Simulator Sickness Management: Enhanced Familiarisation and Screening Processes

Reed, N.[1], Diels, C. [2], and Parkes, A. M.[3]

[1, 2, 3]TRL Limited, Crowthorne House, Wokingham, Berkshire, RG40 3GA, UK

[1]nreed@trl.co.uk, [2]cdiels@trl.co.uk, [3]aparkes@trl.co.uk

Keywords: driving, simulator, training, sickness, screening, SSQ.

Abstract. In a recent simulator training programme (SCOTSIM) more than 700 professional commercial vehicle drivers were trained on two full mission truck simulators with the objective to improve drivers' fuel efficiency and encourage safe driving habits. The programme led to significant performance improvements, though training efficiency was compromised due to high simulator sickness incidence. The study presented here investigated how simulator sickness might be reduced by developing an advanced screening process of potential trainees and improving familiarisation with the simulator before starting formal training. The screening criteria for participation were based on factors that in the original training programme were found to be correlated to SSQ or drop-out, and included motion sickness history and attitude to simulator use. The enhanced familiarisation process consisted of a longer period in which trainees were able to ask any questions they had regarding training and/or the simulators themselves and more time with which to familiarise themselves with the control operation of the simulator. It was anticipated that this would reduce drivers' anxiety before participating in simulator training and lead to a reduction in simulator sickness. The study compared four groups of drivers: 1) control 2) screened drivers, 3) drivers who underwent the enhanced familiarisation process and, 4) drivers who were both screened and underwent the familiarisation process. Results indicated that both the additional processes caused a significant reduction in driver drop-out rate and reported SSQ levels. From a cost-effectiveness perspective, the screening criteria rather than the enhanced familiarisation procedures would benefit future research and training programmes most. The discussion focuses on the practical considerations of screening participants of future commercial simulation-based driver training initiatives.

Introduction

Simulation offers a unique training proposition in which many participants can experience a consistent educational package in complete safety and with detailed evaluation of their performance. Simulation is used widely in the aviation industry and with military land vehicles to train both novices and experienced operators. The benefits are well accepted (see e.g. Williams & Flexman, 1949; Orlansky, Dahlman, Hammon, Metzko, Taylor, & Youngblut, 1994; Moroney & Moroney, 1998) and for certain applications simulator training is a key and necessary component. Truck drivers need to be highly skilled, can be responsible for very valuable and at times dangerous loads, and although they need to operate in a complex and highly dynamic traffic environment, advanced simulator technology for training is not widespread.

Two full mission, high fidelity, motion-base truck simulators were commissioned for the Scottish road haulage industry to investigate how they might support driver training. One of the simulators was housed in a specialised trailer unit and was deployed around the Scottish mainland. The other simulator was based at a fixed location near Glasgow, Scotland. In the course of the project, over 700 qualified commercial vehicle drivers experienced a training programme on the simulators designed to improve fuel efficient and safe driving techniques. Throughout the programme, the incidence of simulator sickness was monitored. The frequency of participants dropping out of the training programme due to symptoms of simulator sickness was undesirably high.

For simulation training to become a significant aspect of the overall driver training prospectus, the incidence of simulator sickness must be minimised. Firstly, to ensure that participants have an enjoyable and useful experience but also to ensure that simulation training retains a good reputation among the target population. Sickness symptoms also promote the risk of negative training effects where participants may adopt unsafe behaviours to reduce sickness symptoms and it is these, rather than the intended skills for which the simulation training was devised, that transfer to real world driving.

This paper reports the levels of sickness observed in the training program and the steps taken to develop and validate measures designed to ameliorate this problem. This consisted of an advanced screening and familiarisation process.

Method SCOTSIM Phase I

Participants. All participants in the SCOTSIM training programme were working for companies based in Scotland and were professional commercial vehicle drivers. Participation guidelines were given in the letter sent to driver managers. These suggested that drivers should be under 50, in good health, have good eyesight (including corrected to normal), not prone to motion sickness, and not sensitive to flickering lights[1].

Equipment. Drivers experienced training on one of two simulators, both provided by Thales. The TRUST 3000 (T3000) was housed in an expandable trailer unit and was therefore mobile, providing training at various locations around the Scottish mainland. The TRUST 5000 (T5000) was installed at a fixed facility in Bellshill, near Glasgow, Scotland. Figure 1 shows a picture of the TRUST 5000 system.

Figure 1. The TRUST 5000 truck simulator.

Both simulators use a real truck cabin mounted on a Stewart platform with six degrees of freedom motion. The main difference between the simulators was that the T3000 used fixed screens surrounding the cabin whereas the T5000 used a larger motion system with 'flying' screens attached to the motion platform (see figure 1) giving a greater range of motion. The visual system uses three video channels to generate a 180° horizontal forward field of view. Three further video channels provide the images for the rear view mirrors and the pavement mirror on LCD monitors. The images are displayed at a refresh rate of 60Hz, a resolution of 1280 × 1024 pixels per channel, and with up to 24 sub-pixels anti-aliasing. The audio system simulates engine noise, aerodynamic and friction noises, braking noises, and the vehicle noise of other road users.

[1] Analysis of questionnaires however revealed that these guidelines were largely ignored, presumably for operational reasons.

Exercises. Trainees were required to drive a fully loaded rigid lorry (UK vehicle category C: large goods vehicle above 3.5t). Before completing the training exercises, all drivers were required to complete a short (5 minute) familiarisation drive to enable them to become accustomed to the controls of the simulator vehicle and the feel of driving in the virtual environment. Four training exercises were created; an 'Industrial exercise' (approximately 5 minutes) where the trainee must reverse the vehicle into a loading bay taking care to avoid pedestrians; a 'Village' exercise (approximately 10 minutes) along rural roads with sweeping bends, some shallow gradients, and some single track roads; a 'Highway' exercise (approximately 7 minutes) involving dual carriageways (two lanes in each direction with central reserve; speed limit 80km/h (50mph) for trucks) and motorways (two lanes plus hard shoulder in each direction with central reserve; speed limit 96 km/h (60mph) for trucks); and a 'City' exercise (approximately 8 minutes) through a built up environment requiring the trainee to negotiate tight turns and busy junctions. The total distance driven across the four exercises was approximately 13.5 km (8.5 miles). After completing the four exercises, each participant was given feedback on their performance and training advice by the instructor. They were then required to complete the four exercises a second time to demonstrate the skills that they had been taught.

Questionnaires. Participants completed a range of questionnaires during their training session. Before driving the simulator, they completed a questionnaire that required them to give information about their background, their perceived driving abilities, their general health state, and their attitudes to technology. The level of simulator sickness was assessed using the Simulator Sickness Questionnaire (SSQ) as presented in Kennedy et al. (1993).

Trial schedule. Each participant spent a half day at the simulator facility engaged in the training process, managed at all times by a trained driver instructor. On arrival at the simulator facility, participants would receive a short briefing about the purposes of the study and were informed of their right to withdraw from the study at any time. Next, they completed the pre-drive questionnaires before driving the familiarisation exercise. They would then begin the training exercises. Participants completed exercises in the order Industrial; Village; Highway; City.

Results SCOTSIM Phase I

Figure 2 shows the SSQ total scores and SSQ subscores. The mean post-training SSQ total score for 598 drivers was 25.7 (SD = 33.2). In comparison with SSQ values in other flight or driving simulators, the observed level was relatively high and typical of HMD-based VR systems which tend to be more provocative (Kennedy & Stanney, 1997; Curry et al., 2002). The profile of SSQ symptoms cluster (N>D>O) also differed from that previously reported to be typical of simulator exposure, i.e., O>N>D (Stanney & Kennedy, 1997).

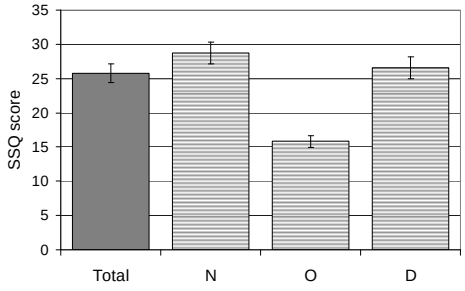

Figure 2. Mean (±SEM) SSQ total and SSQ nausea (N), Oculomotor (O) and Disorientation (D) subscores (n=598).

Table 1 shows the number and percentage of drivers that were unable to complete the simulator training programme due to symptoms of simulator sickness. It can be seen that the driver drop-out rate approached one driver in four. Clearly, the drop-out rate observed in the present study would be unsustainable for a commercial training programme.

Table 1. Driver drop-out rate in the SCOTSIM training programme.

	Completed	Drop-out	Total
N	478	156	634
%	75.4%	24.6%	100.0%

As expected, SSQ score and drop-out status were strongly correlated ($N = 598$; $r = 0.597$; $p < 0.001$). Drivers' age showed a significant positive correlation with drop-out ($N = 633$; $r = 0.12$; $p = 0.003$). Four characteristics in the driver health questionnaire showed positive correlations with drop-out. The strongest correlation was where the participant reported suffering from motion sickness ($N = 633$; $r = 0.32$; $p < 0.001$). There were also weak but significant correlations between driver drop-out and reported suffering from (respectively) migraine ($N = 633$; $r = 0.079$; $p = 0.047$), claustrophobia ($N = 634$; $r = 0.13$; $p = 0.001$), and brain damage ($N = 634$; $r = 0.080$; $p = 0.045$).

Drivers also completed a questionnaire that asked them to rate their agreement with each of 18 statements relating to the use of technology. Agreement was measured on six point scale (1-6) where a score of 1 indicated that the driver completely disagreed with the statement and a score of 6 indicated that the driver completely agreed with the statement. Correlations were calculated between participants' agreement with these statements and SSQ scores and with driver drop-out. Eight of the statements showed weak but significant correlations ($N = 578$-622; $|r| \approx 0.1$; $p < 0.05$ in each case). Agreement with statements that were generally positive towards technology showed negative correlation coefficients with SSQ/drop-out and agreement with statements that were generally negative towards technology showed positive correlation coefficients.

Development of Driver Screening Procedure and Retrospective validation procedure

The items that showed significant correlations with either SSQ or drop-out were used to generate screening criteria that could be applied to drivers wishing to participate in a simulator training programme. Firstly, drivers should be under the age of 60 years; secondly, they should not suffer from motion sickness, migraine headaches, claustrophobia, or have experienced any kind of brain damage; thirdly, drivers should not show a negative attitude towards technology based on their level of agreement with the eight statements that were sensitive to SSQ/drop-out scores – if a drivers' total agreement scores with the statements (measured on the 1-6 scale) was below a threshold score of 20, the driver would be excluded from the analysis.

The number of drivers that would be affected by such criteria was evaluated by applying them retrospectively to the 641 drivers participating in the training programme. For drivers' age, the threshold was set at 60 years, resulting in the exclusion of 16 drivers from the original dataset. For the health criteria, if a driver reported any of the conditions that were correlated with drop-out, then they were excluded. This meant that 92 drivers who reported suffering from motion sickness were excluded; 27 participants who reported suffering from migraine were excluded; 6 participants who reported suffering from claustrophobia were excluded; and 8 participants that reported suffering from brain damage were excluded. Finally, scores from the eight questions that showed significant correlations with SSQ score and/or driver drop-out were aggregated such that if a drivers' total agreement scores with the statements (measured on the 1-6 scale) was below a threshold score of 20, the driver would be excluded from the analysis . This resulted in the exclusion of 33 participants in the retrospective analysis.

Sufficient data were available to apply the exclusion criteria to 625 of the 641 participants in the training programme and resulted in the (retrospective) elimination of 149 participants (23.8%) from the training

programme. Table 2 shows the drop-out rate for the included and excluded participants.

Table 2. Driver drop-out rate and mean post-drive SSQ score observed for participants included and those excluded using the exclusion criteria.

	Driver group	
	Included	Excluded
N	476	149
Completed	397	74
Drop-out	79	75
% drop-out	16.6%	50.3%
Mean SSQ	20.9	43.2

Table 2 shows that for drivers who are considered eligible for simulator training based on the exclusion criteria, the drop-out rate has fallen from the original overall rate of 24.6% to 16.6%. However, for the excluded drivers the drop-out rate exceeds 50% with drivers reporting higher SSQ scores more than double those reported by the included group. An independent samples t-test across the included/excluded groups shows that the differences in drop-out rate ($t(623) = 8.83$; $p < 0.001$) and post-drive SSQ score ($t(588) = 7.06$; $p < 0.001$) are highly significant.

Enhanced Familiarisation Procedures

Large changes in simulator sickness have been reported between the first and the second exposure and have been considered to be a matter of familiarisation concerning the equipment and procedure rather than habituation (e.g., Regan & Price, 1993; Cobb et al., 1999). Regan (1995) noted that some participants report anxiety prior to their first session and it is possible that this anxiety could manifest itself in the form of reported simulator sickness. In fact, feelings of anxiety are typically associated with signs and symptoms similar to those of simulator sickness and include dizziness, pounding heart, sweating or breathing difficulties (Redfern et al., 2001). Although the exact link between simulator sickness and anxiety remains elusive, anxiety has repeatedly been shown to correlate with simulator sickness (Bertin et al., 2004, 2005; Owen et al., 1998; Redfern et al., 2001). It has been suggested that anxiety may indirectly contribute to motion sickness susceptibility in that it modifies susceptibility (Reason & Brand, 1975).

Based on these findings, it was anticipated that an enhanced familiarisation procedure would reduce drivers' anxiety before participating in simulator training and lead to a reduction in the occurrence of simulator sickness.

The enhanced familiarisation process consisted of three to four drivers attending the simulator facility, typically 1-2 days before their scheduled simulator training sessions, and being given more information about the purpose of the simulator training programme by one of the driving instructors. It was anticipated that this would help drivers to overcome anxiety they might feel about the simulator training process in relation to evaluation of their driving and any thought they might have that this could lead to their job being threatened. Trainees were able to ask any questions they had regarding training and/or the simulators themselves and had the opportunity to the simulator in action. The session lasted 30-45 minutes depending on the number of questions asked by the trainees.

Application of Screening Process and Enhanced Familiarisation Procedures

The screening process and enhanced familiarisation procedures were applied in a further study in which 80 professional Scottish truck drivers were recruited to experience driving the simulators. Drivers were only required to drive the four exercises once. Screening was conducted by telephone questionnaire and drivers who wished to attend but met one or more of the exclusion criteria were not permitted to participate in the programme.

Table 3. SSQ scores and drop-out rate for Control drivers; screened drivers (S); drivers who underwent the enhanced familiarisation process (F); or both (S+F).

Process		Driver age (years)	Post-drive SSQ score	Drop out rate
Control	N	30	27	30
	Mean	47.1	18.3	6 (20%)
S	N	20	20	20
	Mean	42.6	3.18	1 (5%)
F	N	15	14	15
	Mean	33.7	12.8	0 (0%)
S+F	N	15	15	15
	Mean	33.1	5.24	1 (7%)

Table 3 shows the observed SSQ scores and comparative percentage drop out rate for drivers not screened or familiarised against those that experienced either/both of the interventions.

Discussion

Table 3 shows that both the additional processes caused a reduction in reported SSQ levels and driver drop-out rate. A relatively small sample was used so it would be hard to derive conclusive evidence based on the numbers of drivers dropping out of the programme. However, there are consistent reductions in reported SSQ for each intervention type. The lowest reported mean SSQ scores are for drivers who have been screened. Therefore it would seem that this is the most important component of the enhanced recruitment process. Recruiting drivers to attend an extended familiarisation process at the simulator facility proved a challenging task and it does not appear to cause a significant benefit over and above that achieved by applying the screening process. It is therefore recommended that the screening criteria and not the enhanced familiarisation procedures would benefit future research and training programmes.

When determining the screening procedures for a training programme one must take care to balance the stringency of the exclusion criteria. Although strict criteria would achieve very low drop-out rates, the size of the potential target population may be greatly reduced. Furthermore, severe restrictions on access to simulation training may provoke opposition from groups that promote equal opportunities in the workplace. Conversely, if the criteria are too relaxed, although the target population will be large, the drop-out rate may be unacceptably high and the reputation of the training programme may suffer.

In conclusion, a simple carefully designed screening process appears to offer the possibility of significantly reducing sickness rates in simulator studies and training programmes.

References

Bertin, R.J.V., Guillot, A., Collet, C., Vienne, F., Espié, S., Graf, W. (2004) Objective measurement of simulator sickness and the role of visual-vestibular conflict situations: a study with vestibular-loss (a-reflexive) subjects. Proceedings Neuroscience 2004 30, San Diego, California.

Bertin, R.J.V., Collet, C., Espié, S., Graf, W. (2005). Optokinetosis or simulator sickness: Objective measurement and the role of visual-vestibular conflict situations. Perception, 34, ECVP Abstract Supplement.

Cobb, S.V.G., Nichols, S., Ramsey, A., Wilson, J.R. (1999). Virtual reality-induced symptoms and effects (VRISE). Presence: Teleoperators and Virtual Environments, 8(2), 169-186.

Curry, R., Artz, B., Cathey, L., Grant, P., Greenberg, J. (2002). Kennedy SSQ results: fixed- vs. motion-base Ford simulators. Driving Simulation Conference Proceedings, Paris, France.

Kennedy, R. S., Lane, N., Berbaum, K. S., & Lilienthal, M. G. (1993). Simulator sickness questionnaire: An enhanced

method for quantifying simulator sickness. The International Journal of Aviation Psychology, 3(3), 203-220.

Kennedy, R.S., Stanney, K.M. (1997). Aftereffects of virtual environment exposure: Psychometric issues. In M. Smith, G. Salvendy, R. Koubek (Eds.), design of computing systems: Social and ergonomic considerations (pp. 897-900). Amsterdam, Netherlands: Elsevier Science Publishers, San Francisco, CA, August 24-29.

Moroney, W.F. and B.W. Moroney (1998) Flight simulation, In: Handbook of Aviation Human Factors, D.J. Garland, J.A. Wise, V.D. Hopkin (Eds.). New York, Erlbaum.

Orlansky J, Dahlman CJ, Hammon CP, Metzko J, Taylor HL, Youngblut C. (1994) The value of simulation for training. IDA paper P-2982, Institute for Defense Analyses, Alexandria, Va., USA.

Owen, N., Leadbetter, A.G., Yardley, L. (1998). Relationship between postural control and motion sickness in healthy subjects. Brain Res Bull, 47(5), 471-474.

Reason, J.T., Brand, J.J. (1975). Motion Sickness. Academic Press, New York.

Redfern, M.S., Yardley, L., Bronstein, A.M. (2001). Visual influence on balance. J Anxiety Disord, 15, 81-94.

Regan, E.C., Price, K.R. (1993). Some side-effects of immersion virtual reality. Army Personnel Research Establishment, MOD, Farnborough, Hampshire, England. APRE Report No. 93 R010.

Regan, E. C. (1995). Some evidence of adaptation to immersion in virtual reality. Displays, 16(3), 135-139.

Stanney, K. M., Kennedy, R. S. (1997). The psychometrics of cybersickness. Communications of the ACM, 40(8), 67-68.

Williams, A. C.,& Flexman, R. E. (1949). Evaluation of the School Link as an aid in primary flight instruction. Aeronautics Bulletin No. 5, University of Illinois, Institute of Aviation.