EFFECTIVE METHODS FOR DRIVERS RESEARCH WITH USE OF A DRIVING SIMULATOR

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Abstract

Paper describes possibilities to use advanced vehicles simulator combined with additional supporting research devices for measuring drivers' behaviour. Analyzing drivers' behaviour with driving simulators is a rapidly growing field of research, which also demands the interdisciplinary approach from different science disciplines like psychology and simulation engineering. Paper presents modern research methods in transport safety researches and devices that are used to understand better driver's behaviour inside the driving simulator, e.g. Vienna Test System and mobile eye-tracker. Paper also explains a problem of simulator sickness that frequently occurs during the studies inside the driving simulators. Main advantage of using simulators is possibility to achieve full standardization of research conditions. Visualization system based on set of four projectors and cylindrical screen with 200 degrees of vision range, which allows to completely cover the range of sight of the driver to enhance driving reality. The view in the car mirrors is presented on three LCD screens which sizes are very close to the mirrors used in real car mirrors. The scenery generated by computer simulation is moving according to the car speed in the simulation. Similarly to the passenger car simulator, simulator of truck and bus is build based on visualization system which is composed of cylindrical screen, with two hundred degrees of horizontal range of view. Simulator gives the ability to trace functioning of few different types of vehicles.

Keywords: *transport, road transport, driver behaviour, driving simulator*

1. Introduction

For last few years driving simulators become inherent in drivers research. Grade of reality representation, which is presented by high-class simulators (equipped in example by real vehicle cabin, advanced movement system of the cabin and possibly full range of view field of the driver with mirrors view simulation) nowadays, seems to be sufficient for laboratory research studies of drivers using it. Advanced technologies available alike in the field of image rendering, generating of computer simulations, and imitating the real movement of the vehicle cabin allows achieving in simulation the conditions similar to the real one. Higher level of realism allows improving the experience of driving, and therefore improves capabilities of referencing studies and experiments to the actual conditions.

All over the world studies using driver simulators are carried out for years in countries like USA, France, Germany and Japan. These countries have dominated the fields of research where the simulators are used. Research are made alike in the field of psychological research, studies over infrastructure and environment of the road, and in higher classes of the simulators research for modelling the vehicle. Each of these research fields is different from each other and forces researchers to use variety of research tools used to build credible indicators.

Use of high-class driving simulator in drivers' research allows executing studies, which couldn't be possible to carry out in real traffic conditions, even using the closed traffic fields. Main advantage of using simulators is possibility to achieve full standardization of research conditions. Programmed research scenario allows preparing the simulation properly adapted to the style of driving of examined person, and simultaneously keeping of the repeatability of traffic conditions in which are made studies. So far scientists try to standardize research conditions in closed traffic fields. Even in that cases they have met significant limitations and technical problems, which cause that examined persons not always have identically same conditions, and what follows not always could compare research results. Taking into account both main advantages of driving simulators and easy recording of wide range of parameters – from accelerator position to steering wheel position – makes that driving simulators used in drivers research where irreplaceable research tool.

Opponents of using simulators in research say that simulations are still too costly and too imperfect. But the number of validation researches which compare set of drivers behaviour between simulators and researches in real traffic conditions indicate, that drivers behaviour is similar in all these environments. For example, research made by Underwood, Crundalla and Chapman (2010) concerning danger perception in traffic conditions, presented that alike in simulators and in real traffic conditions, more experienced drivers better scour the vision field and faster focused gaze in potentially dangerous objects than beginner drivers. On the other hand in Godley's, Triggs and Fildes's (2002) research indicates that drivers behaviour when they encountering objects like slowing lanes which makes they have to slow down to prepare for traffic conditions, is similar in both driver simulators and real conditions. In the other hand, it should be admitted that in last researches concerning driving speed results indicates that drivers drive slower in simulators than in real conditions.

2. Car driving simulator

Driving simulator of passenger car AS 1200-6, of Norwegian AutoSim company, which is possessed by Motor Transport Institute (ITS) is a high-class research simulator. Simulator is built of full sized and fully functional of Opel Astra IV cabin, visualization system, and motion platform with six degrees of freedom. Additionally inside the cabin were generated mechanical stimuli (vibrations of the cabin and vibrations of the driver seat) and sound effects. All these elements allow simulating driving the vehicle as closely as possible. Whole simulator is controlled from the operator seat, in which it is possible also to monitor vehicle motion parameters, and driver behaviour.

Visualization system based on set of four projectors and cylindrical screen with 200 degrees of vision range, which allows to completely cover the range of sight of the driver to enhance driving reality. The view in the car mirrors is presented on three LCD screens which sizes are very close to the mirrors used in real car mirrors. The scenery generated by computer simulation is moving according to the car speed in the simulation.

Motion platform is build based on six actuators, which allow to truly imitating movements of the drivers cabin, both in respect of simulated speeds, linear accelerations and angular accelerations which are, as indicated by the producer of the platform, measured from the seat of the driver, are:

- for angular movements:
- displacement ± 22 (21) degree,
- maximum velocity of displacement ±30 (40) degree/second,
- maximum acceleration of displacement ± 500 (400) degree/second^2,
- for linear movements:
- displacement ± 0.25 (0,18) meter,
- maximum velocity of displacement ± 0.5 (0.3) meter/second,
- maximum acceleration of displacement ± 0.6 (0.5) G,

Advanced software of the computers allows for projection up to 100 traffic objects in a time and imitating driving in more than two hundred kilometres of virtual highways in different atmospheric condition (including snow, rain and mist) and in different traffic conditions (including highways, cities, towns, villages and mountains). Dynamic model of the vehicle and included in

Fig. 1. High class research simulator of passenger car - AS 1200-6

simulation parameters allow imitating different traffic conditions, different types of vehicles and reactions for drivers' actions. In the simulator there is modelled the activity of real devices in the real vehicle, including work of the engine, ratios of the gearbox and other, and environment conditions like state of the surface or weather conditions. There is also the possibility to change the parameters, in example for simulating different types of vehicles, power of engines different types of manual and automatic gearboxes and also simulation of errors and damages of individual systems and components. Additionally operator has possibility to record most of the driving parameters starting from vehicle speed, through the degree of each pedal and ending on degree of turning the steering wheel. The recording may be prepared with the frequency of 60 Hz.

3. Driving simulator of truck and bus - in example AS 1200-6

Motor Transport Institute possessed also high class simulator of truck and bus – AS 1300 produced by AutoSim. Similarly to the passenger car simulator, these one is build based on visualization system which is composed of cylindrical screen, with two hundred degrees of horizontal range of view. For driver disposal were also four mirrors, modelling the range of sights from the real vehicle. Drivers' cabin is based on real cabin construction of Scania. The cabin is fully functional. Vibration generation system, sound effects system significantly increase the reality of conditions in which the driver is.

Simulator gives the ability to trace functioning of few different types of vehicles. In the software are available different types of vehicles (truck, truck with trailer, truck tractor with semitrailer, bus and articulated bus) in which the simulator operator could change and customize main motion parameters. Each of vehicles has properly adapted mechanics of work, which imitates real vehicles, including differences which are observed between trucks and busses. During the simulation there is a possibility to interfere in work of individual systems.

AS 1300 simulator software is compatible with the one used in AS 1200-6 passenger car simulator. Common software, and hence the graphics base, and also the parameters of presented visual and audio effects, positively affect comparability of research results from both truck and bus, and passenger car simulator.

Fig. 2. High class research simulator of truck and bus - AS 1300

4. Use of eye-tracker device in driving simulators

Drivers' researches are one of the most important contemporary fields of studies which revolve around transport and motorization. Studies of that kind are made concerning all three elements of traffic system including: person (the driver), vehicle, and environment. In studies over drivers very important issue is to monitor and record the widest possible spectrum of indicators and parameters associated with their behaviour. Driver interacts a series of experiences, from which the most important in the context of driving information processing are visual signals. Perception of these signals begins from the moment of stimulation the reception area of eyesight analyzer to build the representation of environment around the driver in his mind. But human is not only a passive recipient of the world. According to the Neisser theory, human in his perception cycle don’t only match the received data to his memory, but also actively search for information based on memory cognitive schemes. These differences could be studied using the eye-trackers, which allows monitoring the eyeball movements of the driver, and hence enable studies of how the drivers scours their sight to gain information necessary for functioning in road traffic environment.

There are few main methods of measuring the eye movements: electrooculography which made the measurement by monitoring of bioelectrical potentials of the muscles around the eyeball, coiled measure which performs the monitoring of magnetised elements on the surface of the eyeball, and optical measurement which based on video technology (Holmqvist and others, 2009). The most common eye-trackers are these based on video technology. These types of devices could be divided at: static eye-trackers, motion eye-trackers and these which use so-called head-trackers which track the location in space and movements of the examined person head, which are very often used in motion eye-trackers.

Motion eye-trackers, (so-called head-trackers) are used as the overlay applied to the head (helmet, cap, headband), equipped with appropriate equipment. Same mechanism of eye-tracker work is quite simple. The surface of eye is lighted up, indirectly after light reflection from the eye-tracker glass, with dedicated infrared illuminator. The beam of light falling on the eye causes the eye reflection on the same eye-tracker glass. Reflection is captured by the video-camera, which records the image for further analysis procedure in the software. The determination of direction of sight is calculated using the locations of two characteristic points of eye image. The first one is interpolated point of middle of the pupil. The second one is so-called first Purkinje reflex, which is the reflection of infrared light from the outer surface of the cornea. The fixation (vision focusing) marker is applied at the image of the context video-camera, which records the area ahead of the driver. This solution allows to fully compensating head movements of examined person.

Fig. 3. Use of SMI iView X HED Eyetracker system in passenger car simulator AS1200-6

Motion eye-trackers have the set of advantages, which militate in favour of using it in driving simulators. Mainly eye-trackers are devices used to study, the most important for drivers, sense of sight, in range which is impossible to achieve using other methods and devices. The possibility of observation what cognitive schemes the driver operates, what he gaze the sight at, and how long he gaze his sight on different objects and what objects he noticed and which not, is almost perfect field to study infrastructure and environment objects and elements, peripherals devices in vehicles and differences between drivers. Motion eye-tracker is the device which minimally intrusive in freedom of movement of the driver, and hence in naturalness of his behaviour. These features allow keeping high credibility of research. Main disadvantages resulting of use of motion eye-trackers is slight interference in sight field of the person, because of eye-tracker glass, and difficulties in the correct calibration of the apparatus in such a complicated environment like simulator, and in synchronization of the eye-tracker with the measured data obtained from the simulator like accelerator degree. Despite these potential difficulties, use of eye-tracker in the driving simulator is much easier than use it in the real traffic conditions, because of very variable lighting conditions, which could significantly affect at data lost and quality of gained information.

5. Role of the Vienna Test System in simulator studies

Vienna System of Tests is actually the only one, complex system that supports psychology diagnostics and is dedicated for driver research. The system allows preparing complex and reliable diagnosis of drivers in psychomotor efficiency, intellectual dexterity and personality traits alike. The system basis on tests with scientifically proven reaching of psychometric goodness: for the reliability of drivers' tests above 0.70 and accuracy, standardization, objectification and normalization.

In range of Vienna System Tests were tens of tests, but only several were used mostly to study predisposition to drive. These testes are commonly used in psychology of transport and include:

- standardized Ravens progressive matrices – test which study fluid intelligence and measures perceptual and logical capabilities of the mind,
- signal detection test based on Green and Swets theory – examined detection of weak signals which are presented on changing background,
- test for measuring simple and complex reactions on light and sound stimuli – measurement of the speed of reaction and motoric time,
- test of hand-eye coordination in dynamic system,

- test of coordination that studies two factors: coordination between left and right hand, and coordination between an eye and hand,
- motion-time anticipation test – testing capabilities to analyze and predict movements of objects,
- adaptative tachiscope test for orientation in traffic,
- peripheral sight test – for testing capabilities to evaluate speed, tracking of environment and driving the vehicle,
- test of dividing attention and resistance to stress,
- linear tracking test – examine of targeted and focused visual perception in terms of tracking simple optical structures at the complicated environmental background, and also under time pressure,
- memory span test – test of visual-spatial working memory and visual-spatial learning,
- Vienna risk taking in traffic test.

These tests allowing accurate and complex description the essential features and effectiveness that affect on drivers behaviour. Such studies allows inter alia for bettered differentiation of examined groups of people because of their psychology predisposition to drive vehicles. Use of only the demographic data seems to be insufficient for reliable research, and there is a need of use psychology tests to verify an other individual variables. In addition, research using driving simulators can also be a test for new methodological approaches and verify their accuracy. Suitable adaptation of tests like also their high accuracy and reliability of the results expressly provide for the use of such tests in correlation with studies in a driving simulator. The results could serve both as a comparative basis for other tests, and as a basis for statistical description of investigated issues.

6. Simulator Sickness

One of main difficulties that need to be solved before starting research using driving simulator is issue called Simulator sickness. Simulator sickness is a set of unpleasant in feeling and consequence reaction of the body at stimuli that it affects from the simulator. The feeling is mainly compared with motion sickness, and in principle is very similarly manifested. In fact these sickness is a temporary indisposition of the brain, and more accurately of balance organ.

An organ responsible for detection of movements of the body and detection of gravity is vestibule located in the inner ear. Vestibule is located in the temporal bone in both sides of human head. Vestibule main function is: detection of the changes in linear acceleration and gravity and changes in angular acceleration. Most of the simulator sickness symptoms results from the contradiction between the signals which are send by balance organ and send by sight (Brooks, 2010). In static driving simulators the sight indicates the movement of the body, but the balance organ didn't detect such movement. In dynamic simulators that imitates the movement (depending of the solution) happens, that the acceleration that the body is affected by is opposite to these which outcome from the visual sight. These situation highly increase the risk of simulator sickness appearance. The conflict between the stimuli from visual sight and detected by the balance organ leads to producing by the body the neurotransmitter that is mistakenly taken by the organism as a signal about hallucinogenic poisoning. In reply, the body is trying to release by whatever means (hence, the presence of nausea is one of main simulator sickness symptoms).

There could be observed rather large individual differences in susceptibility for simulator sickness. The same simulation may cause different symptoms in different individuals, or even don't manifests in some cases. Symptoms could manifest also in different configurations. To individual factors that affect the susceptibility for simulator sickness could be counted: age, the level of concentration, experiences with traffic and driving in real and in the simulators (adaptation), flicker frequency threshold, sex, medical history, current state of health, the style of perception and posture stability. The occurrence of symptoms depends also from the type of simulated conditions. Simulation of highways, or external roads where there is not much maneuvers to take and the traffic is running smoothly significantly reduce risk of symptoms in relation to the urban environment, in both the passenger cars simulators and truck and bus simulators.

Measuring the motion (simulator) sickness symptoms, using the SSQ (The Simulator Sickness Questionnaire) developed by a team led by Kennedy (1993), we can distinguish even 16 different symptoms, which were qualified to three groups:

- oculomotoric symptoms – in example: eye fatigue, difficulty in concentration, impaired vision or headache,
- disorientation symptoms – in example: vertigo or dizziness,
- nausea symptoms – in example: nausea, salivation heartburn and loss of appetite,
- In the questionnaire the evaluation of each symptom is prepared in scale of 0 – didn't occurs, to 3 – occurs in significant way.

Actually does not exist the effective way to eliminate simulator sickness. But there is a set of techniques and methods that minimize the effects of their impact. The easiest one is to take frequent breaks while using the driving simulator. Breaks help to reduce the accumulation of simulator sickness symptoms. Maintaining sufficiently low temperature in the room where is the simulator (as well as in the simulator) could also significantly prolong the time in which the symptoms does not occur.

Due to occurring of simulator sickness, while designing the researches should be taken into account that it could cause temporary motor dysfunctions, including problems with eye-hand coordination and instability of posture. It could be the difficulty in returning to home and in particular in driving vehicles. Participants of studies should therefore be advised about possibility occur such difficulties. It should also be provided the place and time to relax for participants, after the session in the simulator.

7. Conclusions

Driving simulators could, after proper adaptation of its subject and range of researches to its nature, be invaluable research tool, which use allows to perform the research concerning almost every element of the process of driving: human (driver), vehicle and environment of the road (including infrastructure), to perform tests on drivers. Interdisciplinary nature of the driving process provides opportunities to perform researches in width thematic scope, starting from psychology of transport, through researches of the equipment ergonomics, up to influence of the environment to the driver. Ability to almost complex standardization of the experiment conditions, resulting obtaining results comparability provide for the using driving simulators in researches of the driving process and traffic systems. Using additional tools like eye-trackers and sets of psychology (and psychomotor) tests further extents opportunities for simulator usage.

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