Virtual Training Environments to Improve Train Driver’s Crisis Decision Making

Jennifer Tichon1; Guy Wallis1 Tony Mildred2
1Visual Computational and Learning Group, University of Queensland
2Railcorp
jtichon@uq.edu.au, gwallis@hms.uq.edu.au, Tony.Mildred@railcorp.nsw.gov.au

Abstract: This paper reports on a current research project in which virtual reality simulators are being investigated as a means of simulating hazardous Rail work conditions in order to allow train drivers to practice decision-making under stress. When working under high stress conditions train drivers need to move beyond procedural responses into a response activated through their own problem-solving and decision-making skills. This study focuses on the use of stress inoculation training which aims to build driver’s confidence in the use of new decision-making skills by being repeatedly required to respond to hazardous driving conditions. In particular, the study makes use of a train cab driving simulator to reproduce potentially stress inducing real-world scenarios. Initial pilot research has been undertaken in which drivers have experienced the training simulation and subsequently completed surveys on the level of immersion experienced. Concurrently drivers have also participated in a velocity perception experiment designed to objectively measure the fidelity of the virtual training environment. Baseline data, against which decision-making skills post training will be measured, is being gathered via cognitive task analysis designed to identify primary decision requirements for specific rail events. While considerable efforts have been invested in improving Virtual Reality technology, little is known about how to best use this technology for training personnel to respond to workplace conditions in the Rail Industry. To enable the best use of simulators for training in the Rail context the project aims to identify those factors within virtual reality that support required learning outcomes and use this information to design training simulations that reliably and safely train staff in required workplace accident response skills.

1. INTRODUCTION

The rail network is one of the critical infrastructure components in most economies around the world [1]. The nature of the rail context has changed enormously over the past decades with relatively fast changing technical systems across all areas including communications, signaling and control functions, and increased information in the driving cab. With the performance of trains ever increasing and the driving task becoming more and more complex. Within a system of limited capacity the industry must meet the capabilities required of both staff and passengers. Safety, efficiency (embracing cost considerations), quality and reliability of the service are all constantly juxtaposed. Against the current background of political and social pressures for more public transport, and actual and proposed new technical and organizational systems, the industry as a whole has seen several high profile accidents [1]. It is against this background that new demands are being placed on simulation training approaches traditionally used in rail.

1.1 Training for Critical Rail Events

Serious accidents are an unfortunate but often inevitable part of everyday life, nowhere more so than in industry, particularly where heavy, human operated machinery is at work. Much effort has been devoted to the task of reducing the chances of such accidents via the introduction of health and safety legislation and employee education programmes. Suitable training in individual and team decision making under stress and crisis management can hugely reduce the impact of such events.

For rail, as for aviation and defence contexts, it is recommended that driver training be devised for situations where conditions are abnormal or degraded because this is where catastrophic consequences can result. Drivers need to be trained for the worst rather than a normal day’s operations [2]. They need enhanced skills to deal with emergencies, particularly cognitive skills known to be subject to degradation under stress, such as critical thinking, problem solving and decision-making.

The use of train simulators and reality centers in the rail industry has increased in popularity in recent years [3,4]. Modern rail simulators
provide a full driving cab and 180 degree projection with 3D virtual images of elements which constitute a normal railway network. Of crucial importance to training, these simulators can also introduce hazardous climactic conditions such as fog, rain, wind, dazzling sun, or specific operating conditions such as heavy traffic, accidents, faulty signs and people on the track [5]. Simulators for rail-related training are now in widespread use. Research reporting on simulation-based driver training, however, has been generally concentrated on such topics as signal recognition, fatigue and vigilance [3,6]. Simulators provide the opportunity for train drivers to repeatedly practice their identification and response to emergencies. The potential to recreate a myriad of potentially threatening situations both relatively cheaply and easily is extensive. It is surprising therefore, that relatively little research emphasis has been given to simulator-based training techniques for preparing train drivers for such critical incidents.

Railcorp has a history of simulator-based in-cab driver training with a focus on safety management. In more recent years reality centers have been used to deliver non-interactive scenes of virtual staff failing to follow rules and procedures. Opportunities to reflect on and discuss appropriate alternatives were the core of the learning design. More recently Railcorp has emphasized an increase in the level of direct interaction in their simulation-based driver training programs. There is an important role for interactive simulators in replicating degraded critical events and establishing them as a core component of rail training programs.

1.2 Training in Virtual Environments

Goals of educating in VR include training individuals to operate complex machinery, to respond appropriately to rapidly unfolding events, or to function in environments that would otherwise be too expensive or hostile to be used on a day-to-day basis [7]. Such established uses of VR are becoming both more widespread and more compelling, prompting investigation of its application to training enhanced critical decision-making skills [8]. VR has been demonstrated to enhance the development of quality decision-making skills, particularly under the stress imposed by time limitations [9] and the facilitation of a trained personnel's memory of learnt skills in virtual environments (VE) [10]. The flexibility of VEs can be used to enhance those features of the environment that are specific to the targeted tasks at the expense of those which are not [11].

Prior research in VR and education has described a number of variables of interest to VR-based decision-making training. Especially in situations where there is an abnormal operation and the goal of training is to respond to worst rather than a normal day’s operations [2]. When simulation-based training goes beyond the acquisition of required knowledge and abilities, and the aim is to prepare the individual to perform effectively in a stressful environment, this is commonly referred to as stress exposure training [12]. This training focuses on developing the cognitive skills such as decision-making, required to maintain effective performance under stress. A crucial element of the approach is to provide opportunity for repeated practice under operational conditions similar to those likely to be encountered in the real-world settings.

A variable widely accepted as being positively related to enhanced learning and performance in VR and therefore highly desirable is ‘presence’ [13]. For stress exposure training, as with other forms of VR training, effectiveness and successful educational outcomes are more strongly dependent on the sense of presence felt by the trainee, than the richness of available images [14]. It is well established that meaningfulness and coherence of a stimulus set promotes learning [15] and in VR, presence has been identified as a key requirement in achieving this.

1.3 Presence in Training

Psychologically, a successful virtual experience will make the user become involved in the world to the point where he or she experiences a sense of presence in the virtual world or of ‘really being there’ [16]. Sense of presence has been widely researched as a key construct facilitating the effectiveness of virtual reality (VR) in training [12, 13] and is reported as one of the major features needed to ensure the transfer of knowledge from the virtual to the real world [9]. A strong sense of presence is linked to the quality of the training, since the experience in the VE has been shown to lead to recallable knowledge in the real world as a consequence of how engrossing the experience in the virtual world was.

Already, much research has been devoted to finding what factors can contribute to a sense of
presence in VEs [17,18]. A widely accepted set of presence causal factors that have been developed over many years by Witmer and Singer [13,19] include measures of involvement, sensory fidelity, adaptation/immersion, and interface quality.

As alternatives to causal factorial approaches to presence measurement, another approach is to ask users to introspect on their experiences in the virtual environment. The main criticisms of introspection are related to the need for subjectivity in responses. Slater [16] claims self-report is not appropriate for measuring presence because the measurement becomes inexplicably tied to personal aspects of the user. However, as stress training VEs rely on an intense emotional response from users, their subjective reports of the VEs ability to achieve this is important. Introspective measures of presence have therefore also gained significant acceptance.

The current project is a pilot test of the level of presence experienced by users of the current Railcorp in-cab driver training simulations. The primary research goal of the pilot is to gain some preliminary data on the immersive impact of the training scene. In a later, large-scale study these measures will be supplemented by physiological measures and measures of rail decision making skills (RDMS). Cognitive task analysis of the train driver task is currently being used to build measures of RDMS. The overall aim is to determine the effectiveness of train driver workplace accident and disaster training using the in-cab simulators. Specifically targeting the enhancement of decision-making skills the main study uses a stress inoculation training design. These findings will then be used to inform ongoing design issues.

2. METHOD

In order to gain some initial data on the effectiveness of the Railcorp in-cab simulator training program in producing participant immersion, the concept of presence was measured in three ways. As previously discussed, presence is thought to influence training outcomes for users, and many of the factors which appear to affect presence are known to enhance learning and performance [17]. While physiological measures will also be included in the larger study this initial pilot study was restricted to self-report measures to include both introspective and causal approaches.

2.1 Participants

12 participants were recruited for the study from Railcorp. They were all male. They had an average of 13.7 (SD=11.4) years experience driving trains. The mean age was 47.1 years (SD=8.31), with a range between 28 and 56 years of age. Participants volunteered to take part in the study and informed consent was gained.

2.2 Measures

2.2.1 Causal Factors

Measures of causal factors rely on self-report but are not classed as introspective as they do not require participants to report on their subjective feelings, but rather gauge their perceptions of various factors or variables that have been demonstrated to influence the experience of presence. While many questionnaires and surveys are available to attempt to measure presence via causal factors, only a small number of these have gained widespread use [12]. The Presence Questionnaire developed by Witmer and Singer is one survey that has gained a significant level of acceptance and has been tested across a number of studies [22,23]. For these reasons it was selected for this study. The PQ measures participant’s perception of display system features across four factors. They are:

1) Involvement occurs if the VE is successful in causing the user to focus their mental energy and attention on a coherent set of stimuli or meaningfully related events. Involvement increases when the interface feels natural and facilitates the user's ability to control activities in the VE.

2) Sensory Fidelity can influence the user's energy and attention. It is proposed that poor sensory information is engaging and makes sense to the user, the more likely they will be able to ignore external distractions to their experience of presence.

3) Adaptation/Immersion is related to the user’s ability to adapt to the VE. Participants who adjust quickly and readily to the VE and its interfaces are more likely to feel immersed in the VE. Within this factor the user’s perceived proficiency of interacting with and operating in the VE will impact on how quickly they adjust to the VE.

4) Interface Quality should influence presence. For example, a poor interface would be likely to increase the time it takes to adapt, translating into performance deficits. This factor
hypothesizes that the increased degree of ability to search, survey or examine objects in the VE will correlate with increased presence.

The items used in the current study consisted of a subset of the original PQ items. The context of the in-cab simulator required some modifications to the original questionnaire.

2.2.2 Introspective Measure

The Igroup Presence Questionnaire (IPQ) [18] aims to measure spatial presence (the sense that a VE is a real place) through asking participants to report on their own individual experience through questions such as, ‘How real did the virtual world seem to you?’ While some of the IPQ items are not introspective the majority are, and in light of its prior testing and subsequent widespread use, it was selected for this study to add to the PQ causal factor measure.

3. RESULTS

Mean, standard deviation and percentage of highest possible score for the IPQ, PQ and sub-factors of the PQ can be found in Table 1. The questions were designed so that larger response values indicated greater presence in the virtual environment. Responses were analyzed separately for each question and for each survey. In addition, the responses for each of the PQ factors: involvement, sensory fidelity, adaptation/immersion, and interface quality were analyzed separately.

<table>
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<tr>
<th>Measure</th>
<th>Mean</th>
<th>SD</th>
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<td>49</td>
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</tr>
<tr>
<td>Interface Quality</td>
<td>16.2</td>
<td>18.0</td>
<td>21</td>
<td>77.14</td>
</tr>
</tbody>
</table>

Table 1. Mean, Standard Deviation and Percentage of Highest Possible Score for the IPQ, PQ and Sub-factors of the PQ

Statistical evaluation due to the small sample size was restricted to simple percentages of highest possible scores across the separate measures. A comparison of the overall PQ and IPQ scores was made using a paired t-test. Scores for the PQ were significantly higher than the IPQ ($t = -3.06, p = 0.011$).

Of the PQ sub-factors Adaptation/Immersion scored highest in terms of level of presence experienced by participants. The factors of sensory fidelity and interface quality, though scoring lower, were not significantly so. Involvement scored lowest and therefore appears to have contributed least to the experience of presence in the train driving simulation.

4. DISCUSSION

Results of this study show that drivers scored presence higher on the casual factor measure (PQ) than the subjective measures (IPQ). This indicates that while feedback on factors within the simulated environment were generally positive, the drivers’ subjective feedback on the extent to which they felt immersed or present in the VE was not as significant. Because stress exposure training for degraded operational environments rests on the simulation’s ability to elicit emotional responses from the trainees, subjective reports of emotional reactions to the simulation are important.

Of the four causal factors examined Adaptation/Immersion scored highest. This would indicate drivers did adapt relatively easily to the cab simulator, and that the interface and control devices did lend themselves to drivers feeling proficient interacting with them.

The Interface Quality score indicates that the simulator provides an acceptable level of fidelity supporting a user’s ability to search, survey or examine objects in the VE. However improvements to support an increase in presence are possible. In an informal round of questioning after exposure to the virtual environment, some drivers reported that their ability to establish distance was hampered by the lack of ‘color quality’. For example, colors of signals and flags did not appear realistic.

Cues to distance include stereo (3D relief through two eyes) and aerial perspective (things appear blurrier and fainter with distance). Neither of these cues is currently being simulated. These will be investigated for inclusion to enhance Interface Quality. Simulating illuminant objects such as fluorescent safety clothes and flags/signals, can be problematic due to the lack of dynamic range in the projected image. Darkening the whole image will be trialed as this leaves more range in the...
top level of brightness for illuminant objects and users usually adapt quickly to the lower light levels.

Sensory Fidelity achieved 76.78% indicating that the simulation was generally successful in engaging user’s attention to the driving environment. One driver reported some distraction from external noises indicating some improvements to soundproofing may enhance levels of presence.

Poor sensory fidelity can interfere with immersion through distracting the user’s attention away from the required task. Simulator sickness was reported by one driver. Simulator sickness is a form of motion sickness induced by discrepancies between visual and vestibular information in a VE. The existence of simulator sickness raises the concern that attention is diverted from the driving task to concern over the unpleasant physical symptoms. While simulator sickness can be a major concern in driving simulators it was only reported by one driver. Some individuals can have increased predisposition to the sickness and so its impact on presence for the training overall can only be determined through further investigation. A possible future step to reduce any visual and vestibular discrepancies is to introduce cab vibration.

The factor of Involvement scored lowest. As the Adaptation/Immersion result indicated, drivers did adapt quickly to the control and interface devices. It therefore seems likely that they would also have felt confident that the simulator would respond to their control activities. Perceived ability to control activities in the VE in part influences Involvement scores. If this aspect of the simulator was not problematic, it may be that the discrepancy between how natural the simulator felt in comparison to a real train, was significant enough to reduce the immersive impact of the experience. While a simulator can never feel as real as a train, the discrepancy between the two can be reduced to a level which supports, rather than degrades, presence.

The only comment pertaining to Involvement during the pilot concerned the lack of physical feedback from the train. Rhythmic vibration can provide an enhanced sense of realism and can also serve as an important cue to vehicle speed. A simple tilt platform, which can also simulate vibrations, may therefore be able to assist to improve the driver’s sense of presence.

The goal of this study was to gain some initial data on the immersive quality of the training simulation through investigation of presence. Based on prior research on the immersive properties of training simulators a higher experience of presence should translate to enhanced skill development and a higher success rate of skill transference to the real world. Therefore, working to gain the highest possible level of presence, in tandem with the use of the best possible educational design, can only serve to improve the effectiveness of the training task. Level of presence also facilitates participants experiencing intense emotions such as stress, which is an integral aspect of a stress training approach to skill development. The results of this study have provided some initial direction in working with the simulator to increase the experience of presence. By addressing some of the issues detracting from presence identified by the causal factor measure, the subjective reports of presence should correspondingly increase also.

REFERENCES


