no difficulty, 10% of respondents had a problem with looking around and absorbing the picture.

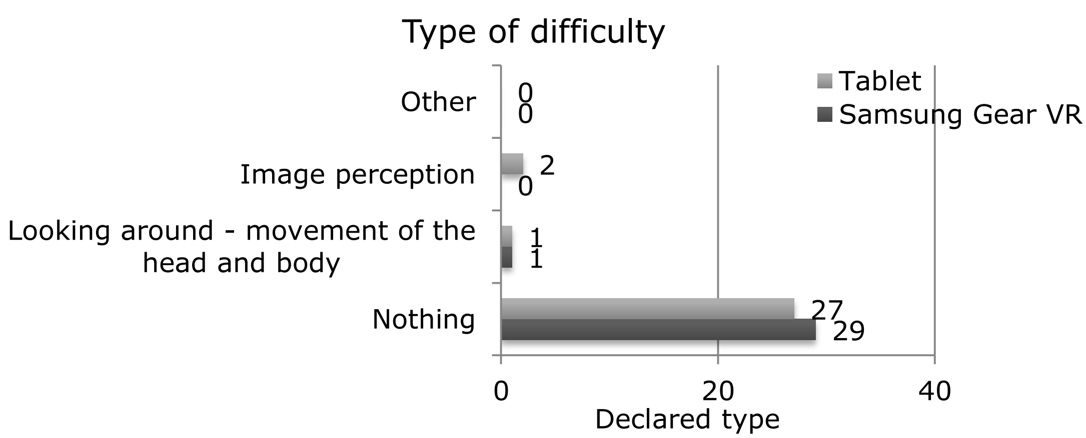


Fig. 27. The type of difficulty the drivers encountered when using virtual reality goggles and the tablet.

As many as 93% of respondents believe that Samsung Gear goggles could be used for driver training. In the case of the tablet, only 36.7% of people believe that 360° films played on this device can be used for driver training.

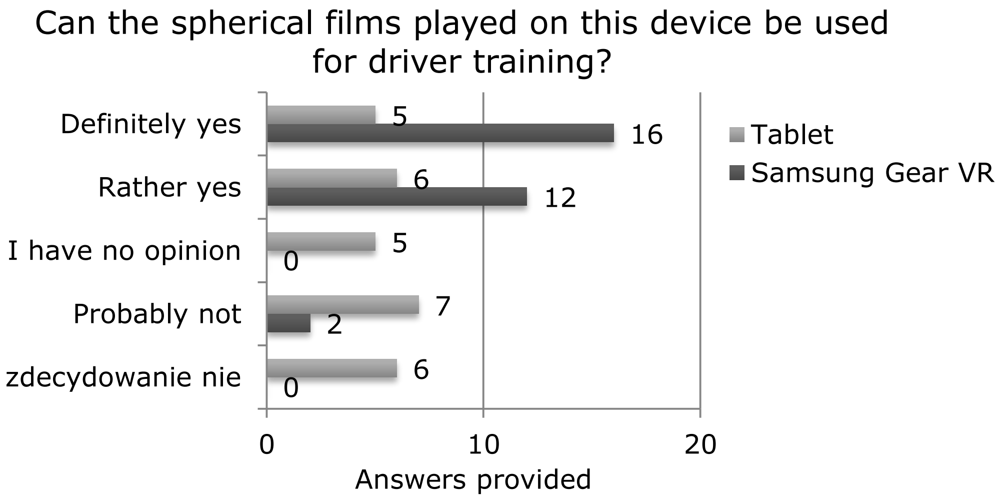


Fig. 28. Subjective assessments of the suitability of virtual reality goggles and tablet for the driver training.

5.7 Summary

Films made in the 360° spherical video technology make it possible to raise the awareness of candidates for professional drivers of the sensitive issues related to many aspects of driving, including road safety. The conclusions and experience gathered during the research conducted have shown that the users prefer the use of spherical films for education and evaluate this technology more favourably in comparison to traditional teaching methods, i.e. 2D flat screen.

For the 360° video projection can be used less technologically advanced mobile virtual reality sets that rely on smart phones and are generally wireless. An example is the Samsung Gear VR goggles used in the study discussed above. The research has shown that they provide higher visual comfort and realism of simulation, which results in greater involvement of trained drivers in learning.

The recommendations discussed in the chapter 7.1.7. should also be taken into account when using spherical films for the drivers training. During the training with the use of spherical films, one of the basic problems requiring observation is the occurrence of simulation sickness symptoms. Counteracting simulation sickness, similarly to traditional Oculus Rift or HTC Vive headsets, is performed mainly through appropriate adaptation to the simulation conditions. However, it should be noted that due to the lack of need to perform movements during simulation, the observed symptoms of the sickness may be smaller than in the case of independent VR sets and simulators. An important element allowing to maintain a high level of immersion, however, is to provide the trainee with conditions similar to those shown on the film (e.g. if the film is recorded from the driver's perspective, it is worth to put the subject in the seat of a real vehicle, in a classic driving simulator or in a designated position for VR training).

Before commencing the training, it is also necessary to verify and exclude the existence of contraindications to participate in the training, that is, significant disturbances of the state of health. It is also recommended to adjust the duration of the training. Training sessions due to the fact that they are static can be longer compared to the dynamic simulations. However, sessions should not exceed a total of 2 hours, and intervals between simulation sessions should be used. Too long exposure to simulation conditions can cause eye fatigue, a feeling of heaviness in the head and subjectively perceived fatigue.

5.8 Bibliography

1. Huang, H.-M., Rauch, U., & Liaw, S.-S., Investigating learners' attitudes toward virtual reality learning environments: Based on a constructivist approach. Computers & Education, 55(3), 1171–1182. 2010
2. Kavanagh S., Luxton-Reilly A., Wuensche B, Plimmer B., Creating 360°educational video: a case study, Proceedings of 28th Australian Conference on Human-Computer-Interaction
3. Wiecha, J., Heyden, R., Sternthal, E., & Merialdi, M., Learning in a virtual world: experience with using second life for medical education. Journal of Medical Internet Research, 12(1) (2010).

6. Applicability of gamification techniques to e-learning platforms

6.1 Introduction

In the recent years, new concepts have been used for strenghtening human motivation to initiate certain activities and changes in behaviour. Gamification is one of such concepts. It is a term which defines implementation of game-based elements to the problems of real people [9]. G. Zichermann and Ch. Cunningham [11] acknowledge that gamification is used for engaging the users and causing them to change their specific behaviour. They state that gamification can be helpful in overcoming real-life limitations by making an influence on people's attitude and mood. In other words, it means a conscious and purposeful usage of different mechanisms and techniques aimed at increasing the engagement, loyalty and habit modification.

Gamification is based on using specific functional elements of game's mechanics and its design rules (game's dynamics) [10]. The most important elements of the gamification are [11]:

– points which are a reward for making progress and conducting desired activities (the ones which help in getting closer to the win) together with the feedback being an environment's reaction to player's activities,

– levels resembling player's status; levels show player's place in the overall ranking which influences the motivation for further game,

– result tables strenghtening further engagement and enabling comparison with other players and boasting with the results,

– badges showing the challenges which players dealt with and what achievements he/she had (they aim at providing player with a feeling of self-satisfaction),

– random or plot-based challenges which need to be taken in order to get points or achieve a higher level [10].

Research on gamification mechanisms indicate that the most frequently used elements are point, badges and result tables [3]. They are aimed at autonomy, competences and relations development [6]. Researchers indicate the necessity of fulfilling certain requirements of gamification systems in order to achieve aspired effects. These are i.e. provision of quick and positive feedback, task customization to user competence level, possibility to repeat tasks, division of the main aim into smaller tasks, design of many paths which lead to achieving the aspired goal, use of differentiated elements of game mechanics and encouraging to further action despite temporary failures [5]. At present, there is however a little research on how people of different personality traits, tendencies and preferences react to specific gamification elements and mechanisms.

Jia et al. [4] observed that extroverts are usually being motivated with the elements such as: points, levels and result tables. People with higher imagination and openness levels are less motivated with avatars. Researchers also stated that there are negative correlations between emotional stability and a few gamification mechanisms. This indicates there might be some limitations for implementing gamification for a large population. In a research on implementing gamification in education Codish and Ravid stated significant differences between extroverts and introverts in a way of perceiving different gamification elements in a examined course. For example extroverts reported lack of freedom and joy with regard to the result table [2].

Due to many existing personality theories, the research conducted in the project used Big Five(extraversion, agreeability, conscientiousness, neuroticism and openness) model. This model is widely accepted and used in the psychological environment.

6.2 Subjects

A total of 30 participants took part in the survey. The analysis is based on full data which was acquired from 23 individuals, 19 men and 4 women. All participants were recognized as NEETs by different local Polish job offices. Being unemployed, they were either encouraged to take such form of vocational training by the office or decided by themselves to do so. Each of them was an active driver with obtained B license. Subjects' participation in the survey was not rewarded.

6.3 Research tools

For the research we used:

- Demographics survey (questions on age, education, vocation, nationality etc.) (Annex 2).
- NEO-FFI questionnaire (used to evaluate the Big Five's personality traits). We used specific scales measuring the openness to experience, extroversion, neuroticism, ageeability and consientiousness.
- An original survey designed in Motor Transport Institute (Annex 1). The survey covered 10 motivational factors resembling the following gamification elements: points, levels, badges, information on one's progress, rankings, challenges, avatar, quick feedback, clear goals and rewards. The subjects were supposed to assess these elements on a 5-grade Likert scale with regard to the ease of use, pleasure, usefulness and reliability.
- External and internal work motivation scale (WEIMS-PL) designed by Małgorzata Chrupała-Pniak & Damian Grabowski, which is a Polish version of Work Extrinsic and Intrinsic Motivation Scale questionnaire [1]. This scale distinguishes autonomous motivation (MW), integration (INTEG), identification (IDEN) and introjection-controlled motivation (INTRO), external regulation (rewards and punishments) (RZ) and amotivation (AMO).

6.4 Test procedure

The survey was taken according to the methodology designed in Motor Transport Institute. The scheme is shown in Fig. 1.

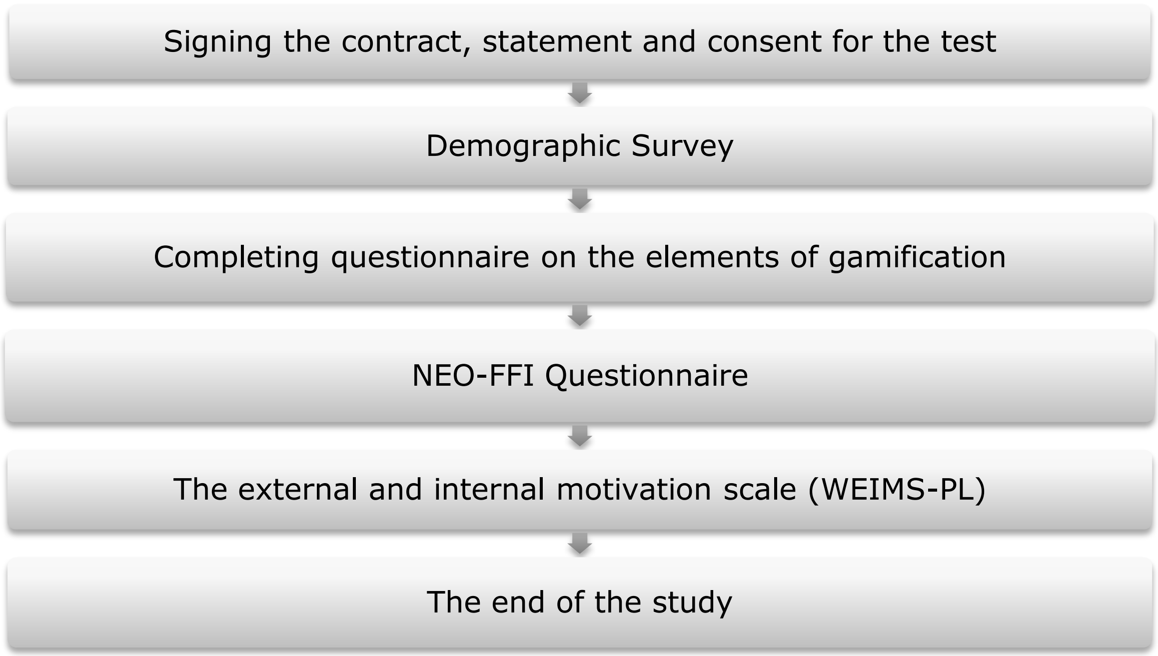


Fig. 29. Scheme of the esearch procedure used for the evaluation of personality-driven, individual assessment of gamification in education.

The survey was implemented in a form of focus groups. Each sessions gathered different number of participants due to their individual availability. By implementing such scheme we aimed at providing a full engagement into the topic. This was aspired to be achieved by introducing the participants to the gamification topic as well as initiating a loose exchange of views.

At first, the participants were introduced to the survey's goal. We also presented the aims of ICT-INEX project. All participants agreed on paper to take part in the survey and hand out the survey for the project purposes. The participants were allowed to resign from the survey at any given moment.

Then, the participants filled out demographics survey (Annex 2), which also contained questions on their traffic behaviour. After filling the questionnaire, we presented the principles of gamification and discussed every gamification element which was to be later assessed by the participants. For this purpose, we prepared a dedicated multimedia-based presentation. The participants were asked to assess in a dedicated survey each of gamification elements right after its presentation and introduction (Annex 1). Then, they filled WEIMS-PL questionnaire.

Overall, the survey took approximately 1 hour.

6.5 Variables

6.5.1 Gamification elements

The survey participants assessed in the questionnaire the ease of use, pleasure, usability and reliability of the following motivational factors (gamification elements):

Points – their are a reward for the covered progress and the activities conducted in the game. A professional driver training-dedicated educational platform may use points as a reward for e.g. finished training modules.

Levels – they create a structure of an educational platform. They are the indicators of user's progress. Reaching a higher level is mostly connected with unlocking additional benefits/bonuses which are not available for lower level users, e.g. new tests or a possibility of getting to previously inaccessible options or topics.

Results table, ranking – it shows user's position in the overall user classification. A ranking enables him/her to compare the results with others and either increase motivation or display individual achievements.

Information on one's progress – For example a statistical information available in a well visible place in educational platform's interface. This information could depict e.g. day streak, average number of questions covered daily, percentage of covered slides, percentage of covered exercises/trail tests. Such information is usually presented as graphs, histograms or simply numbers. The show a current user's performance in relation to the previous ones.

Quick feedback – User of an education platform receives and immediate and consistent feedback on his/her progres. These informations can be shown after the finished module/test. An example of a quick feedback information could be: 'Congratulations! Your score is ... points. You are 10th out of 55 participants taking part in this course'.

Badges – They communicate the information on e.g. finished tasks and challenges or progress and advancement in the game. The badges serve as achievement indicators and could substitute the levels (e.g. by creating a 'novice to master' classification)

Challenges – taking into account educational platform's framework, they could be implemented as tests which comprise of specifically difficult questions or repetition tests. These sets could me made of most difficult tasks and could be customized to individual capabilities.

Rewards – in this case the physical rewards. They can be given for achieving certai progress during the course. The points given for specific activities could become a virtual currency which could be possible to exchange for real-life vouchers, gifts etc.

Clear goals – the user of an educational platform has precisely defined goals which encourage him/her to learn using this tool. The goals should be visualized in a visible place of a platform. Achieving these clearly defined goals is rewarded based on clear rules. It is a form to create user's path through the educational platform. The goals are clearly introduced and they are represented by a system of challenges and rewards.

Avatar – it is a virtual representation of the user, allowing him/her to be clearly identified on the platform. It's goal is also to inform about current user status, being a member of a certain group, given rewards etc. In general, it aims to provide information on the current progress towards a certain educational goal. Sometimes, user is also given a possibility to freely customize the profile according to personal preferences, e.g. by adding a photo.

6.5.2 Personality traits

Below, there are listed the definitione of personality traits measured in the research.

Neuroticism – a trait which resembles one's emotional adaptation vs. emotional imbalance, meaning a susceptibility to experiencing negative emotions such as fear, anger, dissatisfaction, abashment, guilt, sensitivity to stress.

Extroversion – a trait which characterizes quality and number of social interactions as well as the leveles of activity , energy and capability to feeling positive emotions.

Openness to experience – a trait which describes one's tendency to searching and positively evaluating life experiences, tolerance for novelty and curiosity.

Agreeability – a trait which describes positive versus negative attitude towards other peoplea and interpersonal orientation manifested in altruism vs antagonism

Conscientiousness – a trait which characterizes one's level of organization, perseverance and motivation in target-oriented activities. In other words, this trait desribes one's attitude towards work.

6.6 Results

6.6.1 Descriptive statistics

The table below presents the summary of the answers given by the participants in the demographics survey. The answers include gender, education, employment status and ethnicity.

Total number of participants (N=23)	
Gender	Women (17,4%)
	Men (82,6%)
Education	Primary school (0%)
	Vocational school (26,1%)
	Secondary school (47,8%)
	Higher education (26,1%)
Employment status	Unemployed (69,6%)
	Long-term unemployed (4,3%)
	Professionally inactive (8,7%)
	Employed (17,4%)
Ethnicity	Polish (100%)

Fig. 30. Demographic data of the participants

The examined drivers were active drivers for an average of 8.42 years. Yet, there was a significant difference between different individuals due to a high standard deviation value (SD=4,87). Most of the participants assessed themselves either as good drivers (7 persons) or very good drivers (10 persons). They declared that they used to drive everyday (20 persons) or a few times a week (2 persons). 34,8% of the participants covers between 850 and 1700 km a month, 30,4% covers 260-850km while 30,4% of them cover 1700 km. 7 drivers from the whole group were involved in the road event and 1 person was involved in a car accident.

The majority of participants use a computer, smartphone or tablet daily and assesses their skills in using them as good (34,8%) or very good (60,9%). 69,6% of participants used VR devices while 39,1% of them used AR at least once.

43,5% of the participants play games sporadically (once a week) while 26.1% of them play a few times a week. Only 3 persons declared that they didn't play at all. Most participants (34,8%) choose computer games, 26.1% choose board and card games and 21.7% declare that they play all of them.

The majority of subjects did not encounter the idea of gamification yet (60.9%). Only 26.1% of them are acquainted with gamification.

6.6.2 Subjective assessment of gamification elements

Taking into account all 10 gamification elements, the participants were most positive about the progress, clear goals, rewards and challenges. They seemed not to like avatars and levels. On a scale from 1 to 5 (in which 1 equaled disapproval of a concept and 5 equaled a full approval) the participants assessed pleasure and ease of use for 3.13 and 3.84. This means that the respondents understood the basic idea of each gamification element and that these elements play a significant role in utilizing the educational platform. The results were presented in Fig. 3. The best results were highlighted in green and the best ones in red.

	Pleasure of use	Wish to use again, reliability	Helpfulness, usefulness	Ease of use
Points	3,65 (4)	3,65 (4)	4,0 (4)	4,2 (4)
Badges	4,0 (5)	3,65 (4)	3,82 (4)	4,39 (5)
Levels	3,65 (4)	3,60 (4)	3,65 (5)	4,08 (5)
Information about progress	4,08 (5)	3,86 (5)	4,04 (4)	4,43 (5)
Ranking	3,73 (5)	3,65 (5)	3,73 (5)	4,26 (5)
Challenges	4,13 (5)	4,04 (5)	4,08 (5)	**4,47 (5)**
Avatar	**3,13 (4)**	**3,08 (2)**	**3,08 (4)**	**3,86 (4)**
Quick feedback	3,78 (4)	3,78 (4)	3,82 (4)	4,30 (5)
Clear goals	**4,39 (5)**	**4,17 (5)**	**4,26 (5)**	4,39 (5)
Rewards	4,26 (5)	4,13 (5)	4,21 (5)	4,34 (5)

Fig. 31. Average and dominant answers (in brackets) on different gamification elements.

We also analyzed the correlations between different gamification elements in order to determine the differences in individual preferences. The results show that all 10 elements are positively correlated with each other. This means that high note of one element entailed a high note for another element.

The strongest correlations were noticed between points and badges ($r = .892$, $p < .01$), points and information about progress ($r = .889$, $p < .01$), points and rewards ($r = .898$, $p < .01$). This can be explained that the people who like gaining points more frequently enjoy or would enjoy having badges, information about progress or rewards implemented in the education platform.

The weakest correlations were noticed between avatar and clear goals ($r = .493$, $p<.05$), avatar and challenges ($r = .519$, $p < .01$), avatar and rewards($r = .518$, $p < .01$).

6.6.3 Dependency between personality traits and gamification elements

Before getting to specific dependency analyzes we examined the correlations between the participants' independent variables and demographic variables. The results were presented in Tab. 4.

	Average	SD	1	2	3	4	5	6	7

1. Neuroticism	17.04	7.00							
2. Extroversion	33.30	5.55	-,512*						
3. Openness to experience	24.39	4.38	-.196	,487*					
4. Agreeability	29.48	5.12	-.403	.411	.068				
5. Conscientiousness	36.74	7.13	-,585**	,708**	.206	.412			
6. Age	27.50	5.53	.182	-.366	.235	-.165	-,497*		
7. Gender	1.87	.39	.137	-.334	.042	-.094	-.330	.349	
8. Education	3.00	.74	-.158	.178	-.112	.265	.043	-.089	-.318

Fig. 32. Correlations between personality traits and demographics data. A correlation is described as significant when being at 0.05 level (both-sided).

Independent variable, ie. five NEO-FFI personality traits were positively correlated what matched the hitherto research [8]. The correlation between conscientiousness and extroversion was the strongest (r = 0,708, p <0,01) as well as the correlation between conscientiousness and neuroticism (r = - 0,585, p <0,01). This means that the people with higher emotional stability (ie. lover neuroticism level) are more conscientious. People with higher extroversion levels were also more conscientious. Additionally, extroverts are also more open to new experiences (r = 0,487, p <0,05) and less neurotic (r = - 0,512, p <0,05).

When it comes to age, Table 4 show that there is a negative relationship between respondents' age and their conscientiousness (r = - 0,497, p <0,05). We were not able to find correlations between individual personality traits and their gender or education level.

Relationship analyzes between different personality traits and gamification elements showed few significant dependencies. A significant positive correlation between conscientiousness, points and their ease of use was proved (r = 0,445, p <0,05). This means that conscientious people think this element is reliable and competitive. Having such possibility, they would likely use this element. There was also found a positive correlation between openness to experience and avatar (r = 0,445, p <0,05). In other words, the people who tend to think about their goals, view this gamification element as helpful and as motivation drivers.

6.6.4 Relationship between motivation to work and gamification elements

We started the analysis of the results on professional drivers candidates' motivation to work from calculating the mean values for each statement provided in WEIMS-PL motivation scale. The highest values were obtained by the statements resembling internal motivation (M = 5,25), introjection (adopting aspects of another person who is better capable of coping something) (M = 5,46) and (M = 5,5) and external regulation (motivation caused by externally acting influence) (M = 5,2). These motivations are the most important causing the examined professional driver candidates to engage in work.

The lowest values were obtained by the statements resembling amotivation (M = 2,38) and (M = 2,91). This tells of rather high motivation to work among the examinees.

In the next step, we made the correlation analysis of different motivation scales and gamification elements. The results showed that people having higher scores in introjection dimension think that a possibility of gaining points when learning on a educational platform would make the learning process more enjoyable and make fun ($r = 0,473$, $p < 0,05$). These people have similar attitude to levels – there was observed a positive correlation between pleasure of achieving new levels and introjection scale ($r = 0,463$, $p < 0,05$). Additionally, these participants think the levels are reliable and competent ($r = 0,452$, $p < 0,05$).

The additional relationship was proved between information on progress given as a confirmation of learning achievements and introjection dimension ($r = 0,464$, $p < 0,05$).

A positive attitude towards the information on progress is also expressed by the people who are characterized with high internal motivation. We found a positive relationship between internal motivation and the pleasure to use the educational platform when receiving the confirmations on progress ($r = 0,437$, $p < 0,05$).

For those examines who are dominant with external regulation state, ranking seems to be a significant gamification element. We found significant relationships between ease of use and external regulation $r = 0,446$, $p < 0,05$). Besides that, the possibility to place an avatar is important for them too – there was proved a correlation between introjection, willingness to use ($r = 0,430$, $p < 0,05$) and educational usefulness ($r = 0,453$, $p < 0,05$).

Most positive relationships were seen for challenges. They are preferred by the introjective people (the ones who behave according to the external drivers such as ego, shame and guilt). We found correlations between this dimension and pleasure to take on challenging tasks ($r = 0,536$, $p < 0,01$), willingness to use ($r = 0,571$, $p < 0,01$) and educational usefulness ($r = 0,508$, $p < 0,05$).

The challenges were also preferred by the examinees who had strong internal motivation, e.g. people who have a tendency to look for novelties and test themselves. We found positive correlations between the pleasure of using a specific element (r = 0,449, p <0,05), willingness to use (r = 0,486, p <0,05) and educational usefulness (r = 0,424, p <0,05).

Clear goals are preferred by the people who have high values of regulation through identification (they consciously value a goal or regulation so that said action is accepted as personally important) (r = 0,472, p <0,05) and people with higher internal motivation (r = 0,433, p <0,05). Identification concerns the behavior in which one identifies him/herself with the certaing values and meaning, and accepts them as his/her own. Both identification and internal motivation are regulated autonomously

The analysis showed significant relationship between the rewards (the pleasure from the possibility to obtain rewards) and introjection scale (r = 0,415, p <0,05), identification scale (r = 0,428, p <0,05) and internal motivation (r = 0,471, p <0,05).

We found no significant relationship between different motivation scales and both badges and quick feedback.

6.7 Summary

This research helps to understand how the personality traits of professional driver candidates are connected with their view on different gamification elements used for motivating the education platform users. The obtained results indicate that both personality traits and motivation to work influence the preference for specific gamification elements and engagement in the learning process. It is yet important to notice that these motivational, gamification elements may influence different people in a different timespan. The presentation which introduced the participants which the gamification elements could only bring on a first impression. The assessment could then not be a result of a hardly-grounded opinion and long-term thinking about the each of these motivational elements. This should be examined in a long-term and proved by real-life results.

It is also important to be aware of the pilot character of the research, due a limited subject group. The analysis was covered on a group of 23 drivers, therefore its results may serve rather as a hint or a suggestion. It would be worth to conduct a more in-depth research targeted at diagnosing the gamification elements which suit professional driver candidates best.

All in all, conducted research suggests that the implementation of gamification schemes in e-learning may bring many benefits which are connected with increasing drivers' engagement in learning and their vocational development. The results indicate a positive recipience of the proposed gamification elements and high level of their acceptance among the people who are about to enter professional driving profession.

6.8 Bibliography

1. Chrupała-Pniak, M., Grabowski, D., 2016. Skala motywacji zewnętrznej i wewnętrznej do pracy nad sobą (WEIMS-PL) : wstępna charakterystyka psychometryczna polskiej wersji kwestionariusza Work Extrinsic and Intrinsic Motivation Scale. Psychologia Społeczna. 1896-1800. T. 11, nr 3 (2016), s. 339-355.
2. Codish D., Ravid G., 2014. Personality based gamification-educational gamification for extroverts and introverts. In Proceedings of the 9th CHAIS Conference for the Study of Innovation and Learning Technologies: Learning in the Technological Era, 36–44.
3. Hamari J., Koivisto J., Sarsa H. (2014), Does Gamification Work? – A Literature Review of Em-pirical Studies on Gamification [w:] Proceedings of the 47th Hawaii International Conference on System Sciences,DOI: 10.1109/HICSS.2014.377.
4. Jia, Y., Xu, B., Karanam, Y., & Voida, S. (2016). Personality-targeted gamification: A survey study on personality traits and motivational affordances. In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems - CHI ’16 (pp. 2001–2013). doi:10.1145/2858036.2858515
5. Lee J., Hammer J. (2011). Gamification in Education: What, How, Why Bother?, „Academic Exchange Quarterly” no. 15(2).
6. Mekler E.D., Brühlmann F., Tuch A.N., Opwis K. (2015), Towards Understanding the Effects of Individual Gamification Elements on Intrinsic Motivation and Performance, „Computers in Human Behavior”, DOI: 10.1016 /j.chb.2015.08.048.
7. Ryan R.M., Deci E.L., 2000, Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being, American Psychologist, 55(1), s. 68-78.
8. Samuel D. Gosling, Peter J. Rentfrow, and William B. Swann. 2003. A very brief measure of the Big-Five personality domains. Journal of Research in personality 37, 6: 504-528.
9. Tkaczyk, P. (2012). Grywalizacja. Jak zastosować mechanizmy gier w działaniach marketingowych. Gliwice: Helion.
10. Wawer M. (2016). Grywalizacja w edukacji akademickiej – możliwości i ograniczenia jej wykorzystania w kształceniu studentów. Edukacja-Technika-Informatyka 7 (2), 197-205.
11. Zichermann G., Cunningham Ch. (2011), Gamification by Design. Implementing Game Mechanics in Web and Mobile Apps, Sebastopol, CA.

7. Implementation of VR-targeted pilot trainings:

7.1 Polish pilot (Warsaw)

In scope of ICT-INEX project, Motor Transport Institute conducted a pilot which covered two use cases of Virtual Reality's potential implementation in professional driver training curricula. The first piloting activity focused on the comparison of trainees' reaction (both psychophysiological and subjective) to using high-end VR headsets and "traditional", 2D screen-based low-class simulator. In the second piloting activity we examined trainees' reaction to driver training-targeted spherical films and analysed the most efficient methods of displaying these films, so as to the achieve the best educational effect.

In the first part of this chapter, we present a comparative analysis of how virtual reality systems affect the quality of simulation in relation to 2D screens in low-end simulators. We determined the advantages and disadvantages resulting from the properties of particular methods of virtual environment presentation.

The second part of this chapter concerns spherical films (360° films). As the research shows, they may have a greater impact on a trainee than traditional multimedia that were used so far, and thus increase the possibility to shape desired attitudes or behaviours. We conducted a comparative analysis on the influence of two methods of spherical film display - using a low-cost VR headset (smartphone-based) and a tablet, on the phenomenon of immersion and on the simulation sickness among the subjects from project's two target groups. We also evaluated the pros and difficulties associated with these two display methods as well as the subjective assessment of the their usefulness in professional driver training.

7.1.1 Introduction – VR in today's driver training

Virtual Reality provides solutions that support vocational education in many industries today. It also starts to be used in transport industry. Due to the very rapid development of technologies and devices allowing to create a feeling of being completely transferred into a virtual environment, the use of this type of equipment in the driver training seemed only a matter of time.

Due to low implementation costs and scope of impact on the trainee, these tools can be used to complement real-life training. They can also serve as an attractive alternative to traditional e-learning platforms or other forms of theoretical training.

As of today, first implementations of VR in driver training are focused on training safe driving habits, especially for young drivers [11, 8]. VR based training programs are effective in improving inexperienced drivers' ability to predict hidden dangers and prepare them to drive in real traffic. [1, 9]. They are also useful for training professional drivers [4, 12, 13]. Special software provides a capability for the drivers to participate in remote training sessions. These sessions could be conducted under the supervision of a driving instructor from any place. Such scheme could also provide the opportunity to undergo part of practical training, including driving in special conditions and additional training sessions.

The research confirmed the effectiveness of using VR to model behaviour when transferring control in autonomous vehicles [18], as well as to examine driver's frustration, anger and behaviour when driving in adverse road conditions [Agrawal and Vemuri]. Virtual reality is also a useful solution for analyzing the behaviour of other road users, such as cyclists and pedestrians [17]. It can also be used to train the rivers of other professions, e.g. forklift drivers [9].

VR technology has been gaining more and more recognition in the vocational training environment, mainly due to the high level of driver involvement (immersion). The use of VR goggles can potentially separate participants from the real world to a greater extent than flat-screen-based, low-end simulator screens [14, 15, 23]. However, particular attention should be paid to the possibility of the simulator sickness occurring in a virtual reality session [3, 15, 24]. In the context of these advantages and limitations, as well as due to the rapid development of VR technology and VR-based devices, it becomes justified to analyze the impact of VR tools available on the Polish market.

7.1.2 Pilot participants

Trainees were recruited by telephone through an external research company. Their participation in the pilot was rewarded.

Due to wide availability of potential trainees, two out of three project target groups were addressed. The pilot involved a total of 30 drivers, including 15 men aged 20 - 29 (NEETs) and 15 men aged 50 - 65 (50+ year olds). Each participant had to have a valid B category driving license and to be an active driver. For the recruitment purposes, we chose the following criteria:

- having a B category license for at least 3 years,
- driving at least 3000 km per year, from the moment of receiving the licence.

Having arrived to the pilot site, the trainees went through an additional procedure for allowing for participance. It involved stating no contra-indications to participate in the pilot. The assessment was based on participant's health condition, sobriety, not taking medication and lack of chronic illnesses. Additionally, we assessed the results of SSQ (Simulation Sickness Questionnaire) questionnaires which were filled by the participants before the pilot. Questionnaires aimed at checking the contra-indications to using a driving simulator due to trainee's momentary psychophysiological state.

7.1.3 Training tools

The pilot used two different methods of virtual environment display, i.e. using virtual reality goggles - HTC Vive Pro and Oculus Rift as well as conventional screen projection. Compared to a conventional screen which limitates image and visibility of the simulated environment, head mounted displays (HMDs) generate high-quality stereoscopic image. The user has the opportunity to look around, the head movement is also taken into account in the image displayed in the mirrors.

HMD Oculus Rift

Oculus Rift goggles consisted of two OLED displays with an effective resolution of 2160 x 1200 (1080 x 1200 for each eye) with a 90 Hz refresh rate. The device generates an image with an angular size of 110º and provides full range head tracking. It also includes sound effects which are important for achieving the immersion effect, i.e. generates 3D surround sound.

HMD HTC Vive Pro

HTC Vive Pro goggles, similarly to Oculus Rift, use two displays, which create a three-dimensional image from two two-dimensional ones. HTC Vive Pro provides a resolution of 2880 x 1600 (1440 x 1600 for each eye) with dual-OLED display. The refresh rate and the field of view in this HMD is 90 Hz and 110 °, respectively. Goggles also generate 3D surround sound.

Conventional 2D display (PC)

A 40-inch LCD screen with a resolution (1960 x 1080) was used to project the virtual environment. The screen displayed the image at 60 Hz. During the drives, the drivers could observe the virtual environment and change the viewing point of the scene with the help of the steering wheel. The monitor was placed approximately 120 cm from the driver's seat.

Fig. 33. Top: A scene in virtual reality presented using a conventional screen projection. Bottom: Same scene in virtual reality displayed using the HTC Vive Pro goggles.

7.1.4 Testing/training procedure

The pilot was carried out in accordance with the research methodology which was developed in Institute of Motor Transport.

The test stages are shown in Fig. 34.

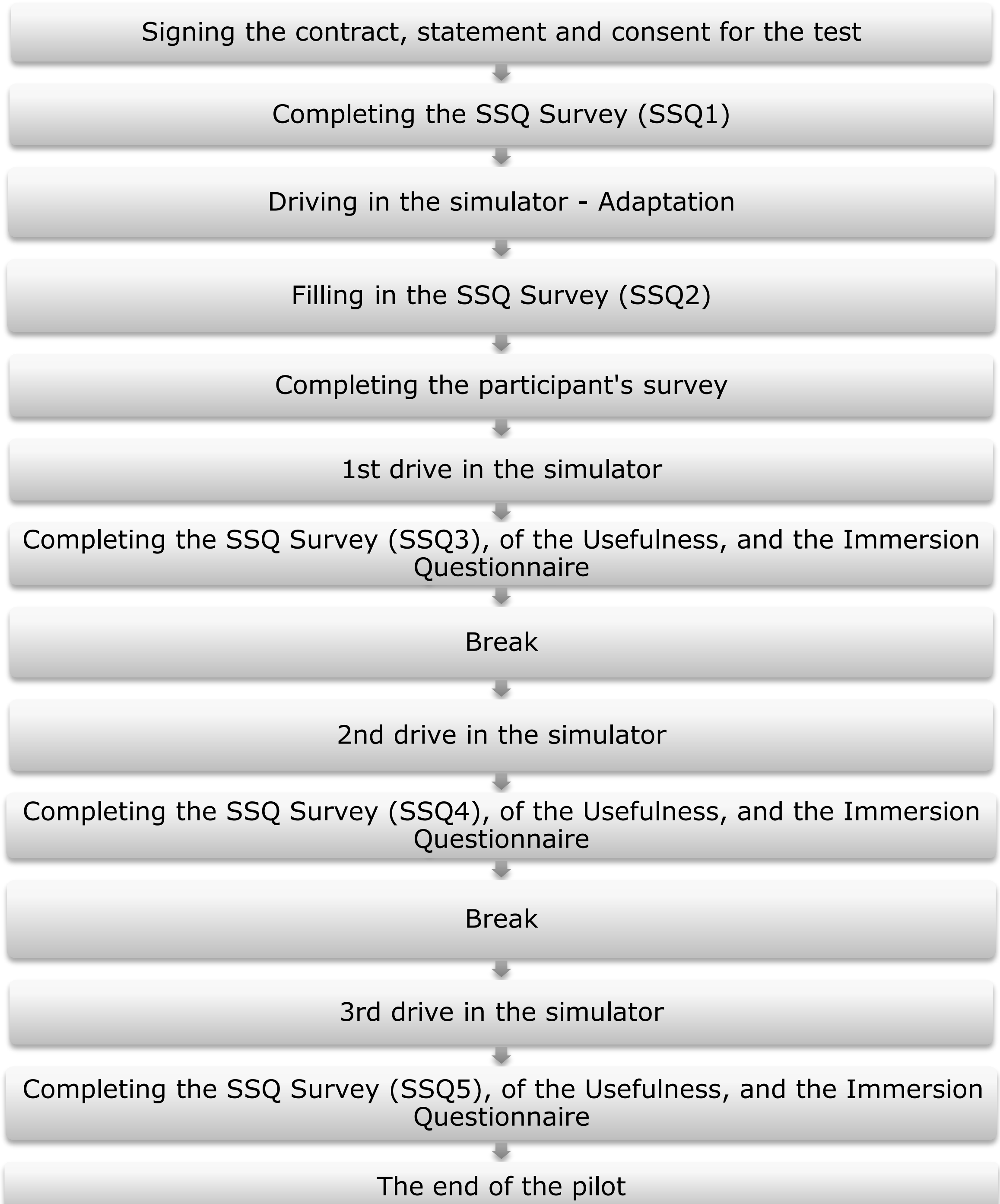


Fig. 34. Diagram of the research procedure used as part of the studies conducted comparing 2D and 3D simulations

Firstly, the participants were familiarized with the study’s purpose and informed about possible adverse participation effects of using virtual reality. Then, they signed a contract for the study participation, a consent to participate in the study and to use the research results for scientific work. They also signed a "statement of a person proceeding to drive on a low-end simulator" which is an attachment to the rules of using the simulator. The participants were allowed to give up their further participation in the study at any time without giving a reason.

Next, the participants filled in the participant's questionnaire (Annex No. 3), containing demographics data and questions about their road traffic behaviour. The survey also included some questions on gaming experiences, such as the frequency of playing games and their type as well as previous experiences with virtual reality and augmented reality. After completing the survey, the participants completed the SSQ1 questionnaire (Simulator Sickness Questionnaire).

The next stage of the test procedure was an adaptation drive in the driving simulator, during which the trainees had the opportunity to become accustomed to steer the vehicle in virtual reality. Adaptation was also aimed at eliminating people who are particularly sensitive and who are vulnerable to the simulation sickness. Before the scenario began, the participants had the opportunity to comfortably position the chair and the steering wheel. They were also informed about how to navigate during the adaptation drive. Trainees were reminded they should immediately inform the staff in case of feeling bad.

Having finished the adaptation drive, the participants completed the SSQ2 survey and had the opportunity to take advantage of a few minutes break. The length of the break depended on how the participant felt and was adjusted to their needs.

After the break the trainees proceeded with the main part of the research, which was covering three research scenarios. Before starting the simulator, the participants were given instructions on what to during the drive. The task of drivers during each scenario was to drive the same route. The section consisted of the local road in the built-up area, a suburban road and the motorway. During two drives, the HTC Vive and Oculus Rift goggles were used. The third scenario, however, was implement using the 2D screen (Fig. 35.).

Fig. 35. Participants during research drives. On the left, a trip in the HTC Vive Pro, on the right, journeys using a 2D display.

In order to avoid the impact of display device sequence on the subsequent participants, the research scenarios were randomly assigned (if one participant first drove using HTC Vive goggles and then in Oculus Rift, the next participant in the first place performed a drive in the Oculus Rift goggles, and the next one in HTC Vive etc.).

Having completed the first research scenario, the participants filled in the SSQ3 questionnaire, the questionnaire on the usefulness of the given projection method and the Immersion Questionnaire by Strojny and Strojny (2014). After that, they had about 10 minutes break, depending on the individual needs. After the break, another instruction was given for the next drive. The trainees sat in the simulator and performed the second research scenario. After completing the drive, the participants filled in SSQ4 questionnaires as well as subsequent questionnaires on immersion and usefulness. Then, they took a third drive. Following that, apart from the next SSQ 5, the questionnaire on immersion and usefulness, the participants had to complete a final questionnaire which aimed at comparing three displays.

A detailed description of the methods used to assess these factors can be found in par. 1.5. The total duration of the study was 1 hour. After completing the test procedure, we made sure that the participant felt good and no simulation sickness occurred.

7.1.5 Testing/training methods and gathered data

Following each drive and drivers' interaction with each virtual reality projection (2D screen, Oculus Rift, HTC Vive Pro), the quality of the experience was assessed. We took into account such factors as perceived usefulness, immersion level, simulation sickness severity and dynamic driving parameters.

7.1.5.1 Usefulness measurement method

In order to evaluate the perceived usefulness, we created two dedicated questionnaires. The respondents were asked to assess the level of difficulty of using a given projection method, the degree of the simulation’s realism, the level of comfort of particular simulation aspects and ease of operation, i.e. comfort of use, visual comfort (smoothness of looking around the scene), contrast and depth level, image sharpness, comfort of controlling a vehicle, controlling the situation in virtual reality and a well-being during driving. The questions were based on a 6-point Likert scale. Additionally, the respondents were asked about the usefulness of using VR goggles for driver training. The questionnaires were completed after each drive and at the end of the study, after completing all trips. In this survey, they had to compare the projection methods used in the study. The used surveys are attached in Annex No. 4, 5 and 6 to this report.

7.1.5.2 Immersion measurement method

To assess the immersion level during the experiment, we used the Polish adaptation of The Immersion Questionnaire [21, 7]. The immersion questionnaire is a tool which was created for the situational immersion measurement. It helps to determine the immersion level, which is a result of interaction between the user and a computer game or simulation. The Polish version of the questionnaire consists of 27 test questions, in which answers are provided on a five-point Likert scale. Questions in the questionnaire relate to six areas: involvement, perception of reality, challenges, transfer to the world of the game, emotional involvement and satisfaction. Relevance and reliability of the Immersion Questionnaire was verified by its authors in three studies. The first one concerned the construction of the questionnaire and verification of its structure, the second verification of the conclusions regarding the structure and composition of the scale and verification of the linkage of its results to the evaluation of the game by selected users and the third, which was an experimental check of the accuracy of immersion scale [21].

7.1.5.3 Simulation sickness measurement methods

In the driving simulator-based studies, the issue of monitoring and controlling the simulation or simulator sickness phenomenon is very important. The questionnaire RSSQ (called the Revised Simulator Sickness Questionnaire) based on the work of the Kennedy team [10] was used to determine the impact of the simulation sickness on the trainees. In the pilot, we used the Polish adaptation of the questionnaire developed at the Motor Transport Institute. RSSQ questionnaire is attached in the Annex No. 9. The method evaluates 28 symptoms in a four-level scale. Symptoms are grouped into three categories:

- nausea symptoms (N),
- oculomotor symptoms (O),
- disorientation symptoms (D).

The assignment of individual symptoms to different categories is presented below.

No.	Symptom	Category		
		Nausea	Oculomotor	Disorientation
1	General discomfort	X	X	
2	Fatigue		X	
3	Boredom			
4	Drowsiness			
5	Headache		X	

No.	Symptom	Category		
		Nausea	Oculomotor	Disorientation
6	Eye strain		X	
7	Difficulties with focusing		X	X
8a	Increased salivation	X		
8b	Dry mouth			
9	Sweating	X		
10	Nausea	X		X
11	Difficulties with concentration	X	X	
12	Depression			
13	Disorientation			X
14	Blurred vision		X	X
15a	Dazed (with eyes open)			X
15b	Dazed (with eyes closed)			X
16	Dizziness			X
17	Memory flashes			
18	General weakness			
19	The need to take a breath			
20	Stomach disorders	X		
21	Loss of appetite			
22	Increased appetite			
23	Need for defecation			
24	Feeling lost			
25	Feeling of eructation	X		
26	Vomiting			

Source: Kennedy 1993

Fig. 36. The 28 symptoms of the RSSQ questionnaire are grouped into three categories

The analysis of RSSQ questionnaires is carried out post factum. Each symptom is assigned a numerical value corresponding the symptom severity marked in the questionnaire. The value of 0 equals the indication of feeling no symptoms, for 1 - the symptoms are "slightly" felt, 2 - the symptoms are felt "moderately" and 3 - the symptoms are "severely” felt. The obtained results are added up in the individual symptoms categories (according to Fig. 4). The results are then multiplied by their weighting factors. The value of these coefficients is:

• 9.54 for the Nausea category,
• 7.58 for the category of Oculomotor symptoms,
• 13.92 for the Disorientation category.

It should be noted here that the symptoms with no indication are not added up. This data is not subject to numerical analysis.

The numerical result of the questionnaire can be used to determine the degree of impact of the sickness on the person examined. It is also possible to calculate a total result for which a weighting factor of 3.74 is used.

The test procedure included answering five SSQ surveys by each participant. The completion of subsequent surveys was followed by:

• directly before using the driving simulator and VR goggles, and before the adaptation scenario,
• directly after the adaptation scenario,
• immediately after the first research scenario;
• directly after the second research scenario;
• directly after the third research scenario;

Completing the RSSQ questionnaires in the abovementioned order allowed to monitor the simulator sickness at each stage of the pilot, depending on the changing display conditions.

7.1.5.4 Driver behaviour measurement method

Driver behaviour was recorded using a widely available modifications of Euro Truck Simulator software. The dynamic data was extracted from the software during each drive.

The following vehicle dynamic data and road events were extracted for the analysis: route driving time, vehicle speed, number and time of speeding cases, number of brake pedal operations, and average fuel consumption during the trip and number of collisions.

7.1.6 Pilot results

7.1.6.1 Descriptive statistics

Participants of the study were recruited divided into two groups of drivers: young and older. 15 men were qualified for both groups. Surveys carried out before the actual tests allowed to determine the characteristic features of both groups of drivers. Young drivers on average have driven the vehicles for 6.67 years (SD = 3.08), and rated their skills to drive a car as good (10 people) or very good (5 people). The respondents declared that they drive a car several times a week (7 people) or every day (7 people), usually covering around 260-850 km per month (10 people). 6 drivers from a given group participated in a road collision, 1 in a road accident.

However, older people with much greater experience in driving vehicles (M = 32.21 years, SD = 7.67) rated their skills as good (12 people) or average (2 people), 1 person rated them as very good. 10 out of 15 drivers declared that they drive a vehicle several times a week. The subjects from this group usually drive 260-850 km per month (7 people), 3 people cover 860-1700 km, 3 people over 1800 km. 5 drivers from a given group participated in a road collision, 1 in a traffic accident.

Most of the drivers surveyed do play various games**.** Only 5 people (1 from the younger group, 4 from the older group) declared that they do not play at all. Older people usually play card games (4 people) or computer games (3 people), while people up to 29 years old usually choose computer games (5 people) or declare that they play all kinds (7 people). Most of the respondents have already met with the concept of "virtual reality" (14 young and 13 older), but only 7 people (3 young and 2 older) used or often use it (2 young). As a rule, the respondents only heard about it (7 young and 8 older). People who have come into contact with this technology usually want to use it again. Definitely less often, the respondents met with the concept of augmented reality. It was not used or only heard of by 9 young people and 13 older ones.

7.1.6.2 Subjective assessment of the immersion level

The subjective immersion level test of the driver was conducted using the Immersion Questionnaire (see chapter 7.1.5.2). The results on the immersion levels obtained in the individual simulations indicate that both HTC Vive Pro and Oculus Rift goggles increase the sense of immersion in the virtual reality. The largest immersion experience was recorded in the Oculus Rift goggles (95.6 points). The level of immersion in the case of HTC Vive Pro amounted to 91.9 pts, but while driving without goggles (screen projection) 86.1 pts. There were also statistically significant differences in experiencing immersion when travelling without goggles between a group of young people (up to 30 years of age) and a group of older people (over 50 years of age). The young people during this simulation experienced a significantly lower level of immersion than older people (76.9 points vs. 95.3 points). The highest level of immersion in each of the studied groups was recorded during trips in Oculus Rift, however, this relationship was not statistically significant.

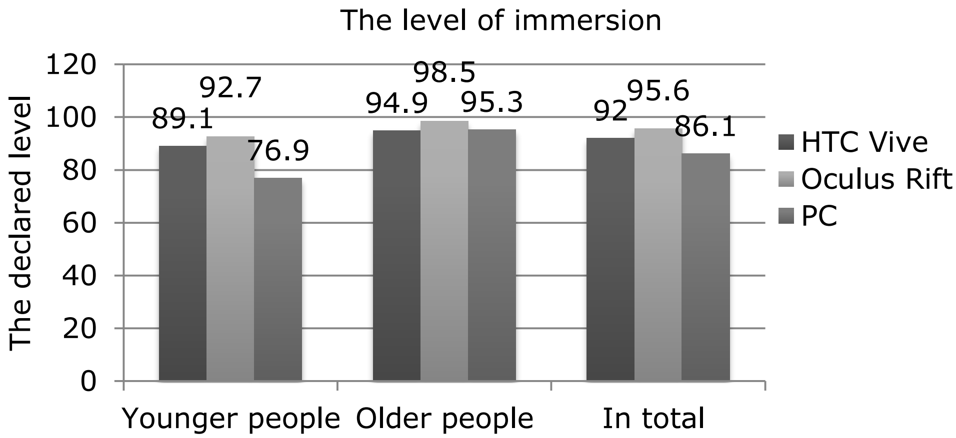


Fig. 37. The feeling of immersion in the group of young, older people and in total, observed during 3D and 2D simulations.

7.1.6.3 Subjective assessment of the usefulness of particular simulation methods

The analysis of the surveys allowed to conclude that almost every aspect of the usefulness was perceived slightly more positively in relation to the traditional 2D screen than virtual reality systems. It should be noted, however, that most of these differences were not statistically significant. Statistically significant differences were found only in the level of declared comfort of use between HTC Vive Pro (3.9pts) and screen projection (4.7pts) and in the level of perceived image sharpness between each of the VR systems and screen projection (HTC Vive Pro - 3, 7 points, Oculus Rift - 4.2 points, screen projection - 4.7 points). As the analyses show, the respondents believed that the simulations in the virtual reality goggles better reflect real driving in the real road conditions. Significantly less realism of the driver's simulation was felt during the screen projection, when they drove without goggles (3.7 points) in comparison with the trip in Oculus Rift goggles (4.4 points). Greater realism was also recorded in the case of HTC Vive (4.0), but this difference was not statistically significant. All image projection systems used in the study were assessed by the drivers as systems of similar difficulty level.

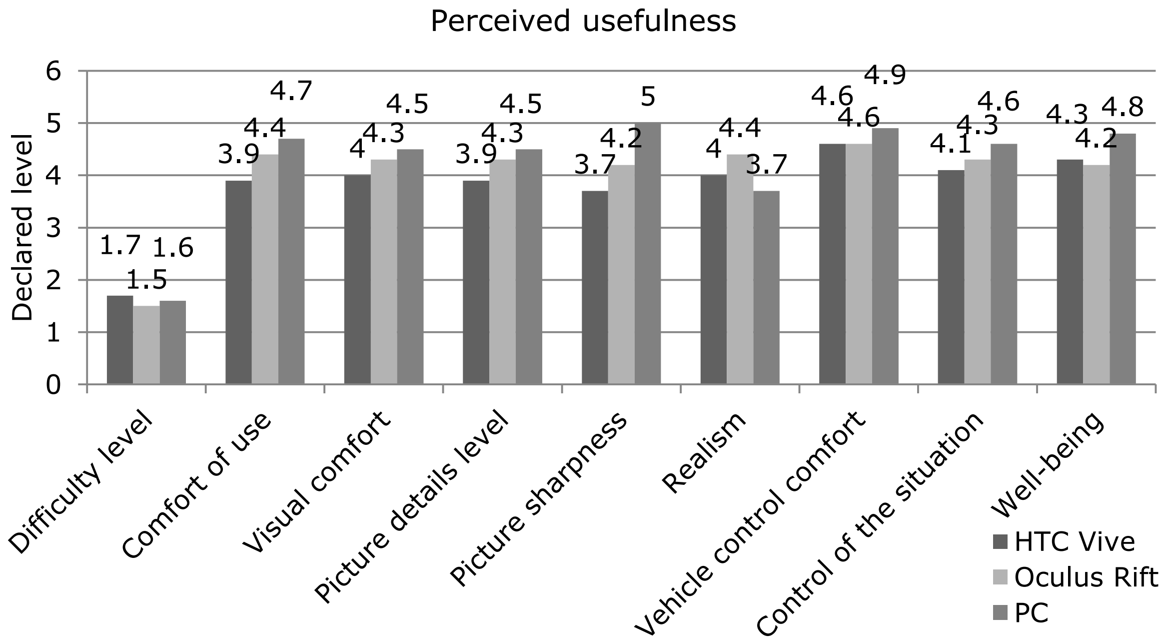


Fig. 38. Perceived usefulness of the individual virtual reality devices and the screen projection.

7.1.6.4 The degree of being affected by the simulator sickness

The analysis of responses provided in the RSSQ (Revised Simulator Sickness Questionnaire) showed that the symptoms of simulation sickness were significantly more frequent in the case of drives using virtual reality than after a simulation in which VR goggles were not used. The overall result, referring to the total effect of the sickness was significantly higher after driving in the HCT Vive Pro (21.2) goggles and Oculus Rift (21.3) ones when compared with the screen projection (8.9). The drives in Oculus Rift and 2D projection proved statistically significantly different $p < 0.05$ ($p = 0.027389$). The drive in HTC Vive and the 2D projection were different at the trend level ($p = 0.054769$). There were no statistically significant differences in the overall result between the two types of goggles used in the study, and the averages were similar.

Similar relationships were observed in all types of symptoms. Symptoms of nausea occurred significantly statistically more often when driving in the Oculus Rift goggles (20.4) than in the simulation without goggles (8.9). There were no statistically significant differences in the symptoms of nausea between the individual types of goggles or between HTC Vive and 2D drive.

When driving in Oculus Rift, significantly more oculomotor symptoms (17.7) were noticed than after the PC simulation drive (8.1). There were differences in oculomotor symptoms between 2D simulation and HTC (16.9) at a trend level ($p = 0.060$). There were no statistically significant differences in the level of oculomotor symptoms between the different types of goggles. The most symptoms of disorientation were recorded when travelling in the HTC Vive Pro (M = 21.8) goggles compared to the 2D simulation (M = 5.6). Differences in the symptoms of disorientation between 2D simulation and Oculus occurred at the level of the trend (p = 0.051288). A slightly higher average of HTC Vive Pro (M = 21.8) compared with Oculus (M = 17.2) was also shown at the trend level (p = 0.053030).

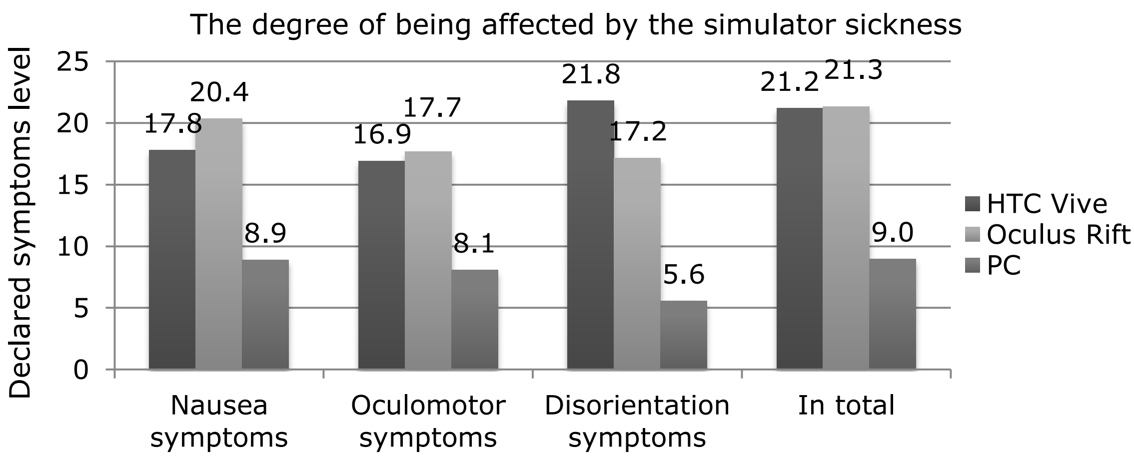


Fig. 39. Symptoms of the simulation sickness and total sickness impact on the subjects observed after 3D and 2D simulations.

7.1.6.5 Analysis of the driving and vehicle control parameters

The analysis of dynamic driving parameters showed that drivers drove faster while travelling in goggles (43.6 km/h in HTC Vive Pro, 44.1 km/h in Oculus Rift) compared to a 2D simulation (41.9 km/h). There were statistically significant differences between both virtual reality systems and screen projection. Detailed analyses were performed according to the age groups. There were no statistically significant differences in the speed achieved between the group of younger people up to 29 years of age and older people over 50 when travelling in VR goggles. During both trips, the respondents drove at similar speeds. The average speed of the younger ones was 44.51 km/h in HTC Vive and 44.63 km/h in Oculus Rift. While, the average speed of the older people was 42.66 km/h and 43.57 km/h respectively. Statistically significant differences were detected in the context of the screen projection. It was shown that during 2D simulations, older people (above 50 years of age) were driving slower (39.5 km/h) than young ones (44.4 km/h).

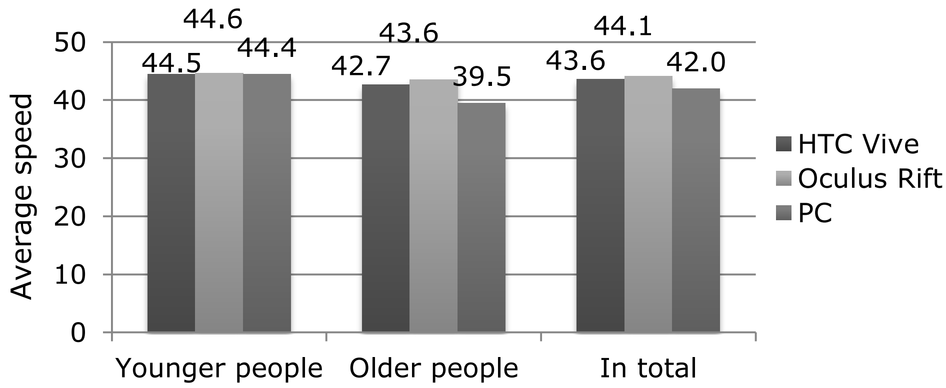


Fig. 40. Average speed in both research groups during 3D and 2D simulations.

Then, the number of speeding cases and their duration were analyzed. The Speeding cases were observed more often during the simulations in Oculus Rift goggles (4.6) in comparison with 2D simulation (3.9). There were no statistically significant differences found between the 2D projection and HTC Vive. There were no statistically significant differences in the number of cases between individual VR systems. The average number of speeding cases for HTC Vive was 4.3 and 4.6 for Oculus Rift. Similar relationships were found in the context of the duration of the speeding. There were no differences found between individual VR simulations. During the trip in HTC Vive, the subjects exceeded the average during 55.5 seconds, while in Oculus - 53.3 seconds. The longest time of speeding has been recorded in the case of HTC Vive Pro (55.3 s.). It was statistically significantly longer compared to the 2D simulation (44.4 s.).

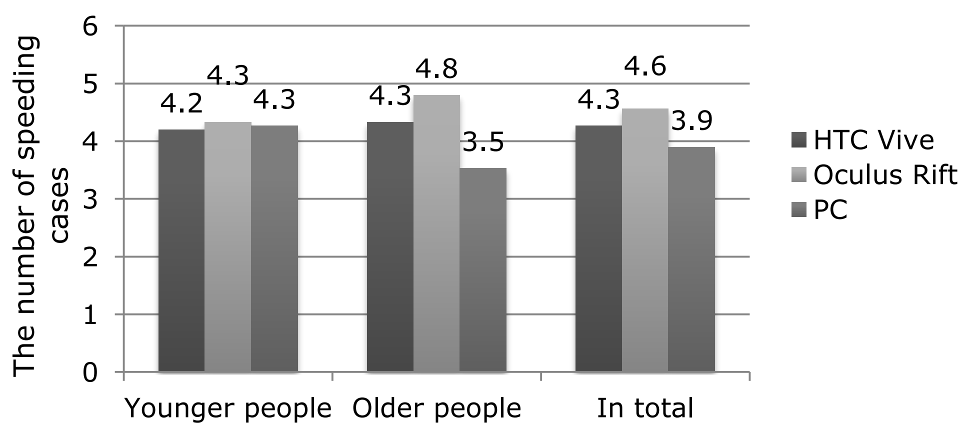


Fig. 41. Number of speeding cases in both research groups during 3D and 2D simulations.

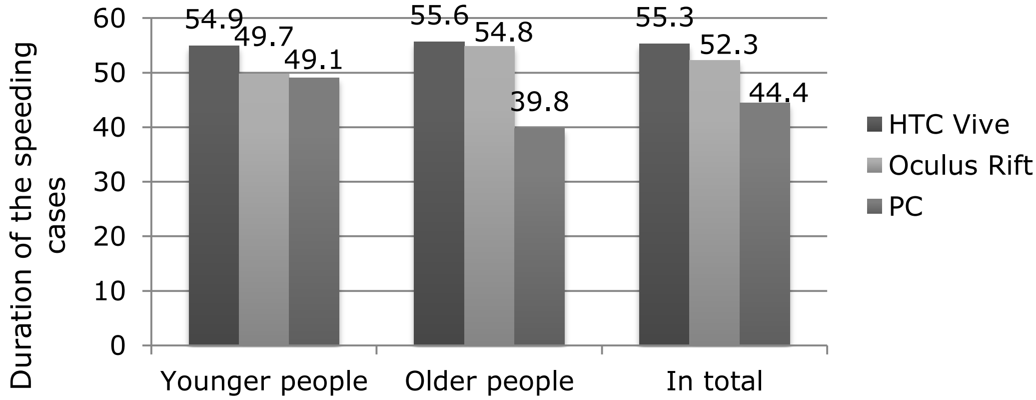


Fig. 42. Duration of the speeding cases in both research groups during 3D and 2D simulations.

It took the longest for the drivers to drive in 2D simulation (441.5 s), compared to the simulation in HTC Vive Pro (421.5 s) and Oculus Rift (415.2 s). The longest trip time was shown in the group of older drivers during 2D simulation (472.8 p.). It was significantly longer than in the case of young drivers (410 s.). There were no statistically significant differences in the driving time between the 2 D and 3D simulations in the group of young people. Analysis of the results of older people shows that during the simulations in the goggles, the subjects performed much better, as shown by shorter driving times.

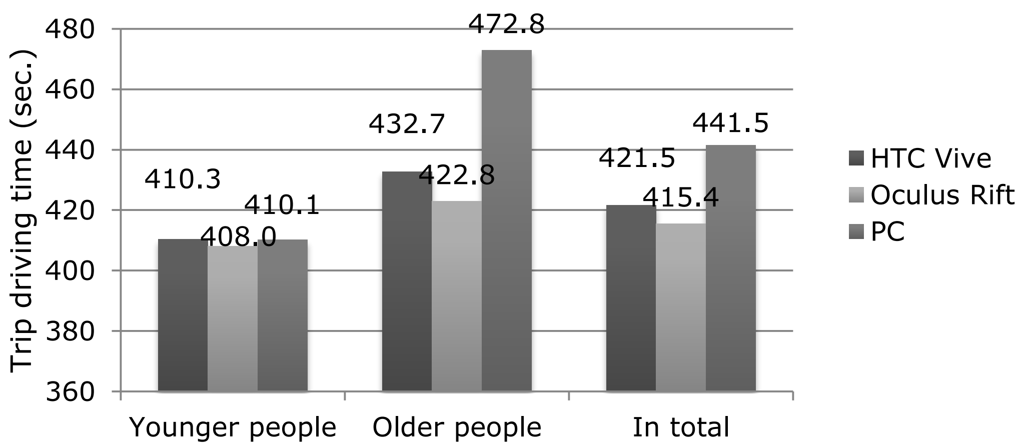


Fig. 43. Trip driving time in both research groups during 3D and 2D simulations.

Additionally, the analysis of dynamic driving parameters did not show statistically significant differences in the number of collisions, brake pedal pressings between 3D and 2D simulation. However, significant differences between research groups have been found. Older and younger drivers differed in terms of the number of collisions caused, respectively 9 vs. 2 collisions during the Oculus Rift and 4 and 1 in HTC Vive. The most collisions were recorded during the Oculus Rift simulation. There were no differences between 2D simulation and the research trip in HTC Vive.

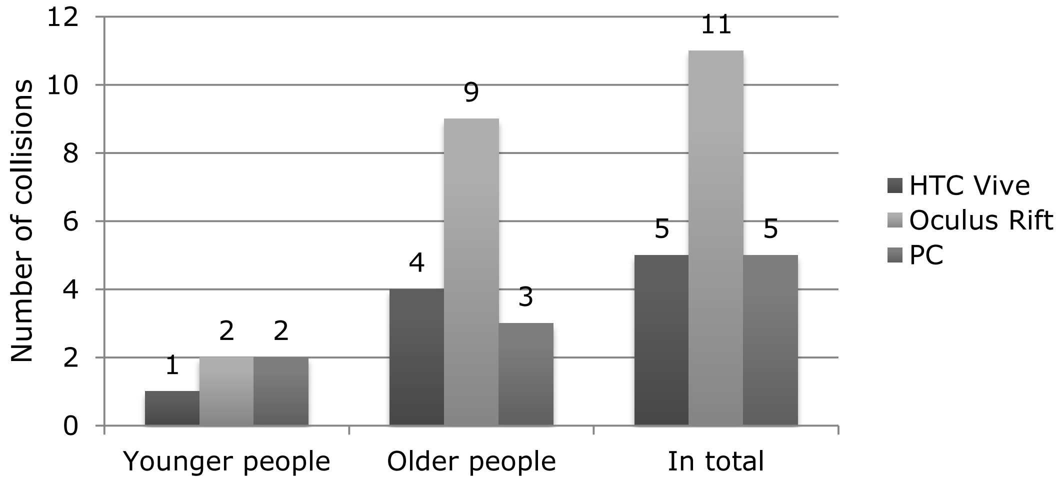


Fig. 44. Number of collisions caused in both research groups during 3D and 2D simulations.

There were also no differences in the average fuel consumption between 2D and 3D simulations, or between different age groups. The highest average consumption was noted during 2D simulations with the older participants (32.7). The lowest in young people during 2D simulation (30.8).

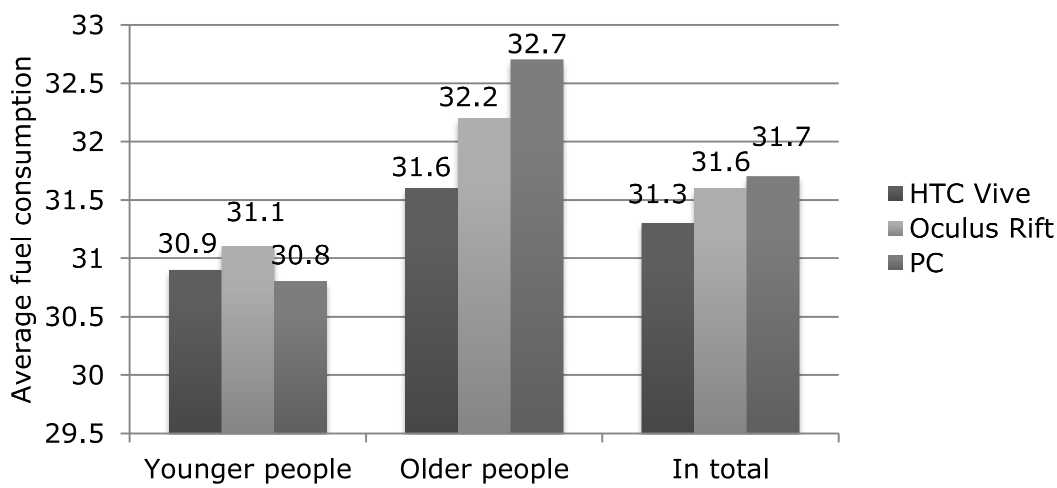


Fig. 45. Average fuel consumption in both research groups during 3D and 2D simulations.

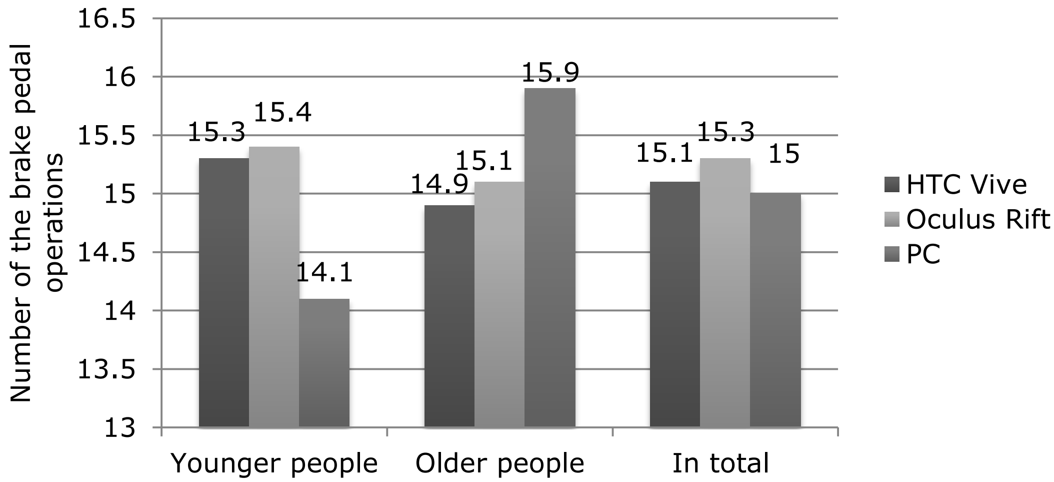


Fig. 46. Number of the brake pedal operations in both test groups during 3D and 2D simulations.

Similar results were obtained with the number of brake pedal operations. Differences were not statistically significant between the age groups as well as between simulations. Young people braked more often while driving in VR goggles, compared to the screen projection. However, older drivers braked more often during 2D simulation, in which no goggles were used. It was a simulation in which the most brakings were observed in the whole study (15.9), the lowest result (the lowest number of brakings) was recorded in young people during 2D simulation (14.1).

7.1.7 Recommendations

Virtual reality is increasingly used in both scientific research and training. It allows, with strict control of the ambient conditions, to examine processes related to modelling safe driving habits and practice related procedures. Apart from many advantages, the use of VR devices brings with it, among other things, the problem of simulation sickness. It can interfere with the reliability of measurement, impair the effectiveness of training, and also be a source of stress for people performing tasks in the virtual world.

Therefore, the programs of training conducted in virtual Reality sets should take into account the possibility of the sickness symptoms occurring in the participants. Simulation sickness can be assessed using subjective and objective measures, understood as indicators of emotional arousal as a result of exposure to environmental stimuli. Among the subjective methods undoubtedly, the key tool is the SSQ questionnaire (Questionnaire for Simulation Disease), developed by Kennedy, while among objective methods, it may be important to record respiratory parameters and skin-galvanic reactions. Due to the capabilities of the training companies and the complexity of the training process, the evaluation of parameters related to simulation sickness requires varying time effort and selection of appropriate research techniques that will allow to gather valuable information sources, but will not be time-consuming and will not involve additional costs. For the training purposes, it is recommended to use subjective methods, including the Simulator Sickness Questionnaire.

Before starting the training, an interview should be conducted regarding previous experiences, propensity to travel sickness and health problems that may affect the occurrence of simulation sickness. It is necessary to verify and exclude the existence of contraindications in order to be able to participate in the training. Contraindications to participate in the training or examination are health disorders important for the assessment of the ability to drive a vehicle, including in particular:
-motion sickness,
-diseases related to the labyrinth,
-disorders or mental illnesses,
-nervous system illnesses (e.g. epilepsy),
-eye illnesses (sight organ),
-diabetes,
-balance and hearing impairment,
-cardiovascular disease,
-the illnesses of the musculoskeletal system,
-kidney failure,
-dependence on alcohol (alcohol abuse),
-dependence on drugs or other similar substances or agents (abuse of these substances),
-having an implanted pacemaker,
-the use of a hearing aid.

In the case of people who wear glasses, it is necessary to check beforehand whether the size of the lenses and frames will allow comfortable fitting into the VR goggles. Due to the different construction of goggles from different manufacturers, this matter must be considered individually. For example - among the two most popular goggle models on the market (Oculus Rift and HTC Vive) there is approx. 10 mm difference in the size tolerances of the frames contained inside them (142 x 50 mm in Oculus and 152 x 60 mm in HTC goggles). An important feature that should also be taken into account in this case is the possibility of changing the optical spacing of the goggles or their regulation in other planes.

The training or research participant should undergo the process of adaptation to VR. It allows to pick up people who are most affected by the sickness and includes at least one driving session in the simulator to familiarize the driver with the driving environment and the vehicle. The adaptation should last about 10 minutes, but due to individual differences, some may undergo the process of adaptation faster, others slower. The driver should get precise instructions before the driving and the route of the scenario should contain elements of the proper testing trip - the driver should perform several manoeuvres (turns, accelerations, braking), the scenario should contain a similar number of traffic users. After each training or research trip, the well-being of the subject should be checked, it is also possible to use the SSQ Questionnaire. Despite the original purpose for research purposes, the questionnaire can be easily adapted to the daily training practice:

1. the trainee should complete the questionnaire before starting the adaptation - its indications can be used to:

    a. to give up the training on a person whose declared well-being is bad when reporting for the training

    b. as a reference point when assessing the condition of a trainee at the subsequent stages of the training

2. the instructor should familiarize himself with the content of the questionnaire completed before the adaptation and decide based on this on allowing the trainee to participate in the training at a given moment or on postponing the training to another date

3. the result of the questionnaire completed by the trainee after the adaptive drive indicates its susceptibility to simulation sickness. On its basis, it is possible to decide on allowing a person to start the training. What is important, the indication of the severity of at least 3-4 symptoms of the sickness may be the basis for possible postponement of the training or (in extreme cases) the resignation from the training using VR

Similarly to the adaptation, the subject should be constantly monitored on an ongoing basis, including the level of symptoms of simulation sickness (Simulator Sickness Questionnaire). Admitting or postponing/giving up the training of a given person using VR technology should ultimately depend on the individual instructor's assessment made based on the current observation of the condition of the trainee and the information about the well-being they received from him. The result of the SSQ is, however, a valuable guide that can help make a decision. Importantly, monitoring the condition of a trainee through the use of SSQ does not require the instructor to know the psychological theories behind it or how to calculate the scores used in specialized research. As indicated above, this condition can be assessed based on an indication of the number and intensity of symptoms of simulation sickness occurring, as well as their change and intensification over time.

In addition, it is recommended to adjust the time and form of training to the age of drivers. The aging process affects the range of adaptation to VR training conditions and attitudes towards them. Designing training for older people should take into account the fact that they do not have experience with VR. Therefore, despite the positive attitude shown in this project by the people aged 50+ towards this technology, these drivers should be given the most accurate instructions before driving in order to reduce anxiety and stress. Detailed and if necessary, repetition of the information several times, will also allow better assimilation of information. It should be remembered that about the age of 50 cognitive abilities begin to decline. The adaptation should be adjusted to the individual needs and abilities of the person. Special attention should be paid to simulation sickness as it is a high-risk group. It is also recommended to provide the possibility of choosing the training method (3D vs. 2D). Based on the research results discussed in chapter 1.6, it is said that younger people are familiar with new technologies including virtual reality - they are more aware of the benefits of using VR devices, but also more critical than older people (there were more negative observations). It is recommended that their adaptation process is also tailored to the individual needs of the driver, but it may be shorter than in the case of older people. Young people are less susceptible to the risk of simulation sickness, but their condition should also be constantly monitored.

The conditions of training in virtual reality are equally important - this applies both to the displays themselves and to the test time. It is assumed that the exposure to a virtual environment, as in the case of sessions on high-end simulators, should not exceed 2 hours, and it is also recommended to use breaks between simulation sessions. The duration of sessions may vary considerably due to the nature of the training (training in a static environment - e.g. bus inspection on a depot vs. a dynamic environment - e.g. driving). This time may also be influenced by elements directly related to the training equipment, among the others: the goggle model used, the training software used, the construction of the training station.

Ultimately, a single session should be as short as possible and should focus on learning one particular skill. This will allow not only to minimize the likelihood of symptoms of simulation sickness, but also to increase the efficiency of teaching. The exercise/task focusing on learning a single skill allows to repeat it in case of a trained person's difficulties until the desired effect is achieved.

VR TRAINING EQUIPMENT AND ITS PROPERTIES

The preparation of the training station for VR training consists of three elements: organizing the training, software and hardware. Each of them has an impact on the final effect of the training, which is influenced by, among the others, an adequate level of immersion and prevention of simulation sickness. In the case of a software, one should take into account the fact that just displaying the VR image is not enough to ensure high learning outcomes - the training software should be designed in a way that reflects its specificity. These applications are programmed with the idea of using VR, enabling, among the others, to reduce the symptoms of simulation sickness, maximizing the capabilities of given goggles or optimizing the use of computing power, and thus the hardware configuration.

In the case of selecting equipment for a training station, one should also be guided by simultaneous increase of immersion and reduction of sickness symptoms. To this end, it is necessary to take care of selecting the right goggles, so that they provide the highest image resolution and sound quality and no delays in contact with the environment, as this will increase realism and speed up the adaptation process. The level of immersion can be additionally increased by reproducing the largest number of relevant (i.e. participating in the interaction with the driver) elements of the virtual environment of the trained person (e.g. elements of the driver's cabin) and parts of the body. For example, greater realism of driving a truck in virtual reality will be provided by a seat that imitates a high driver's position in the semi-trailer tractor's cabin or a steering wheel located in the distance representing the real distance in the cabin. In addition, the more body parts (e.g., hands on the steering wheel) reproduced in VR, the greater the immersion and less simulation sickness. These elements are relatively simple and low-cost to implement - there are many models of adjustable seats used in the construction of driving stations on the market, and the mapping of hand movements in the virtual world can be ensured by separate devices using hand-tracking technology.

The last but important element is the control of the anxiety and mood of the driver trained. Anxiety plays an important role in the severity of symptoms associated with simulator sickness. In summary, people conducting research or training in virtual reality should on one hand monitor the level of symptoms associated with simulator sickness, and on the other - seek to provide optimal comfort to the subjects.

7.1.8 Bibliography

1. Agrawal, R., Knodler, M., Fisher, D., Samuel, S.: Advanced Virtual Reality Based Training to Improve Young Drivers’ Latent Hazard Anticipation Ability. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting. SAGE Publications (2017).
2. Agrawal M., Vemuri K.: A Heterogeneous Traffic Virtual-Reality Simulator to Study Irritation/Anger and Driving Behavior under Adverse Conditions. Published by BCS Learning and Development Ltd. Proceedings of British HCI 2018. Belfast, UK. (2018).
3. Blissing B., Bruzelius F.: Exploring the suitability of virtual reality for driving simulation. In: Proceedings of the Driving Simulation Conference 2018. France (2018).

4. City Car Driving Homepage, http://citycardriving.com/features, last accessed 2019/04/25
5. Ebenholtz S.: Motion sickness and oculomotor systems in virtual environments. Presence 1992;1(3):302–305
6. Harvey, C., Howarth, P.: The Effect of Display Size on Visually-Induced Motion Sickness (VIMS) and Skin Temperature. Proceedings of VIMS2017, 96-103 (2007).
7. Jennett, C., Cox, A. L., Cairns, P., Dhoparee, S., Epps, A.: Measuring and defining the expe¬rience of immersion in games. International Journal of Human-Computer Studies, 66, 641–661 (2008).
8. Lang Y., Liang W., Xu F., Zhao Y., Yu L.: Synthesizing Personalized Training Programs for Improving Driving Habits via Virtual Reality. IEEE Virtual Reality (2018).
9. Hupont, I., Gracia, J., Sanagustín, L., Gracia, M.A.:How do new visual immersive systems influence gaming QoE? A use case of serious gaming with oculus rift. In 2015 Seventh International Workshop on Quality of Multimedia Experience (QoMEX) (2015).
10. Kennedy, R.S., Lane, N.E., Berbaum, K.S., Lilienthal, M.G. (1993). A simulator sickness questionnaire (SSQ): A new method for quantifying simulator sickness. International Journal of Aviation Psychology, 3(3), 203 – 220.
11. Project Toyota TeenDrive365 Homepage, http://www.teendrive365inschool.com, last accessed 2019/04/25
12. Project Eco2Trainer Homepage, http://www.eco2trainer.se/en/ecodriving-utbildning-education, last accessed 2019/04/25
13. Press release about Cargo Dynasty, http://docslide.us/documents/cargo-dynasty-press-release.html, last accessed 2019/04/25
14. Read, J. and Saleem, J.: Task Performance and Situation Awareness with a Virtual Reality Head-Mounted Display. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 61(1), pp.2105-2109 (2017).
15. Ricaud B., Lietar B., Joly C.: Are Virtual Reality headsets efficient for remote driving?. Conference on Road Safety Simulation 2015 (RSS 2015), Oct 2015, Orlando, United States. Proceedings of the International Conference on Road Safety (2015).
16. Savino, M. R. (2009): Standarized names and definitions for driving performance measures.
17. Sobhani, A., Farooq, B.: Impact of Smartphone Distraction on Pedestrians' Crossing Behaviour: An Application of Head-Mounted Immersive Virtual Reality. Journal of Transportation Research Part F: Traffic Psychology and Behaviour, (2018).
18. Sportillo D., Paljic A., Ojeda L., Fuchs P., Roussarie V.: Light Virtual Reality systems for the training of conditionally automated vehicle drivers. IEEE Virtual Reality, Mar 2018, Reutlingen, Germany (2018).

19. Stoffregen T.A., Smart L.J. Jr: Postural instability precedes motion sickness. Brain Res. Bull. 47(5):437–448 (1998).
20. Stoffregen T.A., Hettinger L.J., Haas M.W., Roe M.M.,Smart L.J.: Postural instability and motion sickness in a fixed-base flight simulator. Hum. Factors 2000;42(3):458–469 (2000).
21. Strojny, A., Strojny, P.: Kwestionariusz immersji – polska adaptacja i empiryczna weryfikacja narzędzia, Homo Ludens, iss. 1(6), s. 171-185 (2014).
22. Tiiro, A.: Effect of visual realism on cybersickness in virtual reality.University of Oulu. (2018).
23. Walch, M., Frommel J., Rogers K., Schüssel F., Hock P., Dobbelstein D., Weber M.: Evaluating VR driving simulation from a player experience perspective, pp. 17–25 (2017).
24. Weidner F. , Hoesch A., Poeschl S., Broll W.: Comparing VR and non-VR driving simulations: An experimental user study. In Virtual Reality (VR), 2017 IEEE, pp. 281–282. IEEE. (2017).
25. Youngblut, C., Johnston, R., Nash, S., Wienclaw, R., Will, C.: Review of Virtual Environment Interface Technology. Institute for Defense Analyses (1996).

7.2 Polish pilot (Jaworzno)

7.2.1 Introduction – VR in today's driver training

The professional drivers training process includes min. training in VR conditions on 6-stage driving simulators. On these devices there is a simulation of driving in different road conditions, with the possibility of creating various scenarios including the creation of hazards occurring in road traffic. Under real conditions, it is not possible to reproduce these conditions. They do not occur in such a high intensity that a simulator can create. It should also be noted that such an exercise in real conditions would pose a threat to people participating in the training.

The simulator used by CARGO in driver training meets the requirements of Polish regulations. It uses an innovative on-screen imaging technique. It is characterized by the possibility of displaying the image directly on the cab panes of the vehicle used for training in which the trainee is present. The simulator software generates an image that provides simulation of various types of roads and streets, varied terrain, visualization of the built-up area, weather conditions and driving conditions, season of the year and day. It is possible to map selected failures and malfunctions of individual systems, installations and vehicle systems. The software also simulates selected traffic incidents in real time. The trainer who decides on the choice of scenes decides.

7.2.2 Pilot participants

The program was attended by several dozen people participating in the training taking place at CARGO. The participation criterion was based on belonging to the group of non-working people. They were divided into groups differing in age and nationality. The subject of interest were people aged up to 30 and over 50 years of age.

Fig. 47. The simulator used by CARGO

The future drivers who are interested in the project are young people who are under 30 and are professionally inactive after the age of 50. The level of education varies from basic to higher. They are connected by the need to be in the profession, the desire to acquire the right to get a job and, as a consequence, income. As the personal experience of CARGO indicates, the problem at the start of the training is the lack of knowledge about the scope of material that will need to be absorbed, incomplete knowledge of the time, which should be reserved for training and it is significant. For so-called The initial qualification is 140 hours, for driving licenses several dozen hours depending on the driving license category. Sometimes you are afraid of change, lack of faith in your abilities. For a change, some people show great energy for change, the potential can also be organizational skills, resistance to stress, having a base in the form of a supporting family. It should be remembered, however, that all the above-mentioned features are individualized and each person presents a mix of the above elements.

7.2.3 Training tools

Pilot simulators were used in 3-stage and 6-stage versions. They can create a virtual environment representing a diverse environment (built-up or undeveloped area), it is possible to choose vehicles with different parameters. The simulation also includes changing weather conditions. The simulator used by CARGO uses an innovative "on-screen" imaging technique.

It is characterized by the possibility of displaying the image directly on the cab panes of the vehicle used for training in which the trainee is present. The vehicle cab model is equipped with all control devices. The driver present in it supports the controls as well as being in a typical vehicle cabin. Both automatic and manual transmission options are available. Thanks to a virtual projection using computer technology to generate a virtual terrain image, the generated image contains realistic scenes of the vehicle's surroundings, including acoustic effects. Giving the impression of real driving is possible thanks to a mobile platform with six degrees of freedom.

As part of the research, VR glasses were also used, which allow to "turn off" the person subject to the examination from the natural environment.

7.2.4 Testing/training procedure

Simulation is a method of active teaching and learning in which reality is imitated and thanks to this we gain experience similar to what we will pursue in the real world.

Two procedures were applied: the first one took into account the stage realized with the use of VR glasses, the second one immediately realized the training with the use of simulators. The results obtained are included in the comparative tables. The results were analyzed with particular focus on finding results showing differences between the groups participating in the stage implemented using VR goggles and groups deprived of this stage.

7.2.5 Testing/training methods and gathered data

7.2.5.1 Driver behaviour measurement method

- Response time,
- Number of errors,
- Fuel consumption shown
- Smooth running

The results obtained by the persons participating in the tests were collected in tables. The obtained results were awarded point values according to the following criteria:

- The fuel consumption minimization in relation to driving in various atmospheric conditions was positively assessed,
- The minimization of the number of possible errors was positively assessed,
- A short reaction time to the hazard on the road was positively assessed

The tests were carried out at each stage: using VR goggles, 3-speed driving simulator and 6-stage driving simulator.

7.2.6 Pilot results

Table 1. Pilot results in Cargo

ETS

Responsible partner: ITS / CARGO

Date: 07/02/2019
Target group: 1 2 3 (mark appropriate)
Type of simulator (high-end / low-end) ETS
Gearbox: automatic/manual

1. Driving in the lowest and highest power ranges, with tracing fuel consumption	RESULT	% DEVIATION FROM NORM	NORM	NUMBER OF POINTS
Motorway				
average fuel consumption (l/100km)	24	100%	24	1
travel time	14,8	99%	15	1
number of errors	1,2	120%	1	- 1
number of times brake pedal was pressed	5,2	104%	5	- 1
Mountainous area				
average fuel consumption (l/100km)	30,4	101%	30	- 1
travel time	17	113%	15	- 1
number of errors	1,6	160%	1	- 1
number of times brake pedal was pressed	5,4	108%	5	- 1
Undeveloped area				
average fuel consumption (l/100km)	25,4	98%	26	1
travel time	14,8	99%	15	1
number of errors	1,2	120%	1	- 1
number of times brake pedal was pressed	4	80%	5	2
Developed area				
average fuel consumption (l/100km)	28,8	103%	28	- 1
travel time	16,2	108%	15	- 1
number of errors	1,2	120%	1	- 1
number of times brake pedal was pressed	4,6	92%	5	1
2. Tests of braking in a special area, drawing attention to various effects depending on braking technique: reaction time from noticing an obstacle to the beginning of braking (emergency braking)	RESULT (reaction time)	% DEVIATION FROM NORM	NORM	NUMBER OF POINTS
Undeveloped area – sunny weather	0,6	86%	0,7	2
Undeveloped area – rainy weather	0,8	100%	0,8	1
Developed area – sunny weather	0,74	106%	0,7	- 1
Developed area – rainy weather	0,9	113%	0,8	- 1
			TOTAL POINTS	- 2

**Groups:*
1. Unemployed young people (- <29 years)
2. Persons long-term unemployed (+50 years)
3. Immigrants (including refugees)
*** It is preferred to:*
minimise fuel consumption
shorten travel time
no errors
minimisation of use of brake
reaction time as short as possible

The table above shows the results obtained during classes implemented using Euro Track Simulator. The target group in this case were people under 30 years of age. This research stage was a preparatory stage.

Responsible partner: ITS / CARGO Date: 07/02/2019 Target group: 1 2 3 (mark appropriate) Type of simulator (high-end / low-end) Gearbox: automatic/manual	SIMULATOR after ETS			
1. Driving in the lowest and highest power ranges, with tracing fuel consumption	RESULT	% DEVIATION FROM NORM	NORM	NUMBER OF POINTS
Motorway				
average fuel consumption (l/100km)	21,8	91%	24	1
travel time	13	87%	15	2
number of errors	0,4	40%	1	5
number of times brake pedal was pressed	4,2	84%	5	1
Mountainous area				
average fuel consumption (l/100km)	28,6	95%	30	1
travel time	14,6	97%	15	1
number of errors	0,8	80%	1	5
number of times brake pedal was pressed	4	80%	5	2
Undeveloped area				
average fuel consumption (l/100km)	23,8	92%	26	1
travel time	14	93%	15	1
number of errors	0,6	60%	1	5
number of times brake pedal was pressed	4,2	84%	5	1
Developed area				
average fuel consumption (l/100km)	26,2	94%	28	1
travel time	14,4	96%	15	1
number of errors	0,4	40%	1	5
number of times brake pedal was pressed	4,6	92%	5	1
2. Tests of braking in a special area, drawing attention to various effects depending on braking technique: reaction time from noticing an obstacle to the beginning of braking (emergency braking)	RESULT (reaction time)	% DEVIATION FROM NORM	NORM	NUMBER OF POINTS
Undeveloped area – sunny weather	0,6	86%	0,7	2
Undeveloped area – rainy weather	0,68	85%	0,8	2
Developed area – sunny weather	0,6	86%	0,7	2
Developed area – rainy weather	0,72	90%	0,8	1
			TOTAL POINTS	**41**

**Groups:*
1. Unemployed young people (- <29 years)
2. Persons long-term unemployed (+50 years)
3. Immigrants (including refugees)
*** It is preferred to:*
minimise fuel consumption
shorten travel time
no errors
minimisation of use of brake
reaction time as short as possible

The table above presents the results of the same group achieved on the simulator being the next stage of test research. Checked and scored:

- Time of travel
- Fuel consumption
- Errors in driving
- Smooth running

For comparison, below we present a table showing the results of a control group that had identical classes on the simulator without an introductory stage implemented using the Euro Track Simulator program.

Responsible partner: ITS / CARGO
Date: 07/02/2019
Target group: 1 2 3 (mark appropriate)
Type of simulator (high-end / low-end)
Gearbox: automatic/manual

Simulator without an initial ETS stage

1. Driving in the lowest and highest power ranges, with tracing fuel consumption	RESULT	% DEVIATION FROM NORM	NORM	NUMBER OF POINTS
Motorway				
average fuel consumption (l/100km)	22,8	95%	24	1
travel time	14,4	96%	15	1
number of errors	0,4	40%	1	5
number of times brake pedal was pressed	4,6	92%	5	1
Mountainous area				
average fuel consumption (l/100km)	31,2	104%	30	- 1
travel time	15,2	101%	15	- 1
number of errors	2	200%	1	- 1
number of times brake pedal was pressed	4,8	96%	5	1
Undeveloped area				
average fuel consumption (l/100km)	26	100%	26	1
travel time	15	100%	15	1
number of errors	1,2	120%	1	- 1
number of times brake pedal was pressed	5,4	108%	5	- 1
Developed area				
average fuel consumption (l/100km)	28,4	101%	28	- 1
travel time	14,4	96%	15	1
number of errors	0,8	80%	1	5
number of times brake pedal was pressed	5	100%	5	1
2. Tests of braking in a special area, drawing attention to various effects depending on braking technique: reaction time from noticing an obstacle to the beginning of braking (emergency braking)	RESULT (reaction time)	% DEVIATION FROM NORM	NORM	NUMBER OF POINTS
Undeveloped area – sunny weather	0,66	94%	0,7	1
Undeveloped area – rainy weather	0,82	103%	0,8	- 1
Developed area – sunny weather	0,66	94%	0,7	1
Developed area – rainy weather	0,9	113%	0,8	- 1
			TOTAL POINTS	**12**

**Groups:*
1. Unemployed young people (- <29 years)
2. Persons long-term unemployed (+50 years)
3. Immigrants (including refugees)
*** It is preferred to:*
minimise fuel consumption
shorten travel time
no errors
minimisation of use of brake
reaction time as short as possible

As a result of the tests, a positive impact of the introduction of 3D visualization on both the early and advanced training stage was noticed. It increases the attractiveness of the training itself, which may contribute to the increase in the popularity of training among those interested. It also improves the quality of the message - the trainee shows a greater interest in the information provided, which improves the final result of the training.

Early familiarization with 3D reality eliminates the stage of getting familiar with this visualization system during qualification training.

Test results are also confirmed in other age groups. Studies conducted on people over the age of 50 show similar relationships.

Responsible partner: ITS / CARGO
Date: 07 11 2018
SIMULATOR after ETS
Target group: 1 2 3 (select the correct)
Type of simulator (high-end / low-end)
Gearbox: automatic/manual

1. Driving in the lowest and highest power ranges, with fuel consumption tracking	RESULT (reaction time)	DEVIATION % FROM A NORM	NORM	AMOUNT OF POINTS
Motorways				
the average fuel consumption	25	104%	24	- 1
time of travel	15	100%	15	1
the number of errors	1,8	180%	1	- 1
number of brake pedal operations	4,6	92%	5	1
Mountainous area				
the average fuel consumption	31,4	105%	30	- 1
time of travel	16,2	108%	15	- 1
the number of errors	2,8	280%	1	- 2
number of brake pedal operations	5	100%	5	1
Undeveloped area				
the average fuel consumption	22	85%	26	3
time of travel	15,2	101%	15	- 1
the number of errors	1,8	180%	1	- 1
number of brake pedal operations	4,4	88%	5	1
Built-up areas				
the average fuel consumption	28,8	103%	28	- 1
time of travel	15,4	103%	15	- 1
the number of errors	2,4	240%	1	- 2
number of brake pedal operations	5,4	108%	5	- 1
2. Braking tests in a special area, with attention to different effects depending on the braking technique: reaction time from noticing an obstacle to the beginning of braking (emergency braking)	RESULT (reaction time)	DEVIATION % FROM A NORM	NORM	AMOUNT OF POINTS
Undeveloped area - sunny weather	0,7	100%	0,7	1
Undeveloped area - rainy weather	0,92	115%	0,8	- 1
Built-up area - sunny weather	0,76	109%	0,7	- 1
Built-up area - rainy weather	1,04	130%	0,8	- 2
			TOTALITY	- **9**

** Groups:*
1. Unemployed young people (- <29 years)
2. Long-term unemployed people (+50 years)
3. Immigrants (including refugees)
*** Preferred is:*
minimizing fuel consumption
reduction of travel time
no errors
minimizing the use of the brake
the shortest response time

The table above shows the results for the group that before the test on the simulator took part in classes using ETS, while the table below shows the results obtained on the simulator without preliminary classes from ETS.

Responsible partner: ITS / CARGO
Date: 13 11 2018
Target group: 1 2 3 (select the correct)
Type of simulator (high-end / low-end)
Gearbox: automatic/manual

Simulator without an initial ETS stage

1. Driving in the lowest and highest power ranges, with fuel consumption tracking	RESULT (reaction time)	DEVIATION % FROM A NORM	NORM	AMOUNT OF POINTS
Motorways				
the average fuel consumption	24,2	101%	24	- 1
time of travel	15,4	103%	15	- 1
the number of errors	1,8	180%	1	- 1
number of brake pedal operations	5,4	108%	5	- 1
Mountainous area				
the average fuel consumption	32,6	109%	30	- 1
time of travel	15,4	103%	15	- 1
the number of errors	3	300%	1	- 2
number of brake pedal operations	5,6	112%	5	- 1
Undeveloped area				
the average fuel consumption	26,2	101%	26	- 1
time of travel	14,8	99%	15	1
the number of errors	1,6	160%	1	- 1
number of brake pedal operations	5,6	112%	5	- 1
Built-up areas				
the average fuel consumption	28,6	102%	28	- 1
time of travel	15,8	105%	15	- 1
the number of errors	1,6	160%	1	- 1
number of brake pedal operations	4,8	96%	5	1
2. Braking tests in a special area, with attention to different effects depending on the braking technique: reaction time from noticing an obstacle to the beginning of braking (emergency braking)	RESULT (reaction time)	DEVIATION % FROM A NORM	NORM	AMOUNT OF POINTS
Undeveloped area - sunny weather	0,72	103%	0,7	- 1
Undeveloped area - rainy weather	0,9	113%	0,8	- 1
Built-up area - sunny weather	0,76	109%	0,7	- 1
Built-up area - rainy weather	1,08	135%	0,8	- 2
			TOTALITY	**- 18**

** Groups:*
1. Unemployed young people (- <29 years)
2. Long-term unemployed people (+50 years)
3. Immigrants (including refugees)
*** Preferred is:*
minimizing fuel consumption
reduction of travel time
no errors
minimizing the use of the brake
the shortest response time

Using virtual reality can also have a visible impact on the cost of training provided by training centers. It can reduce the cost of training carried out on vehicles under real driving conditions. A person who is training in 3D is a person who can then master some of the skills, so that the number of hours in real conditions can be kept to a minimum.

Virtual reality also enables training in unreachable conditions in reality, for example simulation of driving in areas that are not located near the center or in climatic conditions inaccessible to the location of the center.

7.3 Finnish pilot

7.3.1 Introduction – VR in today's driver training

VR technology has been introduced gradually in Finland in connection with driver training in the last few years. It has already been explored as one of the possibilities in the renewal of driver training since the first commercial virtual glasses were launched in 2015. Virtual technology is mainly used in exercises where the student can practice independently and the program gives feedback on the performance and guides the student's performance. Finally, the program could also test your skills. In addition, VR technology is used e.g. driving lessons connected to a driving simulator, so driving is more versatile (for example, when driving, there may be, for example, customer service exercises and vehicle loading exercises). In addition, VR exercises are also designed for warehouse work, load handling, loading, vehicle technology, and for example occupational safety and introduction training.

7.3.2 Pilot participants

A total of 40 participants participated in the pilot training during the autumn 2018 and during the spring 2019 on 5 different test days. The participants were adults trained as bus drivers. Some of the participants were immigrants from different countries. The participants had an age range from 40 to 55 years. Most participants were men and one women. Some of the students had just begun their education and some were already in an advanced stage of education (however, no one was still in the job training period).

Fig. 48. Participants during research in TTS.

7.3.3 Training tools

As a training tool, we used the virtual training tool "bus departure check" developed by the project (and produced by the Finnish VR developer). Departure Check is a virtual application where the student can study the correct process of the bus departure check in stages:

1. First, The Virtual Teacher shows to student how to do the departure check. The student looks through the virtual glasses.

2. Then, The student carries out the checking himself at the virtual environment and the application (virtual teacher) directs and guides the performance.

3. Finally, the student can measure his / her own skills by doing a test in a virtual environment. The application no longer guides or tells the right / wrong functions – At the end of the test, the application shows only the outcome, which sections went right and which did not.

The sections included in the program are: motor, chassis, exterior, windshield, interior and auxiliary power supply.

7.3.4 Testing/training procedure

As the software used for pilot training was designed to be fully independent and operational, there was no trainer involved in the training (the trainer only followed the performance and interfered with potential problems due to virtual glass technology). The trainer also took care of the safety of the training because the space used for testing was not built for practice in the virtual environment. The test was carried out at a normal class from which the tables had been removed.

7.3.5 Testing/training methods and gathered data

The training method was an independent exercise in a virtual environment with the help of virtual glasses. The student started the performance by putting their virtual glasses on their heads, adjusting them correctly and taking the guides (controllers) into their hands. From now on, all things were done with virtual glasses and controllers within the virtual environment. The application was ready to run, so the student continued to perform by entering their own ID (number) into the program. The student then completed a tutorial where the program guided him through the functions of the controllers and how the exercises should be performed. After the tutorial, the actual exercise began and it was possible to go up to your skills testing with the bus departure check.

7.3.5.1 Usefulness measurement method

The utility was evaluated on the basis of the results, ie if the student learned from the application the essential things about the departure check of the bus and then did it correctly at virtual environment, the program had to be useful. Another part of the usefulness is portability for the departure check of the right bus, but this was not possible to evaluate with pilot training.

7.3.5.2 Immersion measurement method

The impression section was measured by feedback, ie asking the participant on a scale of 1 to 5 how impressive the experience was (1 not impressive at all and 5 very impressive).

7.3.5.3 Simulation sickness measurement methods

The simulation sickness section was measured by feedback, ie asking the participant on a scale of 1 to 5 showed nausea during the test (1 not at all and 5 very much).

7.3.5.4 Driver behaviour measurement method

This section was not measured at all due to the purpose and nature of the exercise (not driven but was taken to the bus departure check)

7.3.6 Pilot results

The pilot results were encouraging regarding the usability, effectiveness and portability of the method. The results of the program are compiled into a separate excel file with the performance of each participant per point. The listing shows the correct and false performance of the exercises and tests. Each student finally passed the test, except for 6 students who, due to the end of time, failed to complete the test (time limit was 45 minutes per student). The average execution time is about 30 to 40 minutes.

None of the students mentioned the nausea nor did they experience any need to interrupt the performance. The students using eyeglasses mentioned challenges of the image accuracy, ie they did not get the virtual glasses set to be accurate enough. However, this is more of a virtual glasses issue than of the training tool itself. We didn't record them because we cannot influence glass technology within the project.

Almost everyone mentioned that the most influential thing about effectiveness is the controllers that are used: the real departure check is done with your own hands and fingers rather than the controllers. Because of this, the exercise is a little unconvincing. It does not prevent you from learning the thing and practicing it, but it prevents the learning of muscle memory and proper maneuvers.

8. Recommendations

8.1 Training management recommendations

In this section, the most important recommendations are technical and legal recommendations.

First of all, it is important to take into account the possibility of practicing the essential elements of driver work in virtual environments and virtual glasses. The virtual environment provides a safe surraunding for practicing almost all the work of a driver.

Technological development must also be taken into account and attempted to use technical equipments (computers and virtual glasses, etc.) that creates the right environment: sufficient viewing angle, sufficient accuracy, sufficient lightness, sufficient sound world and sufficiently authentic guides (eg gloves that register finger movements) .

Taking into account Cargo's own experience as well as signals from cooperating centers, we recommend introducing changes to the legislation in force aimed at improving the quality and effectiveness of the training.

The state in Poland as of today are several laws and ordinances regulating the driver training process.

The basic law is the "Act on Drivers", the last consolidated text of which was announced on February 21, 2019. It regulates the required age for individual categories of driving licenses, it also determines the scope of entitlements of individual categories. In Chapter 4, it specifies the training process of obtaining a driving license, indicating persons meeting the requirements for conducting training, the document circulation process. Chapter 5 sets out the requirements for the training center. The next document is "Regulation of the Minister of Infrastructure on the training of drivers performing road transport" from 2010, as amended. It specifies in chapter 3 the conditions for training, referring to Annex No. 1 specifying in Table 2 and three specialized subjects related to categories C and D of the driving license. Below we mention recommendations that should be implemented in order to improve the quality, attractiveness and effectiveness of the training while reducing its costs at the same time.

For example, point 1.3 in Table 2 takes into account the subject of loading the vehicle in accordance with the requirements of health and safety and the rules of use of the vehicle. The trainee as part of the exercises should master the correct distribution of load, cargo securing techniques, choosing the most optimal means.

We recommend that you allow the implementation of some of these exercises using the virtual reality simulator. This may result in enriching the offer of means at the disposal of the students, more interesting configuration and creating situations not available at the moment in the training center. At the same time, it will result in a reduction of financial outlays incurred by training centers due to the lack of purchase of real training resources.

In turn, point 1.4 within which the training should be performed simulating mechanical and electrical failures of the vehicle is perfectly suited to transfer to the virtual reality environment using a simulator. This environment gives unlimited possibilities for creating various simulated failures, where the only imagination of its designer can be a limitation.

For Table No. 3 specifying the subject matter of specialist training for category D, point 1.5 includes topics related to simulation of failure, and point 1.7 to calculate the utility load of the vehicle and the distribution of passengers. As you can see, these are topics that are perfectly suitable for training in simulator conditions. We recommend that in the future our legislation gives legal possibilities to use this type of training method.

8.1.1 Transfer of knowledge

The subject taught is usually learned by the same method in real life and in the virtual world. If a virtual environment with it's functions can be built to match the performance in a real life, it is already possible to talk about a good enough data transfer. In a virtual environment, there is no need for the trainer to guide or evaluate the performance. The critical place is the student's feedback on his / her studies and how this feedback guides his / her future exercises.

People undergoing training are future drivers of high-volume vehicles. This group of future drivers is a community that will spend a lot of time behind the wheel of vehicles. If they take part in a road accident, its effects will often be very tragic due to the mass and size of the vehicle. Therefore, the training of these people should put a special emphasis on the awareness of what activities should be done to avoid any traffic incidents at all costs. Young people being the subject of training also find it easier to take risks without experience. Lack of sufficient skills and risk appetite can be seen as the cause of death of about 15,000. young people every year in road accidents in Europe. In many countries such accidents are the main cause of deaths of young people. The instructor using VR tools should create the maximum number of scenarios in which he will present different situations that may arise in real conditions.

8.1.2 Skills maximization

The most effective topics for studying in the virtual world are subjects that do not require movement / driving. This is because, at this stage of the research, virtual glass technology is not yet of sufficient quality for driving studies (requiring more powerful computers, especially graphics cards and more accurate virtual glasses). As an example, in addition to the departure check, customer service, loading and unloading, maintenance, familiarization and occupational safety can be mentioned.

The topics suitable for training with the use of VR are above all situations impossible to obtain in real conditions, due to the unavailability of the terrain, weather conditions, as well as those that may pose a threat to people taking part in the training. The latter definition includes situations that provoke mistakes in driving:

- errors in assessing the situation: not taking into account changing road conditions,
- not taking into account the behavior of other road users,
- lack of ability to predict threats,
- undertaking inappropriate actions,
- inability to refrain from acting,
- ineffective braking,
- ineffective starting from the place,
- improper handling of the steering wheel.

8.1.3 Stakeholders cost minimization

The cost-effectiveness of a virtual environment should be considered at least from the point of view of what the equivalent environment in real life costs (eg hardware and application development vs. the right bus and trainer). The second aspect concerns replicability: the virtual environment can be digitally copied indefinitely (the number of virtual glasses and computers is solved) and the training area required by virtual glasses is much smaller than the real equivalent environment (eg logistics hall, terminal, bus, etc.). This allows for higher training volumes, lower operating costs, lower training costs and shorter training times (when more than one student can study at the same time in a real life, only one student can study in turn.

Driver training centers can reduce vehicle maintenance costs. The creation of VR training station reduces the costs of repairs of used vehicles by several dozen percent, it also reduces fuel consumption.

In the part of the training, which simulates 50% time exercises for subjects of classes with practical conditions implemented interchangeably in a car as a simulator, for application with recommendations in Poland. Document regulating this issue to the "Regulation of the Minister of Infrastructure of April 1, 2010 on the training of drivers performing road transport". Paragraph 7 (4) states that: In the case of practical exercises for driving in the equipment condition of devices referred to in art. 39g paragraph 11 point 2 of the Act, 2 hours of driving in terms of the function without using this device are used as equivalent to 1 hour of driving when using this device.

"The real-life/simulator-based activities which can be replaced with VR-based training from the cost efficiency point of view are:

- simulation of diversified road conditions, including other seasons not available during the training,
- errors in assessing the situation: not taking into account changing road conditions,
- ineffective braking,
- ineffective starting from the place,
- improper handling of the steering wheel.

A coach employed on a simulator or in a vehicle conducting classes in special conditions must have the same competences. Reducing the hours of training on the simulator compared to training conducted in real conditions results in a reduction in the cost of employing a trainer. For example, a group of 20 people to perform 40 hours of training in real conditions, performs 20 hours on the simulator.

8.1.4 Instructor competences

The instructor is required to have ICT skills in the use of the virtual equipment itself, but also the skill to perceive the student's challenges: building a virtual environment should also be able to define the wrong ways to build a virtual environment. In addition, the instructor must have the skill to identify the student's existing skills, as virtual learning environments allow for more effective independent training and, as a result, the contact between the trainer and the student is reduced. This can be a challenge for many trainers, as more attention needs to be paid to measuring skills when studying practical exercises.

The instructor managing the training should have:

- knowledge about the contents of the training program enabling conducting a conversation explaining the problems incomprehensible to the student,
- the ability to learn quickly needed for the current update of the training material due to the frequently occurring update of the regulations,
- openness to changes in the regulations concerning the training program,
- communication skills necessary to contact students,
- the ability to resolve conflicts,
- clarity of expression,
- empathy,
- ease in using multimedia resources,
- openness to new technologies changing the way of training,
- ability to support gamification platforms that support 3D technology,
- the ability to teach students how to use the 3D platform.

8.1.5 Instructor profile

Recommended competences of lecturer - instructor:

- extensive knowledge exhausting the issues discussed in the class,
- the ability to make pupils aware of their goals and didactic tasks,
- ability to transfer your knowledge, including analysis and synthesis of transferred material,
- ability to indicate practical situations in which it is justified to use the acquired theoretical knowledge,
- the ability to assess the predispositions of training participants in terms of assimilating the topics discussed,
- ability to assess the skills acquired by the student and its natural predispositions and to indicate the appropriate next stage of the training,
- the ability to adjust the intensity of the training to the current student's fitness,
- the ability to use the tools used for training,
- the ability to assess the degree to which the training participants assimilate the material for possible expansion of the training by extra-curricular hours.

8.1.6 Training tools specification

The following hardware and software specifications were used in Polish and Finnish VR-targeted pilots. As no standards for VR driver training stands were established yet, we built them according to both desk research and discussions with VR developers. Therefore, the following specifications should be rather treated as a signpost than the official recommendations.

8.1.6.1 Poland

- VR-based driver training stand with:
    - European Truck Simulator software (please note that eventually a VR-dedicated software should be much more in line with the training needs, especially with regard to scenario development, increasing immersion level and reducing the simulation sickness)
    - a desktop computer (prefferably gaming-dedicated one as VR software needs a lot of computing software)
    - LCD monitor (even though the image is displayed inside a VR headset, providing a display on a decent sized monitor allows the trainer to follow the trainee’s progress)
    - virtual reality goggles (it is of high importance to stand in line with the requirements/advices given by VR developers, since VR software can be dedicated for a specific headset. Choosing a different headset could in this case result in suboptimal performance of the software
    - Driver's seat (prefferably a dedicated gaming seat or a real-life truck/bus seat that could increase the immersion effect)

- a gaming steering wheel (in the pilot we used Logitech G27 due to its simplicity; unfortunately there are no truck/bus steering wheels for computer-based driving simulation purposes on the market)

– 3-step simulator containing:
  - for a desktop computer
  - The driver's station with the option of choosing the gearbox in manual or automatic version
  - The driver's seat enabling longitudinal and lateral movements
  - 3 projectors projecting the image

– Simulator of 6-stage truck and bus driving Truck Simulator containing:
  - Rear projection system in FullHD resolution
  - A physical tachograph with the possibility of replacing the card and generating errors
  - for a 5-channel sound system with the ability to change the balance for each of the speakers separately
  - The main desk (vehicle clocks) based on the display (the so-called glass cockpit)
  - A platform system for the entire cockpit with 6 degrees of freedom with electric drive
  - A braking system based on the pneumatic pressure measurement generated on the brake pedal
  - Ability to set the viewing angle in the side mirrors directly from the driver's position
  - Independent air-conditioning system of the interior of the simulator cockpit integrated with the control system of the reflected vehicle's air vents
  - Instructor's station with a steering wheel equipped with a load generation system
  - Inside the cockpit, 2 independent cameras that monitor driver behavior
  - for the actual truck cabin
  - Automatic and manual transmission,
  - Ability to change the information displayed on the dashboard (glass cockpit) directly using the buttons on the steering wheel
  - Instructor station equipped with 6 screens displaying the following information or views:
    - preview of the driver's behavior in the cabin,
    - simulation view on the windshield,
    - simulation view on the left / right side window,
    - view of the current road situation and city map,
    - Isometric view with the possibility of changing the angle of view on the vehicle driven by the student.

- Software with the possibility of generating weather conditions, seasons and days, including:
  - sunny weather,
  - day / night, sunrise and sunset,
  - fog,
  - rain,
  - snowfall,
  - wind with modifiable power,
  - winter conditions.

8.1.6.2 Finland

Technical specifications of VR stand

- ASUS ROG Strix GL12 -computer, Win 10
  - Intel Core i5-8400 –six core processor
  - NVIDIA GeForce GTX 1080 Graphics card

- HTC VIVE PRO VR
  - SteamVR Base Station 2.0 x 2
  - Base station power adapter x 2
  - Mounting kit
  - Link box
  - USB 3.0 cable
  - DisplayPort™ cable
  - Link box power adapter
  - Link box mounting pad
  - Headset with headset cable
  - Cleaning cloth
  - Earphone hole cap x 2
  - Documentation
  - Controller (2018) (with lanyard) x 2
  - Power adapter x 2
  - Micro-USB cable x 2
  - VIVE Pro Headset
- TECHNICAL SPECS OF HTC VIVE PRO VR

Screen:	Dual AMOLED 3.5" diagonal
Resolution:	1440 x 1600 pixels per eye (2880 x 1600 pixels combined)
Refresh rate:	90 Hz
Field of view:	110 degrees

Audio:	Hi-Res certified headset Hi-Res certificate headphone (removable) High impedance headphone support
Input:	Integrated microphones
Connections:	USB-C 3.0, DP 1.2, Bluetooth
Sensors:	SteamVR Tracking, G-sensor, gyroscope, proximity, IPD sensor
Ergonomics:	Eye relief with lens distance adjustment Adjustable IPD Adjustable headphone Adjustable headstrap

- Controller Specs

Sensors:	SteamVR Tracking 2.0
Input:	Multifunction trackpad, Grip buttons, Dual-stage trigger, System button, Menu button
Connections:	Micro-USB charging port

- Tracked Area Requirements

Standing / Seated:	No min. space requirements
Room-scale:	A minimum play area of 2m x 1.5m is required, while the maximum size is 7m x 7m

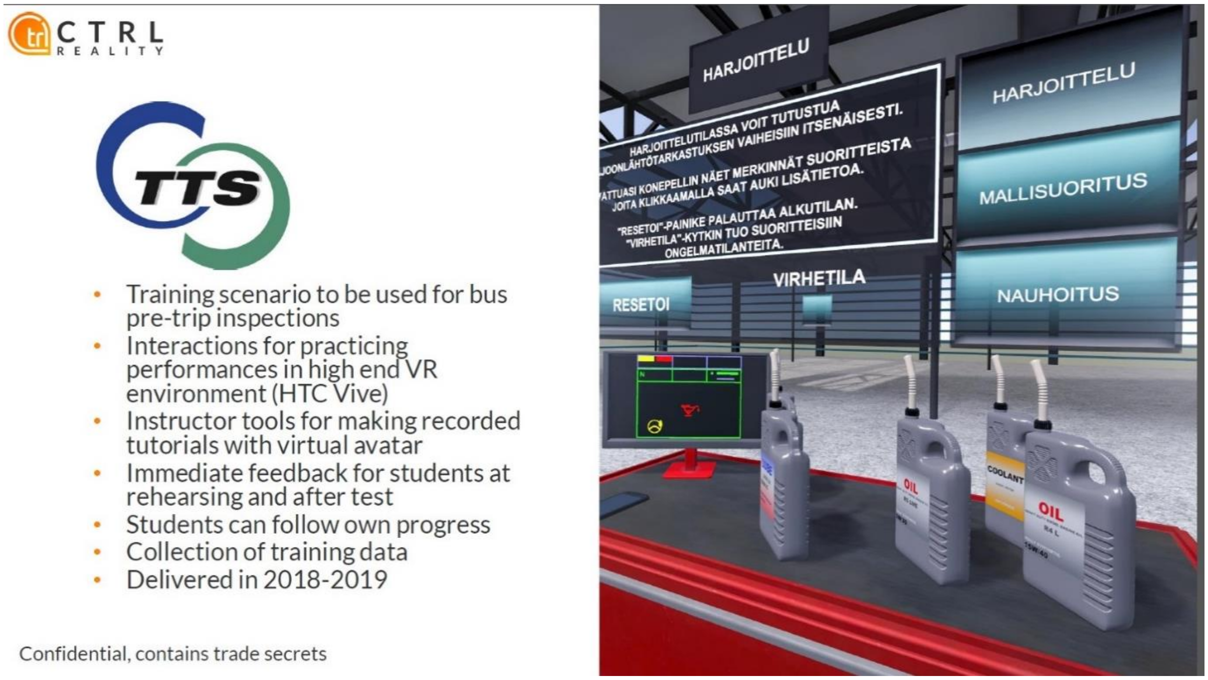


Fig. 49. Training tools specification in TTS

8.1.7 Support of the training management system

In Finland the pilot training application is not yet included into actual training, so it is not supported by the administration at the moment. A lot of support will be needed for this, because the different areas of training for professional drivers must be modeled and rewritten so that they can be transferred to a virtual training environment.

The training management system used in CARGO practice is the original OSK MANAGER program. It allows to manage the center in the area of training planning, assigning places to them, vehicles, students and instructors. With a considerable number of training sessions, and this is the case with CARGO, it is basically a tool necessary to avoid chaos. Thanks to it, you can also get an up-to-date preview of the degree of implementation of the training itself as well as the progress of the trainee.

Supervision of the training completion level is also possible in the e-cargo system. This platform enables setting up trainings, adding users, checking the level of implementation and generating documents related to training.

8.1.8 Combining VR, AR and gamification with other ICT-based training tools

Virtual training environments can currently be combined with an old-fashioned simulator and various gaming applications. In addition, it is possible to combine them with for example e-learning, but the strength of virtual environments is to act independently.

Training conducted under AR conditions may have its continuation in a virtual reality. The combination of both trainings would be the registration of the course of the AR training and its reconstruction under the conditions of the simulator. Here, as part of the next stage, the trainee would correct the errors noticed during the AR training until the acceptable level was reached. At this stage, there would be a return to the AR training if, of course, the conditions in which this stage would be implemented would enable it.

Talking to people who have not been faced with the concept of gamification one can be confronted with the opinion that this element introduced into the education system means trivialization of teaching and implementation of fun elements to this process. Gamification is not a game, though it is perceived in a colloquial way. It is a tool that allows the use of mechanisms governing games to the teaching process.

For the purposes of e-learning used to teach drivers and candidates for drivers at the current stage of system development, gamification is to enable a wider assessment of students by introducing into their assessment not only the issue of progress in learning, but also the possibility of assessing the degree of involvement in the learning process. In this way, additional motivation to learn is introduced. Points can now be obtained for results in acquiring knowledge, the next stage of gamification could be the introduction of points for regularity in participating in classes. Points will also be earned for optional participation in tasks based on scenarios using typical driving situations that contain problematic events that the trainee will have to resolve correctly. The time and quality in which the problem is resolved will affect the number of points obtained. These in turn should allow you to receive rewards and bonuses. The form of reward can be, for example, the possibility of creating your own avatar. This creates an incentive to learn, and does not affect the cost of training a person.

The introduction of the above elements to the training program encourages the simultaneous introduction of a visualization based on 3D technology.

9. National conclusions

9.1 Polish perspective

The ordinance of the Polish Minister of Infrastructure of 8 April 2011 on the device for simulating driving in special conditions specifies the technical and organizational requirements and the scope of the simulator's functionality.

Below we mention recommendations that should be implemented in order to improve the quality, attractiveness and effectiveness of the training while reducing its costs at the same time:

- extension of training programs with 3D visualizations enabling exercises in:
    - for the selection of packaging and pallets
    - for skillful distribution of the load
    - for calculating the quantity and selection of fastening agents
    - on the location of simulated vehicle failures
    - for the implementation of the procedure resulting in the removal of failures

In addition, as part of e-learning training, we postulate the implementation of software enabling route planning, taking into account the distance we can cover in the permissible driving time. The option of such software should enable "manually" entering the driving time and required breaks by the trainee. Such assumptions would then be verified by the software and the trainer.

9.2 Finnish perspective

Finland's perspective on virtual learning environments is currently (in 2019) very open and is being strongly developed in other areas. Virtual environments also offer a different opportunity to export knowledge and education to different continents and abroad, as telecommunication connections already allow online applications to be used almost anywhere in the world. The Finnish legislation does not restrict the use of virtual learning environments, but they are subject to the same sections as simulation training (for professional driver training), but for example, the authorities have set minimum requirements for the field of vision for simulators used in driving instruction. This requirement is not yet met by all common virtual glasses, because they have a field of view of 110 to 130 degrees laterally and should be at least 180 degrees. The field of vision should also be realistic in the vertical direction. In addition, there are requirements for the vehicle controls themselves (ie they must be realistic and the right vehicle). This requirement is not yet met. Manufacturers and developers of virtual glasses, controllers, and applications are under considerable pressure to get their products real enough to make their training more widely available. Stakeholders are still cautious about virtual learning environments, but thanks to the effective dissemination of information and experience, there are several forums and associations in Finland that market potential applications of virtual environments and enable a versatile experiment, allowing stakeholders to form their own opinion.

9.3 Austrian perspective

Since 3s, the Austrian ICT-INEX project partner, did not undertake any Austrian pilot projects on the topic "Integration of advanced 3D visualisation technoloiges & gamification mechanisms with other professional driver candidate training", recommendations will only be made from a more general perspective. These recommendations are also complemented by other research results from similar EU projects in which 3s took part[2].

When it comes to the regulation of professional driver training, the three most important legal acts are the European Directive 2003/59/EC[3] with its recent ammendment from April 2019.[4] Then there is the Austrian ”Regulation on initial and periodic training for professional drivers”[5] and the Austrian ”Regulation for Professional Drivers Apprenticeship”.[6] As already mentioned in the recommendations for the ICT-INEX final report on Deliverable 3[7], the new Directive (EU) 2018/645 suggests that member states should provide a clear option to improve and modernise training practices with the use of information and communication technology (ICT) tools, such as e-learning and blended learning. For the periodic training, the ammendment formulates that training should consist of classroom training as well as practical training and – if available – training by using ICT tools or ”top-of-the-range simulators”. The new Directive does not mention the use of Virtual Reality (VR) tools and serious gaming for professional driver training

[2] For example the Erasmus+ project ICT-DRV (2012-2015) that explored opportunities and challenges of technology-based training methods within the initial and continuous/ periodic vocational training of professional drivers.

[3] Online: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32003L0059 (19.07.2019).

[4] ”Directive (EU) 2018/645 of the European Parliament and of the Council of 18 April 2018 amending Directive 2003/59/EC on the initial qualification and periodic training of drivers of certain road vehicles for the carriage of goods or passengers and Directive 2006/126/EC on driving licences”Online: https://eur-lex.europa.eu/eli/dir/2018/645/oj (19.07.2019).

[5] Grundqualifikations- und Weiterbildungsverordnung – Berufskraftfahrer -GWB, current version from 19.07.2019. Online: https://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=Bundesnormen&Gesetzesnummer=20005794 (19.07.2019).

[6]Online: https://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=Bundesnormen&Gesetzesnummer=20005412 (19.07.2019).

[7] See ICT-INEX Project Deliverable 3 “Guidelines for the integration of SBT with other PD candidate training methods”, (Annex 4, Recommendations).

but nowadays, these are becoming an integral part of ICT tools and simulator-based training (SBT).

In Austria, VR training tools and serious games are scarcely used for the training of professional drivers. The first national and international VR designer companies are entering the Austrian market offering their training products to driving schools and training providers. As mentioned in studies and also during the final ICT-INEX conference in Warsaw, scepticism about these new training opportunities is still very high. Not only because of the fear of high investments and technical challenges, but also because of the phenomenon of motion sickness or the reluctance of many older drivers. In Austria, like in many other European countries, the discussion about the future of PD training is very active, but there seems to be no or hardly any connection between available research on ICT training methods and the practical work of training providers. E-learning approaches for theoretical subjects seem to be widely accepted in driving schools (learning apps, etc.) but there is only one Austrian provider in the province of Tyrol that was accredited three e-learning modules for PD training[8].

In 2015, during the Erasmus+ project ICT-DRV, an Austrian national scenario for "quality indicators" on the implementation of ICT-tools into professional driver training was formulated.[9] For this report, this recommendation will be used and adapted for giving recommendations on the implementation of VR/gamification tools for PD training in Austria.

The first recommendation is yet *another ammendment of the Directive 2003/59/EC* when it comes to the integration of VR and gamificaton tools into PD training. In this new ammendment, it should be indicated whether VR and serious gaming is acceptable for PD training. In Austria, a definition of circumstances under which VR/gamification has to be provided would be appreciated in order to reach legal certainty.

The second recommendation is *comprehensive information and counselling* of end-users and decision makers on VR and gamification technologies. This should enable learners, employers and competent bodies to decide if a VR or gamification training offer meets their requirements.

The third recommendation is to have *specifically trained VR/gamification trainers and tutors*. The training should include the characteristics of learning with VR/gamification tools for individuals and groups, knowledge on the design and

[8] https://berufskraftfahrer.easydrivers.at/weblearning (19.07.2019).
[9] „National implementation scenario of ICT-DRV quality indicators for: Austria". Cf.: Bacher, T. et al (2015), p.

selection of scenarios and on the operation and application of VR/gamification training tools.

A fourth recommendation for implementing VR and gamification tools into PD training is the application of the learning outcomes approach.[10] The learning outcomes approach (definition of knowledge, skills and competences) should be applied on VR and gamification training and would also facilitate the recognition of prior/non- and informal learning and the recognition of learning.

A fifth recommendation is *a sound and thorough instructional and technological interface design for VR and gamification training*. In this context, best practice examples in the field of instructional design should be taken into account.

The next reommendation suggests *continuous evaluation and further development of VR/gamification training courses* in order to adapt to changing needs and requirements and to the state-of-the-art of educational technology.

The final recommendation is maybe one of the most important ones: *to intensify research on VR and serious gaming for PD training combined with sharing and networking on the current realisation of VR/gamification use*. The implementation of VR and serious gaming requires a continuous dialogue and cooperation between education providers, developers of VR and serious games as well as researchers. Therefore continuous sharing, networking and joined research activities need to take place in order to further work on the improvement of the integration of advanced 3D visualisation technologies & gamification mechanisms with other professional driver candidate training methods.

9.4 Bibliography

1. Semichi, M. et al (2014): Status quo of SBT and CBT application within professional driver training in selected European countries. Project report. Online: https://www.project-ictdrv.eu/fileadmin/user_upload/FinDels/ICTDRV_WP2_Report_emergpract_final.pdf (18.07.2019).
2. Bacher, T. et al (2015a): Scientific Framework of CBT and driving simulator application in professional driver training. ICT-DRV project report. ICT-DRV project report. Online. https://www.project-ictdrv.eu/fileadmin/user_upload/FinDels/ICT-DRV_WP1_report_final.pdf
3. Bacher, T. (2015b): National implementation scenario of ICT-DRV quality indicators for: AUSTRIA. ICT-DRV project report. Online: https://www.project-ictdrv.eu/fileadmin/user_upload/FinDels/ICTDRV_WP5_scenario_AT_EN.pdf (24.07.2019).

[10] Cf. https://www.cedefop.europa.eu/en/events-and-projects/projects/learning-outcomes (25.07.2019).

4. Ball, C. et al (2015a): On the way to high-quality technology-supported training for professional drivers: A synopsis of ICT-DRV project results, conclusions and recommendations. ICT-DRV project report. Online: https://www.project-ictdrv.eu/fileadmin/user_upload/FinDels/ICTDRV_WP5_synopsis_final.pdf (18.07.2019).
5. Ball, C. et al (2015b): ICT-DRV quality indicators on technology-support training. ICT-DRV project report. Online: https://www.project-ictdrv.eu/fileadmin/user_upload/FinDels/ICTDRV_WP5_qualityindicators_final_EN.pdf (18.07.2019).
6. ICT-DRV (2015): Transport meets education - Preparing and keeping professional drivers' qualification up-to-date for their chaging job requirements with technoloy-supported learning. Conference and project proceedings. Online: https://www.project-ictdrv.eu/fileadmin/user_upload/FinDels/ICT-DRV_proceedings_final_web.pdf (18.07.2019).

10. Annexes

10.1 Annex No. 1 – Gamification questionnaire with 10 motivational factors

Projekt ICT-INEX

Questionnaire

Annex No. 1 - Gamification questionnaire with 10 motivational factors

Elaboration: Motor Transport Insitute (intellectual output leader)

Country:	**Poland**
Answers:	
Date of commissioning:	

Questionnaire

This questionnaire is designed to check your opinion on each element of gamification presented to you. The four characteristics of each are listed below. On a 5-point scale, specify to what extent you agree or disagree with the given statement.

POINTS

Pleasure

Would the opportunity to earn points for learning on the platform make you enjoy using it and give you fun?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Willingness to use

Do you think this element of gamification is reliable and authoritative? With this opportunity, would you use this element of gamification and rely on it?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

<u>Helpfulness / Usefulness, utility</u>

Given your own goals, do you think this element of gamification can help you learn? Can it affect your motivation to learn?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

<u>Ease of use</u>

Do you think this element of gamification seems easy to use?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Share with us your comments about a given element of gamification. Give the reasons why you like this item or not.

....

....

BADGES

<u>Pleasure</u>

Would being able to receive badges for your actions and for learning on the platform give you pleasure and fun?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

<u>Willingness to use</u>

Do you think this element of gamification is reliable and authoritative? With this opportunity, would you use this element of gamification and rely on it?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

<u>Helpfulness / Usefulness, utility</u>

Given your own goals, do you think this element of gamification can help you learn? Can it affect your motivation to learn?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Ease of use

Do you think this element of gamification seems easy to use?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Share with us your comments about a given element of gamification. Give the reasons why you like this item or not.

....
....

LEVELS

Pleasure

Would the possibility of reaching next levels on the platform affect the pleasure of using the platform?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Willingness to use

Do you think this element of gamification is reliable and authoritative? With this opportunity, would you use this element of gamification and rely on it?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Helpfulness / Usefulness, utility

Given your own goals, do you think this element of gamification can help you learn and use the platform? Can it affect your motivation to learn?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Ease of use

Do you think this element of gamification seems easy to use?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Share with us your comments about a given element of gamification. Give the reasons why

....
....

PROGRESS INFORMATION

Pleasure

Would the regular confirmation of your learning achievements, through constructive information on your progress describing them quantitatively and qualitatively, which you would receive on the platform, affect the pleasure of using the platform?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Willingness to use

Do you think this element of gamification is reliable and authoritative? With this opportunity, would you use this element of gamification and rely on it?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Helpfulness / Usefulness, utility

Given your own goals, do you think this element of gamification can help you learn, is useful in acquiring knowledge?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Ease of use

Do you think this element of gamification seems easy to use?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Share with us your comments about a given element of gamification. Give the reasons why you like this item or not.

....
....

RESULTS TABLE / RANKING

Pleasure

Would the information about your learning results compared to the others that you would receive on the platform in the form of a table / ranking, affect the pleasure of using the platform?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Willingness to use

Do you think this element of gamification is reliable and authoritative? With this opportunity, would you use this element of gamification and rely on it?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Helpfulness / Usefulness, utility

Given your own goals, do you think this element of gamification can help you learn and use the platform? Can it affect your motivation to learn?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Ease of use

Do you think this element of gamification seems easy to use?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Share with us your comments about a given element of gamification. Give the reasons why you like this item or not.

....

....

CHALLENGES

Pleasure

Would the opportunity to take on tasks that are challenging for you, demanding but tailored to your skill level on the platform, make you enjoy using it and give you fun?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Willingness to use

Do you think this element of gamification is reliable and authoritative? With this opportunity, would you use this element of gamification and rely on it?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Helpfulness / Usefulness, utility

Given your own goals, do you think this element of gamification can help you learn? Can it affect your motivation to learn?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Ease of use

Do you think this element of gamification seems easy to use?

No	rather not	it's hard to say	rather yes	yes

1	2	3	4	5

Share with us your comments about a given element of gamification. Give the reasons why you like this item or not.

....
....

AVATAR

Pleasure

Would the possibility of personalizing your profile (adding information, photos) on the platform, make you enjoy using it and give you fun?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Willingness to use

Do you think this element of gamification is reliable and authoritative? With this opportunity, would you use this element of gamification and rely on it?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Helpfulness / Usefulness, utility

Given your own goals, do you think this element of gamification can help you learn and use the educational platform? Can it affect your motivation to learn?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Ease of use

Do you think this element of gamification seems easy to use?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Share with us your comments about a given element of gamification. Give the reasons why you like this item or not.

....
....

FEEDBACK

Pleasure

Would receiving quick feedback after the completed module/test informing about the result, status, place in the ranking on the platform, affect the pleasure of using the platform?

No	rather not	it's hard to say	rather yes	yes

1	2	3	4	5

Willingness to use

Do you think this element of gamification is reliable and authoritative? With this opportunity, would you use this element of gamification and rely on it?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Helpfulness / Usefulness, utility

Given your own goals, do you think this element of gamification can help you learn, is useful in acquiring knowledge?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Ease of use

Do you think this element of gamification seems easy to use?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Share with us your comments about a given element of gamification. Give the reasons why you like this item or not.

....
....

CLEAR GOALS

Pleasure

Would clear, understandable operating principles of the system, precise instructions defining its scope, make you enjoy using it?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Willingness to use

Do you think this element of gamification is reliable and authoritative? With this opportunity, would you use this element of gamification and rely on it?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Helpfulness / Usefulness, utility

Given your own goals, do you think this element of gamification can help you learn and use the educational platform?

No	rather not	it's hard to	rather yes	yes

		say		
1	2	3	4	5

Ease of use

Do you think this element of gamification seems easy to use?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Share with us your comments about a given element of gamification. Give the reasons why you like this item or not.

....

....

AWARDS

Pleasure

Would the knowledge about the possibility of getting a surprise award for the winner of the ranking make you enjoy using the platform and give you fun?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Willingness to use

Do you think this element of gamification is reliable and authoritative? With this opportunity, would you use this element of gamification and rely on it?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Helpfulness / Usefulness, utility

Given your own goals, do you think this element of gamification can help you learn and use the educational platform? Can it affect your motivation to learn?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Ease of use

Do you think this element of gamification seems easy to use?

No	rather not	it's hard to say	rather yes	yes
1	2	3	4	5

Share with us your comments about a given element of gamification. Give the reasons why you like this item or not.

....

....

I would be most motivated to learn by such elements of gamification as:
* put in order from 1 to 10, where 1 - the element of gamification motivating me to learn the most, and 10 - the element has the least impact on my learning.
... .. points
... .. badges
... .. levels
... .. progress information
... .. results table/ranking
... .. challenges
... .. avatar
….. feedback
... .. clear goals
... .. surprise award for the winner of the ranking

10.2 Annex No. 2 – Demographic Survey used in study of gamification techniques

Projekt ICT-INEX

Questionnaire

Annex No. 2 - Survey used in study of gamification techniques

Elaboration: Motor Transport Insitute (intellectual output leader)

Country:	**Poland**
Answers:	
Date of commissioning:	

IDENTIFICATION NO………

DRIVER QUESTIONNAIRE

Gender K M
Age…………
Origin………….
Occupation ....
Possessed driving license categories ....
How many years B category licence ......

The questionnaire you have before you is completely anonymous, the data will be analyzed in groups, and not individually. The reliability of its completion and honesty is very important to us.

1. What is your education?

Primary	Vocational	Secondary	Higher

2. What is your current situation on the labour market?

Unemployed	Long-term unemployed (over 12 months)	Professionally inactive	I work

3. How often do you drive your car?

Daily	Several times a week	Several times a month	Less often

4. How many kilometres do you travel monthly? (average from last year)

Up to 250 km	From 250 km to 850 km	From 850 km to 1,700 km	Above 1,700 km

5. What routes do you usually drive?

Long routes (over 100 km)	Short routes (below 100 km)/	Various

6. What times do you usually drive?

Usually during a day	Usually at night	Various

7. Do you have penalty points, if yes how many?

I don't have	1-10 points	10-20 points	Above 20 points

8. How many times have you participated in a course reducing penalty points (since you gained the license)?

Not once	Once	Twice or more

9. Have you ever caused a road collision?

Yes	No

10. Have you ever caused a traffic accident?

Yes	No

11. How do you assess your driving skills?

Very poor	Poor	Moderate	Good	Very good

12. Do you take part in a gratuitous course?

Yes, gratuitous externally financed	Yes, gratuitous financed by the employer	No, partly paid	No, I pay for it myself

13. How do you assess your motivation to successfully complete this course?

Very weak	Poor	Moderate	High	Very high

14. What could increase your motivation to successfully complete this course?

....

....

15. Do you often use devices such as a computer, tablet, Smartphone etc.?

Never/ Rarely (once a month)	Occasionally (once a week)	Often (several times a week)	Very often (daily)

16. How do you assess your skills in using the above devices?

Very poor	Poor	Moderate	Good	Very good

17. Do you have experience with virtual reality (VR)?

Not	I only heard about it	I saw someone use it	I used it	I use it often

18. Do you have experience with augmented reality (AR)?

Not	I only heard about it	I saw someone use it	I used it	I use it often

19. If you have used VR / AR, what is your opinion on the use of this technology in education?

I did not use it	It is not needed	I have no opinion	It is needed

20. Do you see the desirability of using VR / AR in training professional drivers?

Not	Rather not	I have no opinion	Rather yes	yes

21. Do you play games (e.g. board, card, computer, mobile, etc.)?

Never	Rarely (once a month)	Occasionally (once a week)	Often (several times a week)	Very often (daily)

22. What games do you play?

23. How much time do you spend on average playing?

I don't play/ I play occasionally up to 2 hours a day/ 3-4 hours a day/ 5-6 hours a day

I don't play	I play occasionally up to 2 hours a day	3-4 hours a day	5-6 hours a day

24. Have you previously met with the concept of gamification?

Yes	I don't know	No

25. **Do you have experience in the use of mechanisms / elements of gamification?**

I have never used it	Rarely (once a month)	Occasionally (once a week)	Often (several times a week)	Very often (daily)

26. If you used the mechanisms / elements of gamification, how do you assess their impact on changing your involvement or motivation?

Very poor	Poor	Moderate	Good	Very good

27. Please describe your experience with the use of these elements. Where did you meet the concept of gamification? What elements of gamification did you encounter?

……………………………………………………………

……………………………………………………………

Please ensure that all questions have been answered.

Thank you for completing the survey.

10.3 Annex No. 3 – Demographic Survey used in Pilot Training (ITS)

Projekt ICT-INEX

Questionnaire

Annex No. 3 - Demographic Survey used in Pilot Training (ITS)

Elaboration: Motor Transport Insitute (intellectual output leader)

Country:	**Poland**
Answers:	
Date of commissioning:	

PERSON'S NO. ....

DRIVER'S SURVEY

Below are questions about how to function on the road. Please respond to each question by choosing the right answer (put a cross under the answer of your choice). In some questions / statements it is possible to mark more than one answer. The survey is anonymous and the data will only be used for scientific purposes so we are asking for honest answers.

1. Age ....

2. Gender: Female / Male

3. Education

Basic vocational	Secondary	Higher incomplete	Higher (including bachelor)

4. Driving license category

A/ B/ C/ D/ B+E/ C+E/ D+E

5. How many years have you been driving actively (more than 1000 km per year)?
....

6. How do you assess your driving skills?

Very poor	Poor	Average	Good	Very good

7. How often do you drive a car?

Very rarely (Several times a year)	Rare (Several times a month)	Several times a week	Every day

8. How many kilometres do you drive a month?

Up to 250 km	260-850 km	860-1700 km	Above 1800 km

9. How many hours a day do you spend behind the wheel?

Up to 1 hour	1-3 hours	4-7 hours	8 and above

10. Have you ever caused a road collision?

Yes	No

11. Have you ever caused a traffic accident?

Yes	No

12. Do you play games (e.g. board, card, computer, mobile, etc.)?

Never/ Rarely (once a month)	Occasionally (once a week)	Common (several times a week)	Very common (daily)

13. What games do you play?

I don't play	Board games	Card games	Computer games

14. How much time do you spend on average playing?

I don't play	I play occasionally	up to 2 hours a day	3-4 hours a day	5 or more

15. Have you encountered the term VR (virtual reality)?

Yes	No

16. Do you have any experience with virtual reality (VR)?

Never	Only heard of it	I've seen someone use it	I have used it	I use it often

17. Would you like to test VR again? IF YOU TESTED VR TECHNOLOGIES AT LEAST ONCE

Yes	No

18. Do you have experience with augmented reality (AR)?

Never	Only heard of it	I've seen someone use it	I have used it	I use it often

Please ensure that all questions have been completed.
Thank you for participating in the study.

10.4 Annex No. 4 – Usefulness questionnaire (after driving on a simulator with goggles HTC Vive and Oculus Rift)

Projekt ICT-INEX

Questionnaire

Annex No. 4 - Usefulness questionnaire (after driving on a simulator with goggles HTC Vive and Oculus Rift)

Elaboration: Motor Transport Insitute (intellectual output leader)

Country:	**Poland**
Answers:	
Date of commissioning:	

PERSON'S NO. ....

QUESTIONNAIRE AFTER THE DRIVE (GOGGLES)
☐ HTC ☐ Oculus

1. Please specify the difficulty level of using VR goggles during the simulation.

Easy (nothing was a problem for me)	Medium (some things required learning)	Difficult (I had a lot of problems all the time)	Very difficult (I wasn't able to participate in the simulation with goggles)

2. Please assess on a six-point scale (from 1 to 6) the comfort level of individual

aspects of the simulation and ease of performing activities, where 1-very low, 2-rather low, 3-medium, 4-rather high, 5- high, 6-very high.

	Grade 1 (very low)	Grade 2 (rather low)	Grade 3 (medium)	Grade 4 (rather high)	Grade 5 (high)	Grade 6 (very high)
Looking around - head and body movements						
Image reception						
Steering wheel handling						
Brake and accelerator control						
Direction indicators use						
Sitting comfort						
Other (please specify)						

3. Please rate on a six-point scale (from 1 to 6), where 1-bad, 2-rather bad, 3-average, 4-rather good, 5-good, 6-very good, the degree of simulation realism.

Grade 1 (bad)	Grade 2 (rather bad)	Grade 3 (average)	Grade 4 (rather good)	Grade 5 (good)	Grade 6 (very good)

Please ensure that all questions have been answered.
Thank you for participating in the study.

10.5 Annex No. 5 – Usefulness questionnaire (after driving on a simulator without goggles)

Projekt ICT-INEX

Questionnaire

Annex No. 5 - Usefulness questionnaire (after driving on a simulator without goggles)

Elaboration: Motor Transport Insitute (intellectual output leader)

Country:	**Poland**
Answers:	
Date of commissioning:	

PERSON'S NO. ....

QUESTIONNAIRE AFTER THE DRIVE (2D)

1. Please specify the difficulty level of the driving simulation (driving without goggles)

Easy (nothing was a problem for me)	Medium (some things required learning)	Difficult (I had a lot of problems all the time)	Very difficult (I wasn't able to participate in the simulation)

2. Please assess on a six-point scale (from 1 to 6) the comfort level of individual aspects of the simulation and ease of performing activities, where 1-very low, 2-rather low, 3-average, 4-rather high, 5- high, 6-very high.

	Grade 1 (very low)	Grade 2 (rather	Grade 3 (average)	Grade 4 (rather	Grade 5 (high)	Grade 6 (very high)

		low)		high)		
Looking around - head and body movements						
Image reception						
Steering wheel handling						
Brake and accelerator control						
Direction indicators use						
Sitting comfort						
Other (please specify)						

3. Please rate on a six-point scale (from 1 to 6), where 1-bad, 2-rather bad, 3-average, 4-rather good, 5-good, 6-very good, the degree of simulation realism.

Grade 1 (very low)	Grade 2 (rather low)	Grade 3 (average)	Grade 4 (rather high)	Grade 5 (high)	Grade 6 (very high)

Please ensure that all questions have been answered.
Thank you for participating in the study.

10.6 Annex No. 6 – Usefulness questionnaire - final survey

Projekt ICT-INEX

Questionnaire

Annex No. 6 - Usefulness questionnaire - final survey

Elaboration: Motor Transport Insitute (intellectual output leader)

Country:	**Poland**
Answers:	
Date of commissioning:	

PERSONS NO. ....

QUESTIONNAIRE AFTER THE DRIVE (FINAL)

1. Do you think that virtual reality goggles can be used for driver training?

Definitely Not	Rather not	I have no opinion	Rather yes	Definitely yes

2. If you did decide to use one of these devices as a supplement to the driver training, which one would it be? Please substantiate your answer.

Black goggles	Blue goggles	Simulator (no goggles)

Substantiation:………………………………………………………………………………

3. Which device do you prefer to drive in?

Black goggles	Blue goggles	Simulator (no goggles)

4. Please evaluate individual aspects of the simulation using the simulator. Please use a six-point scale (from 1 to 6), where 1-bad, 2-rather bad, 3-average, 4-rather good, 5-good, 6-very good.

Aspect	**Black goggles**	**Blue goggles**	**Simulator (no goggles)**
Comfort of using the helmet (fitting the head, eye distance) **Or** comfort of using the simulator (without goggles)			
Viewing comfort (smoothness when looking around the scene)			
The level of detail of the image - contrast and depth level			
Image sharpness			
Realism			
Comfort of the vehicle control (steering wheel + pedals)			
Control of the situation in virtual reality			
Well-being in virtual reality			

5. Please describe the most noticeable differences between driving using each device (VR vs 2D)

....

....

6. What did you like during the drive in VR goggles?

....

....

7. What didn't you like during the drive in VR goggles?

....

....

Please ensure that all questions have been answered.

Thank you for participating in the study.

10.7 Annex No. 7 – Usefulness questionnaire (watching video in goggles Samsung Gear VR)

Projekt ICT-INEX

Questionnaire

Annex No. 7 - Usefulness questionnaire (watching video in goggles Samsung Gear VR)

Elaboration: Motor Transport Insitute (intellectual output leader)

Country:	**Poland**
Answers:	
Date of commissioning:	

Questionnaire

10.8 Annex No. 8 – Usefulness questionnaire (watching video on tablet)

Projekt ICT-INEX

Questionnaire

Annex No. 8 - Usefulness questionnaire (watching video on tablet)

Elaboration: Motor Transport Insitute (intellectual output leader)

Country:	**Poland**
Answers:	
Date of commissioning:	

PERSON'S NO. ....

QUESTIONNAIRE AFTER THE DRIVE (TABLET)

1. Please specify the difficulty level of using the device during the simulation.

Easy (nothing was a problem for me)	Medium (some things required learning)	Difficult (I had a lot of problems all the time)	Very difficult (I wasn't able to participate in the simulation)

2. Did something make it difficult for you to use the device? If so, what was it?

Nothing	Looking around - head and body movement	Receiving image	Other (please specify)

3. Please rate on a six-point scale (from 1 to 6), where 1-bad, 2-rather bad, 3-average, 4-rather good, 5-good, 6-very good, the degree of simulation realism.

Grade 1 (bad)	Grade 2 (rather bad)	Grade 3 (average)	Grade 4 (rather good)	Grade 5 (good)	Grade 6 (very good)

4. Do you think that 360 ° movies played on this device can be used for driver training?

Definitely Not	Rather not	I have no opinion	Rather yes	Definitely yes

5. Please rate the individual aspects of the 360 ° movie played on the device. Please use a six-point scale (from 1 to 6), where 1-bad, 2-rather bad, 3-average, 4-rather good, 5-good, 6-very good.

Aspect	Tablet
Viewing comfort (smoothness when looking around the scene)	
The level of detail of the image - contrast and depth level	
Image sharpness	
Well-being during the projection	

Please ensure that all questions have been answered.
Thank you for participating in the study.

10.9 Annex No. 9 – Simulator Sickness Questionnaire (SSQ)

Projekt ICT-INEX

Questionnaire

Annex No. 9 - Simulator Sickness Questionnaire (SSQ)

Elaboration: Motor Transport Insitute (intellectual output leader)

Country:	**Poland**
Answers:	
Date of commissioning:	

Questionnaire SSQ

This questionnaire is to check your current well-being. Please mark with a cross (X) in the box which of the following symptoms relates to your current condition. It is allowed to give only one answer (putting only one cross in one line).

No.	Symptom	Category		
		Nausea	Oculomotor	Disorientation
1	General discomfort	X	X	
2	Fatigue		X	
3	Boredom			
4	Drowsiness			
5	Headache		X	
6	Eye strain		X	
7	Difficulties with focusing		X	X
8a	Increased salivation	X		
8b	Dry mouth			

9	Sweating	X		
10	Nausea	X		X
11	Difficulties with concentration	X	X	
12	Depression			
13	Disorientation			X
14	Blurred vision		X	X
15a	Dazed (with eyes open)			X
15b	Dazed (with eyes closed)			X
16	Dizziness			X
17	Memory flashes			
18	General weakness			
19	The need to take a breath			
20	Stomach disorders	X		
21	Loss of appetite			
22	Increased appetite			
23	Need for defecation			
24	Feeling lost			
25	Feeling of eructation	X		
26	Vomiting			