Evaluation of Projection Systems for Vehicle Simulator

G. Gudzbeler, A. Urban, and M. Dabrowski

***Abstract*—The authors decided to make an attempt to give the preliminary answer to a question: Which of the studied projection systems causes lesser degree of symptoms of simulator sickness during training? For the purposes of the examinations two test platforms were prepared. One equipped with a screen with a cylindrical projection system, the second with "on screen" projection system. This study may be viewed as an instruction for people planning to build similar simulators to those described in the paper. It can be an important support for all those who plan to create such solutions.**

***Index Terms*— simulation, visualization, projection systems, simulation sickness, cylindrical view, on screen.**

I. INTRODUCTION

There are many elements in the simulator which determine the functional properties, such as the moving platform, integrated visualization environment and sounds. Their design and parameters should be selected so that the person using system, regardless of its destination (for purposes of training or research) should in all driving conditions have feelings as close as possible to those that would appear in the real world. Of course for system evaluation purposes, reactions of the same person should be compared, because different people may behave differently in the same circumstances. In order to do so, validation studies should be performed that rely on the measurement of certain quantities related to the moving platform, vehicle motion parameters and a broad range of reactions of the driver (the impact on vehicle control properties such as the steering, clutch pedal, brake and gas, driver's mental or physical conditions, eye tracking, etc.). Of course the ideal situation would be when the corresponding values obtained for the two systems were the same (absolute validation). In practice, however, it is impossible to achieve. Therefore, the current prevailing view is that the quality of the simulator is sufficient (validation relative) if the direction of changes are the same and values are similar or identical in both real and virtual systems. The authors of some works[1] point to the fact that, despite the similar behavior of drivers in the simulator and on the road, some imperfections in the projected image can cause that not all signals from the environment can be perceived by a trainee, and lower resolution causes that many details may not be seen and lighting conditions can be different from the real world. Simulator validation studies should include not only a comparison of such quantities as the speed and trajectory of the vehicle, but also aspects of risk including driver's ability to adapt to a particular dangerous situation on the road.[2] An important factor influencing the reactions of the person using the driving simulator is the mutual coupling between a man and a machine, in short called HMI (Human-Machine-Interfaces). The authors decided to make an attempt to give the preliminary answer to a question: Which from studied projection systems causes lesser degree of symptoms of simulator sickness during training? For the purposes of examinations two test platforms were prepared: one equipped with a screen with a cylindrical projection system, the second with "on screen" projection system.

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II. TEST PLATFORMS SPECIFICATION

The paper presents the results of comparative tests carried in consortium by Police Academy in Szczytno, Poland, as a part of the scientific project "Building simulator of driving privileged vehicles in typical and extreme situations". The study involved a standard and widely used system of cylindrical projection and the increasingly popular projection system called "on screen".
For the purposes of examinations two test platforms were prepared. One equipped with a screen with a cylindrical projection system, the second with "on screen" projection system.
Simulator with cylindrical projection system.
Cabin - of intercity bus Autosan A1012T Leader
Screen (cylindrical: with radius R = 4.1 m and height h = 3.75 m, angles of sight from a point of view of the driver: angle width: vfov = 180 deg, angle height hfov = 50 deg)
Projection system (four projectors Projectiondesign F22 SX +, 1400 x 1050 resolution, brightness - 2100 ANSI lumens, contrast ratio: 2500:1, type of matrix: DLP)
That causes the projection system provided an angular resolution in front of the driver's sight - 2.9 arc minute / pixel.
Photos 1-3 show the simulator with a cylindrical projection system.

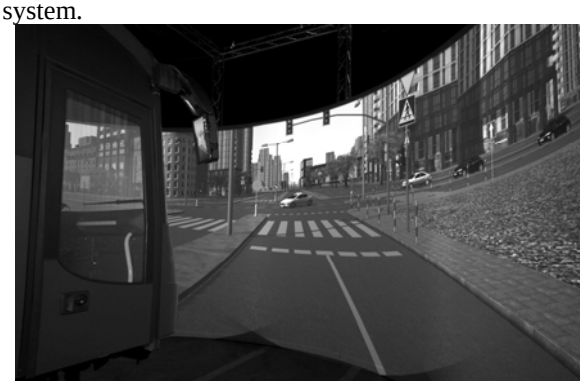

Fig. 1. Simulator with a cylindrical screen - a view of the cabin and the screen with displayed image, from outside and from inside of the cabin.

ISBN: 978-988-19252-4-4
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

Fig. 2. Simulator with a cylindrical screen - a view of the cabin and the screen with displayed image, from outside and from inside of the cabin.

Fig. 3. Simulator with a cylindrical screen - visible cabin, cylindrical screen and projection system.

Simulator with on screen projection system.

- Cabin – Mercedes Acros truck.
- Screen - “on screen” - stuck projection foil to all front and side windows allowing view using the rear projection type, rear windows were completely blacked out.
- Projection system:

3 ultra-short throw projector Mitsubishi WD380U-EST serving as front and left window (brightness: 2800 ANSI lumens, resolution: 1280 x 800, contrast ratio: 3000:1, type of matrix: DLP),

1 projector Panasonic PT-LB1E displays the image on the right window (brightness: 2200 ANSI lumens, contrast ratio: 500: 1, resolution: 1024 x 768, type of matrix: LCD).

That causes the projection system provided an angular resolution in front of the driver's sight - 2.1 arc minute / pixel.

Photos 4-8 show the test stand with "on screen" rear projection system.

Fig. 4. The test simulator with "on screen" projection - visible cabin with "on screen" screens and projectors that support front and left side windows

Fig. 5. The test simulator with "on screen" projection - visible cabin with "on screen" screens on the windscreen and windscreen supports projectors.

III. STUDY RESULTS

The study was performed on 15 individuals who had not previously practiced on simulators. The number of participants in the experiment is not easy to determine and depends on many aspects and especially on the purpose of the evaluation. Generally, the more participants, the more accurate the research is. In preliminary tests, it seems reasonable to involve a homogeneous group of participants of similar age and experience. In ISO 16 673 standards, the sufficient number of participants is 10. Taking this into account, it means that examination of 15 participants is sufficient, the acceptable minimum is 10 people.

A preliminary study performed on these participants did not identify diseases of their eye. Research on simulators with "on screen" and the cylinder projection system was performed at an interval of 10 days.

ISBN: 978-988-19252-4-4
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

Results of research conducted on the simulator with cylinder projection system.

3.1.1 The study carried out before training

A. Interview

In the interview conducted among all participants, there was no disturbance which could have an impact on training on the simulator. 3 people had symptoms of asthenopia negative (age-related abnormal accommodation, causing problems with reading without correction glasses)

B. Concerned ophthalmological examination

1. The study of eye diseases. Refraction survey using computer autorefractometer in 11 participants showed that visual impairment does not exceed + / - 1.5 D, the refractive state, which usually does not require spectacle correction. In 2 participants the defect was -2.0 D, with a -3.75 / -3.5 D, and a -5.0 / -5.5 D. People with these defects are not excluded from training because, according to the rules they may have a driving license.

2. The study of visual acuity. The visual acuity of the right and left eye in 10 participants ranged from 0.8-1.0. In 5 participants it was within the limits 0.5-0.6. So in any of the subjects, there was no reduction in visual acuity which disqualifies them from driving.

3. Examination of the tear film with non-invasive test with a disruption of the tear film (NIBUT)) and the stability of the tear lipid layer films checked with Tearscope camera. NIBUT study showed normal values in all 15 participants (> 10 sec.). Examination of the lipid layer showed no thinness abnormalities in 13 participants (values A-C). In 2 of participants thickness of the lipid layer was thinned (E)

4. Examination of the binocular vision – Worth test. The study showed normal binocular vision in all participants.

5. The study of stereoscopic view - "Fly" test. Very good stereoscopy (Grade 8-9) occurred in 14 participants. A small reduction in stereoscopic occurred in 1 patient (grade 5).

6. The study of eyes setting - "cover test". In this study, there was no stability problems at the position of both eyes during their alternating covering (no small-angle strabismus and latent strabismus).

3.1.2 The study carried out after a training

A. Interview

12 persons after a training session on the simulator did not provide any information about visual disturbances. Three people delivered information about small disturbances in the form of "a strange image", "light disturbances when turning" and "strange impressions associated with non-motion simulator". These symptoms can be classified as a first degree of simulator sickness in Chilow classification.

B. Concerned ophthalmological examination

1. The study of visual acuity. The study showed no difference in visual acuity compared with state before the training on the simulator. Small differences of 0.1 are within the error limits of the method.

2. Examination of the tear film with non-invasive test with a disruption of the tear film (NIBUT)) and the stability of the tear lipid layer films checked with Tearscope camera. NIBUT test showed no prolongation of the tear film break in all the participants. The study of the lipid layer showed no changes in its thickness in 14 participants. In 1 person there was a small thinning of the layer thickness of 1 degree, but it was located within the normal range.

3. Examination of the binocular vision – Worth test. The study showed no changes in binocular vision in all participants after training.

4. The study of stereoscopic view - "Fly" test. After training on the simulator, there was no reduction in stereoscopy in all subjects.

5. The study of eyes setting - "cover test". In this study there was no change in the position of both eyes after a training session on the simulator.

Results of research conducted on the simulator with "on screen" projection system.

3.2.1 The study carried out before training

A. In the interview conducted among all participants, there were no abnormalities that could have an impact on training on the simulator. 3 people had symptoms of asthenopia (age-related abnormal accommodation, causing problems with reading without correction glasses)

1. The study of eye diseases. Refraction survey using computer autorefractometer in 11 participants showed a visual impairment does not exceed + / - 1.5 D, the refractive state, which usually does not require a spectacle correction. 2 participants the defect was -2.0 D, with a -3.5 / -3.25 D, and a -5.25 / -5.25 D. People with these defects are not excluded from training because, according to the Polish rules may they have a driving license (category A and B) in accordance with the Minister of Health regulation from 15 April 2011.

2. The study of visual acuity. The visual acuity of the right and left eye in 10 participants ranged from 0.8-1.0. In 5 participants it was within the limits 0.4-0.7. This means that none of the subjects showed reduction in visual acuity which disqualifies them to drive motor vehicles (Polish driving license category A and B) in accordance with the Minister of Health regulation of 15 April 2011.

3. The examination of the tear film with non-invasive test with a disruption of the tear film (NIBUT)) and the stability of the tear lipid layer films checked with Tearscope camera. NIBUT test showed normal values in 15 participants(> 10 sec.). The examination of the lipid layer showed no thinness abnormalities in 11 participants (the AC). In 4 of them thickness of the lipid layer was thinned (DE value).

4. The examination of the binocular vision – Worth test. The study showed normal binocular vision in all participants.

5. The study of stereoscopic view - "Fly" test. Very good stereoscopy (Grade 8-9) occurred in 14 participants. A small reduction in stereoscopic occurred in 1 patient (grade 5).

6. The study of eyes setting - "cover test". In the study, there was no evidence of impaired stability of the position of both eyes during their alternating covering (no small-angle strabismus and latent strabismus).

ISBN: 978-988-19252-4-4
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

3.2.2 Post-training study

A. Interview

10 persons did not provide any visual disturbances after the training session on the simulator with "on screen" projection system. 5 people reported disorder in the form of "breathing", “a strange image,” light nausea ," twisted image "and dizziness”. These symptoms can be classified as 1 degree in 4 participants, and in one case as a second stage of simulator sickness in Chilow classification.

B. Concerned ophthalmological examination

1. The study of visual acuity. The study showed no difference in visual acuity compared with state before the training on the simulator. Small differences of 0.1 are within the error limits of the method.

2. Examination of the tear film with non-invasive test with a disruption of the tear film (NIBUT)) and the stability of the tear lipid layer films checked with Tearscope camera. NIBUT test showed no prolongation of the tear film break in all the participants. The study of the lipid layer showed no changes in its thickness in 14 participants. In 1 person there was a small thinning of the layer thickness of 1 degree, but it was located within the normal range.

3. Examination of the binocular vision – Worth test. The study showed no changes in binocular vision in all participants after training.

4. The study of stereoscopic view - "Fly" test. After training on the simulator, there was no reduction in stereoscopy in 14 participants. One person showed reduced stereoscopic range of 1 degree (from 5 to 4).

5. The study of eyes setting - "cover test". In this study there was no change in the position of both eyes after the training session on the simulator.

IV. CONCLUSION

The conclusion of the study is that the simulator sickness in analyzed patients is not due to anatomical changes in the parameters and functions of the eye. These results confirm the theory that disease is caused by a lack of correlation between the signals received from different senses. During the training on simulator a person receives strong visual stimuli which apparently indicates the existing virtual movement, which is not accompanied by irritation of the kinetic vertigo receptors. This leads to the confusion (conflict) signals within the central nervous system between small kinetic stimuli coming from the labyrinth and proprioceptors informing about the movements of the head and strong visual stimuli informing the rapid movement of our body. This causes stimulation of the parasympathetic and autonomic symptoms characteristic of simulator sickness. Why simulator sickness was more common in the simulator with the screen "on screen" than in the cylindrical projection system? It seems that this is due to the proximity of the screen. There is an analogy to the occurrence of symptoms when watching movies in 3D. Watching the three-dimensional films at the cinema rarely causes simulator sickness because the screen is far from the viewers. The introduction of 3D technology in television meant that its symptoms began to be felt much more often. It is estimated that it may occur in 10-20% of people watching 3D TV. Because the closer they sit to the screen, the greater probability of feeling symptoms of simulator sickness is.

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