ZESZYTY NAUKOWE POLITECHNIKI RZESZOWSKIEJ 288, Mechanika 85
RUTMech, t. XXX, z. 85 (4/13), październik-grudzień 2013, s. 455-467

Antoni KOPYT[1]
Janusz NARKIEWICZ[2]

TECHNICAL FACTORS INFLUENCING SIMULATOR SICKNESS

Recently, simulators find application not only in the aeronautics, but also in other fields of technology, like robotics, marine etc. Computer-based trainings are offered almost with every modern technology product placed in the market. In the paper the application of simulators to train pilots of mobile platforms (like aircraft, cars, sea-vessels) is considered. The simulator sickness appears due to difficulties in simulating the motion and environment „properly" in the simulator. Similar symptoms, called a virtual reality sickness may be observed within the community of computer game players. The main reason for occurrence of the simulator sickness is that external stimuli (motion and/or vision) give misleading information to a human brain. The aim of this research was to find the relation between the architecture and the technical parameters of different types of simulators and occurrence of the simulator sickness. The focus of this study is the architecture of the simulator and its technical parameters that may influence unfavorable operator reactions during training, such as moving platform, screen size, simulated models, graphics quality, etc. The paper is based on a wide literature review, and it is an introduction to the future experimental research.

Key words: simulator, simulator sickness, moving platform, simulator architecture

1. Introduction

A simulator sickness (SS) sometimes named also a simulator disease describes a specific human reaction during training performed on simulators. It may occur for various types of mobile platforms, like: aircraft, sea vessels or ground vehicles [1, 2]. At the background for this study was the need for analyzing the technical requirements for a car driver simulator to prevent occurrence of the simulator sickness [3]. Due to increasing widespread use of simulators for training operators of various vehicles, the simulator literature is very rich [4]. But it focuses mainly on training of aircraft pilots, due to long tradition (see Fig. 1) and great experience achieved [5]. Several authors describe the simulator

[1] Antoni Kopyt, e-mail: antoni.kopyt@meil.pw.edu.pl
[2] Autor do korespondencji/corresponding author: Janusz Narkiewicz, Warsaw University of Technology, 24 Nowowiejska St., Warsaw, tel. (22) 2347445, e-mail: janusz.narkiewicz@meil.pw.edu.pl

sickness in a similar way, „when a simulator produces effects which are dissimilar then these outcomes which occur, for example, in the aircraft, then these outcomes are logically implicative of the inadequacy of the simulation" [6], or as in the literature [7] „SS is a form of a motion sickness that does not require true motion (...)", or in the literature [8] „(...) sickness occurs when information from visual, vestibular, and other sensory channels is not consistent with the past experience". Considering factors, which promote the simulator sickness, the general statement is that „the simulator sickness is multi-symptomatic disease and strongly depends on individual characteristics of a subject" [2]. Kolasinski [9] these factors grouped within three categories: operator (user), system and the task (Table 1). Analyzing the results presented in an open literature, usually it is not possible to categorize the reasons to one of these groups, as during tests several factors were varied. In the analysis presented in this paper, the research results are discussed within one of the group in Table 1, taking into account the main factor occurring within the research.

Fig. 1. Ground training on an Antoinette simulator

In the literature [10] it was found that all the symptoms of the SS are the result of incorrect simulation [11]. If all aspects of the simulation will be performed correctly and satisfy the requirements suited to the needs of user, all symptoms of simulators will be referred to as motion sickness. Mullen et al. [12] classified simulators due to the occurrence of the SS. The less frequently the simulator sickness occurs, the simulator was classified as better. It confirms that the disease is caused by poor quality of the simulation parameters. In later publications [6, 11] it is stated that if the disease is present during the test, and does not occur after exercise evaluated on the real object, the simulation is performed incorrect. According to Lawrence [6], properly designed simulator is able to imitate the real situation in such a way that its effects on the human state are the same as in reality.

Table 1. Factors influencing on the simulator sickness occurrence

User characteristics	System characteristics	Task characteristics
Physical characteristics	**Display**	**Movement through Virtual Environment**
Age	contrast	control of movement
Gender	flicker	speed of movement
Ethnic origin	luminance level	
Postural stability	phosphor lag	**Visual Image**
State of health	refresh rate	field of view
	resolution	scene content
Experience		viewing region
With virtual reality system	**System lags**	visual flow
With corresponding real-word task	time lag	
	update rate	**Interaction with task**
Perceptual characteristics		duration
Flicker fusion frequency		head movement
Mental rotational ability		sitting vs. standing
Perceptual style		

2. Operator related factors

The extensive research of Mullen et al. [12] was undertaken to investigate the relation between individual characteristics of simulator users such as gender, age, physical form. In this study, more than 200 pilots 23÷42 years old were tested on a helicopter simulator. No relation between the simulation sickness susceptibility and **operator age** has been indicated. But the operator age had the indirect influence, due to reducing the operator field of view (FOV): for 20 year old person the FOV is about 180 degrees, and for 80 year old person FOV is about 135 degrees [13], which may affect the susceptibility tothe SS. An influence of the operator **health status** to the occurrence of the SS was considered in publications [13-15]. The results obtained by de Wit [15] indicate, that when the operator is ill or weakened the use of a simulator may cause adverse effects. An impact of **work experience** is not clear. Tests performed by Renkewitz and Alexander [13] indicated that pilots with extensive experience are more vulnerable to the SS. It was attributed to the fact, that they are more susceptible to the differences of simulator compared with the reality. Lawrence et al. [6] studied performance of 48 fighter pilots in the fixed based F-4 aircraft simulator and found that 88% of subjects had SS symptoms. According to the literature [6] the symptoms of SS were observed among 27% of the pilot training on the Navy maneuvering fixed platform 2E6 Air Combat Simulator (ACMS). The SS symptoms occurred at 47% of experienced pilots with more than 1,500 hours flight. Johnson [7] found that 60% of flight instructor felt SS symptoms, compared to only 12% of students. Crowley [16] also reported that, the Cobra Flight Weapons Simulator (fixed platform) pilots with extensive experience (more than 1000 hours of flight time) showed symptoms SS. These results may prove the thesis that more experienced pilots were more influenced by SS. The SS symptoms may occur several hours after performing exercises on the simulator [6].

Another factor is **experience in simulator flights**. An operator adapted to one type of simulator does not assure higher SS resistance, when training in other simulator. Wright [17] found that a person may be more susceptible to the SS after changing to another simulator; pilots having no symptoms SS in a CH-47 helicopter simulator, showed SS performing the exercises in the UH – 60 simulator. It may be assumed that **pilot adaptation to a particular type of simulator** can significantly reduce the occurrence of disease during operations on simulator. However, instructors training on one type of simulator had no symptoms of SS, while on the other simulator type the instructors were more vulnerable than students [17]. The **influence of the task** performed was studied by Mullen et al. [12]. It was encountered, that the complexity of the task is an essential factor which influences the occurrence of the disease. In an urban area (multiple objects, a lot of turns, heavy traffic, loudness, crossings etc.) the SS occurred more frequently than during driving in a rural environment. In the literature [18] it was found that flight velocity affects the appearance of symptoms of the disease (60 mph and 25 mph). Similar conclusions have been assumed by Lawrence et al. [6], where the subjects were performing the air combat (*Air – to – Air Combat*). Such a task is characterized by rapid changes in the image and requires constant concentration and quick reactions pilot. Bimal et al. [19] described a study of the four different configurations of the simulator and the relationship has been demonstrated that the SS increases with a more complicated task.

Kennedy et al. [20] showed the relationship between **the number of exercise repetitions** and susceptibility to the SS. This study found that within the increase of training hours, the susceptibility to the disease decreases. But it was estimated that 3÷5% of people are not able to overcome the SS symptoms and will never be able to perform properly exercises on the simulator. For many people a long term exercise is required to adapt to the simulator. Therefore, participation of people subjected to motion sickness in the exercises on the simulator should be carefully considered.

3. Technical parameters influencing simulator sickness

System of simulator motion

The technical parameters discussed in this chapter grouped regarding the simulator subsystems: motion of the platform, visualization and projection, images, sound generation, cockpit and the vehicle simulation model. The type and qualities of simulator motion system seems to be the key factor that influences on the occurrence of simulator sickness. According to reported cases the **simulator sickness occurs both in fixed base simulators and in simulators with moving platforms** [20-22]. This observation provokes terminology disputes, which have an impact on the way, in which the influence of simulator motion on the occurrence of the SS is explained. Operators training on fixed based simulators, despite the lack of stimulus movement, encounter SS symptoms are similar to motion sickness. In the literature [9] the term „simulator sickness" is attributed to a fixed based simulator, while in the moving platform simulator a „motion sickness" term is used. Similarly, according to the literature [23], the main difference between the simulator sickness and motion sickness is that the latter occurs in the simulators with moving platform. According to publications [12, 10, 24] simulator sickness which occurs in simulators with moving platform is the same as fixed base simulator. This finding is different to publications [6, 25], where the authors examine the simulator sickness in moving platforms without referring to motion sickness term. The situation is additionally complicated by the fact that pilots may have symptoms of the simulator sickness (in a fixed base simulators), despite the fact that the pilots were not prone to motion sickness (in a moving platform simulators). The symptoms that occur during the simulation tests are also named: „aircraft disease", „seasickness", „astronauts disease" [25], „simulator syndrome". Symptoms similar to the SS are encountered by people using modern computer games [26], they are referred to as Virtual Reality Sickness (VR Sickness), cybersickness, VE sickness. The important quality of a simulator construction is proper **modeling of acceleration**. If, due to the simulator design, acceleration in the simulator does not correspond to the acceleration occurring in reality, it may promote the simulator sickness. McCauley et al. [27] stated that „locomotion sickness is a type of motion sickness and the causative factor is changing speed". The disease can also be induced by **visual stimuli** modeling of the vehicle movement without actually performing motion [23, 28]. Many researchers believe that the main cause of the SS is discrepancy between the information provided by the operator senses of position and motion, and the knowledge about the real motion [9, 20].

In various simulator configurations with moving platform on and off were studied [29]. The pilots found that the tests with moving platform had almost no impact, most of them also stated that the SS symptoms did not occur. Bürki-

-Cohen et al. [30] presented a similar study is. The impact of various arrangements of the simulator was tested divided into the following categories:

- no moving platform, eyes open, 20 s,
- no moving platform, eyes closed, 20 s,
- moving platform, eyes open, 1 min,
- moving platform, eyes closed, 1 min.

The conclusion from this study was that the simulator caused sickness also to people who declared that they were not suffering the motion sickness before. On the other hand, people who encountered the motion sickness, only one lasted to the end of the tests (and simulator sickness symptoms occurred a few hours later). It means that people suffering the motion sickness are likely to be susceptible also to the simulator sickness.

McCauley [8] showed the tests with American army pilots, in which the moving platform is turned off, the SS occurs more frequently. Although in this study more than 1000 pilots and 10 different simulators (with moving and fixed base platform) were engaged, the study did not confirm that the use of the moving platform prevents the simulator sickness [8, 31]. There are opinions, that the use of moving platform does not prevent the simulator sickness [8]. In these tests, the pilots were examined on the moving platform simulator with a large field of view (FOV). Experienced pilots were divided into two groups. One had to perform a given task in a simulator with enabled moving platform, the second group performed the same task with moving platform disabled. The results showed no relationship between the configuration of the simulator and the quality of the job and symptoms SS.

Visualization and projection system

There are three types of visualization systems: external screens, window imitation screens (in cabin) and helmet mounted displays HMD). The HMD systems in the simulator were studied mainly with the aircraft pilots, where the technology is used [32]. Some studies indicate that the HMD systems provoke the SS more often than other methods of visualization [33]. The main reason for the SS while using HMD is inconsistency between the display and the head movement a [34] in presentation of visual information (images). Delays between images presentation and the platform motion also increase the SS appearance. The importance of the lack of synchronization of different signals coming from the simulator to the pilot is pointed out by Ruffner et al. [35]. The HMD devices may have different size of the field of view. According to Kim et al. [10] and Gower et al. [36] a range of 60 degrees is defined as the minimal for proper simulation process. In the literature [16] HMD devices with the field of view of 36, 48, 96 degrees were tested. Arthur [37] stated that restricting the FOV in a HMD display degrades human performance. Psotka and Lewis [38] treated that the range of 75÷180 degrees as FOV sufficient for a real simulation; but creation of a range wider than 75 degrees is associated with higher costs and may result in more frequent occurrence of the SS. But available field of view can be up to 200 degrees. According to Arthur [37] using the HMD display has some drawbacks, as a lack of realism and visual effects far from reality, which increases the susceptibility to the SS. Renkewitz and Alexander [13] concluded that the poor quality of the images is the main element in the occurrence of the SS. With the Simulator Sickness Questionnaire (SSQ) method proposed by Kennedy et al. [20] the SS level for different sizes of the FOV was analyzed [26]. The study showed that the range of the field of view has only slight effect on the SS occurrence. Increasing of the FOV increased the confusion of the subject, but decreased nausea symptoms. However the authors were aware, that these tests might not be statistically reliable (small number of patients) and the main conclusion from this study was that the range of the FOV is not the main reason for the SS.

In most HMD displays a range of the FOV is not greater than 60 degrees. The HMD screen of more than 60 degrees has been studied by Arthur [37]. For screen with the FOV smaller than 60 degrees, there was no sign of SS [39]. Authors based on their previous research claim that within the field of view of less than 50 degrees, the effectiveness of the simulator training decreases [36]. Also the results of the study of Cartmel [26] in which the quality of maneuvering on the simulator with the HMD with various FOV (48÷112 degrees) was measured, showed that the visibility less than 50 degrees decreased the quality of performing the task. Johnson [7] maked it clear that the scope of the field of view has a direct impact on the appearance of the SS. Increased requirements for the use of visual stimuli also increases the risk of the SS [40]. Thomas [41] showed that increasing field of view significantly affects the appearance of the SS. If the simulation is closer to the reality, the disease may be more likely to occur. Jarvis et al. [42] investigated how different configurations of the screen, motion and other conditions may affect the simulation of the appearance of the SS. External screens were used in the simulation in the literature [12], where it was used for the fixed platform simulator (car) without a cab with the screen of 135 degrees. The display is made up of three LCD monitors. Cartmell investigations [26] have been carried out on the simulator with 200 degree FOV, 800 x 600 resolution, frame rate – 60 Hz. Too wide field of view in the litarature [9] can also cause the SS (defined as VRS). This is confirmed by publications [11, 13] which state that in case of narrower FOV the risk of the SS is smaller.

Image Quality

An image flicker effect is usually avoided during simulator design. But sometimes it appears due to low refresh rate, which should be adjusted to the expected image brightness and simulator FOV. For higher brightness and larger FOV the refresh rate should also be increased. An image flicker is distracting for the operators, when performing complicated tasks and contributes to the „eye fatigue" feeling [11]. It is also mentioned as a major factor contributing to occurrence of the SS [9, 11, 27]. Mourtant and Thattacherry [18] used the HMD display with 60 degrees field of view, a resolution of 640 x 480 and the refresh time 20 frames per second, the study showed that the level of nausea has dropped down comparing to other studies. The author states that the improvements in HMD displays may decrease the SS symptoms. In study of Kim et al. [10] refresh time is 60 frames/second, and the resolution was 2 x 180 000 pixels. The sensitivity to image flicker varies substantially among the people. Mullen et al. [12] found that the type of image texture and the type of simulated environment does not affect the SS appearance. Arthur [37] found that using HMD in simulations results in a lack of realism and weaker visuals far from reality, which greatly increases the possibility of occurrence of the disease simulators.

Synchronization

The most often provided explanation for the SS is that various stimuli acting on the simulator operator are not well synchronized. For the fixed based simulators poor synchronization may be caused by delays associated with sound generation and displaying the image [6, 37]. But according to later publications [6, 43] this lack of synchronization does not influence on the SS appearance. The main factor is the synchronization of simulator platform motion with displayed images. The lack of synchronization of the system and displaying also is studied by McCauley [8]. Author states that the asynchronies must be limited to less than 150 or 200 ms. According to Renkewitz and Alexander [13], the delay between motion and image must be less than 300 ms. However, in HMD simulations carried out by Kim et al. [10] the required delays were smaller, in the range 125÷200 ms. Johnson [25] found that the simulator sickness is often associated with the conflict between visual information and that received by vestibular system. In other words, if the screen shows a motion that is not transmitted to operator (fixed base platform), or if the motion is not well synchronized or improperly invoked due to the visual effects.

Parameters of Sound

Audio performance impact on the simulator disease plays a secondary role [44].

Fixed based and moving platform simulators

Thomas [41] concluded that the lack of a moving platform can increase the risk of occurrence of the simulator sickness. Similarly Gower [36] assumed that if a fixed base simulator is properly designed, the lack of movement produces stronger impact on the operator's delusions. Mullen et al. [12] found that the occurrence of the SS was higher in the fixed based car simulator equipped in dashboard and steering wheel than in the fully equipped simulator. This paper shows that poor equipment of the simulator intensifies the risk of appearance of the SS. The research conducted by Draper [24] showed that in the fixed platform the AH – 64 A SS occurred in 68% of cases. The degree of subject involvement into the task affects the appearance of the SS. During the survey of the aircraft crew it was reported that the SS symptoms are weaker in co-pilots and other crew members than in the pilots [11]. Hulme et al. [11] stated that the delays in the simulator do not affect the SS. However, the authors point out that the type of control joystick or steering wheel does not affect the test object as much as the movements of the head in the case of the HMD display. In later publications [45, 46] it is found that the common effect of the outbreak of simulators is the inability to provide sufficient detail accelerations that act on the driver of the car. This is due to the fact that even moving platforms are not able to provide any acceleration as it happens in reality. Therefore, there it is a discrepancy between the visual and physical effects.

4. Conclusion

The literature review presented in the paper shows that the simulator sickness is an important and actual research subject. It is a very complex phenomenon which is the subject of intensive research in various places. Despite the fact, that the phenomena influencing the susceptibility to the SS are being investigated for a long time, it is difficult to formulate the conclusive results. The paper is the first attempt to identify the main technical parameters, before formulating the further research plans or recommendations for the design.

References

[1] Rabihah I.: Simulator sickness: A threat to simulator training. MIROS, SCI-COSH 2011.

[2] Kennedy R.S., Jennifer E.: Fowlkes simulator sickness is polygenic and olysymptomatic: Implications for research essex corporation. Int. J. Aviation Psychology, 2 (1992), 23-38.

[3] Lozia Z.: Symulatory jazdy samochodem. Wydaw. Komunikacji i Łączności, Warszawa 2008.

[4] Szczepański C.: Antropocentryczne systemy sterowania ruchem symulatorów. Prace Naukowe Instytutu Technicznego Wojsk Lotniczych, z. 19, Warszawa 2005.

[5] Greenyer F.: A history of simulation: Part II. Early days. MS&T Magazine, 5/2008.

[6] Lawrence F., Kennedy R.S., Kellogg R.S.: Simulator sickness: A reaction to a transformed perceptual world: I. Scope of the problem. Report AD – A192 438, 1983.

[7] Johnson D.M.: Simulator sickness research summary. U.S. Army Research Institute for the Behavioral and Social Science, Alabama, USA 2005.

[8] McCauley M.E.: Do army helicopter training simulators needs motion base? Technical Report, USA Research Institute for the Behavioral and Social Sciences, February 2006.

[9] Kolasinski E.M.: Simulator sickness in virtual environments. Simulator system research unit. Technical Report 1027, May 1995.

[10] Young Youn Kim, Hyun Ju Kim, Eun Nam Kim, Hee Dong Ko, Hyun Taek Kim: Characteristic changes in the physiological components of cybersickness. Department of Psychology, Korea University, Imaging Media Research Center, Korea Institute of Science and Technology, Seoul, Korea. Psychophysiology, 42 (2005), 616-625, Blackwell Publishing Inc., USA.

[11] Hulme K.F., Guzy L.T., Kennedy R.S.: Holistic design approach to analyze simulator sickness in motion-based environments. Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC) 2011.

[12] Mullen N.W., Weaver B., Riendeau J.A., Morrison L.E., Be'dard M.: Driving performance and susceptibility to simulator sickness: Are they related? American J. Occupation, April 2009.

[13] Renkewitz H., Alexander T.: Perceptual issues of augmented and virtual environments. Research Institute for Communication Information Processing, and Ergonomics (FKIE), Wachtberg, Germany 2007.

[14] Rizzo M.: Demographic and driving performance factor in simulator adaptation syndrome. 2nd Int. Driving Symposium on Human Factors in Driver Assessment. Training and Vehicle Design, 2003.

[15] de Wit G.: Acquired sensivity to seasickness after an inflezna infection. Pract. Oto-Rhino-Laryngologica, 19 (1957), 579-58.

[16] Crowley J.S.: Simulator sickness: A problem for army aviation. Aviation, Space, and Environmental Medicine, 58, 1987, 355-357.

[17] Wright R.: Helicopter simulator sickness: A state of the art, review of its incidence, causes, and treatment. Technical Report, USA Research Institute for the Behavioral and Social Sciences, November 1993.

[18] Mourtant R.R., Thattacherry T.R.: Simulator sickness in a virtual environments driving simulator. Proc. of the IEA 2000/HFES 2000 Congress.

[19] Bimal L. Aponso, Beard S.D., Schroeder J.A.: The NASA ames vertical motion simulator. A facility engineered for realism. Royal Aeronautical Society Spring 2009 Flight Simulation Conference, London, UK, 3-4 June 2009.

[20] Kennedy R.S., Lane N.E., Berbaum K.S., Lilienthal M.G.: Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. Int. J. Aviation Psychology, 3 (1993), 203-220.

[21] Handbook of Virtual Environments. Design, Implementation, and Applications, Kay M. (ed.). Stanney University of Central Florida Lawrence Erlbaum Associates Publishers 2002 Mahwah, New Jersey London.

[22] Barret G.V., Thornton C.L.: Relationship between perceptual style and simulator sickness. Goodyear Aerospace Corporation, Acron, Ohio Journal of Applied Psychology, 1968, 52, 4, 304-308.

[23] New, Improved, Comprehensive, and Automated Driver's License Test and Vision Screening System. Final Report 559(1). SRA Consulting Corporation, May 2005.

[24] Draper M.H.: The adaptive effects of virtual interfaces: Vestibulo – ocular reflex and simulator sickness, PhD dissertation. University of Washington, USA 1998.

[25] Johnson D.M.: Simulators sickness during emergency procedures training in a helicopter simulator: Age, flight experience, and amount learned. Technical Report, USA Research Institute for the Behavioral and Social Sciences, September 2007.

[26] Cartmell D.H.: Evaluation of flight simulator pilot cueing system performance. AIAA Modeling and Simulation Technologies Conference and Exhibit, Monterey, California 5-8 August 2002.

[27] McCauley M., Kennedy L.F.R., Kellogg R.: Simulator sickness: A special case of the transformed perceptual world 1. Scope of the problem. Proc. of 2nd Symposium of Aviation Psychology, Ohio State University, Columbus OH, 25-28 April 1983.

[28] Johnson W.W., Kaiser M.K.: Perspective imaginary in synthetic scenes used to control and guide aircraft turing landing and taxi: Some issues and concerns. NASA/TM – 2003 – 212808, Nasa Ames Research.

[29] http://www.ciop.pl/22396.html.

[30] Bürki-Cohen J., Sparko A.L., Bellman M.: Flight simulator motion literature pertinent to airline-pilot recurrent training and evaluation. AIAA Modeling and Simulation Technologies Conference, Portland, Oregon 08-11 August 2011.

[31] Bonnet C.T., Faugloire E., Riley M.A., Bardy B.G., Stoffregen T.A.: Motion sickness preceded by unstable displacements of the center of pressure. Human Movement Science, 25 (2006), 800-820.

[32] Johnson D.M.: Introduction to and review of simulator sickness research. U.S. Army Research Institute for the Behavioral and Social Sciences, Research Report 1832, April 2005.

[33] Bailey R.E., Arthur J.J. III, Lance Prinzel III, Kramer L.J.: Evaluation of head-worn display concepts for commercial aircraft taxi operations. NASA Langley Research Center, Hampton, VA 2007.

[34] Zaychik K.B., Cardullo F.M.: Simulator sickness: the problem remains. AIAA Modeling and Simulation Technologies Conference and Exhibit, Austin, Texas 2003.

[35] Ruffner J.W., Piccione D., Woodward K.: Development of a night driving training aid concept. Final Report, DCS-SBIR-97-3106, 1997.

[36] Gower D.W. Jr., Fowlkes J., Baltzley D.R.: Simulator sickness in the CH-47 (Chinook) flight simulator (USAARL Report No. 89-28). Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory, 1989.

[37] Arthur K.W.: Effects of field of view on performance with head. Mounted displays, PhD dissertation. University of North Carolina, Chapel Hill 2000.

[38] Psotka J., Lewis S.A.: Effects of field of view on judgments of self – location. USARI Technical Report, draft.

[39] Psotka J.: Immersive training systems: Virtual reality and education and training. Instructional Science, 23, 1995, 405-431.

[40] Toet A., van der Hoeven M., Kahrimanović M., Delleman N.J.: Effects of field of view on human locomotion. Proc. of SPIE 6955 69550H-1.

[41] Thomas T.G.: From virtual to visual and back? AIAA Modeling and Simulation Technologies Conference ad Exhibit, Providence, Rhode Island 16-19 August 2004.

[42] Jarvis P., Spira D., Lalonde B.: Flight simulator modeling and validation approaches and pilot-in-the-loop fidelity. AIAA Modeling and Simulation Technologies Conference and Exhibit, Honolulu, Hawaii 18-21 August 2008.

[43] Pausch R., Crea T.: A literature survey for virtual environments: Military flight simulator visual systems and simulator sickness. Computer Science Report No. TR-92-25, August 1992.

[44] Hulme K.F., Guzy L.T., Kennedy R.S.: Holistic design approach to analyze simulator sickness in motion. Environments, Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC) 2011.

[45] Virtual Environments for Intuitive Human – System Interaction. Final Report of Task Group TR-HFM-121, Human Factors Considerations in the Design, Use, and Evaluation of AMVE-Technology.

[46] Kappe B.: Driving simulators for driver training: state of the art. TNO Defense, Security and Safety.

Acknowledgment

The research was co-financed by National Centre for Research and Development in years 2011-2013 under a scientific-research project „Driving privileged vehicles simulator during typical and extreme actions" No. O ROB 0011 01/ID/11/1.

CZYNNIKI TECHNICZNE WPŁYWAJĄCE NA CHOROBĘ SYMULATOROWĄ

Streszczenie

Symulatory mają zastosowanie nie tylko w lotnictwie, ale również w obrębie innych obszarów techniki, takich jak robotyka, techniki okrętowe itp. Szkolenia komputerowe są oferowane z prawie każdym produktem technologicznym znajdującym się na rynku. W pracy jest rozważane zastosowanie symulatorów do szkolenia pilotów platform mobilnych, takich jak samoloty, samochody, statki morskie itp. Choroba symulatorowa jest wynikiem trudności we właściwym symulowaniu ruchu i środowiska przez symulator. Podobne objawy nazywane chorobą wirtualnej rzeczywistości można zaobserwować w społeczności graczy komputerowych. Główną przyczyną występowania choroby symulatorowej jest to, że bodźce zewnętrzne (ruch i/lub obraz) wysyłają błędne informacje do ludzkiego mózgu. Celem badań było znalezienie związku pomiędzy architekturą i parametrami technicznymi różnych typów symulatorów a wystąpieniem choroby symulatorowej. Badania skupiono na architekturze i parametrach technicznych symulatora, które wpływają niekorzystnie na reakcje operatora podczas treningu, takie jak ruchome platformy, rozmiar ekranu, symulowane modele, jakość grafiki itd. Publikacja przedstawia rozbudowany przegląd literatury i jest wstępem do dalszych badań eksperymentalnych.

Słowa kluczowe: symulator, choroba symulatorowa, platformy mobilne, architektura symulatora

DOI:10.7862/rm.2013.41

Otrzymano/received: 15.09.2013 r.
Zaakceptowano/accepted: 22.11.2013 r.