Multi variable strategy reduces symptoms of simulator sickness

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Introduction

Interactive 3D environments are valuable tools for the assessment and adjustment of human behavior. Driving a virtual car is cheaper, safer and more sustainable than driving on road [1]. However there is one major problem related to the use of 3D environments for assessment and training. A significant part of simulator operators suffer from symptoms resembling motion sickness, or more specifically simulator sickness. A common indicator for experienced operators is 30%, however this varies greatly. Symptoms can persist for long periods of time. Some drivers are not able to drive their vehicle after a simulator session [1]. This discomfort has a negative influence on the acceptance of 3D environments for assessment and adjustment of human behavior. Research by Johnson [2], Kingdon et al. [3] and Stanney et al. [4] indicates that in 1 to 1.5% of the operators that are exposed to a simulated environment, vomiting is induced

To prevent unnecessary delay of 3D environment development as a tool for the assessment and adjustment of human behavior, users and producers of interactive 3D environments will have to find effective methodology to reduce the severity of symptoms caused by simulator sickness. In addition new methods are needed to decrease the intensity of simulator sickness.

Variables

Differences in susceptibility for simulator sickness are not only observed between experienced and novice operators but also amongst experienced operators. Experienced car drivers react differently to specific configurations of driving simulators. They experience less symptoms of simulator sickness in a driving simulator with a wide view display, made with 5 LCD computer monitors (Figure 1), compared to a driving simulator with a wide view display made with 3 projectors (Figure 2). The main difference between these two simulators is the display surface. The total LCD monitor surface is $0.57m^2$ and the projector surface is $2.03m^2$. The display surface seems to be a variable that influences simulator sickness. A decrease in display surface results in lower susceptibility to simulator sickness. It is likely that there are more variables that have an influence on simulator sickness. Perhaps tuning those variables will reduce the severity of the symptoms and perhaps even solve the problem of simulator sickness.

Figure 1: Simulator with 5 LCD screens

Figure 2: Simulator with 3 beamers

In the literature many variables related to simulator sickness are discussed. A significant part of the available literature was produced by the US Army. The US Army did most of its research on simulator sickness in flight simulators and tank simulators [2][5] The variables can be classified as personal related, scenario related and

technical related variables [6][7]. Table 1 gives an overview of variables related to simulator sickness. Variables with a strong influence on simulator sickness are: experience, history, session duration and optic flow.

Personal related variables		
Experience and age	Symptoms of simulator sickness can increase with experience. Becoming experienced is normally a process of many years. Therefore age and experience are correlated. Novice drivers experience less symptoms of driving simulator sickness than older drivers.	Miller et al. (1960) Reason et al. (1975) McGuiness et al. (1981) Crowly (1987) Hein (1993) Naoke et al. (2012)
Gender	Females seem more susceptible for simulator sickness than males. Males also need less time to adjust to a virtual environment like a driving simulator.	Hein (1993) Torant et al. (2000) Jeager et al. (2001)
History	A history of motion sickness, like car sickness or simulator sickness, correlates with the susceptibility for simulator sickness.	Gower et al. (1988) Lampton et al. (1994) Regan et al. (1994) Delahaye et al. (2004) Brooks et. al. (2010)
Scenario related variables		
Exposure	After a period of 5-10 minutes the symptoms of simulator sickness can grow fast.	Sparto et al. (1992) Jeager et al. (2001) Stanney et al. (2003) Bertin et al. (2007)
Velocity and acceleration	Navigation with high speed stimulates the symptoms of simulator sickness. Change of speed or direction stimulates the symptoms of simulator sickness.	Reason et al. (1975) Torant et al. (2000) So et al. (2001)
Scene complexity	Details needed for a realistic reproduction of a 3D environment stimulate the symptoms of simulator sickness.	Van Cott (1990) Jeager et al. (2001) Kingdon et al. (2001) So et al. (2001)
Navigation	A restriction on free navigation stimulates the	Lackner (1992)

	symptoms of simulator sickness.	Stanney et al. (1998) Jeager et al. (2001) Sharples (2008)
Technical related variables		
Motion	Motion systems with strong motion cues can increase the symptoms of simulator sickness. In particular when the motion cues and visual cues are not synchronized.	Kingdon et al. (2001) Johnson (2007) Plouzeau et al. (2013)
View angle and display surface	A large vertical and horizontal viewing angle stimulates the symptoms of simulator sickness. A large display surface stimulates the symptoms of simulator sickness.	Kennedy et al. (1989) Van Cott (1990) Sharples et al. (2008)

Table 1: Simulator sickness variables.

Sensory conflict

Several theories attempt to explain the mechanism of action that underlies simulator sickness. The neural mismatch theory of Reason [8] has been generally accepted. This theory relates simulator sickness to a sensory conflict during information processing which causes a mismatch signal in the brain. Divergent vestibular information plays a crucial role. People with a poorly functioning vestibular system do not suffer from symptoms of motion sickness. This mismatch signal stimulates the vomit center in the brain. As a reaction to this theory new methods that focus on increasing fidelity (realism) to solve the sensory conflict and decrease simulator sickness have been developed. Until now these methods haven't successfully dealt with the problem of motion sickness. I suggest a new approach. The mismatch signal seems to act like the neurotransmitter 'Substance P'. Substance P plays an important role in activation of the vomiting area in the brain. In the event of a mismatch signal causing symptoms of simulator sickness, weakening the signal can be a good strategy to decrease the severity of these symptoms. This particular method should decrease or even stop the release of the involved neural transmitter. The variables with the most influence on neurotransmitter release and activation of the vomiting centers of the brain should be identified and manipulated.

There are big differences in susceptibility of simulator sickness between operators of interactive 3D environments. Many variables are involved. The manipulation of specific variables has so far not led to an effective methodology for reducing simulator sickness. Pre-selection of operators based on motion sickness history seems a good method but is not effective enough and in many situations it is not desirable to exclude operators from a simulator session. A test run improves the effectiveness of preselecting. Preselecting can also help to determine which precautions should be taken to avoid simulator sickness.

Multi variable strategy

I propose a multi variable strategy for the alleviation of simulator sickness symptoms. Manipulation of multiple variables might be a good solution to increase the effectiveness of simulator sickness prevention. Variables with a high impact on simulator sickness are session duration and optic flow. For example session durations should not exceed 5 minutes. This strategy will keep the concentration of neurotransmitters below the threshold of activation of the vomiting centers in the brain.

The optic flow variable is influenced by variables like velocity, acceleration, angular acceleration and screen size. The screen size can be changed easily for driving simulators without effects for the scenario. Adjustments made to the vertical field of view (FOV) decreasing the image surface enormously. The display of graphics with

wide screen monitors instead of computer projectors or adding black areas can decrease the image size up to 80% (Figure 3).

Figure 3: the vertical FOV is minimized with wide screens monitors and black areas

This strategy seems to have a significant effect on most operators of driving simulators. Results of two commercial driving simulator tests with 111 and 826 participants respectively showed that this multi variable strategy decreased the percentage of operator who experienced motion sickness from 29% to less than 0.2%. The first is the base line test. Operators drove a standardized driving style test. 29% operators reported severe symptoms of motion sickness like drowsiness and nausea. This is a common rate for experienced drivers. The standardized driving style test was conducted using a driving simulator with beamer projection without using the multi variables method (Figure 2). The same driving style test was used in the second project. The multi variables strategy was used to lower the symptoms of motion sickness. The virtual FOV was decreased using the driving simulator with the LCD monitors (Figure 1) in combination with the black areas (Figure 3). In case the operator experienced motion sickness the black areas where activated. The session duration was maximized to 3 minutes followed by a break instead of 15 minutes continuous simulator use. 2% of the operators (15 persons) reported symptoms of motion sickness. After reduction of the vertical FOV with the black areas, only 0.2% (2 persons) reported still having related symptoms. One operator had to stop before the driving style ended. None of the operators displayed actual vomiting. The dropout rate of 0.1% is very low and a big improvement compared to single variable strategies like the motion sickness assessment questionnaire (MSAQ) of Brooks [9]. Books et al noted a 10% dropout.

Surveys held under driving simulator participants of the first and second test indicated not only a lower percentage of dropouts, but also an improvement of the user acceptance of interactive 3D environments as an alternative for a real environment. 24% compared to 16% in the first test.

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