FEASIBILITY STUDY
DEVELOPMENT AND DEMONSTRATION OF VIRTUAL REALITY SIMULATION TRAINING FOR THE BHPB OLYMPIC DAM SITE INDUCTIONS

Research Overview – November 2009
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Background
This research overview presents the findings of the project “Feasibility Study: Development and Demonstration of Virtual Reality Simulation Training for the BHPB Olympic Dam Site Inductions.”

The project was a collaborative exercise between the University of New South Wales (UNSW) - School of Mining Engineering, the University of Adelaide - Australian Centre for Visual Technologies (ACVT), BHPB Olympic Dam Expansion, RESA, TAFESA and Skills DMC.

The Chief Investigators were Dr Phillip Stothard UNSW and Prof Anton van den Hengel University of Adelaide and the project was intended as a pilot study that looked into the feasibility of developing interactive virtual reality simulations for mine site inductions in the hard rock industry of South Australia.

Many simulations had already been successfully implemented into the coal industry and the aim was to build a relevant pilot module that assessed a high risk environment on a surface mine that would also have application to the wider construction industry and other heavy industries.

The project collaborators came together as a group of parties interested in virtual reality simulation. The research, development and deployment, was jointly led by UNSW and the University of Adelaide. Invaluable input was provided by the industry collaborators.

The project had a value of $431,306. Of which $208,563 was in cash and $222,743 was in kind. The budget was fully expended during the course of the project.

The chosen subject area was ‘Working at Heights’ because it is a high risk area that has application on mine sites, construction sites and heavy industry in general. Substantial documentation, mining industry input and effort was placed on building the five sub-modules that form the Working at Heights module. These sub-modules are,

- Correctly Erected Scaffolding
- Incomplete Scaffolding
- Open Excavation
- Light Globe Change using Ladders
- Elevated Work Platform

The outcome of the research was a high quality generic interactive visualisation of an area of the Olympic Dam Mine Site (See Figure 1 and 2).

This high quality visualisation was enhanced by the inclusion of interactive events within the module that require the user to interrogate information within the virtual mine site and to assess and understand issues that arise when working at heights in relation ladders, scaffolding, open excavations and elevated work platforms.

3D Model and Interactive Module Building

Much project emphasis and time was placed on producing the 3D model and as much information as possible was placed into the module itself as this was to be a pilot example to show capability and possibilities to the Olympic Dam Expansion Project Team and the wider industry.

The module was built in 3D Studio Max and Maya which are common 3D modelling packages. The rapid prototyping was performed in a virtual reality / game engine known as Virtools.
At the project outset Virtools was used so that the capability of the Mining VR team at UNSW could be leveraged and also so that any ‘Working at Heights’ pilot module could be shown on a scaleable visualisation platform ranging from a 360 fully immersive system, down to a mobile laptop computer.

Virtual Reality / Game Engine Review

One of the project tasks performed was an evaluation and identification of available game engines with favourable functionality, licensing, access and community support. The outcome of the review was the recommendation that in any subsequent continuation in the development of the module, a substitute or alternative game engine should seriously be considered.

The report recommends that – depending on the planned visualisation platform for any formal deployment, the engine used should be either, Unreal Engine 3, Virtools or Ogre. If the clustering of PCs is not required, then the game engine Unity should also be considered. Ogre is considered the best ‘overall’ when considering platforms, price, quality and so-on.

Video Trace and Module Content

The development of the module leveraged OEM drawings, site drawings, photographs, videos and access to equipment hire companies. Collecting this information and building models is very time consuming.

The development team produced a fully interactive 3D model of the mine site environment to a high level of resolution and fidelity. However, model development time has always been a concern and the development of 3D models for the population of virtual reality or games is labour intensive and hence a general evaluation of the University of Adelaide’s ACVT VideoTrace software was performed from a developer and user perspective.

The outcome of these investigations was that VideoTrace is potentially a very powerful and fast tool for producing 3D models and although the study found limitations in its application and that some areas required further development work, the models produced to populate the model for level of detail and scene complexity were very good.

One project recommendation is that ACVT’s VideoTrace software continues to be developed and improved inline with the developer and user comments in the report as a matter of urgency.

Psychological and Educational Evaluation

An aspect of interactive 3D simulation development that must be considered is the psychological and educational evaluation of developed modules. Hence, the Working at Heights module was subjected to an experimental site deployment at Thebarton in Adelaide where engineering apprentices were exposed to the simulation.

A course was designed that implemented the simulation as part of a Working at Heights course. The outcomes from this evaluation from a trainee
The deployment at Thebarton showed the project teams how the interactive nature and instructional design of the module needed to be considered much more carefully with respect to cognitive load theory. That is, the training course developers and the module developers should consider the course design with respect to educational principles and engagement of the trainee.

A result of the experimental deployment was that one of the sub-modules was re-designed slightly and took into account more detailed cognitive load theory within the ladders sub-module. The module was then formally assessed for its benefits compared to traditional PowerPoint delivery under scientific conditions.

Figure 3. Experimental Module Deployment

The outcomes of the controlled study produced some interesting results and found the following.

Firstly, research into virtual reality environments remains fragmented. However, in recent years, an important expansion of work has centred upon the educational value of virtual environments. This field of work on virtual reality learning remains in its formative years. The current study endeavoured to add to this growing body of research, by answering the following questions below.

**Do more immersive learning environments promote a stronger sense of presence than non immersive learning environments?**

The current study hypothesized that more immersive learning environments lead to a greater sense of presence. By comparing presence questionnaire scores across the PowerPoint and Virtual Reality Group conditions, a significant difference was found. The overall presence experienced by students was significantly greater in the immersive training group, with a stronger sensation of “being there” experienced when the training was delivered as a virtual reality desktop display, rather than a PowerPoint presentation. A virtual on-site experience is the goal of simulation. Therefore, the current experiment yields evidence that media has an effect on student’s sense of presence.

**Do more immersive learning environments endorse more (or less) learning than non immersive learning environments?**

There are conflicting arguments within the literature with regards to the impact that immersion has on learning. One group argue that learning in immersive environments is promoted through an increase in presence and interest, and a decrease in cognitive load. Whereas others argue that immersion inhibits learning as individuals become distracted and overloaded.

Within the project, a comparison was made in regards to learning (recall, quasi transfer and retention) between the PowerPoint and Virtual Reality Group conditions. The Virtual Reality Group was presented with an immersive learning environment and experienced a higher sense of Presence. This did not lead to a significant difference in learning in comparison to those presented with a no immersion PowerPoint.

While both groups experienced a slight knowledge retention loss, no significant difference was found between the two groups. An increased sense of presence did not lead to an increase or decrease in learning. In addition, in relation to interest theory, as measured by the satisfaction survey, there was no significant difference between the levels of interest the two groups experienced.

The findings of the current experiment are not consistent with the view that immersion promotes learning, nor that immersion impedes learning. It is
Does active learning in virtual reality environments endorse more (or less) learning than passive learning in virtual reality environments?

There exists a debate whether active learning (whereby the user has control of the virtual reality environment) leads to an increase in learning. Within this study, a comparison was made in regards to learning (recall, quasi transfer and retention) between the passive virtual reality group and active virtual reality individual instructions. While presence experienced was similar across both groups, a significant difference was found across learning for the two conditions. By involving students in the learning task, the active group (i.e. virtual reality individual) experienced significantly greater scores on both knowledge tests. This finding is consistent with the view that active learning in virtual reality environments promotes more learning. Furthermore, a certain level of guidance was provided for those actively controlling the virtual reality system (namely directional arrows), it is suggested that the active learners experienced an appropriate level of cognitive load. In addition, due to their lack of involvement, it may be the case that the passive group were in fact underloaded, thus creating boredom, inattentiveness, and a reduction in learning.

Overall, this is a promising finding for virtual reality training, as the advantages of individual learning have the potential to transcend into distance or mobile learning. Within the mining sphere for instance, due to the isolated nature of many sites, the opportunity to train new employees on safety processes before they arrive at the site (i.e. on the home PC) is not only appealing logistically, but also has the potential to save time and money.

The conclusions drawn in this study are influenced by both the participant’s familiarity with the technology and also the topic at hand. Participants in this study were novices to mining safety this lack of meaning may negatively influence the level of presence the individuals experience. Furthermore, fully immersive virtual reality technologies were not adopted in this study. While objects in the desktop display virtual reality were three dimensional, reality could still disappear with the wave of a hand. Thus in certain cases, the immersive effect of virtual reality may have become jeopardised.

Conclusions drawn regarding the retention loss from the two knowledge tests should also be considered. Within this study, the retention loss findings were somewhat confounded by the test medium. While the questions presented in both tests were identical, Test 1 was presented using virtual reality technology, and Test 2 using Microsoft Word. Furthermore, while Test 1 was presented to all participants using the same computers, Test 2 was displayed on participants’ home computers, resulting in a lack of a common platform (such as different sized screens).

Finally the role of social context should be considered. Several theories state that students working in small groups produce higher achievement that students working alone. Yet within this study, overall those training individually yielded higher knowledge scores. To date within virtual reality research there remains a lack of empirical evidence surrounding the influence of social context.

In relation to future directions, additional research is required in order to explore the circumstances is which virtual reality environments can promote learning. For instance, would there be a variation in the findings if the training was longer (i.e. more than one module)? In addition, would the results vary if mining experts were scientifically tested rather than novices to mining safety? As mentioned above, social context may also influence the results. Thus it is also suggested that future directions consider the inclusion of a comparison group, namely PowerPoint in individual setting. In doing so, the influence of social context (i.e. group versus individual) on learning in both PowerPoint and virtual reality can be established. It is also suggested that future research examines the influence of screen size (i.e. large versus small) to determine whether this affects presence and/or learning. Furthermore, as mentioned above, fully immersive virtual reality environments were not included in this study. As
such, future research could also include the examination of mining safety training through 360 degree displays.

In relation to cognitive load, it may also be the case that the content of the safety training is not taxing enough, thus creating a cognitive underload. While ceiling effects were found in this study it would be unethical to make the training more complex, as it relates to occupational health and safety. However, future research could involve other forms of skills training. In addition, future research could also include measures of cognitive load, to determine in what virtual reality training settings cognitive underload and overload takes place.

In summary, while the BHP Billiton ‘light globe’ virtual reality training module facilitated an increase in presence, in comparison to the PowerPoint instruction it did not promote an increase in learning (recall, quasi-transfer and retention). Furthermore, trainees experiencing the virtual reality environment did not experience a significantly greater level of enjoyment (as measure by the entertainment item in the satisfaction survey). As a result, in relation to Kirkpatrick’s framework, the virtual reality module was not more ‘effective’ than the PowerPoint instruction. However, promising findings did eventuate when the trainee was given control over the virtual reality environment. Overall, the findings from this study reveal that virtual reality technology does not always promote an increase in learning. Thus to ensure that virtual reality is an effective instructional tool, immersion, fidelity and human learning have to be taken into consideration.

This will be achieved through the cooperation of instructional and technological experts during the design and development of virtual reality tools.

**Olympic Dam Deployment**

The ‘Working at Heights’ module complete with the modified scenario was deployed on site at Olympic Dam and implemented into the Working at Heights course. The accommodation of the module at Olympic Dam is acknowledged. Figure 3 shows the facility.

The outcomes of the deployment at Olympic Dam were positive and revealed that for any module deployment, the module must be ideally be implemented into a purpose built facility with appropriate support. The installation at Olympic Dam was temporary and not an ideal set up. Nevertheless, the deployment was useful and in future iterations, the developed content and simulation course structure must be developed in closer consultation with the trainers who will use the module. This will promote ownership on site which is essential.

Aspects of simulation course design with respect to cognitive load theory must be implemented as found in the educational evaluation. The course design must also reflect and consider the people that will use the simulation – it must be cognisant of their abilities and experience. That is, the people on site are practical, intelligent and like to experience things hands on simulation and training must take this into account. In general, during the deployment the trainees liked the interactive nature of the simulation, but they are practical and want to do things in the simulation – not just observe.

Any subsequent virtual reality course material should get the trainees to problem solve and interact personally with the material at a level relevant to their prior knowledge. The cognitive load on the trainees must also be considered both within the simulation module and the course as a whole.

Trainees must also be able to engage with the training material and be able to directly relate and apply the solution of problems encountered and learned about in the simulation to a real mine site. They need to transfer safe human responses from the simulator to their work environment and demonstrate competency for the outcome to be truly positive.

**Project Risk**

Unfortunately, the module suffered the unforeseen impact of the global financial crisis with the Olympic Dam Expansion Project Team members being retrenched. This severely
impacted on the project budget and the outcomes of the project.

The Olympic Dam Site has since accommodated the project, but the momentum in the project was unavoidably impeded due to limited budgets within that organisation, logistics issues, the distances involved and impact on daily operations. However, the accommodation of the site deployment and travel by BHPB OD is gratefully acknowledged and allowed the project to come to completion.

The perseverance and patience of all the team members in getting this project to completion is also recognised.

Another serious impact on the project as a result for the global financial crisis was the liquidation of the company that supplies Virtools licenses. The agreements negotiated and in place with that company ended when the supply company folded and subsequent re-negotiation has impacted on the project deliverables. This has however been resolved via a web-player conversion.

In future projects and with hind site, a project risk assessment should be performed to assess the impact of such unforeseen events. The impact on small short term projects such as this can be extreme.

Conclusions and Recommendations

A high quality pilot simulation module and pilot project feasibility study has been performed and implemented.

The outcomes have been,
  - Identification of software components for model building and interaction.
  - Building of a usable Working at Heights module through industry consultation.
  - A formal evaluation of ACVT’s VideoTrace.
  - Formal psychological and educational evaluation of the module and design considerations.
  - Prototype Field trials.
  - The module has also been deployed at Olympic Dam in Pilot format and a future direction for the module identified.

The recommendations are,
  - A project risk assessment should be performed prior to commencing any future project.
  - Development of the Working at Heights and other modules should continue.
  - Psychological and educational design of the module with respect to cognitive load theory is a priority. The course and module may not be delivering what we want it to.
  - Experienced researchers and educational psychologists at University level should be closely involved in any subsequent virtual reality course material development on this or other projects.
  - Simulation training course material should be performed in collaboration with industry trainers and adult educational establishments to achieve the best outcome.
  - A formal simulation course should be designed that incorporates and leverages the existing simulation - Working at Heights.
  - Module development must be based on a formal specification derived prior to any work being performed. This should be a considered a priority.
  - A commercial entity should be used to produce both the model and module.
  - Future modules should be deployed via a large screen group environment on site in a purpose built facility.
  - Future modules should also be made accessible offsite (as appropriate) to ensure that modules are available to the widest possible audience.
  - A formal investigation and experimental process should be designed at University level to assess the issue of demonstrating competency in Working at Heights and other high risk activities in computer-based environments. At present the modules do not do this and a great deal of work needs to be done to address this area.
  - Federal and State Government Funding should be the target for future simulation projects and should be combined with industrial funding where possible.
  - Any future project should be a strategic project of approximately three years duration.
Finally, any site implementation requires a person experienced in technology transfer and this person should be site based for periods of time to ensure a smooth transition of virtual reality simulations into industry.

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References


Information

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