THE EFFECT OF DRIVING ENVIRONMENTS ON SIMULATOR SICKNESS

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In order to be an effective tool for driver evaluation and education, driving simulators need to be better designed to reduce simulator sickness. This study investigated driving in four environments (country, suburban, city, and curves) using a simulator. When driving on straight roads (city and suburban environments) subjects reported less simulator sickness then driving in the city environment (which included left and right turns) and on curves. A mini-SSQ was used to measure the accumulation of simulator sickness over trials. From trial 1 to trial 5, reported simulator sickness increased linearly. From trial 5 through 8, the rate of increase in simulator sickness decreased. We suggest that the rapid and distorted optic flow experienced while executing turns and driving on curves in driving simulators makes a substantial contribution to simulator sickness.

INTRODUCTION

In order for driving simulators to be effective and generally adopted for driver training and licensing, they need to accommodate most of the population. One problem is that a considerable number of people experience simulator sickness (occulomotor discomfort, disorientation, nausea, etc.) while using a driver simulator. Research studies utilizing virtual environments have also reported considerable cyber-sickness and dropouts, i.e. subjects who do not complete the session(s) due to simulator sickness (Stanney, et. al, 2002).

In driving simulators the degree of simulator sickness maybe related to particular driving environments and their associated scenarios. For example, Park, et. al., (2006) found more sickness associated with executing left turns. Chrysler & William (2005) lessen the sickness associated with driving on curves by using large radii and having few roadside objects in peripheral view.

The degree of simulator sickness with respect to gender is unclear. Several investigators (Mourant and Thattacherry, 2000; Allen, et. al., 2003) reported that females have more sickness than males. Yet other studies (Stanney, 2002; Kolasinski and Gibson, 1998) reported no differences in simulator sickness due to gender.

Another factor that may effect simulator sickness when using a driving simulator is the amount of optic flow that a driver experiences. Mourant, et. al. (2006) studied optic flow in a driving simulator and found that is could be used to produce vehicle velocities of 60 mph but not 30 mph. The greater optic flow experienced by drivers when making turns and driving on curves in a simulator may induce simulator sickness.

In the present study we investigated the effects of gender, type of driving environment, and type of road surface on the degree of simulator sickness.

It is desirable to measure a subject's degree of simulator sickness as the experiment proceeds. Traditionally, the Simulator Sickness Questionnaire (SSQ) (Kennedy, et. al, 1993) is used to measure simulator sickness. However, administering the total SSQ periodically would introduce significance delays and possible allow for sickness factors to go away with time. We created a "mini-SSQ" which may be an effective method to estimate a subject's degree of simulator sickness during the course of an experiment.

METHOD

Participants

Participants were faculty and staff members at Northeastern University. A total of 16 subjects, 8 males and 8 females were recruited. All had a valid driver's license and driven at least 5000 miles in the last year. Ages of the participants ranged between 50 and 65. All had corrected vision of 20/30 or better.

Apparatus

The fixed-base driving simulator consisted of a real vehicle buck, a large curved screen located 12 feet in front of the driver's eyes, an LCD projector, and a computer. The image resolution was 1024 by 768 with a 45 degree horizontal field of view. The frame rate was a constant 60 frames per second. Subjects used a force feedback steering wheel, and the vehicle's accelerator and brake pedals.

Procedure

Subjects filled out the SSQ Questionnaire and were given a familiarization trial in the driving simulator before actual data collection runs. They were then randomly assigned one of 16 sequences of 8 trials. Each of the sequences consisted of 4 trials of roads with textured (or shaded) surfaces followed by trials of roads with shaded (or textured) surfaces. Textured surfaces are generated using images while shaded surfaced are simply colored pixels. Each four trials consisted of driving in a counterbalanced sequence of 4 environments. The four driving environments were country, suburban, city, and curves as shown in Figures 1 through 4.

Subjects were instructed to drive normally, and obey all traffic signals and signs.

At the end of each of the eight trials, participants were asked the following questions shown in Table 1.

Table 1
Mini-SSQ

Do you feel general discomfort?
Do you have a headache?
Do you have blurred vision?
Are you sweating?
Do you feel faint?
Do you have stomach discomfort?

The possible responses were, None, Slight, Moderate, or Severe which correspond to the SSQ.
We call this a "Mini SSQ".

At the completion of all 8 trials, subjects again filled out the SSQ. Trials last between 5 and 7 minutes and the between trial time was minimal (10 to 20 seconds). Each subject spent about 48 minutes driving the simulator.

Experimental Design

A 4x2x2 experimental design was used. The first factor, Driving Environment had four levels, country, suburban, city, and curves. The second factor was Type of Road Surface (shaded or textured) and the third factor was Gender (female or male).

Figure 1. Country driving environment.

Figure 2. Suburban driving environment.

Figure 3. City driving environment.

Figure 4. Curves environments.

Figure 6 presents the amount of increase in SSQ scores before and after testing by individual subjects. Arbitrarily choosing an increase of 5 or lower in the SSQ score, results in 5 of the 16 subjects having only moderate increases in reported SSQ scores.

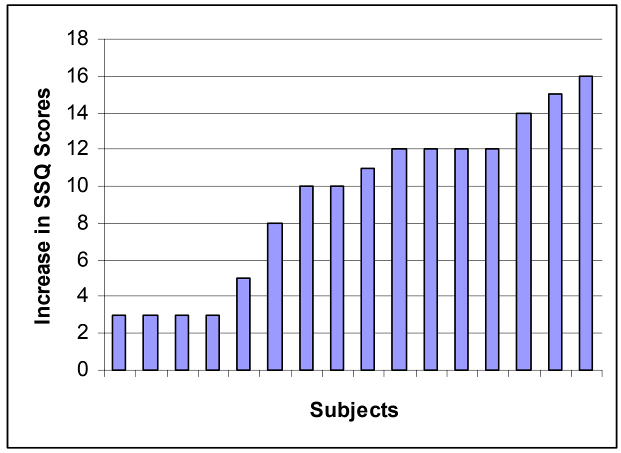

Figure 6. Increase in SSQ scores by individual subjects.

RESULTS

SSQ Scores

Figure 5 shows the mean SSQ scores before data collection (2.1) and after data collection (11.4).

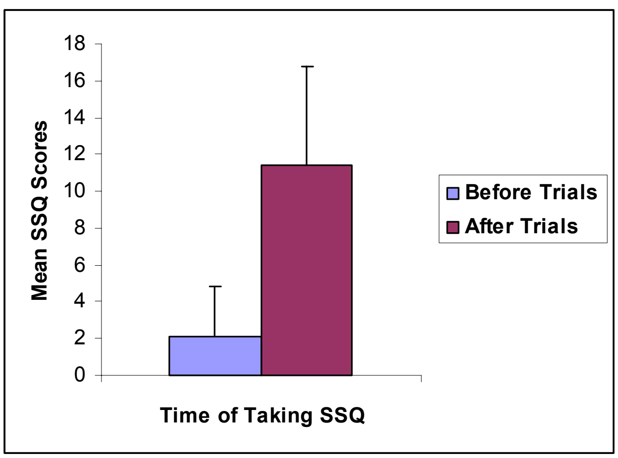

Figure 5. SSQ scores before and after data collection.

These means were significantly different (Wilcoxon matched pairs test, $p<.01$).

The mean SSQ scores for females (2.1) and males (1.8) before data collection were not statistically different (Mann-Whitney U Test, $p = .11$). Similarly, mean SSQ scores for females (10.8) and males (12.0) after the 8 trials were not statistically different (Mann-Whitney U Test, $p=.56$).

Mini SSQ Scores

In Figure 7 are the mean mini-SSQ scores while driving on straight roads (country and surburban) versus driving on roads with turns (city) and curves.

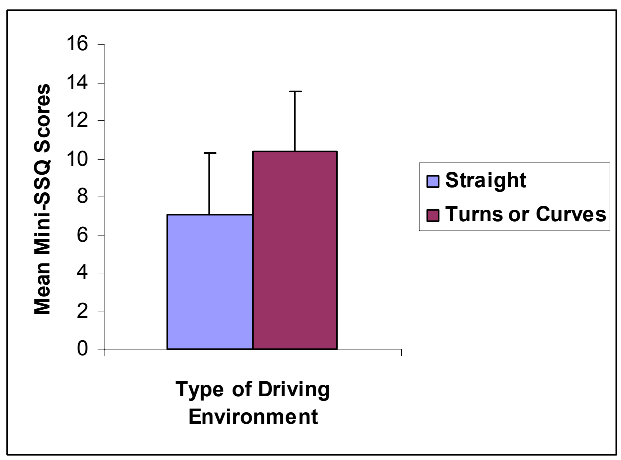

Figure 7. Mini SSQ score on straight roads versus roads with

turns or curves.

These means (7.1 and 10.4) were significantly different (Wilcoxon matched pairs test, $p<.01$).

Figure 8 gives the mean of the mini-SSQ scores while driving on the shaded road surface (8.4) and the textured road surface (9.2). These differences were not statistically different.

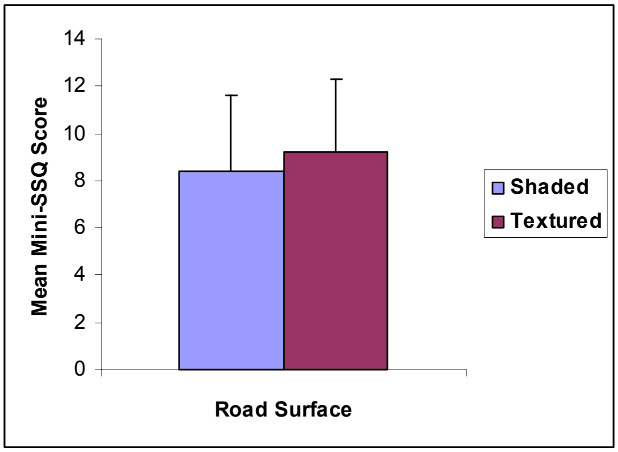

Figure 8. Mini-SSQ scores for shaded and textured roads.

The mean mini-SSQ scores revealed in Figure 9 showed that they increased as a function of trials. The linear increase between trial 1 and trial 4 is apparent.

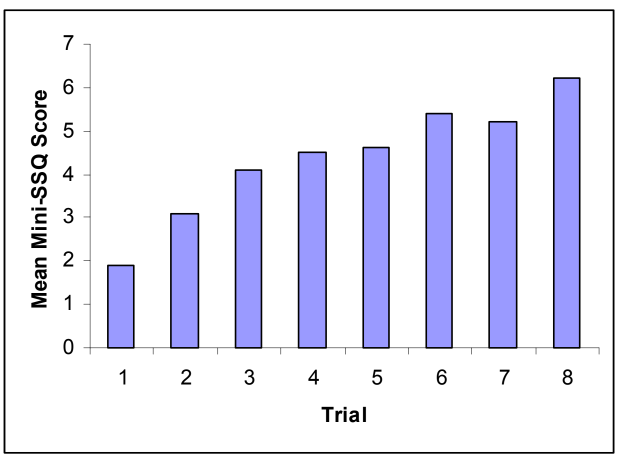

Figure 9. Mini-SSQ scores by trial order.

Subject Comments

1. "I think the narrow field of view in the simulator (as compared to real-world driving) contributed to my feeling sick." (The simulator had a 45 degree FOV.

2. "Stopping real made me feel sick. Turning was also sickening."

3. "Started to get upset stomach - made me perspire."

DISSCUSION

SSQ Scores

Although there was a significant increase in reported SSQ scores after experiencing the eight driving trials, no subject dropped out of this study. Other investigators (Park, et. al (2006) have reported that their subjects could not continue with the experiment due to simulator sickness. The number of drop outs may be effected by the amount of time in the simulator as well as the number of required left and right turns.

Type of Environment

When driving on straight roads in the country and suburban environments, subjects reported significantly lower mini-SSQ scores then when driving in the city environment (which required right and left turns) and in the curves environment. Other investigators have also reported that making turns in a driving simulator increased the degree of simulator sickness (Park, et. al., 2006; Edwards, et. al., 2003). There may be at least two problems associated with making 90 degree turns in driving simulators: 1) the optic flow rate perceived by the driver is very fast, and 2) the texture(s) associated with the optic flow appear distorted. At the present time 3D graphics technology does not have a solution to this problem.

Road Surface

We expected environments with shaded road surfaces to result in less simulator sickness than those with textured road surfaces. However, there was no statistically significant difference in reported simulator sickness between these two conditions. When driving in a simulator the optic flow of a textured road is fastest immediately in front of you and rapidly decreases as a function of distance in front of your vehicle. Most drivers look a considerable distance in front of their vehicle, and thus may have ignored the fast optic flow of the textured road surface directly in front of their vehicle.

Other Findings

We found that subjects reported increased mini-SSQ scores as a function of time in the simulator. Others have found similar effects (Kennedy, Stanney, & Dunlap, 2000; Stanney & Salvendy, 1998). Proving rest breaks between trials may help reduce the accumulation of simulator sickness.

CONCLUSIONS

Simulator sickness remains a serious problem for driving simulators. When driving on curves or making left/right turns, the amount of reported simulator sickness increases significantly. While driving on curves and making turns, the optic flow from textures is distorted and very rapid. Techniques need to be developed to correct this.

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