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VIRTUAL REALITY MANUAL HANDLING INDUCTION TRAINING: IMPACT ON HAZARD IDENTIFICATION

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Abstract

Use of Virtual reality (VR) for safety training programs enables instructors to present a wide variety of controlled stimuli to multiple, dispersed users. Often VR scenarios replace traditional text information with a visual representation and assumptions are made on how interacting with the computer-generated scenarios will improve skills. Research investigating whether VR does in fact improve safety skills and in what areas of learning or skill development this medium is superior is limited. This project assessed a VR training program in manual handling developed for two high risk industries, Mining and Construction. Manual handling training delivered to novice trainees via either non-interactive PowerPoint slides or interactive VR scenarios were compared. While participants scored similarly in multiple-choice assessments the interactive VR group scored significantly higher when assessed by visually-based assessments such as photographs (30% more correct answers) and video (20% more correct answers) of manual handling events. Through use of a visual identification assessment, both groups were able to identify when another person was using correct manual handling techniques more than incorrect techniques. However, the VR group were 15- 20% better at identifying when others were undertaking dangerous manual handling actions which has important implications for contributing to safer workplaces. Using a visual rather than multiple choice assessment, not only assessed their knowledge, but also their hazard awareness. Results are discussed in terms of the effectiveness of interactive VR versus passive text-based training and the importance of assessment to ascertain the range and type of knowledge gained during safety training.

Keywords: Manual Handling, Safety Induction, Hazard Awareness, Virtual Reality

1. Introduction

The construction and mining industries are priority industries for work health and safety in Australia (Safe Work Australia, 2013). Federal statistics indicate serious injuries in construction/mining occur at more than 1.5x the national average (Safe Work Australia, 2013). Despite steady workplace improvements these sectors remain dangerous because work must be undertaken in close proximity to a range of hazards that have the potential to cause serious injury (Burgess-Limerick & Steiner, 2006).

A key part of training preparation includes ensuring appropriate safety information and obligations are provided to workers prior to commencing work. *Standard 11* (mining) and *White Card* (construction) induction training include processes for identifying and delivering competent, safe and efficient work teams (Queensland Government, 2012). These training programs cover, among other topics: principles of risk management; identifying hazards and control measures; interpreting and applying safety information; using safe work practice; and training in basic emergency procedures and manual handling.

Currently, the majority of induction training programs in these industries consist of traditional learning activities delivered via classroom-based teaching or online methods. Schofield et al. (2001) reviewed these methods in the mining industry () and suggested a number of serious problems, concluding that: "…rote learning of information is the most common technique used by trainers with the same sets of training media being used from year to year. Many teaching methods present too much material, too rapidly, with little or no opportunity for worker involvement… Skill degradation is an important issue. When the hazards of a mine environment are combined with the issue of skill degradation, the need for realistic training becomes paramount (p.154)."

2. Use of Virtual Reality in Training Within the Mining Sector

For more than a decade Virtual Reality (VR) has been discussed as offering an opportunity to improve safety related training in the minerals sector. It has been asserted that workers' capacity to remember safety information after interacting in a three-dimensional scenario is far greater than the ability to translate information from a printed page (Schofield, et al., 2001). As a consequence, the potential for improved safety has been embraced by the mining industry with VR being increasingly adopted. Since 2005, the NSW Coal Services Health and Safety Trust has provided more than $8M for the development and deployment of VR training facilities utilised by Coal Services Mines Rescue to provide training at four NSW locations. In 2010-2011, 14,000 miners were exposed to this training (Coal Services Annual Report, 2011). Rio Tinto has invested in VR training facilities at North Parkes mine.

Internationally, VR has also been identified as a potential avenue for safety training in the minerals industry for some time (Filigenzi et al., 2000; Wilkes, 2001). VR was specifically identified as a desirable research focus by the US National Research Council, Committee on Technologies for the Mining Industry as far back as 2002. However, while there are a number of international reports of safety training being conducted in VR, there is very little evaluation reported other than descriptions of usability and/or subjective responses of trainees (Schafrik et al., 2003, 1998; NIOSH, 2009).

The use of serious games is also rapidly gaining popularity, with a number of training alternatives based on this technology appearing in the area of mines safety training. For example, the US National Institute for Occupational Safety and Health (NIOSH) offers desktop VR training in underground coal mine map reading using their "Mine Navigation Challenge" program, built using a first person shooter computer game engine. Field testing was conducted using a qualitative survey which gauged the degree to which trainees liked or enjoyed the session, what parts of the course they liked best and if they would like computer-based sessions in future training (NIOSH, 2009). No measures were implemented to evaluate the effectiveness of the immersive game-based environment on map reading.

Despite the growing use of VR safety training in high risk industries, knowledge underpinned by objective research is limited in regard to the effectiveness of current VR safety training applications. Those developing computer-based scenarios for training miners should be devising associated evaluations (Mallet & Orr, 2008) to ensure poorer than expected training outcomes are not occurring, nor resulting in the potential for greater dangers to personnel and that expected cost-benefit outcomes of VR investment are realized. This project undertook a direct comparative assessment of manual handling training delivered via text-based power point slides and interactive VR scenarios.

3. Manual Handling Training

Manual handling is a common occupational hazard and knowing how to reduce the risks is important. This includes investigations into whether alternatives to manual handling, such as the use of mechanical aids, supports safe lifting techniques. In safety induction training, such as the Construction sector's White Card, trainees not only need to demonstrate they have the required knowledge in this topic, but they must also be able to identify manual handling hazards and know how to report these (Construction & Property Services Industry Skills Council, 2015).

Research in aviation and medicine indicate a high transfer of training can be achieved through expanding simulation-based curriculums to smaller screens, desktop PCs and mobile technologies, instead of focusing exclusively on complete immersion in costly, centralized high-fidelity interfaces (Thomas, 2004). The ongoing developments in low-cost 3D VR training can assist industries such as construction and mining to overcome the challenges of delivering traditional VR training to large numbers of widely distributed personnel. The logistical and financial constraints of taking distributed personnel offline and transporting them to a central location to access VR training has resulted in the current focus on development and use of VR training scenarios deliverable on mobile technologies via the Cloud. The current project assesses a VR safety induction training module addressing manual handling. The aim of the research is to ascertain what benefits there are, if any, in delivering the course materials via interactive VR modules online compared to the same course content delivered via commonly used text-based PowerPoint slides.

4. Methods

Participants

Ten people, aged 18 to 26 (*M*= 21.1, *SD* =2.99), participated in the experimental component of the study. Of the 10 participants, 7 were female and 3 were male, 9 spoke English as their first language and 1 spoke Mandarin as their first language. All participants were University students enrolled in first year Psychology courses at Griffith University, Mt Gravatt, 9 had never done Manual Handling training before and 1 had completed online Manual Handling training 1 to 2 years before. Participants were recruited through an internal subject pool that allowed students to participate in studies within the University for course-credit. Each participant was awarded one credit point (worth 1% of their course grade) for participation.

The experiment took place on campus at Griffith University, using a basic desktop computer in a quiet office environment. The researcher remained in the room with the individual participants throughout the experiment.

Design

This study was a between-subjects experimental design. The independent variable of the study was the method of training each group was randomly assigned to. The control group were trained through a PowerPoint slide presentation about Manual handling, while the experiment group engaged in PC-based Virtual Reality Manual Handling Scenarios after reading through the PowerPoint slides, which were inserted into the VR program and read before commencing the training. The dependent variable of the study was participant's assessment scores.

As the experiment was intended to be a preliminary pilot study, a minimum of 10 participants was desired (5 per condition).

5. Materials

Consent form and Information sheet

The study was approved by the Griffith University Research Ethics Committee and all participants signed informed consent forms.

Manual Handling Training Slides

Generic 'Manual Tasks & Office Ergonomics' on-line training slides were used and adapted for this study. The slides contained information about safe lifting and carrying of items and pushing and pulling items with a trolley. Any items relating to Office Ergonomics were removed leaving only those regarding manual tasks. Examples of items related to Manual Tasks are "Manual task risk factors include: layout of the work area, design and use of tools and equipment, work environment, work organisation and individual factors" and "Reducing the Risk of Manual Task Injury: [Lifting] Weight of the item: keep the item as close to your body as possible regardless of weight, how often and for how long the item must be lifted. Ask yourself "is the weight evenly distributed?" Examples of trolley use information include:

"Pushing and Pulling: It is preferable to push loads rather than pull as it requires less exertion by the muscles of the lower back" and "Hand trolleys used to carry loads should be as light as possible with larger than normal wheels or castors."

Assessment Tool

The assessment tool consisted of three sections; Section A: 17 multiple-choice questions, Section B: 12 photographs with short answer questions and Section C: two videos with short answer questions. All three assessment sections contained questions, photographs and videos relating to the three topics covered in the slides (lifting items, carrying items and pushing and pulling trolleys). Example multiple-choice questions are "What is the first thing you need to do before you lift a load? What should I do to safely lift an object? What is the main factor to consider about distance when carrying a load?" and "Is it preferable to push a load rather than pull?"

The photographs were a variety of images showing one or two people lifting, carrying, pushing or pulling items either safely, unsafely or a combination of safe and unsafe movements. The participants were asked to write as many dot point notes about what they thought was safe or unsafe about the photograph. For Section C of the assessment, participants were shown a video and of a man lifting a box from a pallet to a conveyor belt followed by a second video showing a man carrying a box from the conveyor belt to a store room. The participants were able to watch the video up to three times and were instructed to write dot-point notes about what they thought was correct and incorrect about the manual handling displayed in the video. At the time of the assessment, the participants were given the photographs with short answers to complete first, followed by the videos with short answers and then finally the multiple-choice questions.

Virtual Reality Manual Handling Training

The VR Manual Handling training program began by firstly displaying information about safe manual handling (the same information as the PowerPoint training slides in the control group). This was followed by a practical tutorial that explained the keyboard and mouse controls for using the program and allowed the participant to practice using the controls until they understood how to work the program. The program had three scenarios to complete. Scenario 1 was about lifting and carrying items from shelves in a warehouse and placing them into a truck. Scenario2 was about lifting items from shelves in a warehouse on to a small trolley to then load into a truck. Scenario 3 was about lifting items from shelves in a warehouse onto a large trolley to load into a truck. Scenario 2 and 3 both had options to "Request Assistance" (by left clicking the item) for large items. The virtual person controlled by the participant was designed to have a certain amount of energy that would run out if items were held for too long. Additionally, a notification would pop up on screen if the virtual person was lifting unsafely, dropped the item or should have asked for help to lift a load. It should be noted that the PowerPoint training slides did not cover asking for assistance for lifting larger items.

	
Scenario 1-single lift	Scenario 1 – double lift
	
Scenario 2	Scenario 3

Figure 3. Examples of Scenarios in the Manual Handling program.

6. Procedure

PowerPoint Group

The researcher explained to each participant that they were to read through the PowerPoint slides about Manual Handling and then complete an assessment task about what they had read. Participants were able to read the slides at their own pace and typically spent 5 to 10 minutes. They then completed the assessment task at their own pace, which typically took fifteen to twenty-five minutes. At the end of the experiment, the participants were given the opportunity to try the VR game or were free to leave.

Virtual Reality Group

The Researcher explained to each participant that they were to read through the PowerPoint slides about Manual Handling and then complete the VR program tutorial, which typically took four to seven minutes. Once the tutorial was completed, participants completed the program's three scenarios, beginning with Scenario 1 (simple lifting and carrying tasks), followed by Scenario 2 (lifting and carrying tasks with the use of a small, two-wheeled trolley) and lastly, Scenario 3 (lifting and carrying with the use of a larger, four-wheeled trolley).The total time each participant took to complete all three scenarios was between fifteen and twenty-two minutes. Once all three scenarios were completed, the participants were asked to complete the assessment. The participants in the VR group typically took an additional twenty to thirty minutes to complete the assessment.

7. Results

Section A – Multiple-choice

In Section A of the assessment tool, participants were tested across lifts, double lifts and trolley use with 17 Multiple choice questions. The two groups performed very similarly on this section with the Virtual Reality trained group recording 67 correct responses in total (mean = 13.4 per participant) and the PowerPoint slide group scoring 60 correct responses in total (mean = 12 per participant). It was found that both groups had greater incorrect answers for the trolley related questions than the lifting related questions. However, the PowerPoint (PP) group performed better than the VR group on the trolley questions and the VR group performed better at the lifting and carrying questions. Results displaying number of incorrect responses are in Figure 4.

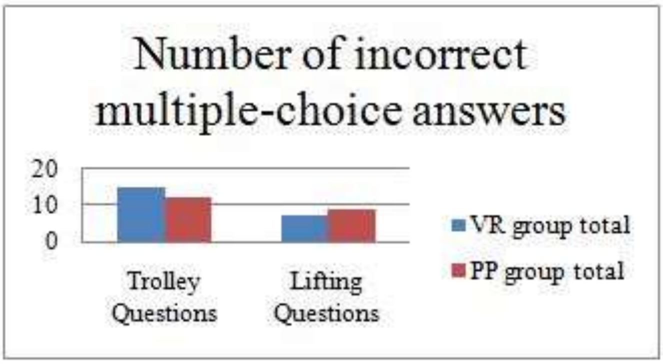

Figure 4. Comparison of incorrect answers in Section A of the assessment.

Section B –Photographs

Scoring for Section B and C was different to Section A as there were no "incorrect" answers, only the number of identified safe and unsafe manual handling movements that participants recorded in the assessment tool. Therefore, the results for Section B and C are the total number of identified movements per group and average number of identified movements per participant within each group. Section B displayed photographs of people lifting (single and double) and trolley use. Examples of answers given by participants regarding safe movements identified were: correct use of a semi-squat, multiple people for heavy lift, secure hand positioning, enclosed shoes and weight held close to body. Examples of unsafe manual handling movements identified were: too many boxes on a trolley, not looking where subject is heading with load, awkward lifting position, holding box at incorrect height, both hands not on trolley, pulling not pushing of trolley, lifting box from top and knees not bent. Figure 5 displays and compares the mean scores of both groups for Section B. The total correctly identified safe manual handling movements for the VR group was 116 and the PP group total was 82 (i.e. the PP group was 30% lower than the VR group). The total correctly identified unsafe manual handling movements for the VR group was slightly less at 107 and the PP group total was slightly more at 88 (i.e. the PP group was 18% lower than the VR group).

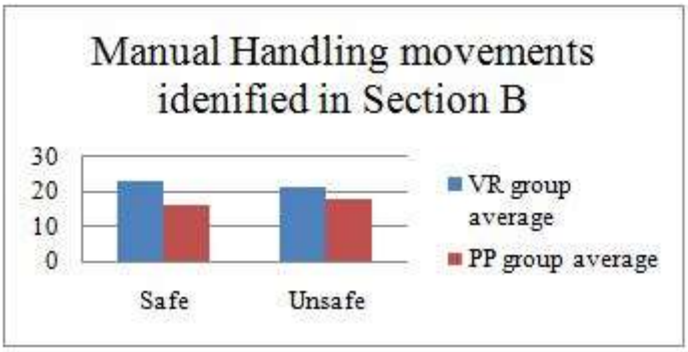

Figure 5. Comparison of correctly identified manual handling movements between groups.

Section C – Videos

Section C displayed two videos of lifting and carrying. Examples of answers regarding safe movements recorded by participants on their response forms were: correct hand positioning, load near hips and use of assistance. Examples of unsafe manual handling movements identified were: bent back, twisting to get past obstacles, overloaded trolley, carrying on side hip and obstructions/risks in path. Figure 6 displays each groups average number of identified manual handling movements for Section C. Group totals for correctly identified safe movements were 25 for the VR group and 20 for the PP group (i.e. the PP group was 20% lower than the VR group). Group totals for correctly identified unsafe movements were 42 for the VR group and 36 for the PP group (i.e. the PP group was 14% lower than the VR group).

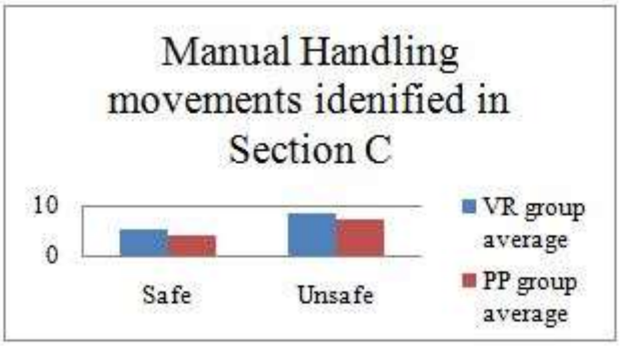

Figure 6. Comparison of correctly identified manual handling movements between groups.

Discussion

These preliminary findings though restricted from generalisations by the limited participant numbers, indicate that safety training delivered via VR may provide more effective training. This is supported by the VR group gaining higher performance scores over both their knowledge about and their skill in identifying, manual handling hazards. These results have practical significance for the high-risk sectors, as they indicate that the use of more interactive and visually-based methods can significantly improve hazard awareness which should positively impact incident prevention on-site. The manual handling program tested here used an economical VR training technique.

In safety induction training, trainees not only need to demonstrate that they have the required knowledge, but they must also be able to identify manual handling hazards and know how to report these (Construction & Property Services Industry Skills Council, 2015). The mixed results that we achieved using a mix of assessment types reiterates the importance of establishing clear and appropriate assessment conditions to be able to establish whether any training has produced a satisfactory level of performance from trainees. Assessment of all safety training should be linked to skills testing and not be limited to knowledge only. Skills testing is more easily able to be linked directly to the measures of competency required by mandatory safety induction training.

To be able to report a hazard, a person needs to be able to visually identify it. Use of text-only assessments does not ensure the safety training meets the requirements of the unit of competency, principles of assessment or rules of evidence. VR provides a method of delivery that is more applied to a specific employer's needs. For example, live sites can be replicated with practical scenarios that reflect real job requirements. Text-only PowerPoint slides supported by still images cannot provide the experiential learning opportunities that support visual evaluations of site surroundings, practice in being vigilant on the job, or awareness of changing, dynamic hazards. Worksite issues that arise requiring individuals to assess the correct and incorrect manual handling techniques to use can only be trained during interactive training scenarios.

With much safety induction training moving online, the requirement for 'demonstration' has often been removed from assessment. Terms such as 'identify' or 'describe' hazards cannot be practicably used and adequately assessed (Construction & Property Services Industry Skills Council, 2015). However, this project has demonstrated an assessment method as simple as providing photographic examples of job situations that involve assessment of manual handling risks can provide a very powerful tool. It not only assesses hazard awareness, but it can also demonstrate significant differences between learning outcomes across training types that a simple multiple-choice assessment cannot.

Conclusion

Industrial and commercial interest in VR desktop safety training (both induction and advanced levels) is high as it can potentially eliminate problems inherent with traditional methods, such as variation among skill levels of trainers and subjective influences, conscious or unconscious, when observational assessments of manual handling skills are made. It records individual scores in a manner that can facilitate for 3rd party verification of compliance to industry standards for increased transparency across sectors which rely on high numbers of registered training organisations such as construction.

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