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Evaluating Virtual Reality-based Training Programs for Mine Rescue Brigades in New South Wales (Australia)

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Evaluating Virtual Reality-based Training Programs for Mine Rescue Brigades in New South Wales (Australia)

This thesis is submitted in fulfilment of the requirements for the award of the degree

Doctor of Philosophy

from

UNIVERSITY OF WOLLLONGONG

by

SHIVA PEDRAM

Faculty Engineering and Information Science

School of Computing and Information Technology

CERTIFICATION

I, Shiva Pedram, declare that this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Faculty of Engineering and Information Science (EIS), School of Computing and Information Technology (SCIT), University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. This document has not been submitted for qualification at any other academic institution.

ABSTRACT

Most safety critical industries such as mining, rail or aviation aim to comply with Highly Reliable Organisation (HRO) standards. HROs have been defined as organisations that operate in hazardous conditions but manage to maintain almost error-free levels of performance. Accidents do not occur in isolation, they are usually the consequence of a chain of events ranging from the organisational level to unsafe acts of individual employees. Hence, it is of prime importance to design and deliver effective training programs that can not only expose workers to workplace hazards but also, and more importantly, ensure that this knowledge is adequately mobilised later on. The Australian mining industry has steadily achieved remarkable performance and safety results through the continuous improvement of its training standards. Virtual Reality-based (VR-based) training is the most recent technology used to enhance miners' competencies in a safe and controlled environment that allows for replicable testing of extreme event scenarios. Like any other training method, VR-based training needs to be assessed in order to evaluate the advantages and limitations of this innovative technology, compared with more traditional approaches. Our research aims to design and implement an evaluation framework that can be used to assess VR-based training programs across four dimensions: (1) the actual training needs, (2) the limitations of traditional training approaches, (3) the theoretical capabilities of VR environments for training purposes and (4) the perceived learning outcomes.

Our research was conducted in collaboration with Mines Rescue Pty Ltd, a training provider for the coal mining industry in Australia, and focussed on training programs developed for mine rescue brigades. These brigades are made up of highly specialized volunteers who are the primary responders for major mining incidents or accidents. The study examined the relationships between the training needs of 372 trainees, the technological capabilities of two VR training environments (360-degree immersive theatre and a desktop interactive simulator) and the implementation of training scenarios over a twelve month period. Our mixed-method approach included direct observations of training sessions, pre- and post-session surveys of trainees and interviews (including competency tests) with trainers and VR program designers. The findings suggest that VR-based training programs are able to address the identified training needs and overcome some of the limitations and constraints of traditional onsite training. The study also highlights current weaknesses of the VR technology-in-use and suggests future enhancement pathways. The assessment framework is generic enough to be easily adapted for other training objectives in the mining industry or for other high risk industries.

Keyword: virtual reality, safety training, mining industry, assessment framework

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I would like to acknowledge the Health and Safety Trust, from Coal Services Pty Ltd, for their financial support that was instrumental in expanding our study from one to four training facilities.

A special thanks to my family and my partner Amir. Words cannot express how grateful I am to my mother, father, brothers and my partner for all of the sacrifices that you've made on my behalf. Your prayer for me was what sustained me thus far. I would also like to thank all of my friends who supported me, and incensed me to strive towards my goal.

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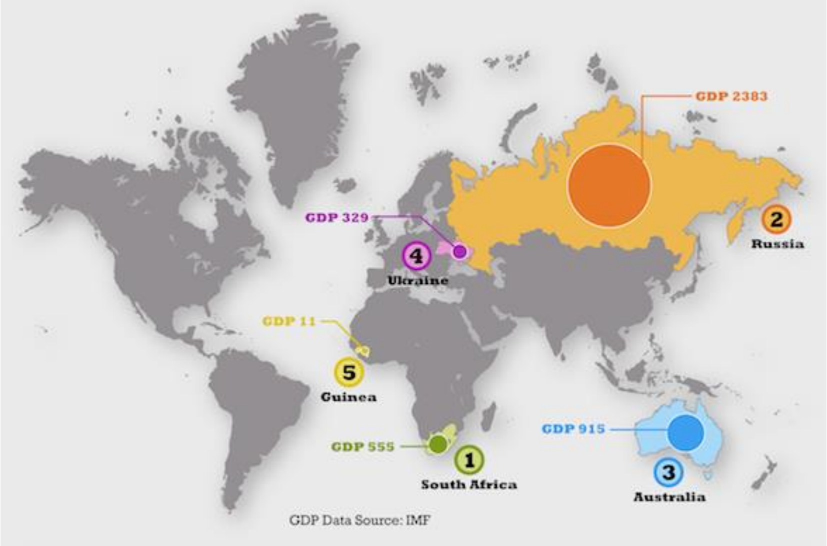
Chapter I: Introduction

1.1 Safety records in the mining industry

Mining industries are a major source of wealth for many countries. Around the world, countries such as Russia, Australia, South Africa, Ukraine, Guinea and USA are highly reliant on income from their mining activities. Figure 0-1 below shows the top five countries around the world in terms of mining and their gross domestic product (GDP).



GDP Data Source: IMF

Figure 0-1: Top five mining countries and their GDP (Australian Mining Media 2013)

The mining industry is usually categorised into three sectors: coal, non-coal and petroleum (Trade and Investment Resources and Energy, 2012). The non-coal sector is further divided into three sub-groups: metalliferous (including metals and mineral sand), extractives (including construction and industrial materials) and others (including gemstones). According to Azapagic (2004), 1% of the world's workforce was involved in the mining industry in 2004.

Even though the mining industry is a great source of wealth, historically it has been one of the most hazardous industrial activities in the world. Although, safety in mining operations has progressively become a priority for most mining companies and governments, miners continue to be exposed to potentially dangerous situations where serious injuries or fatalities might occur. Figure 0-2 summarises the breakdown of 2803 internationally reported incidents per agent of fatality (NSW Resources and Energy, 2014). Apart from fall of roof/sides/high-wall category, operational incidents like unintentional use of equipment or contact with moving/rotating plant are becoming prime causes of injuries and fatalities (All mining sectors included).

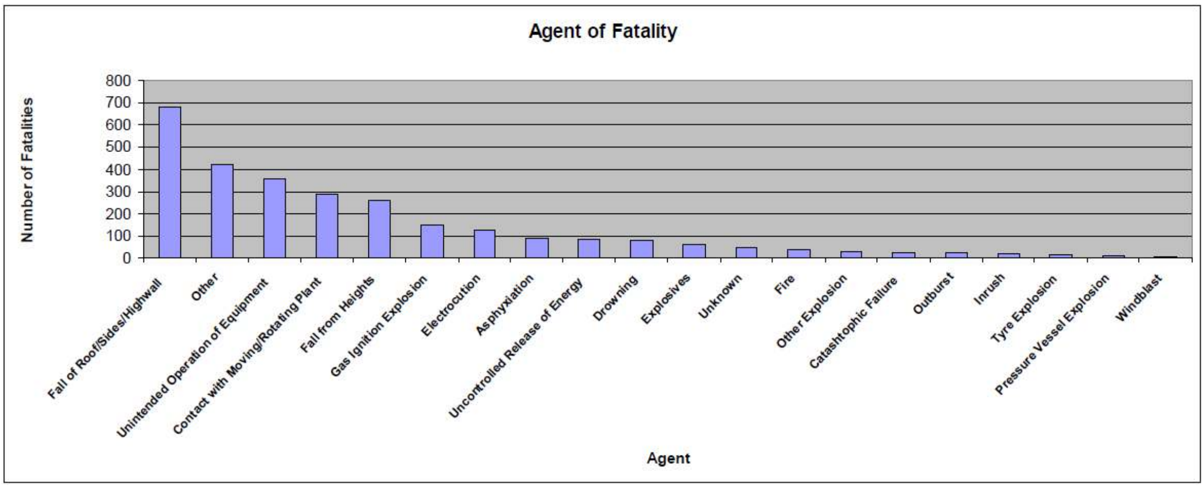


Figure 0-2: Number of international mining incidents per agent of fatality (NSW Resources and Energy, 2014)

In 2013, 2.2% of the Australian workforce, around 245,000 people, was employed in the mining industry (Safe Work Australia, 2014). Figure 0-3 shows the evolution of the fatality rate (grey line) and number of fatalities (red line) for the Australian mining industry for the period from 2003-2013. Fatalities peaked in 2007, when 311 people were killed in mining accidents.

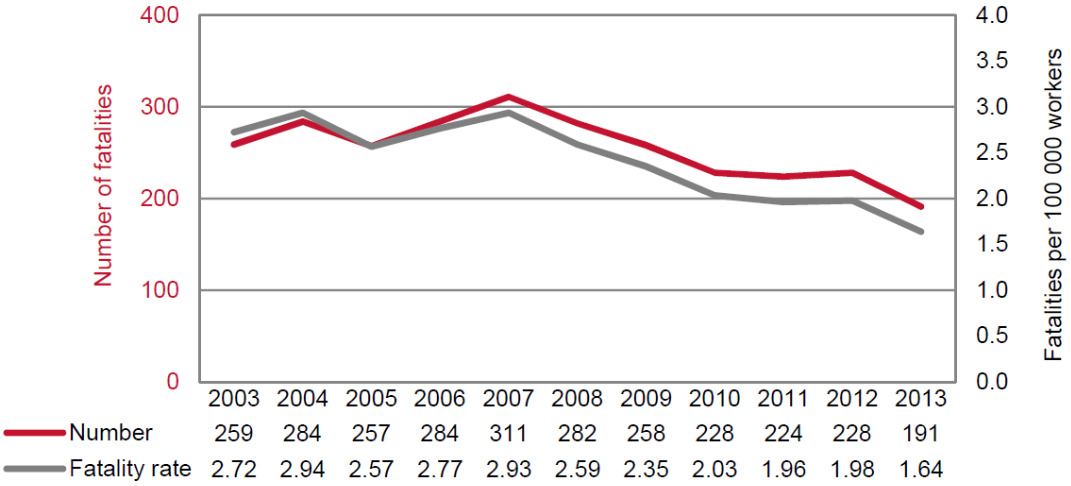


Figure 0-3: Number of fatalities in the mining industry; 2003-2013 period (Safe Work Australia, 2014)

In 2013, 3765 mines were recorded as being active in the State of New South Wales (NSW). Figure 0-4 provides the number of incidents and their causes as reported by the NSW Trade and Investment Organisation between 2004 and 2014 in NSW. These figures show that local statistics – across all mining sectors – follow international trends (Figure 0-2) with mechanical equipment (mobile), work environment problems and electrical energy being major causes of incidents (injuries and fatalities) alongside more traditional causes like gas. Over the 2007-2014 period, 90% of these incidents occurred in coal mines (underground and open-cut).

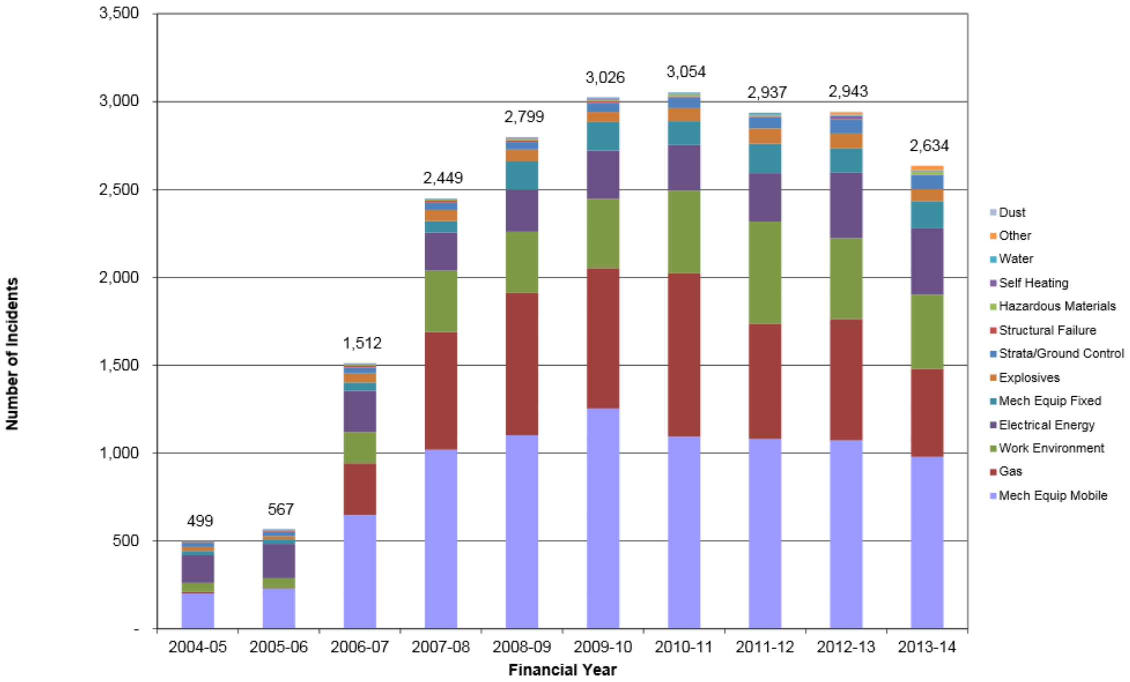


Figure 0-4: Reported mining incidents in NSW; 2004-2014 period (NSW Resources and Energy, 2014)

During the same reporting period, the average Fatal Injury Frequency Rate (FIFR) decreased by 65.1% and the overall lost time injury frequency rate (LTIFR) by 58.4%. However, the total number of reported incidents increased by 7.5% between 2007 and 2014 (unfortunately methods of reporting prior 2007 do not allow for proper comparison). Although minor incidents do not include fatalities or severe bodily harm, they require significant human resources to respond to the incident, investigate its cause and mitigate its re-occurrence, not to mention eventual down time of equipment or shut down of the mine itself.

According to Willamson (1990), 60% of mining accidents in Australia are (still) due to human errors. Likewise, the US Bureau of Mines has reported that almost 85% of all accidents resulted from at least one human error (Rushworth et al., 1999). Examining 1334 incidents recorded in Australian mines, the NSW Resources and Energy 2014 report (2014) estimates that 20% of them were due to procedural errors and 2% to direct misconduct. The report also identified that nearly 27% of these incidents happened during production activities, 17% during transportation activities and 14% during maintenance activities.

Failure to notice a hazard has been identified as a main cause of fatalities as well as non-fatal incidents (Kowalski-Trakofler and Barrett, 2003). Hence, there is a strong incentive for the mining industry to investigate and identify the factors which contribute to human errors and understand the reasons for workers to make such mistakes.

1.2 Classification of human errors

In safety critical industries such as mining, rail or aviation, the role of human factors in accidents is of prime importance. For example, around 70% of civil and military aviation accidents result from human error (Wiegmann and Shappell, 2001). While there has been a dramatic decline in mechanical failure rates over time, human errors have not changed substantially. Until now most incident investigations have focused on engineering and mechanical failures, with comparatively little research on human errors (Tichon and Burgess-Limerick, 2011). Unlike the tangible and quantifiable data available about mechanical failures, human errors are qualitative and as a result the accident database on their contributions is sparse and ill-defined (Patterson and Shappell, 2010).

1.2.1 Human Factors Analysis and Classification System (HFACS)

The Human Factors Analysis and Classification System (HFACS) is a systematic approach developed by Wiegmann and Shappell (2005). It is based on Reason's concept of latent and active failures (Reason, 1990). Reason defines deficiencies as "holes" at the organizational level, which could be categorized as either active or latent failures. Active failures refer to the unsafe acts of operators who are in direct contact with the system that can cause incidents. These active failures can further be classified as mistakes or violations and occur as the result of intentional or unintended actions. Unintended actions are automatic actions that result from attentional failures or memory lapses. Mistakes occur when the employee fails to complete the action as intended or if the action was not a suitable reaction for the particular situation. Violations refer actions where the employee intentionally bends the rules and regulations. This results in a latent system condition which promotes errors and weakens the system's defences (2000). Finally the combination of active and latent failures causes incidents (Figure 0-5).

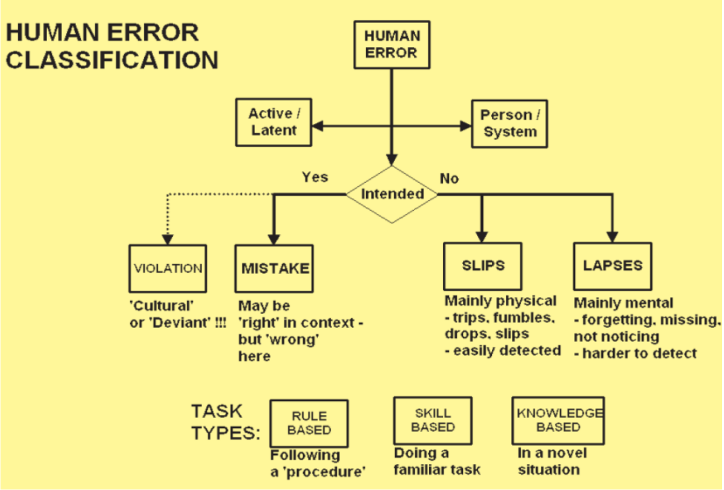


Figure 0-5: Human Error Classification (Trade and Investment Resources and Energy, 2013)

The HFACS framework was originally developed for, and used by, the US Navy and Marine Corps. HFACS has been implemented in various hazardous industries, such as:

- Civil aviation (Wiegmann and Shappell, 2001, Wiegmann et al., 2005, Shappell et al., 2007),
- Air traffic control (Broach and Dollar, 2002),
- Logistics (Reinach and Viale, 2006, Baysari et al., 2008, Celik and Cebi, 2009), and
- Medicine (ElBardissi et al., 2007).

Patterson and Shappell (2010) later developed a conceptual model specifically for the mining industry, known as HFACS-MI (Figure 0-6). HFACS is a systematic and evidence-based framework aimed at designing, assessing and enhancing interactions between individuals, technology (including equipment) and the organisation (Wiegmann and Shappell, 2001). The framework helps organisations identify plausible human factors that could lead to human error. HFACS describes human error at each of four levels of failure: 1) the unsafe acts of operators, 2) the preconditions for unsafe acts, 3) unsafe supervision, and 4) organizational influences and outside factors.

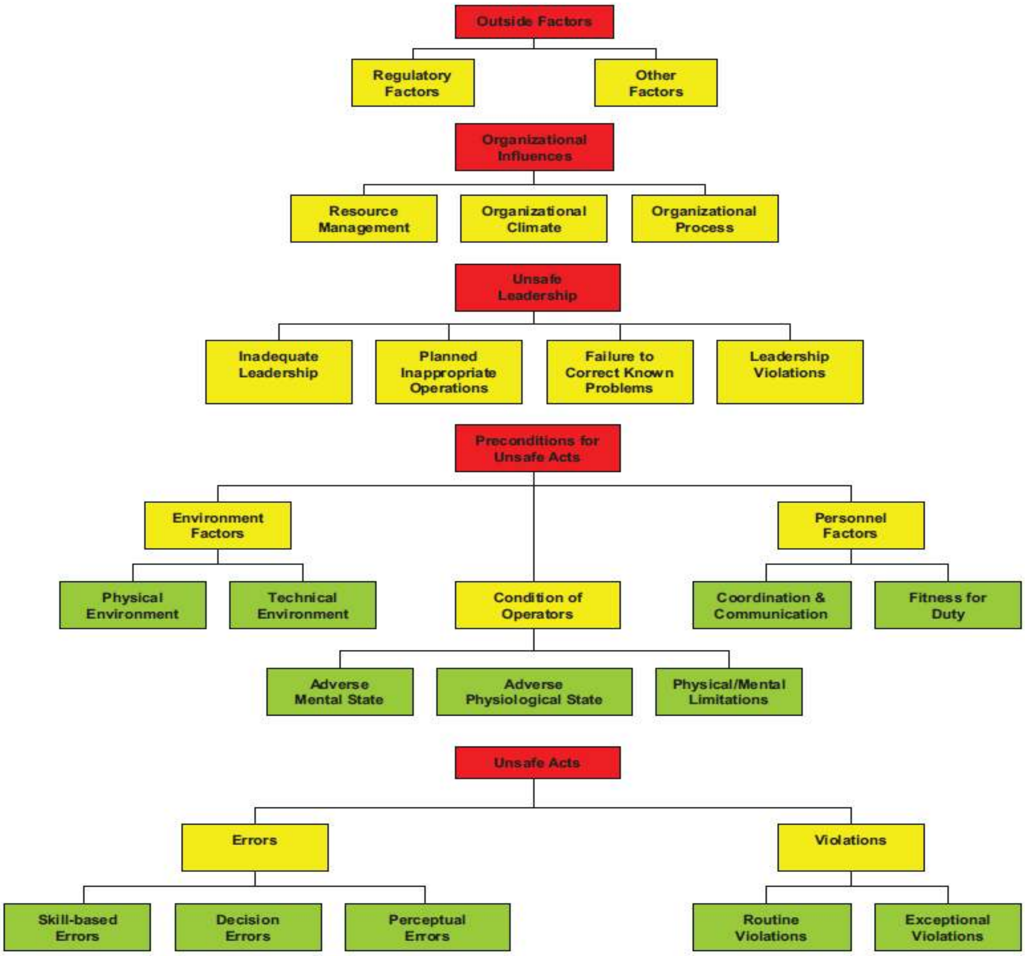


Figure 0-6: Human Factors Analysis and Classification System for Mining Industry (Patterson and Shappell, 2010)

1.2.2 Details of HFACS-MI classification

Unsafe acts

Such unsafe acts can be divided into **errors**, where the activity is legal but fails to reach the required outcome, and **violations**, where the employee wilfully bends the rules. **Errors** can be sub-divided into:

- **Decision errors** which represent intentional actions that proceed as intended, but which prove to be inadequate or inappropriate for the situation. Decision errors or "honest mistakes" (Wiegmann and Shappell, 2001) can categorised as either *rule-based errors*, *knowledge-based errors* or *problem-solving errors*. Rule-based errors occur when a particular situation is either not understood or misdiagnosed, and thus an incorrect/inappropriate approach is applied. By contrast, knowledge-based errors occur when an incorrect/inappropriate approach is chosen from the different plan options (Patterson and Shappell, 2010).
- **Perception errors** occur when there is some sort of sensory limitation (for example a miner is working underground in limited visibility conditions due to low light). While environmental effects on employees have received little research, they can directly affect the performance of employees.
- **Skill-based errors** (or routine disruption mistakes) occur when the employee becomes comfortable and familiar with the task, and as a result, after a while, he/she no longer puts the required attention into the task, leading to mistakes. Wiegmann and Shappell (2001) report that from a total of 119 accidents in commercial aviation in the USA (1990-1996 period), 60% were attributed to skill-based errors and 29% to decision-based ones. Patterson and Shappell, (2010) report that from a total of the 508 mining incidents in the Queensland, 50% were attributed to skill-based errors and 41% to decision-based ones.

Violations can be classified as **routine violations** and **exceptional violations**. Routine violations refer to disobeying rules made by the organisation. These sorts of violations occur frequently and in order to prevent them it is necessary that these rules are enforced. Exceptional violations refer to the wrongful acts of operators – these violations are unpredictable and hard to detect.

Preconditions for Unsafe Acts

The preconditions for unsafe acts are generally categorized as latent system errors which can lie dormant for long periods of time before causing an accident. Understanding the preconditions that workers are placed under should help identify areas for organizational improvement. The preconditions for unsafe acts include environmental factors and personnel factors:

- **Physical environment**: This includes both the operational environment (tools and machinery) and the ambient environment (e.g. the temperature and weather). The physical environment in mining operations is usually hazardous. Miners, especially those working underground, are often exposed to high temperatures (which can result in reduced attention), dusty conditions (that reduce visibility), and dehydration, all of which can contribute to unsafe acts (Patterson and Shappell, 2010).

- **Technological Environment**: It refers to the interactions between the operators and equipment. In Australia, most mining machinery and equipment is imported from overseas and designed in countries that may have different standards.
- **Conditions of Operators**: This may refer to an adverse mental state (such as mental fatigue, distraction, frustration, or a lack of motivation) or an adverse physiological state (such as a medical condition) of the operators.
- **Physical/Mental Limitations**: In some situations the required activities may exceed the physical or mental capabilities of the operator. For example, it is hard for some individuals to operate complex or heavy duty machines, or they may not able to tolerate tough physical environments etc., which may impact the quality of their performance.
- **Communication and Coordination:** Both communication and coordination are essential for industry success. Lack of proper communication and coordination can lead to confusion between managers, personnel and contractors. The outcome of poor communication and coordination is often work breakdown and failure.
- **Fitness for Duty:** It is important that employees turn up to work in conditions that let them perform at their best. For example, lack of sleep, an unhealthy diet, and the consumption of either alcohol or drugs before their shift will have a negative impact on their performance.

Unsafe Leadership

The actions and decisions of workers in leadership positions can affect the industry at all levels. This category can be divided into 4 levels of:

- **Inadequate Leadership:** Leaders are responsible for providing a safe work environment for operators. For example, leaders authorize and arrange the training for their employees. If appropriate training opportunities are not provided then employee competency and skill level may fall below the standards required to act safely. Likewise, it also the leader's responsibility to provide employee oversight in order to prevent repeated violations.
- **Planned Inappropriate Operations:** Some activities might put operators and employees at an unacceptable level of risk. These actions might be acceptable in emergency situations but should be avoided in normal situations. For example, giving extra shifts to workers after the completion of a long shift.
- **Failure to Correct Known Problem:** Such failures occur when a problem has been identified but no action has been taken to correct the situation. This might arise when supervisors or managers are

not around. Creating a culture of care where everyone takes part in correcting problems will help to maintain the safe environment.

- **Leadership Violations:** These sorts of violations refer to situations where rules and regulations are wilfully neglected by leaders (i.e., where disobeying the rule is the dominant culture; this is rare in real life).

Organizational Influences

Organisational failures, industry deficiencies and outside factors are difficult to detect and identify, unless a clear understanding of the organisation framework has been provided. Also, identification of causal factors at this level can also be covered up by the reluctance to place blame on the company for fear of liability.

1.3 Managing critical incidents

Accidents, failures and mistakes potentially leading to disastrous outcomes, are to be expected in complex socio-technical systems. However the aim is to minimise errors as much as possible. As the level of the complexity of the systems or organisations increases, management of the system's risk and safety level becomes a challenging task (Madni and Jackson, 2009). There is a strong need for these systems to develop **resilience engineering**, defined by Madni and Jackson (2009) as a "*proactive approach that manages the monitoring of system's risk and the balance between safety levels and productivity*". In a resilience engineering framework, failure refers to the inability of the system to adapt to the changes with limited and pre-determined resources and time. By contrast, success refers to the ability of the system to adapt to the changes in risk profile and take appropriate actions to avoid disastrous damage. Madni and Jackson (2009) measured success as the capability of the system to predict and anticipate risk prior to it occurring and causing damage. Resilience may be interpreted as swift reaction while adaptation requires long-term learning. Madni and Jackson (2009) argue that for some systems (e.g. air traffic) it is safer and more reliable not to fully automate the system as it is necessary to maintain human detection and handling of unpredicted situations. Therefore, it is critical to have competent workers.

However, under the high pressure of production, safety practices might not be followed properly, potentially leading to critical disruption. A disruption refers to any event or conditions that interrupt the usual operation of the system. Disruptions can be due to operational contingencies, natural disasters and financial meltdowns. Humans can have dual roles, sometimes they are the source of the disruption and sometimes they must respond to the disruption by adapting to the new situation (Madni and Jackson, 2009).

There are two major schools of thought that aim to explain accidents which occur in complex organisations and hazardous environments: the Normal Accident Theory (NAT) and the High Reliability Organisation (HRO) approach.

According to the Normal Accident Theory (NAT) accidents are unavoidable in complex organisations that operate in high-risk and technology intensive situations. Perrow (2011) proposes that failures can occur due to two main characteristics of these types of organisations: tight coupling and interactive complexity. However, Leveson et al. (2009) argue that Perrow's (1967) categorisation of industries as either 'high risk' or 'low risk' is too broad to be meaningful in regards to revealing incidents rates. Importantly, they argue that NAT fails to suggest how the risk of accidents may be reduced (Hopkins, 1999).

By contrast, the High Reliability Organisation (HRO) approach states that accidents in complex organisations and hazardous environments are avoidable because processes can be put in place to efficiently prevent and avoid catastrophic errors, helping them to attain a consistent record of safety over long periods of time (Roberts, 1990, Porte and Consolini, 1998). By definition HRO-oriented industries: (1) should be preoccupied with failure; (2) should not take previous successes for granted; (3) assume that their cumulative knowledge is fragile and that there is potential for failure; (4) require a means to identify potential problems; and (5) should take the appropriate course of action if problems arise (Madni and Jackson, 2009). According to this HRO approach, safety is regarded as an ongoing process and a dynamic capability which is required to be reinforced and invested. Madni and Jackson (2009) argue that safety is based on 'what an organisation does' other than 'what an organisation has'. Learning orientation, continuous training, and prioritizing safety all contribute to increase safety records (Roberts et al., 2001).

While NAT assumes that accidents are unavoidable, the HRO approach suggests that training has the potential to improve safety. Accordingly, this thesis favours the HRO approach.

1.3.1 High Reliability Organisations (HROs)

Highly reliability organisations (HROs) have been defined as organisations which operate in hazardous conditions but manage to maintain almost error-free levels of performance (Weick and Sutcliffe, 2011); in such organisations the consequences of any error can often be disastrous.

There is an abundant literature discussing the characteristics of an HRO, the key features that need to be adopted to create an HRO, and the ways that are needed to control the risks facing hazards organisations. The following facets and processes are characteristic of HROs (Weick and Sutcliffe, 2011):

1. **Successful containment of unexpected events:**

- Having back-up systems and redundancies in place; double checking decisions.
- Enabling experts, regardless of rank or position, to make critical safety-related decisions.
- Clear hierarchical structure and understanding of decisional chain.
- Proper investment in training and technical competence.
- Well-defined procedures for all plausible unpredicted events.

2. **Effective anticipation of potential failures through:**

- Sensitivity to operations.
- Preoccupation with failure, including seemingly insignificant incidents.
- Avoiding simplifying and making assumptions regarding the nature of past failures.
- Avoiding a culture of blaming individuals or operators.

3. **A just culture:**

- Employees must be able to report near misses and accidents without fear of being punished.
- After identifying the reason for the accident, corrective actions should follow.
- Empowering employees to carry out their responsibilities on safety grounds.
- Encouraging employees to be more accountable for their own safety.

4. **Learning orientation:**

- Constant technical and non-technical training.
- Systematic analysis of incidents to identify the reasons for, and the types of, accidents.
- Proper investigation and open communication about accidents and their outcomes.
- Updating procedures in line with the organisational knowledge base.

5. **Mindful leadership:**

- Identifying similar accidents and conducting audits to recognise the underlying problems.
- Creating a culture of communicating bad news from the operational level to leaders.
- Building the capability of leaders to manage the balance between profits and safety.

Although Weick and Sutcliffe (2011) acknowledge that mistakes can still happen in HRO-oriented organisations, they argue that the severity of incidents and long-term consequences (such as the loss of reputation or liability) will be less damaging compared with non-HRO-oriented organisations.

Our objective is to investigate the potential for Virtual Reality-based training to contribute to an HRO approach in the mining industry, using the HFACS-MI framework to evaluate training content and outcomes. In order to firm up our research questions we need to examine key aspects of learning and vocational training approaches that will inform our methodological framework.

1.4 Vocational safety training in the mining industry

(Madni and Jackson, 2009) identify two types of safety training for high risk industries such as the mining industry. The first one focuses on prevention by learning to recognise hazards and avoid incidents. The second one is concerned with the management of incidents when they occur. Based on extensive study of safety training programs in the US mining industry, Peters and colleagues (2010) conclude that trainees must have hands-on tasks when training their motor skills and that these motor skills need to be repeated otherwise they will be forgotten later on. Their study included two groups of trainees: control and treatment. The control group did not receive any further training and after a year they were unable to recall the procedures, while the experimental group had refresher training throughout the year and at the end 65% were still able to perform up to the required standard.

Moreover, based on their review, they published a list of recommendations for effective training: "*1) only one procedure should be taught; 2) training should be hands-on, with evaluation and feedback; 3) training ought to be conducted out of mine to minimize the interruption of production; 4) hands-on practice should be scheduled as part of fire drills and other emergency preparedness routines; 5) training models with easily cleaned and replaceable mouthpieces ought to be used; 6) distributed mental rehearsals could be provided between hands-on practice sessions; and 7) trainers should sample their workforce periodically and do spot evaluations in order to keep track of proficiency levels, with remediation given as needed*" (Peters et al., 2010).

Henceforth, it seems natural that the coming of age of VR-based training in the defence, aeronautics and automotive industries led to their appropriation by the mining industry in order to address several of the aforementioned recommendations (Tichon and Burgess-Limerick, 2011). For example, the American Mine Safety and Health Administration made an early call for advanced training environments (Filigenzi et al., 2000), as well as the South African Mine Health and Safety Authority (Kizil, 2003). Following Pithers (1998), these vocational training programs are generally competency-focused in order to ensure that training content translates into effective learning and long-lasting skills.

1.5 Research Objectives

In this chapter we have established the importance of safety standards for the mining industry and the importance of human errors in the occurrence of incidents, some of them resulting in the loss of lives. We have also established that competency-focussed training plays a major role in ensuring that workers contribute to the existence of High Reliability Organisations (HROs) despite hazardous environments and operations. Drawing from existing VR-based training programs delivered to the underground coal mining industry in New South Wales (NSW, Australia), we wish to address the following questions:

- What are the actual training needs of underground coal miners?
- What are the inherent limitations of traditional training for underground coal miners?
- What are the potential capabilities of VR-based training to address these limitations?
- Which factors influence the effective delivery of VR-based training?
- How VR can enhance training programs for the underground mining industry? rather than just answering if VR influences the learning outcome?

Answering these questions will help us to address the overall aim of this research:

Evaluating Virtual Reality-based Training Programs for Mine Rescue Brigades in New South Wales (Australia)

In order to achieve the aim of this study, the following research activities will be conducted:

- A review of the existing evaluation techniques will be conducted.
- The factors affecting the learning process and its outcomes will be identified.
- An analytical and methodological evaluation framework will be developed.
- The systematic framework will be applied to existing VR-based training programs.
- A generic VR-based learning model will be inferred from the above case study.

1.6 Organization of the thesis

This thesis examines the use of VR-based training for mine rescue brigades in NSW, Australia. Chapter II reviews the available literature on VR-based training approaches and on current training evaluation techniques. Then, Chapter III describes and justifies our systematic evaluation framework, as well as quantitative and qualitative methodologies. Chapter IV presents the results of our evaluation for two VR environments (360-VR and Desktop-VR). In Chapter V, our results are interpreted and discussed in relation to relevant literature. Finally, Chapter VI concludes on the contribution of this study to the advancement of knowledge and proposes directions for complementary research addressing some of the limitations of our study.

2 Chapter II: Literature Review

2.1 Technology-Mediated Learning

Learning can be defined as a psychological process involving a change in the way a person responds to a situation based on experience (Pithers, 1998a). This change might be reflected in the person's behaviour, for instance the development of new operational skills. It might also result in knowledge acquisition and attitude formation (Dewey and Boydston, 1985). Ideally, these changes should be long-lasting in order to be recalled whenever a relevant situation arises. Therefore, effective learning is not only about the mere acquisition of knowledge or skills, but it lies also in the ability to transfer them into real-life situations that can be associated to the initial training context (Pithers, 1998). According to the US Office of Mine Safety and Health Research (OMSHR, 2014) the development of successful adult training programs should be based on understanding adult learning principles. Adults respond best to learning that is active, experience-based, independent, real-life centred, task-centred, problem-centred, solution-driven, skill-seeking, self-directing, internally and externally motivated, and which recognizes the learner as an expert. Achieving an acceptable level of competency is the main purpose of training programs. Pithers (1998b) defines competencies as attributes which underlie successful performance. Learning occurs as a result of practice (i.e., the act of repeating an action). Causal queues and repetitions are meant to stimulate individual experiences and to enrich corresponding mental models (Jou and Wang, 2012). Ultimately, this iterative learning in context should limit the number of human errors to a tolerable level as skill sets dramatically improve (Deaton et al., 2005). Effective learning from training delivery is crucial for quality performance and outcomes in high risk industries like mining.

The ultimate aim of training is to improve task performance towards expert levels. Ericson and colleagues (1993) conducted studies across various activity domains and concluded that, on average, it required nearly 10 years (or 10,000 hours) for a person to achieve expert level performance in his/her domain of activity. Therefore, one of the fundamentals for training design is to reduce the gap in knowledge between experts and novices. Tichon and Burgess-Limerick (2009), who studied learning differences between novices and experts, identified the following three sources of differentiation: perception, decision making, actions and attention. Novices and experts differ in their capability to understand and make sense of sensory information (for example, perceive an environmental hazard). Based on the same sensory information, experts are better able to recognise patterns, predict the future, anticipate problems and take appropriate decisions. Experts are more capable at discriminating between perceptual events (Blignaut, 1979) such as errors or hazards. However, evidence suggests that perceptual skills can be acquired through training (Starkes and Lindley, 1994, Williams and Grant, 1999). Experts are generally faster at making decisions and mobilising relevant knowledge and procedures (Tichon and Burgess-Limerick, 2011). Moreover, experts tend to react and move faster than novices due to their higher perceptual abilities, body control and focus (Tichon and Burgess-Limerick, 2011). However, Chapman (2011), when studying novice and expert drivers, concluded that novice drivers could significantly modify their behaviour after appropriate training.

Studies have shown that a mere 33% of accidents in the mining industry are due to poor individual decisions (Patterson and Shappell, 2010). Therefore, training programs must focus on decisional skills. Structured or analytical decision making have proven far too demanding in emergency or critical situations. An alternate and more cost-effective model, called the ‘recognition-primed decision model’, focuses on the natural process of decision making (Klein et al., 1989). According to this model an option is generated and tested for its feasibility and then either implemented or rejected. This cognitive process works well for highly experienced employees; however, novices usually do not have the ability to generate meaningful options. Computer-aided training, from an online course to immersive simulation, has the potential to contribute to this demand-driven approach to vocational training (Newton et al., 2002). Over the last decades, computer-assisted training has gained momentum (Jou and Wang, 2012).

Technology-mediated learning has been defined as learning environment in which learners’ interaction with others, objects or instructor is mediated through information technology (Alavi and Leidner, 2001). Despite heavy investments in education and technology (Wan et al., 2007), the key factors related to learning success (such as the individual learners’ characteristics (Vician and Davis, 2003), and an emphasis on recognising the factors that lead to favourable learning outcomes) have been ignored over the years (Ma et al., 2000).

To achieve better learning outcomes from investments in technology within the educational environment, it is crucial for researchers to develop a more comprehensive framework to better understand the roles that technology can play in technology mediated learning (Wan et al., 2007). Alavi et al.’s (2001) framework for technology-mediated learning focusses on instructional, psychological, and environmental factors that enhance learning outcomes. By contrast, Piccoli et al.’s (2001) proposed framework merely focusses on the participants themselves and ignores the role of learning processes that mediate the relationships between instructional design/technology dimensions and learning outcomes. A few years later, Benbunan-Fich et al. (2003) proposed a framework which highlighted the mediating effect of learning processes on the relationship between design, technology, and learning outcomes. Wan et al. (2007) has developed a comprehensive learning mediated technology framework (Figure 2-1) which includes items from all three previously mentioned frameworks. As Figure 2-1 illustrates the five main dimensions of this technology-mediated learning framework:

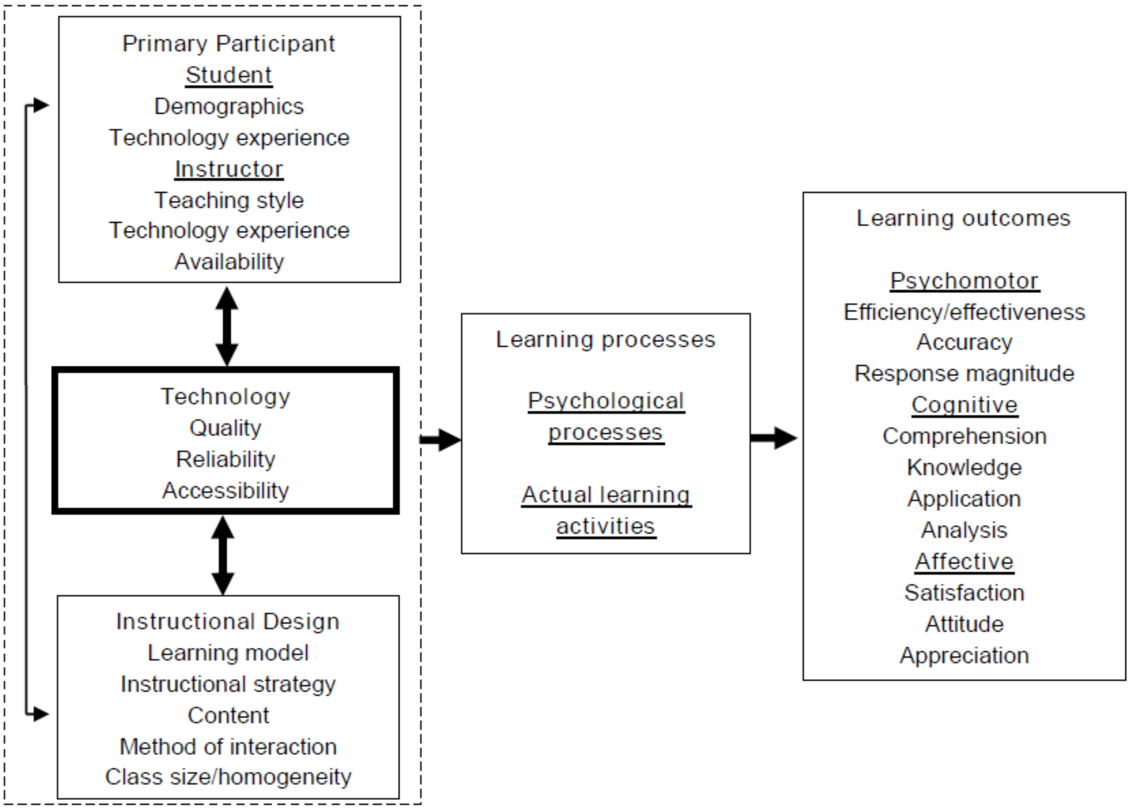


Figure 2-1: Framework for technology-mediated learning (Wan et al., 2007)

- The trainees and instructors who are identified as the primary participants (Piccoli et al., 2001). Trainee factors include socio demographics, language and communication skills (Piccoli et al., 2001). Technology experience and computer anxiety are also other factors that are commonly investigated (Arbaugh and Duray, 2002). It might appear that instructors are less important in technology mediated learning environment. However research has shown that instructor characteristics such as availability and engagement, level of technology experience, self-efficacy, (Piccoli et al., 2001, Benbunan-Fich and Hiltz, 2003) and the feedback that they provide are all important (Marks et al., 2005).
- Instructional design is another dimension in the technology-mediated learning framework which includes the learning model, instructional strategy, learning content, the method of interaction, and class size / homogeneity (Wan et al., 2007, Hardaway and Scamell, 2005). According to Leidner et al. (1995) there are five main learning models: objectivism, behaviourism, constructivism, cognitive constructivism, and social constructivism. Objectivism assumes that everything related to learning is predictable therefore, one learning-model fits all (Nawaz, 2010). Likewise, behaviourism gives priority to the stimulus response relationship in learning and underplays the role of cognition (it therefore regards the learning environment in a similar fashion objectivism (Young, 2003). Constructivism advocates that reality is constructed by human beings subjectively (Nawaz, 2010). Constructivists believe that

there is no single version of reality, rather a multitude of realities situated within each learner (Nawaz, 2010). As such, learning is dependent upon the learner's ability to analyse, synthesize and evaluate information to create meaningful, personalized knowledge (Phillips et al., 2008). Cognitive constructivism gives priority to the cognitive powers of an individual (Nawaz, 2010). For example, the 'learning-style' of every learner indicates his/her cognitive trends. Since students vary in their cognitive or learning styles, they also benefit from those teaching techniques that appeal to their individual styles (Cagiltay et al., 2006). In contrast to cognitive-constructivism, 'social constructivism' emphasizes 'collective-Learning' where the role of teachers, parents, peers and other community members in helping learners becomes prominent. Social constructivists emphasize that learning is active, contextual and social, and therefore the best method is 'group-learning' where teacher is a facilitator and guide (Tinio, 2002). Social constructivists explain the technology-adoption as a process of involving social groups into the innovation process where learning takes place on the learners' experiences, knowledge, habits and preferences (Bondarouk, 2006). In contrast to traditional classrooms where teachers used a linear model and one-way communication, the modern learning is becoming more personalized, student centric, nonlinear and learner-directed (Cagiltay et al., 2006).The most traditional model is objectivism and the most popular model is constructivism (Leidner and Jarvenpaa, 1995). With the emergence of collaborative technologies, it has been recognized that behaviourist models do not fit with contemporary teaching and learning environments, therefore current research will focuson developing constructivist models of computer-based instructional development (Young, 2003). The strengths of constructivism lie in its emphasis on learning as a process of personal understanding and the development of meaning where learning is viewed as the construction of meaning rather than as the memorization of facts.
Instructional strategy refers to the methods used for presenting, sequencing, and synthesizing the learning content (Alavi and Leidner, 2001). The way in which the content of the training is selected and ordered, as well as the way in which the relationships between the various topics is established, are both essential for successful learning outcomes (Piccoli et al., 2001).

- Information technology is broadly about computing, communication and data management and an important determinant factor on the success of learning program and trainees satisfaction (Arbaugh and Duray, 2002, Marks et al., 2005). While Piccoli et al. (2001) argues that information technology should be treated as part of instructional design dimension, Alavi and Leidner (2001) have argued otherwise. Excluding information technology from instructional design creates an opportunity to explore more interaction options between the information technology and other dimensions (Wan et al., 2007). In general, information technology itself does not provide the desirable outcome and it works the best when primary participant, information technology and instructional design dimensions are intertwined.

- The learning process, which refers to the actual learning activities and psychological processes involved, and is another dimension of this technology-mediated learning model. Psychological processes (Alavi and Leidner, 2001) include the individual learner's cognitive and information processing activities, motivations, interests, and cognitive structures. The actual learning activities refer to the learners' active or passive participation and interaction.
- The final dimension of this model is the learning outcome. According to Sharda et al. (2004) the outcomes of training can be divided into: (i) psychomotor outcomes, measured as efficiency, accuracy, and response magnitude; (ii) cognitive outcomes, measured as comprehension knowledge, application and analysis; and lastly (iii) affective outcomes, measured in terms of trainee's satisfaction and appreciation of the learning experience.

The important point is technology-mediated learning might be suitable for wide range of topics but its success can depend on a variety of factors, including the learning model adopted and the instructional design (Piccoli et al., 2001).

2.2 Virtual Reality (VR)

Virtual simulation is defined as a simulation involving real people operating simulated systems. Virtual simulations inject humans-in-the-loop in a central role, by exercising motor skills, decision skills, or communication skills (Knerr, 2007). In the late 80s, the coming together of computer technology, the gaming industry and military training needs gave way to a first wave of training simulators for the US military, like Marine Doom – a battlefield training simulator directly adapted from its famous gaming counterpart Doom (Barles et al., 2005). The next decade saw a surge in large-budget flight simulators for air force or navy training, like AVCATT-A (Zhao, 2009). However, during the same period these military applications were progressively matched by a growing number of civil applications in the aeronautic or automotive industries as evidence of training effectiveness became clearer (Blickensderfer et al., 2005). As 'virtual reality' became a widely adopted terminology to describe immersive simulations, early studies demonstrated that skill acquisition through VR-based training was dependent upon the task to be trained, as well as the amount and type of training (Hays et al., 1992). Other studies compared the quality of VR-based training outcomes with traditional programs (classroom and flying lessons) (Jacobs et al., 1990). High risk industries progressively adopted VR environments as a means to address some of the limitations associated with traditional onsite and classroom training (Bliss et al., 1997; Tichon and Burgess-Limerick, 2009). As an example, in the context of high risk industries like mining, Virtual Reality (VR) can emulate hazardous situations that will allow trainees to explore unchartered realities and gain new experiences (Fox et al., 2009). VR-based training might create an opportunity to expose trainees to many different scenarios, generate 'virtual' options and reinforce 'virtual' expertise through repetition.

Although onsite training for high risk industries maximises the fidelity of the experience, it is not always the preferred method. Overall, VR technology has gained momentum in contexts where traditional training, conducted onsite, faced one of the following issues:

- It is impossible to replicate a training scenario due to practical or cost limitations.
- The number of plausible and useful training scenarios is too high for onsite training.
- There are serious risks associated with conducting an extreme scenario onsite.
- The skill set to be learnt requires a large amount of time to be mastered by trainees.

For example, firefighter training often involves sophisticated and costly facilities where buildings or large vehicles can be set on fire in a replicable way (Bliss et al., 1997). Engaging with actual environments and resources also exposes trainees to a variety of health and safety issues, such as the inhalation of toxic fumes, extreme heat or exposure to unstable materials (Tichon and Burgess-Limerick, 2009). Also, onsite training often competes against scheduled activities of the plant or the mine, limiting training opportunities. Therefore, VR-based training is seen as a promising and complementary option to traditional approaches whereby trainees can be exposed to various and often extreme scenarios in a safe, replicable and cost-effective environment.

2.3 VR as a Training Environment

The use of computer simulations as learning environments has progressively embraced technological innovations from chart-based interfaces to fully immersive environments (Bell et al., 1990, Jou and Wang, 2012). VR technology has brought immersive and interactive features which allow users to ‘feel’ the experiment (Raskind et al., 2005). VR technology has been used to train for various operations and dangerous circumstances where it is believed that training objectives cannot be achieved easily or the cost will prohibitive. Van Wyk and de Villiers (2009) define VR-based training environments as “real-time computer simulations of the real world, in which visual realism, object behaviour and user interaction are essential elements”. The use of VR-based training environments assumes that Human-Machine interaction stimulates learning processes through better experiencing and improved memorization, leading to a more effective transfer of the learning outcomes into workplace environments (Chen et al., 2009). As stated by Meadows (2001): “When I hear, I forget; when I see, I remember; when I do, I understand”. Fulton and colleagues (2011) argue that interactive models like flight simulators are designed to improve the trainee’s understanding of the consequences of decisional queues under limited resource availability (material, time or energy) and uncertain or hazardous conditions (unintended consequences). Seymour and colleagues (2005) argue that the more realistic the experience is, the better the learning. In situations where real life training opportunities are limited, hazardous or impossible, like emergency responses, virtual reality simulators offer the opportunity to emulate many wide-ranging experiments (Seymour et al., 2002). Jou and colleagues (2012), in their review of VR-based training, consider the following fields of application: “virtual technical skill training”, “virtual laboratory”, “virtual instructions”, “virtual campus”, and “virtual distance learning”. Defence and aerospace industries are good examples of using VR technology for flight simulation in order to train pilots for high risk skill sets in a safe environment (Honey et al., 2009, Schmitt et al., 2012). The application of VR technology is also growing rapidly in different fields of science. In neuropsychology, researchers use VR technology to study, assess and rehabilitate cognitive or functional processes or attention disorders (Rizzo et al., 2000). VR technology is also beneficial for medical education, such as teaching advanced surgery or life support skills (Gorman et al., 1999). VR-based training can also benefit students with disabilities, allowing them to experience dangerous, expensive, inaccessible events and also to experience field trips at their own pace (Raskind et al., 2005). Moreover, Sacks et al. (2013) investigated the role of VR for construction purposes, and found that trainees perceived the virtual construction site environment as being a sufficiently authentic simulation of a construction site to facilitate learning. They also found that virtual reality instruction was more effective than safety training using traditional classroom training methods (such as slide presentations). Finally, manufacturing companies working on dangerous goods increasingly use VR for training their staff (Bell et al., 1990). Salzman and colleagues (1999) argue that VR-based training can support a second-order learning process through which designers, trainers and managers gain insights into the interactions between workers and their environment. Analysing training scenarios, trainee performance and feedback after the session could lead to better workplace conditions by modifying features of the current environment. In their analysis of NewtonWorld, Salzman and colleagues (1999) realised that students had misconceptions about some basic concepts in physics and that these beliefs and misunderstandings were so strong that it was nearly impossible to change them through conventional classroom teaching. They realized that students needed to experience the physical process in order to accept the actual/true concepts. Later, Moreno and Mayer (2007) explained the learning with media through a cognitive-affective model of learning (Figure 2-2). They explained the process as working memory using essential processing and generative processing to select new information and make sense of it. Both processes interact to limit the amount of information being assessed and stored. The outcome of this process is meaningful learning. In interactive learning environments such as VR students learn better when they are guided through the cognitive process instead of receiving direct instruction or being left alone to purely explore, this is referred to as the “guided activity principle”. Drawing from research on early age development and learning, Piaget (1973) observed that individuals are surrounded by continuously changing environments and they try to understand these changes through reflexive analysis of the perceived environment. When individuals cannot reconcile their new perceptions with their already established knowledge, it creates a conflict referred to as “cognitive dissonance”. When this potential conflict is resolved through self-regulation, it leads to the creation and acceptance of new knowledge, through a learning process. This constructivist theory (or constructivism) of learning is often associated with pedagogic approaches that promote active learning or learning by doing (Rieber, 1996). According to Piaget (1973), the construction of new knowledge requires two processes:

- Assimilation: new information is assimilated into an already existing framework without changing that framework.
- Accommodation: new knowledge involves reframing one's mental representations to fit the new experiences.

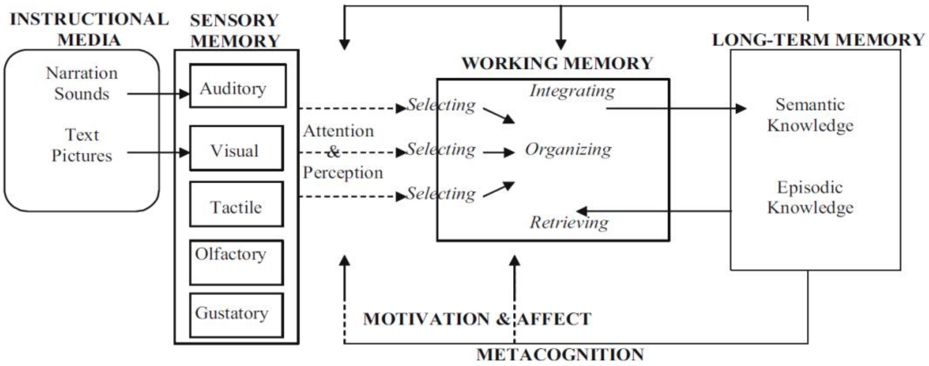


Figure 2-2: A cognitive-affective model of learning with media, (Moreno and Mayer, 2007)

However, a crucial condition for VR technology to deliver satisfying training transfer is its ability to reproduce faithfully not only the physical environment but also the functional features of the simulated operations. In the case of flight simulators, Hays et al. (1992) demonstrated that the quality of training transfer is highly correlated to the level of fidelity of the simulated environment (relative to the real world). Orlansky and String (1977) argue that the effectiveness of VR-based training is influenced by (1) the type of simulator in use, (2) the level of experience of participants, and (3) the quality of scenario design and delivery. Considerable evidence exists to support the effectiveness of VR environments (Tichon and Burgess-Limerick, 2011). Also, Chen et al. (2000) have reported on how the various technical capabilities of VR technology can support constructivist learning principles, which are consistent with the constructivist educational design principles by Dalgarno (1998). Constructivist learning principles focus on active learning and discovery activity to encourage diverse ways of thinking; and interesting, appealing and engaging problem representation to provide intrinsic motivation (Lee et al., 2010). In the following sub-sections examples of successful VR applications will be discussed.

2.3.1 Flight Simulators

Flight simulators are a popular type of simulator, which are used for various purposes such as the training airline, fighter, and general aviation pilots (Blickensderfer et al., 2005). Even though they can result in successful skill acquisition, studies show that the success of this training is affected by the task to be trained, amount and type of training. In particularly, they indicate that flight simulators work the best for training take-offs and landings (Hays et al., 1992). Generally flight simulators are used to complement pilot training and the aviation industry does not have any intention of substituting real life training. A study by Jacobs et al. (1990) shows that simulators produce better training outcomes than real aircraft-only training. Furthermore, a study by Deaton et al. (2005) concluded that the flight simulators are successful because they can provide an overall view of the action that is not possible with video cameras. Flight simulators can provide a view of the action from any perspective and are not limited by camera locations. Also, flight simulators can provide a variety of aids to analyze and depict events. They can provide the opportunity in the context of realistic simulated operations, to practice cognitive and decision making skills that will foster adaptability and the capability to respond to rapidly changing situations (Deaton et al., 2005). Focused, repetitive, deliberate practice, with feedback based on performance, is an effective method for training the recognition of situations and developing expertise (Deaton et al., 2005) . Cognitive and decision making skills can be trained even if some physical tasks cannot be performed in the situation. Kennedy et al. (2010) used a flight simulator to investigate the roles of age, expertise, and their relationship on aviation decision making and flight control performance during a flight simulator task. The result of their study suggested that older participants tend to make less accurate decisions compared to younger participants and that experts performed better.

2.3.2 Medical Simulators

VR has been used in various fields of medicine from surgical training to patient rehabilitation programs. Studies have found that medical trainees who received training in VR performed much better in their first real life surgeries compared to those who had not received such a training (Seymour et al., 2002, Gurusamy et al., 2008). Technological innovations, such as virtual reality simulation have led to consistent improvements in learning outcomes, and VR already plays an important role in surgical residency training programmes (Graafland et al., 2012).

Moreover, Gal et al. (2011) conducted a study to assess the impact of VR force feedback simulators to assess the simulator's ability to serve as a tool for dental instruction. This VR training system provided a haptic feedback through the device being held by the user. Experienced dental faculty members, as well as advanced dental students, found that the simulator had significant potential benefits in teaching manual skills in dentistry.

In addition to medical training, simulation has also be used for medical treatment and rehabilitation. Additionally, Mendes et al. (2012) evaluated the learning, retention and transfer of performance improvements after Nintendo Wii Fit™ training in patients with Parkinson's disease. Motor rehabilitation can be characterised as a process of 'relearning' how to move to respond satisfactorily to the demands of daily living, and is based on the premise that training leads to improved performance both in terms of acquiring new skills and adapting or refining previously acquired skills (Krakauer, 2006). Patients with Parkinson's disease showed good performance and retention of learning on seven of the ten games and showed marked learning deficits on three other games. This deficit appears to be associated with cognitive demands of the games which required decision-making, response inhibition, divided attention and working memory. Also, patients with Parkinson's disease were able to transfer motor ability trained on the games to a similar untrained task.

Furthermore, VR has proved beneficial for stroke rehabilitation. Virtual reality and interactive video gaming have emerged as new treatment approaches in stroke rehabilitation (Saposnik et al., 2011) These approaches may be advantageous because they provide the opportunity to practice various range of activities. Also, virtual reality programs are often designed to be more interesting and enjoyable than traditional therapy tasks, thereby encouraging higher numbers of repetitions (Laver et al., 2012)..

2.3.3 Driving Simulators

Driving Simulators are one of the most common VR applications that integrate users within a learning experience. Evidence exists to support the use of VR training for car (Turpin and Welles, 2006) and truck drivers (Masciocchi, 2007), both in terms of increasing the safety of their actions and behaviours, as well as in order to improve fuel efficiency. Konstantopoulos et. al., (2010), in their study used VR to study driver's behaviour by comparing driving instructors' and learner drivers' performance. He recorded their eye movements while they drove three virtual routes that included day, night and rain routes in a driving simulator. The results of their study showed that driving instructors had an increased sampling rate, shorter processing time and broader scanning of the road than learner drivers. Also it was found that poor visibility conditions, especially rain, decrease the effectiveness of drivers' visual search. Ahmed et al. (2016) focused on the most important driving behaviours that have to be adapted by any driver, such as switching lanes and giving priority to pedestrians in order to reduce the rate of car accidents. VR tracking system was used as part of the system that analyses the player's behaviour to alter the scene and expose the driver to unexpected situations. Their survey's results showed that 88% of the test subjects believed that this teaching experience helped to correct the addressed driving behaviours and 84% of them found it amusing. The statistical analysis of the change of the drivers' behaviours showed an average increase of 21% in correct actions and an average decrease of 17% in incorrect actions (Ahmed et al., 2016).

Moreover, virtual reality has also proven to be beneficial for train drivers. Some technological advances in trains have added to the complexity of driving, and Eichinger et al. (2005) report that VR training can be an useful tool for train drivers however, there was no evaluation outcome reported. Schmitz et al. (2009) in their report refer to the lack of simulation training evaluation as a serious issue in the filed obstacle in simulators for driving training. So far VR has been proven effective for training employees in perceptual-motor skills (Hamblin, 2005). Also, research conducted by Fisher et al. (2006) revealed that using VR has increased hazard awareness in novice drivers.

2.3.4 Road Crossing Simulators

Additionally, VR has been used to teach children to cross the road safely (Thomson et al., 2005) and results have shown safer road crossing within simulated scenarios in the simulation. However there was no further evidence that this safety learning had translated into long-lasting real world behaviour.

2.3.5 Other Types of VR Training

In the maintenance and inspection domain, research on the benefits and possible uses of VR technology is still limited (Linn et al., 2017). Vora et al. (2017) investigated the use of VR technology for the training and education of technicians and employees in performing maintenance processes. In this study the advantages of a VR based inspection training system was compared to a classical PC-based system. The results showed that the VR system was preferred due to the higher degree of immersion and subjective presence it generated which affected task performance.

Moreover, Situation Awareness (SA) is an essential skill in Air Attack Supervision (AAS) for aerial based wildfire firefighting. Clifford (2018) evaluated the potential of the Oculus Rift Head-Mounted Display (HMD) and a 270° cylindrical simulation for the use in aerial firefighting supervisor training scenarios. They reported that participants had greater ability to acquire SA inside the immersive HMDs. Also, participants felt the strongest presence with the HMDs, however this did not lead to significantly different SA results. Additionally, the HMD induced the most simulator sickness. They did however conclude that both types of display could afford greater SA over conventional monitor systems.

The application of virtual simulations and serious games is also becoming more widespread within fire fighter education and training. However, as Williams-Bell et al. (2015) reported one of the greatest issues has been the limited use and reporting of quantitative measures to accurately assess the effectiveness and efficacy of these simulations along with their ecological validity. Spatial awareness (Stone et al., 2009), crew resource management (Nullmeyer et al., 2006), decision making under stress (Stansfield et al., 2000) and team training are some different applications examined in VR. The issue remains that there is not yet any systematic evaluation method to assess VR-based training in these fields.

2.4 Mining Industry and VR

2.4.1 Mining equipment operation

A range of equipment simulators including dozers, dragline, haul truck, shovel, continuous miner, longwall and roof bolter are available (Tichon and Burgess-Limerick, 2011). While reports of their use are available (Williams et al., 1998, Wilkes, 2001), no systematic performance evaluations have yet been conducted (Tichon and Burgess-Limerick, 2011). A jackleg drill simulation (MinerSIM) aimed at training new operators (Nutakor, 2008, Dezelic et al., 2005, Hall et al., 2008) has also been constructed. A VR environment, called MinerSIM, was developed by Nutakor (2008) at university of Missouri in US to train miners to install rock bolts. The training package includes an online tutorial and a virtual reality simulator. To date, the usability of the web tutorial is the only aspect of this training package that has been evaluated.

2.4.2 Mining equipment safety

A virtual conveyor belt safety training program has also been developed and studied (Lucas and Thabet, 2008, Lucas et al., 2007). The simulation consists of an instructional module, and a task-based training module in which the trainee completes assigned tasks. A knowledge assessment test has been used to evaluate desktop or immersive versions of the conveyer belt safety training program. However the evaluation only involved twelve trainees who had been assigned to either using a desktop or immersive versions. The result of evaluation indicated that there was not a significant difference in the average increase in knowledge for the desktop and immersive versions of the training. Since only twelve participants were examined, the power of the comparison was extremely low. A similar application for pre-shift inspection for haul trucks was described by McMahan et al. (2008). In this study the training was also provided in both desktop and immersive virtual environments. The purpose of the training was to illustrate the necessary steps prior the shift inspection. Afterwards the trainees were debriefed on the consequences of their decisions. The success of the training was measured in terms of the level of knowledge retention by using a knowledge assessment test before and after the simulation. The outcome of evaluation indicated that there was a significant improvement in knowledge as a result of the training. Moreover, a comparison of the effectiveness of the desktop version (with sample size of 9) to the immersive CAVE version (with sample size of 10), and to a conventional "PowerPoint" presentation (with sample size of 10) was also reported. The report of evaluation indicated that there were no significant differences in knowledge retention between the three platforms. However, again the statistical power of the comparisons was very low, and thus the conclusion drawn (that the platforms were equally effective) might well be erroneous.

2.4.3 Mining hazard identification

VR has also been used for hazard identification in mining (e.g., Filigenzi et al, 2000; Orr et al, 1999). Squelch (1997; 2001) compared the use of desktop virtual reality to traditional methods for hazard awareness training using two different groups of 30 miners. The result of the evaluation indicated that the trainees preferred virtual reality training. Unfortunately, no quantitative comparison between two training media was possible. VR has also been used to recreate accidents and emphasise the consequences of unsafe acts (Schafrik et al., 2003) in order to influence safety culture, although no evaluation of the effectiveness of this training has been undertaken to date. Training in hazard identification has also been extended to include procedural information (e.g., Ruff, 2001). For example, Wyk & Villiers (2009) trained underground mine workers in hazard recognition and correct safety procedures using desktop virtual reality. Although there no results are available, it has been stated that the results were positive in the context of South African mining. Stothard et al. (2008) similarly aimed to improve trainee understanding of hazards, procedures and processes. A survey of 51 trainees was undertaken to assess immersive tendency and presence (i.e., the feeling of being in the virtual environment), however no evaluation of the understanding they gained was reported.

2.4.4 Safe act practice with VR

The potential of VR to improve safety has been discussed by Schofield et al (2001) and others (Filigenzi et al., 2000, Wilkes, 2001). Schofield et al. (2001) have argued that humans can translate safety information from three-dimensional computer worlds better than from the printed page. Grabowski et al. (2015) proposed using VR to practice the correct behaviour the of miners in a controlled, safe environment. This study involved 21 miners who took part in two simulations, using two different motion capture systems: Razer Hydra or a vision based system. Additionally, they compared Head Mounted Displays (HMDs) with different fields of view (FoV), either wide (110 degrees) or relatively narrow (45 degrees). It has been anecdotally reported in almost all cases, that highly immersive VR combined with wide FoV is judged to be the best solution for training (Grabowski et al., 2015).

2.5 Evaluation Techniques

Patton (1997) defines evaluation as the systematic collection of information about the activities, characteristics, and outcomes of programmes to make judgements about the programme, improve programme effectiveness, and/or inform decisions about future programming. One measure of the effectiveness of a simulator, after it is fully developed, is how much an operator's performance in a real world task is improved by training on this simulator (Tichon and Burgess-Limerick, 2011). Despite the wide acceptance of simulators as valid training tools, few studies exist that actually measure this type of training transfer (Lathan et al., 2002). Unlike operational training where the worker performance can be measured while they are doing their everyday work, the outcome of safety training can only be measured when accidents happen. Training for disaster response and rescue operations where events are entirely unpredictable is different to training in some other high stress environments (such as aviation) where event progression can often be more easily modelled. Different techniques are required for obtaining objective measures of trainee performance. Therefore, it might not always be possible to measure the training outcome and therefore the focus might need to be on the training tool and process instead. The potential for improved safety suggested by Schofield et al. (2001) and others (e.g., Bise, 1997; Filigenzi, et al, 2000; Wilkes, 2001) has been embraced by the mining industry, and virtual reality simulation is beginning to be adopted. However, while there are a number of reports of safety related training being conducted in virtual minerals industry environments, there is little evaluation reported other than in terms of its usability or subjective trainee responses.

2.5.1 User Opinion

In this technique users are asked to give their opinions about the conducted training, the method of the training and the features affecting the process. This technique is only useful if it is not possible to measure performance and training outcomes. However, this technique does not reflect on knowledge creation and training transfer (Nutakor, 2008).

2.5.2 SWOT Analysis

Strength, Weakness, Opportunity and Threat (SWOT) analysis is commonly used in businesses (Rizzo and Kim, 2005). In the context of this study, which investigates the use of VR as a training tool: 1) strengths can be defined as the ability of VR to achieve the training objectives and the rich resources it provides to staff trainees and trainers; 2) weaknesses refer to the limitations of the technology which impedes the progress in achieving the defined training objectives for instance (e.g. the generation of simulator sickness or perceived level of unrealism); 3) opportunities refer to what the VR training environment can offer or what the technology can provide more effectively (such as the ability to conduct relatively low cost, but at the same time effective, training); 4) threats can be any unwanted or unplanned situation in VR environment which limits and creates barriers to achieve training goals. The outcome of SWOT and need analysis will help organisations to take advantage of the new technology's opportunities, and by using its strengths and addressing its threats to overcome or correct its weaknesses, and also reach the acceptable level of technology acceptance as a training tool - thereby using the technology's capability to its maximum level.

This technique does not reflect on knowledge creation and training transfer but provides good insight about what position VR holds at the moment and what the future will be for this kind of training environment. Depending on who we ask we may get different answers as the point of views are different but everyone will judge VR based on their own experience with the technology.

2.5.3 Usability Study

Krug (2000) proposed a usability study as a method of making sure that a system works well enough that a person of average ability and experience can use it for its intended purpose without becoming frustrated. Usability is not a single, one dimensional property of a user interface, but has multiple components. Usability is traditionally associated with five usability attributes including learnability, efficiency, memorability, errors, and satisfaction (Nielsen, 1993). Benefits of usability testing are associated with the increase of ease of use and productivity, and decrease in human error. For example, Nutakor (2008) ran the usability tests throughout the web tutorial development life cycle. The statistical results and user comments from the evaluation of the Web tutorial, suggested that a task must be sufficiently complex (e.g., drilling and bolting, but not scaling) in order to render the traditional paper based method less effective than computer based method.

2.5.4 Situation awareness (SA)

Situation awareness and hazard perception are highly correlated with performance. The Situation Awareness and Global Assessment Technique (SAGAT) is a method used to measure the awareness in virtual environment. In a flight simulation study conducted by Endsley (1988), pilot perceptions and comprehension was assessed using SAGAT. A major criticism of the approach is the need for regular (and disruptive) interruptions during the training session. Another study by Van De Merwe (2012) suggested the potential for eye movements as a means to assess situation awareness (SA) in a flight simulator setting. In a scenario, SA was hampered by introducing a system malfunction in the form of a fuel leak that resulted in a fuel imbalance. Twelve airline pilots participated in the experiment and their visual scanning behaviour was tracked across the areas of interest in the cockpit. Differences in attentional focus and scanning entropy were observed when the crews searched for the malfunction, suggesting the virtual training was an effective tool

2.5.5 Measure of cognition

In attempts to move from outcome to process measurement approaches, eye tracking and cognitive modelling have been used to evaluate both user interfaces and visual displays in supporting tactical decision making (Morrison et al, 1997). It has been proposed that eye-tracking technology can help measuring the cognitive behaviour of the trainees (Rosch, 2013). Therefore, a gaze path or eye-tracking pattern developed by experts to accomplish a certain task can be used as a reference to benchmark progress from more junior trainees. This technique has been used in the mining industry for shuttle car operators (Kowalski-Trakofler and Barrett, 2003). Eye-movements are recorded using a head mounted eye tracker to identify fixation locations and scan paths.

2.5.6 Skill acquisition analysis

Another commonly used evaluation technique is the short-term and long-term analysis of skill acquisition. The focus is on the outcome of the training and not the learning process. In short-term analysis, trainees are assessed post-training on the skills and knowledge developed during the session. Long-term analysis focuses on studies pre- and post-training (Kowalski et. al.(2003). Longitudinal studies are often exposed to cross-influences from hidden and independent factors.

2.5.7 Longitudinal survey of outcomes

An alternative approach for evaluating a training session is to use a longitudinal follow-up study (Kowalski-Trakofler and Barrett, 2003), which analyses the number of incidents before and after conducting the training sessions. However, it is often impossible to determine how much of the reduction is due to the training as there are typically many other factors which could conceivably have had an impact on the rate of incidents (Tichon and Burgess-Limerick, 2011).

2.5.8 Some Limitations of Existing Evaluation Techniques

The following limitations and shortcomings of existing evaluation methods justify our research endeavour:

- Laboratory-based evaluations provide an objective and accurate assessment of the VR-based training process. However, the generalisation of these findings is usually limited by the experimental setting. The experimental setting creates a bias as conditions might differ drastically from the usual training environment.
- Direct physiological measurements (from eye-tracking to muscle tension) often create distractions or even interruptions during the training session. Besides, these measurements often require lengthy calibration or expensive equipment that affects the number of trainees who can be assessed.
- Longitudinal evaluation of outcomes is probably the approach that makes most sense from a productivity and industry perspective. Unfortunately, in hazardous environments like underground mining, many independent factors might influence the correlation between a training program and its outcomes in the workplace. Besides, these approaches often need a substantial amount of time to deliver meaningful results.
- Subjective evaluations conducted through surveys or interviews allow for on-site evaluation of large number of trainees. However, individual characteristics influence the way trainees will answer the questions. Post-session surveys or interview also carry the risk of eliciting information from filtered memory cues rather than direct experience.

However, the very most important question which has not thus far received enough attention in the field of mining industry is: “How VR can enhance training programs for underground mining industry?” rather than just answering if VR is influencing the learning outcome? To answer the aforementioned question and after considering the above mentioned limitations I have decided to use User opinion and SWOT analysis evaluation techniques in this thesis research. However, firstly it is crucial to identify what the gap is in current literature and what dimensions of technology mediated approach have been studied so far or still have not yet received enough attention. Then after identifying which factors have been previously argued to impact on learning experience and outcomes, I will lastly present my hypothesized evaluation framework. This proposed hypothesized framework will be developed by reviewing and collecting the factors that affect learning experiences/outcomes from the existing literature.

2.6 Research Gap

Training research (Salas et al., 1998, Stewart et al., 2002, Stewart et al., 2008) has demonstrated that the lack of clear performance assessment criteria fails to fully exploit the effectiveness of simulation-training events. Considering learning, it is important to identify factors which influence learning effectiveness in virtual training environments. For instance, Baker et al. (2010) and Moreno et al. (2007) focused on the learners' cognitive–affective state, whereas Ragan (2010) focused on the simulation's field of view (FoV). Grabowski (2015) focused on the impact of different FoV and combined with different levels of immersion. On the other hand, Stothard (2004) focused on the training content and the details of objects within the virtual world. Based on their findings, expert input on each scenario and the presence of detailed objects that the trainees could relate to in these simulations were both essential factors for successful VR training.

Salzman et al. (1999) developed more comprehensive model for studying learning in virtual environments. According to Salzman and colleagues (1999), learning can be described in terms of both process and outcome. The learning process refers to the information to be taught to the trainees and the learning outcome refers to the trainees' level of understanding after attending the training session. Factors affecting the learning process include the "learner's characteristics", the "interaction experience" and the "learning experience". The characteristics of the individual (such as for example, their previous knowledge, their experience of simulator sickness and the way that they learn new knowledge) can play a role in creating learning (Figure 2-3). However these individual characteristics can also affect the interactive experience, especially the level of comfort felt by users in dealing with the simulator itself and the learning experience at large (Salzman et al., 1999).

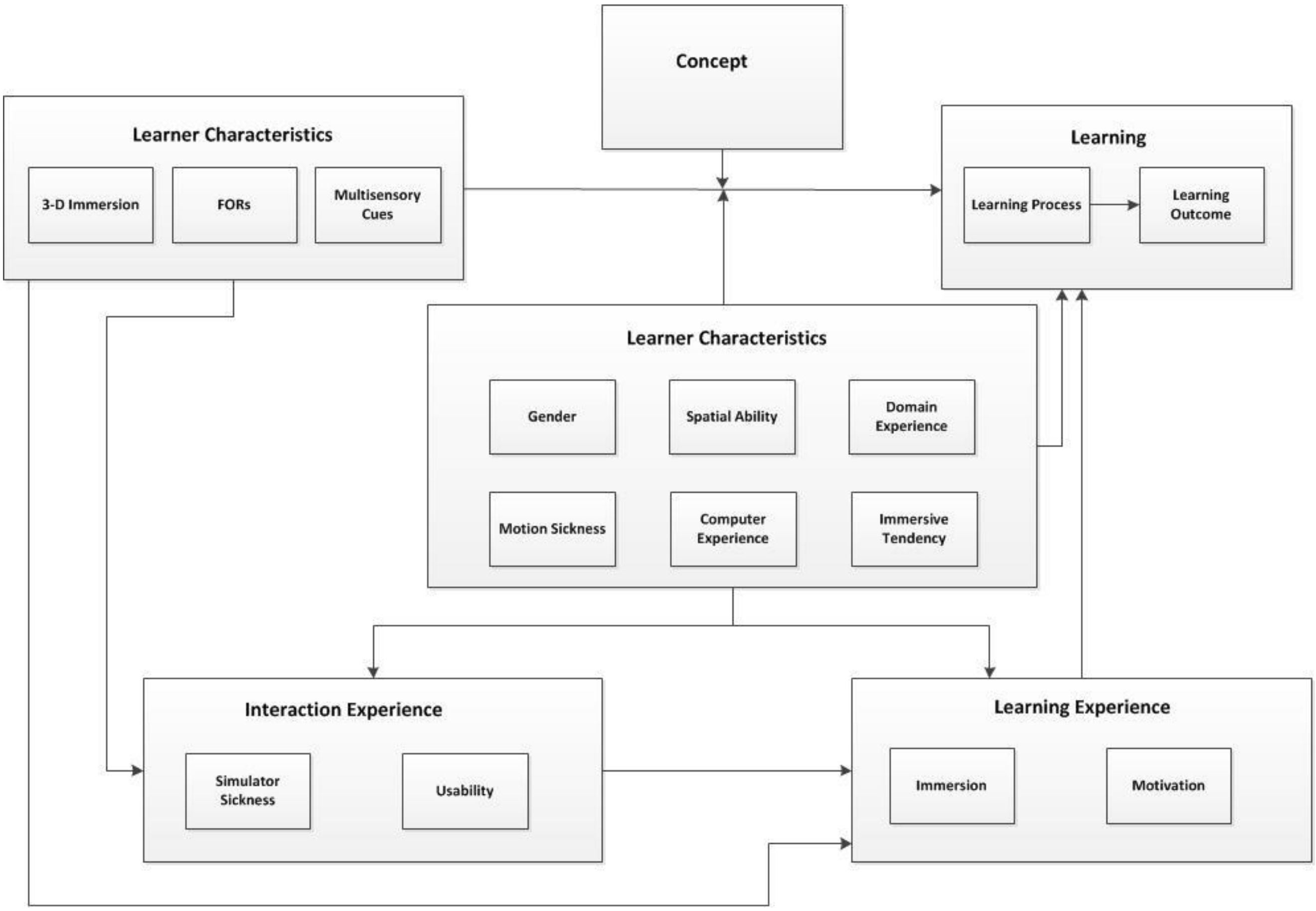


Figure 2-3: Learning in a VR environment (Salzman et al., 1999)

Salzman et al. (1999) identify six learner's characteristics thought to affect the learning process in a VR environment: gender, spatial ability, immersive tendency, computer experience, domain experience and motion sickness. Salzman et al. (1999) have also defined the interaction experience in terms of two factors: simulator sickness and usability. Streman (2000) supports the importance of usability in his study. He stated that participants of virtual worlds must 1) accept it, 2) believe that what they are going to learn and experience in VR is applicable to the real world, and 3) it is consistent with what they will face in real world. Only then might a successful training outcome be expected.

Later, Lee et al. (2010) conducted study on high school science students and developed a general model (Figure 2-4) to examine the underlying psychological processes of reflective thinking, cognitive benefits, motivation, active control, and presence in their 3D virtual reality-based training. Based on their findings VR features had significant impact on learning outcomes through the psychological processes included in their model. Their hypothesized model consisted of the following VR features: 1) representational fidelity and immediacy of control; 2) usability (measured as perceived usefulness and ease of use); 3) presence. The model also included the following: 4) motivation; 5) cognitive benefits; 6) control and active learning; 7) reflective thinking; and 8) learning outcomes (which were measured by performance achievement, perceived learning effectiveness and satisfaction).

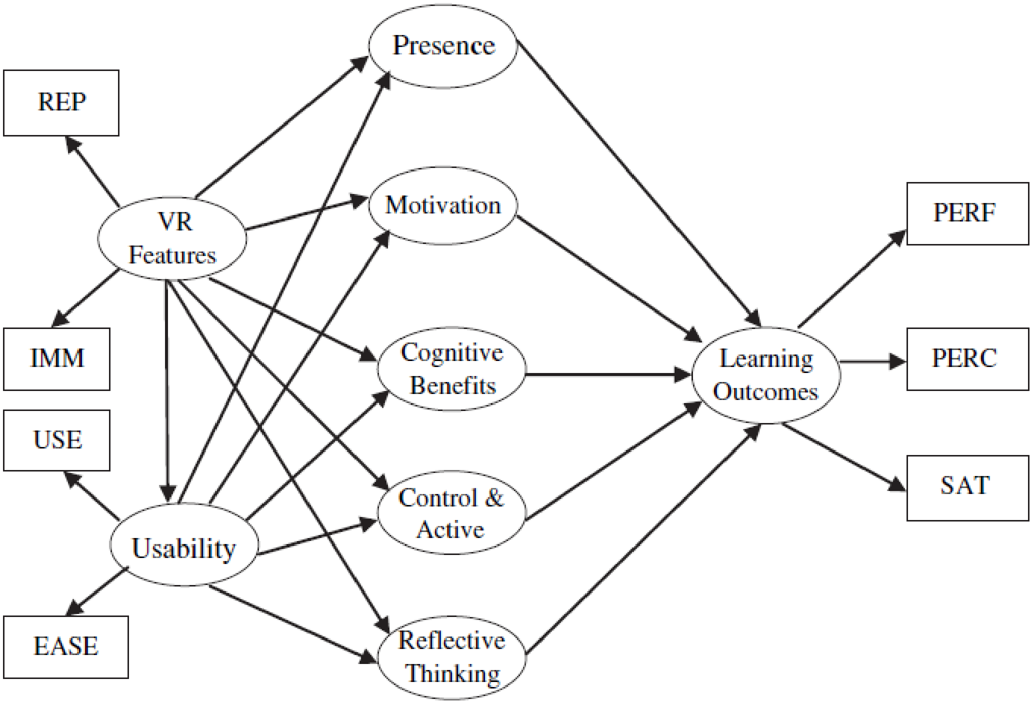


Figure 2-4: Structural Model (Lee et al., 2010)

Subsequently, Merchant et al. (2012), based on Lee et al. (2010) and the Salzman et al. (1999) framework, developed a model (Figure 2-5) to test the impact of perceptual and psychological processes associated with the learning of science concepts that involve understanding spatial relationships. The framework which consisted of the perceived usability of the features of the environment, the sense of presence in the environment, spatial orientation skills, and self-efficacy provided a good account of students' performance on the chemistry test. In this framework, REP = Presentational fidelity; IMM = Immediacy of control; USE = Perceived usefulness; EASE = Perceived ease of use; PERF = Performance achievement, PERC = Perceived learning Effectiveness; SAT = Satisfaction. Based on their findings, usability strongly mediated the relationship between 3D virtual reality features, spatial orientation, self-efficacy, and presence. Spatial orientation and self-efficacy had statistically significant, positive impact on the chemistry learning test.

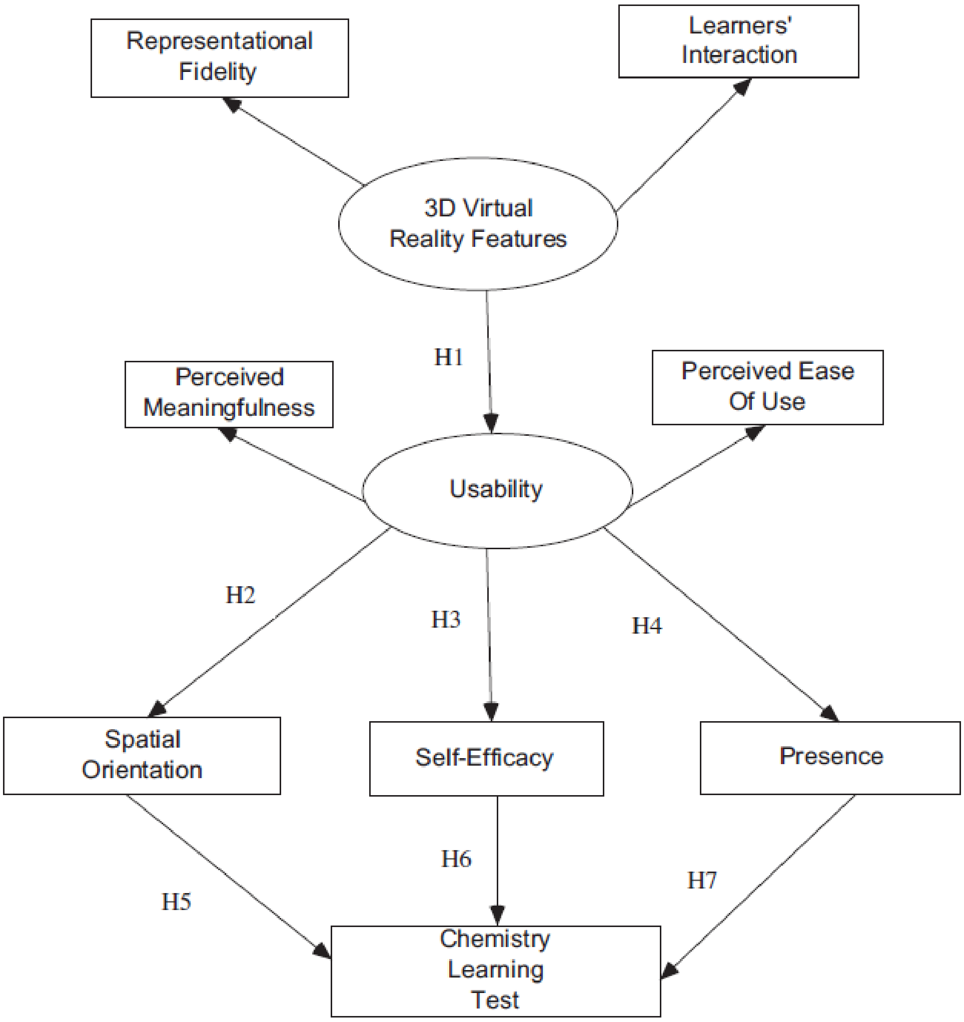


Figure 2-5: Theoretical Model (Merchant et al., 2012)

As it has been presented so far, a number of researchers have focused on evaluating VR and its effectiveness, and their findings is summarised in Table 2-1. The model developed by Salzman et al. (1999) was a foundation for future investigations by Alavi and Leidner (2001), Piccoli et al. (2001), Benbunan-Fich and Hiltz (2003), Sharda et al. (2004), Wan et al. (2007), Lee et al. (2010) and Merchant et al. (2012). However, recently Zhang et al. (2017) has introduced a new dimension (Task-technology fit) as mediating variable in immersive or technology-mediated learning models.

Table 2-1: Comparison between various evaluation models

Article	Participant Dimension	Technology Feature	Learning experience	Task-Technology Fit	Learning Outcome
Salzman et al. (1999)	X	X	X		X
Alavi and Leidner (2001)					
Piccoli et al. (2001)	X		X		X
Benbunan-Fich and Hiltz (2003)	X		X		X
Sharda et al. (2004)	X	X			X
Lee et al. (2010)	X	X	X		X
Merchant et al. (2012)	X	X	X		X
Zhang et al. (2017)		X		X	X

There is a need for a framework which provides a standardized and structured definition of the users' experience in virtual reality learning domain and therefore provides a common understanding of the domain to the involved subject matter experts. The pedagogical benefits of VR as a learning tool need to be examined in a more comprehensive way and the direct and indirect effects of learners' characteristics and VR features on learning experiences and outcomes have to be measured. Finally, a research-based path model needs to be developed to explain the relationships between these constructs.

2.7 Factors Affecting Learning Experience and Learning Outcomes in VR learning Environments

In this section the factors which are thought to effect learning in VR environments are reviewed from the existing literature. These factors will assist us to develop a framework which provides a standardized and structured definition of the users' experience in the virtual reality learning domain and therefore provides a common understanding of the domain to the involved subject matter experts.

2.7.1 Socio Demographic Features

Over the past two decades, there have been conflicting findings about older users' computer attitudes and computer training outcomes. Some studies such as Laguna et al. (1997) reported that older people's experiences with, and attitudes towards, computers are negative in comparison to younger users. However, other studies by Ansley et al. (1988) suggest that age has little to no impact on attitudes towards computers. Furthermore, Dyck et al. (1994) stated that older adults actually displayed more positive attitudes towards computers than younger adults. There are other studies which suggest that generally older people have positive attitudes about computer and technology use (Eisma et al., 2004, Weatherall, 2000). Having said that, it has been reported that there is a belief held by older people that they are too old to use technology to learn new skill set (Timmermann, 1998), but their poor performance using the technology cannot be ascribed solely to negative self-belief (Hawthorn, 2007). It is has also been stated that cognitive functioning declines with aging (Plancher et al., 2010). Experimental research has shown that, compared to younger people, older people are impaired in remembering the when and where (spatiotemporal context) of items, but perform at a similar level on what the item is (Mitchell et al., 2000). Additionally, a teacher's negative stereotypical views and way of using the technology for education also has an impact on older adult performance both in terms of how they use the technology and how they learn from technology (Broady et al., 2010). Evidence suggest that attitudes toward computers are negatively correlated with computer anxiety, meaning that the more anxious person is toward computers the more person will have a negative attitude towards using them (Igbaria and Chakrabarti, 1990). Moreover, as a person gets older, computer-related anxiety appears to increase (Laguna and Babcock, 1997). Laguna et al. (1997) and later Hawthorn's (2007) observations suggest that a negative attitude about technology and computers is correlated with the level of experience with computers. However, based on Czaja et al.'s (1998) study on participants with different technology experiences, attitudes are related to age with the assumption that older people generally have more negative attitudes towards computers than younger people. Hawthorn (2007) also adds that older people are not necessarily avoiding the technology, they are more concerned to reduce making errors by limiting use of technology. However, it needs to be highlighted that in general younger people have had more exposure to technology than older people (Renaud and Ramsay, 2007). Furthermore, it has been stated that when older people are made aware of the advantages of using the technology they were willing to use it (Eisma et al., 2004). In general, the barriers to older people's acceptance and use of technology include being unsure of how to use the technology, the fear of unknown (Hawthorn, 2007), a lack of confidence (Marquié et al., 2002) and lastly being unsure of the benefit of products and services related to technology (Rice et al., 2007).

In addition to what has been discussed, regardless of age, adult ways of learning also vary. This can be influenced by the learners' experience, personality and prior knowledge (Demirbilek, 2010). Park and colleagues (2009) refer to the 'expertise reversal effect', first introduced by Kalyuga (2005), to analyse the influence of prior knowledge on learning through a highly immersive and interactive environment (VR) compared with a more traditional approach. The study showed that participants with higher prior knowledge on the topic obtained better outcomes with highly interactive and immersive simulations compared with more traditional training. However, participants with lower prior knowledge performed better in the low interactive and immersive environment (Park et al., 2009). In recent years, this concept of the expertise reversal effect developed within cognitive load theory, emphasising the interactions between the levels of learner prior knowledge and the effectiveness of different instructional techniques and procedures (Kalyuga and Renkl, 2010). Working memory has a limited storage and capacity for processing new information for a very limited duration. This paired with an unlimited long-term memory as a knowledge base, are the fundamentals of human cognitive architecture (Sweller, 2004). Cognitive load theory is based on this human cognitive architecture (Kalyuga and Renkl, 2010). The limitation of the working memory makes it critical to avoid cognitive overload (e.g., by limiting the excessive amount of interacting elements of information that learner needs to proceed). Based on cognitive load theory there are two different loads: 1) intrinsic load which makes learning possible and 2) extraneous load which interferes with learning (for example, by integrating textual explanations into diagrams in order to minimize the cognitive load or replacing visual text with auditory narration (Sweller et al., 1998). As the learner becomes more expert with higher prior knowledge the redundant material can be eliminated which otherwise can overload the working memory. Therefore the level of the user's knowledge and expertise prior to the training session can be an important factor to be considered.

2.7.2 Gaming and Technology Experience

Studies show that prior experience might be a predictor of a students' perception of the technology (Wan et al., 2007). As it has been presented by Igbaria et al.(1990), evidence suggests that as the anxiety towards computers increase, it is more likely that users will have negative attitudes toward technology. It has been reported that anxiety towards computers is higher among older people (Laguna and Babcock, 1997) and older people usually have the perception that they do not have adequate technology experience and knowledge (Hawthorn, 2007) therefore it might be concluded that a lack of computer experience is correlated with the learners' attitudes toward technology. For instance, a study conducted by Czaja et al. (1998), which involved 384 participants ranging between 20 to 75 years old, found that prior experience with computers varied. Overall, 27.0% of participants reported no prior computer experience, 21.7% reported very little experience, 36.1% reported some experience, and just 14.9% rated themselves as having considerable experience. Of relevance, they reported that older people felt less comfortable with the technology. However some recent studies have also reported mixed findings. For example Arbaugh et al. (2002) reported that students with prior technology experience were more satisfied with training, while Marks et al. (2005) reported no difference between the two group's perceived learning and satisfaction.

2.7.3 Technology Form Factor

Some technologies are best suited to support specific theoretical learning models (Leidner and Jarvenpaa, 1995), while others provide general support for different learning models (Piccoli et al., 2001). VR computer simulations can be presented in various forms, ranging from computer renderings of 3-D geometric shapes on a desktop computer to highly interactive, fully immersive multisensory environment in laboratory (Ausburn and Ausburn, 2004, Mikropoulos and Natsis, 2011). Researchers have categorised VR based on its level of immersion and interaction, for instance, Lee et al. (2014) divided VR environments into immersive and non-immersive, whereas Nakatsu et al. (2000) introduced two classifications of passive immersion and active immersion. In this classification the key is the lack or the existence of interaction. Active immersion includes interacting with environment and object, whereas in passive immersion there is no interaction with the environment.

Desktop-VR is also known as "non-immersive VR" (Merchant et al., 2014). In this form of VR, the user interacts with 3-D images that are generated on a personal computer through keyboard, mouse or joystick, touch screen, headphones, shutter glasses, and data gloves (Chen et al., 2004, Gazit et al., 2006). Even though Desktop-VR has been categorised as non-immersive, it will allow multiple users to train collectively. Desktop virtual reality training for miners has been of interest for some years, with one of the earlier desktop applications being used to educate mine workers on the hazards of mining (Orr et al, 1999). For instance NIOSH offers desktop VR training to train miners read underground mine map. Also, "Mine Navigation Challenge" was developed to train miners to use their navigation skills. This was built using a first person shooter computer game engine and mainly focused on new miners. To successfully complete the tasks, trainees count cross-cuts, go through man doors and find belt crossovers. This study was only evaluated qualitatively and was limited to asking trainees: 1) what part of the training they liked the most; and 2) whether they wanted to have more training conducted in Desktop VR in future. Also, Tichon et al.(2011) in her review on VR discusses work based in Queensland, Australia based on a serious-games project developed called CANARY. This project offers the opportunity for trainees to practice their hazard awareness. It was built on a virtual battle space 2 platform which has been used by Australian and international defence before deploying soldiers to battle field. The hazard awareness scenario is designed to be used in a facilitator-led classroom and depicts a mine site workshop in which a clean-up needs to be performed while identifying key hazards and apply tagging and isolation processes. However, no evaluation has been reported to determine whether it was successful. There have been few attempts to use serious games to train miners, and little or no evaluation of their effectiveness (if evaluations have been done they are not available to the public). The military, both in Australia and overseas, but most notably in the United States, are investing significantly in what is still to a large degree an experimental use of this technology. There may be value in such applications, however much military research is not accessible to researchers working in civilian industries. Clearly those developing computer-based scenarios for training miners should be devising associated evaluations (Mallet & Orr, 2008).

On the other hand there is a full immersive VR environment. As it has been argued by Dalgarno et al. (2002) the sense of immersion or presence(these terms are defined in section 2.7.5) is highly correlated with the representational fidelity, the high degree of interaction and the level of control users have on their avatar or environment itself rather than just unique attribute of the environment. Furthermore, immersive environments are typically presented on room size screens or through stereoscopic, head-mounted displays. Lee et al.(2008) have categorised immersive VR environments as being either semi-immersive, fully immersive or Augmented Reality (AR). The high cost and simulator sickness are two problems related to immersive VR environments. However, Desktop-VR provides an alternative to immersive VR and retains the benefits interacting with virtual representations of the reality (Merchant et al., 2014, Merchant et al., 2012). Desktop-VR is also capable of supporting a Constructivist learning model (Lee et al., 2010). This learning philosophy believes that learning is constructed through experience and activity (Martens et al., 2007). There is a research to support Desktop-VR success for teaching geoscience (Fung-Chun et al., 2002), physic concepts (Kim et al., 2001) and driving rules (Chen, 2006). Moreover, it is important to recognise that an immersive virtual learning environment, will not necessarily facilitate the development of conceptual understanding (Dalgarno et al., 2002). Therefore, as it has been highlighted by Dalgarno et al. (2002) the learning task has to be designed in a way to be associated with appropriate task support, which learners find it easy to use and useful. This concept has also been supported by Task-Technology Fit (TTF) (Goodhue and Thompson, 1995) which needs to be also taken into account to choose the right platform for the right purpose.

2.7.4 Sense of Interaction

Educational psychologists often argue that human learning involves the construction of new knowledge based on prior information (Dewey et al., 1985, Piaget, 1973, Vygotsky, 1978, Bruner, 1966). For instance, according to Dewey and colleagues (1985), active experiences (such as interactions between learners and the environment) could lead to the construction of new knowledge. In this regard, educators and trainers can be seen as facilitators (Hunkins and Ornstein, 1998) who help trainees to shape their learning experience and promote learning. Dewey et al. (1985) suggest that the main purpose of the education is to improve the reasoning processes. Constructivist techniques to learning emphasise the development of problem solving and discovering a meaning, the new knowledge is formed around the process of discovery where the educators are there to guide them through creative interactive process rather than focusing on outcome-based teaching (Huang, 2002). Early on, constructivist theorists extended the traditional focus on individual learning to address collaborative and social dimensions of learning. For example, Vygotsky (1978) examined the social context of the learning process – i.e., the importance of socio-cultural context and its impact on what is learned. This theory, known as social constructivism, states that learning is an interactional process between the learner, the educator and their environment; in short, the theory refutes that learning could happen in isolation. Although collaborative learning has proven to increase motivation amongst learners it also raises the issue of participants who fail to engage with the group (Petraglia, 1998).

Moreno and Mayer (2007) propose three elements of interaction to characterise VR technologies: i) the physical element (the feeling that you are actually in the replication of physical world), ii) the social element (the feeling that you are sharing the experience with someone else) and iii) the self-presence element (seeing virtual version of yourself). In a learning context, the interaction is based on learner's actions and responses (Moreno and Mayer, 2007). The system's responsiveness to the learner's action will define the interaction. The lowest level of interaction corresponds to pre-defined simulations that do not respond to the trainee's decisions. On the other side of the spectrum, VR technologies which allow multi-directional communication are described as being highly interactive. The main purpose behind interaction is to construct knowledge and add information to the learner's memory. Unlike more passive computer-aided training approaches (videos or webinars), VR-based training provides an intimate level of interaction between trainees and the learning content, allowing for more flexible problem-solving and decision-making processes. Shifting from batch simulation to VR technology may require more investment but allows one to evaluate more possibilities and options (Kirkpatrick and Bell, 1989). Additionally, providing feedback is also a form of interaction. Moreno and colleagues (2002) state that there are two forms of feedback: "corrective feedback", where the trainee will be informed whether he/she was right or wrong, and "explanatory feedback", where the explanation is given why he/she was right or wrong. Their study shows that trainees who received explanatory feedback performed better in solving complex problems compared to the other group who just received the corrective feedback.

2.7.5 Sense of Immersion and Presence

The concepts of presence and immersion are the source of some confusion in their own right (Skarbez, 2017). Witmer and Singer (1998) defined presence as "the subjective experience of being in one place or environment, even when one is physically situated in another" p. 226. Therefore, presence is a subjective and internal feeling elicited by sense perceptions. Fox and colleagues (2009) define immersion as: "The psychological experience of losing oneself in the digital environment and shutting out cues from the physical world is known as immersion". Slater (1999) regard immersion as an objective characteristic of a VE system, unlike presence. Thinking of immersion as an objective measure, VR learning environments can be categorised based on their level of immersion as presented by Moreno and Mayer, 2002: (i) no immersion (such as illustrated text), (ii) medium immersion (such as games and computer displays) and (iii) high immersion (such as head-mounted displays). High degrees of immersion increase the sense of presence which might lead to more engagement and deeper learning compared to approaches where trainees remain observers (Salzman et al., 1999). Interest theory (Salzman et al., 1999) states that the higher the sense of presence that the trainees feel the more motivated they will be, and this in turn might motivate them to work harder to grasp deeper learning. On the other hand, interference theory states that highly immersive environments might overload trainees with too much of information (Moreno and Mayer, 2002).

According to Orlansky and String (1977) the major objection to VR technology is its lack of ability to transfer and stimulate trainee's sensorial experience. Sense of immersion and presence are important aspects of VR environments (Tichon and Burgess-Limerick, 2011). Sense of presence is a subjective feeling and experience of ‘being there’ without even physically being in that place (Jung et al., 2008). Sense of presence has been identified as a major factor for a successful training transfer from the VR environment to the real world (Romano and Brna, 2001). Riva and Gamberini (2000) argue that the sense of presence is more important for effective training transfer than the visual realism of the VR environment. The Immersion and Presence Questionnaire (IPQ) is one of the techniques widely used to measure sense of presence (Witmer and Singer, 1998a). The IPQ questionnaire focuses on four causal factors: involvement, sensory fidelity, immersion and interface quality. An alternative approach is to ask trainees to retrospectively report on their training experience. A major criticism of this method is that it draws more from filtered memory cues than objective and replicable recollection of experience (Slater, 1999). Finally, physiological measurements are also possible such as: posture, skin conductance, respiration rate, cardiovascular and muscle tension and bio-chemical measures such as salivary amylase (Tichon and Burgess-Limerick, 2011).

Based on a review by Alsina-Jurnet and Gutiérrez-Maldonado (2010), the major factors responsible for the sense of presence in virtual environments are: 1) field of view, 2) foreground/background manipulations, 3) update rate, 4) stereoscopy, 4) geometry field of view, 5) pictorial realism, 6) image motion, 7) the use of a CAVE versus a desktop VR or HMD, 8) spatial sound, 9) the number of audio channels, 10) the inclusion of tactile, olfactory or auditory cues, 11) the use of head tracking, 12) the amount of feedback delay, 13) the possibility of interacting with the virtual environment or body movement. Although presence is a psychological phenomenon the user characteristics involved in its engagement have not been widely studied (Alsina-Jurnet and Gutiérrez-Maldonado, 2010). Alsina-Jurnet et al. (2010) found that their students felt greater sense of presence in a test anxiety environment than in a neutral environment. Thus, the learning process might need to be ‘authentic’, which means that it might need to match the real life experience in terms of the emotions it generates, the learning content, and key aspects of the environment itself (Brookfield, 2007). Trainees may be willing to spend more time and concentration on a task which is presented in a well-designed immersive training world where they can have realistic interactions (Salzman et al., 1999). A high sense of immersion makes the trainees feel the experience, therefore making the learning activities more memorable (Romano et al., (2001). Participants must accept the technology in order to get involved in the training, be motivated by its content and be challenged by its objectives (Lackey et al., 2016).

Immersive tendency is another key aspect of VR-based training that involves both the characteristics of the VR environment and of the trainees. There are two important individual factors that shape immersive tendency: ‘willingness to suspend disbelief’ and ‘prior experience with VR world’ (Lombard and Ditton, 1997). The Immersive Tendency Questionnaire (ITQ) is being used to measure immersive tendency amongst VR technology users (Witmer and Singer, 1998b). Generally, the higher the ITQ score is, the higher the sense of presence in a VR environment (Wilfred, 2004). Another concept recently proposed by Thornson et al. (2009) is included in the Tendency towards Presence Inventory (TPI). The TPI questionnaire includes six factors cognitive involvement (active), spatial orientation, introversion, cognitive involvement (passive), ability to construct mental models and empathy. Despite this, future work is still needed in order to evaluate the predictive validity of these factors (Alsina-Jurnet and Gutiérrez-Maldonado, 2010).

2.7.6 Sense of Realism and Fidelity

Fidelity is another factor considered by researchers to evaluate the effectiveness of VR-based training; however, it is controversial factor. There is no direct correlation between fidelity and learning and no clear indication of the level of fidelity required to achieve a successful VR-based training (Hoffman et al., 2001). Baker and colleagues (2005) observe that realistically rendered VR scenarios do not contribute to a successful training as much as a realistic task and context which trainees can relate back to their workplace experience. The sense of fidelity includes four components: physical, functional, task-based and psychological fidelity (Hays and Singer, 2012). A study by Kemeny and Panerai (2003) shows that users of a driving simulator were more receptive to the accurate flow of moving objects rather than their detailed rendering as motor vehicles. Bednarz (2010) has stated Interactive Virtual Reality (IVR) system has the potential for providing an "enhanced" teaching medium as humans tend to remember events/situations better when they experience those events in person.

2.7.7 Sense of Comfort

Motivation is another factor affecting the learning process (Salzman et al., 1999). According to constructivist learning theory (Dewey et al., 1985) motivation is important factor in learning process, and other factors such as stress and worry will distract trainees from learning. Therefore items from Short Stress State Questionnaire (SSSQ) can be used to measure sense of motivation, stress, pressure and worry to ascertain how these factors were affecting the learning process. Additionally, based on flow theory discussed by Rieber (1996) enjoyment from activities resulted when the challenge of an activity is optimised which means the training is as realistic as possible and person is fully concentrated and in control of activity in a way he/she lost track of time. Based on the stated theory if I can create a learning environment that enhances the pleasure of the experience, the outcome of training can be optimised. Research shows that if the purpose of training is to acquire skills, active involvement tends to produce better results than traditional theory-based learning. One successful example of this is the active use of flight simulators in aviation skills training (Deaton et al., 2005). The realistic training environment that these flight simulators provide gives trainees the opportunity to put prior theoretical knowledge into practice, while being mentored and supervised by an expert. Interactive environments and motivational factors also have an impact on cognitive engagement of trainees (Amorim et al., 2000). Learning can also benefit from a safe, positive and motivating environment where learners are able to ask questions, contribute answers, experience failure and try again (Kember et al., 1997). In this environment educators must monitor and warrant the quality of discussions and learning. In his flow theory, Rieber (1996) states that enjoyment is a key indicator of the quality of the learning experience whereby the adequate level of challenge is proposed to learners in order for them to focus on the task while keeping their level of motivation.

2.7.8 Sense of Simulator sickness

Another factor to consider in evaluating the effectiveness of VR-based training is simulator sickness. Trainees who experience simulator sickness will be distracted from the training and will not be able to concentrate on content, possibly resulting in lower sense of presence and even lead them to withdraw from training. Some individuals (such as older people) are at higher risk of simulator sickness (Arns and Cerney, 2005). Longer periods of immersion might cause more sickness; however, symptom severity usually reduces after a few exposures to VR immersion (Kennedy et al., 1993). Simulator sickness is usually thought to be caused by "*discrepancies between visual and vestibular information*" (Tichon and Burgess-Limerick, 2011). One way of reducing discomfort is by introducing rest frames (Duh et al., 2004). A rest frame is any stationary object which helps VR technology users to distinguish which object is moving and which object is stationary. The Simulator Sickness Questionnaire (SSQ) developed by Kennedy and colleagues (1993) can be used to measure the individual level of simulator sickness. SSQ contains 16 questions grouped in 3 sub-classes: nausea, oculomotor discomfort and disorientation.

2.7.9 Technology Acceptance and Technology fitting the purpose

In the information technology literature, there are two significant models which explain utilisation and user behaviour: the Technology Acceptance Model (TAM), first proposed by Davis and colleagues (1989), and the Task Technology Fit (TTF), developed by Goodhue and Thompson (1995). These two models explore the factors that explain technology use and its connection with user's performance. TAM focuses on attitudes towards using a technology, based on the perceived ease of use and perceived usefulness. As it has been stated by Chow et al. (2012), TAM is a predictive model attempts to uncover the relationship between constructs that have an impact on the intentions of people to use technology. It emphasises that an individual's intention to use a system is determined by two beliefs: perceived usefulness and perceived ease of use. Perceived usefulness is also posited as being directly impacted by perceived ease of use. Chow et al. (2012) also declares that numerous studies have found that the model consistently explains typically about 40% of the variance in usage intentions, and that it compares favourably with alternative models such as the Theory of Reasoned Action and the Theory of Planned Behaviour (Venkatesh and Davis, 2000).

TAM consists of five main factors: attitude towards use, intention to use, perceived ease of use, perceived usefulness and actual tool use. A number of meta-analyses on the TAM have demonstrated that it is a valid, robust and powerful model. Lederer, Maupin, Sena, and Zhuang (2000) have recorded more than 15 published studies that examined the existing relations between perceived ease of use, perceived usefulness, attitude towards use, and usage of information technologies over a period of 10 years (from 1989 to 1999). The results of these studies support the use of the TAM as a predictive or explanatory model of the usage of different technologies. King and He (2006) identified 88 studies published on the TAM. The results of this meta-analysis confirm that the model can be used in a wide variety of contexts and that the impact of ease of use on the intent to use is mainly brought about by perceived usefulness. In a critical review of the TAM, Legris, Ingham and Collerette (2003) retained 22 studies that tested the model in its integrity with a well-defined methodology as well as complete and available results. Their conclusions follow the same direction as those of King and He (2006), that is, the TAM is a theoretical model used in different contexts to help understand and explain the use of information technologies. The studies retained were testing among others, the use of technologies such as word processing and telemedicine software, electronic mail, the internet, personal computers and university resource centres.

TAM is not capable of explaining the functionality of the technology as it is not task-focused. Davis and colleagues (1989) have developed a standard questionnaire to address TAM factors. By contrast, TTF focuses more on the technology's functionality and what users need to achieve. TTF aims at matching the capabilities of a technology to the demands of a task. TTF consists in five main factors: task requirements, tool functionality, task-technology fit, tool experience and actual use.

The complementarity between the two models led Dishaw and colleagues (1999) to develop an integrated TAM/TTF model offering a significant explanatory power over technology acceptance and task performance (Figure 2-6).

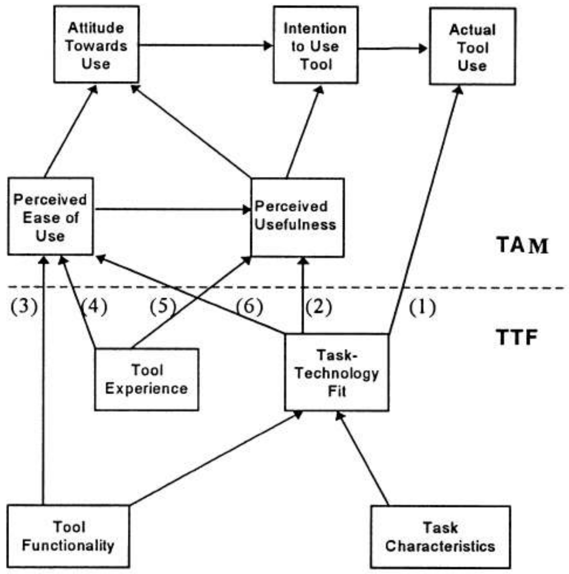


Figure 2-6: Integrated TAM/TTF model (Dishaw et al., 1999)

Paths 2 to 4 in Figure 2.3 indicate that the technology assessment affects participants' beliefs regarding how useful and easy to use the technology is. Perceived ease of use is being partly determined by technology's functionality (Path 3) and partly by participants' experience with the technology (Path 4). Technologies with more functionality are more complicated and therefore harder to work with on the other hand as the experience with the technology improves it become easier to deal with it. As the experience with the technology increases participants develop understanding of technology's functionality therefore they find it useful and easy to use (Path 5-6). Based on Goal Theory (Blumenfeld, 1992), the training session to be successful the content of the training must be meaningful and include variety, diversity, challenge, control. Generally, when a given task displays variety and diversity trainees tend to engage better with the training. However the reaction of the trainees to the challenge depends on their perception of the training material or environment. The quality of their engagement will increase if they perceive that what they are learning is meaningful. Meaningfulness has been defined as training and material that "makes cognitive sense" or/and creates "interest and value". According to Webster and Hackley (1997), it is the instructional implementation of technology, and not technology itself, that determines learning outcomes. The technology must facilitate the training in a way to enhance users' learning behaviour, which is the determination of learning outcomes. When technology is fitting to solve learning tasks, it can ameliorate some of the users' characteristics about learning, like reflective thinking, to influence learning outcomes. Moreover, it is important to understand that a virtual learning environment with a high degree of fidelity and user control, modelled on a real-world system, will not necessarily facilitate the development of conceptual understanding.

2.8 The Hypothesised VR Learning Model

This study aims to investigate the users' learning experience in a VR-based learning environment by measuring various dimensions of technology mediated approach. To do this, a broad conceptual framework will be presented which will bring different dimensions such as the learners' characteristics, technology features, learning experience, task technology fit and perceived learning together to introduce the holistic view into the matter of assessing trainees' learning experience in VR learning environment.

As a consequence, I propose to develop an in-situ evaluation framework that will assess groups of trainees in their usual training environment, using non-disruptive objective and subjective information (Figure 2-7).

As stated at the end of Chapter I, this thesis aims to establish a systematic and comprehensive framework to evaluate VR-based training programs developed for mines rescue brigades in NSW (Australia). In order to address this objective, I need to answer the following questions:

- What are the actual training needs of underground coal miners?
- What are the inherent limitations of traditional training for underground coal miners?
- What are the potential capabilities of VR-based training to address these limitations?
- Which factors influence the effective delivery of VR-based training?

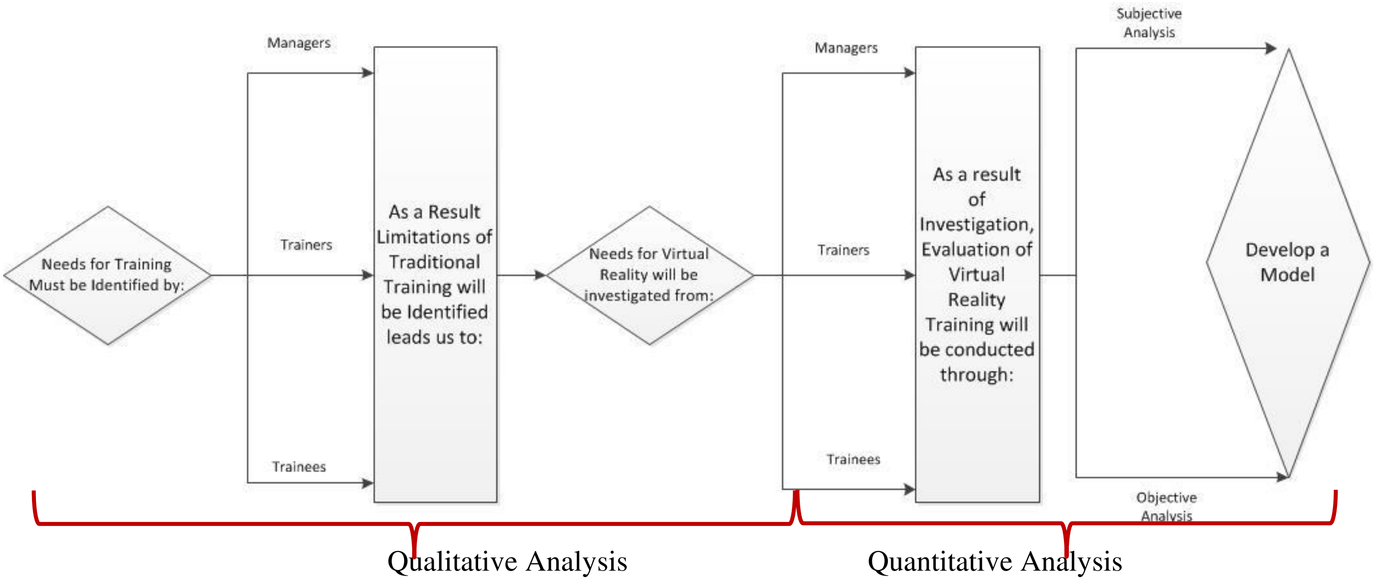


Figure 2-7: Proposed research evaluation framework

The idea is to let the trainer conduct a VR-based training session as usual without distracting the trainees and to embed our evaluation into an annual cycle of training. The evaluation should not only address procedural and substantive factors (sense of immersion, sense of fidelity, comfort, sickness…) but also reflexive ones (usefulness, success, realism). Objective evaluation should be estimated through a rapid skill test conducted prior and after the session. It is also essential to get feedback from trainers, managers and VR designers in order to better understand how VR-based training programs-in-use address the needs of the trainees and the industry. Henceforth, I propose to focus our analysis on factors affecting the quality of training transfer and investigate the eventual impact of VR technology on this training transfer.

Our systematic framework is based on one developed previously by the US army for flight simulator studies (Seibert et al., 2012). The original framework included three layers: utilisation, capabilities and challenges. However, Sterman (2000) noted that for VR-based training to be successful, participants needs to understand that: (a) what they experience in a VR environment is related to the real world; and (b) what they learn in a VR environment is consistent with the real tasks that they actually have to perform. Other studies have proposed that for the training program to be effective there needs to be a good cognitive fit between the operational problem at hand and the procedural solution proposed during the learning process (Dishaw et Strong, 1999; Salzman et al., 1999). Therefore, I have introduced a fourth analytical layer: the actual training needs (Figure 2-8).

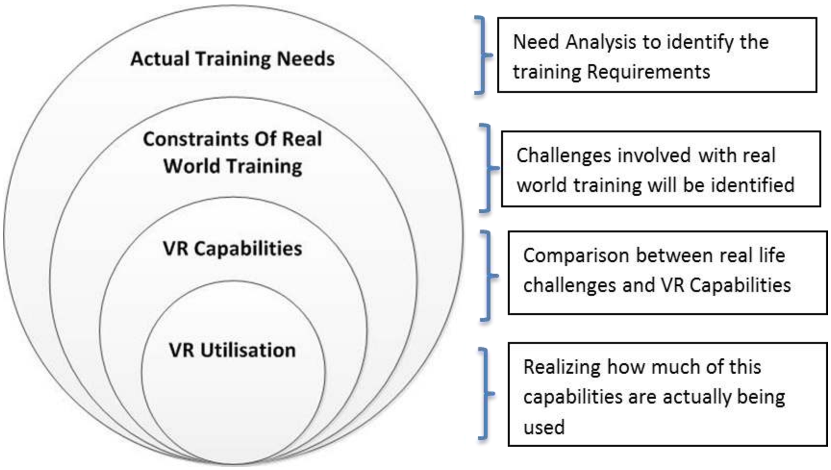


Figure 2-8: Evaluation framework (adapted from Seibert et al., 2012)

The outermost layer of this framework corresponds to the actual training needs. The second layer focuses on the constraints associated with traditional onsite and classroom training. The third layer focuses on the capabilities of the VR technology-in-use (360 VR and Desktop-VR). Finally, the innermost layer corresponds to the learning process experienced by trainees. Then in order to be able to answer the questions “Does VR enhance training outcome ?” and if yes, “How VR-based training environment enhance the training outcome?” I proposed the following framework taking into consideration various dimensions of immersive and technology-mediated learning models. Our hypothesise model (Figure 2-9) includes fifteen construct which each has been informed by one or more factors.

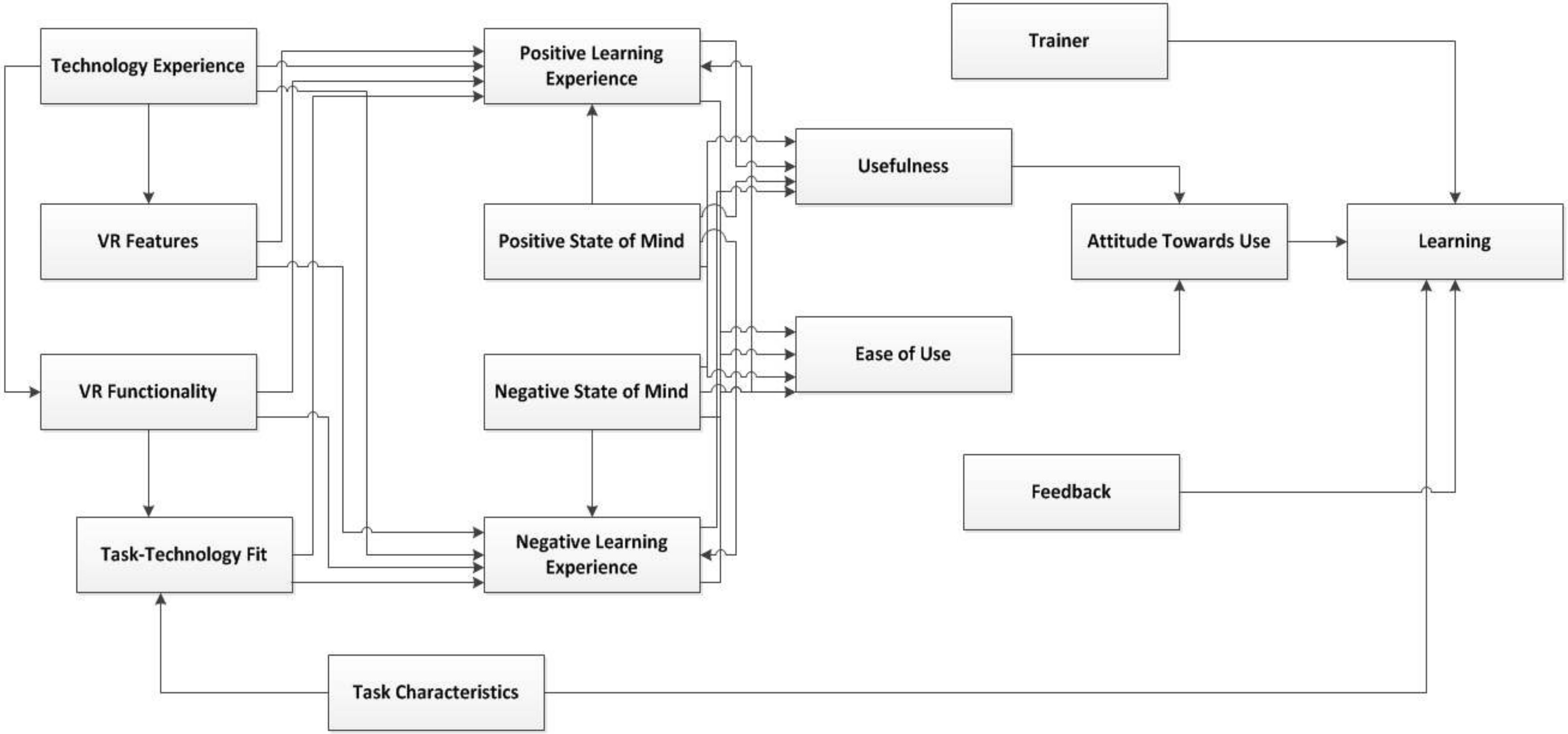


Figure 2-9: Hypothetical Causality VR-Learning Model

In our hypothetical model, technology experience will be informed by “gaming experience” and “digital world involvement” factors. VR features will be informed by “immersion”, “interaction” and “realism”. Positive state of mind will be informed by “alert”, “motivation”, “confidence”, “wellbeing” and “competition”. Negative state of mind will be informed by “stress” and “worry”. Positive learning experience will be informed by “presence”, “engagement” and “enjoyment”. Negative learning experience will be informed by “stress”, “worry and pressure” and “simulator sickness”. VR functionality, task-technology fit, task characteristics, perceived usefulness and ease of use, attitude towards use, trainer, feedback and perceived learning will be directly informed by items taken from the post-training questionnaire.

Based on the findings of the previous studies outlined in section 2.7, it is predicted that training in a VR environment will be enhanced by: 1) The trainees having a positive state of mind prior experiencing VR learning environment; 2) The trainees having more previous experience with technology; 3) The trainees having a positive learning experience when in the VR learning environment; 4) Technology features, 5) task-technology fit, 6) task characteristic, 7) tool functionality, 8) technology being easy to use, 9) trainees finding technology useful and 10) trainees’ attitude towards technology; Also, 11) the trainers, providing positive contributions prior, during and after (feedback) the training session.

Additionally it is predicted that trainee learning experiences and outcomes will be impaired by: 1) the trainees having a negative state of mind prior to experiencing the VR learning environment; and 2) the trainees having a negative learning experience when in VR learning environment.

The predictions are formalised by the hypothesised VR learning model provided in Figure 2-9. Here I will test these hypotheses by conducting SWOT analysis and User opinion approach. The factors will be measured by using standard questionnaires (the questionnaires are outlined in Section 3.5). Then In order to analyse the data I am going to use SPSS and AMOS statistic software package to check the assumption and perform Structural Equation Modelling.

3 Chapter III: Methodology

3.1 Study Context

The research was conducted in collaboration with Mines Rescue Pty Ltd, a training provider for the coal mining industry in Australia that operates four training stations in New South Wales (Woonona, Lithgow, Newcastle, and Singleton). Each centre delivers classroom, onsite and VR-based training programs ranging from induction courses for new recruits to highly specialised courses for more experienced miners.

Our study focussed on training programs developed for mine rescue brigades. These brigades are made of five to seven highly specialized volunteers who act as primary responders in case of major mining incidents or accidents. Each volunteer is an already experienced underground miner. The methodological framework was designed and tested at Woonona station, located only a few kilometres from the University of Wollongong. Then, the study was conducted across the four aforementioned stations between March and December 2015.

3.1.1 Technology-in-use

Although Mines Rescue Pty Ltd has invested in various VR technologies (individual domes, 360 degree immersive theatre, GEN4 desktop immersive simulation and, more recently, Oculus Rift), this research focuses on training programs developed for the 360 degree immersive theatre (360-VR) and semi-immersive desktop simulator (Desktop-VR). The 360-VR is a 10m diameter, 4m high cylindrical screen that displays a 3D stereo, 360 degree virtual environment, providing a fully immersive experience to participants equipped with 3D glasses (Figure 3-1).

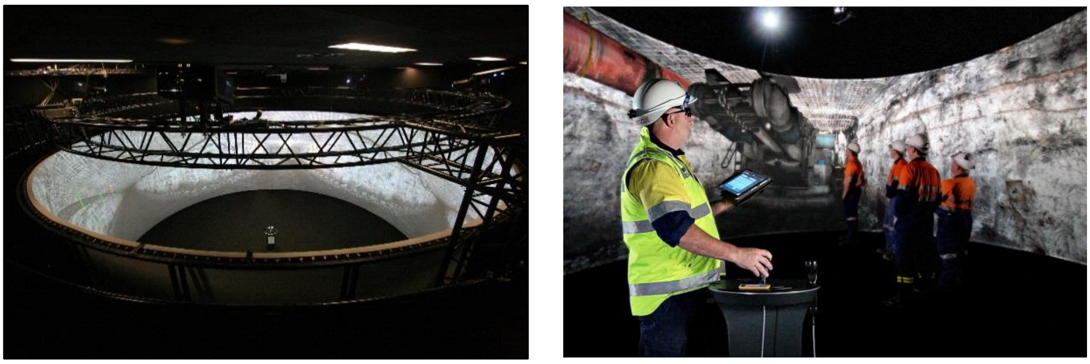


Figure 3-1: 360 degree immersive theatre (360 VR) in Woonona, NSW (credits: Mines Rescue Pty Ltd)

The large area within the theatre allows for a mixed reality experience, with small groups of trainees (5 to 7) able to interact both with props (virtual gas detectors) and with each other, in order to ensure that appropriate responses, activities and reflexes are included as part of the training experience. The trainer (yellow jacket holder on Figure 3.1) guides the trainees through successive stages of the scenario, prompting them for appropriate actions or responses. On the other hand, Desktop-VR is a semi-immersive platform allowing a team of trainees to have individual training experiences (Figure 3-2). Trainees use joysticks to control their avatar in the VR environment. Prior to the training, the trainers explained to trainees how to use the joysticks.

Figure 3-2: Semi-immersive desktop simulator (Desktop-VR) in Woonona, NSW (credits: Mines Rescue Pty Ltd)

Training scenarios have developed been by Mines Rescue Pty Ltd using Unity3D, a multi-platform game engine, resulting in a unique whole-of-mine VR environment including 50km of roadway and covering all regular underground mining activities. In order to limit the heterogeneity of responses across groups of trainees, the study focused on a single scenario, specifically created by the VR designers. An accident involving an underground vehicle starts a fire at the bottom of the transport drift. The fire is uncontained and spreads to the coal, contaminating several galleries and roadways with toxic gases. The incident occurs during a night shift at 3.06 am on a Sunday morning. At the time of the incident seven people are underground and three people on the surface. Visibility in the galleries is down to about 50 metres and it has been reported that one of the miners is missing and the others are safe. The task is assigned to the mine rescue brigade to undertake search and rescue for the missing man.

3.1.2 Participants

Between March and August 2015, forty five 360 VR-based training sessions were conducted, and a total of 284 trainees took part in this study. Moreover, between July and December 2015, thirty five Desktop-VR sessions were conducted and another group of 243 trainees took part in this study. From the overall cohort of 372 trainees, 155 successively experienced 360 VR and Desktop VR environments. All of the participants in the study were male, aged between 24 and 64 years, with their time spent in mining and mines rescue ranging from between 5 and 40 years. In order to test the influence of socio-demographic factors on learning outcomes, I successively split our sample population between (1) younger (<40 years old) and older (>40 years old) trainees, (2) experienced (>10 year) and less experienced (<10 year) miners and (3) experienced (>10 year) and less experienced (<10 year) rescuers.

3.2 Conceptual framework

The potential benefit of VR technology for the mining industry is not only about introducing a more convenient training environment for workers, but mainly to increase competency, improve workplace safety conditions and establish a culture of safety within the organisation. These factors lead to more effective management of human resources and assets and, ultimately, to more sustainable production, more profitable industry and better social responsibility.

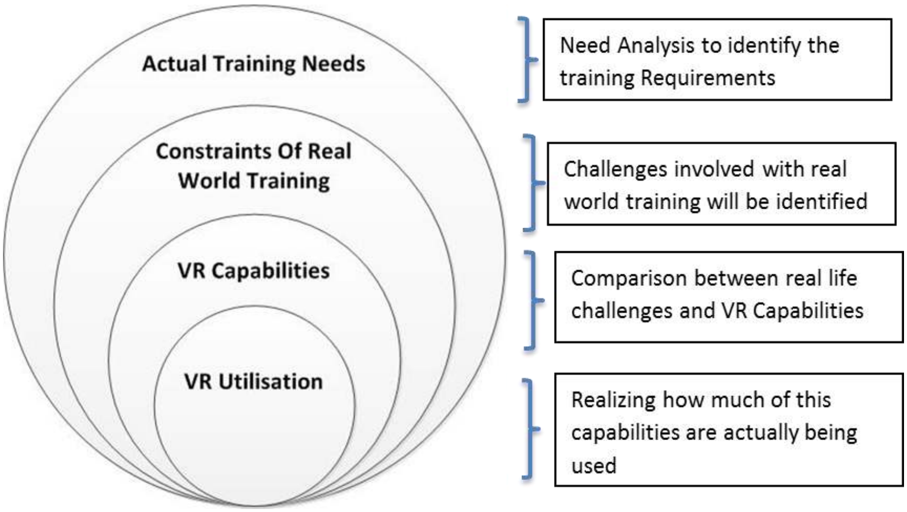


Figure 3-3: Evaluation framework (adapted from Seibert et al., 2012)

In the evaluation framework (Figure 3-3) the outermost layer of this framework corresponds to the actual training needs. Interviews with trainers, mine managers and station managers formed the main source of this information. The second layer focuses on the constraints associated with traditional onsite and classroom training. The third layer focuses on the capabilities of the VR technology-in-use (360 VR and Desktop-VR). In-depth interviews with VR designers were used to better understand the potential and actual use of this technology. Finally, the innermost layer corresponds to the learning process experienced by trainees. Pre- and post-training questionnaires were used to evaluate the quality of the training session, alongside direct observations of trainees interacting within the 360 VR environment during training. Finally, a skill test was designed and implemented prior and after training sessions to estimate training transfer.

3.3 Experimental design

The proposed training scenario drew on existing VR-based training packages developed by Mines Rescue Pty Ltd for mines rescue brigades. The testing regime included two successive rounds of training: (1) first round in the 360 VR environment with the original search and recovery scenario, then (2) a second round with the Desktop VR environment (GEN4 technology), using the same scenario.

The aim was to evaluate trainee's level of learning during the 360 VR round and the extent of training transfer into a different environment (Desktop VR round). Therefore, the scenario had to include a broad range of training components, such as procedural (safety rules, communication protocols, etc.) or substantive (mine environment, equipment, etc.) knowledge.

During the training phase (360 VR), trainees underwent collective training session with a trainer taking them through the scenario and prompting them for responses. During the assessment phase (Desktop VR), trainees were physically separated but interacting with each other in the virtual environment through their individual avatars, allowing for individual decision-making, multi-tasking and coordination. Hence, the assessment phase (Desktop VR) allowed us to evaluate the extent of training transfer between the two VR environments.

In terms of experiential differences, the 360 VR round exposed to the following conditions: training as a group, taking collective decisions (prompted by trainer), passive immersion in the VR environment and absence of coordination or multi-tasking. By contrast, the Desktop VR round exposed trainees to: active and individual control of their avatar, coordinated and isolated tasks and remote communication through avatars (trainer is just an observer).

The quality of training transfer between the two rounds was partially assessed through a skill test survey handed over prior and after the 360 VR and Desktop VR rounds. This experimental setting did not aim to formally compare the two VR environments but rather at using the successive rounds to evaluate learning performance through contrasted training environments, the second environment were used required more autonomy from the trainees (a metaphor for transfer from training to workplace contexts).

3.4 Methodology

3.4.1 Overall approach

Before entering the VR environment (360 VR or Desktop VR), each trainee was handed a pre-training questionnaire that consisted of thirty response-scaling questions (each of these being 10 point Likert-items) and one open-ended question related to the challenges of traditional onsite training. A post-training questionnaire was handed over just after the training session, including seventy response-scaling questions (also 10 point Likert items) and four open-ended questions associated with a SWOT (i.e. Strengths, Weaknesses, Opportunities and Threats) analysis of the VR-based training. Also, a short skill test was also handed over to each trainee prior and after the session. In addition to this questionnaire data, the trainers, managers and VR designers were also involved in open-ended interviews. Trainers and VR designers were also subjected to a SWOT analysis. Researchers and trainers also recorded observations during the training sessions (without interfering with trainees).

3.4.1.1 Data acquisition - Actual training needs

As stated by McKillip (1987), our needs analysis stems from task and performance analyses in order to infer a training suitability analysis. This process was conducted with managers and VR designers through semi-structured interviews. The trainees' perspective was also sought for using the following questions in the pre- and post-training questionnaires:

- In your opinion what are the challenges involved with onsite training? [pre-training]
- What were the weaknesses of VR as a training environment? [post-training]

3.4.1.2 Data acquisition - Onsite training constraints

The trainers and managers were also asked to identify: (1) the constraints associated with onsite training and (2) the potential for VR-based training to overcome these limitations. These answers were partially validated against two open-ended questions directed to trainees:

- In your opinion what are the challenges involved with onsite training? [pre-training]
- What are the strengths of VR as a training environment? [post-training]

3.4.1.3 Data acquisition - VR-based training capabilities

Open-ended interviews with the VR designers and trainers were also aimed at identifying: (1) the current capabilities of 360 VR or Desktop VR, (2) the actual limitations of 360 VR or Desktop VR and their potential for upgrades, as well as (3) the relevance of 360 VR or Desktop VR with regards to training needs.

3.4.1.4 Data acquisition - VR-based training utilisation

The pre-training and post-training questionnaires were designed in order to capture most factors included in the learning model (Figure 2.2) proposed by Salzman and colleagues (1999) and supported by the integrated TAM/TTF model (Figure 2.3) of technology acceptance and use proposed by Dishaw and colleagues (1999). The post-training questionnaire also included elements of a SWOT analysis. A detailed description of the questionnaires is provided in the next section (3.4).

3.4.1.5 Data analysis – Need analysis

The need analysis focused on the tasks and procedures specifically performed by the mine rescue brigades to the exclusion of any other activities related to the daily operations of an underground coal mine. In practice, many interviewees used recursive reasoning, starting from current training programs (onsite, classroom or VR-based) to identify gaps with real world activities and re-formulating the needs from that standpoint. An equivalent recursive process was used to further analyse the needs from trainee's viewpoint, using the following questions in the pre- and post-training questionnaires:

- In your opinion what are the challenges involved with onsite training? [pre-training]
- What were the weaknesses of VR as a training environment? [post-training]

3.4.1.6 *Data analysis – SWOT analysis*

From the post-training questionnaire the following questions were used to inform an extended SWOT analysis (Strength, Weakness, Opportunity and Threat), including subjective judgement from trainees and trainers on the usefulness of the training session, success in completing the tasks and realism of the VR environment. The following questions were used for the extended SWOT analysis:

- What were the strengths of VR as a training tool? [open ended]
- What was the weakness of VR as a training tool? [open ended]
- How successful was the training in VR? [10 point Likert item]
- How useful do you think this training was? [10 point Likert item]
- How consistent was your experience with real life conditions? [10 point Likert item]
- Do you prefer VR training over traditional training? [10 point Likert item]
- Would you recommend VR training to others? [10 point Likert item]

Each SWOT category was then correlated with the perceived usefulness of the training session, success in performing the tasks and realism of the VR environment.

3.4.1.7 *Data analysis – Descriptive correlations*

The 30 variables from the pre-training questionnaire were grouped into ten (Table 3-1) analytical categories:

Table 3-1: Pre-Training Questionnaire Factors

Pre-Training Questionnaire				
Stress	**Worry**	**Motivation**	**alertness**	**Confidence**
Competition	**Perceived digital involvement**	**Perceived digital engagement**	**Gaming experience**	**Well-being**

Likewise, the 70 variables from the post-training questionnaire were grouped into eighteen analytical categories (Table 3-2):

Table 3-2: Post-Training Questionnaire Factors

Post-Training Questionnaire				
Perceived sickness	**Degree of realism**	**Degree of immersion**	**Amount of presence**	**Amount of interaction**
Amount of engagement	**Degree of enjoyment**	**Stress level**	**Level of worry and pressure**	**Technology ease of use**
Technology usefulness	**Tool functionality**	**Task-characteristics (concept to be taught)**	**Task-Technology Fit (TTF)**	**Attitude towards use (behaviour of use)**
Feedback	**Trainer's attitude**	**Degree of learning**		

Each category was then correlated with the 'degree of learning' one, considered as a proxy subjective judgment on the quality of the training transfer.

3.4.1.8 Data analysis - Competency analysis

Responses to the skill test, before and after the training session, were scored based on the answer sheet provided by Mines Rescue Pty Ltd. There were four technical questions and each question was worth one mark. Each participant received a mark out of four. The analysis consisted in comparing overall scores prior and after the training session.

3.4.1.9 Data modelling – Principal component analysis

Principle Component Analysis (PCA) has been used to investigate the underlying relationship among different variables. This technique results in factor reduction based on hidden relationships. Then, we ran a regression analysis with the newly categorised and reduced items (principle components) acting as independent variables and the 'degree of learning' as the dependent variable. This method identifies which categories and primary variables most influenced learning, from individual characteristics (pre-training questionnaire) to experiential features (post-training questionnaire).

3.4.1.10 Data modelling – Causal model of learning

As it has been discussed in literature review section (2.8), we developed a causal model of learning (Figure 3-4). The model integrates objective and subjective viewpoints to calculate the impact of different factors on learning capabilities. Each factor is informed by data extracted from our study. We used a path analysis to test every connection in the model. For example, if the path between "learner's characteristics" and "perceived ease of use" does not weight significantly we can conclude that relationship does not exist and that hypothesis will be rejected.

To test the model:

- Technology experience will be informed by "gaming experience" and "digital world involvement" factors.
- VR features will be informed by "immersion", "interaction" and "realism".
- Positive state of mind will be informed by "alert", "motivation", "confidence", "wellbeing" and "competition".
- Negative state of mind will be informed by "stress" and "worry".
- Positive learning experience will be informed by "presence", "engagement" and "enjoyment".
- Negative learning experience will be informed by "stress", "worry and pressure" and "simulator sickness".
- VR functionality, Task-technology fit, Task characteristics, Perceived usefulness, Ease of use, Attitude towards use, Trainer, Feedback and perceived learning will be directly informed by items taken from the post-training questionnaire.

SPSS and AMOS statistical software packages were used to analyse the data. After checking the assumptions of the statistical tests, Structural Equation Modelling (SEM) was performed to estimate multiple and interrelated dependence between the constructs. Data in the social sciences often have non-normal distribution (Bentler and Chou, 1987, Malthouse, 2001). If the distribution of data differed from normal distribution, then different transformations techniques were performed to restore normality. However, as mentioned by Ullman and Bentler (2012) some variables do not restore normality or are not expected to be normally distributed in the population. In that case, an estimation method was used that addresses the non-normality.

One of the estimation techniques used in SEM that does not assume normality is Unweighted Least Square (ULS). In this study, I am using ULS to estimate the direct and indirect impacts. The least squares criterion is a computationally convenient measure of fit. It corresponds to maximum likelihood estimation when the data is normally distributed with equal variances. If the model is reasonable, the parameter estimates will produce an estimated matrix that is close to the sample covariance matrix. "Closeness" is evaluated by fit indices such as the Goodness-of-Fit statistic (GFI -Ullman and Bentler, 2012). Since Unweighted least squares estimation (ULS) does not standardly yield a (Chi-square) $\chi 2$ statistic or standard errors, in this study the goodness of the model will be reported by GFI and NFI (normed fit index). The GFI statisticis an alternative to the Chi-Square test and calculates the proportion of variance that is accounted for by the estimated population covariance (Tabachnick and Fidell, 2007). NFI assesses the model by comparing the $\chi 2$ value of the model to the $\chi 2$ of the null model. The null/independence model is the worst case scenario as it specifies that all measured variables are uncorrelated. Values for this statistic range between 0 and 1 with Bentler and Bonnet (1980) recommending values greater than 0.90 indicating a good fit. In a review by McDonald and Ho (2002) also confirms that the most commonly reported fit indices are the GFI, NFI and CFI.

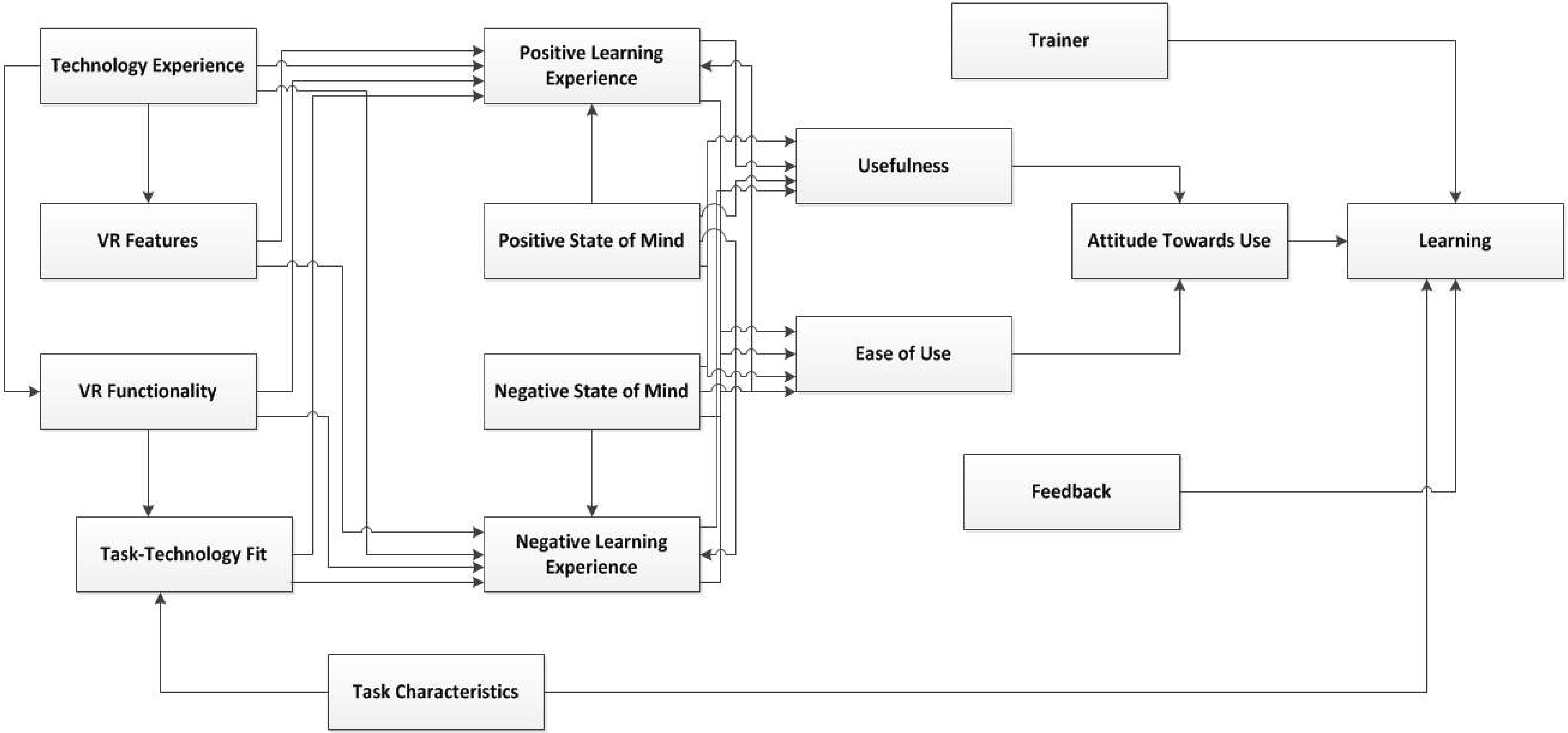


Figure 3-4: VR Causality learning model

3.5 Pre-training and post-training questionnaires

3.5.1 Pre-training questionnaire

The pre-training questionnaire (Appendix B.2) focuses on the trainees' characteristics, their competency and knowledge level prior to attending the training session. The design of the questionnaire drew from the learning model proposed by Salzman and colleagues(1999), as well as the TAM/TTF model proposed by Dishaw and colleagues (1999). This evaluation being embedded into an actual training program with relatively tight scheduling constraints, we had to limit the number of items explored in the questionnaire. However, we ran several pilot sessions to test the coherence of the content and the reliability of the answers. Questions were group into thematic categories, following pre-existing evaluation frameworks described in Chapter II:

- Demographics (DEM): age; gender; workplace; experience in the mining industry; experience with mines rescue brigades.
- Game Experience Measure (GEM): trainee's prior experience with computers and video games (Taylor and Barnett, 2011).
- Immersive Tendencies (ITQ): sense of focus, involvement and alert prior training session (Witmer and Singer, 1998a).
- Simulator Sickness (SSQ): history of motion or simulator sickness (nausea, disorientation and oculomotor symptoms) and self-assessment prior training (Kennedy et al., 1993).
- Dundee Stress State (DSSQ): sense of engagement, distress or worry prior training session (Matthews et al., 1999).
- Intrinsic Motivation Inventory (IMI): sense of motivation, confidence and competition prior training session (McAuley et al., 1989).

One open-ended question prompted trainees to describe current challenges facing onsite training (or real world training).

3.5.2 Post-training questionnaire

The post-training questionnaire (Appendix B.3) focuses on procedural, substantive and reflexive aspects of the training session as perceived by trainees. The design of the questionnaire drew from the learning model proposed by Salzman and colleagues (1999), as well as the TAM/TTF model proposed by Dishaw and colleagues (1999). Usually, training schedules allowed for slightly more time at the end of the training session which enabled us to design a longer questionnaire.

- Technology Acceptance & Task Fitting (TATF): attitude towards technology and VR, as well as judgement on fitness-to-task (based on Dishaw and colleagues, 1999).

- Simulator Sickness (SSQ): sense of sickness during session (based on Kennedy, Lane et al. 1993).
- User Interface (UIQ): easiness to use and perceived realism (Taylor and Barnett, 2011).
- Game Engagement (GEQ): sense of engagement with scenario and environment (Taylor and Barnett, 2011).
- Involvement and Presence (IPQ): sense of presence and involvement during session (Witmer and Singer, 1998a)
- Intrinsic Motivation Inventory (IMI): enjoyment and motivation during session (Witmer and Singer, 1998a)
- Immersive Tendencies (ITQ): sense of focus and immersion during session (Witmer and Singer, 1998a)
- Dundee Stress State (DSSQ): sense of pressure or tension during session (Matthews et al., 1999).

Four open-ended questions prompted trainees to describe strengths, weaknesses, opportunities and threats associated with VR-based training in order to inform our SWOT analysis.

Finally, to measure the amount of learning, trainees were asked how much they believed they had learned from the training session. Moreover, we asked trainees "How useful do you think was this training session for you?", "How successful would you rate this training session?" and "Can you describe the worst interaction you had in the system? What were you doing?"

As it has been mentioned in section 2.6, there is a need for a framework which provides a standardized and structured definition of the users' experience in virtual reality learning domain and therefore provides a common understanding of the domain to the involved subject matter experts. The pedagogical benefits of VR as a learning tool need to be examined in a more comprehensive way and the direct and indirect effects of learners' characteristics and VR features on learning experiences and outcomes have to be measured. Ultimately, a research-based path model needs to be developed to explain the relationships between these constructs. In the following section the result will be presented which will allow me to define the direct and indirect relationship between the constructs and validate the hypothesised VR learning model.

4 Chapter IV: Results

4.1 Overview

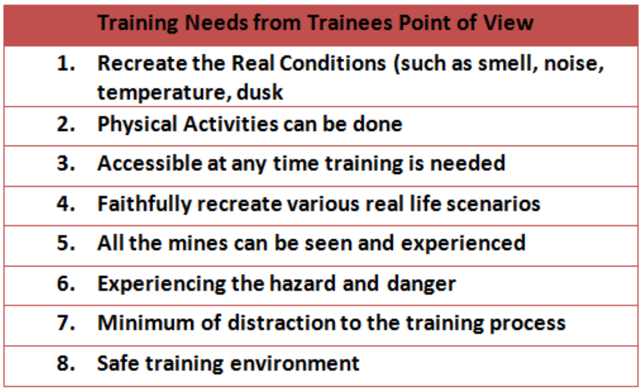
All the data collected from the training (360-VR) and assessment (Desktop-VR) rounds (which included responses to the four technical questions, as well as the pre and post-training questionnaires) were transferred and securely stored on UOW computers. The statistical package SPSS was used to perform the analyses described below. Qualitative and quantitative results stem from surveys and semi-structured interviews conducted with trainees, trainers, VR designers and mine managers. The following analyses were conducted:

- Reliability tests for all Likert-based answers in pre and post-training questionnaires.
- Categorisation of responses from semi-structured interviews with trainers and managers for the need analysis and identification of the challenges of onsite training and capabilities of VR technology.
- Categorisation of open-ended responses from pre and post-training questionnaires to inform the SWOT analysis.
- SWOT analysis for trainees and trainers and cross-tabulation between onsite training challenges and SWOT components (trainees only).
- Descriptive statistics of all Likert-based answers, followed by correlation matrices between variables within and between questionnaires. Results allowed us to create categorical factors.
- Correlation matrices between five categorical factors (perceived realism, usefulness, success, level of recommendation and preference).
- Testing the effect of demographic information on responses to the questionnaires (age, experience as a miner, experience as a mine rescuer)
- Regression analysis and causal modelling to determine which factors act as predictors and have the most influence on training outcomes.

4.2 Need Analysis

After our semi-structured interviews with managers and VR designers, the two open-ended questions filled by trainees allowed us to confirm 8 essential needs (Table 4-1).

Table 4-1: Training needs from trainee’s viewpoint



	Training Needs from Trainees Point of View
1.	Recreate the Real Conditions (such as smell, noise, temperature, dusk
2.	Physical Activities can be done
3.	Accessible at any time training is needed
4.	Faithfully recreate various real life scenarios
5.	All the mines can be seen and experienced
6.	Experiencing the hazard and danger
7.	Minimum of distraction to the training process
8.	Safe training environment

Recreate the Real Conditions – Interviewees and trainees mentioned that training environment must “recreate real conditions” such as “uneven ground, water, heat humidity” and “uneven ground affect whilst walking”.

Physical Activities are possible - Miners must wear safety gear and perform physical activities when underground on work shifts. So, there is also an identified need to allow physical activity during training sessions to allow trainees to experience physical exertion while undertaking usual underground activities.

Accessible at any time training is needed – Interviewees and trainees also stressed the need for training to be more accessible and flexible, without a need to organise sessions with the mines.

Faithfully recreate various real life scenarios - several trainees mentioned the need to “allow [for] more scenarios”, or a larger “variety of scenarios” as summarised by one interviewee: “we can be shown additional things [that] will give us better understanding of various situations and how they occur”.

All the mines can be seen and experienced - Another identified need is that the training must be able to prepare rescue brigades for all of the possible environments that they might face, for instance: “to do various activities in various mine layouts”.

Experiencing the hazard and danger – Trainees mentioned the need for experiencing “fatigue and stress”, “dangerous conditions”, “slip and trips” and “no go zones, injuries, dust [or] toxic [conditions]”.

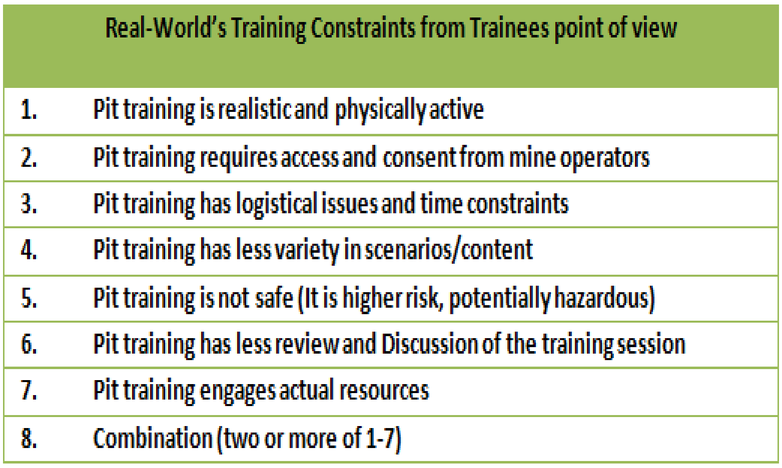
Minimum of distraction – Interviewees mentioned the need for the training environment to allow them to focus on the task at hand without usual distractions like “noise”, “mud”, “uneven floor” or “machinery working close by”.

Safe training environment – Interviewees mentioned the need for the training to be safe (“not exposed to hazards”) and to allow for trainees to “make mistakes with no [harmful] consequences”.

4.2.1 Onsite training constraints

Trainees were asked to identify the constraints they thought were associated with conducting training at actual mine sites. They indicated that onsite training (in the pit) felt more realistic. However, they mentioned that there were some challenges which would affect training and ultimately learning outcomes. Table 4-2 summarises the reported constraints of onsite training (statistical results in Appendix A

Table 4-2: Onsite training constraints from trainee's viewpoint



	Real-World's Training Constraints from Trainees point of view
1.	Pit training is realistic and physically active
2.	Pit training requires access and consent from mine operators
3.	Pit training has logistical issues and time constraints
4.	Pit training has less variety in scenarios/content
5.	Pit training is not safe (It is higher risk, potentially hazardous)
6.	Pit training has less review and Discussion of the training session
7.	Pit training engages actual resources
8.	Combination (two or more of 1-7)

Pit training is realistic and physically active - Interviewees mentioned: "realism and fatigue", "adapting to the new mines environment", "uneven walking conditions", and "continuous physical demand (carrying equipment on long distances)".

Pit training requires access and consent from mine operators - Interviewees mentioned: "access", "getting access into the pit these days is a challenge due to mine site requirements and time busy nature of each mine" and "not a lot of [companies] allow training in their mine these days".

Pit training has logistical issues and time constraints - Interviewees mentioned: "time constraints", "access to people", "length of [training] time is much longer when training in a pit", "distance to travel or walk", "transport availability, supervision, day to day requirements" and "logistics and access".

Pit training has less variety in scenarios/content - Interviewees mentioned: "there is less variety in scenarios conducted in the pit", "cannot simulate fires [in pit]" and "[not easy] to focus on correct technique and improve it". One trainee summarised this as follows: "pit training is normal life for us whereas in the VR we can be shown additional things which will give us better understanding of various situations and how they occur within a safe environment".

Pit training is not safe (It is higher risk, potentially hazardous) – Interviewees mentioned: “more hazardous environmental conditions in pit”, “risk of injury”, “noise and other tasks taking place”, “machinery interaction” or “interaction with operating coal mine”. One trainee summarised the potentially hazardous pit training environment as follows: “slips, trips, falls, moving machinery, no-go-zones, injuries, dust and toxic noxious waste”.

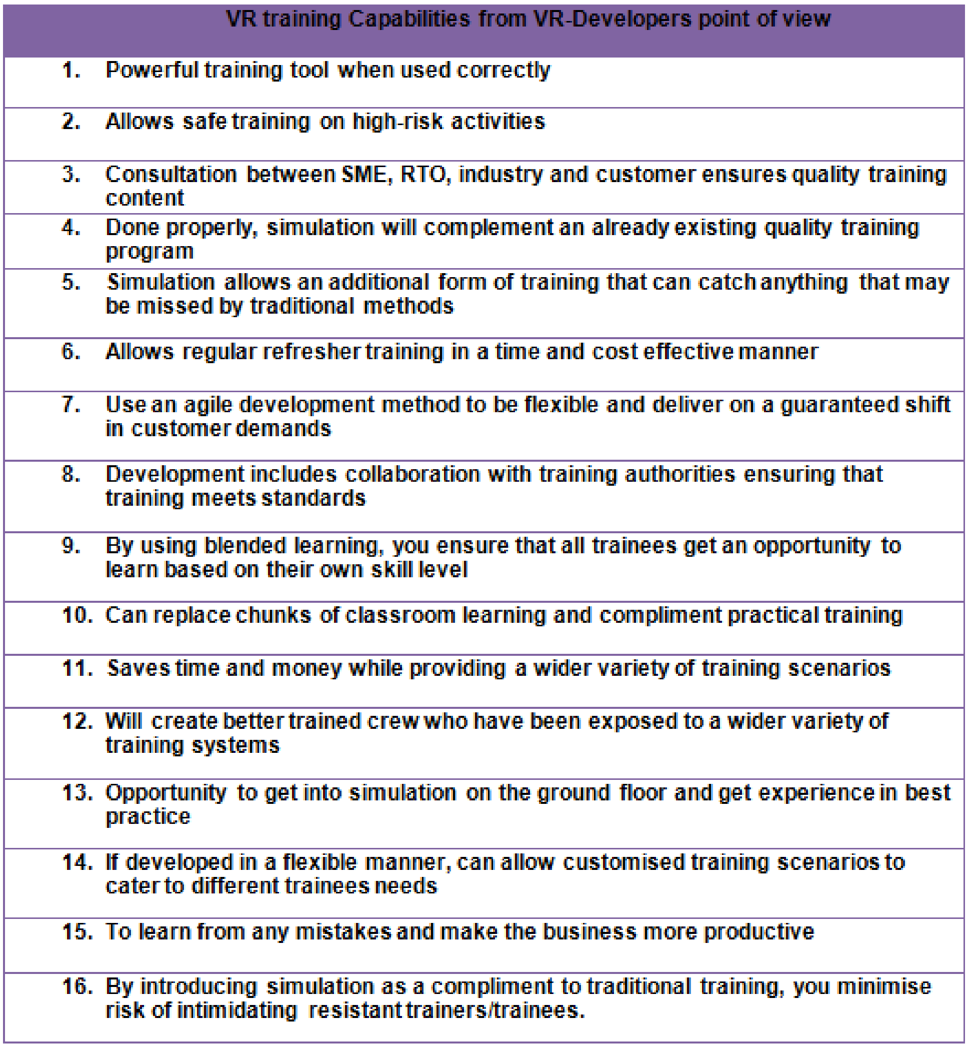
Pit training has less review and discussion of the training session – Interviewees mentioned: “not being able to review the training”, “in pit you can’t stop and discuss the training” and “no way to replay the training”.

Pit training engages actual resources – Interviewees mentioned: “time and resources required [for pit] training”, “the cost involved to companies” and “having an area to train that will not affect production, logistics of getting equipment and people to and from the mine site”.

4.2.2 VR-based training capabilities from the VR Developer’s viewpoint

Table 4-3 summarises the VR training capabilities as a result of interviewing the VR-developers. The original list was rather extensive, henceforth we provided below a shortlist of capabilities.

Table 4-3: VR training Capabilities from VR-Developers point of view



VR training Capabilities from VR-Developers point of view
1. Powerful training tool when used correctly
2. Allows safe training on high-risk activities
3. Consultation between SME, RTO, industry and customer ensures quality training content
4. Done properly, simulation will complement an already existing quality training program
5. Simulation allows an additional form of training that can catch anything that may be missed by traditional methods
6. Allows regular refresher training in a time and cost effective manner
7. Use an agile development method to be flexible and deliver on a guaranteed shift in customer demands
8. Development includes collaboration with training authorities ensuring that training meets standards
9. By using blended learning, you ensure that all trainees get an opportunity to learn based on their own skill level
10. Can replace chunks of classroom learning and compliment practical training
11. Saves time and money while providing a wider variety of training scenarios
12. Will create better trained crew who have been exposed to a wider variety of training systems
13. Opportunity to get into simulation on the ground floor and get experience in best practice
14. If developed in a flexible manner, can allow customised training scenarios to cater to different trainees needs
15. To learn from any mistakes and make the business more productive
16. By introducing simulation as a compliment to traditional training, you minimise risk of intimidating resistant trainers/trainees.

4.3 SWOT analysis of 360 VR environment

After trainees attended the 360 VR session they were asked to answer the following four questions:

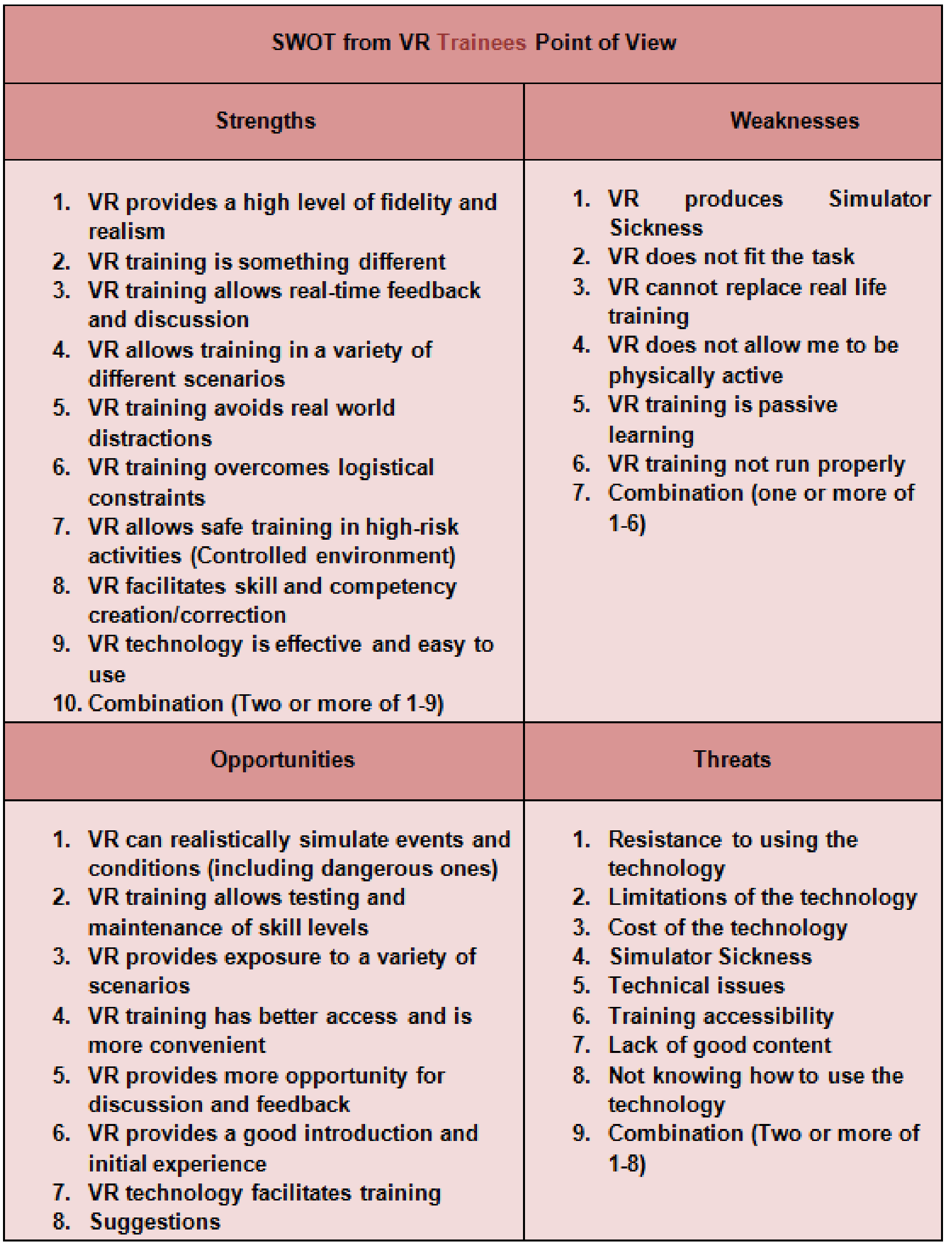
- What were the strengths of Virtual reality as a training environment?
- What were the weaknesses of Virtual reality as a training environment?
- What opportunities does Virtual reality provide as a training environment/tool?
- What would prevent the use of Virtual reality as a training environment/tool?

Their answers were used to conduct a SWOT analysis and to compare trainees reactions with statements collected from their trainers and the VR developers during separate semi-structured interviews.

4.3.1 SWOT – From the trainee's viewpoint

Table 4-4 summarises the feedback from trainees regarding the strengths, weaknesses, opportunities and threats associated with 360 VR environments for training purposes. While the reported strengths and weaknesses often related to their own personal experiences during training sessions, the opportunities and threats mentioned typically were related to the broader consequences of this VR training, as well as generalisations and assumptions about VR in this context.

Table 4-4: SWOT analysis from trainee's viewpoint



SWOT from VR Trainees Point of View	
Strengths	**Weaknesses**
1. VR provides a high level of fidelity and realism 2. VR training is something different 3. VR training allows real-time feedback and discussion 4. VR allows training in a variety of different scenarios 5. VR training avoids real world distractions 6. VR training overcomes logistical constraints 7. VR allows safe training in high-risk activities (Controlled environment) 8. VR facilitates skill and competency creation/correction 9. VR technology is effective and easy to use 10. Combination (Two or more of 1-9)	1. VR produces Simulator Sickness 2. VR does not fit the task 3. VR cannot replace real life training 4. VR does not allow me to be physically active 5. VR training is passive learning 6. VR training not run properly 7. Combination (one or more of 1-6)
Opportunities	**Threats**
1. VR can realistically simulate events and conditions (including dangerous ones) 2. VR training allows testing and maintenance of skill levels 3. VR provides exposure to a variety of scenarios 4. VR training has better access and is more convenient 5. VR provides more opportunity for discussion and feedback 6. VR provides a good introduction and initial experience 7. VR technology facilitates training 8. Suggestions	1. Resistance to using the technology 2. Limitations of the technology 3. Cost of the technology 4. Simulator Sickness 5. Technical issues 6. Training accessibility 7. Lack of good content 8. Not knowing how to use the technology 9. Combination (Two or more of 1-8)

4.3.1.1 360 VR's strengths listed by trainees (see Appendix A.2 for statistical results)

Strength - Level of Fidelity and Realism

Interviewees mentioned: "being able to simulate a real underground fire and change gas level", "very life like situation", "simulated smoke", "closest to real thing and can relate", "getting a sense of real time working" and "it felt real".

Strength - Something Different, Great opportunity for blended Training

Interviewees mentioned: “it’s something different”, “different to what we are used to” or “something different to normal run”.

Strength - VR training allows real-time feedback and discussion
Interviewees mentioned: “the opportunity to discuss the exercise after the event in a controlled environment”, “stop and discuss” and “ability to review, read and explore options”.

Strength - VR allows training in a variety of different scenarios
Interviewees mentioned: “expose to variety of scenarios”, “see different mine layout standards” and “being able to see fires, smoke, and other hazards”.

Strength - VR training avoids real world distractions
Interviewees mentioned: “it is clean”, “got to see a lot of a pit, in a smoky environment without getting dirty”, “can concentrate on scenario”, “minimal exertion, able to concentrate on task”.

Strength - VR training overcomes logistical constraints
The 360 VR environment allowed them to: “covering large amount of distance over a short period of time”, “[be] time efficient”, “easily accessible”, “being able get through a lot more in a shorter period of time” and “you do not need access to underground colliery”.

Strength - VR allows safe training in high-risk activities (Controlled environment)
Interviewees mentioned: “seeing possible hazardous conditions without the real life exposure” and “If there was a failure of equipment the consequence is not potentially life threatening, easier to ask questions” as a result we can get “some exposure to an incident that could not be simulated down a pit” and “train in scenarios not encounter in normal mining operation, train for emergency conditions” moreover, “you can have an over view of the whole situation and not be in harm, it gives you the chance to stop pause, rewind” and “cover a lot of hazards in a short period of time” therefore you can “experience everything without real danger”.

Strength - VR facilitates skill and competency creation/correction
Interviewees mentioned: “able to get a good overview of entire mine”, “planning with mine plan, carrying out search quickly allowing plenty of discussion for other aspects to consider”, “seeing how incident was initiated”, “going back over an incident to correct yourself”, “trainers could stop or alter exercise easily to facilitate learning and understanding of competencies” and “gives you another aspect on training makes you look at things differently”, “Covering a large area in short amount of time”.

Strength - VR technology is effective and easy to use
According to the interviewees, the 360 VR training environment was “easy to operate”, “ease of use”, “easy to show people a simulated mine environment”, “easy to run” and “easy to interact”.

4.3.1.2 360 VR's weaknesses listed by trainees (see Appendix A.3 for statistical results)

Weakness - 360 VR produces Simulator Sickness

Interviewees mentioned that the 360 VR training environment "can cause motion sickness (not totally though)", "you get light headed" or "disorientation with rapid movement on screen" and "dizziness, [I] felt dizzy when moving fast in simulator". However, the advice given to them by the trainers to' "walk-in-place" during simulated movement/translation would appear to help: "[having] to move as if you are walking helps the sickness". Overall, getting slightly sick did not appear to prevent trainees benefiting from the 360 VR training: "[I am] getting slight motion sickness but it is worth it".

Weakness – 360 VR does not fit the task

Some weaknesses of this type were scenario-specific (i.e., it is more problematic for some training scenarios than others), for instance: "[I was] unable to split the team for search" or "having each person being in the same scene even if on different tasks". However, other weaknesses of this type were more general in nature: "the limited size of the area" o "the amount of people in a group, VR should be limited to 3-4 persons".

Weakness – 360 VR cannot replace real life training

Some interviewees mentioned the lack of realism of the 360 VR environment: "moving around in VR room is not realistic", "[it is] not realistic, cannot smell or feel or hear anything", "reduced ability to orientate, not fully demanding physically or mentally" and "can seem unrealistic at time".

Weakness – 360 VR does not allow for being physically active

The lack of physical activity or even exertion was seen by many interviewees as a significant weakness: "fake walking", "carrying a heavy load without actual moving", "not enough hands on" and "it is not physically exerting".

Weakness – 360 VR training is passive learning

This is another limitation perceived by several trainees: "[I had] no control of the movement", "not being an active user", "usually only 1-2 operators, [this] limits control", "[it is] getting boring" and "Having someone else control your movements".

Weakness - VR training doesn't run properly

Rapid movements or changes of direction in the virtual environment left some trainees disoriented: "disorientation with rapid movement on screen", "not familiar with program and find it confusing at times", "was [too] fast", "nearly felling over due to going in a different directions fast to what I was looking" and "if movements [are] too fast, feel like you want to fall backwards".

4.3.1.3 360 VR's opportunities listed by trainees (see Appendix A.4 for statistical results)

Opportunity - VR can realistically simulate events and conditions (including dangerous ones)
Interviewees mentioned: “getting close to dangerous situations”, “familiarization with closest thing to real thing”, “can encounter scenario without exposure (e.g. Smoke, fire, etc.)”, “great for simulated scenarios especially scenarios which you could not setup underground”, “[it] provides realistic events, fire, machines etc. without going down [the] pit” and “a safe environment to train with no interference with a working pit”.

Opportunity - VR training allows testing and maintenance of skill levels
Several trainees mentioned 360 VR’s ability to “to keep skills up”, “[maintain] training competence”, “create environments for decision making”, “put competencies into action” and “put in to practice lessons learnt in class”.

Opportunity - VR provides exposure to a variety of scenarios
While 360 VR’s capacity to create many scenarios was broadly perceived as a strength, several interviewees also indicated the learning opportunities they provided: “lots of opportunities”, “creating unusual circumstances”, “simulating actual events that do not [often] occur in real life”, “variety of scenarios in one [training] location” and “easy way to set up different situations”.

Opportunity - VR training has better access and is more convenient
Several interviewees identified the 360 VR’s accessibility and safety as opportunities for better/improved training: “it provides realistic scenes when real mine site are difficult to access”, “a lot [of opportunities] because you don’t have to be down the mine as it is all there in front of you”, “[training] and travel time savings” and “to go to places that are not accessible [during training like] high gas levels”.

Opportunity - VR provides more opportunity for discussion and feedback
The ability to engage with the trainer during and after the session was mentioned by several trainees: “the ability to stop and discuss and go back over things”, “easily pin point mistakes and improvements through and after the training”, “overview of the emergency from different views”, “to be able stop and talk about better ways to do things” and “[you] can replay scenario”.

Opportunity - VR provides a good introduction and initial experience
The opportunity for beginners to experience underground reality was often mentioned: “it is a good training tool for beginners”, “available for other people not yet in industry to get an idea before going underground”, “realistic [underground] simulation for people who have not been down a real mine” and “it shows unexperienced personnel what happens [underground]”.

Opportunity - VR technology facilitates training
Interviewees mentioned: “easier/ different training”, “[it is easy] to show people a simulated mine environment”, “training on equipment in a noise-free and clean environment” and “[capacity to change locations and scenes easily and quickly”.

Opportunity - Suggestions
Many trainees mentioned that the 360 VR was a “very useful training tool; better than classroom but never as good as the real underground environment ”, “Overall pretty good”, “System works very well, maybe [needs] a little floor movement”, “Can be adapted to all industries. Certain hazards/ emergencies can be done in real life” and “Gives different subjects to study when doing deputies”.

4.3.1.4 360 VR’s threats listed by trainees (see Appendix A.5 for statistical results)

Threat - Resistance to using the technology
Resistance to the use of 360 VR technology for training was a risk identified by several trainees, despite overwhelmingly positive responses to the survey: “willingness to participate is required”, “non-acceptance by trainees”, “[problem] if user don’t like to use it”, “[trainees] not believing it is a good device” and “if other blocks do not want to use it”.

Threat - Limitations of the technology
Current limitations of 360 VR technology were also described as potential hurdles to its broader usage: “[lack of] physical space for the team”, “number [of trainees] is limited in VR”, “Person does not get a full experience of the dynamics of a mine, [like]: ever changing terrain, live energy sources, ventilation, dust” and “lack of hands-on [activities], a lot of just standing there looking, doing nothing”.

Threat - Cost of the technology
Although not fully aware of the investment made by coal services into 360 VR technology, several interviewees mentioned “cost”, “funding”, “technology investment” and “cost of power” as potential threats to its development.

Threat - Simulator Sickness
While simulator sickness was regarded as an actual weakness with limited impact on the training capacity itself, several trainees mentioned it might become a threat to the development of the technology “if an individual is extremely affected by motion sickness”, “some people may get sick (motion)” and experience “vertigo issues”.

Threat - Technical issues
Several potential (or experienced) issues were pointed at as threats to the development of the technology: “power outage”, “technical glitches”, “black out” and “power/ software”.

Threat - Training accessibility
Although 360 VR training facilities were regarded by many interviewees as an opportunity for easier and safer training programs, several trainees also mentioned that access to the training facility and training time schedules were themselves matters of concern ("availability [of 360 VR training]", "access to the VR" and "training availability").

Threat - Lack of good content
Although generally satisfied with the content of the scenarios they had to interact with, several trainees mentioned the following risk for VR developers and trainers: to experience a "lack of imagination in designing, different scenarios", "[poor] computer programing of simulated areas", "[risk of] unrealistic scenario or of little use", "not keeping [the IT system] updated" and "lack of scenarios".

Threat - Not knowing how to use the technology
Finally, several interviewees mentioned the risk presented by "people not familiar [with] the technology" and "not knowing how to use it".

4.3.2 SWOT - From the trainers' viewpoint

Table 4-5 summarises feedback from trainers regarding the strengths, weaknesses, opportunities and threats associated with 360 VR environments for training purposes. This SWOT analysis showed high agreement with the one conducted on the trainees. However, two differences were noticeable:

- The trainers articulated more clearly that the 360 VR provides high fidelity scenarios (strength) that are probably realistic enough to replace theory-based classes (opportunity) but probably not adequate (yet) to entirely replace traditional onsite training despite all its logistical constraints.
- Trainees were more negative about the relative passivity of the current 360 VR environment and scenarios (compared with a real pit training) while they were more positive about the ability of 360 VR to promote better concentration on the tasks or better engagement with the trainers.

Table 4-5: SWOT analysis from trainer’s viewpoint

<table>
<tr><th colspan="2">SWOT from the Trainer’s Point of View</th></tr>
<tr><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td>1. High level of Fidelity and Realism
2. Safe and Control Training Environment
3. Create High level of Skill and Competency
4. Overcoming Logistics constraints</td><td>1. Side Effects and Simulator Sickness
2. Not realistic enough to replace underground training
3. Technology Compatibility
4. Technology Constraints</td></tr>
<tr><th>Opportunities</th><th>Threats</th></tr>
<tr><td>1. Realistic enough to replace theory based classes
2. Training New comers
3. Opportunity of training all different scenario</td><td>1. High Initial Investments
2. Side Effects
3. Technology Constraints
4. Limited facilities equipped with this technology</td></tr>
</table>

4.3.3 SWOT – From the VR Developer’s viewpoint

Table 4-6 summarises feedback from the VR developers regarding the strengths, weaknesses, opportunities and threats associated with 360 VR environments for training purposes. As expected, they provide a richer and more nuanced SWOT analysis compared with those from the trainees and the trainers as the designed phase itself followed its own SWOT analysis prior our evaluation.

Table 4-6: SWOT from the VR-Developer's viewpoint

SWOT from the VR-Developer's Point of View	
Strengths	**Weaknesses**
1. Powerful training tool when used correctly 2. Allows safe training on high-risk activities 3. Consultation between SME, RTO, industry and customer ensures quality training content 4. Done properly, simulation will complement an already existing quality training program 5. Simulation allows for capturing richer training situations compared with traditional training 6. Allows regular refresher training in a time and cost effective manner 7. Use an agile development method to be flexible and deliver on a guaranteed shift in customer demands 8. Development includes collaboration with training authorities ensuring that training meets standards 9. By using blended learning, you ensure that all trainees get an opportunity to learn based on their skill level	1. Expensive to start off 2. New methodologies and business practices need to be established 3. Still requires practical training 4. Course creation is resource intensive 5. Requires development effort for best outcomes. 6. Off-the-shelf training packages may not deliver on all training requirements 7. At this stage, technology doesn't really allow major removal of traditional training methods 8. Difficult to prove improved training outcomes due to it being anecdotal in nature. 9. Agile businesses are alien within the military/government space. 10. Small minority may be resistant to change 11. Seen as a game
Opportunities	**Threats**
1. Can replace chunks of classroom learning and compliment practical training 2. Saves time and money while providing a wider variety of training scenarios 3. Establish ownership by all parties 4. Will create better trained crew who have been exposed to a wider variety of training systems 5. Opportunity to get into simulation on the ground floor and get experience in best practice 6. If developed in a flexible manner, can allow customised training scenarios to cater to different trainees needs 7. To learn from any mistakes and make the business more productive 8. By introducing simulation as a compliment to traditional training, you minimise risk of intimidating resistant trainers/trainee.	1. Seen as a luxury 2. Being seen as a magic bullet, using it instead of practical training 3. Preference to have agreement by all parties otherwise can be opened to criticism 4. Expensive to initially develop a decent asset library 5. A small minority of the population can resist change which is a challenge that needs to be managed 6. If not done correctly may not deliver training outcomes that are expected 7. Critical team members leaving and taking knowledge with them 8. Extra time and effort required during content creation stage to collaborate with all parties

4.4 Reported learning outcomes

In the following section we analysed the correlations between the real world training challenges (as identified by the trainees in section 3.1.2) and the results of the 360 VR's SWOT analysis (as identified by the trainees in section 3.2.1). This section will help us to realise to what extent VR based training is able to overcome the challenges in onsite training.

4.4.1 Onsite training challenges x 360 VR's strengths

Table 4-7 shows that a majority of trainees (124 out of 226) identified onsite training (or pit training) as challenging since the pit is a physically demanding and noisy environment. Exhaustion and distraction result in a lack of attention to the training content and details. Amongst these trainees, 23% (53 out of 226) indicated that 360 VR helped them focus better on the tasks to be performed and another 15% (36 out of 226) indicated that its controlled environment provided safe conditions to perform high-risk activities (Table 4-8).

Table 4-7: Frequency of real-world training constraints according to trainees

Challenges

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Pit training is realistic and physically active	143	50.2	55.9	55.9
	Pit training requires access and conset from mine operators	18	6.3	7.0	62.9
	Pit training has logistical issues and time constraints	33	11.6	12.9	75.8
	Pit training has less variety in scenarios/content	11	3.9	4.3	80.1
	Pit training is not safe (It is higher risk, potentially hazardous)	22	7.7	8.6	88.7
	Pit training has less review and Discussion of the training session	4	1.4	1.6	90.2
	Pit training engages actual resources	4	1.4	1.6	91.8
	Combination (two or more of 1-7)	21	7.4	8.2	100.0
	Total	256	89.8	100.0	
Missing	99.00	28	9.8		
	System	1	.4		
	Total	29	10.2		
Total		285	100.0		

Table 4-8: Frequency of VR training Strength components (SWOT analysis – trainees)

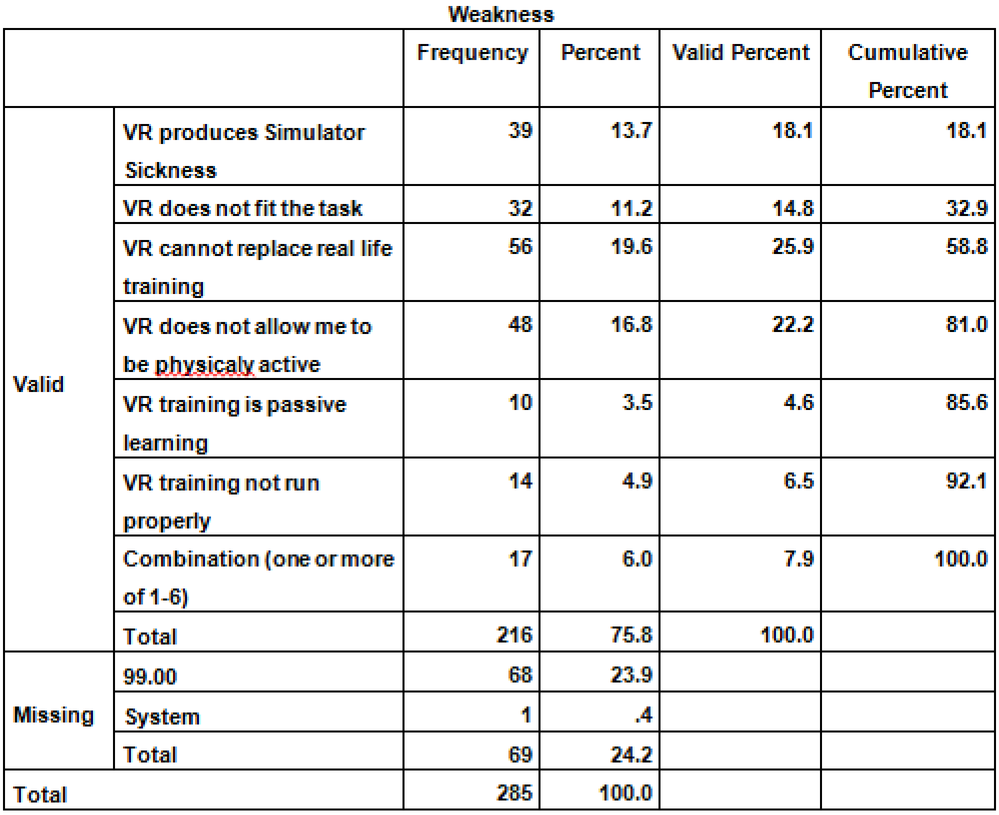
Strength

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	VR provides a high level of fidelity and realism	31	10.9	12.6	12.6
	VR training is something different	12	4.2	4.9	17.4
	VR training allows real-time feedback and discussion	18	6.3	7.3	24.7
	VR allows training in a variety of different scenarios	24	8.4	9.7	34.4
	VR training avoids real world distractions	64	22.5	25.9	60.3
	VR training overcomes logistical constraints	15	5.3	6.1	66.4
	VR allows safe training in high-risk activities (Controlled environment)	37	13.0	15.0	81.4
	VR facilitates skill and competency creation/correction	20	7.0	8.1	89.5
	VR technology is effective and easy to use	6	2.1	2.4	91.9
	Combination (Two or more of 1-9)	20	7.0	8.1	100.0
	Total	247	86.7	100.0	
Missing	99.00	37	13.0		
	System	1	.4		
	Total	38	13.3		
Total		285	100.0		

4.4.2 Onsite training challenges x 360 VR's weaknesses

Table 4-9 show that amongst the majority of interviewed trainees (110 out of 198) who identified exhaustion and distraction as main challenges of real world training, 28% also indicated that 360 VR could not entirely replace real life training and 25% indicated that the current VR environment does not include adequate physical activities. This apparent contradiction supports the trainers' viewpoint that 360-VR is mature enough to replace most of classroom training but still lacks a degree of realism in order to entirely replace pit training.

Table 4-9: Frequency of VR training Weakness components (SWOT analysis – trainees)



Weakness

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	VR produces Simulator Sickness	39	13.7	18.1	18.1
	VR does not fit the task	32	11.2	14.8	32.9
	VR cannot replace real life training	56	19.6	25.9	58.8
	VR does not allow me to be physicaly active	48	16.8	22.2	81.0
	VR training is passive learning	10	3.5	4.6	85.6
	VR training not run properly	14	4.9	6.5	92.1
	Combination (one or more of 1-6)	17	6.0	7.9	100.0
	Total	216	75.8	100.0	
Missing	99.00	68	23.9		
	System	1	.4		
	Total	69	24.2		
Total		285	100.0		

4.4.3 360 VR Strengths x 360 VR Weaknesses

The cross-tabulation shows that the same numbers of trainees (56 out of 205) indicated that (i) one strength of 360 VR was being able to avoid real world distractions; and (ii) one weakness of 360 VR was its inability to fully replace pit training; 19 out of 56 trainees (34%) mentioned both statements confirming the apparent contradiction identified in previous section (see Appendix A.7 for statistical results).

4.4.4 360 VR's threats x 360 VR's opportunities

The cross-tabulation shows that 52 out of 174 trainees consider that 360 VR presents a good opportunity to simulate various scenarios (including dangerous situations). However, trainees also mention simulator sickness and the lack of sufficient content as current threats to its potential development. Likewise, 42 out of 174 trainees consider that 360 VR presents a good opportunity to introduce new staff to underground conditions; however, many of them also mention the lack of hands-on activities and sufficient contents as current threats to its potential development (see Appendix A.8 for statistical results).

4.5 Quantitative Analysis – 360 VR

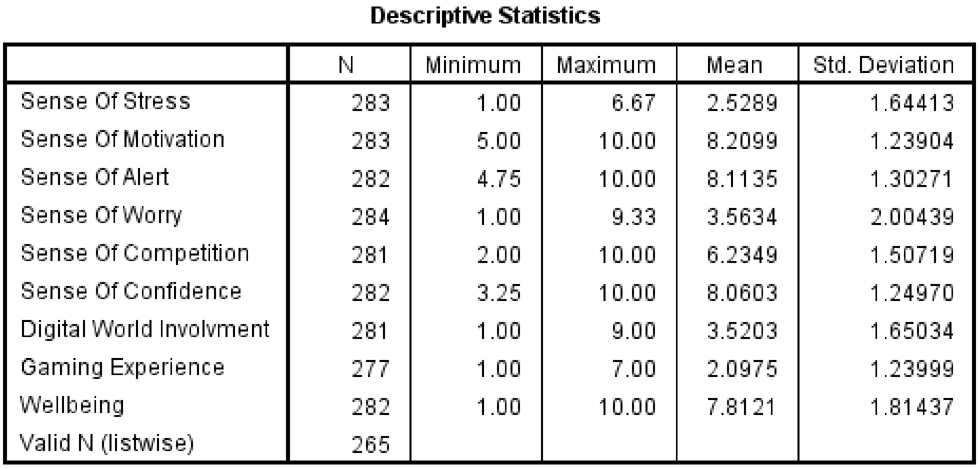
4.5.1 Reliability Test for pre-training factors

The pre-training questionnaire was aimed at assessing the trainees' perceived levels of "stress", "motivation", "alertness", "worry", "competition", "confidence", "perceived digital involvement', "perceived digital environment engagement", prior "gaming experience" and current "well-being". Cronbach's Alpha test can be viewed as the expected correlation of two tested items that measure the same construct; a value above 0.7 means they are measuring the same thing and that the factor passed the reliability test. All the *pre-training factors* returned a Cronbach's Alpha value superior to 0.7. We can conclude that all factors are statistically reliable.

4.5.2 Pre-training factors at a glance

Table 4-10 summarises the statistical results for the nine pre-training factors. Overall, trainees were feeling motivated (*M* = 8.02, *SD* = 1.23), confident (*M* = 8.06, *SD* = 1.24) and alert (*M* = 8.11, *SD* = 1.30), as well as feeling generally well (*M* = 7.81, *SD*= 1.81). In average it has been reported low level of stress (*M* = 2.52, *SD* =1.60), worry (*M* = 3.5, *SD*= 2.00) and gaming experience (*M* = 2.09, *SD* = 1.23).

Table 4-10: Statistical results of pre-training factors



Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Sense Of Stress	283	1.00	6.67	2.5289	1.64413
Sense Of Motivation	283	5.00	10.00	8.2099	1.23904
Sense Of Alert	282	4.75	10.00	8.1135	1.30271
Sense Of Worry	284	1.00	9.33	3.5634	2.00439
Sense Of Competition	281	2.00	10.00	6.2349	1.50719
Sense Of Confidence	282	3.25	10.00	8.0603	1.24970
Digital World Involvment	281	1.00	9.00	3.5203	1.65034
Gaming Experience	277	1.00	7.00	2.0975	1.23999
Wellbeing	282	1.00	10.00	7.8121	1.81437
Valid N (listwise)	265				

4.5.3 Reliability Test for post-training factors

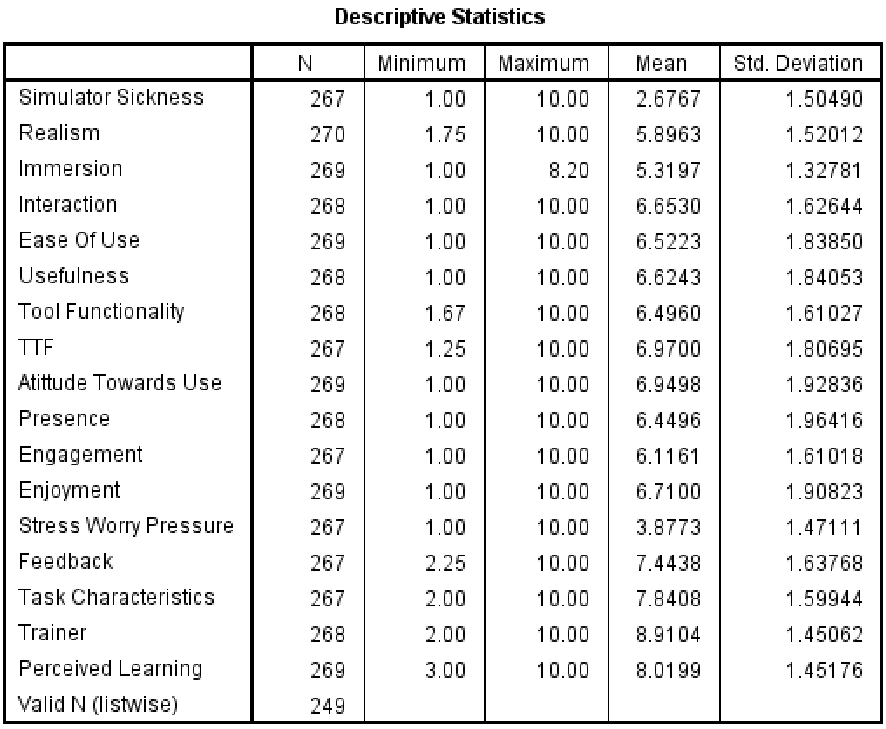
The post-training questionnaire was aimed at assessing the seventeen post-training factors (via self-report): perceived "level of simulator sickness", "degree of realism", "degree of immersion", "amount of interaction", "amount of presence", "amount of engagement", "degree of enjoyment", "stress level", "amount of worry and pressure", "ease of use", "technology usefulness", "tool functionality", "task-functionality”, “Task-Technology Fit (TTF)”, “attitude towards use”, “feedback”, “task characteristics”, “trainer’s attitude” and “degree learning”.

All the *post-training factors* returned a Cronbach’s Alpha value superior to 0.7. We can conclude that all factors are statistically reliable.

4.5.4 Post-training factors at a glance

Table 4-11 summarises statistical results for the seventeen post-training factors. Overall, the trainees have a highly positive perceived degree of learning (*M*=8.01, *SD*= 1.45), the trainer’s performance (*M*=8.9, *SD*= 1.4), task characteristics (*M*=7.8, *SD*= 1.59) and feedback (*M*=7.4, *SD*= 1.63). On average, trainees also report positive experiences with the 360-VR environment as showed by the scores reached by factors such as interaction (*M*=6.65, *SD*= 1.62), engagement (*M*=6.11, *SD*= 1.61), enjoyment (*M*=6.71, *SD*= 1.90), presence (*M*=6.44, *SD*= 1.96), ease of use (*M*=6.52, *SD*= 1.83), usefulness (*M*=6.62, *SD*= 1.84), tool functionality (*M*=6.49, *SD*= 1.61), task-technology fit (*M*=6.97, *SD*= 1.80). Additionally, participants reported very low level of simulator sickness (*M*=2.67, *SD*= 1.50) and stress, worry and pressure (*M*=3.87, *SD*= 1.47).

Table 4-11: Statistical results of post-training factors



Descriptive Statistics

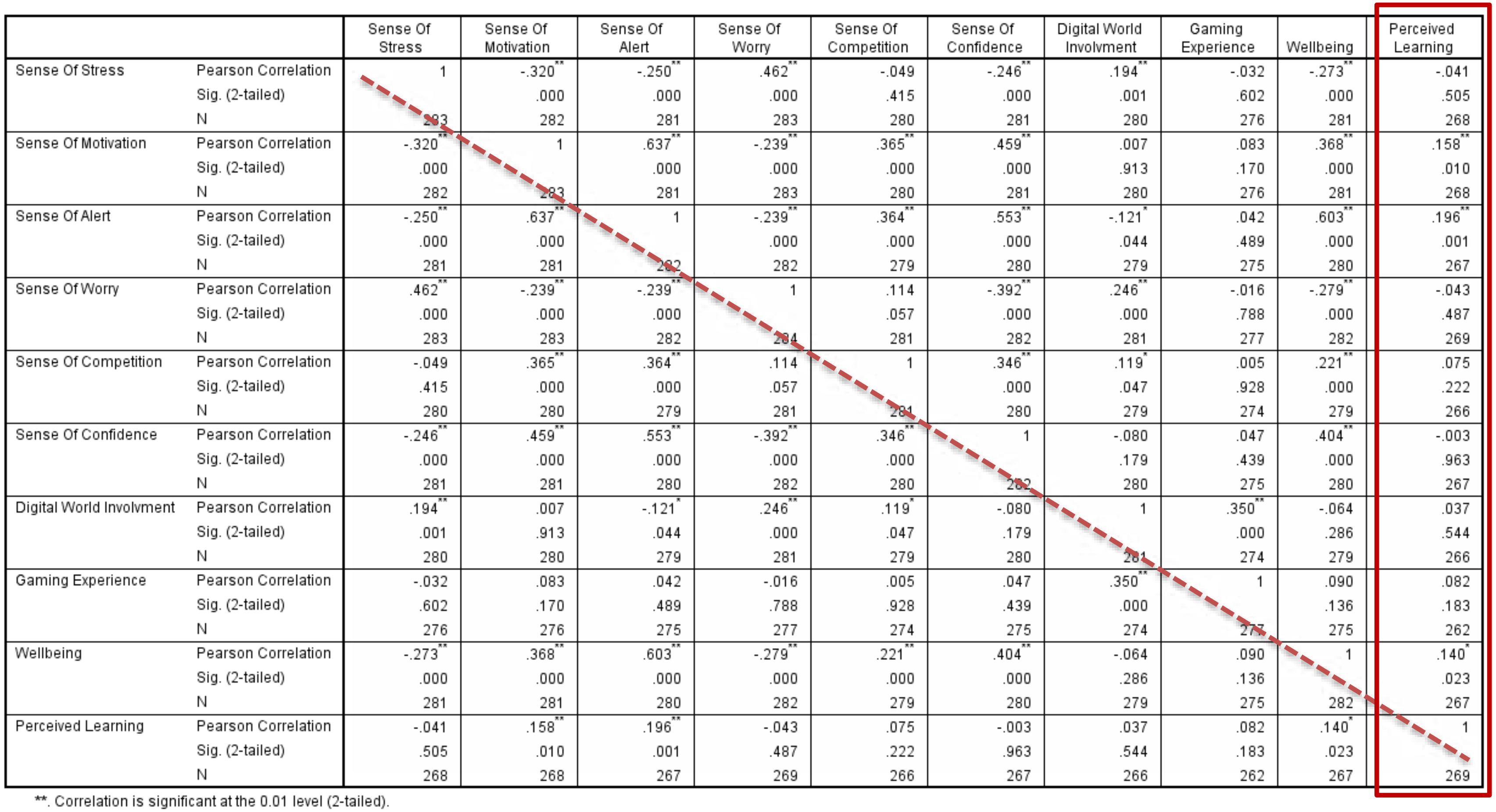
	N	Minimum	Maximum	Mean	Std. Deviation
Simulator Sickness	267	1.00	10.00	2.6767	1.50490
Realism	270	1.75	10.00	5.8963	1.52012
Immersion	269	1.00	8.20	5.3197	1.32781
Interaction	268	1.00	10.00	6.6530	1.62644
Ease Of Use	269	1.00	10.00	6.5223	1.83850
Usefulness	268	1.00	10.00	6.6243	1.84053
Tool Functionality	268	1.67	10.00	6.4960	1.61027
TTF	267	1.25	10.00	6.9700	1.80695
Atittude Towards Use	269	1.00	10.00	6.9498	1.92836
Presence	268	1.00	10.00	6.4496	1.96416
Engagement	267	1.00	10.00	6.1161	1.61018
Enjoyment	269	1.00	10.00	6.7100	1.90823
Stress Worry Pressure	267	1.00	10.00	3.8773	1.47111
Feedback	267	2.25	10.00	7.4438	1.63768
Task Characteristics	267	2.00	10.00	7.8408	1.59944
Trainer	268	2.00	10.00	8.9104	1.45062
Perceived Learning	269	3.00	10.00	8.0199	1.45176
Valid N (listwise)	249				

4.5.5 Influence of pre and post-training factors on perceived learning

Pre-training factors

The correlation matrix on the next page (Table 4-12) shows that ‘perceived learning’ (last column) is only significantly (and positively) correlated with ‘motivation’ (**r** = .158, $P < .01$), ‘sense of alertness’ (**r** = .196, $P < .01$) and wellbeing (**r** = .140, $P < .05$). This demonstrates that pre-training factors can have small but significant effects on learning after 360 VR training session. Henceforth, it can be concluded that reported individual circumstances (‘competitiveness’ or ‘worry’) or experiences (‘digital world involvement’ or ‘gaming experience’) do not significantly influence the way trainees engage with the training scenario and their perceived learning.

Table 4-12: Correlation matrix between pre-training factors and perceived learning



		Sense Of Stress	Sense Of Motivation	Sense Of Alert	Sense Of Worry	Sense Of Competition	Sense Of Confidence	Digital World Involvment	Gaming Experience	Wellbeing	Perceived Learning
Sense Of Stress	Pearson Correlation	1	-.320**	-.250**	.462**	-.049	-.246**	.194**	-.032	-.273**	-.041
	Sig. (2-tailed)		.000	.000	.000	.415	.000	.001	.602	.000	.505
	N	283	282	281	283	280	281	280	276	281	268
Sense Of Motivation	Pearson Correlation	-.320**	1	.637**	-.239**	.365**	.459**	.007	.083	.368**	.158**
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.913	.170	.000	.010
	N	282	283	281	283	280	281	280	276	281	268
Sense Of Alert	Pearson Correlation	-.250**	.637**	1	-.239**	.364**	.553**	-.121*	.042	.603**	.196**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.044	.489	.000	.001
	N	281	281	282	282	279	280	279	275	280	267
Sense Of Worry	Pearson Correlation	.462**	-.239**	-.239**	1	.114	-.392**	.246**	-.016	-.279**	-.043
	Sig. (2-tailed)	.000	.000	.000		.057	.000	.000	.788	.000	.487
	N	283	283	282	284	281	282	281	277	282	269
Sense Of Competition	Pearson Correlation	-.049	.365**	.364**	.114	1	.346**	.119*	.005	.221**	.075
	Sig. (2-tailed)	.415	.000	.000	.057		.000	.047	.928	.000	.222
	N	280	280	279	281	281	280	279	274	279	266
Sense Of Confidence	Pearson Correlation	-.246**	.459**	.553**	-.392**	.346**	1	-.080	.047	.404**	-.003
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.179	.439	.000	.963
	N	281	281	280	282	280	282	280	275	280	267
Digital World Involvment	Pearson Correlation	.194**	.007	-.121*	.246**	.119*	-.080	1	.350**	-.064	.037
	Sig. (2-tailed)	.001	.913	.044	.000	.047	.179		.000	.286	.544
	N	280	280	279	281	279	280	281	274	279	266
Gaming Experience	Pearson Correlation	-.032	.083	.042	-.016	.005	.047	.350**	1	.090	.082
	Sig. (2-tailed)	.602	.170	.489	.788	.928	.439	.000		.136	.183
	N	276	276	275	277	274	275	274	277	275	262
Wellbeing	Pearson Correlation	-.273**	.368**	.603**	-.279**	.221**	.404**	-.064	.090	1	.140*
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.286	.136		.023
	N	281	281	280	282	279	280	279	275	282	267
Perceived Learning	Pearson Correlation	-.041	.158**	.196**	-.043	.075	-.003	.037	.082	.140*	1
	Sig. (2-tailed)	.505	.010	.001	.487	.222	.963	.544	.183	.023	
	N	268	268	267	269	266	267	266	262	267	269

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Moreover, as can be seen in Table 4-12, “stress” and “worry” both displayed very significant negative relationships with the following factors: “motivation”, “alertness”, “confidence” and “wellbeing”. Also, “motivation” displayed very significant positive relationships with the “alertness”, “confidence” and “competitiveness”. However, "digital world involvement" is significantly and positively related to "Stress", "worry”, "gaming experience" and “competitiveness". Also, it is also significantly negatively related to "alertness". Moreover, “gaming experience” did not display statistically significant relationships with the individual’s perception.

Post-training factors

The correlation matrix below (Table 4-13) shows that all post-training factors have a statistically significant relationship with perceived learning. Excluding ‘simulator sickness’ (**r** = -.238, *P* < .01) and ‘stress worry and pressure’ (**r** = -.257, *P* < .01) that display a negative relationship, all the other factors are positively correlated with perceived learning (**r** = .371 to 0.803, **P** < .01). These results demonstrate that the selected post-training factors were highly relevant to this study. Thirteen of these factors appeared to contribute to having a positive training experience in a 360 VR environment. The remaining two factors appeared to detract from this training experience.

Table 4-13: Correlation matrix between post-training factors and perceived learning

Correlations

		Simulator Sickness	Realism	Immersion	Interaction	Ease Of Use	Usefulness	Tool Functionality	Atittude Towards Use	Presence	Engagement	Enjoyment	Stress Worry Pressure	Feedback	Task Characteristics	Trainer	Perceived Learning
Simulator Sickness	Pearson Correlation	1	-.170**	-.096	-.287**	-.333**	-.264**	-.319**	-.379**	-.303**	-.258**	-.388**	.215**	-.139*	-.203**	-.122*	-.238**
	Sig. (2-tailed)		.005	.117	.000	.000	.000	.000	.000	.000	.000	.000	.000	.023	.001	.047	.000
	N	267	267	266	265	266	265	265	266	265	264	266	264	264	264	265	266
Realism	Pearson Correlation	-.170**	1	.510**	.594**	.626**	.666**	.601**	.585**	.525**	.481**	.446**	-.209**	.267**	.405**	.301**	.486**
	Sig. (2-tailed)	.005		.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000
	N	267	270	269	268	269	268	268	269	268	267	269	267	267	267	268	269
Immersion	Pearson Correlation	-.096	.510**	1	.607**	.593**	.585**	.604**	.558**	.637**	.675**	.454**	.208**	.324**	.397**	.245**	.371**
	Sig. (2-tailed)	.117	.000		.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000	.000	.000
	N	266	269	269	267	269	267	267	268	267	266	268	266	266	266	267	268
Interaction	Pearson Correlation	-.287**	.594**	.607**	1	.827**	.765**	.765**	.661**	.704**	.713**	.572**	-.129*	.458**	.521**	.396**	.571**
	Sig. (2-tailed)	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.036	.000	.000	.000	.000
	N	265	268	267	268	267	266	266	267	266	265	267	265	265	265	266	267
Ease Of Use	Pearson Correlation	-.333**	.626**	.593**	.827**	1	.849**	.817**	.725**	.712**	.700**	.625**	-.172**	.365**	.479**	.326**	.530**
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.005	.000	.000	.000	.000
	N	266	269	269	267	269	267	267	268	267	266	268	266	266	266	267	268
Usefulness	Pearson Correlation	-.264**	.666**	.585**	.765**	.849**	1	.831**	.766**	.718**	.714**	.620**	-.154*	.407**	.526**	.378**	.562**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.012	.000	.000	.000	.000
	N	265	268	267	266	267	268	266	267	266	265	267	265	265	265	266	267
Tool Functionality	Pearson Correlation	-.319**	.601**	.604**	.765**	.817**	.831**	1	.768**	.759**	.736**	.633**	-.110	.438**	.520**	.349**	.573**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.075	.000	.000	.000	.000
	N	265	268	267	266	267	266	268	268	267	265	267	265	265	265	266	267
AtittudeTowardsUse	Pearson Correlation	-.379**	.585**	.558**	.661**	.725**	.766**	.768**	1	.835**	.776**	.770**	-.186**	.452**	.556**	.420**	.622**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.002	.000	.000	.000	.000
	N	266	269	268	267	268	267	268	269	268	266	268	266	266	266	267	268
Presence	Pearson Correlation	-.303**	.525**	.637**	.704**	.712**	.718**	.759**	.835**	1	.813**	.701**	-.056	.459**	.531**	.370**	.562**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.362	.000	.000	.000	.000
	N	265	268	267	266	267	266	267	268	268	265	267	265	265	265	266	267
Engagement	Pearson Correlation	-.258**	.481**	.675**	.713**	.700**	.714**	.736**	.776**	.813**	1	.679**	.034	.435**	.523**	.327**	.535**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.581	.000	.000	.000	.000
	N	264	267	266	265	266	265	265	266	265	267	267	265	265	265	266	267
Enjoyment	Pearson Correlation	-.388**	.446**	.454**	.572**	.625**	.620**	.633**	.770**	.701**	.679**	1	-.250**	.389**	.469**	.377**	.551**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000
	N	266	269	268	267	268	267	267	268	267	267	269	267	267	267	268	269
Stress Worry Pressure	Pearson Correlation	.215**	-.209**	.208**	-.129*	-.172**	-.154*	-.110	-.186**	-.056	.034	-.250**	1	-.093	-.192**	-.205**	-.257**
	Sig. (2-tailed)	.000	.001	.001	.036	.005	.012	.075	.002	.362	.581	.000		.132	.002	.001	.000
	N	264	267	266	265	266	265	265	266	265	265	267	267	265	265	266	267
Feedback	Pearson Correlation	-.139*	.267**	.324**	.458**	.365**	.407**	.438**	.452**	.459**	.435**	.389**	-.093	1	.695**	.644**	.673**
	Sig. (2-tailed)	.023	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.132		.000	.000	.000
	N	264	267	266	265	266	265	265	266	265	265	267	265	267	265	266	267
Task Characteristics	Pearson Correlation	-.203**	.405**	.397**	.521**	.479**	.526**	.520**	.556**	.531**	.523**	.469**	-.192**	.695**	1	.645**	.803**
	Sig. (2-tailed)	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.002	.000		.000	.000
	N	264	267	266	265	266	265	265	266	265	265	267	265	265	267	266	267
Trainer	Pearson Correlation	-.122*	.301**	.245**	.396**	.326**	.378**	.349**	.420**	.370**	.327**	.377**	-.205**	.644**	.645**	1	.724**
	Sig. (2-tailed)	.047	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.000	.000		.000
	N	265	268	267	266	267	266	266	267	266	266	268	266	266	266	268	268
Perceived Learning	Pearson Correlation	-.238**	.486**	.371**	.571**	.530**	.562**	.573**	.622**	.562**	.535**	.551**	-.257**	.673**	.803**	.724**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
	N	266	269	268	267	268	267	267	268	267	267	269	267	267	267	268	269

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix A.12: Correlation between Pre-training and Post-training factors (360-VR)) shows that “simulator sickness” does not have a statistically significant relationship with any pre training factor except “motivation” (*r* = -0.162, *P* <0.01). “Perceived realism” also did not have a statistically significant relationship with any pre training factor (at either the *P* <0.01 or *P* <0.05 level of significance). “Immersion” only showed a significant relationship with “confidence” (*r* = -0.162, *P* <0.01) and “digital world involvement” (*r* = 0.202, *P* <0.01). “Level of interaction” had statistically significant relationships with “motivation” (*r* = 0.137, *P* <0.05), “gaming experience” (*r* = 0.170, *P* <0.01) and “digital world involvement” (*r* = 0.131, *P* <0.05). “Technology ease of use” only displayed significant relationships with “motivation” (*r* = 0.138, *P* <0.05) and gaming “experience” (*r* = 0.134, *P* < 0.05) while “perceived usefulness” only showed a significant relationship with “motivation” (*r* = 0.149, *P* < 0.05). “Tool functionality” only had a significant relationship with “motivation” (*r* = 0.143, *P* < 0.05) while “Task technology fit” showed relationship with “motivation” (*r* = 0.151, *P* < 0.05) and “wellbeing” (*r*= 0.155, *P* < 0.05). “Attitude towards using the technology” however was significantly correlated with “motivation” (*r* = 0.231, *P* <0.05), “alertness” (*r* = 0.185, *P* <0.05), “sense of competition (*r* = 0.155, *P* < 0.05) and “wellbeing” (r = 0.160, *P* < 0.01). “Presence” (*r* = 0.191, *P* <0.05), “enjoyment” (*r* = 0.241, *P* <0.01) and “engagement” (*r* = 0.195, *P* <0.01) all displayed significant relationships with “motivation” and “sense of alertness” with “Presence” (r=0.144, *P* <0.05) “enjoyment” (r=0.151 at *P* <0.05) and “engagement” (r=0.195 *P* <0.01). Moreover, “enjoyment” and “engagement” were significantly and positively correlated with “wellbeing” (*r* = 0.153 and *r* = 0.157 at *P* <0.05) and sense of enjoyment and competition (*r* = .0139, *P* <0.05). Sense of stress and worry and pressure has a positive relationship with digital world involvement (*r* =0.147, *P* <0.05) which is due to the fact that the participant of this study had a very low and limited technology exposure and involvement. Feedback has only relationship with sense of alert (*r* =0.129, *P* <0.05) and wellbeing (*r*= 0.136, *P* <0.05). Task characteristics and trainers performance only has a relationship with the level of motivation (*r*=0.151, r=0.131 and *P* <0.05 respectively) and alert (*r*=0.161, *P* <0.01 and *r*=0.147, *P* <0.05).

4.5.6 Influence of demographic factors

We also decided to test the influence of three demographic factors on pre- and post-training factors:

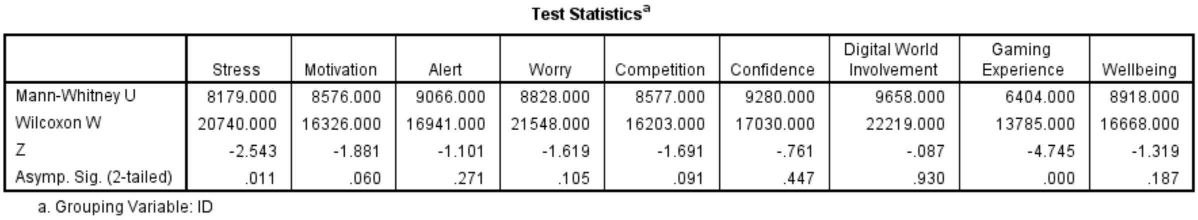
- **Age** - we divided our survey sample into two groups: 24 to 40 year-old and 41 to 64 year-old.
- **Rescue experience** - we divided our survey sample into two groups: junior rescuers with less than 10 year-experience and senior rescuers with 10 years of experience or more.
- **Mining experience** - we divided our survey sample into two groups: junior miners with less than 10 year-experience and senior miners with 10 years of experience or more.

As most pre and post-training factors did not follow a normal distribution (see Appendix A.10: Normality test on pre-training factors and Appendix A.11: Normality test on post-training factors), we used non-parametric Mann-Whitney tests for two independent samples to test for differences between these groups.

4.5.6.1 Influence of Age on reported pre-training factors

Mann-Whitney U Tests (Table 4-14) compared the younger (24-40 years) and older (41-64 years) groups of trainees on a variety of pre-training factors (stress, motivation, alertness, worry, competition, confidence digital world involvement, gaming experience and well-being). However these two groups of trainees were only found to differ significantly on two of these eight pre-training factors. The younger group of trainees reported that they had significantly more gaming experience than the older group of trainees, Z=-4.745; $p < 0.05$. By contrast, the older trainees reported experiencing significantly higher levels of stress prior to the training than the younger trainees, Z=-2.543; $p= < 0.05$.

Table 4-14: influence of Age on reported pre-training factors



Test Statistics[a]

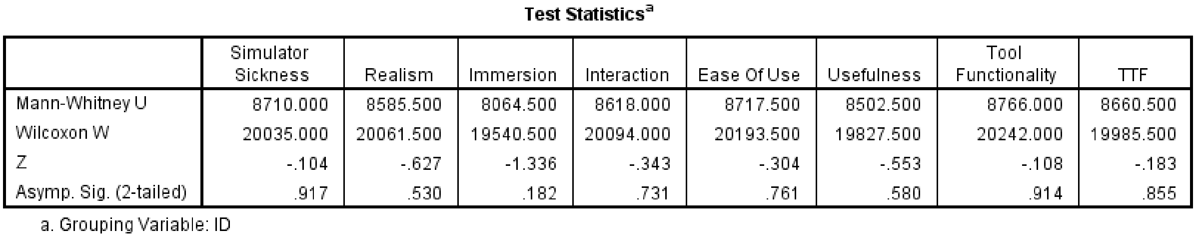
	Stress	Motivation	Alert	Worry	Competition	Confidence	Digital World Involvement	Gaming Experience	Wellbeing
Mann-Whitney U	8179.000	8576.000	9066.000	8828.000	8577.000	9280.000	9658.000	6404.000	8918.000
Wilcoxon W	20740.000	16326.000	16941.000	21548.000	16203.000	17030.000	22219.000	13785.000	16668.000
Z	-2.543	-1.881	-1.101	-1.619	-1.691	-.761	-.087	-4.745	-1.319
Asymp. Sig. (2-tailed)	.011	.060	.271	.105	.091	.447	.930	.000	.187

a. Grouping Variable: ID

4.5.6.2 Influence of Age on reported post-training factors

Mann-Whitney U Tests (Table 4-15) compared the younger (24-40 years) and older (41-64 years) groups of trainees on a variety of post-training factors (Simulator sickness, realism, immersion, interaction, ease of use, usefulness, tool functionality, task technology fit, attitude towards use, presence, engagement, enjoyment, stress/worry and pressure, feedback, task characteristics, trainer and perceived learning). However as can be seen from Table 4-15, there were no statistically significant differences between the younger and older trainees across all reported post-training factors (all $p > .05$).

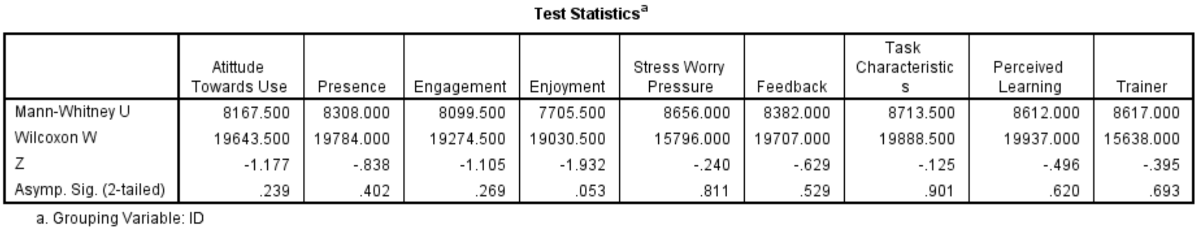
Table 4-15: influence of Age on reported post-training factors



Test Statistics[a]

	Simulator Sickness	Realism	Immersion	Interaction	Ease Of Use	Usefulness	Tool Functionality	TTF
Mann-Whitney U	8710.000	8585.500	8064.500	8618.000	8717.500	8502.500	8766.000	8660.500
Wilcoxon W	20035.000	20061.500	19540.500	20094.000	20193.500	19827.500	20242.000	19985.500
Z	-.104	-.627	-1.336	-.343	-.304	-.553	-.108	-.183
Asymp. Sig. (2-tailed)	.917	.530	.182	.731	.761	.580	.914	.855

a. Grouping Variable: ID



Test Statistics^a

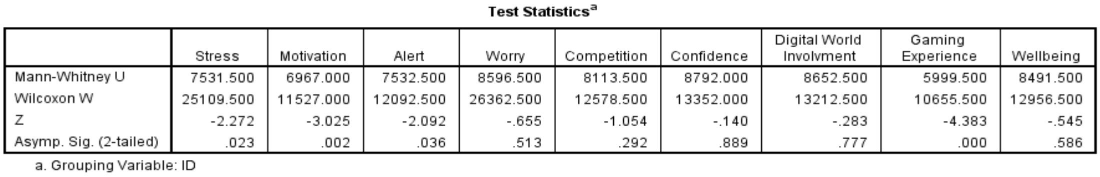
	Attitude Towards Use	Presence	Engagement	Enjoyment	Stress Worry Pressure	Feedback	Task Characteristics	Perceived Learning	Trainer
Mann-Whitney U	8167.500	8308.000	8099.500	7705.500	8656.000	8382.000	8713.500	8612.000	8617.000
Wilcoxon W	19643.500	19784.000	19274.500	19030.500	15796.000	19707.000	19888.500	19937.000	15638.000
Z	-1.177	-.838	-1.105	-1.932	-.240	-.629	-.125	-.496	-.395
Asymp. Sig. (2-tailed)	.239	.402	.269	.053	.811	.529	.901	.620	.693

a. Grouping Variable: ID

4.5.6.3 Influence of Rescue Experience on reported pre-training factors

Mann-Whitney U Tests (Table 4-16) compared the novice rescuers (<10-year rescue experience) and expert rescuers (>10-year rescue experience) on a variety of pre-training factors (stress, motivation, alertness, worry, competition, confidence digital world involvement, gaming experience and well-being). These two groups of trainees were found to differ significantly on four of the eight pre-training factors. The novice rescuers were found to have a significantly more "motivation" (Z=-3.025; p=< 0.05), "alertness" (Z=-2.092; p> 0.05) and "gaming experience" (Z=-4.383; p=.000<.05), than expert rescuers. Conversely, the expert rescuers reported more "stress" than novice rescuers, Z=-2.272; p=.023<.05.

Table 4-16: influence of Rescue Experience on reported pre-training factors



Test Statistics^a

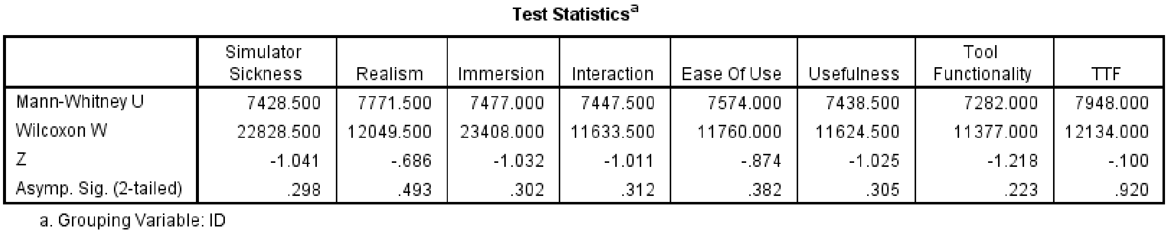
	Stress	Motivation	Alert	Worry	Competition	Confidence	Digital World Involvment	Gaming Experience	Wellbeing
Mann-Whitney U	7531.500	6967.000	7532.500	8596.500	8113.500	8792.000	8652.500	5999.500	8491.500
Wilcoxon W	25109.500	11527.000	12092.500	26362.500	12578.500	13352.000	13212.500	10655.500	12956.500
Z	-2.272	-3.025	-2.092	-.655	-1.054	-.140	-.283	-4.383	-.545
Asymp. Sig. (2-tailed)	.023	.002	.036	.513	.292	.889	.777	.000	.586

a. Grouping Variable: ID

4.5.6.4 Influence of Rescue Experience on reported post-training factors

Mann-Whitney U Tests (Table 4-17) compared the novice rescuers (<10-year rescue experience) and expert rescuers (>10-year rescue experience) on a variety of post-training factors (sickness, realism, immersion, interaction, ease of use, usefulness, tool functionality, Task technology fit, attitude towards use, presence, engagement, enjoyment, stress/worry and pressure, feedback, task characteristics, trainer and perceived learning). However these two groups of trainees were not found to differ significantly on any of the post-training factors (p > 0.05).

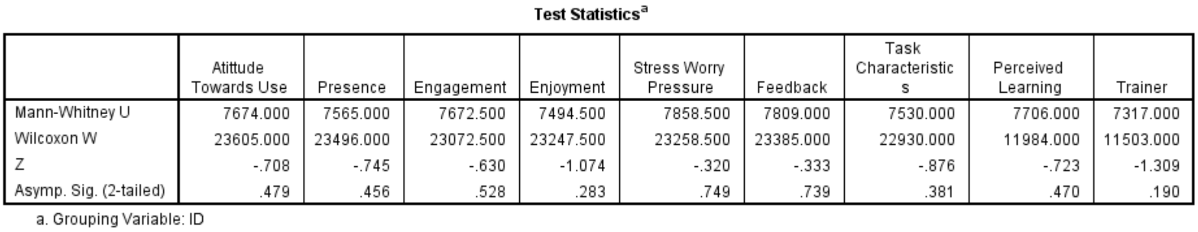
Table 4-17: influence of Rescue Experience on reported post-training factors



Test Statistics^a

	Simulator Sickness	Realism	Immersion	Interaction	Ease Of Use	Usefulness	Tool Functionality	TTF
Mann-Whitney U	7428.500	7771.500	7477.000	7447.500	7574.000	7438.500	7282.000	7948.000
Wilcoxon W	22828.500	12049.500	23408.000	11633.500	11760.000	11624.500	11377.000	12134.000
Z	-1.041	-.686	-1.032	-1.011	-.874	-1.025	-1.218	-.100
Asymp. Sig. (2-tailed)	.298	.493	.302	.312	.382	.305	.223	.920

a. Grouping Variable: ID



Test Statistics^a

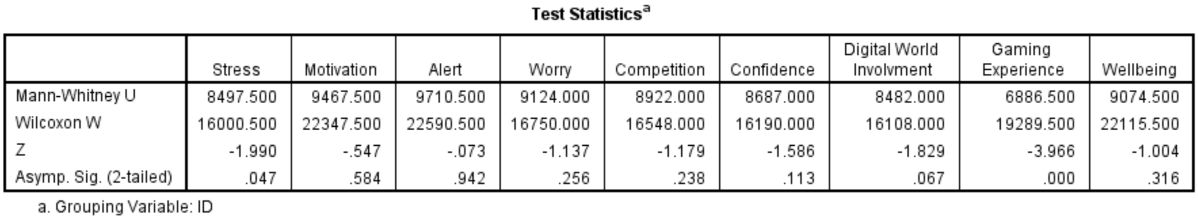
	Attitude Towards Use	Presence	Engagement	Enjoyment	Stress Worry Pressure	Feedback	Task Characteristics	Perceived Learning	Trainer
Mann-Whitney U	7674.000	7565.000	7672.500	7494.500	7858.500	7809.000	7530.000	7706.000	7317.000
Wilcoxon W	23605.000	23496.000	23072.500	23247.500	23258.500	23385.000	22930.000	11984.000	11503.000
Z	-.708	-.745	-.630	-1.074	-.320	-.333	-.876	-.723	-1.309
Asymp. Sig. (2-tailed)	.479	.456	.528	.283	.749	.739	.381	.470	.190

a. Grouping Variable: ID

4.5.6.5 *Influence of Mining Experience on reported pre-training factors*

Mann-Whitney U Tests (Table 4-18) compared the novice miners (<10-year mining experience) and expert miners (>10-year mining experience) on a variety of pre-training factors (stress, motivation, alertness, worry, competition, confidence digital world involvement, gaming experience and well-being). However these two groups of trainees were only found to differ significantly on two of these eight pre-training factors. The novice miners reported that they had significantly more "gaming experience" than expert miners, Z=-3.966; p=.000<.05. Conversely, the expert miners reported experiencing significantly higher levels of "stress" prior to the training than the novice miners, Z=-1.990; p=.047<.05.

Table 4-18: influence of Mining Experience on reported pre-training factors



Test Statistics^a

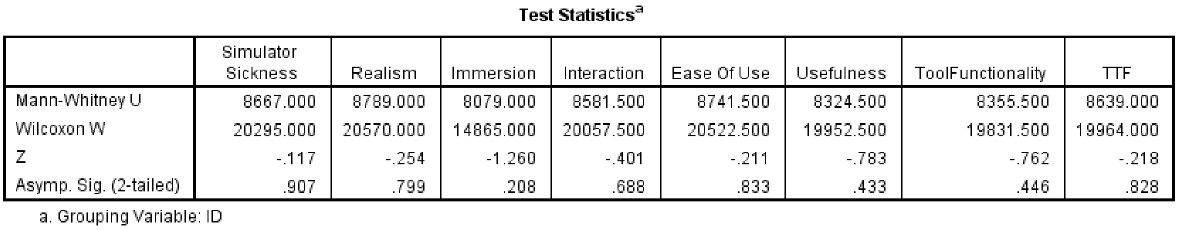
	Stress	Motivation	Alert	Worry	Competition	Confidence	Digital World Involvment	Gaming Experience	Wellbeing
Mann-Whitney U	8497.500	9467.500	9710.500	9124.000	8922.000	8687.000	8482.000	6886.500	9074.500
Wilcoxon W	16000.500	22347.500	22590.500	16750.000	16548.000	16190.000	16108.000	19289.500	22115.500
Z	-1.990	-.547	-.073	-1.137	-1.179	-1.586	-1.829	-3.966	-1.004
Asymp. Sig. (2-tailed)	.047	.584	.942	.256	.238	.113	.067	.000	.316

a. Grouping Variable: ID

4.5.6.6 *Influence of Mining Experience on reported post-training factors*

Mann-Whitney U Tests (Table 4-19) compared the novice miners (<10-year mining experience) and expert miners (>10-year mining experience) on a variety of post-training factors (sickness, realism, immersion, interaction, ease of use, usefulness, tool functionality, task technology fit, attitude towards use, presence, engagement, enjoyment, stress/worry and pressure, feedback, task characteristics, trainer and perceived learning). Results show no statistically significant differences between the two groups across all reported post-training factors, (p> 0.05)

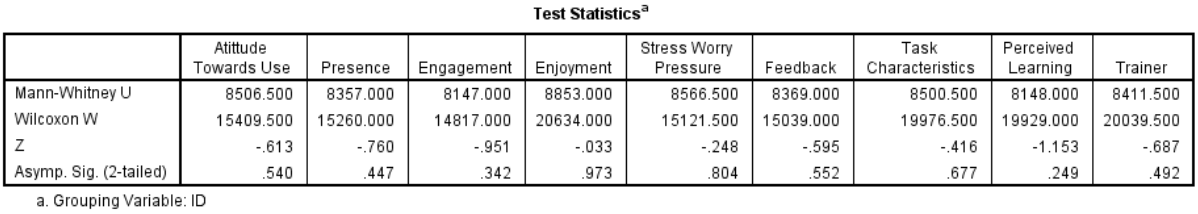
Table 4-19: influence of Mining Experience on reported post-training factors



Test Statistics^a

	Simulator Sickness	Realism	Immersion	Interaction	Ease Of Use	Usefulness	ToolFunctionality	TTF
Mann-Whitney U	8667.000	8789.000	8079.000	8581.500	8741.500	8324.500	8355.500	8639.000
Wilcoxon W	20295.000	20570.000	14865.000	20057.500	20522.500	19952.500	19831.500	19964.000
Z	-.117	-.254	-1.260	-.401	-.211	-.783	-.762	-.218
Asymp. Sig. (2-tailed)	.907	.799	.208	.688	.833	.433	.446	.828

a. Grouping Variable: ID



Test Statistics^{a}

	Atittude Towards Use	Presence	Engagement	Enjoyment	Stress Worry Pressure	Feedback	Task Characteristics	Perceived Learning	Trainer
Mann-Whitney U	8506.500	8357.000	8147.000	8853.000	8566.500	8369.000	8500.500	8148.000	8411.500
Wilcoxon W	15409.500	15260.000	14817.000	20634.000	15121.500	15039.000	19976.500	19929.000	20039.500
Z	-.613	-.760	-.951	-.033	-.248	-.595	-.416	-1.153	-.687
Asymp. Sig. (2-tailed)	.540	.447	.342	.973	.804	.552	.677	.249	.492

a. Grouping Variable: ID

We can safely conclude from this analysis that age, rescue experience and mining experience play no significant role in the way trainees respond to 360-VR training environment. In particular, the fact that older generations – probably more experienced miners and rescuers – report weaker gaming experience and higher level of stress prior training doesn't seem to affect their ability to engage with and learn from the 360-VR training session.

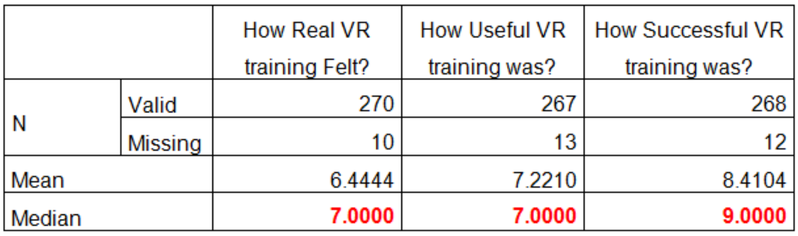
4.6 Reported Training Outcomes for 360-VR training

After each 360-VR training session, trainees were asked (in the post-training questionnaire) to answer the following questions:

- "How successful was the training in 360-VR?"
- "How useful do you think this training was?"
- "How consistent was your experience with real life conditions?"
- "Do you prefer 360-VR training over traditional training?"
- "Would you recommend 360-VR training to others?"

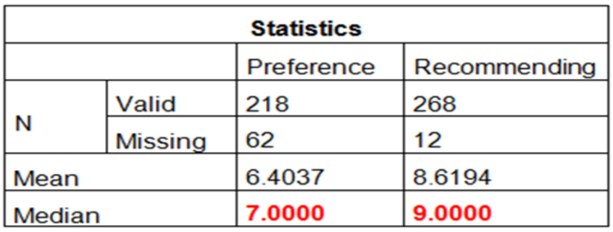
Trainees responded to each question on a Likert scale of 0-10 where ratings from "4" to "0" indicates progressively less successful, useful and realistic, ratings of "5" indicate neutrality, and ratings from "6" to "10" indicates progressively more successful, useful, and realistic. Table 4-20 shows that on average the 360-VR training was rated as highly successful, reasonably useful and fairly realistic by trainees and likewise, as Table 4-21 shows that trainees prefer 360-VR over traditional onsite or classroom training approaches and most likely they are going to recommend this training to others.

Table 4-20: 360-VR training's perceived level of realism, usefulness and success.



		How Real VR training Felt?	How Useful VR training was?	How Successful VR training was?
N	Valid	270	267	268
	Missing	10	13	12
Mean		6.4444	7.2210	8.4104
Median		7.0000	7.0000	9.0000

Table 4-21: 360-VR training's level of preference and recommendation



Statistics			
		Preference	Recommending
N	Valid	218	268
	Missing	62	12
Mean		6.4037	8.6194
Median		**7.0000**	**9.0000**

4.6.1 Cross-tabulation Usefulness x Realism

Figure 4-1show that many trainees indicated that 360-VR was a useful training environment despite reservations about its level of realism (see Appendix A.13 for statistical results).

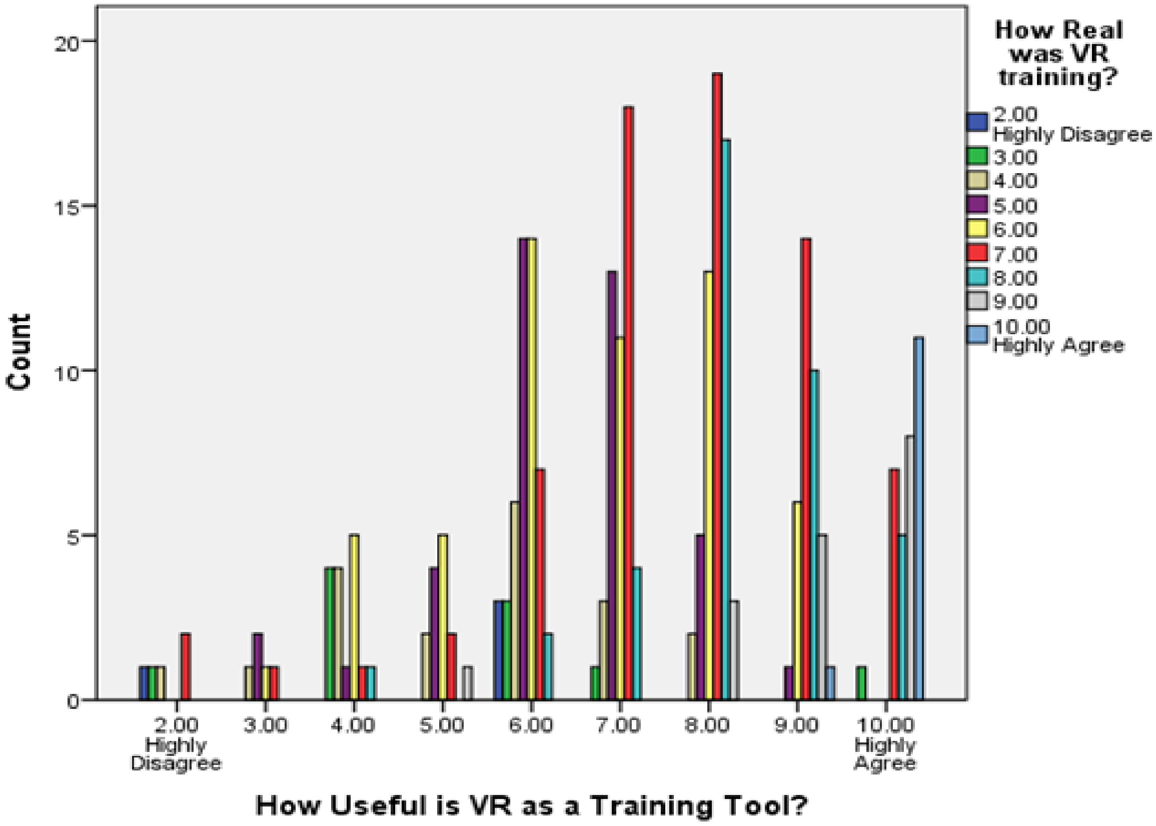


Figure 4-1: Cross-tabulation between perceived levels of realism and usefulness.

178 trainees (67%) considered 360-VR as ‘useful’ or ‘very useful’ (categories 7 to 10). Amongst these 178 trainees, 56 indicated that their training was poorly to fairly consistent with real life experiences (categories 2 to 6). Therefore, even though realism has been identified as one of the key training needs by trainers and VR designers (see Need Analysis section), this result suggests that trainees see value in a training environment that allows them to focus on the requested tasks and get useful feedback on dangerous situations.

4.6.2 Cross-tabulation Success x Realism

Figure 4-2 show that a large majority of trainees indicated that 360-VR was a successful training environment despite reservations about its level of realism (see Appendix A.14 for statistical results).

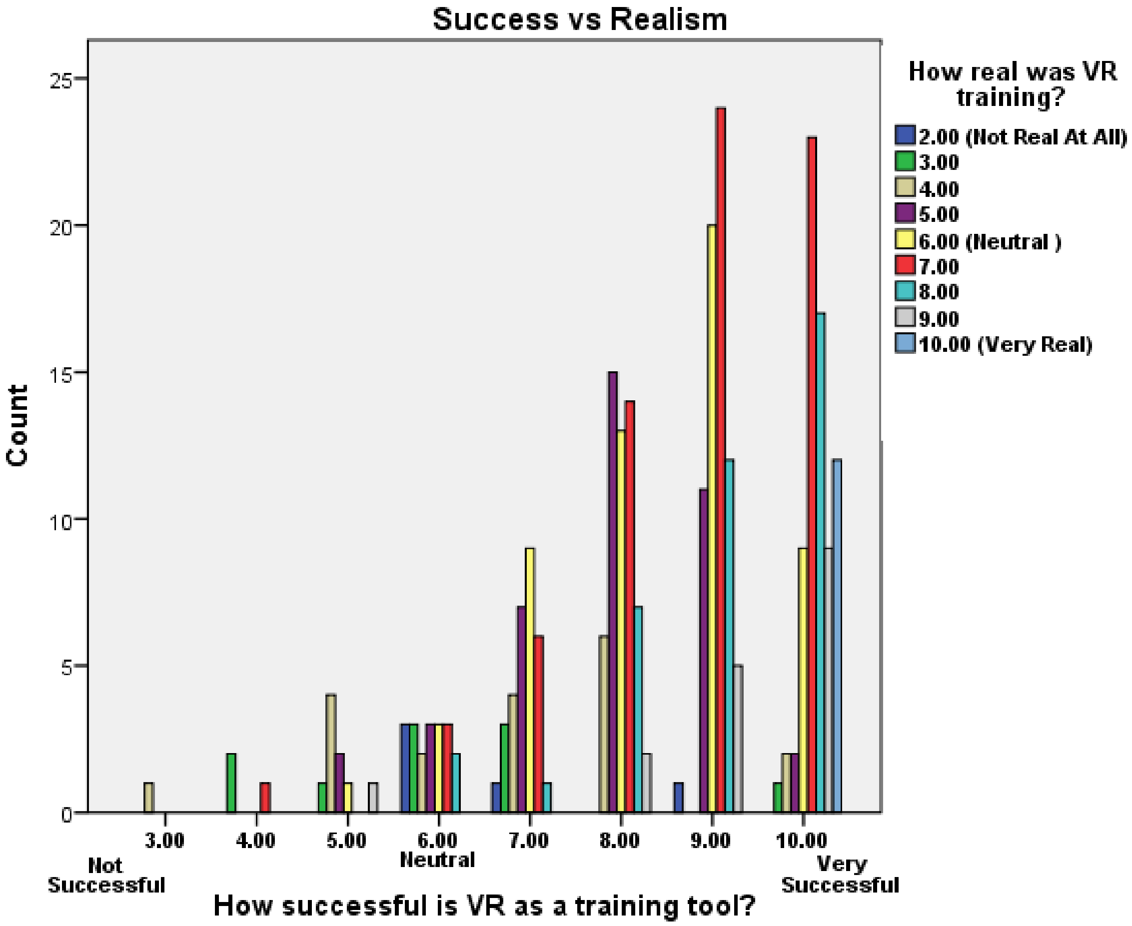


Figure 4-2: cross-tabulation between perceived levels of realism and success.

236 trainees (88%) indicated that they found 360-VR training successful to highly successful (categories 7 to 10). Amongst these 236 trainees, 104 indicated that their training was poor to fairly consistent with real life experiences (categories 2 to 6). Therefore, these results confirm that trainees not only found the 360-VR training to be useful but also successful despite a lack of realism. This result suggests that trainees see value in a training environment that allows them to perform well on the requested tasks and improve their skills to respond to dangerous situations.

4.6.3 Cross-tabulation Success x Usefulness

Figure 4-3 show that 88% of trainees indicated that the VR training was successful, from which 70% indicated that it was also a useful tool (see Appendix A.15 for statistical results).

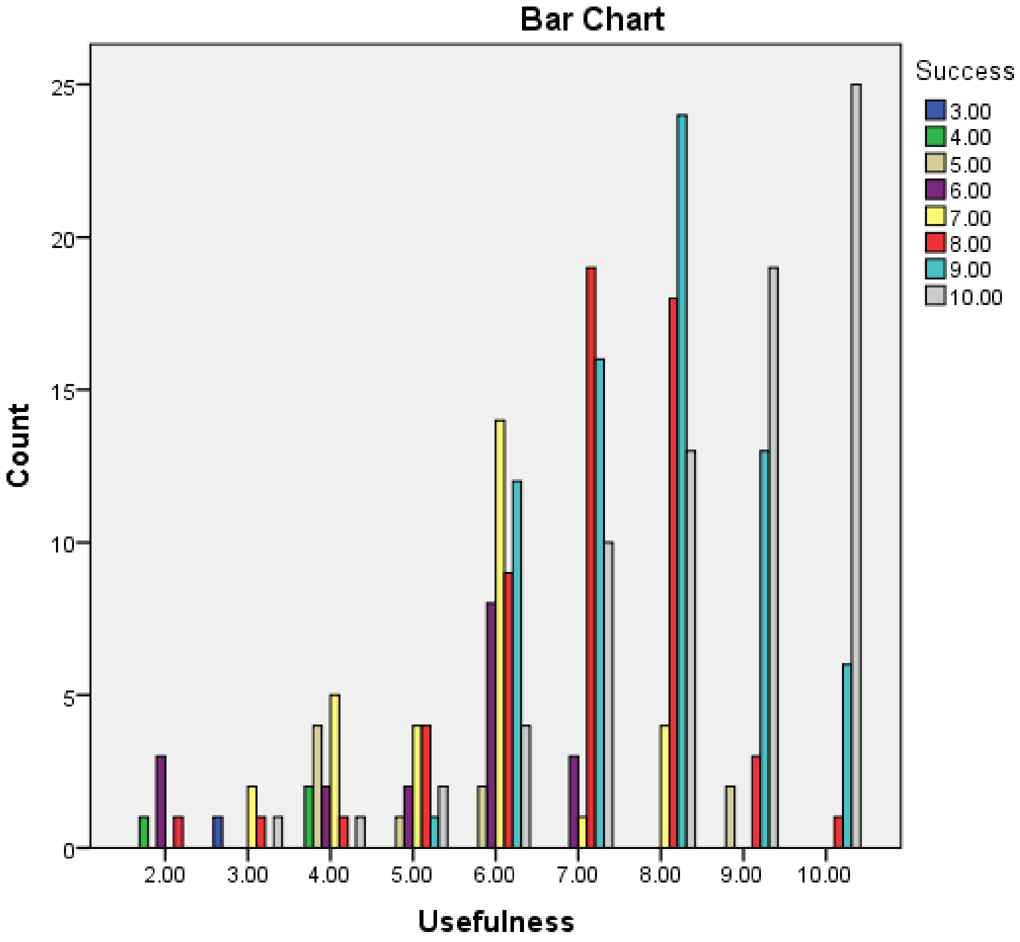


Figure 4-3: cross-tabulation between perceived usefulness and success.

236 trainees (88%) indicated that they found the 360-VR training successful to highly successful (categories 7 to 10). Amongst the 236 trainees, only 62 regarded the 360-VR training as 'not useful' or 'fairly useful' (categories 2 to 6). Therefore, the majority of trainees (65%) found 360-VR training both useful and successful. This result suggests that trainees see value in a training environment that allows them to perform well in response to proposed situations due to its ability to help them focusing on the requested tasks.

4.6.4 Cross-tabulation Preference x Recommendation

Figure 4-4 show that 88% of trainees indicated that they would recommend VR training to others. However, only 52% of these trainees preferred VR training over traditional approaches (see Appendix A.15 for statistical results).

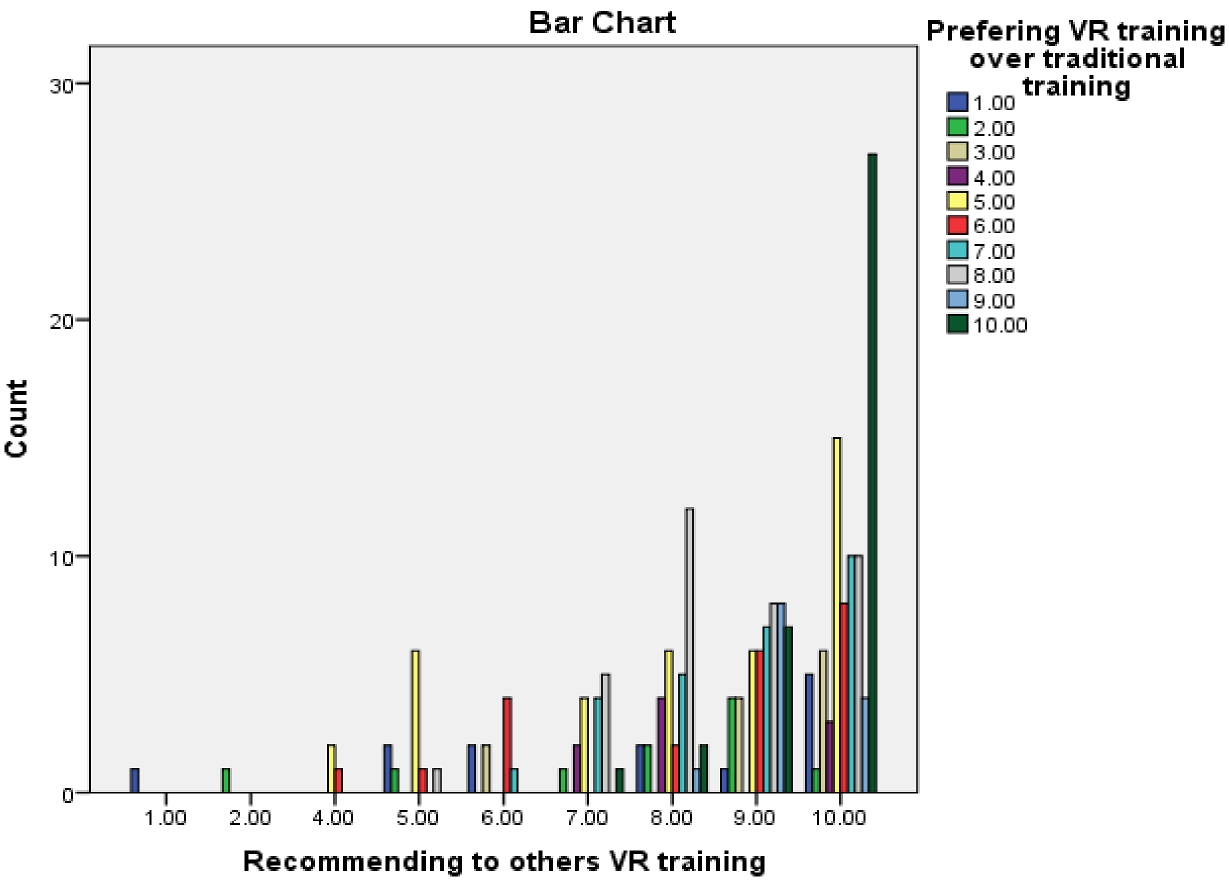


Figure 4-4: Cross-tabulation between perceived Preference and Recommendation

193 trainees indicated that they would recommend 360-VR training to other colleagues. However, only 113 of them indicated they preferred 360-VR over traditional on-site training. This result suggests that VR is a successful complement to the traditional onsite training. It is apparent that users have recognised its added value to the industry and the current training system but none of the techniques should substitute one another.

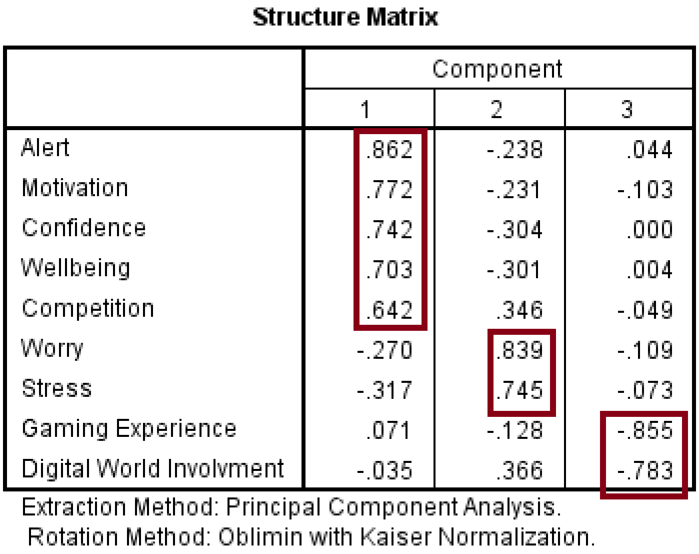
4.7 Modelling of Perceived Learning (360 VR)

Next we attempted to determine how much of the trainees' perceived learning could be explained by pre-training (9 in total) and post-training (16 in total) factors. The relatively small size of the sample (231 observations for 17 predictors) and the high level of correlation between variables led us to a two-stage modelling process: (1) Principal Component Analysis to reduce the number of predictors; and (2) linear regression between perceived learning and aggregated predictors.

4.7.1 Principle Component Analysis (PCA) on pre-training factors

Table 4-22 show that the first Component, explaining 34% of the variance, is characterised by 5 factors: “Alertness”, “Motivation”, “Confidence”, “Wellbeing” and “Competitiveness”. The second Component, explaining 17% of the variance, is characterised by 2 strongly correlated factors: “Worry” and “Stress”. The third Component, explaining 13% of the variance, is characterised by 2 strongly correlated factors: “Gaming Experience” and “Digital World Involvement”. Together these 3 Components explained 64% of the total variance (see Appendix A.16 for statistical results).

Table 4-22: Structure Matrix – PCA on pre-training factors



Structure Matrix

	Component		
	1	2	3
Alert	.862	-.238	.044
Motivation	.772	-.231	-.103
Confidence	.742	-.304	.000
Wellbeing	.703	-.301	.004
Competition	.642	.346	-.049
Worry	-.270	.839	-.109
Stress	-.317	.745	-.073
Gaming Experience	.071	-.128	-.855
Digital World Involvment	-.035	.366	-.783

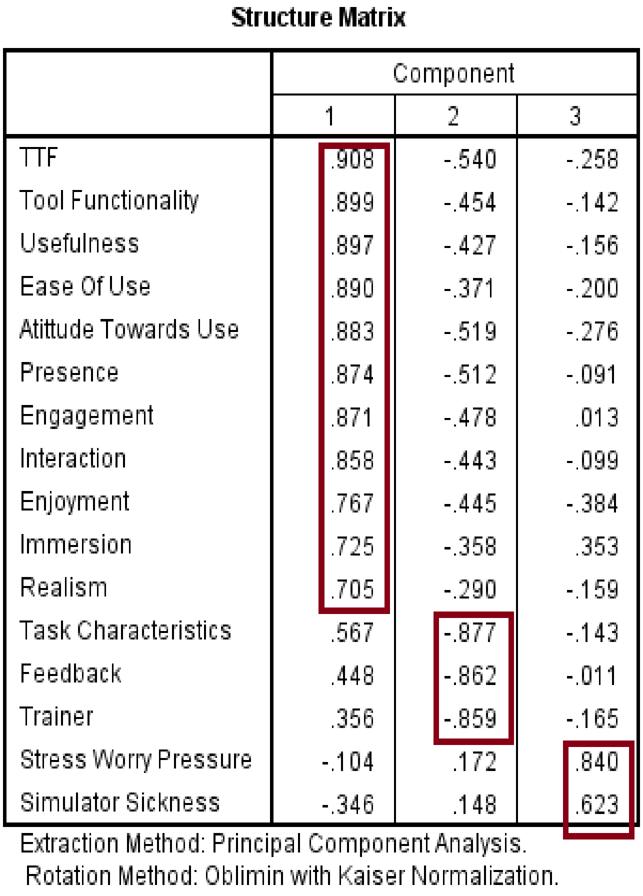
Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

Based on the nature of the factors mostly contributing to each component we have used the first 3 Components to create 3 new aggregated variables: “Positive State of Mind” (Component 1), “Negative State of Mind” (Component 2) and “Technology Experience” (Component 3).

4.7.2 Principle Component Analysis (PCA) on post-training factors

Table 4-23 show that the first Component, explaining 56% of the variance, is characterised by 11 correlated variables: “Task-Technology Fit”, “Functionality”, “Usefulness”, “Ease of use”, “Attitude”, “Presence”, “Engagement”, “Interaction”, “Enjoyment”, “Immersion” and “Realism”. The second Component, explaining 9% of the variance, is characterised by 3 strongly correlated variables: “Task Characteristics”, “Feedback” and “Trainer”. The third Component, explaining 8% of the variance, is characterised by 2 strongly correlated variables: “Stress” and “Simulation Sickness”. These 3 Components explain 73% of the total variance (see Appendix A.17 for statistical results).

Table 4-23: Structure Matrix – PCA on post-training variables



Structure Matrix

	Component		
	1	2	3
TTF	.908	-.540	-.258
Tool Functionality	.899	-.454	-.142
Usefulness	.897	-.427	-.156
Ease Of Use	.890	-.371	-.200
Atittude Towards Use	.883	-.519	-.276
Presence	.874	-.512	-.091
Engagement	.871	-.478	.013
Interaction	.858	-.443	-.099
Enjoyment	.767	-.445	-.384
Immersion	.725	-.358	.353
Realism	.705	-.290	-.159
Task Characteristics	.567	-.877	-.143
Feedback	.448	-.862	-.011
Trainer	.356	-.859	-.165
Stress Worry Pressure	-.104	.172	.840
Simulator Sickness	-.346	.148	.623

Extraction Method: Principal Component Analysis.
Rotation Method: Oblimin with Kaiser Normalization.

Based on the nature of the variables mostly contributing to each component we have used the first 3 Components to create 3 new aggregated variables: “Positive Learning Experience” (Component 1), “Negative Learning Experience” (Component 2) and “Learning Context” (Component 3).

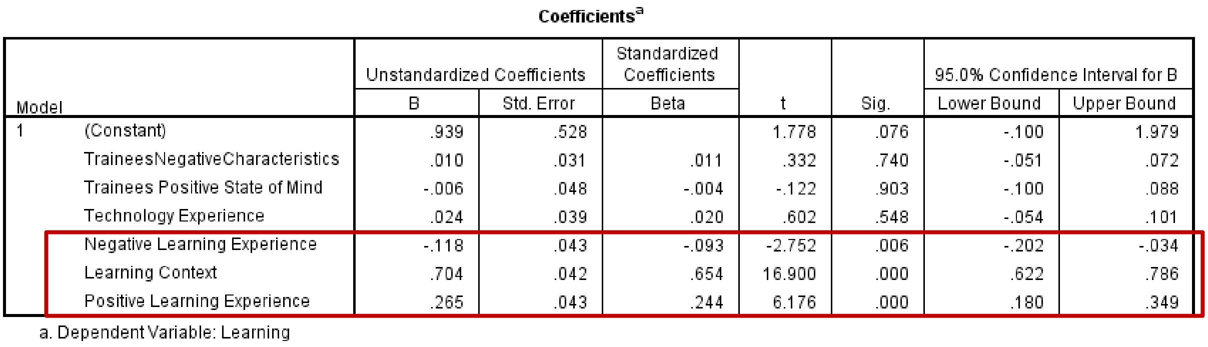
4.7.3 Linear regression based on aggregated variables

A multiple linear regression was calculated to predict perceived learning (PL) based on the following 6 aggregated variables (3 pre-training ones and 3 post-training ones): “Positive state of mind (PSM)”, “Negative state of mind (NSM)”, “Technology experience (TE)”, “Positive Learning experience (PLE)”, “Negative Learning experience (NLE)” and “Learning context (LC)” (see Appendix A.18 for statistical results). Table 4-24 shows that a significant regression equation was found (F(6, 277) = 116.133 , p< .000), with an R^2 of 0.709:

$$PL = 0.939 + 0.704 (LC) + 0.265 (PLE) - 0.118 (NLE)$$

In conclusion, 3 out of 6 aggregated variables were found to be significant predictors of perceived learning in this study. None of the pre-training aggregated variables (i.e. “Positive State of Mind”, “Negative State of Mind” and “Technology Experience”) significantly predicted perceived learning.

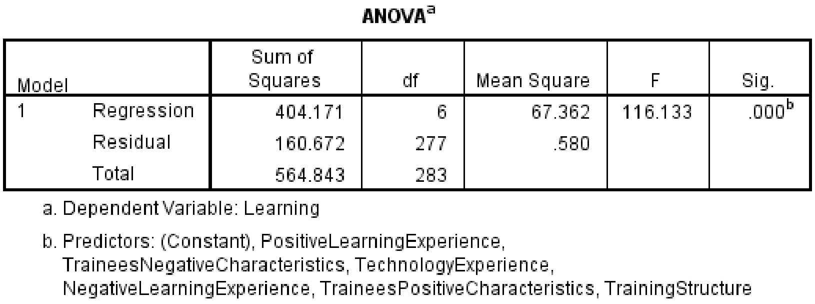
Table 4-24: Coefficients of linear regression modelling



Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	.939	.528		1.778	.076	-.100	1.979
	TraineesNegativeCharacteristics	.010	.031	.011	.332	.740	-.051	.072
	Trainees Positive State of Mind	-.006	.048	-.004	-.122	.903	-.100	.088
	Technology Experience	.024	.039	.020	.602	.548	-.054	.101
	Negative Learning Experience	-.118	.043	-.093	-2.752	.006	-.202	-.034
	Learning Context	.704	.042	.654	16.900	.000	.622	.786
	Positive Learning Experience	.265	.043	.244	6.176	.000	.180	.349

a. Dependent Variable: Learning

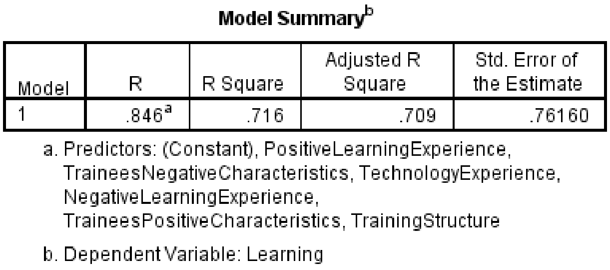


ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	404.171	6	67.362	116.133	.000[b]
	Residual	160.672	277	.580		
	Total	564.843	283			

a. Dependent Variable: Learning

b. Predictors: (Constant), PositiveLearningExperience, TraineesNegativeCharacteristics, TechnologyExperience, NegativeLearningExperience, TraineesPositiveCharacteristics, TrainingStructure



Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.846[a]	.716	.709	.76160

a. Predictors: (Constant), PositiveLearningExperience, TraineesNegativeCharacteristics, TechnologyExperience, NegativeLearningExperience, TraineesPositiveCharacteristics, TrainingStructure

b. Dependent Variable: Learning

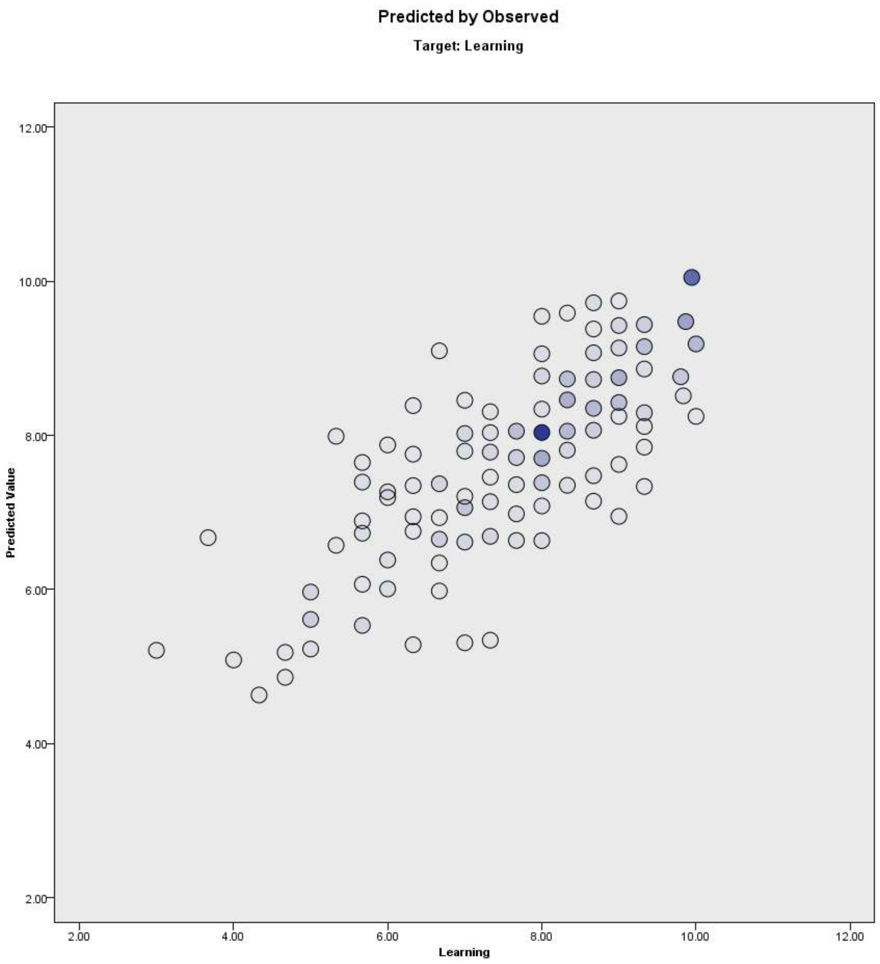


Figure 4-5: Observed Vs predicted values of Learning (Linear regression model)

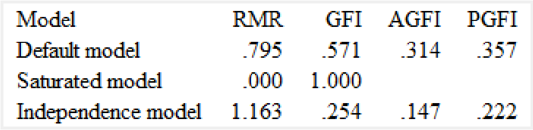
These results confirm that pre-training individual characteristics did not significantly influence the perceived learning of the trainees (as indicated by the trainees after the training session). However, the context of the training session and the (positive or negative) individual experiences during the session did significantly impact the perceived learning. Although the linear regression model explains only 71% of the observed variance, the overall fit between observed and predicted values for the "perceived learning" has statistically significant (Figure 4-5).

4.7.4 Causality Modelling and Analysis

As discussed in chapter 3, a causal model of learning was developed (Chapter III, Figure 3-4) to conduct an in-depth causality analysis. The path analysis was performed using the trainees' "Positive state of mind prior training" (including: presence, alertness, motivation, competitiveness, confidence and wellbeing), "Negative state of mind prior training" (including: sense of stress and worry), "Technology experience" (including: gaming experience and digital world involvement), "VR features" (including: realism, immersion and interaction), "Positive learning experience" (including: presence, engagement, enjoyment), "Negative learning experience" (including: stress, worry and pressure), "VR functionality", “Task-technology fit”, “Technology usefulness”, “Ease of use”, “Attitude towards using” the technology”, “Trainers”, quality of “Feedbacks” and “Perceived learning” (Figure 3.4).

Our path analysis approach displayed poor fitting results (GFI = .571 <0.90), meaning that some components were associated with low loadings (Table 4-25). This result is consistent with previous conclusion drawn from the regression model (section 4.7.3) whereby pre-training individual characteristics seem to be poor predictors of the perceived learning outcomes.

Table 4-25: Path analysis model fit



Model	RMR	GFI	AGFI	PGFI
Default model	.795	.571	.314	.357
Saturated model	.000	1.000		
Independence model	1.163	.254	.147	.222

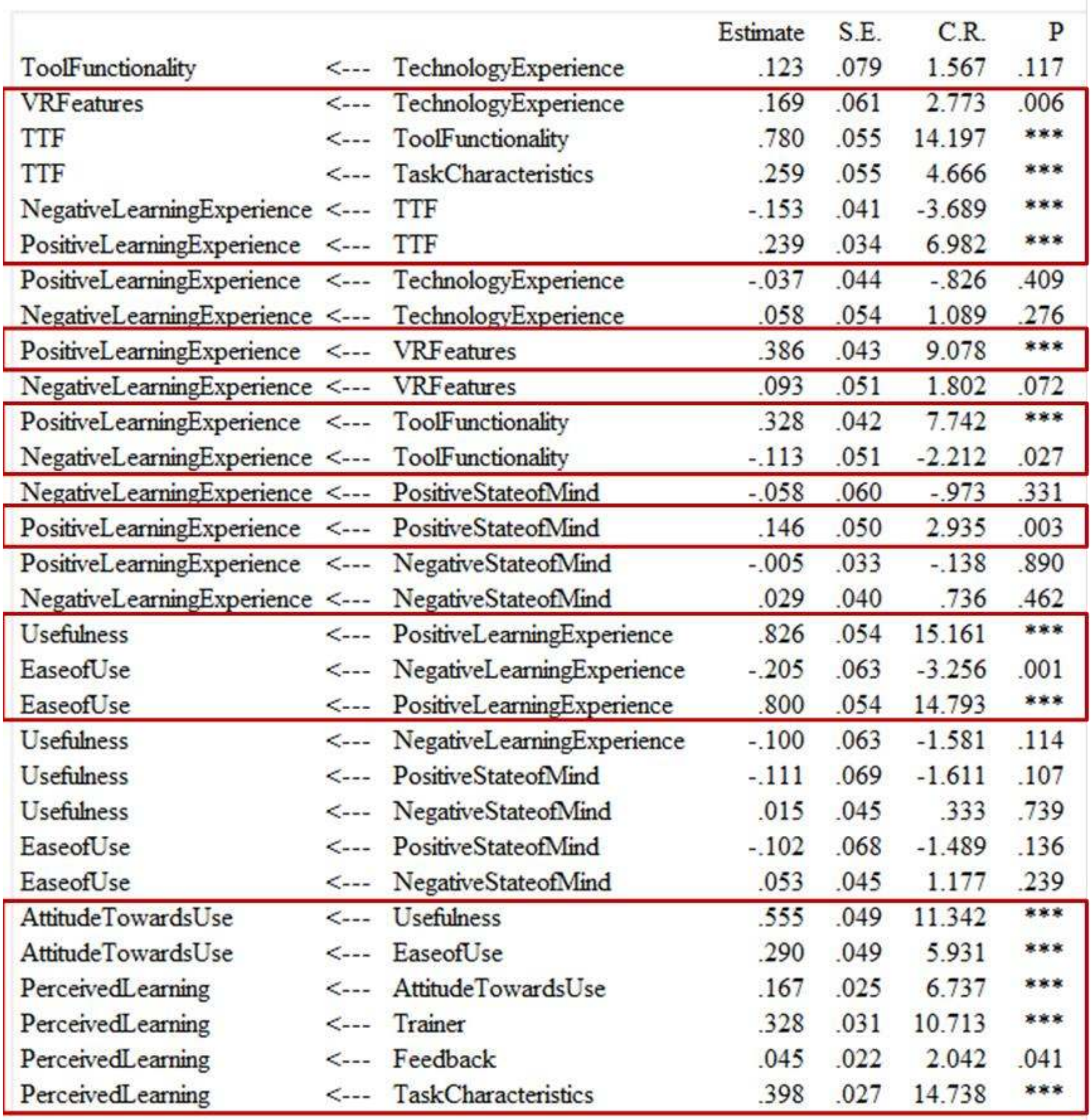
It has to be noticed that our hypothetical model was built a priori, based on our literature review (Chapter II), as well as data acquisition and processing (Chapter III). Henceforth, one would expect that not all the plausible causal links embedded in the initial model could have a significant contribution to perceived learning in our specific context. The following components have a significant effect ($p<0.05$) (Table 4-26):

- **Positive state of mind** has a significant *indirect effect* on perceived learning with participation in positive learning experience (β= 0.146), ease of use (β= 0.129), usefulness (β= 0.126) attitude towards use (β= 0.017) and perceived learning (β= 0.003).
- **Negative state of mind** has a significant *indirect effect* on perceived learning with participation in ease of use (β= -0.010), usefulness (β= -0.007) and attitude towards use (β= 0.017) and perceived learning (β= 0.003).
- **Positive learning experience** has a significant *direct* and *indirect effect* on perceived learning with participation in ease of use (β= 0.800), usefulness (β= 0.826) and attitude towards use (β= 0.690) and perceived learning (β= 0.116).
- **Negative learning experience** has a significant *direct* and *indirect effect* on perceived learning with ease of use (β= -0.205), usefulness (β= -0.100) attitude towards use (β= -0.115) and perceived learning (β= -0.019).
- **Technology Experience** has a significant *direct* and *indirect effect* on perceived learning with participation in Task-technology-fit (β= 0.096), positive learning experience (β= 0.129), negative learning experience (β= -0.013), ease of use (β= 0.064), usefulness (β= 0.072) attitude towards use β= 0.058), VR features (β= 0.169) and perceived learning (β= 0.010).
- **Tool functionality** has a significant *indirect effect* on perceived learning with participation in positive learning experience (β= 0.186 for indirect effect and β= 0.328 for direct effect), negative learning experience (β= -0.119 for indirect effect and β= -0.113 for direct effect), ease of use (β=

0.459), usefulness (β= 0.448) attitude towards use (β= 0.382), task technology fit (β= 0.780) and perceived learning (β= 0.003).

- **Task Characteristics** has a significant *direct* and *indirect effect* on perceived learning with participation in positive learning experience (β= 0.062), negative learning experience (β= -0.039), ease of use (β= 0.058), usefulness (β= 0.055), attitude towards use (β= 0.047 for indirect effect), TTF (β= 0.259) and perceived learning (β= 0.062).
- **Task technology fit** has a significant *direct* and *indirect effect* on perceived learning with participation in positive learning experience (β= 0.239), negative learning experience (β= -0.153), ease of use (β= 0.222), usefulness (β= 0.213) attitude towards use (β= 0.183) and perceived learning (β= 0.031).
- **VR Features** has a significant *indirect effect* on perceived learning with participation in positive learning experience (β= 0.386,), ease of use (β= 0.290), usefulness (β= 0.310) attitude towards use (β= 0.256) and perceived learning (β= 0.043).
- **Ease of use** has a significant *indirect effect* on perceived learning with participation in attitude towards use (β= 0.290) and perceived learning (β= 0.049).
- **Usefulness** has a significant *indirect effect* on perceived learning with participation in attitude towards use (β= 0.555) and perceived learning (β= 0.093).
- **Feedback** (β= 0.45), **Trainer** (β= 0.328) and **Attitude towards use** (β= 0.167) have a significant *direct effect* on perceived learning.

Table 4-26: Path analysis – Significance of links between components (significant links in red boxes)



			Estimate	S.E.	C.R.	P
ToolFunctionality	<---	TechnologyExperience	.123	.079	1.567	.117
VRFeatures	<---	TechnologyExperience	.169	.061	2.773	.006
TTF	<---	ToolFunctionality	.780	.055	14.197	***
TTF	<---	TaskCharacteristics	.259	.055	4.666	***
NegativeLearningExperience	<---	TTF	-.153	.041	-3.689	***
PositiveLearningExperience	<---	TTF	.239	.034	6.982	***
PositiveLearningExperience	<---	TechnologyExperience	-.037	.044	-.826	.409
NegativeLearningExperience	<---	TechnologyExperience	.058	.054	1.089	.276
PositiveLearningExperience	<---	VRFeatures	.386	.043	9.078	***
NegativeLearningExperience	<---	VRFeatures	.093	.051	1.802	.072
PositiveLearningExperience	<---	ToolFunctionality	.328	.042	7.742	***
NegativeLearningExperience	<---	ToolFunctionality	-.113	.051	-2.212	.027
NegativeLearningExperience	<---	PositiveStateofMind	-.058	.060	-.973	.331
PositiveLearningExperience	<---	PositiveStateofMind	.146	.050	2.935	.003
PositiveLearningExperience	<---	NegativeStateofMind	-.005	.033	-.138	.890
NegativeLearningExperience	<---	NegativeStateofMind	.029	.040	.736	.462
Usefulness	<---	PositiveLearningExperience	.826	.054	15.161	***
EaseofUse	<---	NegativeLearningExperience	-.205	.063	-3.256	.001
EaseofUse	<---	PositiveLearningExperience	.800	.054	14.793	***
Usefulness	<---	NegativeLearningExperience	-.100	.063	-1.581	.114
Usefulness	<---	PositiveStateofMind	-.111	.069	-1.611	.107
Usefulness	<---	NegativeStateofMind	.015	.045	.333	.739
EaseofUse	<---	PositiveStateofMind	-.102	.068	-1.489	.136
EaseofUse	<---	NegativeStateofMind	.053	.045	1.177	.239
AttitudeTowardsUse	<---	Usefulness	.555	.049	11.342	***
AttitudeTowardsUse	<---	EaseofUse	.290	.049	5.931	***
PerceivedLearning	<---	AttitudeTowardsUse	.167	.025	6.737	***
PerceivedLearning	<---	Trainer	.328	.031	10.713	***
PerceivedLearning	<---	Feedback	.045	.022	2.042	.041
PerceivedLearning	<---	TaskCharacteristics	.398	.027	14.738	***

Therefore the finalised model is as shown in Figure 4-6 where all of the relationship have been confirmed and validated by the data collected from 280 miners who had participated this VR training.

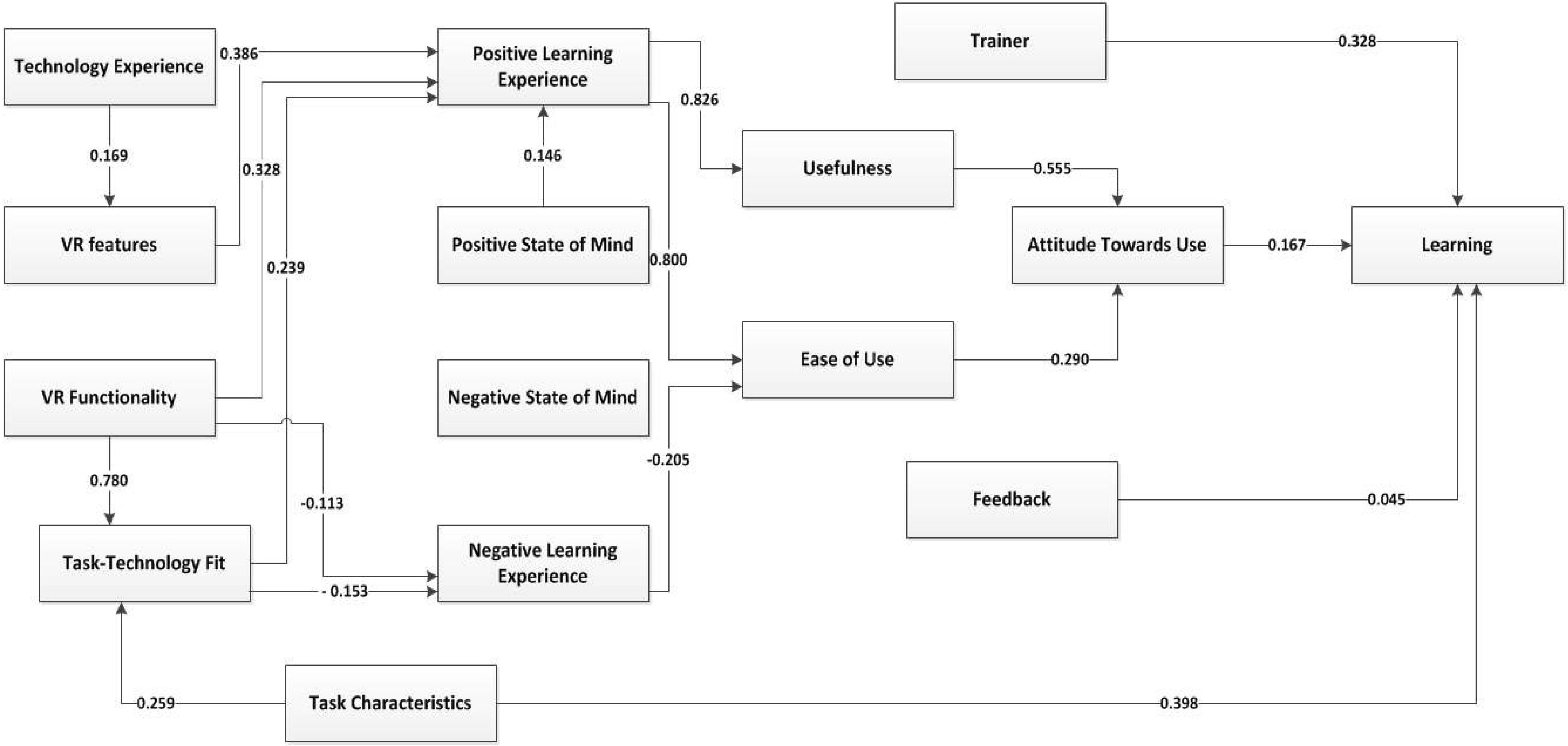


Figure 4-6: VR-learning Casaulity Model

4.8 Competency Evaluation

4.8.1 Skill test

Perceived Learning was assessed based on a subjective statement made by trainees after the VR-based training session. It reflected as much upon the individual's self-esteem as on their actual learning outcomes. Thus, we also designed a short competency test (skill test) to objectively evaluate the quality of the learning process. This test was completed by each trainee prior to the VR-based training session and then again one month later. Figure 4-7 shows that 52% of the trainees improved their score on the second test; the others keeping their initial highest score (4). This result tends to confirm that Perceived Learning corresponds to an actual gain of competency for many trainees. However, these results are limited to the format and content of the test and cannot pre-empt on the way this improved knowledge can translate into actual competency in action.

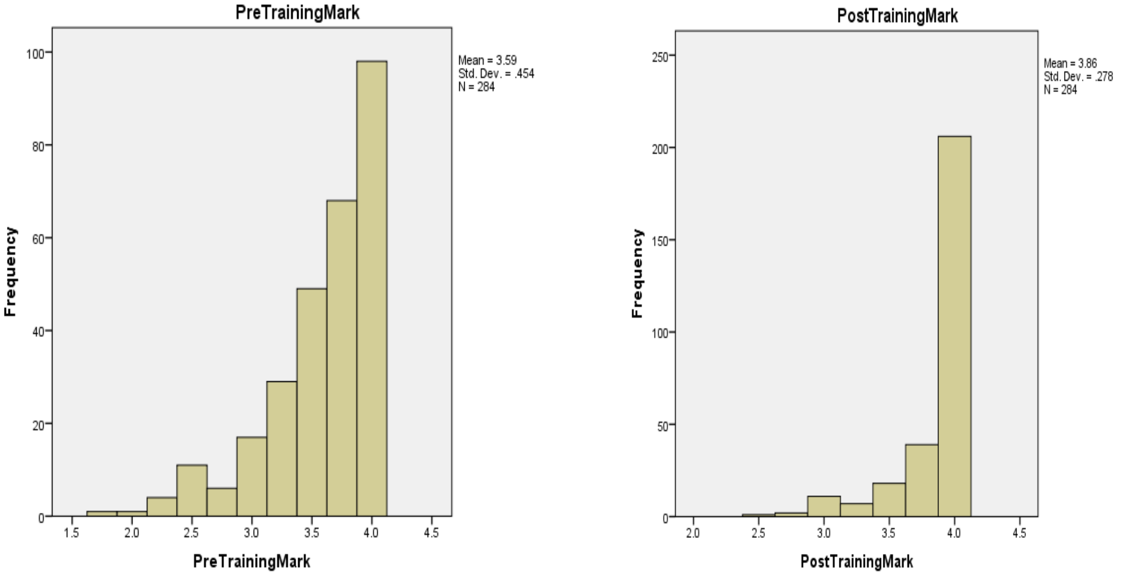


Figure 4-7: Results of the competency test (left: before the 360 VR training session; right: one month later)

We also conducted statistical test to determine whether "age", "experience as a miner" and "experience as a rescuer" had an impact on this competency result (see Appendix A.22: Mann-Whitney Test for Competency marks. Results indicate that none of these variables had a significant effect on competency. Therefore, we can conclude that neither age nor prior experience had significant effect on perceived learning or revealed competency in our experimental conditions.

4.9 Desktop-VR Training Sessions

Out of the 288 trainees who were trained in the 360-VR environment, 155 of them subsequently attended a Desktop VR-based training session (GEN4 technology). They were joined by 88 trainees who had not been previously exposed to the 360-VR environment. Henceforth, a total of 243 trainees were trained in the Desktop VR environment. The same post-training questionnaire used for the 360-VR sessions was completed by trainees directly after these Desktop VR sessions. This second series of training sessions allowed us to:

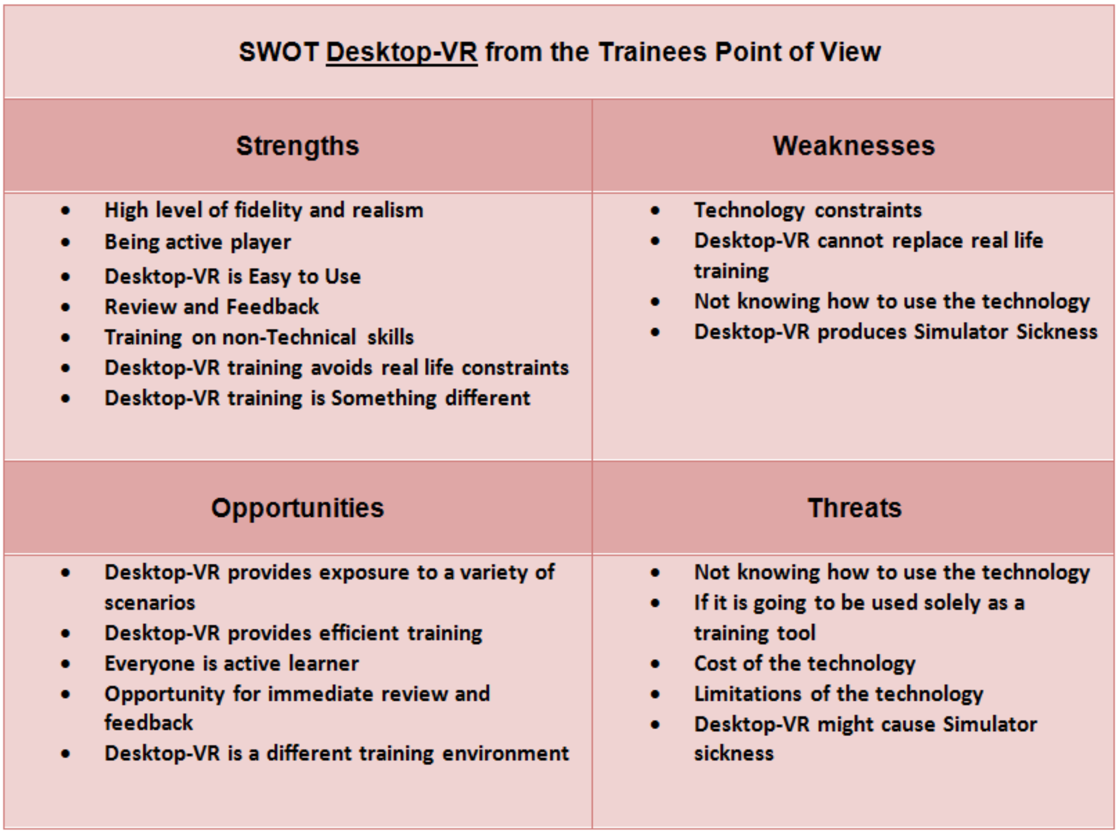
- Investigate the role of Desktop-VR as a training tool (243 observations)
- Compare the trainees' responses across the two training sessions (155 observations).
- Benchmark responses from trainees who undertook both sessions (155 observations) with a control group (72 observations) who only undertook a Desktop VR session.

4.10 SWOT Analysis (Desktop-VR)

4.10.1 SWOT - Trainee's viewpoint

Table 4-27 summarises responses to the 4 questions associated in the post-training questionnaire associated with a SWOT analysis.

Table 4-27: SWOT Analysis from the Trainees' point of view



SWOT Desktop-VR from the Trainees Point of View

Strengths	Weaknesses
• High level of fidelity and realism • Being active player • Desktop-VR is Easy to Use • Review and Feedback • Training on non-Technical skills • Desktop-VR training avoids real life constraints • Desktop-VR training is Something different	• Technology constraints • Desktop-VR cannot replace real life training • Not knowing how to use the technology • Desktop-VR produces Simulator Sickness
Opportunities	**Threats**
• Desktop-VR provides exposure to a variety of scenarios • Desktop-VR provides efficient training • Everyone is active learner • Opportunity for immediate review and feedback • Desktop-VR is a different training environment	• Not knowing how to use the technology • If it is going to be used solely as a training tool • Cost of the technology • Limitations of the technology • Desktop-VR might cause Simulator sickness

4.10.1.1 Desktop-VR’s strengths listed by trainees (Appendix A.20 - statistical results)

Strength - High level of fidelity and realism
20% of trainees described Desktop-VR as:

- “*very real*”,
- “*technically accurate to what the environment can be like*”,
- “*very real without physical exercise*”, “*realistic, ability to rehearse search patterns*” and
- “*Give you a better sight into a real situation and helps you to communicate and work as a team*”.

Strength - Being an active player
Trainees also indicated that being involved in the training process and actively engaged were strengths of Desktop-VR:

- “*individual participation*”,
- “*being in control*”,
- “*separate movements, makes it more interactive*”,
- *“ability to work as a individuals within the same environment*”,
- “*not standing still, you control your own movement, you are always involved, don’t get bored*”.

Strength - Desktop-VR is easy to use
Trainees indicated that Desktop-VR was easy to use:

- “*easy to use*”,
- “*easy to navigate*”,
- “*comfortable learning, easy communication*” and
- “*easy and pretty fun*”.

Strength - Review and feedback
Trainees mentioned review and feedback as other Desktop-VR’s strengths for training:

- “*being able to play it back review*”,
- “*allows people to learn from their mistakes and learn from them as this is only simulation*”,
- “*saw how we did the search*”, “*being able to review what happened in playback*” and
- “*the review (birds eye view) system to see how we perform as a group*”.

Strength - Training on non-technical skills
Another indicated strength was that Desktop-VR also allowed for non-technical skill development (such as interactions with other group members, team work, group discussion and decision making): “*interaction with fellow team members*”,

- “*good team communication*”,
- “*team work in conducting search, able to see if not maintain line of sight of all team members*” and
- “*able to discuss as a group decision making*”.

Strength - Desktop-VR training avoids real life constraints
Trainees noted that the training could be conducted without real life constraints such as

- "*speed of exercise, no time wasted, travelling to mine*",
- "*more situation was able to be simulated very easily without having access to a mine site*",
- "*covered a lot of different areas of a potential situation*",
- "*can focus more at job at hand and not on work environment*" and
- "*less time consuming*".

Strength - Desktop-VR training is something different
Trainees mentioned that Desktop-VR is a different training environment to what they are used to and accordingly it could offer them new experiences:

- "*something different to normal training*",
- "*new experience*", and
- "*different perspective of training methods*".

4.10.1.2 Desktop-VR's Weaknesses listed by trainees (Appendix 24: Frequency of VR training Weakness components (SWOT analysis – trainees) statistical results)

Weakness - Technological constraints
Some trainees indicated that the technology needed more development in some aspects and these technological constraints were identified as weaknesses of Desktop-VR, for example:

- "*limited range of movements, functions at this stage of development*",
- "*not able to walk forward and look sideways at same time*",
- "*not enough features, hooters, red cylinders, gas detectors*",
- "*surrounding/ background noise still heard with earphones on*" and
- "*small screen*".

Weakness- Desktop-VR cannot replace real life training
Some trainees mentioned that VR training could never substitute onsite training: "*good but does not replace real thing*" and "*it will not replace actual real time exercise, it is a very good tool*". There were technological limitations which make replacing real life training difficult/impractical, such as

- "*no physical element*",
- "*not feeling the physical drain*",
- "*not having the U/G feeling e.g. air direction*",
- "*not quite interactive enough, could not assist casually*",
- "*operating restricts, not being able to look up upcast or open hydrant lids, pick up or carrying things, not able to take gas samples*".

Weakness- Not knowing how to use the technology
Nearly 10% of trainees mentioned that they struggled with the interface (Note: based on pre-training questionnaire, a majority of trainees had a very limited gaming or computing experience):

- "*unfamiliar with set-up and controlling figure on screen*",

- “*not been a computer person found it on the hard side*”, however
- “*getting used to joy stick controller is a bit hard [but] not really an issue*”.

Weakness- Desktop-VR produces simulator sickness
Only one user out of 222 trainees mentioned simulator sickness as a weakness: “*feeling a bit of motion sickness*”.

4.10.1.3 Desktop-VR’s Opportunity listed by trainees (Appendix 25: Frequency of VR training Opportunity components (SWOT analysis – trainees)statistical results)

Opportunity-Desktop-VR provides exposure to a variety of scenarios
Nearly 21% of trainees indicated that that the greatest opportunity Desktop-VR provides is the opportunity to be exposed to variety of scenarios in a safe setting when training for extreme/hazardous situations:

- “*can train for situations that is not possible in real life*”,
- “*able to be put into a dangerous scenario*”,
- “*you can cover many topics*”,
- “*ability to do extra features, bad roof, spon comb, team member suit fail etc. fire/ explosions*” and
- “*multiple scenarios, exposure to multiple scenarios in one setting*”.

Opportunity- Desktop-VR provides effective training
Effective training was identified by 19% of trainees as another opportunity that Desktop-VR provides as a training tool. It can overcome real life constraints by providing:

- “*limitless scenarios without travelling and short time frame*”,
- “*opportunities to use trial and error in scenarios to see what does and does not work etc.*”,
- “*opportunities to train more regularly*”,
- “*to explore on U/G mine without getting dirty*” and to
- “*focus on technical aspects*”.

Opportunity- Everyone is active learner
Trainees indicated that being active learner was another opportunity that Desktop-VR provides:

- “*will make everyone think more. Not just the captain*”,
- “*can conduct tasks in isolation, work in groups where required, can view others*”,
- “*see other parts of people's duties*” and
- “*keeps everyone busy*”.

Opportunity- Immediate review and feedback
Trainees regarded the review and discussion as another great opportunity that Desktop-VR offers:

- “to *simulate activities then review what happened*”,
- “*evaluation of exercise at finish*”,
- “*it was good to go back and overview the whole thing*”,

- "*tell you where you went wrong*" and
- "*able to see what is done right/wrong*".

Opportunity-Desktop-VR is a different training environment
Providing "*a different training environment to what the trainees were used to*" was identified as an opportunity by 7% of trainees:

- "*different training sessions*",
- "*you change the environment to where you go everyday*",
- "*a different way of training*" and
- "*something different*".

4.10.1.4 Desktop-VR's Threat listed by trainees

Threat - Not knowing how to use the technology
Trainees indicated that not having computer experience might prevent trainees from using Desktop-VR as a training tool in the future: "*people not computer trained*", "*not having knowledge of how to use a computer*", "*ageing workforce may not like change such as new technologies*" and "*resistance to change*".

Threat - If it is going to be used solely as a training tool
Trainees mentioned that if Desktop-VR is used as a substitute to practical onsite training, then trainees might lose interest. Many indicated that they thought Desktop-VR training needed to be complemented by real life training: "*good to use but do need actual U/G as real*", "*it is no substitute for real life hands on*", "*it is a non-actual activity on its own*" and "*it is still not a real thing*".

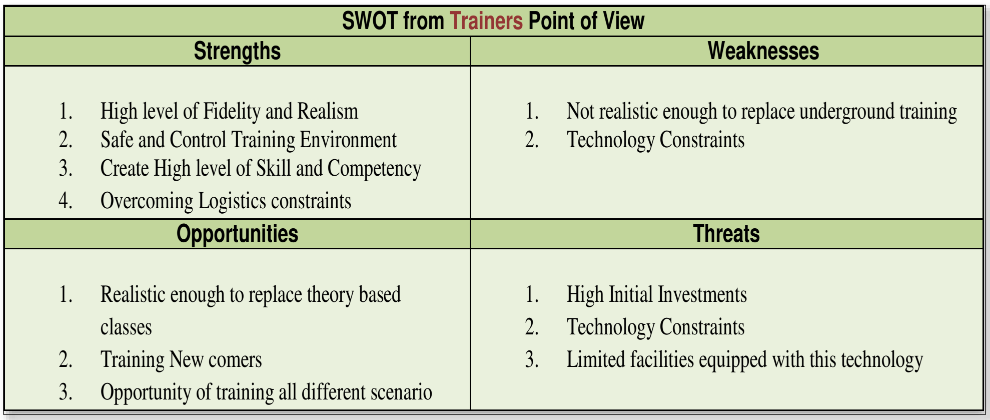
Threat - Cost of the technology
Trainees mentioned the cost of equipment and development might be a threat for its future use.

Threat - Desktop-VR might cause simulator sickness
Only 5 trainees mentioned that simulator sickness might prevent trainees from using Desktop-VR as a training tool.

4.10.2 SWOT – Trainer's viewpointThe factors reported by trainers is in line with the previously mentioned factors by trainees and will be discussed in the discussion chapter.

Table 4-28 summarises feedback from trainers regarding the strengths, weaknesses, opportunities and threats associated with Desktop-VR environments for training purposes. The factors reported by trainers is in line with the previously mentioned factors by trainees and will be discussed in the discussion chapter.

Table 4-28: SWOT from Trainer's viewpoint



SWOT from Trainers Point of View

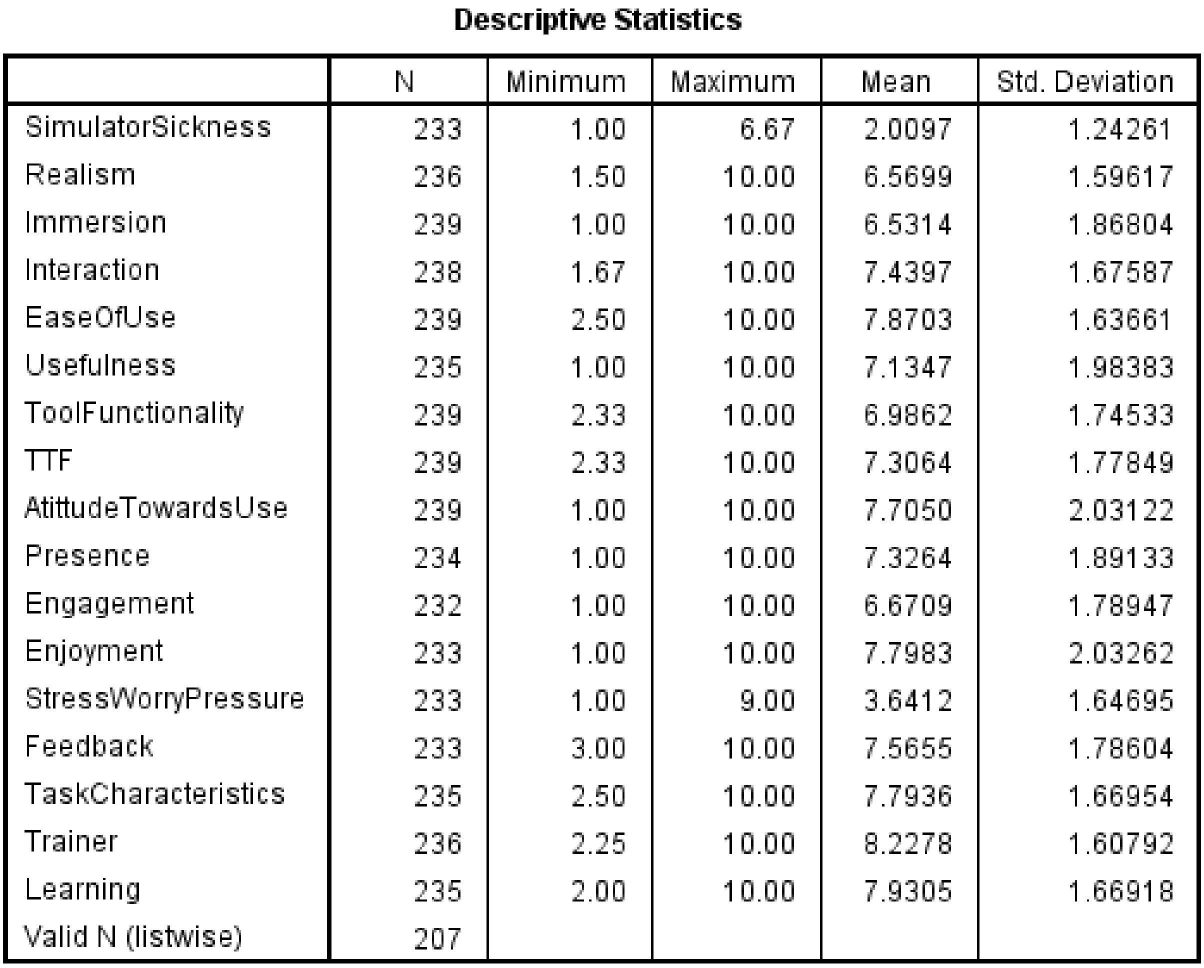
Strengths	Weaknesses
1. High level of Fidelity and Realism 2. Safe and Control Training Environment 3. Create High level of Skill and Competency 4. Overcoming Logistics constraints	1. Not realistic enough to replace underground training 2. Technology Constraints
Opportunities	**Threats**
1. Realistic enough to replace theory based classes 2. Training New comers 3. Opportunity of training all different scenario	1. High Initial Investments 2. Technology Constraints 3. Limited facilities equipped with this technology

4.11 Quantitative Analysis (Desktop-VR)

4.11.1 Post-training factors at a glance

Table 4-29 summarises statistical results for the seventeen post-training factors. Overall, trainees reported a high degree of perceived learning experience (*M*=7.9, *SD*= 1.66), reported positive trainer performance (*M*=8.2, *SD*= 1.60), beneficial task characteristics (*M*=7.79, *SD*= 1.66) and useful feedback (*M*=7.56, *SD*= 1.78). On average, trainees also report positive experiences with the Desktop-VR environment, indicating that it promoted interaction (*M*=7.43, *SD*= 1.62) and engagement (*M*=6.67, *SD*= 1.78), was enjoyable (*M*=7.79, *SD*= 2.03), promoted presence (*M*=7.32, *SD*= 1.89), was relatively easy to use (*M*=7.87, *SD*= 1.63), was usefulness (*M*=7.134, *SD*= 1.98), and had good tool functionality (*M*=6.98, *SD*= 1.74), TTF (*M*=7.30, *SD*= 1.77). Additionally, participants reported little simulator sickness (*M*=2.00, *SD*= 1.24), as well as manageable levels of stress, worry and pressure (*M*=3.64, *SD*= 1.64).

Table 4-29: Statistical results of post-Desktop VR training factors



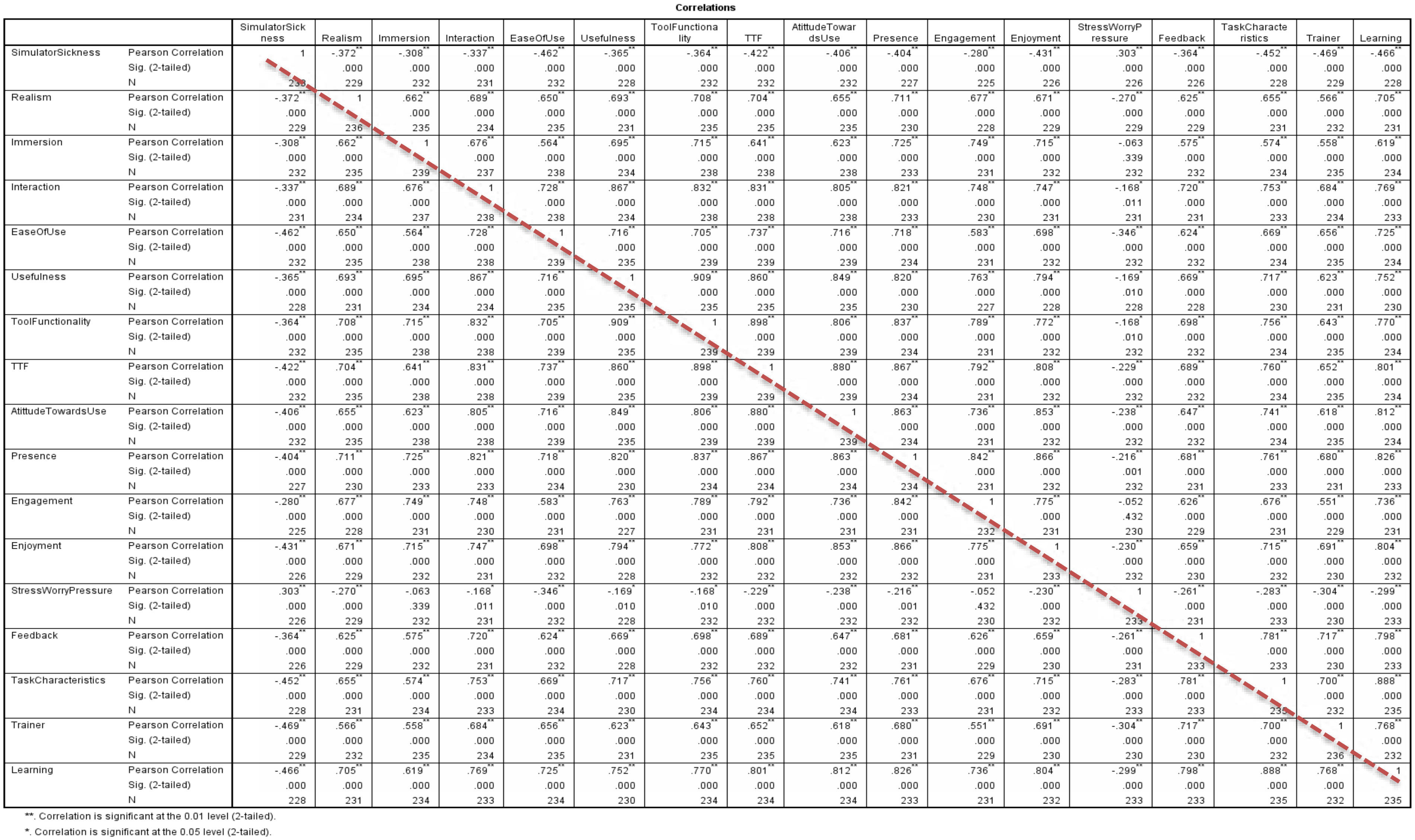
Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
SimulatorSickness	233	1.00	6.67	2.0097	1.24261
Realism	236	1.50	10.00	6.5699	1.59617
Immersion	239	1.00	10.00	6.5314	1.86804
Interaction	238	1.67	10.00	7.4397	1.67587
EaseOfUse	239	2.50	10.00	7.8703	1.63661
Usefulness	235	1.00	10.00	7.1347	1.98383
ToolFunctionality	239	2.33	10.00	6.9862	1.74533
TTF	239	2.33	10.00	7.3064	1.77849
AtittudeTowardsUse	239	1.00	10.00	7.7050	2.03122
Presence	234	1.00	10.00	7.3264	1.89133
Engagement	232	1.00	10.00	6.6709	1.78947
Enjoyment	233	1.00	10.00	7.7983	2.03262
StressWorryPressure	233	1.00	9.00	3.6412	1.64695
Feedback	233	3.00	10.00	7.5655	1.78604
TaskCharacteristics	235	2.50	10.00	7.7936	1.66954
Trainer	236	2.25	10.00	8.2278	1.60792
Learning	235	2.00	10.00	7.9305	1.66918
Valid N (listwise)	207				

4.11.2 Influence of post-training factors on perceived learning

The correlation matrix (Table 4-30) shows that all post-training factors have a statistically significant relationship with perceived learning. Excluding ‘simulator sickness’ (**r** =- .466, *P* < .01) and ‘stress worry and pressure’ (**r** = -.299, *P* < .01) that display a negative relationship, all of the other factors were positively correlated with perceived learning (**r** = .619 to 0.888, **P** < .01). These results demonstrate that the selected post-training factors were highly relevant to this study and that all of these factors either contributed to, or in a few cases disrupted, a positive training experience in a Desktop-VR (as was the case with the 360-VR environment).

Table 4-30: Correlation matrix between post-training factors and perceived learning



Correlations

		SimulatorSickness	Realism	Immersion	Interaction	EaseOfUse	Usefulness	ToolFunctionality	TTF	AtittudeTowardsUse	Presence	Engagement	Enjoyment	StressWorryPressure	Feedback	TaskCharacteristics	Trainer	Learning
SimulatorSickness	Pearson Correlation	1	-.372**	-.308**	-.337**	-.462**	-.365**	-.364**	-.422**	-.406**	-.404**	-.280**	-.431**	.303**	-.364**	-.452**	-.469**	-.466**
	Sig. (2-tailed)		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	233	229	232	231	232	228	232	232	232	227	225	226	226	226	228	229	228
Realism	Pearson Correlation	-.372**	1	.662**	.689**	.650**	.693**	.708**	.704**	.655**	.711**	.677**	.671**	-.270**	.625**	.655**	.566**	.705**
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	229	236	235	234	235	231	235	235	235	230	228	229	229	229	231	232	231
Immersion	Pearson Correlation	-.308**	.662**	1	.676**	.564**	.695**	.715**	.641**	.623**	.725**	.749**	.715**	-.063	.575**	.574**	.558**	.619**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.339	.000	.000	.000	.000
	N	232	235	239	237	238	234	238	238	238	233	231	232	232	232	234	235	234
Interaction	Pearson Correlation	-.337**	.689**	.676**	1	.728**	.867**	.832**	.831**	.805**	.821**	.748**	.747**	-.168*	.720**	.753**	.684**	.769**
	Sig. (2-tailed)	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.011	.000	.000	.000	.000
	N	231	234	237	238	238	234	238	238	238	233	230	231	231	231	233	234	233
EaseOfUse	Pearson Correlation	-.462**	.650**	.564**	.728**	1	.716**	.705**	.737**	.716**	.718**	.583**	.698**	-.346**	.624**	.669**	.656**	.725**
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	232	235	238	238	239	235	239	239	239	234	231	232	232	232	234	235	234
Usefulness	Pearson Correlation	-.365**	.693**	.695**	.867**	.716**	1	.909**	.860**	.849**	.820**	.763**	.794**	-.169*	.669**	.717**	.623**	.752**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.010	.000	.000	.000	.000
	N	228	231	234	234	235	235	235	235	235	230	227	228	228	228	230	231	230
ToolFunctionality	Pearson Correlation	-.364**	.708**	.715**	.832**	.705**	.909**	1	.898**	.806**	.837**	.789**	.772**	-.168*	.698**	.756**	.643**	.770**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.010	.000	.000	.000	.000
	N	232	235	238	238	239	235	239	239	239	234	231	232	232	232	234	235	234
TTF	Pearson Correlation	-.422**	.704**	.641**	.831**	.737**	.860**	.898**	1	.880**	.867**	.792**	.808**	-.229**	.689**	.760**	.652**	.801**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	232	235	238	238	239	235	239	239	239	234	231	232	232	232	234	235	234
AtittudeTowardsUse	Pearson Correlation	-.406**	.655**	.623**	.805**	.716**	.849**	.806**	.880**	1	.863**	.736**	.853**	-.238**	.647**	.741**	.618**	.812**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000
	N	232	235	238	238	239	235	239	239	239	234	231	232	232	232	234	235	234
Presence	Pearson Correlation	-.404**	.711**	.725**	.821**	.718**	.820**	.837**	.867**	.863**	1	.842**	.866**	-.216**	.681**	.761**	.680**	.826**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.001	.000	.000	.000	.000
	N	227	230	233	233	234	230	234	234	234	234	231	232	232	231	233	231	233
Engagement	Pearson Correlation	-.280**	.677**	.749**	.748**	.583**	.763**	.789**	.792**	.736**	.842**	1	.775**	-.052	.626**	.676**	.551**	.736**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.432	.000	.000	.000	.000
	N	225	228	231	230	231	227	231	231	231	231	232	231	230	229	231	229	231
Enjoyment	Pearson Correlation	-.431**	.671**	.715**	.747**	.698**	.794**	.772**	.808**	.853**	.866**	.775**	1	-.230**	.659**	.715**	.691**	.804**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000
	N	226	229	232	231	232	228	232	232	232	232	231	233	232	230	232	230	232
StressWorryPressure	Pearson Correlation	.303**	-.270**	-.063	-.168*	-.346**	-.169*	-.168*	-.229**	-.238**	-.216**	-.052	-.230**	1	-.261**	-.283**	-.304**	-.299**
	Sig. (2-tailed)	.000	.000	.339	.011	.000	.010	.010	.000	.000	.001	.432	.000		.000	.000	.000	.000
	N	226	229	232	231	232	228	232	232	232	232	230	232	233	231	233	230	233
Feedback	Pearson Correlation	-.364**	.625**	.575**	.720**	.624**	.669**	.698**	.689**	.647**	.681**	.626**	.659**	-.261**	1	.781**	.717**	.798**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000
	N	226	229	232	231	232	228	232	232	232	231	229	230	231	233	233	230	233
TaskCharacteristics	Pearson Correlation	-.452**	.655**	.574**	.753**	.669**	.717**	.756**	.760**	.741**	.761**	.676**	.715**	-.283**	.781**	1	.700**	.888**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000
	N	228	231	234	233	234	230	234	234	234	233	231	232	233	233	235	232	235
Trainer	Pearson Correlation	-.469**	.566**	.558**	.684**	.656**	.623**	.643**	.652**	.618**	.680**	.551**	.691**	-.304**	.717**	.700**	1	.768**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000
	N	229	232	235	234	235	231	235	235	235	231	229	230	230	230	232	236	232
Learning	Pearson Correlation	-.466**	.705**	.619**	.769**	.725**	.752**	.770**	.801**	.812**	.826**	.736**	.804**	-.299**	.798**	.888**	.768**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
	N	228	231	234	233	234	230	234	234	234	233	231	232	233	233	235	232	235

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

4.11.3 Influence of demographic factors

We tested the effect of our three demographic variables (age, experience as miner and experience as rescuer) on perceive learning. As it was the case for 360 VR environment, the Mann-Whitney U Test didn't reveal any statistically significant effect of these variables.

4.12 Reported Training Outcomes (Desktop-VR)

Similarly to 360-VR training session, trainees were asked (post-training questionnaire) to answer the following questions:

- "How successful was the training in Desktop-VR?"
- "How useful do you think this training was?"
- "How consistent was your experience with real life conditions?"
- "Does he prefer Desktop-VR training over traditional training?"
- "Does he recommend 360-VR training to others?"

Each question used a Likert's scale between 1 ('very low opinion') to 10 ('very high opinion') to rank trainee's responses.

4.12.1 Usefulness x Realism (Appendix A.27: cross-tabulation between perceived levels of realism and usefulness (Desktop-VR))

Figure 4-8 shows that many trainees tend to consider Desktop-VR as a very useful training environment despite some reservations about its level of realism.

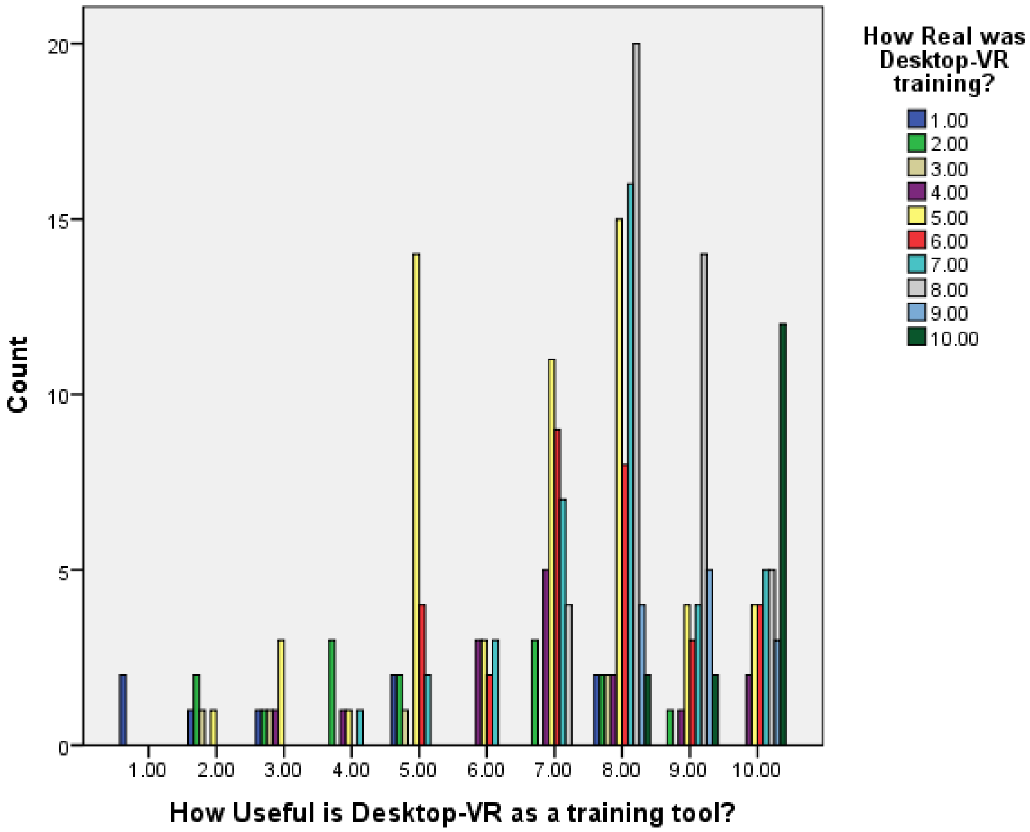


Figure 4-8: Cross tabulation between perceived Usefulness and Realism

181 trainees (76%) considered Desktop-VR as 'useful' or 'very useful' (categories 7 to 10). Amongst 234 trainees, 128 indicated that their training was poorly to fairly consistent with real life experiences (categories 2 to 6). Therefore, even though realism has been identified as one of the key training needs by trainers and VR designers (see Need Analysis section), this result suggests that trainees see value in a training environment that allows them to focus on the requested tasks and get useful feedback on dangerous situations.

4.12.2 Success x Realism (Appendix A.28: cross-tabulation between perceived levels of realism and Success (Desktop-VR))

Appendix A.28: cross-tabulation between perceived levels of realism and Success (Desktop-VR)Figure 4-9 shows that a large majority of trainees tends to consider Desktop-VR as a very successful training environment despite some reservations about its level of realism.189 trainees (80%) indicated that they found 360-VR training successful to highly successful (categories 7 to 10). Amongst these 234 trainees, 127 indicated that their training was poor to fairly consistent with real life experiences (categories 2 to 6). Therefore, these results confirm that trainees not only find Desktop-VR training useful but also successful despite a lack of realism. This result suggests that trainees see value in a training environment that allows them to perform well on the requested tasks and improve their skills to respond to dangerous situations.

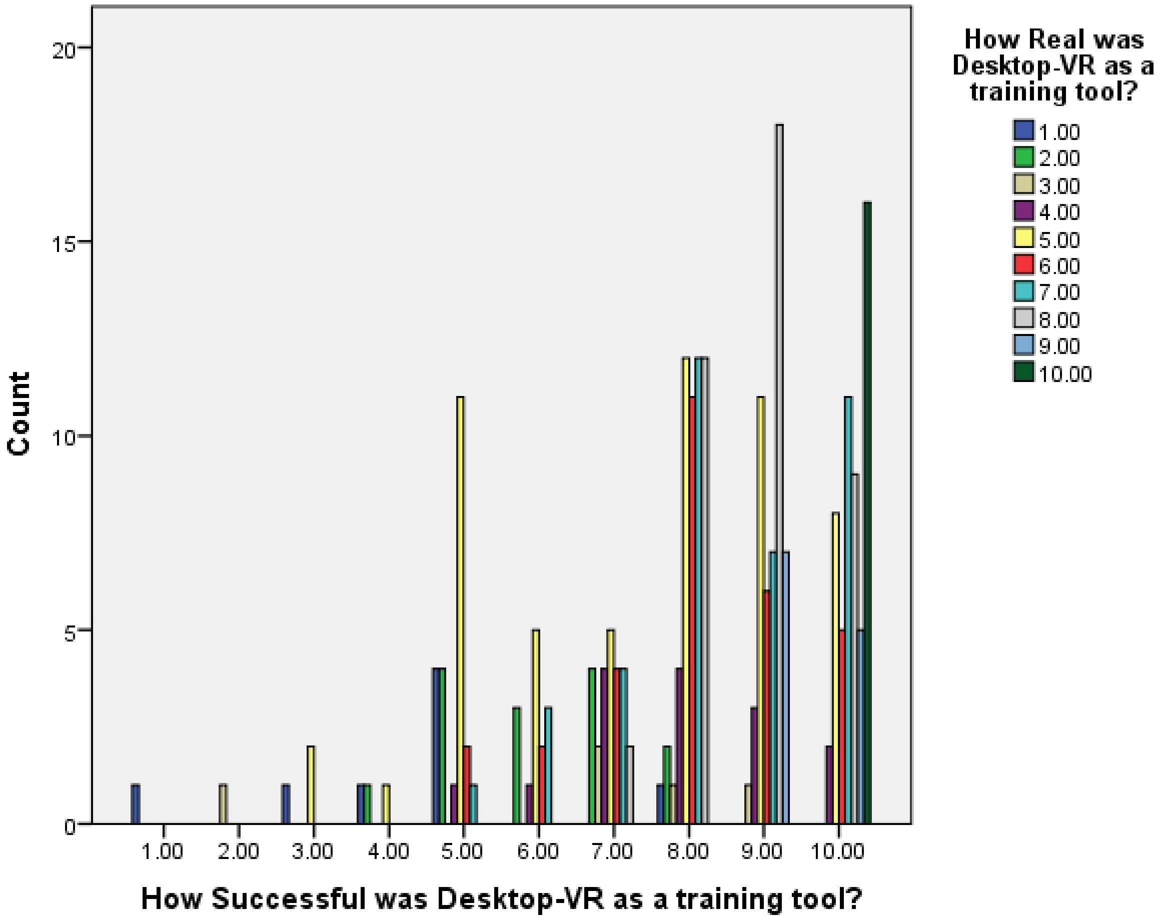


Figure 4-9: cross-tabulation between perceived levels of realism and success.

4.12.3 Recommending x Preference (

4.12.4 Appendix A.29: cross-tabulation between Recommendation and Preference (Desktop-VR))

Trainees were also asked whether they ‘preferred VR-based training over classroom training’ and ‘if they would recommend this Desktop-VR technology to others’. As a result of the analysis, 130 (55%) of trainees agreed or strongly agreed (category 7-10) that they preferred Desktop-VR training over traditional classroom training and 80% of trainees agreed or strongly agreed (category 7-10) about recommending Desktop-VR training to other colleagues (Table 4-10).

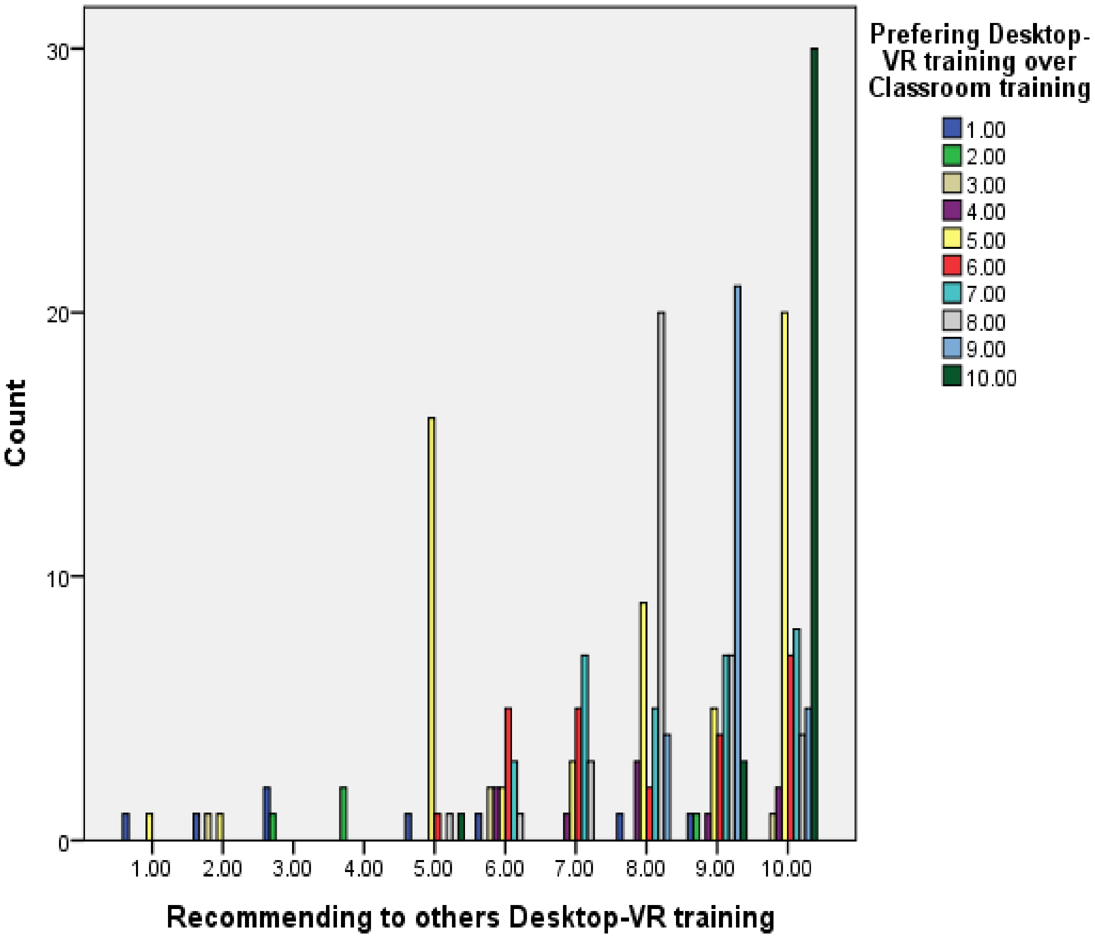


Figure 4-10: Cross tabulation between Recommending Desktop VR and Preferring Desktop-VR

4.13 Comparing responses from 360 VR and Desktop VR sessions

We conducted a series of Mann-Whitney U Tests, Table4-31 (

Appendix A.30: Rank Table comparing responses from 360 VR and Desktop VR training sessions) to compare responses on a variety of post-training factors between Desktop-VR and 360-VR sessions (155 observations). Keeping only statistically significant results ($p<0.05$), we found that trainees experienced less simulator sickness (Z=-4.517) or stress/worry/pressure (Z=-4.594) with Desktop VR over 360 VR, as well as higher levels of realism (Z=-3.940), immersion (Z=-7.520), interaction (Z=-3.446), ease of use (Z=-5.361), usefulness (Z=-3.286), tool functionality (Z=-2.853), task-technology fit (Z=-2.240), attitude towards use (Z=-3.633), presence (Z=-3.380), engagement (Z=-4.497), enjoyment (Z=-3.834) and trainers (Z=-2.600) with Desktop-VR than in 360-VR. There was no statistically significant difference between the two VR environments for task characteristics, feedback and perceived learning ($p> 0.50$).

We conducted further analyses to assess the impact of age or experience in mining on responses from trainees. The 150 trainees were split into two age groups (< 40 year old and > 40 year old), then into two levels of mining experience groups (< 10 year experience and > 10 year experience).

4.13.1 Influence of age

We used Mann-Whitney U tests to indirectly compare the younger (24-40 years) and older (41-64 years) groups of trainees on their experience with Desktop-VR versus 360-VR (Table 4-32). Keeping only ranking results that were statistically significant for both groups ($p<0.05$), we found that the older group clearly gave a greater preference to Desktop VR over 360 VR, compared with the younger group, for the following factors: sickness (Z=-4.334 and -2.025 respectively), engagement (Z=-4.338 and -1.892 respectively) and enjoyment (Z=-3.305 and -2.030 respectively).

4.13.2 Influence of experience

We used Mann-Whitney U tests to indirectly compare the less experienced (<10 years) and more experienced (>10 years) groups of trainees on their experience with Desktop-VR versus 360-VR (Table 4-33). Keeping only ranking results that were statistically significant for both groups ($p<0.05$), we found that the more experienced group clearly gave a greater preference to Desktop VR over 360 VR, compared with the less experienced one, for the following factor: enjoyment (Z=-3.528 and -2.167 respectively).

4.13.3 Benchmarking with control group

Table 4-34 compares the group of trainees who attended both 360-VR and Desktop-VR sessions (‘treatment group’) with the group of trainees who only attended Desktop VR (‘control group’). There aren’t any statistically significant differences between the two groups for all post-training variables ($p>0.05$ for each of them).

Table4-31: Comparison between 360 VR and Desktop VR; post-training variables.

Test Statistics[a]

	Desktop-VR Simulator Sickness - 360-VR Simulator Sickness	Desktop-VR Realism - 360-VR Realism	Desktop-VR Immersion - 360-VR Immersion	Desktop-VR Interaction - 360-VR Interaction	Desktop-VR Ease Of Use - 360-VR Ease Of Use	Desktop-VR Usefulness - 360-VR Usefulness	Desktop-VR Tool Functionality - 360-VR Tool Functionality	Desktop-VR TTF - 360-VR TTF	Desktop-VR Attitude Towards Use - 360-VR Attitude Towards Use	Desktop-VR Presence - 360-VR Presence	Desktop-VR Engagement - 360-VR Engagement	Desktop-VR Enjoyment - 360-VR Enjoyment	Desktop VR Stress/Worry/Pressure - 360-VR Stress/Worry/Pressure	Desktop-VR Feedback - 360-VR Feedback	Desktop-VR Task Characteristics - 360-VR Task Characteristics	Desktop-VR Trainer - 360-VR Trainer	Desktop-VR Perceived Learning - 360-VR Perceived Learning
Z	-4.517[b]	-3.940[c]	-7.520[c]	-3.446[c]	-5.361[c]	-3.286[c]	-2.853[c]	-2.240[c]	-3.633[c]	-3.380[c]	-4.497[c]	-3.834[c]	-4.594[b]	-.612[c]	-.612[b]	-2.600[b]	-.597[c]
Asymp. Sig. (2-tailed)	.000	.000	.000	.001	.000	.001	.004	.025	.000	.001	.000	.000	.000	.541	.540	.009	.550

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

c. Based on negative ranks.

Table 4-32: Comparison of 360 VR and Desktop VR for post-training variables (top: < 40 year old; bottom: > 40 year old)

Test Statistics[a]

	Desktop-VR Simulator Sickness - 360-VR Simulator Sickness	Desktop-VR Realism - 360-VR Realism	Desktop-VR Immersion - 360-VR Immersion	Desktop-VR Interaction - 360-VR Interaction	Desktop-VR Ease Of Use - 360-VR Ease Of Use	Desktop-VR Usefulness - 360-VR Usefulness	Desktop-VR Tool Functionality - 360-VR Tool Functionality	Desktop-VR TTF - 360-VR TTF	Desktop-VR Attitude Towards Use - 360-VR Attitude Towards Use	Desktop-VR Presence - 360-VR Presence	Desktop-VR Engagement - 360-VR Engagement	Desktop-VR Enjoyment - 360-VR Enjoyment	Desktop VR Stress/Worry/Pressure - 360-VR Stress/Worry/Pressure	Desktop-VR Feedback - 360-VR Feedback	Desktop-VR Task Characteristics - 360-VR Task Characteristics	Desktop-VR Trainer - 360-VR Trainer	Desktop-VR Perceived Learning - 360-VR Perceived Learning
Z	-2.075[b]	-2.472[c]	-5.142[c]	-1.908[c]	-3.811[c]	-2.423[c]	-2.412[c]	-1.365[c]	-2.456[c]	-1.527[c]	-1.892[c]	-2.030[c]	-3.045[b]	-1.622[b]	-1.397[b]	-2.701[b]	-1.658[b]
Asymp. Sig. (2-tailed)	.038	.013	.000	.056	.000	.015	.016	.172	.014	.127	.058	.042	.002	.105	.162	.007	.097

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

c. Based on negative ranks.

Test Statistics[a]

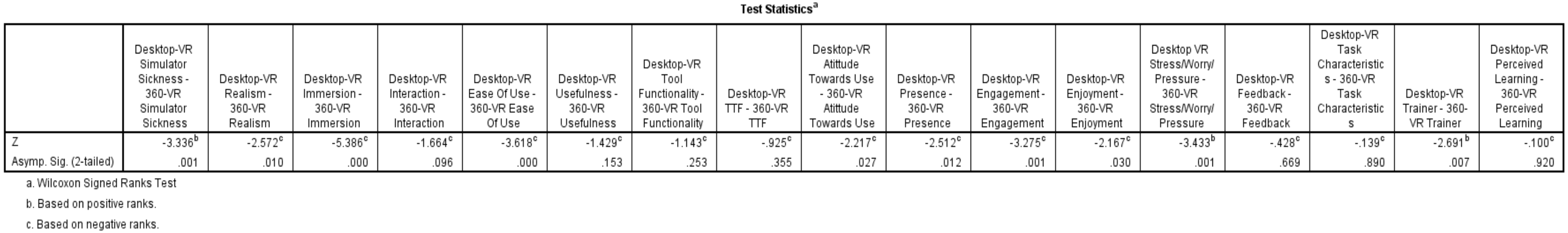
	Desktop-VR Simulator Sickness - 360-VR Simulator Sickness	Desktop-VR Realism - 360-VR Realism	Desktop-VR Immersion - 360-VR Immersion	Desktop-VR Interaction - 360-VR Interaction	Desktop-VR Ease Of Use - 360-VR Ease Of Use	Desktop-VR Usefulness - 360-VR Usefulness	Desktop-VR Tool Functionality - 360-VR Tool Functionality	Desktop-VR TTF - 360-VR TTF	Desktop-VR Attitude Towards Use - 360-VR Attitude Towards Use	Desktop-VR Presence - 360-VR Presence	Desktop-VR Engagement - 360-VR Engagement	Desktop-VR Enjoyment - 360-VR Enjoyment	Desktop VR Stress/Worry/Pressure - 360-VR Stress/Worry/Pressure	Desktop-VR Feedback - 360-VR Feedback	Desktop-VR Task Characteristics - 360-VR Task Characteristics	Desktop-VR Trainer - 360-VR Trainer	Desktop-VR Perceived Learning - 360-VR Perceived Learning
Z	-4.334[b]	-3.106[c]	-5.468[c]	-3.004[c]	-3.792[c]	-2.312[c]	-1.604[c]	-1.878[c]	-2.751[c]	-3.013[c]	-4.338[c]	-3.305[c]	-3.474[b]	-2.149[c]	-.463[c]	-1.123[b]	-2.198[c]
Asymp. Sig. (2-tailed)	.000	.002	.000	.003	.000	.021	.109	.060	.006	.003	.000	.001	.001	.032	.644	.261	.028

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

c. Based on negative ranks.

Table 4-33: Comparison of 360 VR and Desktop VR for post-training variables (top: < 10 year experience; bottom: > 10 year experience)



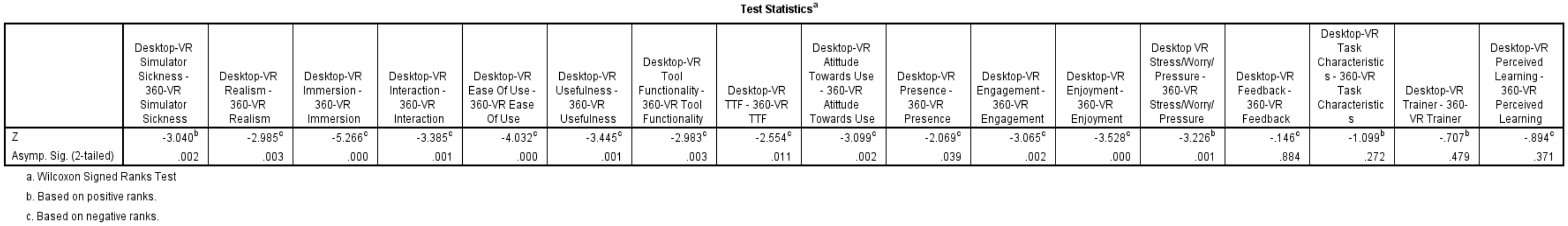
Test Statistics[a]

	Desktop-VR Simulator Sickness - 360-VR Simulator Sickness	Desktop-VR Realism - 360-VR Realism	Desktop-VR Immersion - 360-VR Immersion	Desktop-VR Interaction - 360-VR Interaction	Desktop-VR Ease Of Use - 360-VR Ease Of Use	Desktop-VR Usefulness - 360-VR Usefulness	Desktop-VR Tool Functionality - 360-VR Tool Functionality	Desktop-VR TTF - 360-VR TTF	Desktop-VR Atittude Towards Use - 360-VR Atittude Towards Use	Desktop-VR Presence - 360-VR Presence	Desktop-VR Engagement - 360-VR Engagement	Desktop-VR Enjoyment - 360-VR Enjoyment	Desktop VR Stress/Worry/ Pressure - 360-VR Stress/Worry/ Pressure	Desktop-VR Feedback - 360-VR Feedback	Desktop-VR Task Characteristics - 360-VR Task Characteristics	Desktop-VR Trainer - 360-VR Trainer	Desktop-VR Perceived Learning - 360-VR Perceived Learning
Z	-3.336[b]	-2.572[c]	-5.386[c]	-1.664[c]	-3.618[c]	-1.429[c]	-1.143[c]	-.925[c]	-2.217[c]	-2.512[c]	-3.275[c]	-2.167[c]	-3.433[b]	-.428[c]	-.139[c]	-2.691[b]	-.100[c]
Asymp. Sig. (2-tailed)	.001	.010	.000	.096	.000	.153	.253	.355	.027	.012	.001	.030	.001	.669	.890	.007	.920

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

c. Based on negative ranks.



Test Statistics[a]

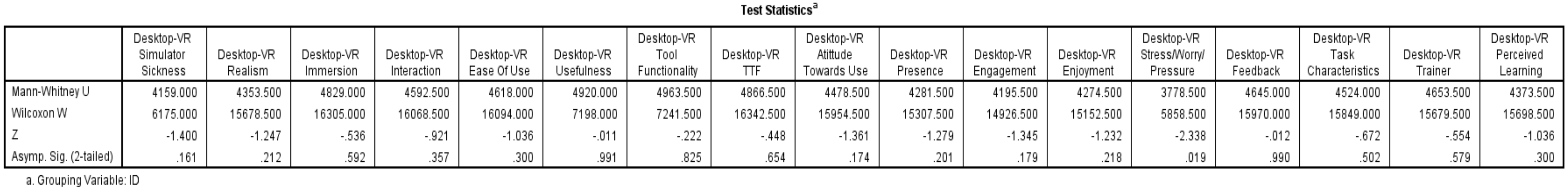
	Desktop-VR Simulator Sickness - 360-VR Simulator Sickness	Desktop-VR Realism - 360-VR Realism	Desktop-VR Immersion - 360-VR Immersion	Desktop-VR Interaction - 360-VR Interaction	Desktop-VR Ease Of Use - 360-VR Ease Of Use	Desktop-VR Usefulness - 360-VR Usefulness	Desktop-VR Tool Functionality - 360-VR Tool Functionality	Desktop-VR TTF - 360-VR TTF	Desktop-VR Atittude Towards Use - 360-VR Atittude Towards Use	Desktop-VR Presence - 360-VR Presence	Desktop-VR Engagement - 360-VR Engagement	Desktop-VR Enjoyment - 360-VR Enjoyment	Desktop VR Stress/Worry/ Pressure - 360-VR Stress/Worry/ Pressure	Desktop-VR Feedback - 360-VR Feedback	Desktop-VR Task Characteristics - 360-VR Task Characteristics	Desktop-VR Trainer - 360-VR Trainer	Desktop-VR Perceived Learning - 360-VR Perceived Learning
Z	-3.040[b]	-2.985[c]	-5.266[c]	-3.385[c]	-4.032[c]	-3.445[c]	-2.983[c]	-2.554[c]	-3.099[c]	-2.069[c]	-3.065[c]	-3.528[c]	-3.226[b]	-.146[c]	-1.099[b]	-.707[b]	-.894[c]
Asymp. Sig. (2-tailed)	.002	.003	.000	.001	.000	.001	.003	.011	.002	.039	.002	.000	.001	.884	.272	.479	.371

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

c. Based on negative ranks.

Table 4-34: Comparison of post-training variables between treatment group (150) and control group (72)



Test Statistics[a]

	Desktop-VR Simulator Sickness	Desktop-VR Realism	Desktop-VR Immersion	Desktop-VR Interaction	Desktop-VR Ease Of Use	Desktop-VR Usefulness	Desktop-VR Tool Functionality	Desktop-VR TTF	Desktop-VR Atittude Towards Use	Desktop-VR Presence	Desktop-VR Engagement	Desktop-VR Enjoyment	Desktop-VR Stress/Worry/ Pressure	Desktop-VR Feedback	Desktop-VR Task Characteristics	Desktop-VR Trainer	Desktop-VR Perceived Learning
Mann-Whitney U	4159.000	4353.500	4829.000	4592.500	4618.000	4920.000	4963.500	4866.500	4478.500	4281.500	4195.500	4274.500	3778.500	4645.000	4524.000	4653.500	4373.500
Wilcoxon W	6175.000	15678.500	16305.000	16068.500	16094.000	7198.000	7241.500	16342.500	15954.500	15307.500	14926.500	15152.500	5858.500	15970.000	15849.000	15679.500	15698.500
Z	-1.400	-1.247	-.536	-.921	-1.036	-.011	-.222	-.448	-1.361	-1.279	-1.345	-1.232	-2.338	-.012	-.672	-.554	-1.036
Asymp. Sig. (2-tailed)	.161	.212	.592	.357	.300	.991	.825	.654	.174	.201	.179	.218	.019	.990	.502	.579	.300

a. Grouping Variable: ID

4.13.4 Competency Comparison with control group

The competency test (skill test) was also completed by trainees attending the Desktop VR sessions. Out of 155 trainees who had previously attended a 360-VR session, 150 completed the test. Out of 88 whom only attended a Desktop VR session (control group), 72 completed the test (Appendix A.20: Competency Comparison between 360-VR attendees and control Group). Results from the Mann-Whitney U ranking test show that trainees who first attended a 360 VR session outperformed the control group, although results from the latter were highly positive. We can conclude – in the context of our experiment - that although perceived learning, as a subjective statement, didn't show any statistical difference between the groups, objective measurements (skill test) seem to indicate a positive reinforcement effect between the two successive sessions. However, learning outcomes - stated or revealed - for trainees who only attended Desktop VR training session (control group) were largely satisfying. This result might be associated with the judgement from a majority of trainees who attended both sessions and found Desktop VR environment more interactive and enjoyable, though less immersive, than 360 VR technology.

5 Chapter V: Discussion

5.1 Overview

Drawing from relevant literature on safety training needs in High Risk Organisations (HROs) in general and the coal mining industry in particular, and building upon existing VR-based training programs delivered to the underground coal mining industry in New South Wales (NSW, Australia), we designed and implemented a research program that aimed to address the following questions:

- What are the actual training needs of underground coal miners?
- What are the inherent limitations of onsite training for underground coal miners?
- What are the potential capabilities of VR-based training to address these limitations?
- Which factors influence the effective delivery of VR-based training?

This discussion chapter will successively address each of our aforementioned initial questions. The last question, the topic of which constitutes the core of our fieldwork, will be further examined by also addressing these following questions:

- Which factors mostly affect the learning process and outcomes?
- How do these factors interact with different VR environments?
- How VR-based training environment enhance the training outcome?
- How does training content translate into workplace competency?

We intended for this thesis to deliver both theoretical and practical outcomes. On the theoretical side, we hoped to build an evaluation framework that could be applied (or adapted) to any HRO investing into VR-based training technology. On the practical side, we wanted to provide an evidence-based evaluation of VR-based training programs currently being implemented by Mines Rescue Brigades in NSW (Australia). In order to achieve these objectives, the following research activities were conducted:

- Existing evaluation techniques were reviewed.
- Factors affecting the learning process and its outcomes were identified.
- An analytical and methodological evaluation framework was developed.
- The systematic framework was applied to existing VR-based training programs.
- A generic VR-based learning model was inferred from the above case study.

As many industries take interest in VR technology for their current and future training needs, the initial financial and human investment, alongside a fast moving technological landscape, necessitates a reliable assessment and monitoring framework in order to avoid swaying from wishful optimism to doubtful pessimism as challenges arise (Rizzo and Kim, 2005).

In order to answer the question how does desktop or 360-VR enhance the learning outcome, both qualitative and quantitative analyses were performed. Some form of technologies are best suited to support specific theoretical learning models (Leidner and Jarvenpaa, 1995), while others provide general support for different learning models (Piccoli et al., 2001).VR computer simulations can be presented in various forms, ranging from computer renderings of 3-D geometric shapes on a desktop computer to highly interactive, fully immersive multisensory environment in laboratory(Ausburn and Ausburn, 2004, Mikropoulos and Natsis, 2011), but to begin with the focus was on identifying what are the training needs, gaps and then outlining the capabilities of Desktop and 360-VR.

5.2 What are the actual training needs of underground coal miners?

Our Needs Analysis (sections 3.4.1.1, 3.4.1.5 and 4.2) was informed by interviews with managers and VR designers, as well as the answers of trainees, to two open-ended questions. This allowed us to identify seven critical training needs for mine rescuers:

- Recreating real conditions and scenarios
- Allowing for physical activity
- Providing a variety of scenarios and mine environments
- Experiencing hazards and danger under safe conditions
- Limited level of distraction from training task
- Training opportunity accessible at any time
- The possibility to repeat the drills and learn from mistakes

The findings from the current study are in line with those of van Wyk and de Villiers (2009). Miners are required to work in underground, dark, hot, dusty and muddy conditions with large pieces of machinery working and moving around in a confined environment. Therefore, a training environment should be able to reproduce *conditions close to those experienced in real life* (e.g. smoke, haze, heat, uneven floors, etc.). Additionally, mine rescuers must wear heavy and cumbersome safety gear to perform physical activities during emergency interventions. Furthermore, often incidents happen underground where they might needed to walk a few kilometres and this can take a significant amount of time, adding fatigue to the environmental constraints and hazards. Thus, there is also an identified need for *allowing physical activity* during training. Furthermore, training must be able to offer *a large variety of scenarios* as essential skills learnt in a well-known and rehearsed training scenario can become useless when rescuers are faced with actual unexpected circumstances. This requirement is partly related to another identified need, *experiencing hazards and danger*, whereby trainees have to be able to ‘expect the unexpected’ and be confronted with extreme scenarios (coal blast, underground fire, etc.) in various conditions and environments. This has been a long-lasting challenge for traditional onsite (mine pit) training and a critical issue for mine rescuers as they both need to practice their technical and non-technical skills (team communication and coordination) in a realistic setting. It is also important for mine rescuers to be able to experience different mine configurations corresponding to the ones they might have to intervene into one day.

Trainees have identified *distraction from a training task* as a serious impediment to effective learning. Major sources of distraction include disturbing noises and environmental hazards while practicing their skills. This is particularly the case for onsite training as operations cannot be suspended to accommodate training needs. There is definitely a tension between the need for trainees to be able to focus on their task and their request for a training environment that can include or emulate realistic hazards and dangers. Training must be real and safe.

Accessibility of training opportunities was another identified need. Several trainees complained about the constraints associated with training whereby transport and access to the training site are often an issue. Scheduling of training sessions and programs also add constraints, especially for mine rescuers who are all volunteers. Here again, onsite training faces many challenges as mines are often located in remote sites and operate continuously, raising health and safety concerns.

The elicited need for *repeating drills and learning from mistakes* corresponds to a pillar of the theory and practice of learning. Causal cues and repetitions are meant to stimulate individual experiences and to enrich corresponding mental models (Jou and Wang, 2012). Ultimately, this contextualised reinforcement process should lead to a drastic reduction of human errors as skill sets dramatically improve (Deaton et al., 2005).

5.3 What are the constraints associated with onsite training?

Our constraint analysis (sections 3.4.1.2 and 4.2.1) informed by interviews with managers and trainers, as well as by answers from trainees to again two open-ended questions, allowed us to identify seven major constraints associated with onsite (pit) training for mine rescuers:

- Pit training is physically demanding
- Access to pit and consent from mine operators
- Logistical and time constraints
- High risk environment
- Limited opportunities for reviewing during the session
- Limited variety of scenarios and environments
- Feasibility of engaging actual resources

'Pit training is physically demanding' means that trainees need to walk underground sometimes for hours before reaching the training site, leading to serious fatigue even before tasks are being performed.

Additionally, mines are operating non-stop and it is often difficult to *access the pit* and to be given *consent by mine operators* to conduct training on site. Usually, mine operators are reluctant to allow training sessions during mine operations and prefer to allow access only during limited downtimes. Therefore, if Mines Rescue Pty Ltd wanted to rely purely on pit training they might only be conducting a few sessions each year, affecting the overall competency levels of rescue brigades in NSW.
Travelling to onsite training locations often involves *logistical and time constraints*, resulting in a poor ratio between effective training time and overall time committed by trainees and trainers. Several interviewees also mentioned the difficulty for trainees and trainers to stay onsite and debrief the session.

Although most trainees reported that onsite training felt 'more real' than a classroom or a VR theatre, they also acknowledged that an active pit, with its inherent noise and moving machinery, is a very *distracting environment* that effects their capacity to focus on the requested tasks. However, the key limitation advanced by VR designers in their interview was the *impossibility to recreate dangerous scenarios* in the pit. Although relatively infrequent, typical search and rescue operations include the immediate aftermath of a gas outburst or spontaneous combustions with dangerous gases, opaque smoke and scorching temperatures. These conditions cannot be reproduced – even at very small scale – in the pit as it would put too many lives at risk (trainees, trainers and other miners) and could compromise the mining operations.

Another limitation of onsite training mentioned by VR designers and confirmed by trainees and trainers is the inability to review a sequence of action in near real time and from different perspectives. Real world role playing can only offer this kind of feedback if the setting allows for instant recording and play back, as well as enough time to review this information. Unfortunately, these are two opportunities that pit training cannot offer. There are very *limited opportunities for reviewing during training sessions*. Trainers struggle to provide targeted *real time feedback*. Knowing the importance of constructive feedback on effective learning (Salzman et al., 1999), it isn't surprising that this is one of the key advantages they see in VR-based training.

Lastly, *engaging actual resources* is not always feasible for training purposes. Down in the pit, training competes – with a very low level of priority - with normal operations for transportation and access to machinery or specific sites. As previously mentioned, underground mines are confined and highly optimised environments that don't offer much flexibility in terms of space management and scheduling.

So far, our study has been able to clearly identify training needs for mine rescuers and limitations associated to onsite training (in the pit) despite its unique ability to bring trainees *in situ* in order to acquire or improve safety skills while experiencing real conditions. As VR-based training is sought to lift many of these constraints and limitations, it is time to review our evidence regarding VR technology's capabilities and its actual implementation by Mines Rescue Pty Ltd.

5.4 What are the actual capabilities of VR-based training?

Our capability assessment of VR technology (Sections 4.2.3 and 4.2.2) was initially informed by semi-structured interviews with VR designers. However, we found that the SWOT analyses conducted with trainees, trainers and VR designers (Sections 3.4.1.6, 4.3.1, 4.3.2, 4.3.3, 4.11.1 and 4.11.2) allowed us to create a smooth transition between potential and actual capabilities. Henceforth, we will discuss the two aspects in the following sections.

5.4.1 Potential capabilities of VR-based training

The potential capabilities listed by VR designers (Table 4.3) can be grouped into three categories:

- Design capabilities: agile development to suit the needs; iterative development with customer; blending within existing training programs.
- Implementation capabilities: safe environment for high risk skills; immersive and/or interactive environment; cost-effective access to regular and diverse training; possible customisation of scenarios; real-time feedback and play-back; no disturbance of mining operations.
- Evaluation capabilities: possibility of gradual introduction in training programs; compliance with training standards authority; easy feedback from trainers and trainees.

These capabilities cover many aspects of best practice training program, described in the Instructional System Design (Gordon, 1994) and echo the call for agility made by Salas and colleagues (2001). The progressive introduction of VR-based training into existing programs is a key aspect of the strategy put in place by Mines Rescue Pty Ltd as the underground coal mining industry is a rather risk-averse and conservative one.

5.4.2 Actual capabilities of VR-based training

Our SWOT analysis showed that VR-based training was regarded by trainees and trainers as having the following strengths:

- Novelty of a different and rich training environment
- Reasonable level of fidelity and realism
- Practising high-risk activities in a controlled environment
- Rich variety of scenarios and mining environments
- Allowing for real time feedback and discussions
- Supporting reinforcement learning through repeated drills
- Easy-to-use and fit-for-purpose

However some weaknesses were also identified by trainees, trainers and designers:

- Side effects and simulator sickness
- Adapting trainer’s attitude to the new environment
- Virtual reality isn’t the real thing
- Content creation is resource intensive
- Lack of technology fit for some specific scenarios
- Technological glitches and overall cost

We will review some of these strengths and weaknesses in the following sections.

5.4.2.1 Strength of VR-based training

Something new and different

Trainees commented that VR technology is a step closer to reality and a step away from traditional classroom-based training. Traditionally, the mining industry had developed training programs including classroom sessions and onsite training activities. The former can be run regularly and at low cost for many trainees while the latter engage substantial resources and interfere with mining operations. The former promotes passive learning while the latter promotes active learning. VR-based training comes in the middle and introduce a new perspective that can significantly affect training outcomes as it enhances the trainee’s qualitative insight (Salzman et al., 1999).

As stated by Meadows (2001): “*When I hear, I forget; when I see, I remember; when I do, I understand*”. Fulton and colleagues (2011) argue that interactive models, like flight simulators, are designed to improve the trainee’s understanding of the consequences of decisional cues under limited resource availability (material, time or energy) and uncertain or hazardous conditions (unintended consequences). Therefore, VR-based training - being ‘new and different’ – takes trainees into a stimulating environment that looks like reality, creates hyper-reality (extreme scenarios with gas outburst for example), immerses participants into a familiar environment while keeping them safe from danger, noise and distractions. As a matter of fact, a majority of trainees stated that the strength of VR was to immerse them into the reality of a pit without its constraints such as: “*no dust, mud or noise, comfortable environment*”, “*no noise, dust, smell*”, “*good effect, do not get dirty*” or “*didn’t get wet or cold, stayed clean*”.

Reasonable level of fidelity

To the degree of realism achieved by a VR environment, Rizzo and colleagues (2005) prefer the concept of *ecological validity*. Ecological validity has been defined as the functional closeness of a VR environment to its real world model. Henceforth, high resolution rendering does not necessarily enhance the ecological validity of VR environment as much as the activities that are to be performed and the key interactions with the simulated environment (Rizzo and Kim, 2005). Hayes and Singer (2012) differentiate between physical, functional, task-based and psychological fidelity. In our study, nearly 88% of interviewees assessed their training session as 'successful' to 'very successful' despite the fact that 36% of them found that the environment lacked realism.

High risk activities in a safe environment

A positive learning environment must create a safe and motivating context where trainees are able to try-and-fail and are encouraged to ask questions (Kember et al., 1997). In the context of safety training for mine rescuers, trainees need to experience dangerous scenarios without the fear of putting anyone's life at risk or damaging any equipment. Trainees reported the benefits of "*seeing possible hazardous conditions without the real life exposure*" in VR simulation training and mentioned the advantage over onsite training: "*somewhat expose to an incident that could not be simulated down a pit*" or "*you can have an over view of the whole situation and not be in harm, it gives you the chance to stop pause, rewind*".

Mines Rescue Pty Ltd, as a Registered Training Organisation, has a team of education specialists that work with Subject Matter Experts to create content that is the most suitable activity for the course. Practical training is almost always the most vital component of the courses. However, simulation can provide complimentary benefits to practical training as stated by many trainees and trainers in their SWOT responses. VR designers confirmed that their agile development approach could cater for a progressive integration of VR-based content into existing training programs.

Rich variety of scenarios and mining environments

Goal theory affirms that quality of training is affected by three factors: task, evaluation and authority (Blumenfeld, 1992). For a given task, trainees tend to better engage and learn from a series of scenarios that present slight variations of the same task, like different locations in the simulated pit. Pointing at VR technology's strength, trainees mentioned that they "*[had been] able to train in various different situations and conditions*", "*[had been] exposed to different mining specific environment*s", or that they "*covered a lot of training whilst in the VR room*".

However proper engagement and effective learning depend on the perception trainees have of the quality and relevance of the proposed material (Salzman et al., 1999). Meaningful content needs to make cognitive sense and creates interest and value amongst trainees. For instance, VR developers stated that simulated scenarios in the VR environment aimed at progressively covering all procedural aspects of underground safety protocols, including (but not limited to) isolation techniques, confined spaces, first aid, search & rescue, incident management, fire-fighting, self-escape, manual handling, task analysis, ventilation management, spontaneous combustion or supervisor inspection. There currently are nearly 100 different scenarios that can be used independently or in customised narratives.

Real time feedback and discussions

Fox and colleagues (2009) insist on the power of simulation-based training to provide immediate feedback on decisions made by trainees within a given scenario. Training sessions within the 360 VR environment are particularly good at creating and capturing these moments of intense cognitive activity: first, trainees are prompted by the trainer to take action in a given situation, then trainees immediately experience the consequences of their collective decision (sometimes with very dramatic visual effects!) and the trainer engages directly with the group to elicit their immediate reaction and discuss an alternate course of action. Unlike onsite or classroom training, where the scenario has to stop during the discussion phase, the 360 VR environment allows the trainer to keep the virtual environment in a 'suspended' mode whereby trainees still receive visual and audio cues while discussing the issue. This strength of VR-based training was mentioned by many trainees and trainers: "*going back over an incident to correct yourself*", "*trainers could stop or alter [an] exercise easily to facilitate learning and understanding of competencies*" (see sections 4.3.1, 4.3.2, 4.11.1 and 4.11.2).

Supporting reinforcement learning

Learning occurs as a result of practice and practice is the act of repeating an action. Repetitions are meant to stimulate individual experiences and to enrich corresponding mental models (Jou and Wang, 2012). Ultimately, this learning in context should limit the number of human errors to a tolerable level as skill set acquisition accelerates (Deaton et al., 2005).

The experience reported by 155 trainees who first attended a 360 VR session and then, a few months later, attend the Desktop VR session is highly relevant here. The search and rescue scenario had to be slightly modified to suit the new VR environment (GEN4 technology) and the (virtual) mine location was changed in order to provide some variety in the training (see above). Most trainees found the 360 VR environment highly immersive and engaged reasonably well with the scenario despite an overall feeling to be relatively passive. Their answers to the second SWOT survey showed that they had happily traded away immersion for a more interactive environment (Desktop VR) that allowed for more realistic implementation of the search and rescue scenario and the development of non-technical skills like communication and coordination. Henceforth, there is a strong connection between repeated drills, simulated scenarios and the VR technology-in-use.

Easy-to-use and fit-for-purpose technology

A large proportion of the 372 trainees who participated in the study were not computer or gaming proficient. Nevertheless a majority of SWOT responses confirmed, both for 360 VR and Desktop VR, that trainees were comfortable with the technology: "*easy to operate*", "*ease of use*", "*easy to show people a simulated mine environment*", "*easy to run*" and "*easy to interact*". We have addressed in the previous paragraph the degree of fitness to the task of the technology-in-use and suggested that the technology and the scenarios should follow the learning process in order to reinforce existing skills and reveal new ones. This dialectic relationship between learning process and technology adaptation constitutes an interesting extension to the integrated TAM/TTF model proposed by Dishaw and Strong (1999).

5.4.2.2 Weaknesses of VR-based training

Side effects and simulation sickness

For VR training tool to be acceptable and useful it is crucial to consider its side effects and resolve the associated issues. Simulation sickness which includes nausea, vomiting, disorientation, eye-strain, ataxia and vertigo are commonly reported by VR users in various fields (Kennedy et al., 1993). Simulation sickness usually results from conflict or lack of harmony between sensory cues and what trainees experience in the VR environment. In our study, the trainer had a crucial role to play in the 360 VR environment as his handling of the scenario (fast-forwarding, rapid spinning or jumping to another simulated location) had a direct impact on how some trainees felt. Conversely, sessions where the trainer ran the scenario smoothly, no significant complaint were made in the post-training questionnaire.

Regardless of the role played by the trainer, all 360 VR sessions faced the same problem and resorted to the same solution: as a highly immersive cylindrical environment, the 360 VR scenario revolves around the group of trainees located at the centre of the theatre, forcing their mind to accept motion while keeping physically still; VR designers had to ask trainers to encourage trainees to 'walk in place' in order to limit motion sickness.

Adapting trainer's attitude to the new environment

The way trainers deal with VR technology as a training tool directly affects its usefulness. Therefore, it makes technology acceptance by trainees highly dependent upon the trainers' perception of it. This is an important aspect of VR-based training that models developed by Salzman and colleagues (1999) or Dishaw and Strong (1999) have so far overlooked. Whenever trainers are (1) reluctant to use the technology, (2) uncomfortable with its use or (3) doubtful about its added-value, they will transfer their attitude to trainees. Several trainees mentioned these consequences in their SWOT answers: "*[it] felt rushed*", "*trainer rushed us through the scenario, didn't have time to complete the task*", "*trainer not familiar with the program and [I] found it confusing at times*" or "*[I] felt bored*".

Virtual reality isn't the real thing

VR-based training has made impressive progress over the last ten years as technology continues to evolve. Nevertheless, effective learning depends upon a training environment that trainees (and trainers) trust to be realistic enough to be useful. From an ecological validity perspective, Rizzo and colleagues (2005) conclude that there is still significant progress to be made in order to be able to entirely suppress real world training. In the context of our study, many trainees mentioned the lack of realistic details that would make the VR environment more 'like it' such as: ventilation, smell, heat, mud or uneven ground. These haptic capacities, also known as 4D virtual reality, are still a work-in-progress. Although their absence raised comments from trainees like "*not as conditions you would find in mine*", "*it doesn't truly simulates the difficulties in a real underground experiences*", or "*not the real environment…uneven grounds, not walking, clean environment, no mud, heat or smell*", these limitations play also a crucial role in a strength of VR-based training mentioned by many trainees: the ability to concentrate on the requested task without having to deal with all the constraints and distractions encountered in onsite training (see relevant section above).

Lack of technology fit

Streman (2000) argues that participants in VR-based training sessions must accept the technology and the fact that their virtual experience is applicable to the real world. Dishaw and Strong (1999), in their TAM/TTF model, developed the concept of 'cognitive fit' to explain the need for the training environment to support all aspects of a problem-solving task to be performed. From that perspective, functional and procedural details are as important, if not more, as sensorial cues.

We already mentioned the 'walk in place' solution to limit motion sickness in a 360 VR theatre. Beyond the physiological effects, this immersive and passive environment has also a direct impact on trainee's attitude towards the training content itself as reported by several trainees: "*standing in the one spot with a suit on your back*", "*having someone else controlling your movements*" or "*I feel bored when just standing and need to perform a task*". Boredom translates into distraction and ultimately results in poor learning. The development of a Desktop VR environment (GEN4 technology) was a direct response by Mines Rescue Pty Ltd to this issue. For example, the search and rescue scenario that was used in our study necessitated for the rescue brigade to split and undertake a search pattern in a hazardous environment (thick smoke); GEN4 technology allowed each trainee to take control of the actions of their avatar while trying to coordinate with their team members: "*[GEN4] gives you a better sight into a real situation and helps you to communicate and work as a team*", another trainee noted that "*[it gave us the] ability to work as a individuals within the same environment*", or "*you control your own movement, you are always involved, don't get bored*". These comments confirm the complex relationship between sensorial fidelity and learning, mentioned in our literature review (Hoffman et al., 2001; Baker et al., 2005).

Work-in-progress

Despite undeniable advances, VR-based training for underground mining developed by Mines Rescue Pty Ltd still suffers from human and technological limitations, such as:

- Lack of properly trained trainers who can take advantage of all the resources and opportunities offered by 360 VR and Desktop VR environments. From our observations, VR designers still play a crucial role in developing and improving training content.
- VR-based training is well-suited for small groups of trainees (4 to 6 trainees at a time). In retrospect, our choice to focus on training for rescue brigades was probably judicious as this is the actual size

of a rescue team. Other types of VR-based programs, like induction courses, are more problematic as classes usually involve a larger number of trainees.

- Investment into VR technology, regular technical upgrades and support to a VR designing team is a relatively costly exercise that needs to demonstrate its cost-effectiveness. Therefore, it is crucial to implement a systematic evaluation program in order to demonstrate value-for-money.
- Like any other advanced technology, VR-based training suffers from unexpected technical glitches that can distract trainees and trainers or even disrupt the whole training session. Unlike onsite training (in the pit), trainers are often left aimless under such circumstances as resolution of the issue has to be managed by VR designers.

Henceforth, it has become clear during the course of this study that the sustainable development of VR-based training by Mines Rescue Pty Ltd can only happen if trainers can accept and fully appreciate the technology as this is the first and crucial step into technology acceptance and task fitness objectives (Dishaw and Strong, 1999). Fully engaged trainers can better customise the content of a session to suit the needs of a group of trainees. They will also be able to mitigate any negative effects, like simulation sickness, by better controlling the pace of the narrative in a 360 VR environment.

5.5 Construction of a VR learning model and its Impact on Learning Outcomes

This study explored the role of psychological and perceptual processes in the learning of safety concepts for mine rescue brigades in a 3D virtual reality environment. As it has been stated in literature review, the learning model developed by Salzman et al. (1999) and technology-mediated learning are converging therefore, a theoretical model was developed and tested using path analysis (Figure 5-1). With such, a conceptual framework that based on an input, process and output metaphor that emphasizes on the psychology learning factors is developed to guide the research design for evaluating how VR enhances learning. Our experimental design included pre-training and post-training questionnaires in order to understand trainee's characteristics and attitudes prior the training session and subjective account of their learning experience after the session (sections 3.4.1.4, 3.4.1.7, 3.4.1.9 and 3.5). Trainees were also subjected to skill tests in order to have an objective measurement of training transfer (section 3.4.1.8). We will first discuss the influence of individual characteristics and attitudes on the trainees' assessment of the session (usefulness, realism and success), as well as learning outcomes; then, we will discuss the influence of their learning experience onto the same indicators (sections 4.5, 4.6, 4.12 and 4.13).

Hypothetical framework includes, the trainees' *positive state of mind prior training* (includes: presence, alertness, motivation, competitiveness, confidence and wellbeing), *negative state of mind prior training* (includes: sense of stress and worry), *technology experience* (includes: gaming experience and digital world involvement), *VR features* (includes: realism, immersion and interaction), *positive learning experience* (includes: presence, engagement, enjoyment), *negative learning experience* (including: stress, worry and pressure), as well as *VR functionality*, *task-technology fit*, *technology usefulness*, *ease of use*, *attitude towards using the technology*, *trainer*, *quality of feedback* and *perceived learning.*

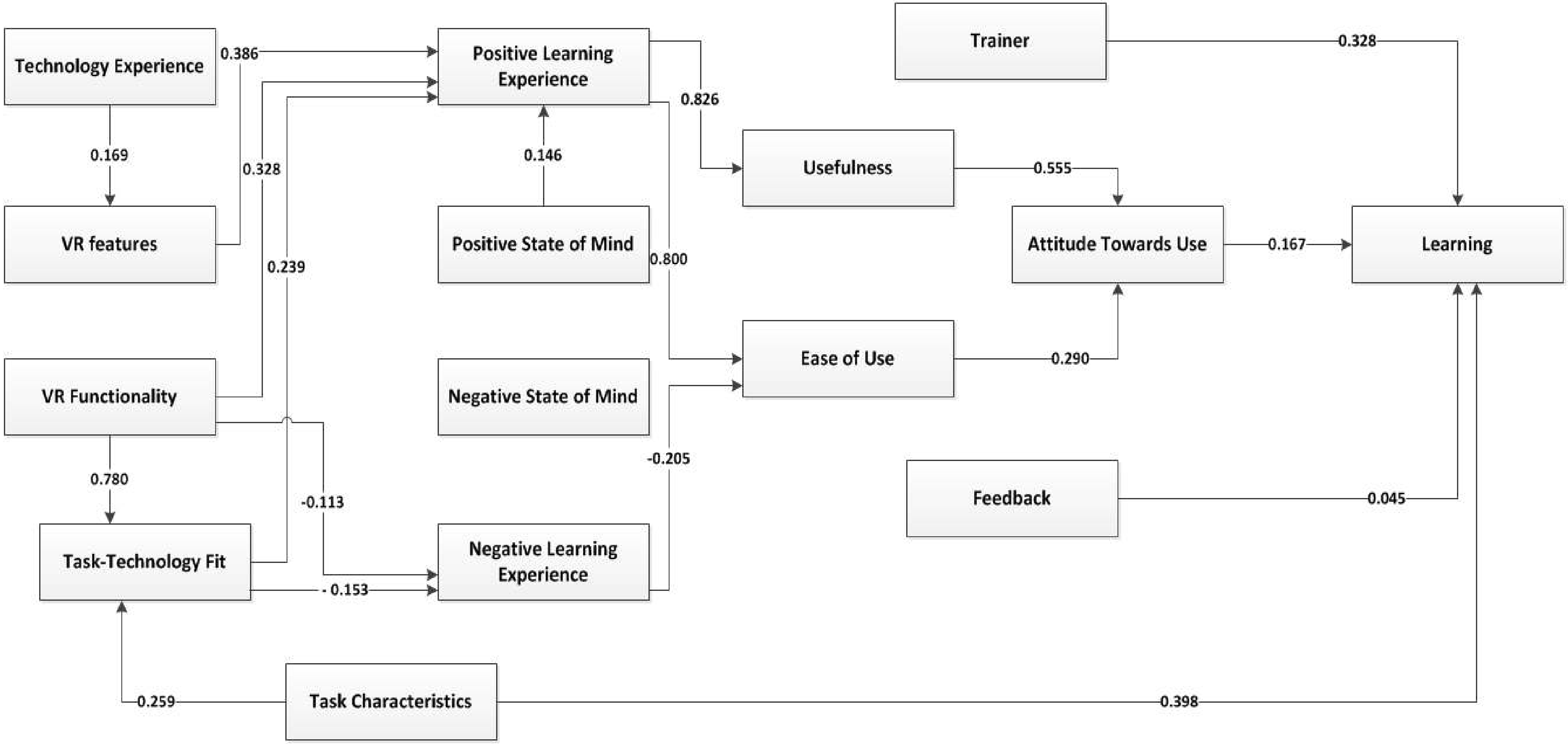


Figure 5-1: VR Causality Learning Mode

5.5.1 Demographics and Technology Experience

The impact of age, expertise and technology experience (including: gaming experience and digital world involvement) was also investigated on learning process and outcome. As review of literature by Broady et al. (2010) also highlighted, there are marked similarities between attitudes and experiences of young and older adults in using computers and technology. Our analysis of pre-training questionnaires indicated that younger trainees (24-40 y.o.) reported, on average, higher levels of gaming experience while older trainees (41-64 y.o.) reported, on average, higher level of stress before the training session. However, these were the only two pre-training variables that displayed statistically significant differences. These findings are also supported by Renaud and Ramsay (2007), who have stated that in general younger people have had more exposure to technology than older people. Moreover, Igbaria and Chakrabarti (1990) suggested that attitudes toward computers are negatively correlated with computer anxiety, meaning that the more anxious person is toward computers the more person will have negative attitude towards using them. Therefore, as person gets older, computer-related anxiety appears to increase (Laguna and Babcock, 1997). Additionally, due to the strong correlation between age and mining experience, the same results were found between experienced (>10 years) and less experienced (<10 years) trainees. Comparison between experienced rescuers (>10 years) and less experienced ones (>10 years) indicated the same differences as for mining experience; however, it also showed that less experienced rescuers declared, on average, a higher level of motivation and alertness. Ultimately, none of the age or expertise (as miner or rescuer) had a statistically significant influence on the learning process and perceived leaning, regardless of the VR form factor (360 VR or Desktop VR) (sections 4.5.6 and 4.12). Our findings is consistent with Parnell and Carraher (2003) findings, they reported that there was no connections between student age, gender, GPA (grade point average) and choice of web-based or traditional course and learning outcome. Also, the findings in this study suggest that prior gaming experience or technology experience does not have impact on learning process and outcome. This is in line with findings by Marks et al. (2005) which mentioned that there is no difference between the two group's perceived learning and satisfaction. Even though prior experience might not have direct impact on learning process or outcome but it might be a predictor of trainee perceptions of the technology (Wan et al., 2007). However, when we compared answers to the question about preference of VR technology compared with onsite training, results showed that older and more experienced trainees were relatively more attracted to Desktop VR compared with 360 VR. Thus, it seems that older and more experienced miners tend to prefer a more interactive and task-focused system (Desktop VR) to a more immersive and passive one (360 VR).

These results are encouraging for Mines Rescue Pty Ltd and the mining industry at large as it appears that VR technology does not create any inequalities between younger and older generations, less and more experienced miners in terms of adoption.

5.5.2 Positive and negative State of mind before training

In our framework positive state of mind prior training (includes: presence, alertness, motivation, competitiveness, confidence and wellbeing) and negative state of mind prior training (includes: sense of stress and worry). Our result revealed that trainees who felt more stressed and worried before the session also reported lower levels of motivation, alertness and confidence. Conversely, when they felt more confident, they reported, on average, higher levels of motivation and a greater sense of competition. Motivation is important factor in the learning process and other factors such as stress and worry will distract trainees from learning (Dewey and Boydston, 1985). Our older trainees were on average more stressed than younger trainees. Suggests Hawthorn (2007) that the reason older people are more anxious is there are barriers to older people's acceptance and use of technology which include being unsure of how to use the technology, the fear of unknown (Hawthorn, 2007) and a lack of confidence (Marquié et al., 2002). Additionally, Rice et al. (2007) argues that one barrier to older adults using technology is being unsure of the benefit of products and services related to technology. Nevertheless, as it has been highlighted both 360- or Desktop-VR participants mostly were well aware of the benefits of VR as a safety training environment and as a result were comfortable with the concepts of using VR as a training tool. Usability was also a significant antecedent to motivation (Lee et al., 2010). Therefore, the level of stress has been reported might be due to the uncertainty about the training scenario or other unknowns. However, the quantitative analyses revealed that each trainee' pre-training *state of mind* (positive or negative) had only a limited impact on their experience during the 360-VR session and on their *perceived learning* at the end of the session. None of the variables associated with positive or negative state of mind had a direct and statistically significant influence on the learning process and perceived leaning in VR despite the fact that motivation was significantly correlated with some of the positive learning experience factors (see below) Salzman et al. (1999) and later Benbunan-Fich and Hiltz (2003) research also confirm this finding and indicate that motivation is important factor affecting the leaning process.

5.5.3 VR Feature

VR features which include realism, immersion and interaction, as our findings confirm, have direct impact on learning experience and ultimately indirect impacts on learning outcomes. Our findings support what other researchers have argued in terms of leveraging the uniqueness of the VR technology to enhance the learners' interaction experience and learning experience, which in turn influence the learning outcomes (Barnett et al., 2005, Lee et al., 2010). Lee and Wong (2014) also investigated the impact of VR features and their findings are in line with the findings of this research and reported that VR features have an indirect effect on the learning outcomes which are mediated by the interaction experience and learning experience. However, Lee et al. (2010) measured VR features through the scene realism and immediacy of control (immediacy of control refers to the ability to change the view position or direction) and reported that these are two unique features of desktop VR played a significant role in influencing the interaction and learning experiences of the learners, which also led to enhance the degree of learning outcomes. Additionally, Merchant et al. (2014) defined VR features as the sense of realism and interaction. Their findings also support the findings of the current study, and confirm the importance of VR features on learning process and outcome. VR features that were measured by the representational fidelity and the ability to interact with the virtual objects and environment in the desktop VR-based learning environment collectively influenced the interaction experience of the users. As the level of interaction and fidelity increase the perceived usability this also enhanced the impacts on the trainees' positive and negative learning experience.

5.5.4 Positive and Negative Learning experience

Positive learning experience (including: presence, engagement, enjoyment), negative learning experience (including: stress, worry and pressure) are important constructs in learning process and outcome. Most of the factors measured in the post-training questionnaire were found to be significantly correlated with each other and having an influence on perceived learning. Thus it was difficult to single out key primary factors driving learning outcomes. Henceforth, our modelling attempts aimed at grouping these factors into positive or negative learning experience in order to infer the global and intertwined effects of these factors. Our explanatory model shows that 71% of the variance associated with perceived learning can be attributed to 3 aggregated variables describing positive and negative experiences during the session and learning context.

As it has been presented by Salzman et al. (1999) and then later confirmed by Lee et al. (2010) and Merchant et al. (2014), presence has an indirect impact on learning outcomes. This is in line with our findings where the sense of presence, engagement and enjoyment combined create a positive learning experience. Additionally, categorising presence, enjoyment and engagement is also justifiable based on flow theory. Flow theory discussed by Rieber (1996) confirms that enjoyment from activities resulted when the challenge of an activity is optimised which means the training is as realistic as possible and person is fully concentrated and in control of activity in a way he/she lost track of time (feeling present). Based on the stated theory if we can create a learning environment that enhances the pleasure of the experience, the outcome of training can be optimised. The findings of this study provide evidence on the causality relationship between positive learning experience and learning outcome.

5.5.5 Usefulness and Ease of use

Positive learning experience was initiator for usefulness while ease of use was influenced by both positive and negative learning experience. These findings imply that presence, enjoyment and engagement influenced perceived usefulness, while perceived ease of use is not only impacted by those factors but also stress, pressure and worry has impact. Perceived usefulness and ease of use were highly related to the variable attitudes towards use. This finding is consistent with the model proposed by Salzman et al. (1999) and later studied by Merchant et al. (2012) where learners' usability is another significant mediator in the learning process. Moreover, our findings are in line with the technology acceptance model (Davis et al., 1989) where the importance of considering task meaningfulness and ease to use computer interface has been highlighted (Davis, 1989). Lastly, as highlighted in SWOT analysis, “Easy-to-use and fit-for-purpose” was identified as one of the strengths of VR training.

5.5.6 Attitude towards use

Even though in various studies (Broady et al., 2010, Chen et al., 2009) it has been stated that age and computer experience impact on users’ attitude toward technology, the findings of this study proved that regardless of age, expertise or level of experience with technology when trainees find technology easy to use and useful they will have positive attitude towards its use. This is also supported by study conducted by Chow et al. (2012) where they reported that perceived ease of use was the most influential construct to directly affect behavioural intention. Huang et al. (2010) also reported that learners may have a negative attitude toward learning in a VR. Participants must accept the VR in order to get involved in the training, motivated by its content and challenged by its objectives (Lackey et al., 2016). Additionally these finding is consistent with technology acceptance model (Davis et al., 1989) and as it has been illustrated attitude toward use is a significant antecedent to learning outcome.

5.5.7 Task Characteristics and Task Technology Fit

As it has been illustrated in the causality learning model, Task characteristics had an impact on perceived task technology fit. It is crucial to choose the appropriate tool/technology for a specific purpose. Some forms of technologies are best suited to support specific theoretical learning models (Leidner and Jarvenpaa, 1995), while others provide general support for the different learning models (Piccoli et al., 2001). Our findings are consistent with technology acceptance model (Davis et al., 1989).

In the case of this study due to the nature of the training scenario (search and rescue) which required trainees to perform individual activities, trainees felt that they were mostly observers during the 360-VR sessions. In other words, trainees discussed the issues together; then, the one person who was in charge of the group’s movements interacted with the VR environment via a joystick. As a consequence, only 52% of trainees reported that the 360-VR environment was consistent with their workplace reality. However, nearly 85% of them indicated that 360 VR was a useful training tool (answers ranking from 7 to 10 on the Likert’s scale) and 90% indicated that they managed to successfully perform their tasks (answers ranking from 7 to 10 on the Likert’s scale). Moreover, nearly 80% of the trainees ranked their perceived learning as highly satisfactory (answers ranking from 9 to 10 on the Likert’s scale).

Thus, despite its aforementioned limitations, the 360 VR technology seems to successfully deliver a highly immersive content associated with high risk scenarios that trainees cannot experience through onsite training. From that perspective, technology acceptance (TAM) stems from the need for trainees to confront the ‘known unknown’ despite a sub-optimal task-technology fit (TTF). From an ecological validity viewpoint (Salas et al., 2001), the scenario’s substantive content (e.g. ‘the narrative’) tends to override procedural approximations (for example, the inability to physically split the team during the search and rescue mission). In comparison, reactions to the Desktop-VR sessions showed that, despite the use of a less immersive technology, nearly 81% of trainees reported that the session had been useful (answers ranking from 7 to 10 on the Likert’s scale) and 86% of them reported that they had been successful at performing the request tasks. Surprisingly, a slightly higher proportion of trainees reported Desktop VR to be realistic and immersive (answers ranking from 7 to 10 on these Likert scale), compared with 360 VR. In accordance with ecological validity theory (Salas et al., 2001), physical segregation, individual tasking and team communication available with Desktop VR technology were perceived as (slightly) more ‘realistic’ features compared with highly immersive visual cues proposed by 360 VR technology. These findings are consistent with previous research from Taylor and colleagues (1999) who found that increased visual fidelity did not automatically affect the usefulness of the training or the effectiveness of the learning. Thus, we can conclude that while reported *usefulness* of the training and *success* in completing the requested tasks were positively correlated with *perceived learning*, consistency with workplace reality (or ‘*realism*’) had a much looser connection with perceived training outcomes.

5.5.8 Tool Functionality (Training technology form factor)

The groupings of learning factors into *positive* and *negative learning experience*s and *training context* allowed us to compare 360-VR with Desktop-VR. Overall, trainees reported a more positive *learning experience* and less *negative learning experience* in Desktop-VR. They also reported a better *training context* with Desktop-VR compared with 360-VR. However, there is no statistical difference between the two technologies on reported *perceived learning*. It should be acknowledged here that our experimental design did not cater for a proper comparison, as the 360 VR training was always conducted first and the Desktop VR sessions were aimed at estimating training transfer from the first session (155 trainees only). Although Desktop VR had just been released by Mines Rescue Pty Ltd at the time if this study and the VR designers and trainers were dealing with procedural fine tuning, the positive response from trainees confirms that the move towards a less immersive and more interactive technology appears to be the correct one for this type of scenario and audience.

5.5.9 Learning context

The learning context which includes trainer, task characteristics and feedback factors had the highest statistical impact on *perceived learning*, regardless of the VR technology in use (360 VR or Desktop VR). This result confirms the conclusions of the SWOT analysis that the trainer’s acceptance of the technology, their demonstrable comfort with the technology, their ability to use the technology to provide a better experience and their feedback to trainees were essential factors to effective learning. As our findings suggest trainers had a high impact on learning outcome, other studies such as Martins and Kellermanns (2004) and Wan et al. (2007) also examined the importance of trainers or instructors in technology mediated learning environments. This is a noticeable result that confirms the conclusions of the SWOT analysis: trainer's acceptance of the technology, their demonstrable comfort with the technology and their ability to use the technology to provide a better experience and feedback to trainees are essential factors to effective learning, this conclusion is consistent to Piccoli et al. (2001) findings. They have stated that instructors' level of technology experience and self-efficacy, in terms of having the ability to control the technology and having a positive attitude toward it, affect students' learning outcomes.

5.5.10 Learning Outcome

Perceived learning is a subjective statement made by trainees after the VR-based training session. It reflects as much upon the individual's self-esteem as on the actual learning outcomes. Hence, the results of the competency test (skill test) provided us with a more objective assessment of the quality of the learning process. Nearly 52% of the trainees improved their score after the 360 VR session; the others kept their initial highest score (Figure 4-7). This result tends to confirm that (reported) perceived learning corresponded to an actual gain of competency for many trainees. However, these results are limited to the format and content of the test and cannot pre-empt on the way this improved knowledge can translate into actual competency in action.

We also compared results from the group of trainees who attended both 360-VR and Desktop-VR sessions ('treatment group') with the group of trainees who only attended Desktop VR ('control group'). We did not find any statistically significant differences between the two groups for all reported post-training variables (Table 4-34).

We also compared results to the competency test (skill test) from both groups. Out of 155 trainees who had previously attended a 360-VR session, 150 completed the test. Out of the 88 who only attended a Desktop VR session (control group), 72 completed the test (Appendix A.20: Competency Comparison between 360-VR attendees and control Group). Results show that trainees who first attended a 360 VR session outperformed the control group, although results from the latter were highly positive. We can conclude – in the context of our study - that although perceived learning did not show any statistical differences between the groups, objective measurements (the skill test) indicate a positive reinforcement effect between the two successive sessions. However, learning outcomes - stated or revealed - for trainees who only attended Desktop VR training session (control group) were statistically significant. This result might be associated with the judgement made by the majority of trainees who attended both sessions that the Desktop VR environment was more interactive and enjoyable, though less immersive, than 360 VR technology.

As this 360-VR environment has illustrated the capability of knowledge correction/creation we can conclude that our proposed VR causality learning model is valid in illustrating the relationship between constructs which have impact on learning outcome.

6 Chapter VI: Conclusion

Human errors have been recognised as a major reason for accidents in the mining industry. Therefore there is a strong need to design, implement and evaluate effective training programs (Pithers, 1998b). Virtual Reality (VR) is perceived by the industry as a potential solution to enhance effective learning to miners. Our case-based study focused on the VR-based training programs implemented by Mines Rescue Pty Ltd, a training provider for the mining industry in Australia.

Based on a thorough literature review, we have proposed a systematic evaluation framework and applied it to training sessions specifically designed for mines rescue brigades in New South Wales, Australia. A total of 372 trainees were surveyed across two VR environments (360 VR and Desktop VR). The construction of this proposed framework involved:

- Conducting a need analysis,
- Identifying constraints associated with onsite training,
- Identifying VR's training capabilities,
- Analysing actual training experiences and learning outcomes,
- Inferring a causality model for learning in a VR environment.

Our Need Analysis elicited several training needs for underground coal mining, regardless of the technology-in-use:

- Recreating real conditions and scenarios
- Allowing for physical activity
- Training opportunity accessible at any time
- Providing a variety of scenarios and mine environments
- Experiencing hazards and danger
- Limited level of distraction from training task
- Possibility to repeat the drills and learn from mistakes

Interviews with trainers, managers and VR designers, alongside answers from trainees, led us to identifying the following limitations and constraints associated with onsite (pit) training:

- Access to pit and consent from mine operators
- Logistical and time constraints
- High risk environment
- Limited opportunities for reviewing during the session
- Limited variety of scenarios and environments

By contrast, our first SWOT analysis showed that training sessions in a 360 VR environment displayed the following strengths:

- Novelty of a different and rich training environment
- Reasonable level of fidelity and realism
- Practising high-risk activities in a controlled environment
- Contributing to higher skill level and competency
- Supporting reinforced learning through repeated drills
- Allowing for real time feedback and discussions
- Overcoming logistical constraints of pit training

However, some weaknesses were mentioned by trainees, trainers and designers:

- Side effects and simulator sickness
- Adapting trainer's attitude to the new environment
- Virtual reality cannot entirely replace real world training
- Content creation is resource intensive
- Lack of technology fit for some specific scenarios
- Technological glitches and overall cost

Our quantitative analyses showed that pre-training individual characteristics had a limited impact on either experiences during the 360-VR training session on their perceived learning at the end of the session. By contrast, their experiences during the session had significant impacts on their perceived learning. Our explanatory model shows that 71% of the variance associated with perceived learning can be attributed to 3 aggregated variables describing the positive and negative experiences of trainees during the 360-VR session and learning context.

Overall 88% of interviewees evaluated their 360 VR-based training session as 'successful' to 'very successful' despite the fact that 36% of them found that the environment lacked realism. Thus, it appears that the capacity to focus on a task, to get immediate feedback, to be exposed to various hazardous scenarios associated with 360 VR technology largely compensate for technological limitations. However, some of these limitations seem to limit the types of scenarios that can be usefully deployed: lack of group coordination, lack of separate individual activities, lack of physical activity or lack of active motion (most trainees 'see' the environment revolving around them rather than proactively exploring it). Some of these limitations have been directly addressed by the Desktop-VR technology.

Our second SWOT analysis showed that Desktop-VR based training displayed the following strengths:

- High level of fidelity and realism

- Being active player
- Review and Feedback
- Training on non-Technical skills
- Desktop-VR training avoids real life constraints
- Novelty of a different and rich training environment

Although some weaknesses were mentioned by trainees and trainers, some of them were a direct consequence of the relative novelty of the tool at the time of the study:

- Some technological constraints
- Desktop-VR cannot replace real life training
- Not knowing how to use the technology
- Desktop-VR produces Simulator Sickness

Overall, 80% of trainees indicated that they found Desktop-VR training to be *successful* and 76% trainees considered Desktop-VR as *useful* and consistent with workplace reality. Although Desktop-VR scored less for perceived *usefulness* and *success* than the 360 VR, it scored higher for *positive learning experience* and *learning context* and scored less for *negative learning experience*. However, the comparison between perceived learning in 360-VR and Desktop-VR did not indicate any difference.

As *perceived learning* is inherently subjective, we used a short competency test (skill test) to assess actual learning, at least from a theoretical viewpoint. This questionnaire was completed by trainees before the 360 VR session and then again a month later. Results show that 52% of trainees improved their scores during the second round of testing.

Finally, a second round of training sessions using the Desktop VR environment included 222 trainees, amongst which 150 had previously experienced 360 VR training (treatment group) and 72 who had not previously been involved (control group). Although the analysis of *perceived learning* (reported by trainees) did not show any significant difference, *actual learning* (recorded through the skill test) showed that the treatment group obtained a statistically significant higher score.

Finally, we used evidence gathered throughout the study to validate a hypothetical causality model for learning in a VR environment. The final model (Figure 5.1) shows that individual characteristics prior a training session did not have an impact on *perceived learning*, whereas positive and negative learning experiences during the session were able to explain 71% of the variance of *perceived learning*.

6.1 Limitations of this study

Despite all the constructive and innovative results generated by our research, some limitations have also been identified:

- Our evidence-based findings and causality model rely on a statistically significant group of trainees (372 in total); however, this group was rather specific (mine rescuers) and their training program adapted to their needs. Furthermore, our study relied on one training scenario only (search and rescue) and we have mentioned that technology-task fitness is a crucial factor for effective learning.
- Desktop-VR technology was deployed by Mines Rescue Pty Ltd later on during the course of our study. Thus, we had to adapt our experimental design to fit this technology and gain new knowledge comparing training in two VR environments. As a consequence, Desktop-VR was used previously as a learning assessment tool rather than a proper treatment in a comparative study.
- Due to technical constraints neither the 360 VR nor the Desktop VR technologies allowed us to record activity logs during sessions. Hence, we could not rely on objective measurements of success in performing tasks and had to limit our analysis to performance reported by trainees after the session.
- The causality model of learning been calibrated against our experimental evidence using a path analysis. However, we haven't had a chance to validate this model against other data sets yet.
- Finally, the quality of training transfer (resulting in effective learning) was estimated through reported *perceived learning* and recorded scores of a competency test. Obviously, the ultimate test should be based on a workplace evaluation of skills and competences. Unfortunately, due to the nature of the tasks to be performed by mine rescuers, it was not feasible to design a robust evaluation framework.

6.2 Future Research

This study is a starting point for developing a systematic evaluation approach to VR-based training programs for high risk industries. It would be beneficial to extend this study and design to real world experiment that would involve VR-based and non-VR-based implementation of the same learning content. The VR-based component could include several technologies as we attempted with 360 VR and Desktop VR. Such an experimental design could inform the following lines of research:

- Does VR-based training teach trainees faster?
- Do trainees remember better in a VR environment?
- Is VR-based training cost-effective?
- Which VR-specific skills need to be developed by trainers?
- Which metrics need to be recorded with VR technology to deliver a fair evaluation?

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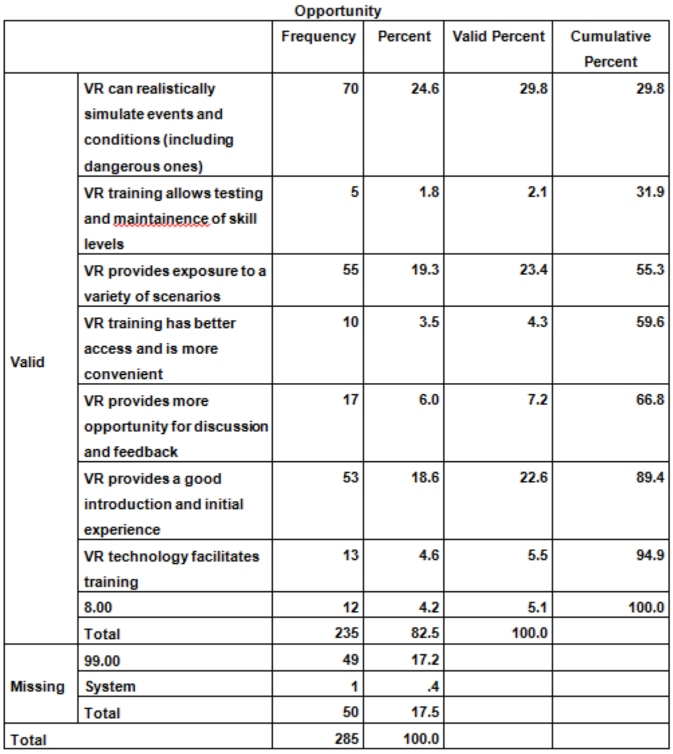
8 Appendices

8.1 Appendix A

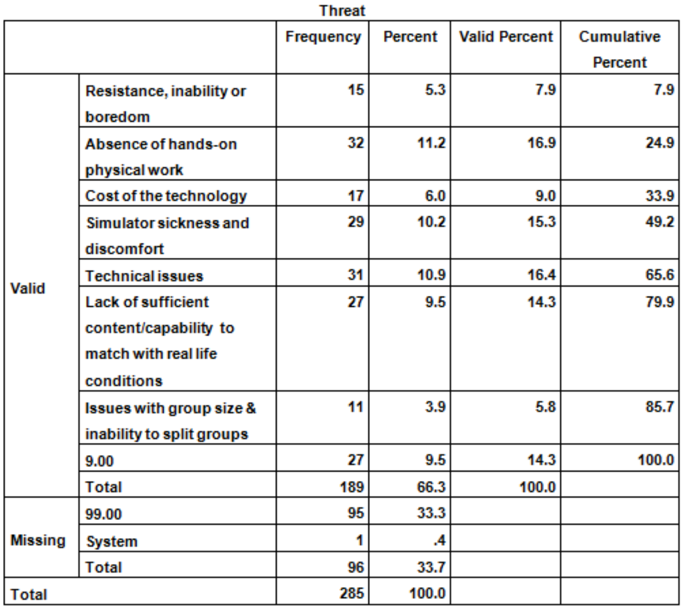
1. Appendix A.4: Frequency of VR training Opportunity components (SWOT analysis – trainees)



Opportunity

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	VR can realistically simulate events and conditions (including dangerous ones)	70	24.6	29.8	29.8
	VR training allows testing and maintainence of skill levels	5	1.8	2.1	31.9
	VR provides exposure to a variety of scenarios	55	19.3	23.4	55.3
	VR training has better access and is more convenient	10	3.5	4.3	59.6
	VR provides more opportunity for discussion and feedback	17	6.0	7.2	66.8
	VR provides a good introduction and initial experience	53	18.6	22.6	89.4
	VR technology facilitates training	13	4.6	5.5	94.9
	8.00	12	4.2	5.1	100.0
	Total	235	82.5	100.0	
Missing	99.00	49	17.2		
	System	1	.4		
	Total	50	17.5		
Total		285	100.0		

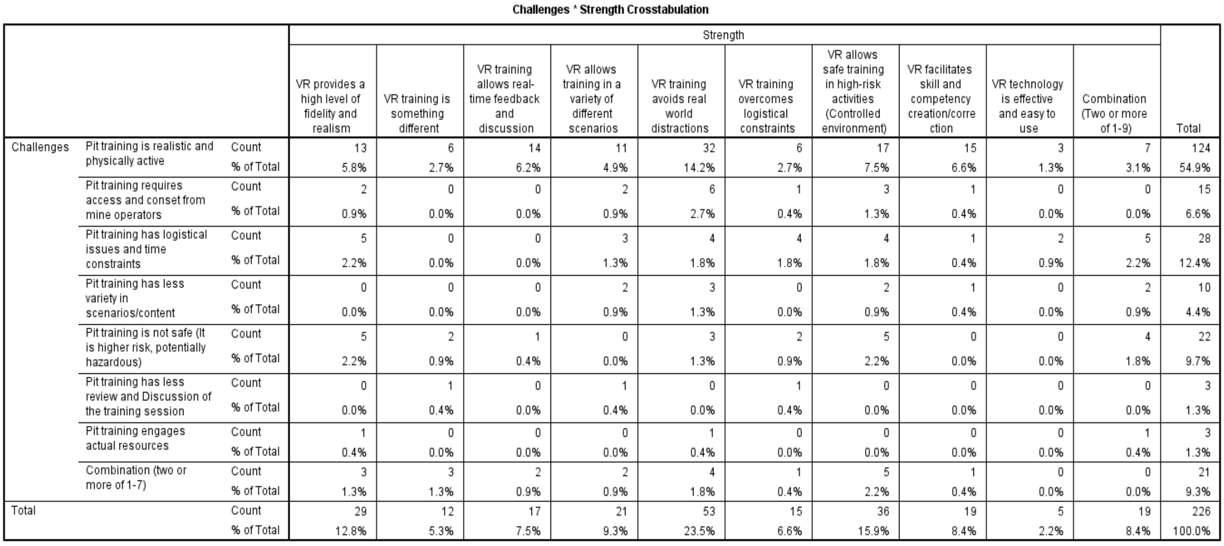
2. Appendix A.5: Frequency of VR training Threat components (SWOT analysis – trainees)



Threat

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	**Resistance, inability or boredom**	**15**	**5.3**	**7.9**	**7.9**
	Absence of hands-on physical work	**32**	**11.2**	**16.9**	**24.9**
	Cost of the technology	**17**	**6.0**	**9.0**	**33.9**
	Simulator sickness and discomfort	**29**	**10.2**	**15.3**	**49.2**
	Technical issues	**31**	**10.9**	**16.4**	**65.6**
	Lack of sufficient content/capability to match with real life conditions	**27**	**9.5**	**14.3**	**79.9**
	Issues with group size & inability to split groups	**11**	**3.9**	**5.8**	**85.7**
	9.00	**27**	**9.5**	**14.3**	**100.0**
	Total	**189**	**66.3**	**100.0**	
Missing	**99.00**	**95**	**33.3**		
	System	**1**	**.4**		
	Total	**96**	**33.7**		
Total		**285**	**100.0**		

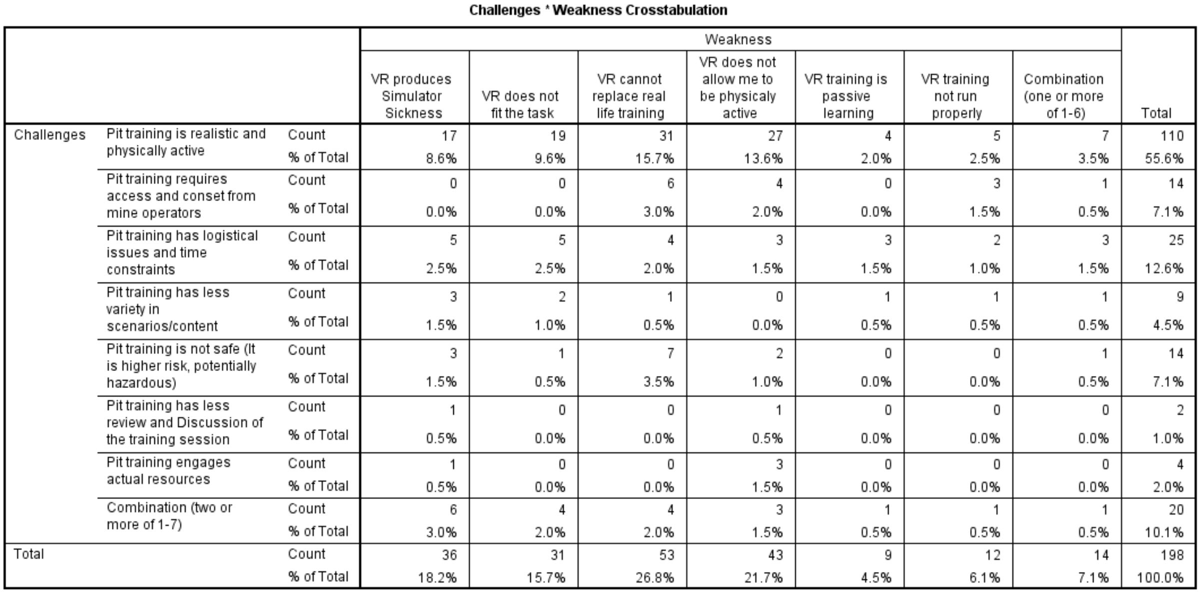
3. Appendix A.6: Cross tabulation between real life training constraints and 360-VR's strengths



Challenges * Strength Crosstabulation

			Strength										
			VR provides a high level of fidelity and realism	VR training is something different	VR training allows real-time feedback and discussion	VR allows training in a variety of different scenarios	VR training avoids real world distractions	VR training overcomes logistical constraints	VR allows safe training in high-risk activities (Controlled environment)	VR facilitates skill and competency creation/correction	VR technology is effective and easy to use	Combination (Two or more of 1-9)	Total
Challenges	Pit training is realistic and physically active	Count	13	6	14	11	32	6	17	15	3	7	124
		% of Total	5.8%	2.7%	6.2%	4.9%	14.2%	2.7%	7.5%	6.6%	1.3%	3.1%	54.9%
	Pit training requires access and conset from mine operators	Count	2	0	0	2	6	1	3	1	0	0	15
		% of Total	0.9%	0.0%	0.0%	0.9%	2.7%	0.4%	1.3%	0.4%	0.0%	0.0%	6.6%
	Pit training has logistical issues and time constraints	Count	5	0	0	3	4	4	4	1	2	5	28
		% of Total	2.2%	0.0%	0.0%	1.3%	1.8%	1.8%	1.8%	0.4%	0.9%	2.2%	12.4%
	Pit training has less variety in scenarios/content	Count	0	0	0	2	3	0	2	1	0	2	10
		% of Total	0.0%	0.0%	0.0%	0.9%	1.3%	0.0%	0.9%	0.4%	0.0%	0.9%	4.4%
	Pit training is not safe (It is higher risk, potentially hazardous)	Count	5	2	1	0	3	2	5	0	0	4	22
		% of Total	2.2%	0.9%	0.4%	0.0%	1.3%	0.9%	2.2%	0.0%	0.0%	1.8%	9.7%
	Pit training has less review and Discussion of the training session	Count	0	1	0	1	0	1	0	0	0	0	3
		% of Total	0.0%	0.4%	0.0%	0.4%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	1.3%
	Pit training engages actual resources	Count	1	0	0	0	1	0	0	0	0	1	3
		% of Total	0.4%	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.4%	1.3%
	Combination (two or more of 1-7)	Count	3	3	2	2	4	1	5	1	0	0	21
		% of Total	1.3%	1.3%	0.9%	0.9%	1.8%	0.4%	2.2%	0.4%	0.0%	0.0%	9.3%
Total		Count	29	12	17	21	53	15	36	19	5	19	226
		% of Total	12.8%	5.3%	7.5%	9.3%	23.5%	6.6%	15.9%	8.4%	2.2%	8.4%	100.0%

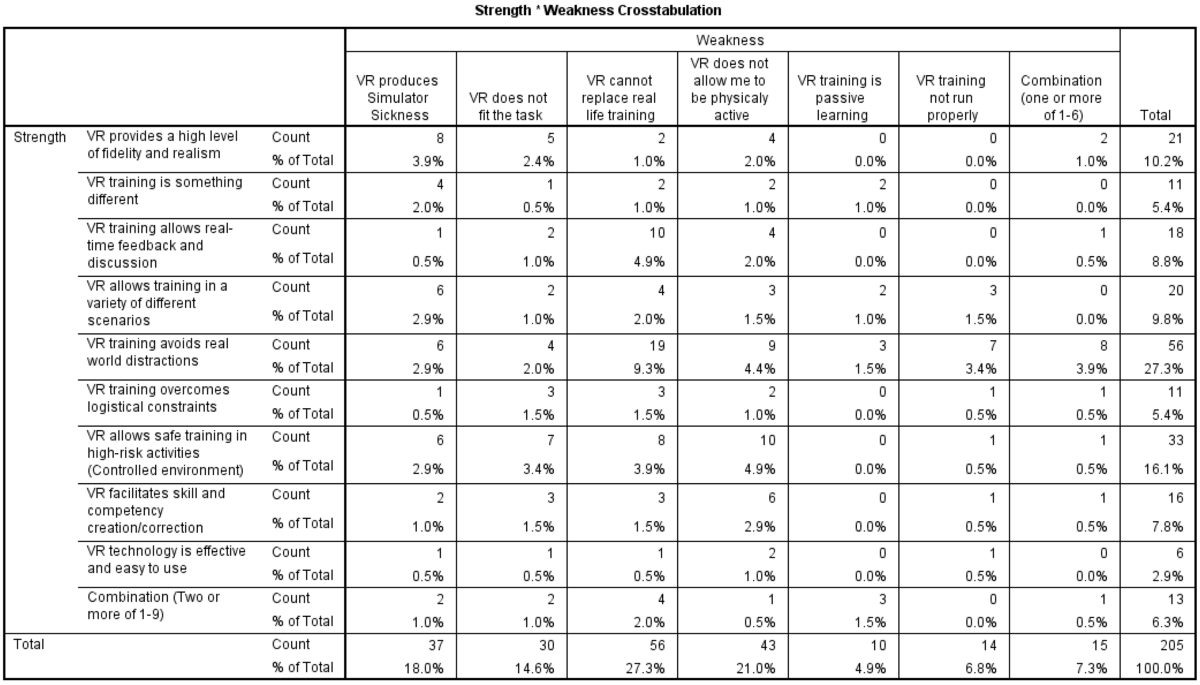
4. Appendix A.7: Cross tabulation between real life training challenges and 360-VR's weaknesses



Challenges * Weakness Crosstabulation

			Weakness							
			VR produces Simulator Sickness	VR does not fit the task	VR cannot replace real life training	VR does not allow me to be physicaly active	VR training is passive learning	VR training not run properly	Combination (one or more of 1-6)	Total
Challenges	Pit training is realistic and physically active	Count	17	19	31	27	4	5	7	110
		% of Total	8.6%	9.6%	15.7%	13.6%	2.0%	2.5%	3.5%	55.6%
	Pit training requires access and conset from mine operators	Count	0	0	6	4	0	3	1	14
		% of Total	0.0%	0.0%	3.0%	2.0%	0.0%	1.5%	0.5%	7.1%
	Pit training has logistical issues and time constraints	Count	5	5	4	3	3	2	3	25
		% of Total	2.5%	2.5%	2.0%	1.5%	1.5%	1.0%	1.5%	12.6%
	Pit training has less variety in scenarios/content	Count	3	2	1	0	1	1	1	9
		% of Total	1.5%	1.0%	0.5%	0.0%	0.5%	0.5%	0.5%	4.5%
	Pit training is not safe (It is higher risk, potentially hazardous)	Count	3	1	7	2	0	0	1	14
		% of Total	1.5%	0.5%	3.5%	1.0%	0.0%	0.0%	0.5%	7.1%
	Pit training has less review and Discussion of the training session	Count	1	0	0	1	0	0	0	2
		% of Total	0.5%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	1.0%
	Pit training engages actual resources	Count	1	0	0	3	0	0	0	4
		% of Total	0.5%	0.0%	0.0%	1.5%	0.0%	0.0%	0.0%	2.0%
	Combination (two or more of 1-7)	Count	6	4	4	3	1	1	1	20
		% of Total	3.0%	2.0%	2.0%	1.5%	0.5%	0.5%	0.5%	10.1%
Total		Count	36	31	53	43	9	12	14	198
		% of Total	18.2%	15.7%	26.8%	21.7%	4.5%	6.1%	7.1%	100.0%

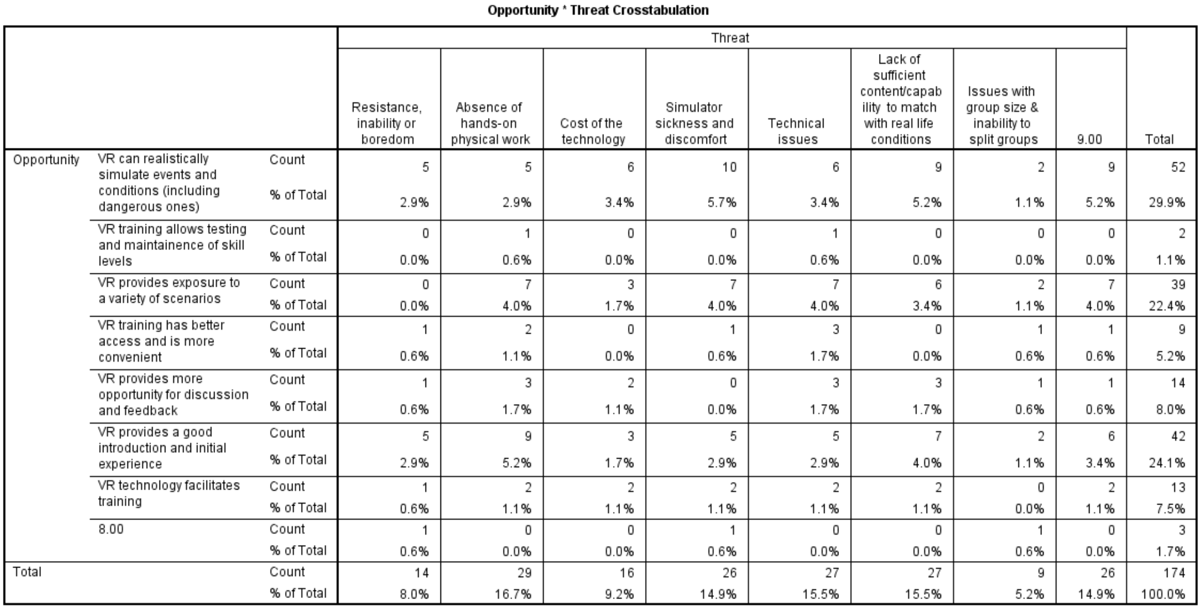
5. Appendix A.8: Cross tabulation between 360-VR's strengths and 360-VR's weaknesses



Strength * Weakness Crosstabulation

			Weakness							
			VR produces Simulator Sickness	VR does not fit the task	VR cannot replace real life training	VR does not allow me to be physicaly active	VR training is passive learning	VR training not run properly	Combination (one or more of 1-6)	Total
Strength	VR provides a high level of fidelity and realism	Count	8	5	2	4	0	0	2	21
		% of Total	3.9%	2.4%	1.0%	2.0%	0.0%	0.0%	1.0%	10.2%
	VR training is something different	Count	4	1	2	2	2	0	0	11
		% of Total	2.0%	0.5%	1.0%	1.0%	1.0%	0.0%	0.0%	5.4%
	VR training allows real-time feedback and discussion	Count	1	2	10	4	0	0	1	18
		% of Total	0.5%	1.0%	4.9%	2.0%	0.0%	0.0%	0.5%	8.8%
	VR allows training in a variety of different scenarios	Count	6	2	4	3	2	3	0	20
		% of Total	2.9%	1.0%	2.0%	1.5%	1.0%	1.5%	0.0%	9.8%
	VR training avoids real world distractions	Count	6	4	19	9	3	7	8	56
		% of Total	2.9%	2.0%	9.3%	4.4%	1.5%	3.4%	3.9%	27.3%
	VR training overcomes logistical constraints	Count	1	3	3	2	0	1	1	11
		% of Total	0.5%	1.5%	1.5%	1.0%	0.0%	0.5%	0.5%	5.4%
	VR allows safe training in high-risk activities (Controlled environment)	Count	6	7	8	10	0	1	1	33
		% of Total	2.9%	3.4%	3.9%	4.9%	0.0%	0.5%	0.5%	16.1%
	VR facilitates skill and competency creation/correction	Count	2	3	3	6	0	1	1	16
		% of Total	1.0%	1.5%	1.5%	2.9%	0.0%	0.5%	0.5%	7.8%
	VR technology is effective and easy to use	Count	1	1	1	2	0	1	0	6
		% of Total	0.5%	0.5%	0.5%	1.0%	0.0%	0.5%	0.0%	2.9%
	Combination (Two or more of 1-9)	Count	2	2	4	1	3	0	1	13
		% of Total	1.0%	1.0%	2.0%	0.5%	1.5%	0.0%	0.5%	6.3%
Total		Count	37	30	56	43	10	14	15	205
		% of Total	18.0%	14.6%	27.3%	21.0%	4.9%	6.8%	7.3%	100.0%

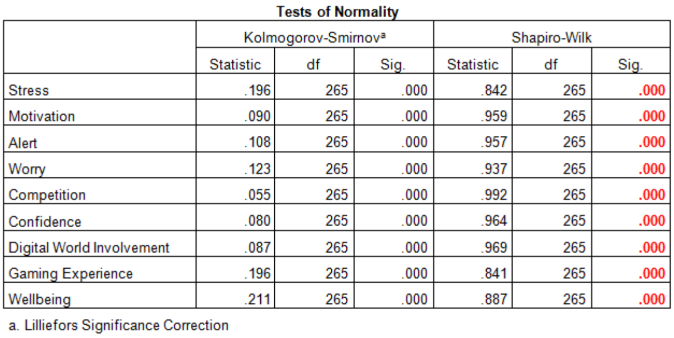
6. Appendix A.9: Cross tabulation between 360-VR’s opportunities and 360-VR’s threats



Opportunity * Threat Crosstabulation

			Threat								
			Resistance, inability or boredom	Absence of hands-on physical work	Cost of the technology	Simulator sickness and discomfort	Technical issues	Lack of sufficient content/capability to match with real life conditions	Issues with group size & inability to split groups	9.00	Total
Opportunity	VR can realistically simulate events and conditions (including dangerous ones)	Count	5	5	6	10	6	9	2	9	52
		% of Total	2.9%	2.9%	3.4%	5.7%	3.4%	5.2%	1.1%	5.2%	29.9%
	VR training allows testing and maintainence of skill levels	Count	0	1	0	0	1	0	0	0	2
		% of Total	0.0%	0.6%	0.0%	0.0%	0.6%	0.0%	0.0%	0.0%	1.1%
	VR provides exposure to a variety of scenarios	Count	0	7	3	7	7	6	2	7	39
		% of Total	0.0%	4.0%	1.7%	4.0%	4.0%	3.4%	1.1%	4.0%	22.4%
	VR training has better access and is more convenient	Count	1	2	0	1	3	0	1	1	9
		% of Total	0.6%	1.1%	0.0%	0.6%	1.7%	0.0%	0.6%	0.6%	5.2%
	VR provides more opportunity for discussion and feedback	Count	1	3	2	0	3	3	1	1	14
		% of Total	0.6%	1.7%	1.1%	0.0%	1.7%	1.7%	0.6%	0.6%	8.0%
	VR provides a good introduction and initial experience	Count	5	9	3	5	5	7	2	6	42
		% of Total	2.9%	5.2%	1.7%	2.9%	2.9%	4.0%	1.1%	3.4%	24.1%
	VR technology facilitates training	Count	1	2	2	2	2	2	0	2	13
		% of Total	0.6%	1.1%	1.1%	1.1%	1.1%	1.1%	0.0%	1.1%	7.5%
	8.00	Count	1	0	0	1	0	0	1	0	3
		% of Total	0.6%	0.0%	0.0%	0.6%	0.0%	0.0%	0.6%	0.0%	1.7%
Total		Count	14	29	16	26	27	27	9	26	174
		% of Total	8.0%	16.7%	9.2%	14.9%	15.5%	15.5%	5.2%	14.9%	100.0%

7. Appendix A.10: Normality test on pre-training factors

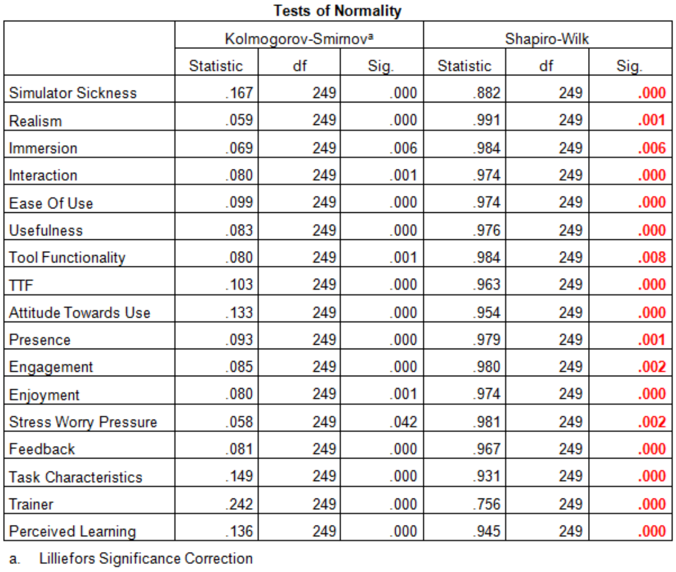


Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Stress	.196	265	.000	.842	265	.000
Motivation	.090	265	.000	.959	265	.000
Alert	.108	265	.000	.957	265	.000
Worry	.123	265	.000	.937	265	.000
Competition	.055	265	.000	.992	265	.000
Confidence	.080	265	.000	.964	265	.000
Digital World Involvement	.087	265	.000	.969	265	.000
Gaming Experience	.196	265	.000	.841	265	.000
Wellbeing	.211	265	.000	.887	265	.000

a. Lilliefors Significance Correction

8. Appendix A.11: Normality test on post-training factors

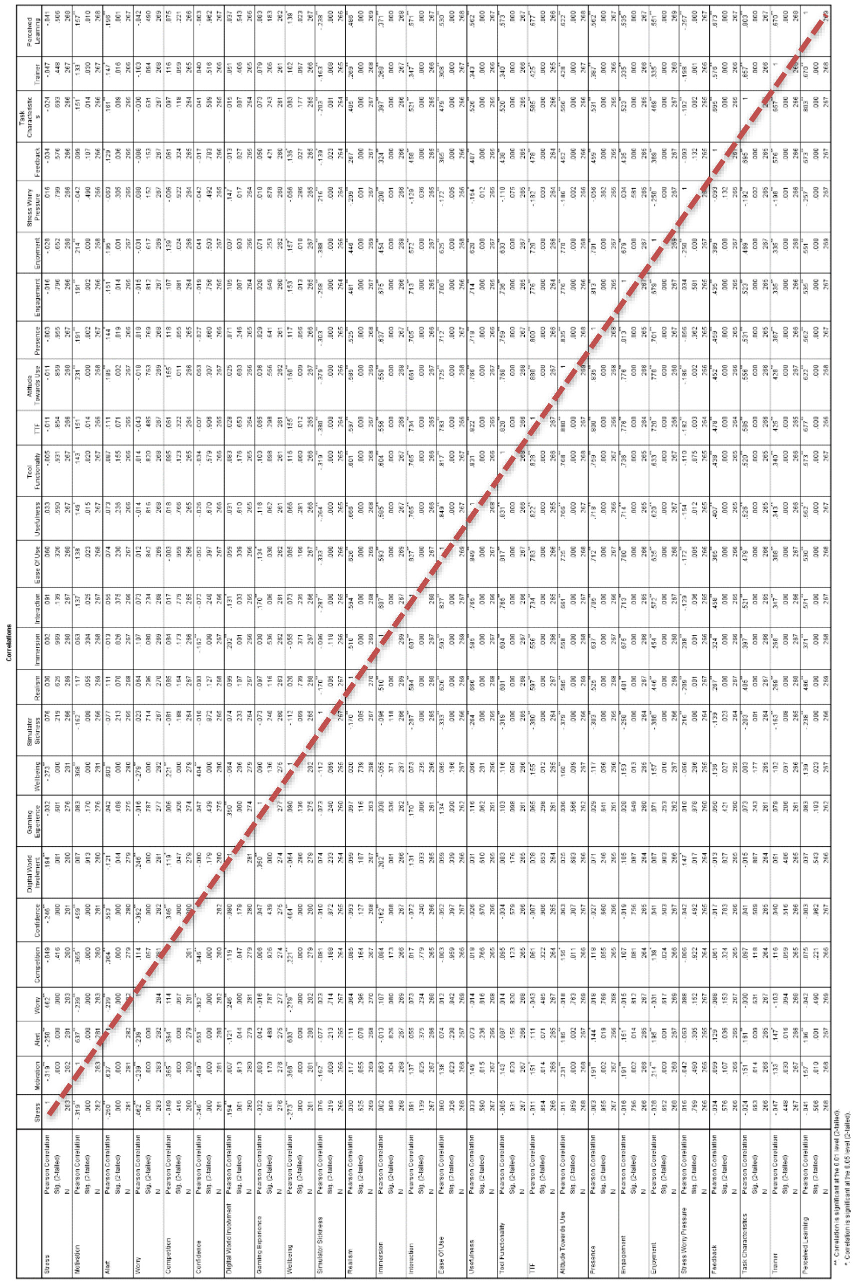


Tests of Normality

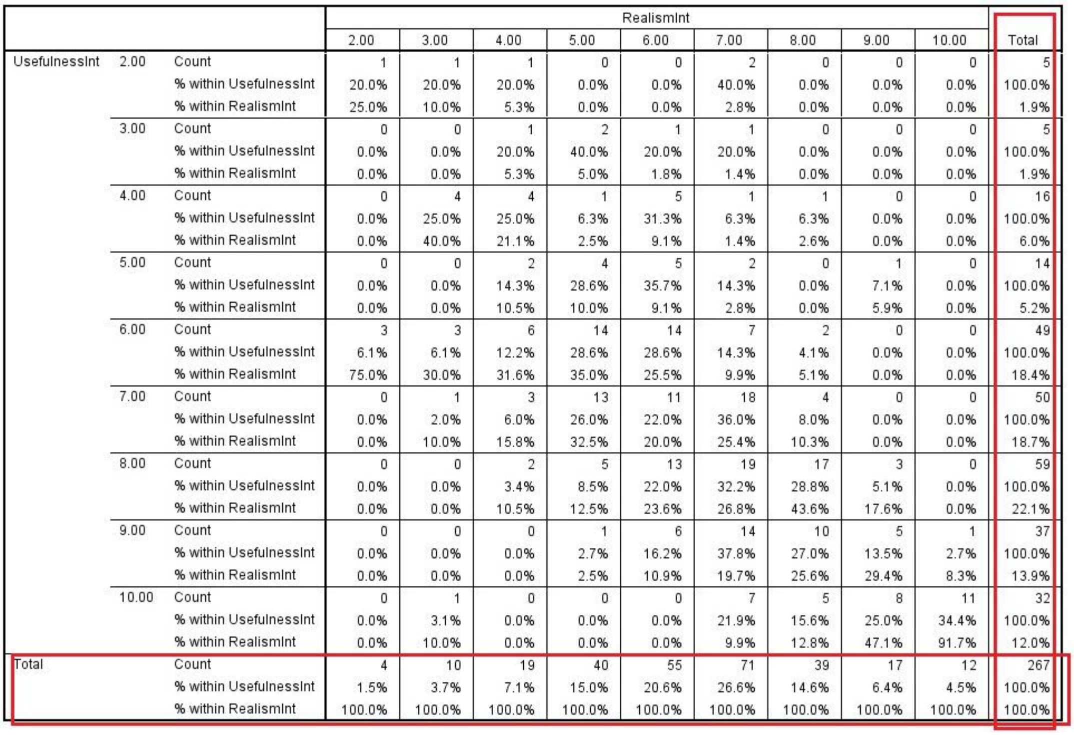
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Simulator Sickness	.167	249	.000	.882	249	.000
Realism	.059	249	.000	.991	249	.001
Immersion	.069	249	.006	.984	249	.006
Interaction	.080	249	.001	.974	249	.000
Ease Of Use	.099	249	.000	.974	249	.000
Usefulness	.083	249	.000	.976	249	.000
Tool Functionality	.080	249	.001	.984	249	.008
TTF	.103	249	.000	.963	249	.000
Attitude Towards Use	.133	249	.000	.954	249	.000
Presence	.093	249	.000	.979	249	.001
Engagement	.085	249	.000	.980	249	.002
Enjoyment	.080	249	.001	.974	249	.000
Stress Worry Pressure	.058	249	.042	.981	249	.002
Feedback	.081	249	.000	.967	249	.000
Task Characteristics	.149	249	.000	.931	249	.000
Trainer	.242	249	.000	.756	249	.000
Perceived Learning	.136	249	.000	.945	249	.000

a. Lilliefors Significance Correction

9. Appendix A.12: Correlation between Pre-training and Post-training factors (360-VR)

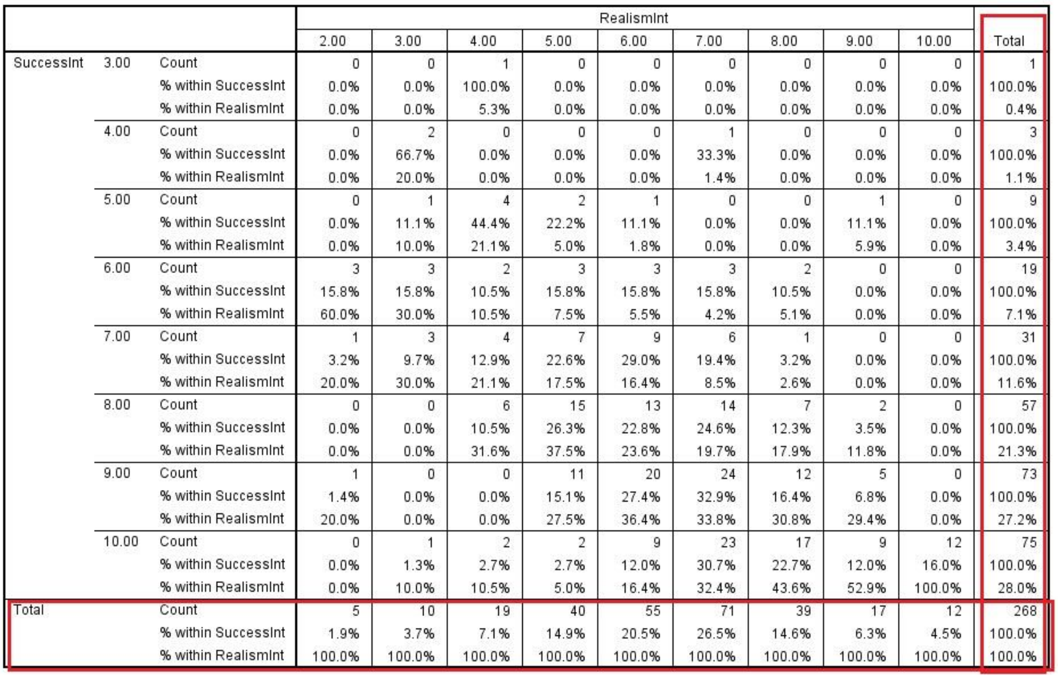


10. Appendix A.13: cross-tabulation between perceived levels of realism and usefulness (360-VR)



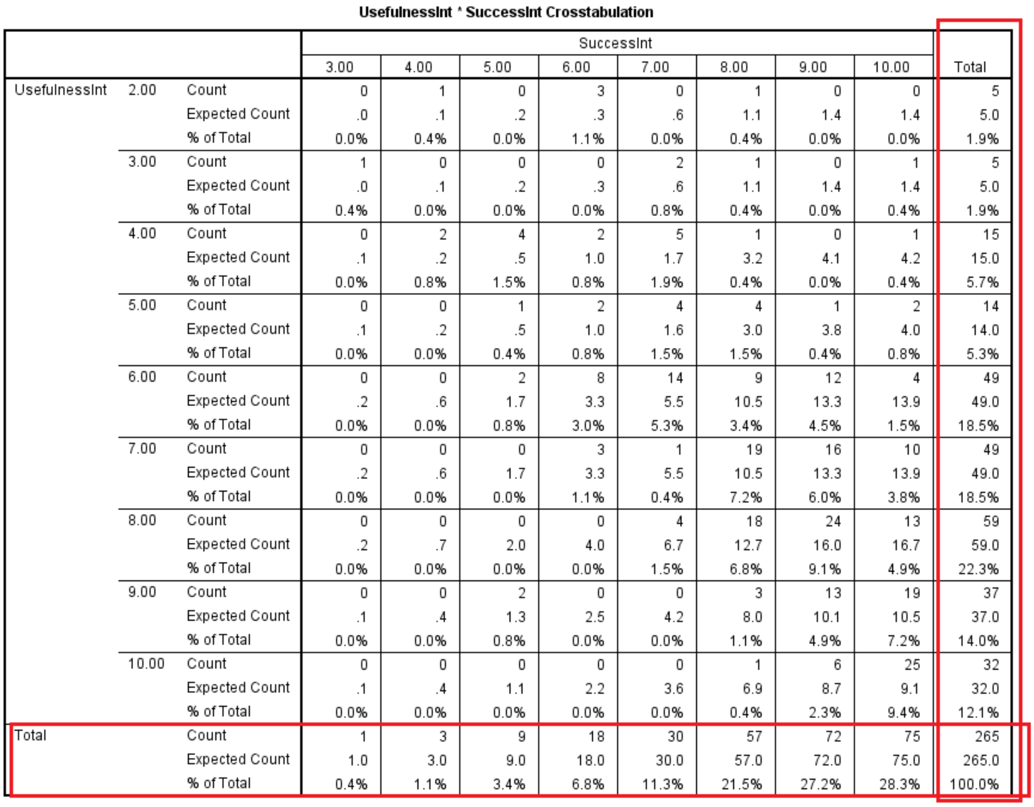
			RealismInt									
			2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	Total
UsefulnessInt	2.00	Count	1	1	1	0	0	2	0	0	0	5
		% within UsefulnessInt	20.0%	20.0%	20.0%	0.0%	0.0%	40.0%	0.0%	0.0%	0.0%	100.0%
		% within RealismInt	25.0%	10.0%	5.3%	0.0%	0.0%	2.8%	0.0%	0.0%	0.0%	1.9%
	3.00	Count	0	0	1	2	1	1	0	0	0	5
		% within UsefulnessInt	0.0%	0.0%	20.0%	40.0%	20.0%	20.0%	0.0%	0.0%	0.0%	100.0%
		% within RealismInt	0.0%	0.0%	5.3%	5.0%	1.8%	1.4%	0.0%	0.0%	0.0%	1.9%
	4.00	Count	0	4	4	1	5	1	1	0	0	16
		% within UsefulnessInt	0.0%	25.0%	25.0%	6.3%	31.3%	6.3%	6.3%	0.0%	0.0%	100.0%
		% within RealismInt	0.0%	40.0%	21.1%	2.5%	9.1%	1.4%	2.6%	0.0%	0.0%	6.0%
	5.00	Count	0	0	2	4	5	2	0	1	0	14
		% within UsefulnessInt	0.0%	0.0%	14.3%	28.6%	35.7%	14.3%	0.0%	7.1%	0.0%	100.0%
		% within RealismInt	0.0%	0.0%	10.5%	10.0%	9.1%	2.8%	0.0%	5.9%	0.0%	5.2%
	6.00	Count	3	3	6	14	14	7	2	0	0	49
		% within UsefulnessInt	6.1%	6.1%	12.2%	28.6%	28.6%	14.3%	4.1%	0.0%	0.0%	100.0%
		% within RealismInt	75.0%	30.0%	31.6%	35.0%	25.5%	9.9%	5.1%	0.0%	0.0%	18.4%
	7.00	Count	0	1	3	13	11	18	4	0	0	50
		% within UsefulnessInt	0.0%	2.0%	6.0%	26.0%	22.0%	36.0%	8.0%	0.0%	0.0%	100.0%
		% within RealismInt	0.0%	10.0%	15.8%	32.5%	20.0%	25.4%	10.3%	0.0%	0.0%	18.7%
	8.00	Count	0	0	2	5	13	19	17	3	0	59
		% within UsefulnessInt	0.0%	0.0%	3.4%	8.5%	22.0%	32.2%	28.8%	5.1%	0.0%	100.0%
		% within RealismInt	0.0%	0.0%	10.5%	12.5%	23.6%	26.8%	43.6%	17.6%	0.0%	22.1%
	9.00	Count	0	0	0	1	6	14	10	5	1	37
		% within UsefulnessInt	0.0%	0.0%	0.0%	2.7%	16.2%	37.8%	27.0%	13.5%	2.7%	100.0%
		% within RealismInt	0.0%	0.0%	0.0%	2.5%	10.9%	19.7%	25.6%	29.4%	8.3%	13.9%
	10.00	Count	0	1	0	0	0	7	5	8	11	32
		% within UsefulnessInt	0.0%	3.1%	0.0%	0.0%	0.0%	21.9%	15.6%	25.0%	34.4%	100.0%
		% within RealismInt	0.0%	10.0%	0.0%	0.0%	0.0%	9.9%	12.8%	47.1%	91.7%	12.0%
Total		Count	4	10	19	40	55	71	39	17	12	267
		% within UsefulnessInt	1.5%	3.7%	7.1%	15.0%	20.6%	26.6%	14.6%	6.4%	4.5%	100.0%
		% within RealismInt	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

11. Appendix A.14: cross-tabulation between perceived levels of realism and success (360-VR)



			RealismInt									
			2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	Total
SuccessInt	3.00	Count	0	0	1	0	0	0	0	0	0	1
		% within SuccessInt	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within RealismInt	0.0%	0.0%	5.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
	4.00	Count	0	2	0	0	0	1	0	0	0	3
		% within SuccessInt	0.0%	66.7%	0.0%	0.0%	0.0%	33.3%	0.0%	0.0%	0.0%	100.0%
		% within RealismInt	0.0%	20.0%	0.0%	0.0%	0.0%	1.4%	0.0%	0.0%	0.0%	1.1%
	5.00	Count	0	1	4	2	1	0	0	1	0	9
		% within SuccessInt	0.0%	11.1%	44.4%	22.2%	11.1%	0.0%	0.0%	11.1%	0.0%	100.0%
		% within RealismInt	0.0%	10.0%	21.1%	5.0%	1.8%	0.0%	0.0%	5.9%	0.0%	3.4%
	6.00	Count	3	3	2	3	3	3	2	0	0	19
		% within SuccessInt	15.8%	15.8%	10.5%	15.8%	15.8%	15.8%	10.5%	0.0%	0.0%	100.0%
		% within RealismInt	60.0%	30.0%	10.5%	7.5%	5.5%	4.2%	5.1%	0.0%	0.0%	7.1%
	7.00	Count	1	3	4	7	9	6	1	0	0	31
		% within SuccessInt	3.2%	9.7%	12.9%	22.6%	29.0%	19.4%	3.2%	0.0%	0.0%	100.0%
		% within RealismInt	20.0%	30.0%	21.1%	17.5%	16.4%	8.5%	2.6%	0.0%	0.0%	11.6%
	8.00	Count	0	0	6	15	13	14	7	2	0	57
		% within SuccessInt	0.0%	0.0%	10.5%	26.3%	22.8%	24.6%	12.3%	3.5%	0.0%	100.0%
		% within RealismInt	0.0%	0.0%	31.6%	37.5%	23.6%	19.7%	17.9%	11.8%	0.0%	21.3%
	9.00	Count	1	0	0	11	20	24	12	5	0	73
		% within SuccessInt	1.4%	0.0%	0.0%	15.1%	27.4%	32.9%	16.4%	6.8%	0.0%	100.0%
		% within RealismInt	20.0%	0.0%	0.0%	27.5%	36.4%	33.8%	30.8%	29.4%	0.0%	27.2%
	10.00	Count	0	1	2	2	9	23	17	9	12	75
		% within SuccessInt	0.0%	1.3%	2.7%	2.7%	12.0%	30.7%	22.7%	12.0%	16.0%	100.0%
		% within RealismInt	0.0%	10.0%	10.5%	5.0%	16.4%	32.4%	43.6%	52.9%	100.0%	28.0%
Total		Count	5	10	19	40	55	71	39	17	12	268
		% within SuccessInt	1.9%	3.7%	7.1%	14.9%	20.5%	26.5%	14.6%	6.3%	4.5%	100.0%
		% within RealismInt	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

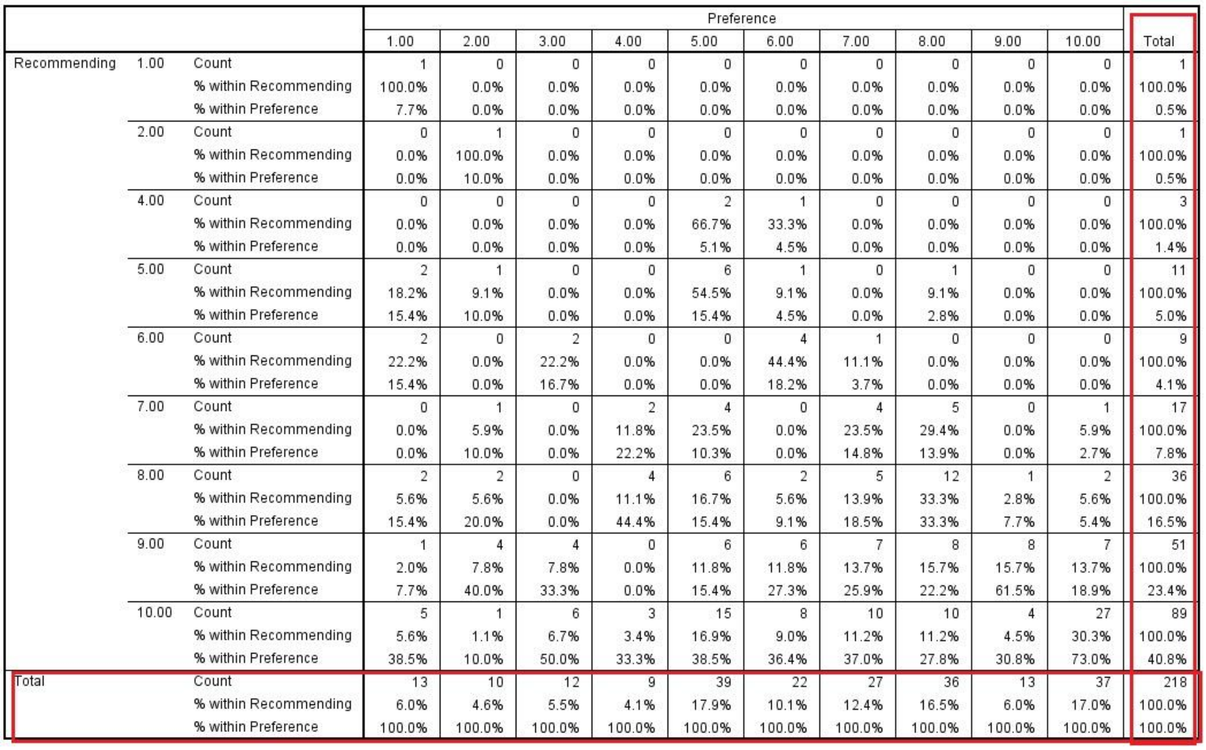
12. Appendix A.15: cross-tabulation between perceived usefulness and success (360-VR)



UsefulnessInt * SuccessInt Crosstabulation

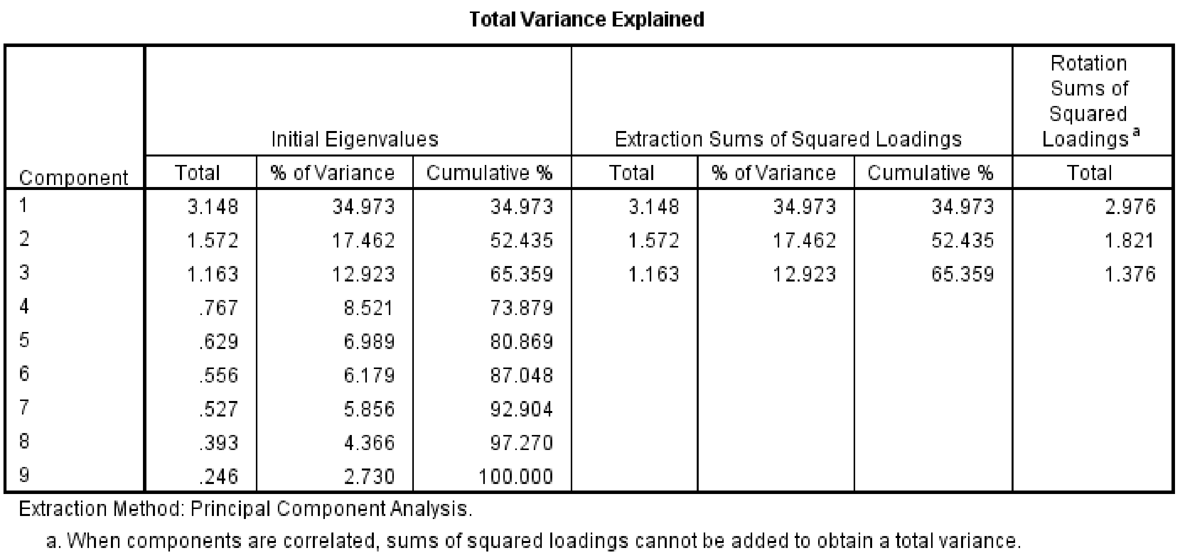
			SuccessInt								Total
			3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	
UsefulnessInt	2.00	Count	0	1	0	3	0	1	0	0	5
		Expected Count	.0	.1	.2	.3	.6	1.1	1.4	1.4	5.0
		% of Total	0.0%	0.4%	0.0%	1.1%	0.0%	0.4%	0.0%	0.0%	1.9%
	3.00	Count	1	0	0	0	2	1	0	1	5
		Expected Count	.0	.1	.2	.3	.6	1.1	1.4	1.4	5.0
		% of Total	0.4%	0.0%	0.0%	0.0%	0.8%	0.4%	0.0%	0.4%	1.9%
	4.00	Count	0	2	4	2	5	1	0	1	15
		Expected Count	.1	.2	.5	1.0	1.7	3.2	4.1	4.2	15.0
		% of Total	0.0%	0.8%	1.5%	0.8%	1.9%	0.4%	0.0%	0.4%	5.7%
	5.00	Count	0	0	1	2	4	4	1	2	14
		Expected Count	.1	.2	.5	1.0	1.6	3.0	3.8	4.0	14.0
		% of Total	0.0%	0.0%	0.4%	0.8%	1.5%	1.5%	0.4%	0.8%	5.3%
	6.00	Count	0	0	2	8	14	9	12	4	49
		Expected Count	.2	.6	1.7	3.3	5.5	10.5	13.3	13.9	49.0
		% of Total	0.0%	0.0%	0.8%	3.0%	5.3%	3.4%	4.5%	1.5%	18.5%
	7.00	Count	0	0	0	3	1	19	16	10	49
		Expected Count	.2	.6	1.7	3.3	5.5	10.5	13.3	13.9	49.0
		% of Total	0.0%	0.0%	0.0%	1.1%	0.4%	7.2%	6.0%	3.8%	18.5%
	8.00	Count	0	0	0	0	4	18	24	13	59
		Expected Count	.2	.7	2.0	4.0	6.7	12.7	16.0	16.7	59.0
		% of Total	0.0%	0.0%	0.0%	0.0%	1.5%	6.8%	9.1%	4.9%	22.3%
	9.00	Count	0	0	2	0	0	3	13	19	37
		Expected Count	.1	.4	1.3	2.5	4.2	8.0	10.1	10.5	37.0
		% of Total	0.0%	0.0%	0.8%	0.0%	0.0%	1.1%	4.9%	7.2%	14.0%
	10.00	Count	0	0	0	0	0	1	6	25	32
		Expected Count	.1	.4	1.1	2.2	3.6	6.9	8.7	9.1	32.0
		% of Total	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	2.3%	9.4%	12.1%
Total		Count	1	3	9	18	30	57	72	75	265
		Expected Count	1.0	3.0	9.0	18.0	30.0	57.0	72.0	75.0	265.0
		% of Total	0.4%	1.1%	3.4%	6.8%	11.3%	21.5%	27.2%	28.3%	100.0%

13. Appendix A.16: cross-tabulation between preference and recommendation (360-VR)



			Preference										Total
			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	
Recommending	1.00	Count	1	0	0	0	0	0	0	0	0	0	1
		% within Recommending	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within Preference	7.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%
	2.00	Count	0	1	0	0	0	0	0	0	0	0	1
		% within Recommending	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within Preference	0.0%	10.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%
	4.00	Count	0	0	0	0	2	1	0	0	0	0	3
		% within Recommending	0.0%	0.0%	0.0%	0.0%	66.7%	33.3%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within Preference	0.0%	0.0%	0.0%	0.0%	5.1%	4.5%	0.0%	0.0%	0.0%	0.0%	1.4%
	5.00	Count	2	1	0	0	6	1	0	1	0	0	11
		% within Recommending	18.2%	9.1%	0.0%	0.0%	54.5%	9.1%	0.0%	9.1%	0.0%	0.0%	100.0%
		% within Preference	15.4%	10.0%	0.0%	0.0%	15.4%	4.5%	0.0%	2.8%	0.0%	0.0%	5.0%
	6.00	Count	2	0	2	0	0	4	1	0	0	0	9
		% within Recommending	22.2%	0.0%	22.2%	0.0%	0.0%	44.4%	11.1%	0.0%	0.0%	0.0%	100.0%
		% within Preference	15.4%	0.0%	16.7%	0.0%	0.0%	18.2%	3.7%	0.0%	0.0%	0.0%	4.1%
	7.00	Count	0	1	0	2	4	0	4	5	0	1	17
		% within Recommending	0.0%	5.9%	0.0%	11.8%	23.5%	0.0%	23.5%	29.4%	0.0%	5.9%	100.0%
		% within Preference	0.0%	10.0%	0.0%	22.2%	10.3%	0.0%	14.8%	13.9%	0.0%	2.7%	7.8%
	8.00	Count	2	2	0	4	6	2	5	12	1	2	36
		% within Recommending	5.6%	5.6%	0.0%	11.1%	16.7%	5.6%	13.9%	33.3%	2.8%	5.6%	100.0%
		% within Preference	15.4%	20.0%	0.0%	44.4%	15.4%	9.1%	18.5%	33.3%	7.7%	5.4%	16.5%
	9.00	Count	1	4	4	0	6	6	7	8	8	7	51
		% within Recommending	2.0%	7.8%	7.8%	0.0%	11.8%	11.8%	13.7%	15.7%	15.7%	13.7%	100.0%
		% within Preference	7.7%	40.0%	33.3%	0.0%	15.4%	27.3%	25.9%	22.2%	61.5%	18.9%	23.4%
	10.00	Count	5	1	6	3	15	8	10	10	4	27	89
		% within Recommending	5.6%	1.1%	6.7%	3.4%	16.9%	9.0%	11.2%	11.2%	4.5%	30.3%	100.0%
		% within Preference	38.5%	10.0%	50.0%	33.3%	38.5%	36.4%	37.0%	27.8%	30.8%	73.0%	40.8%
Total		Count	13	10	12	9	39	22	27	36	13	37	218
		% within Recommending	6.0%	4.6%	5.5%	4.1%	17.9%	10.1%	12.4%	16.5%	6.0%	17.0%	100.0%
		% within Preference	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

14. Appendix A.17: Principal Component Analysis on pre-training variables (360 VR)

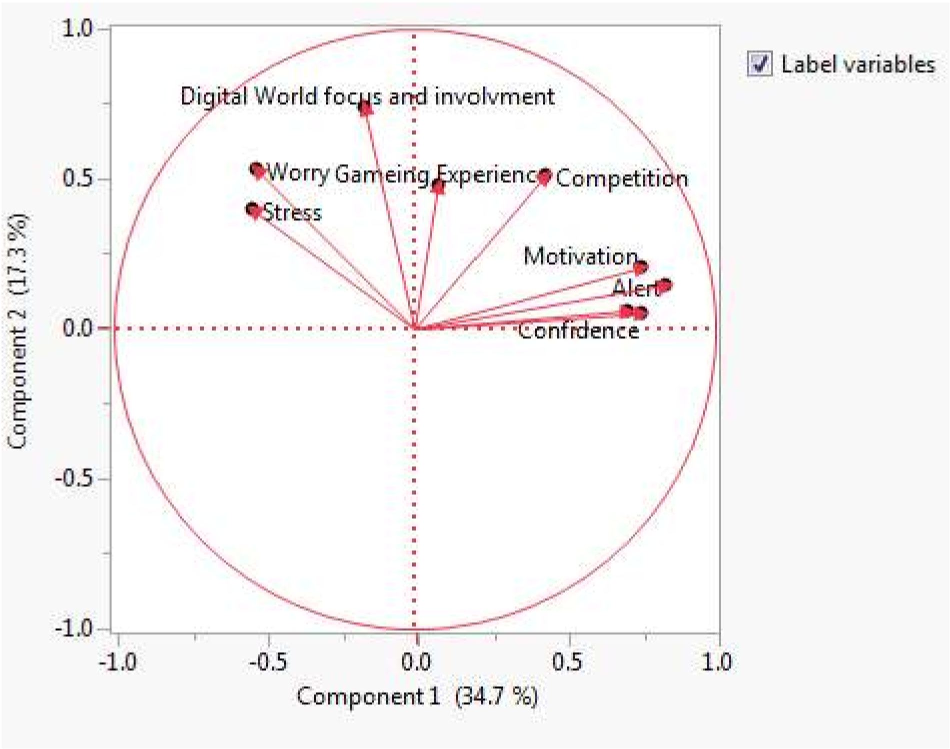


Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	3.148	34.973	34.973	3.148	34.973	34.973	2.976
2	1.572	17.462	52.435	1.572	17.462	52.435	1.821
3	1.163	12.923	65.359	1.163	12.923	65.359	1.376
4	.767	8.521	73.879				
5	.629	6.989	80.869				
6	.556	6.179	87.048				
7	.527	5.856	92.904				
8	.393	4.366	97.270				
9	.246	2.730	100.000				

Extraction Method: Principal Component Analysis.

a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.



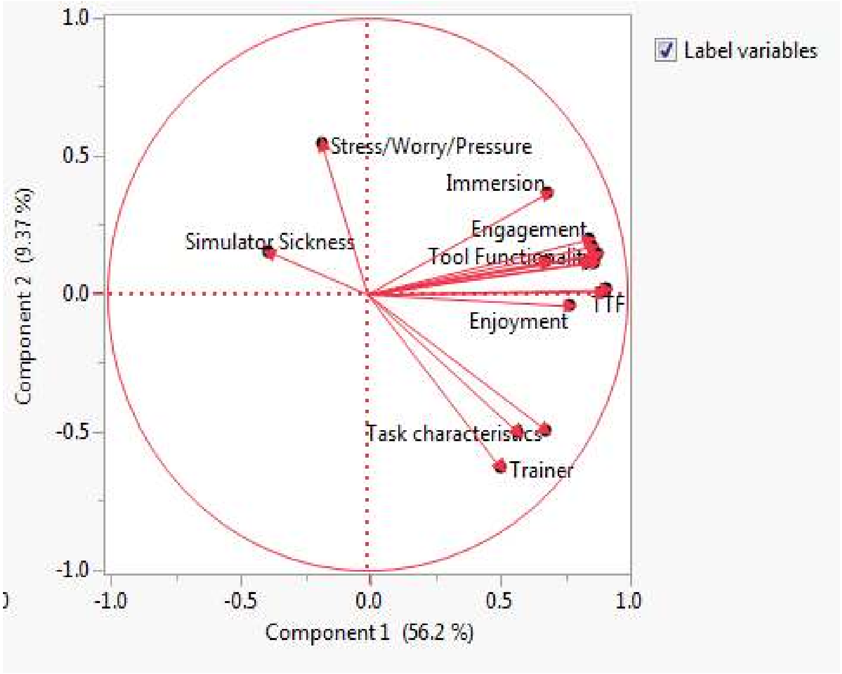
15. Appendix A.18: Principal Component Analysis on post-training variables (360 VR)

Total Variance Explained

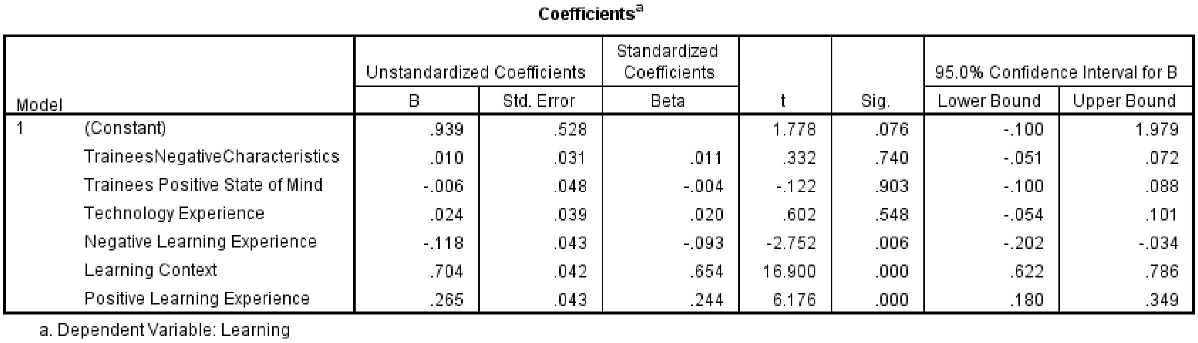
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[a]
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	8.943	55.893	55.893	8.943	55.893	55.893	8.661
2	1.494	9.340	65.232	1.494	9.340	65.232	4.485
3	1.330	8.314	73.546	1.330	8.314	73.546	1.685
4	.877	5.483	79.029				
5	.618	3.865	82.894				
6	.477	2.982	85.875				
7	.407	2.541	88.416				
8	.377	2.355	90.771				
9	.275	1.716	92.487				
10	.262	1.635	94.122				
11	.234	1.463	95.586				
12	.172	1.072	96.658				
13	.167	1.043	97.701				
14	.151	.946	98.646				
15	.123	.771	99.417				
16	.093	.583	100.000				

Extraction Method: Principal Component Analysis.

a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.



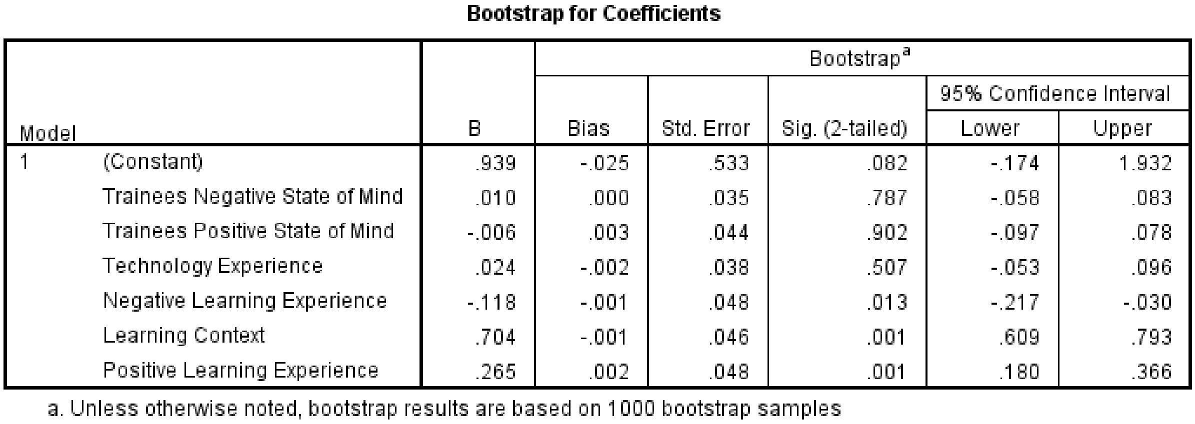
16. Appendix A.19: Linear regression between Perceived Learning and 6 aggregated variables (360 VR)



Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	.939	.528		1.778	.076	-.100	1.979
	TraineesNegativeCharacteristics	.010	.031	.011	.332	.740	-.051	.072
	Trainees Positive State of Mind	-.006	.048	-.004	-.122	.903	-.100	.088
	Technology Experience	.024	.039	.020	.602	.548	-.054	.101
	Negative Learning Experience	-.118	.043	-.093	-2.752	.006	-.202	-.034
	Learning Context	.704	.042	.654	16.900	.000	.622	.786
	Positive Learning Experience	.265	.043	.244	6.176	.000	.180	.349

a. Dependent Variable: Learning

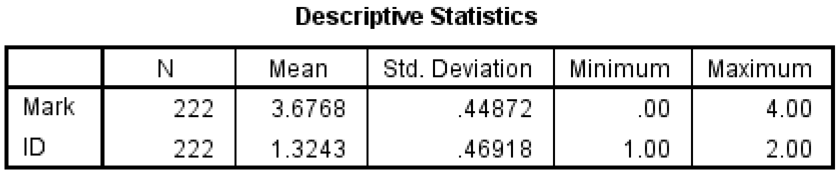


Bootstrap for Coefficients

Model		B	Bootstrap[a]				
						95% Confidence Interval	
			Bias	Std. Error	Sig. (2-tailed)	Lower	Upper
1	(Constant)	.939	-.025	.533	.082	-.174	1.932
	Trainees Negative State of Mind	.010	.000	.035	.787	-.058	.083
	Trainees Positive State of Mind	-.006	.003	.044	.902	-.097	.078
	Technology Experience	.024	-.002	.038	.507	-.053	.096
	Negative Learning Experience	-.118	-.001	.048	.013	-.217	-.030
	Learning Context	.704	-.001	.046	.001	.609	.793
	Positive Learning Experience	.265	.002	.048	.001	.180	.366

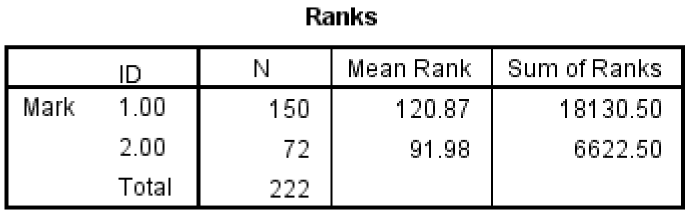
a. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

17. Appendix A.20: Competency Comparison between 360-VR attendees and control Group



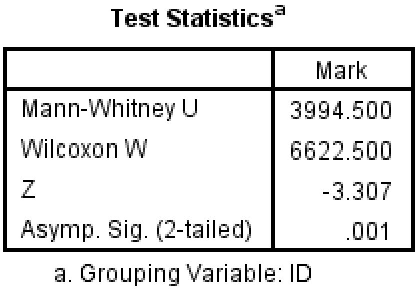
Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Mark	222	3.6768	.44872	.00	4.00
ID	222	1.3243	.46918	1.00	2.00



Ranks

	ID	N	Mean Rank	Sum of Ranks
Mark	1.00	150	120.87	18130.50
	2.00	72	91.98	6622.50
	Total	222		

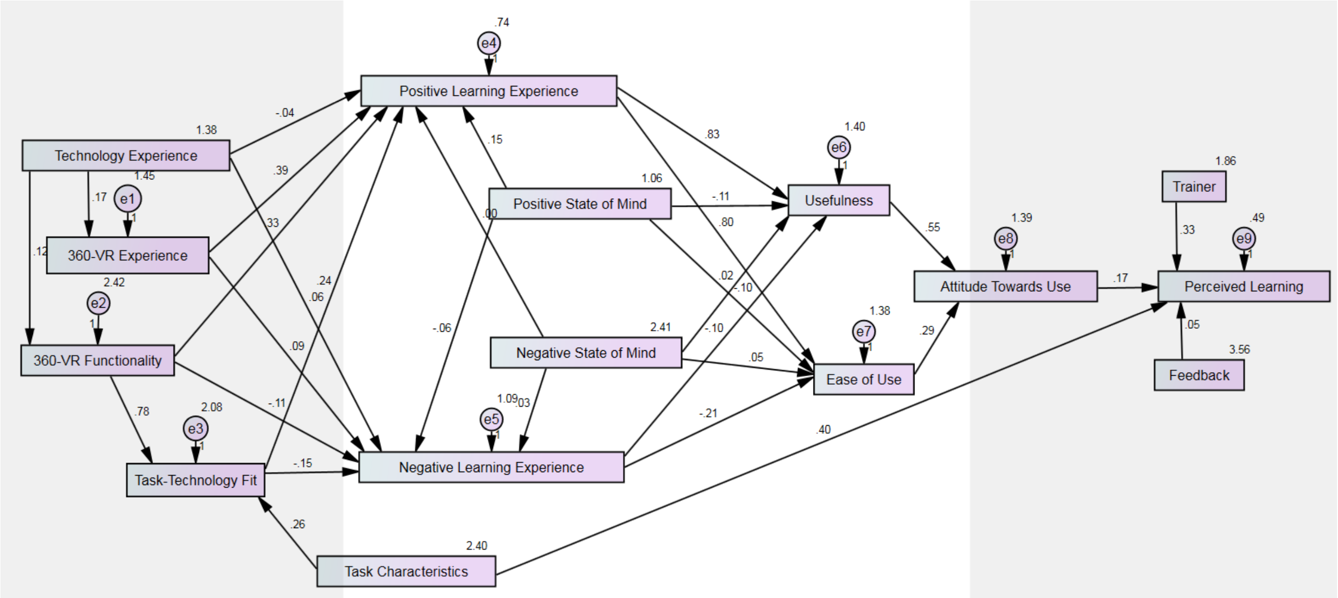


Test Statistics[a]

	Mark
Mann-Whitney U	3994.500
Wilcoxon W	6622.500
Z	-3.307
Asymp. Sig. (2-tailed)	.001

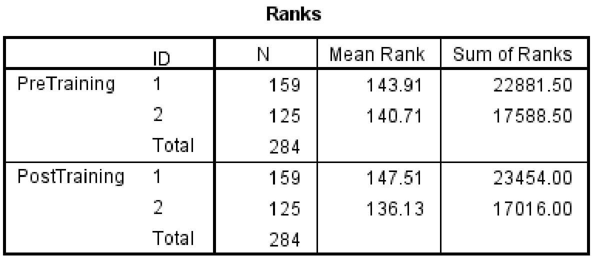
a. Grouping Variable: ID

18. Appendix A.21: Path analysis



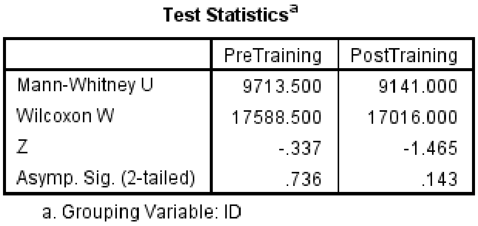
19. Appendix A.22: Mann-Whitney Test for Competency marks

- Group 1(age < 40) and Group 2(age>40)



Ranks

	ID	N	Mean Rank	Sum of Ranks
PreTraining	1	159	143.91	22881.50
	2	125	140.71	17588.50
	Total	284		
PostTraining	1	159	147.51	23454.00
	2	125	136.13	17016.00
	Total	284		

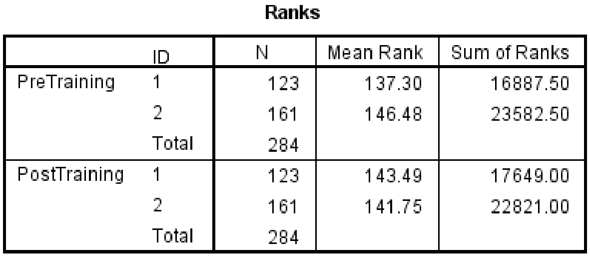


Test Statistics[a]

	PreTraining	PostTraining
Mann-Whitney U	9713.500	9141.000
Wilcoxon W	17588.500	17016.000
Z	-.337	-1.465
Asymp. Sig. (2-tailed)	.736	.143

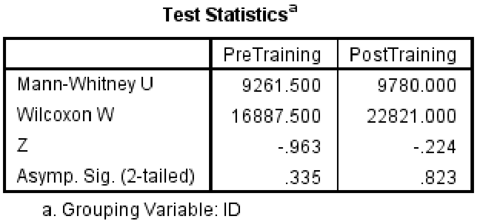
a. Grouping Variable: ID

- Group 1 (Mining Experience <10 years) and Group 2 (Mining Experience >10 years)



Ranks

	ID	N	Mean Rank	Sum of Ranks
PreTraining	1	123	137.30	16887.50
	2	161	146.48	23582.50
	Total	284		
PostTraining	1	123	143.49	17649.00
	2	161	141.75	22821.00
	Total	284		

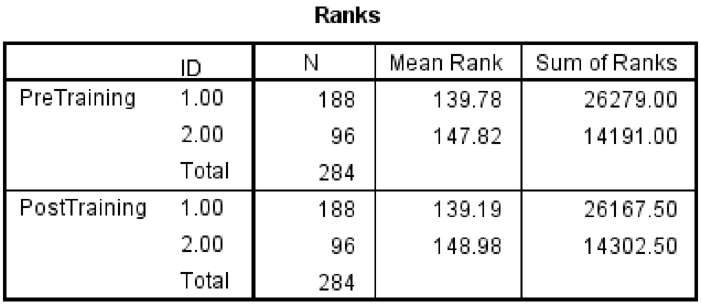


Test Statistics[a]

	PreTraining	PostTraining
Mann-Whitney U	9261.500	9780.000
Wilcoxon W	16887.500	22821.000
Z	-.963	-.224
Asymp. Sig. (2-tailed)	.335	.823

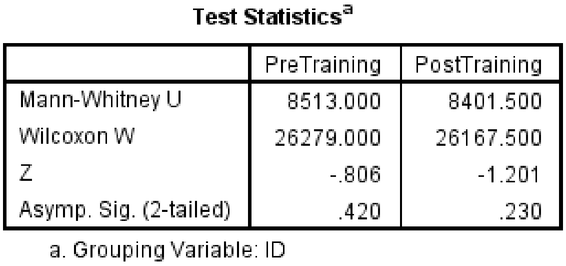
a. Grouping Variable: ID

- Group 1(Mine Rescuer <10 years) and Group 2 (Mine Rescuer >10 years)



Ranks

	ID	N	Mean Rank	Sum of Ranks
PreTraining	1.00	188	139.78	26279.00
	2.00	96	147.82	14191.00
	Total	284		
PostTraining	1.00	188	139.19	26167.50
	2.00	96	148.98	14302.50
	Total	284		

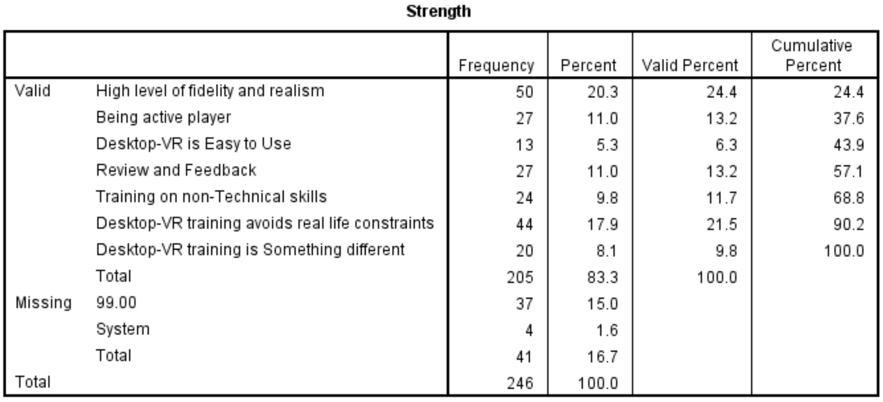


Test Statistics[a]

	PreTraining	PostTraining
Mann-Whitney U	8513.000	8401.500
Wilcoxon W	26279.000	26167.500
Z	-.806	-1.201
Asymp. Sig. (2-tailed)	.420	.230

a. Grouping Variable: ID

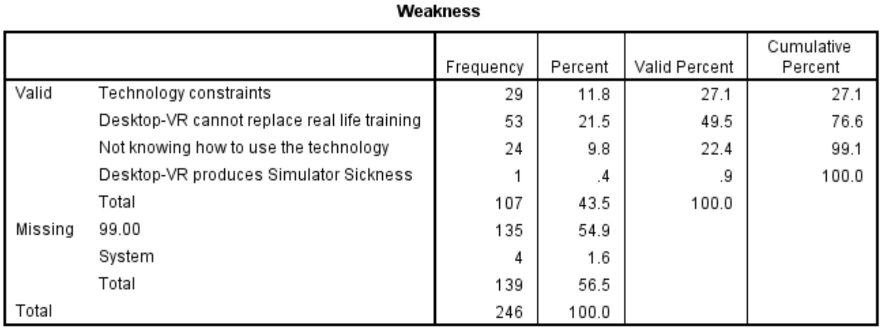
20. Appendix A.23: Frequency of VR training Strength components (SWOT analysis – trainees)



Strength

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	High level of fidelity and realism	50	20.3	24.4	24.4
	Being active player	27	11.0	13.2	37.6
	Desktop-VR is Easy to Use	13	5.3	6.3	43.9
	Review and Feedback	27	11.0	13.2	57.1
	Training on non-Technical skills	24	9.8	11.7	68.8
	Desktop-VR training avoids real life constraints	44	17.9	21.5	90.2
	Desktop-VR training is Something different	20	8.1	9.8	100.0
	Total	205	83.3	100.0	
Missing	99.00	37	15.0		
	System	4	1.6		
	Total	41	16.7		
Total		246	100.0		

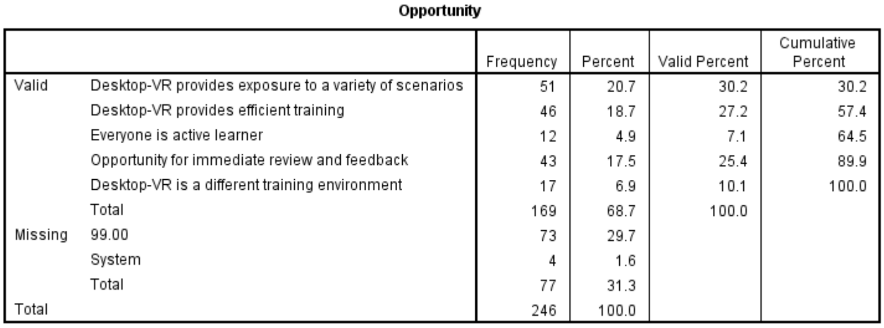
21. Appendix 24: Frequency of VR training Weakness components (SWOT analysis – trainees)



Weakness

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Technology constraints	29	11.8	27.1	27.1
	Desktop-VR cannot replace real life training	53	21.5	49.5	76.6
	Not knowing how to use the technology	24	9.8	22.4	99.1
	Desktop-VR produces Simulator Sickness	1	.4	.9	100.0
	Total	107	43.5	100.0	
Missing	99.00	135	54.9		
	System	4	1.6		
	Total	139	56.5		
Total		246	100.0		

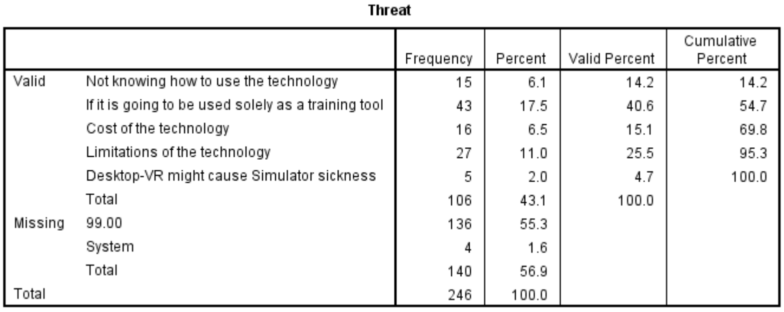
22. Appendix 25: Frequency of VR training Opportunity components (SWOT analysis – trainees)



Opportunity

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Desktop-VR provides exposure to a variety of scenarios	51	20.7	30.2	30.2
	Desktop-VR provides efficient training	46	18.7	27.2	57.4
	Everyone is active learner	12	4.9	7.1	64.5
	Opportunity for immediate review and feedback	43	17.5	25.4	89.9
	Desktop-VR is a different training environment	17	6.9	10.1	100.0
	Total	169	68.7	100.0	
Missing	99.00	73	29.7		
	System	4	1.6		
	Total	77	31.3		
Total		246	100.0		

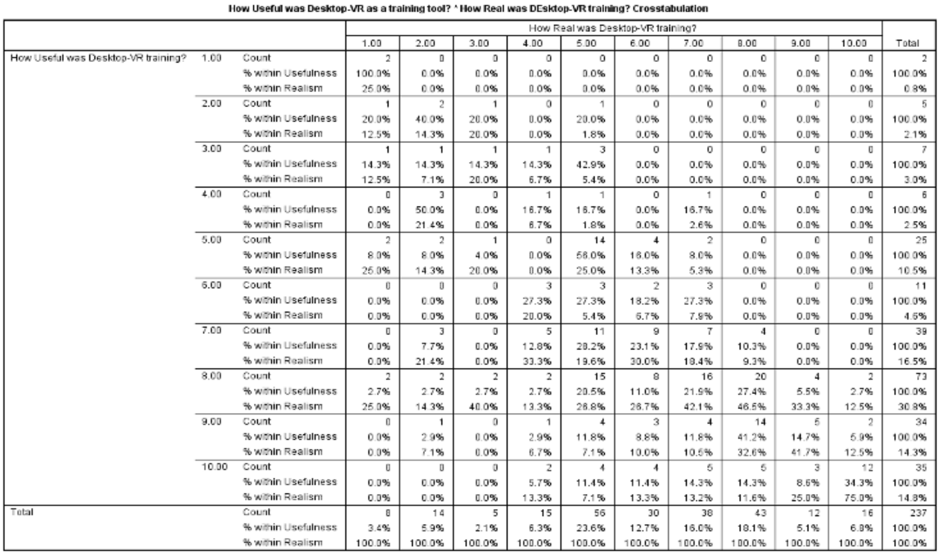
23. Appendix A.26: Frequency of VR training Threat components (SWOT analysis – trainees)



Threat

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not knowing how to use the technology	15	6.1	14.2	14.2
	If it is going to be used solely as a training tool	43	17.5	40.6	54.7
	Cost of the technology	16	6.5	15.1	69.8
	Limitations of the technology	27	11.0	25.5	95.3
	Desktop-VR might cause Simulator sickness	5	2.0	4.7	100.0
	Total	106	43.1	100.0	
Missing	99.00	136	55.3		
	System	4	1.6		
	Total	140	56.9		
Total		246	100.0		

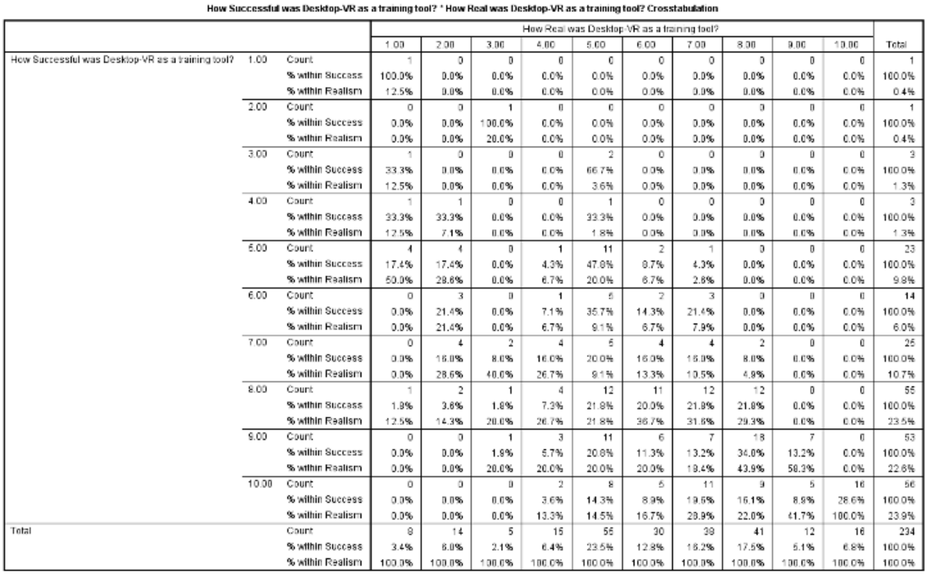
Appendix A.27: cross-tabulation between perceived levels of realism and usefulness (Desktop-VR)



How Useful was Desktop-VR as a training tool? * How Real was DEsktop-VR training? Crosstabulation

			How Real was Desktop-VR training?										Total
			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	
How Useful was Desktop-VR training?	1.00	Count	2	0	0	0	0	0	0	0	0	0	2
		% within Usefulness	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within Realism	25.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%
	2.00	Count	1	2	1	0	1	0	0	0	0	0	5
		% within Usefulness	20.0%	40.0%	20.0%	0.0%	20.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within Realism	12.5%	14.3%	20.0%	0.0%	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	2.1%
	3.00	Count	1	1	1	1	3	0	0	0	0	0	7
		% within Usefulness	14.3%	14.3%	14.3%	14.3%	42.9%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within Realism	12.5%	7.1%	20.0%	6.7%	5.4%	0.0%	0.0%	0.0%	0.0%	0.0%	3.0%
	4.00	Count	0	3	0	1	1	0	1	0	0	0	6
		% within Usefulness	0.0%	50.0%	0.0%	16.7%	16.7%	0.0%	16.7%	0.0%	0.0%	0.0%	100.0%
		% within Realism	0.0%	21.4%	0.0%	6.7%	1.8%	0.0%	2.6%	0.0%	0.0%	0.0%	2.5%
	5.00	Count	2	2	1	0	14	4	2	0	0	0	25
		% within Usefulness	8.0%	8.0%	4.0%	0.0%	56.0%	16.0%	8.0%	0.0%	0.0%	0.0%	100.0%
		% within Realism	25.0%	14.3%	20.0%	0.0%	25.0%	13.3%	5.3%	0.0%	0.0%	0.0%	10.5%
	6.00	Count	0	0	0	3	3	2	3	0	0	0	11
		% within Usefulness	0.0%	0.0%	0.0%	27.3%	27.3%	18.2%	27.3%	0.0%	0.0%	0.0%	100.0%
		% within Realism	0.0%	0.0%	0.0%	20.0%	5.4%	6.7%	7.9%	0.0%	0.0%	0.0%	4.6%
	7.00	Count	0	3	0	5	11	9	7	4	0	0	39
		% within Usefulness	0.0%	7.7%	0.0%	12.8%	28.2%	23.1%	17.9%	10.3%	0.0%	0.0%	100.0%
		% within Realism	0.0%	21.4%	0.0%	33.3%	19.6%	30.0%	18.4%	9.3%	0.0%	0.0%	16.5%
	8.00	Count	2	2	2	2	15	8	16	20	4	2	73
		% within Usefulness	2.7%	2.7%	2.7%	2.7%	20.5%	11.0%	21.9%	27.4%	5.5%	2.7%	100.0%
		% within Realism	25.0%	14.3%	40.0%	13.3%	26.8%	26.7%	42.1%	46.5%	33.3%	12.5%	30.8%
	9.00	Count	0	1	0	1	4	3	4	14	5	2	34
		% within Usefulness	0.0%	2.9%	0.0%	2.9%	11.8%	8.8%	11.8%	41.2%	14.7%	5.9%	100.0%
		% within Realism	0.0%	7.1%	0.0%	6.7%	7.1%	10.0%	10.5%	32.6%	41.7%	12.5%	14.3%
	10.00	Count	0	0	0	2	4	4	5	5	3	12	35
		% within Usefulness	0.0%	0.0%	0.0%	5.7%	11.4%	11.4%	14.3%	14.3%	8.6%	34.3%	100.0%
		% within Realism	0.0%	0.0%	0.0%	13.3%	7.1%	13.3%	13.2%	11.6%	25.0%	75.0%	14.8%
Total		Count	8	14	5	15	56	30	38	43	12	16	237
		% within Usefulness	3.4%	5.9%	2.1%	6.3%	23.6%	12.7%	16.0%	18.1%	5.1%	6.8%	100.0%
		% within Realism	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

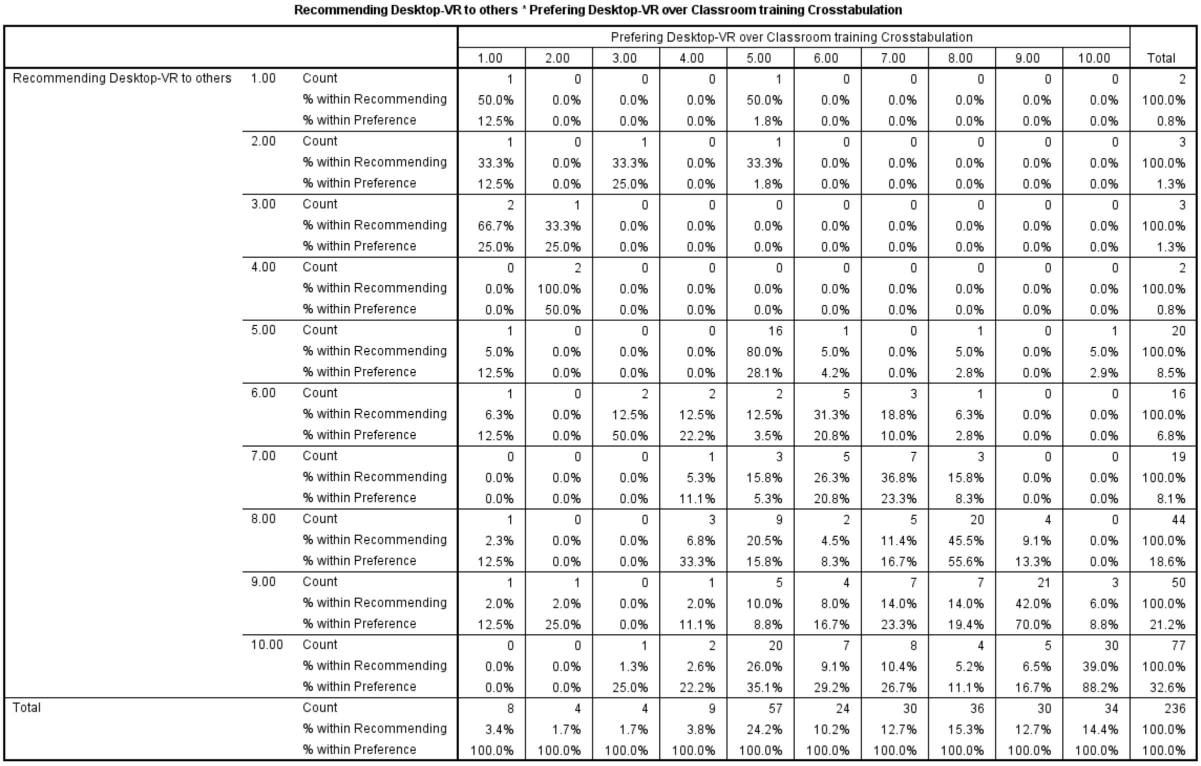
Appendix A.28: cross-tabulation between perceived levels of realism and Success (Desktop-VR)



How Successful was Desktop-VR as a training tool? * How Real was Desktop-VR as a training tool? Crosstabulation

			How Real was Desktop-VR as a training tool?										Total
			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	
How Successful was Desktop-VR as a training tool?	1.00	Count	1	0	0	0	0	0	0	0	0	0	1
		% within Success	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within Realism	12.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
	2.00	Count	0	0	1	0	0	0	0	0	0	0	1
		% within Success	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within Realism	0.0%	0.0%	20.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
	3.00	Count	1	0	0	0	2	0	0	0	0	0	3
		% within Success	33.3%	0.0%	0.0%	0.0%	66.7%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within Realism	12.5%	0.0%	0.0%	0.0%	3.6%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%
	4.00	Count	1	1	0	0	1	0	0	0	0	0	3
		% within Success	33.3%	33.3%	0.0%	0.0%	33.3%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within Realism	12.5%	7.1%	0.0%	0.0%	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%
	5.00	Count	4	4	0	1	11	2	1	0	0	0	23
		% within Success	17.4%	17.4%	0.0%	4.3%	47.8%	8.7%	4.3%	0.0%	0.0%	0.0%	100.0%
		% within Realism	50.0%	28.6%	0.0%	6.7%	20.0%	6.7%	2.6%	0.0%	0.0%	0.0%	9.8%
	6.00	Count	0	3	0	1	5	2	3	0	0	0	14
		% within Success	0.0%	21.4%	0.0%	7.1%	35.7%	14.3%	21.4%	0.0%	0.0%	0.0%	100.0%
		% within Realism	0.0%	21.4%	0.0%	6.7%	9.1%	6.7%	7.9%	0.0%	0.0%	0.0%	6.0%
	7.00	Count	0	4	2	4	5	4	4	2	0	0	25
		% within Success	0.0%	16.0%	8.0%	16.0%	20.0%	16.0%	16.0%	8.0%	0.0%	0.0%	100.0%
		% within Realism	0.0%	28.6%	40.0%	26.7%	9.1%	13.3%	10.5%	4.9%	0.0%	0.0%	10.7%
	8.00	Count	1	2	1	4	12	11	12	12	0	0	55
		% within Success	1.8%	3.6%	1.8%	7.3%	21.8%	20.0%	21.8%	21.8%	0.0%	0.0%	100.0%
		% within Realism	12.5%	14.3%	20.0%	26.7%	21.8%	36.7%	31.6%	29.3%	0.0%	0.0%	23.5%
	9.00	Count	0	0	1	3	11	6	7	18	7	0	53
		% within Success	0.0%	0.0%	1.9%	5.7%	20.8%	11.3%	13.2%	34.0%	13.2%	0.0%	100.0%
		% within Realism	0.0%	0.0%	20.0%	20.0%	20.0%	20.0%	18.4%	43.9%	58.3%	0.0%	22.6%
	10.00	Count	0	0	0	2	8	5	11	9	5	16	56
		% within Success	0.0%	0.0%	0.0%	3.6%	14.3%	8.9%	19.6%	16.1%	8.9%	28.6%	100.0%
		% within Realism	0.0%	0.0%	0.0%	13.3%	14.5%	16.7%	28.9%	22.0%	41.7%	100.0%	23.9%
Total		Count	8	14	5	15	55	30	38	41	12	16	234
		% within Success	3.4%	6.0%	2.1%	6.4%	23.5%	12.8%	16.2%	17.5%	5.1%	6.8%	100.0%
		% within Realism	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

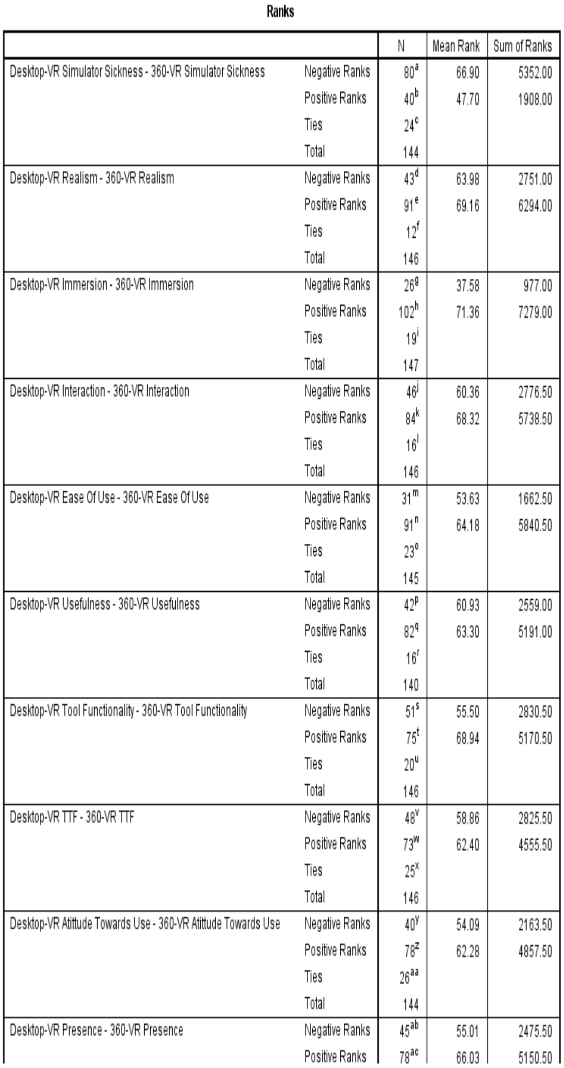
24. Appendix A.29: cross-tabulation between Recommendation and Preference (Desktop-VR)



Recommending Desktop-VR to others * Prefering Desktop-VR over Classroom training Crosstabulation

			Prefering Desktop-VR over Classroom training Crosstabulation										Total
			1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	
Recommending Desktop-VR to others	1.00	Count	1	0	0	0	1	0	0	0	0	0	2
		% within Recommending	50.0%	0.0%	0.0%	0.0%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within Preference	12.5%	0.0%	0.0%	0.0%	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%
	2.00	Count	1	0	1	0	1	0	0	0	0	0	3
		% within Recommending	33.3%	0.0%	33.3%	0.0%	33.3%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within Preference	12.5%	0.0%	25.0%	0.0%	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%
	3.00	Count	2	1	0	0	0	0	0	0	0	0	3
		% within Recommending	66.7%	33.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within Preference	25.0%	25.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%
	4.00	Count	0	2	0	0	0	0	0	0	0	0	2
		% within Recommending	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within Preference	0.0%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%
	5.00	Count	1	0	0	0	16	1	0	1	0	1	20
		% within Recommending	5.0%	0.0%	0.0%	0.0%	80.0%	5.0%	0.0%	5.0%	0.0%	5.0%	100.0%
		% within Preference	12.5%	0.0%	0.0%	0.0%	28.1%	4.2%	0.0%	2.8%	0.0%	2.9%	8.5%
	6.00	Count	1	0	2	2	2	5	3	1	0	0	16
		% within Recommending	6.3%	0.0%	12.5%	12.5%	12.5%	31.3%	18.8%	6.3%	0.0%	0.0%	100.0%
		% within Preference	12.5%	0.0%	50.0%	22.2%	3.5%	20.8%	10.0%	2.8%	0.0%	0.0%	6.8%
	7.00	Count	0	0	0	1	3	5	7	3	0	0	19
		% within Recommending	0.0%	0.0%	0.0%	5.3%	15.8%	26.3%	36.8%	15.8%	0.0%	0.0%	100.0%
		% within Preference	0.0%	0.0%	0.0%	11.1%	5.3%	20.8%	23.3%	8.3%	0.0%	0.0%	8.1%
	8.00	Count	1	0	0	3	9	2	5	20	4	0	44
		% within Recommending	2.3%	0.0%	0.0%	6.8%	20.5%	4.5%	11.4%	45.5%	9.1%	0.0%	100.0%
		% within Preference	12.5%	0.0%	0.0%	33.3%	15.8%	8.3%	16.7%	55.6%	13.3%	0.0%	18.6%
	9.00	Count	1	1	0	1	5	4	7	7	21	3	50
		% within Recommending	2.0%	2.0%	0.0%	2.0%	10.0%	8.0%	14.0%	14.0%	42.0%	6.0%	100.0%
		% within Preference	12.5%	25.0%	0.0%	11.1%	8.8%	16.7%	23.3%	19.4%	70.0%	8.8%	21.2%
	10.00	Count	0	0	1	2	20	7	8	4	5	30	77
		% within Recommending	0.0%	0.0%	1.3%	2.6%	26.0%	9.1%	10.4%	5.2%	6.5%	39.0%	100.0%
		% within Preference	0.0%	0.0%	25.0%	22.2%	35.1%	29.2%	26.7%	11.1%	16.7%	88.2%	32.6%
Total		Count	8	4	4	9	57	24	30	36	30	34	236
		% within Recommending	3.4%	1.7%	1.7%	3.8%	24.2%	10.2%	12.7%	15.3%	12.7%	14.4%	100.0%
		% within Preference	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

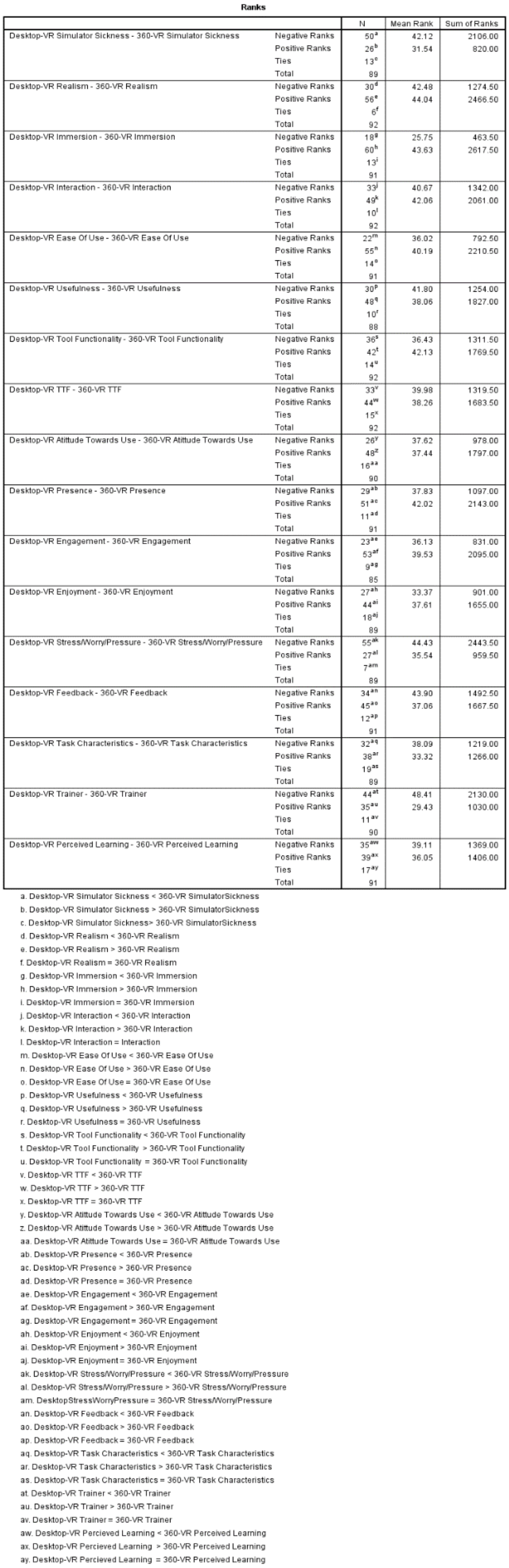
25. Appendix A.30: Rank Table comparing responses from 360 VR and Desktop VR training sessions



Ranks

		N	Mean Rank	Sum of Ranks
Desktop-VR Simulator Sickness - 360-VR Simulator Sickness	Negative Ranks	80[a]	66.90	5352.00
	Positive Ranks	40[b]	47.70	1908.00
	Ties	24[c]		
	Total	144		
Desktop-VR Realism - 360-VR Realism	Negative Ranks	43[d]	63.98	2751.00
	Positive Ranks	91[e]	69.16	6294.00
	Ties	12[f]		
	Total	146		
Desktop-VR Immersion - 360-VR Immersion	Negative Ranks	26[g]	37.58	977.00
	Positive Ranks	102[h]	71.36	7279.00
	Ties	19[i]		
	Total	147		
Desktop-VR Interaction - 360-VR Interaction	Negative Ranks	46[j]	60.36	2776.50
	Positive Ranks	84[k]	68.32	5738.50
	Ties	16[l]		
	Total	146		
Desktop-VR Ease Of Use - 360-VR Ease Of Use	Negative Ranks	31[m]	53.63	1662.50
	Positive Ranks	91[n]	64.18	5840.50
	Ties	23[o]		
	Total	145		
Desktop-VR Usefulness - 360-VR Usefulness	Negative Ranks	42[p]	60.93	2559.00
	Positive Ranks	82[q]	63.30	5191.00
	Ties	16[r]		
	Total	140		
Desktop-VR Tool Functionality - 360-VR Tool Functionality	Negative Ranks	51[s]	55.50	2830.50
	Positive Ranks	75[t]	68.94	5170.50
	Ties	20[u]		
	Total	146		
Desktop-VR TTF - 360-VR TTF	Negative Ranks	48[v]	58.86	2825.50
	Positive Ranks	73[w]	62.40	4555.50
	Ties	25[x]		
	Total	146		
Desktop-VR Atittude Towards Use - 360-VR Atittude Towards Use	Negative Ranks	40[y]	54.09	2163.50
	Positive Ranks	78[z]	62.28	4857.50
	Ties	26[aa]		
	Total	144		
Desktop-VR Presence - 360-VR Presence	Negative Ranks	45[ab]	55.01	2475.50
	Positive Ranks	78[ac]	66.03	5150.50

- Trainees with less than 10 years of Experience



Ranks

		N	Mean Rank	Sum of Ranks
Desktop-VR Simulator Sickness - 360-VR Simulator Sickness	Negative Ranks	50[a]	42.12	2106.00
	Positive Ranks	26[b]	31.54	820.00
	Ties	13[c]		
	Total	89		
Desktop-VR Realism - 360-VR Realism	Negative Ranks	30[d]	42.48	1274.50
	Positive Ranks	56[e]	44.04	2466.50
	Ties	6[f]		
	Total	92		
Desktop-VR Immersion - 360-VR Immersion	Negative Ranks	18[g]	25.75	463.50
	Positive Ranks	60[h]	43.63	2617.50
	Ties	13[i]		
	Total	91		
Desktop-VR Interaction - 360-VR Interaction	Negative Ranks	33[j]	40.67	1342.00
	Positive Ranks	49[k]	42.06	2061.00
	Ties	10[l]		
	Total	92		
Desktop-VR Ease Of Use - 360-VR Ease Of Use	Negative Ranks	22[m]	36.02	792.50
	Positive Ranks	55[n]	40.19	2210.50
	Ties	14[o]		
	Total	91		
Desktop-VR Usefulness - 360-VR Usefulness	Negative Ranks	30[p]	41.80	1254.00
	Positive Ranks	48[q]	38.06	1827.00
	Ties	10[r]		
	Total	88		
Desktop-VR Tool Functionality - 360-VR Tool Functionality	Negative Ranks	36[s]	36.43	1311.50
	Positive Ranks	42[t]	42.13	1769.50
	Ties	14[u]		
	Total	92		
Desktop-VR TTF - 360-VR TTF	Negative Ranks	33[v]	39.98	1319.50
	Positive Ranks	44[w]	38.26	1683.50
	Ties	15[x]		
	Total	92		
Desktop-VR Atittude Towards Use - 360-VR Atittude Towards Use	Negative Ranks	26[y]	37.62	978.00
	Positive Ranks	48[z]	37.44	1797.00
	Ties	16[aa]		
	Total	90		
Desktop-VR Presence - 360-VR Presence	Negative Ranks	29[ab]	37.83	1097.00
	Positive Ranks	51[ac]	42.02	2143.00
	Ties	11[ad]		
	Total	91		
Desktop-VR Engagement - 360-VR Engagement	Negative Ranks	23[ae]	36.13	831.00
	Positive Ranks	53[af]	39.53	2095.00
	Ties	9[ag]		
	Total	85		
Desktop-VR Enjoyment - 360-VR Enjoyment	Negative Ranks	27[ah]	33.37	901.00
	Positive Ranks	44[ai]	37.61	1655.00
	Ties	18[aj]		
	Total	89		
Desktop-VR Stress/Worry/Pressure - 360-VR Stress/Worry/Pressure	Negative Ranks	55[ak]	44.43	2443.50
	Positive Ranks	27[al]	35.54	959.50
	Ties	7[am]		
	Total	89		
Desktop-VR Feedback - 360-VR Feedback	Negative Ranks	34[an]	43.90	1492.50
	Positive Ranks	45[ao]	37.06	1667.50
	Ties	12[ap]		
	Total	91		
Desktop-VR Task Characteristics - 360-VR Task Characteristics	Negative Ranks	32[aq]	38.09	1219.00
	Positive Ranks	38[ar]	33.32	1266.00
	Ties	19[as]		
	Total	89		
Desktop-VR Trainer - 360-VR Trainer	Negative Ranks	44[at]	48.41	2130.00
	Positive Ranks	35[au]	29.43	1030.00
	Ties	11[av]		
	Total	90		
Desktop-VR Perceived Learning - 360-VR Perceived Learning	Negative Ranks	35[aw]	39.11	1369.00
	Positive Ranks	39[ax]	36.05	1406.00
	Ties	17[ay]		
	Total	91		

a. Desktop-VR Simulator Sickness < 360-VR SimulatorSickness
b. Desktop-VR Simulator Sickness > 360-VR SimulatorSickness
c. Desktop-VR Simulator Sickness> 360-VR SimulatorSickness
d. Desktop-VR Realism < 360-VR Realism
e. Desktop-VR Realism > 360-VR Realism
f. Desktop-VR Realism = 360-VR Realism
g. Desktop-VR Immersion < 360-VR Immersion
h. Desktop-VR Immersion > 360-VR Immersion
i. Desktop-VR Immersion = 360-VR Immersion
j. Desktop-VR Interaction < 360-VR Interaction
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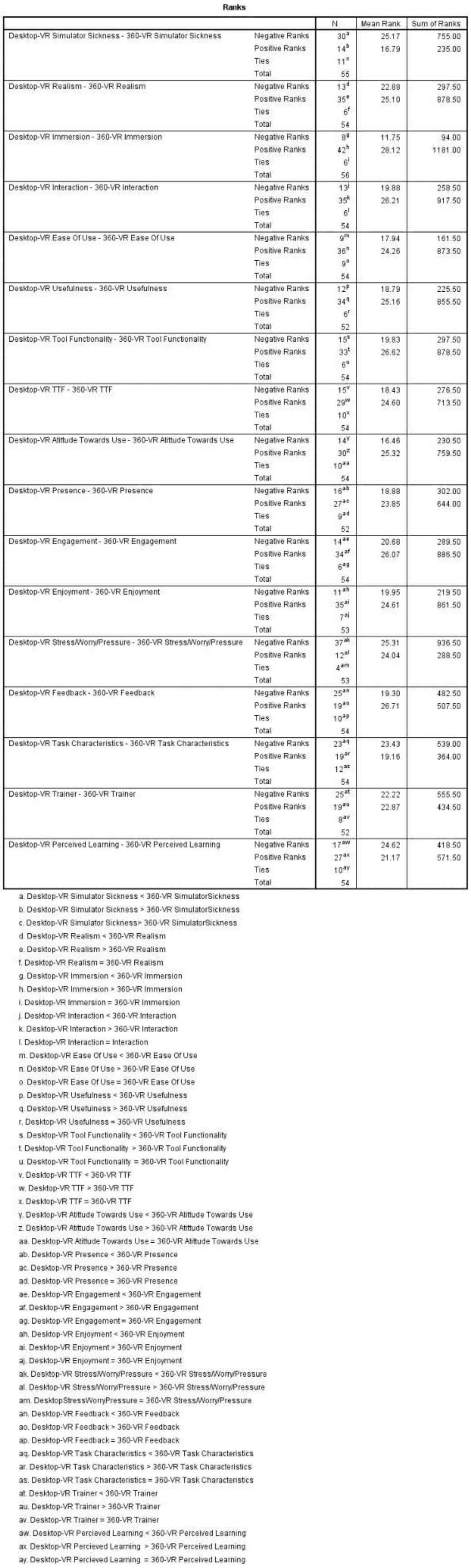
aw. Desktop-VR Percieved Learning < 360-VR Perceived Learning
ax. Desktop-VR Percieved Learning > 360-VR Perceived Learning
ay. Desktop-VR Percieved Learning = 360-VR Perceived Learning

- Trainees with more than 10 years of Experience



Ranks

		N	Mean Rank	Sum of Ranks
Desktop-VR Simulator Sickness - 360-VR Simulator Sickness	Negative Ranks	30[a]	25.17	755.00
	Positive Ranks	14[b]	16.79	235.00
	Ties	11[c]		
	Total	55		
Desktop-VR Realism - 360-VR Realism	Negative Ranks	13[d]	22.88	297.50
	Positive Ranks	35[e]	25.10	878.50
	Ties	6[f]		
	Total	54		
Desktop-VR Immersion - 360-VR Immersion	Negative Ranks	8[g]	11.75	94.00
	Positive Ranks	42[h]	28.12	1181.00
	Ties	6[i]		
	Total	56		
Desktop-VR Interaction - 360-VR Interaction	Negative Ranks	13[j]	19.88	258.50
	Positive Ranks	35[k]	26.21	917.50
	Ties	6[l]		
	Total	54		
Desktop-VR Ease Of Use - 360-VR Ease Of Use	Negative Ranks	9[m]	17.94	161.50
	Positive Ranks	36[n]	24.26	873.50
	Ties	9[o]		
	Total	54		
Desktop-VR Usefulness - 360-VR Usefulness	Negative Ranks	12[p]	18.79	225.50
	Positive Ranks	34[q]	25.16	855.50
	Ties	6[r]		
	Total	52		
Desktop-VR Tool Functionality - 360-VR Tool Functionality	Negative Ranks	15[s]	19.83	297.50
	Positive Ranks	33[t]	26.62	878.50
	Ties	6[u]		
	Total	54		
Desktop-VR TTF - 360-VR TTF	Negative Ranks	15[v]	18.43	276.50
	Positive Ranks	29[w]	24.60	713.50
	Ties	10[x]		
	Total	54		
Desktop-VR Atittude Towards Use - 360-VR Atittude Towards Use	Negative Ranks	14[y]	16.46	230.50
	Positive Ranks	30[z]	25.32	759.50
	Ties	10[aa]		
	Total	54		
Desktop-VR Presence - 360-VR Presence	Negative Ranks	16[ab]	18.88	302.00
	Positive Ranks	27[ac]	23.85	644.00
	Ties	9[ad]		
	Total	52		
Desktop-VR Engagement - 360-VR Engagement	Negative Ranks	14[ae]	20.68	289.50
	Positive Ranks	34[af]	26.07	886.50
	Ties	6[ag]		
	Total	54		
Desktop-VR Enjoyment - 360-VR Enjoyment	Negative Ranks	11[ah]	19.95	219.50
	Positive Ranks	35[ai]	24.61	861.50
	Ties	7[aj]		
	Total	53		
Desktop-VR Stress/Worry/Pressure - 360-VR Stress/Worry/Pressure	Negative Ranks	37[ak]	25.31	936.50
	Positive Ranks	12[al]	24.04	288.50
	Ties	4[am]		
	Total	53		
Desktop-VR Feedback - 360-VR Feedback	Negative Ranks	25[an]	19.30	482.50
	Positive Ranks	19[ao]	26.71	507.50
	Ties	10[ap]		
	Total	54		
Desktop-VR Task Characteristics - 360-VR Task Characteristics	Negative Ranks	23[aq]	23.43	539.00
	Positive Ranks	19[ar]	19.16	364.00
	Ties	12[as]		
	Total	54		
Desktop-VR Trainer - 360-VR Trainer	Negative Ranks	25[at]	22.22	555.50
	Positive Ranks	19[au]	22.87	434.50
	Ties	8[av]		
	Total	52		
Desktop-VR Perceived Learning - 360-VR Perceived Learning	Negative Ranks	17[aw]	24.62	418.50
	Positive Ranks	27[ax]	21.17	571.50
	Ties	10[ay]		
	Total	54		

a. Desktop-VR Simulator Sickness < 360-VR SimulatorSickness
b. Desktop-VR Simulator Sickness > 360-VR SimulatorSickness
c. Desktop-VR Simulator Sickness> 360-VR SimulatorSickness
d. Desktop-VR Realism < 360-VR Realism
e. Desktop-VR Realism > 360-VR Realism
f. Desktop-VR Realism = 360-VR Realism
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k. Desktop-VR Interaction > 360-VR Interaction
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n. Desktop-VR Ease Of Use > 360-VR Ease Of Use
o. Desktop-VR Ease Of Use = 360-VR Ease Of Use
p. Desktop-VR Usefulness < 360-VR Usefulness
q. Desktop-VR Usefulness > 360-VR Usefulness
r. Desktop-VR Usefulness = 360-VR Usefulness
s. Desktop-VR Tool Functionality < 360-VR Tool Functionality
t. Desktop-VR Tool Functionality > 360-VR Tool Functionality
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v. Desktop-VR TTF < 360-VR TTF
w. Desktop-VR TTF > 360-VR TTF
x. Desktop-VR TTF = 360-VR TTF
y. Desktop-VR Atittude Towards Use < 360-VR Atittude Towards Use
z. Desktop-VR Atittude Towards Use > 360-VR Atittude Towards Use
aa. Desktop-VR Atittude Towards Use = 360-VR Atittude Towards Use
ab. Desktop-VR Presence < 360-VR Presence
ac. Desktop-VR Presence > 360-VR Presence
ad. Desktop-VR Presence = 360-VR Presence
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ah. Desktop-VR Enjoyment < 360-VR Enjoyment
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av. Desktop-VR Trainer = 360-VR Trainer
aw. Desktop-VR Percieved Learning < 360-VR Perceived Learning
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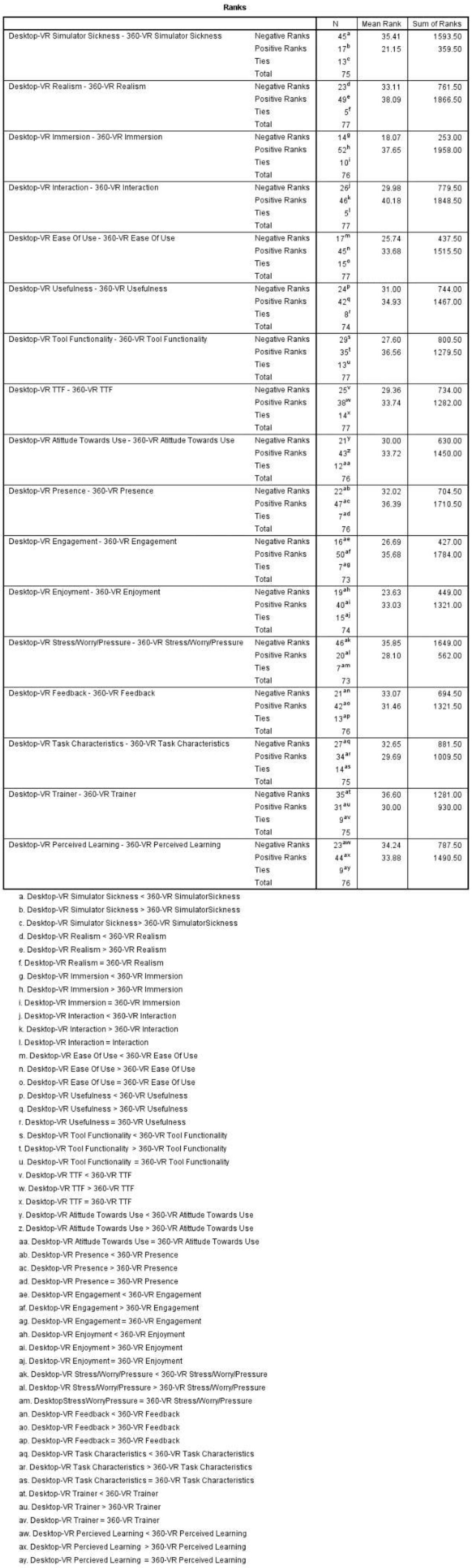
ay. Desktop-VR Percieved Learning = 360-VR Perceived Learning

- Trainees with age less than 40 years old



Ranks

		N	Mean Rank	Sum of Ranks
Desktop-VR Simulator Sickness - 360-VR Simulator Sickness	Negative Ranks	45[a]	35.41	1593.50
	Positive Ranks	17[b]	21.15	359.50
	Ties	13[c]		
	Total	75		
Desktop-VR Realism - 360-VR Realism	Negative Ranks	23[d]	33.11	761.50
	Positive Ranks	49[e]	38.09	1866.50
	Ties	5[f]		
	Total	77		
Desktop-VR Immersion - 360-VR Immersion	Negative Ranks	14[g]	18.07	253.00
	Positive Ranks	52[h]	37.65	1958.00
	Ties	10[i]		
	Total	76		
Desktop-VR Interaction - 360-VR Interaction	Negative Ranks	26[j]	29.98	779.50
	Positive Ranks	46[k]	40.18	1848.50
	Ties	5[l]		
	Total	77		
Desktop-VR Ease Of Use - 360-VR Ease Of Use	Negative Ranks	17[m]	25.74	437.50
	Positive Ranks	45[n]	33.68	1515.50
	Ties	15[o]		
	Total	77		
Desktop-VR Usefulness - 360-VR Usefulness	Negative Ranks	24[p]	31.00	744.00
	Positive Ranks	42[q]	34.93	1467.00
	Ties	8[r]		
	Total	74		
Desktop-VR Tool Functionality - 360-VR Tool Functionality	Negative Ranks	29[s]	27.60	800.50
	Positive Ranks	35[t]	36.56	1279.50
	Ties	13[u]		
	Total	77		
Desktop-VR TTF - 360-VR TTF	Negative Ranks	25[v]	29.36	734.00
	Positive Ranks	38[w]	33.74	1282.00
	Ties	14[x]		
	Total	77		
Desktop-VR Atittude Towards Use - 360-VR Atittude Towards Use	Negative Ranks	21[y]	30.00	630.00
	Positive Ranks	43[z]	33.72	1450.00
	Ties	12[aa]		
	Total	76		
Desktop-VR Presence - 360-VR Presence	Negative Ranks	22[ab]	32.02	704.50
	Positive Ranks	47[ac]	36.39	1710.50
	Ties	7[ad]		
	Total	76		
Desktop-VR Engagement - 360-VR Engagement	Negative Ranks	16[ae]	26.69	427.00
	Positive Ranks	50[af]	35.68	1784.00
	Ties	7[ag]		
	Total	73		
Desktop-VR Enjoyment - 360-VR Enjoyment	Negative Ranks	19[ah]	23.63	449.00
	Positive Ranks	40[ai]	33.03	1321.00
	Ties	15[aj]		
	Total	74		
Desktop-VR Stress/Worry/Pressure - 360-VR Stress/Worry/Pressure	Negative Ranks	46[ak]	35.85	1649.00
	Positive Ranks	20[al]	28.10	562.00
	Ties	7[am]		
	Total	73		
Desktop-VR Feedback - 360-VR Feedback	Negative Ranks	21[an]	33.07	694.50
	Positive Ranks	42[ao]	31.46	1321.50
	Ties	13[ap]		
	Total	76		
Desktop-VR Task Characteristics - 360-VR Task Characteristics	Negative Ranks	27[aq]	32.65	881.50
	Positive Ranks	34[ar]	29.69	1009.50
	Ties	14[as]		
	Total	75		
Desktop-VR Trainer - 360-VR Trainer	Negative Ranks	35[at]	36.60	1281.00
	Positive Ranks	31[au]	30.00	930.00
	Ties	9[av]		
	Total	75		
Desktop-VR Perceived Learning - 360-VR Perceived Learning	Negative Ranks	23[aw]	34.24	787.50
	Positive Ranks	44[ax]	33.88	1490.50
	Ties	9[ay]		
	Total	76		

a. Desktop-VR Simulator Sickness < 360-VR SimulatorSickness
b. Desktop-VR Simulator Sickness > 360-VR SimulatorSickness
c. Desktop-VR Simulator Sickness> 360-VR SimulatorSickness
d. Desktop-VR Realism < 360-VR Realism
e. Desktop-VR Realism > 360-VR Realism
f. Desktop-VR Realism = 360-VR Realism
g. Desktop-VR Immersion < 360-VR Immersion
h. Desktop-VR Immersion > 360-VR Immersion
i. Desktop-VR Immersion = 360-VR Immersion
j. Desktop-VR Interaction < 360-VR Interaction
k. Desktop-VR Interaction > 360-VR Interaction
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m. Desktop-VR Ease Of Use < 360-VR Ease Of Use
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o. Desktop-VR Ease Of Use = 360-VR Ease Of Use
p. Desktop-VR Usefulness < 360-VR Usefulness
q. Desktop-VR Usefulness > 360-VR Usefulness
r. Desktop-VR Usefulness = 360-VR Usefulness
s. Desktop-VR Tool Functionality < 360-VR Tool Functionality
t. Desktop-VR Tool Functionality > 360-VR Tool Functionality
u. Desktop-VR Tool Functionality = 360-VR Tool Functionality
v. Desktop-VR TTF < 360-VR TTF
w. Desktop-VR TTF > 360-VR TTF
x. Desktop-VR TTF = 360-VR TTF
y. Desktop-VR Atittude Towards Use < 360-VR Atittude Towards Use
z. Desktop-VR Atittude Towards Use > 360-VR Atittude Towards Use
aa. Desktop-VR Atittude Towards Use = 360-VR Atittude Towards Use
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ah. Desktop-VR Enjoyment < 360-VR Enjoyment
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aw. Desktop-VR Percieved Learning < 360-VR Perceived Learning
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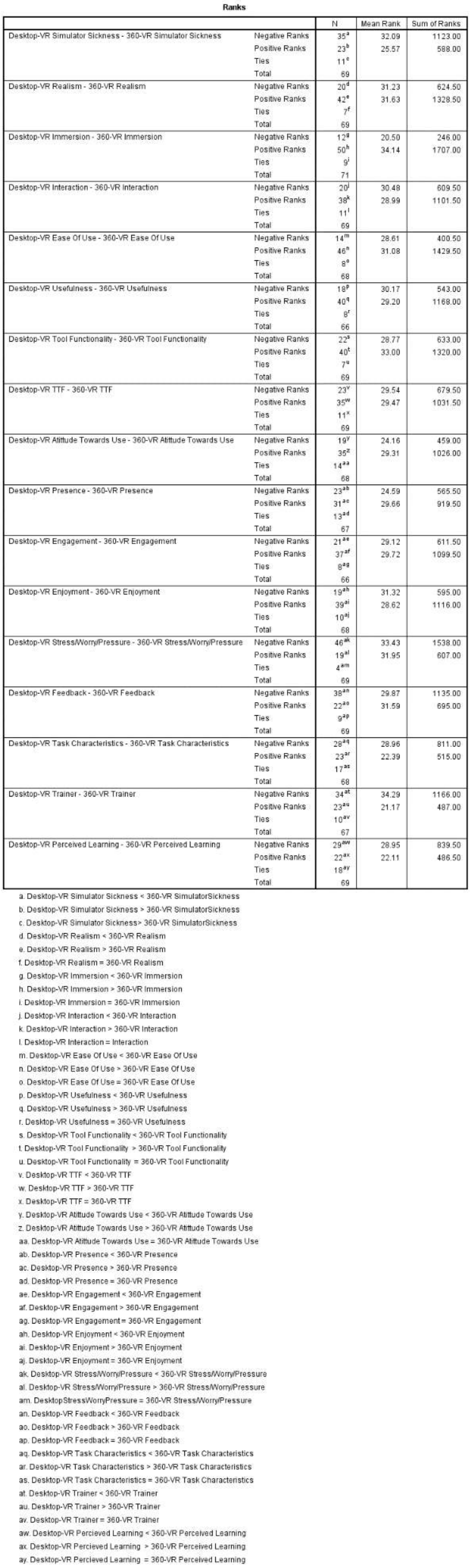
- Trainees with age more than 40 years old



Ranks

		N	Mean Rank	Sum of Ranks
Desktop-VR Simulator Sickness - 360-VR Simulator Sickness	Negative Ranks	35[a]	32.09	1123.00
	Positive Ranks	23[b]	25.57	588.00
	Ties	11[c]		
	Total	69		
Desktop-VR Realism - 360-VR Realism	Negative Ranks	20[d]	31.23	624.50
	Positive Ranks	42[e]	31.63	1328.50
	Ties	7[f]		
	Total	69		
Desktop-VR Immersion - 360-VR Immersion	Negative Ranks	12[g]	20.50	246.00
	Positive Ranks	50[h]	34.14	1707.00
	Ties	9[i]		
	Total	71		
Desktop-VR Interaction - 360-VR Interaction	Negative Ranks	20[j]	30.48	609.50
	Positive Ranks	38[k]	28.99	1101.50
	Ties	11[l]		
	Total	69		
Desktop-VR Ease Of Use - 360-VR Ease Of Use	Negative Ranks	14[m]	28.61	400.50
	Positive Ranks	46[n]	31.08	1429.50
	Ties	8[o]		
	Total	68		
Desktop-VR Usefulness - 360-VR Usefulness	Negative Ranks	18[p]	30.17	543.00
	Positive Ranks	40[q]	29.20	1168.00
	Ties	8[r]		
	Total	66		
Desktop-VR Tool Functionality - 360-VR Tool Functionality	Negative Ranks	22[s]	28.77	633.00
	Positive Ranks	40[t]	33.00	1320.00
	Ties	7[u]		
	Total	69		
Desktop-VR TTF - 360-VR TTF	Negative Ranks	23[v]	29.54	679.50
	Positive Ranks	35[w]	29.47	1031.50
	Ties	11[x]		
	Total	69		
Desktop-VR Atittude Towards Use - 360-VR Atittude Towards Use	Negative Ranks	19[y]	24.16	459.00
	Positive Ranks	35[z]	29.31	1026.00
	Ties	14[aa]		
	Total	68		
Desktop-VR Presence - 360-VR Presence	Negative Ranks	23[ab]	24.59	565.50
	Positive Ranks	31[ac]	29.66	919.50
	Ties	13[ad]		
	Total	67		
Desktop-VR Engagement - 360-VR Engagement	Negative Ranks	21[ae]	29.12	611.50
	Positive Ranks	37[af]	29.72	1099.50
	Ties	8[ag]		
	Total	66		
Desktop-VR Enjoyment - 360-VR Enjoyment	Negative Ranks	19[ah]	31.32	595.00
	Positive Ranks	39[ai]	28.62	1116.00
	Ties	10[aj]		
	Total	68		
Desktop-VR Stress/Worry/Pressure - 360-VR Stress/Worry/Pressure	Negative Ranks	46[ak]	33.43	1538.00
	Positive Ranks	19[al]	31.95	607.00
	Ties	4[am]		
	Total	69		
Desktop-VR Feedback - 360-VR Feedback	Negative Ranks	38[an]	29.87	1135.00
	Positive Ranks	22[ao]	31.59	695.00
	Ties	9[ap]		
	Total	69		
Desktop-VR Task Characteristics - 360-VR Task Characteristics	Negative Ranks	28[aq]	28.96	811.00
	Positive Ranks	23[ar]	22.39	515.00
	Ties	17[as]		
	Total	68		
Desktop-VR Trainer - 360-VR Trainer	Negative Ranks	34[at]	34.29	1166.00
	Positive Ranks	23[au]	21.17	487.00
	Ties	10[av]		
	Total	67		
Desktop-VR Perceived Learning - 360-VR Perceived Learning	Negative Ranks	29[aw]	28.95	839.50
	Positive Ranks	22[ax]	22.11	486.50
	Ties	18[ay]		
	Total	69		

a. Desktop-VR Simulator Sickness < 360-VR SimulatorSickness
b. Desktop-VR Simulator Sickness > 360-VR SimulatorSickness
c. Desktop-VR Simulator Sickness> 360-VR SimulatorSickness
d. Desktop-VR Realism < 360-VR Realism
e. Desktop-VR Realism > 360-VR Realism
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v. Desktop-VR TTF < 360-VR TTF
w. Desktop-VR TTF > 360-VR TTF
x. Desktop-VR TTF = 360-VR TTF
y. Desktop-VR Atittude Towards Use < 360-VR Atittude Towards Use
z. Desktop-VR Atittude Towards Use > 360-VR Atittude Towards Use
aa. Desktop-VR Atittude Towards Use = 360-VR Atittude Towards Use
ab. Desktop-VR Presence < 360-VR Presence
ac. Desktop-VR Presence > 360-VR Presence
ad. Desktop-VR Presence = 360-VR Presence
ae. Desktop-VR Engagement < 360-VR Engagement
af. Desktop-VR Engagement > 360-VR Engagement
ag. Desktop-VR Engagement = 360-VR Engagement
ah. Desktop-VR Enjoyment < 360-VR Enjoyment
ai. Desktop-VR Enjoyment > 360-VR Enjoyment
aj. Desktop-VR Enjoyment = 360-VR Enjoyment
ak. Desktop-VR Stress/Worry/Pressure < 360-VR Stress/Worry/Pressure
al. Desktop-VR Stress/Worry/Pressure > 360-VR Stress/Worry/Pressure
am. DesktopStressWorryPressure = 360-VR Stress/Worry/Pressure
an. Desktop-VR Feedback < 360-VR Feedback
ao. Desktop-VR Feedback > 360-VR Feedback
ap. Desktop-VR Feedback = 360-VR Feedback
aq. Desktop-VR Task Characteristics < 360-VR Task Characteristics
ar. Desktop-VR Task Characteristics > 360-VR Task Characteristics
as. Desktop-VR Task Characteristics = 360-VR Task Characteristics
at. Desktop-VR Trainer < 360-VR Trainer
au. Desktop-VR Trainer > 360-VR Trainer
av. Desktop-VR Trainer = 360-VR Trainer
aw. Desktop-VR Percieved Learning < 360-VR Perceived Learning
ax. Desktop-VR Percieved Learning > 360-VR Perceived Learning
ay. Desktop-VR Percieved Learning = 360-VR Perceived Learning

8.2 Appendix B

Appendix B.1: Consent Form

CONSENT FORM

Evaluating the Impact of Interactive Virtual Reality (IVR) Training environment on Mining Industry Safety, Management and Productivity.

Researcher: Shiva Pedram

I have been given information about research and discussed the project with Shiva Pedram who is conducting this research as part of a PhD supervised by Prof. Pascal Perez and Associate Prof. Stephen Palmisano in the SMART Infrastructure Facility at the University of Wollongong.

I understand that if I consent to participate in this project I will be asked to fill in two questionnaires (one before and one after the training session each taking approximately 10 minutes to complete). The information I provide will be used for the purpose of evaluating my learning and training experience with the Virtual Reality environment. The pre training questionnaire has three sections, one which measures my experience with games, one assessing my characteristics , and finally a section assessing how I feel at the moment. The post training questionnaire also has three sections (how I feel at the moment? What did I experience? plus conclusion and comments).

I understand that my contribution will be confidential and that there will be no personal identification in the questionnaires. I have been advised there are no risks and burdens associated with this research and that I will have an opportunity to ask Shiva Pedram any questions that I may have about this research and my participation in it.

I understand that: (1) my participation in this research is voluntary, (2) I am free to refuse to participate in this research and (3) I am free to withdraw from the research at any time. My refusal to participate or my withdrawal of consent will not affect my treatment in any way. It will also not affect my relationship with either the Coal Services centre or the University of Wollongong.

If I have any enquiries about the research, I can contact (Shiva Pedram , Prof. Pascal Perez 02 and Associate Prof. Stephen Palmisano 02) or if I have any concerns or complaints regarding the way the research is or has been conducted, I can contact the Ethics Officer, Human Research Ethics Committee, Office of Research, University of Wollongong on 4221 3386 or email**:** rso-ethics@uow.edu.au.

I understand that the identified data collected from me will be used for Shiva's research thesis and possible journal publications, etc, and I consent for it to be used in this fashion.

Signed.. Date........./........./.........

Name (please print) ....

Date of Birth ....

Years of experience as a mine rescuer ………………….

Appendix B.2 - PRE TRAINING QUESTIONNAIRE:

The information you provide will be used for the purpose of evaluating your learning and training experience with the Virtual Reality environment. This questionnaire has three sections, starting with assessment of your experience with games, followed by what are your characteristics and ending with how you feel at the moment.

1. How many years of experience do you have in the mining industry?

   0-2 years   2-5 years   5-10 years   More than 10 years

2. Which mine site do you work at?

   ----

3. In your opinion what are the challenges involved with the **training in the pit** in comparison with VR?

----

4. I feel stressed about this training session.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

5. I feel tense about attending this training session.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

6. I do not feel mentally ready/prepared for this training session.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

7. I am motivated to do this training.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

8. I want to succeed on this training.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

9. I am committed and motivated to attain my training performance goals.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

10. I am confident that I can do well in this training.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

11. I am excited to participate in this training course because the training environment is different.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

12. I feel active right now.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

13. I feel mentally alert right now.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

14. I am aware of everything happening around me right now.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

15. I am fully conscious right now.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

16. I am worried especially when I am not sure what the scenario is going to be.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

17. I will worry about the training session until it is over.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

18. I am worried about how I am going to perform in this training session.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

19. I am/feel competitive.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

20. I think about how my peers are going to perform in this training session.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

21. I train hard in the hope of gaining recognition.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

22. I feel confident about my abilities.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

23. I feel that I am in control of the situation.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

24. I feel that I am competent.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

25. I feel that I have enough knowledge to be a part of the rescue brigades.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

26. I become deeply involved in movies or video games (i.e. I feel as if I am inside the game or movie).

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

27. When watching a movie or playing video games, I become so involved that I lose track of time or my location.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

28. Do you ever become so involved in a movie or video games that you are not aware of things happening around you?

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

29. I have remained apprehensive or fearful long after watching a scary movie.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

30. I have become excited during a chase or fight scene on TV or in the movies.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

31. How many hours per week have you played video games in the past 6 months?

0-9 hours 10-19 hours 20-29 hours 30-39 hours 40+ hours

32. What is your level of experience with video games in general?

Very Low Average
Very High

1	2	3	4	5	6	7	8	9	10

33. How do you feel physically and mentally right now?

Very Bad Neutral
Very Well

1	2	3	4	5	6	7	8	9	10

Appendix B.3 - POST TRAINING QUESTIONNAIRE:

The information you provide will be used for the purpose of evaluating your learning and training experience with Virtual Reality environment. This questionnaire has three sections, starts with how you feel? Follows by what did you experience? and ends with the conclusion and comments.

What were the **<u>strengths</u>** of Virtual reality as a training environment?

What were the **<u>weaknesses</u>** of Virtual reality as a training environment?

What **<u>opportunities</u>** does Virtual reality provide as a training environment/tool?

What would **<u>prevent</u>** the use of Virtual reality as a training environment/tool?

How do you feel right now? (If not good, why?)

Very Bad Neutral
Very well

1	2	3	4	5	6	7	8	9	10

Is simulator sickness bothering you right now? (If yes, how?)

Very Low Neutral
Very High

1	2	3	4	5	6	7	8	9	10

Do you feel discomfort as a result of attending the training session in Virtual training environment?

Very Low Neutral
Very High

1	2	3	4	5	6	7	8	9	10

My experience in the computer generated world seemed consistent with my experiences in the real world.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

The computer generated world (Virtual world) seemed real to me.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

The details of the Mine environment in the virtual training environment were presented effectively.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I felt like I was looking at pictures.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I sometimes found myself to become very involved with the Virtual reality training world.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I felt detached from the outside world.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

To me it felt like only a very short amount of time had passed.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I was concerned about how I am going to perform in Virtual reality.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I was completely captivated by the computer generated world.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I interacted with other colleagues when I was in the Virtual reality training environment.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

Cooperation in the Virtual reality training environment was helpful for my/our learning.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

The Virtual reality training environment aided/facilitated social interaction between trainees (chat, etc).

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

It improved my ability to work as part of a team.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

Overall, I found the Virtual reality training environment easy to use.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

Interacting with the Virtual reality training environment was easy.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

It was easy for me to become skilful at using and interacting with Virtual reality as a training tool and environment.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

Virtual reality enhanced my learning.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

Using Virtual Reality as a training environment has improved the quality of my training.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

This Virtual reality training has improved my knowledge.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I found this Virtual reality training environment useful.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

The Virtual reality environment is a useful training tool.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

The Virtual reality training environment can duplicate real world scenarios successfully.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

The Virtual reality training environment improved my confidence and competency.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

The Virtual reality training environment helped me improve my technical and non-technical skills.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

Attending this training session has increased my skill set and competence.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I am satisfied with my performance in the virtual environment.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I was able to be “myself” while I was in the Virtual reality environment.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I performed quite well in this training session.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I gained enough knowledge and experience from this training session to perform well in the future and in real mine scenarios.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

The Virtual reality training environment is a useful tool to train mine rescuers how to deal with catastrophic situations.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

It was a good idea to use Virtual reality for training.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I have a favourable attitude toward using the Virtual reality environment for training.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I like the idea of using the Virtual reality environment for training.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I felt mentally alert while I was in the Virtual reality training environment.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I felt that I was present in the virtual space.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I was aware of everything happening around me.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

When I was in the virtual environment the experience felt real.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

When I was in the virtual environment I embraced my role and became deeply involved with the scenario and virtual environment.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

When I was in the virtual environment I felt the strong sense of interaction and engagement with the environment and other trainees.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

When I was in the virtual environment I lost track of time or where I was.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

When I was in the virtual environment I saw the impact of my decisions.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I enjoyed the training session.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

The training session and materials held my attention at all time.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

The training session in Virtual reality training environment was fun.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I fully concentrated on activities when I was in the virtual environment.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I could not perform effectively in the scenarios and the virtual environment.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

It was challenging to receive training in the Virtual reality environment.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I put too much of effort into the Virtual reality training session.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I felt nervous about participating in the Virtual reality training session.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I felt pressured while doing my task inside the virtual environment.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I received feedback on my progress after attending the training session.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I received useful feedback and comments on my success and mistakes.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

The feedback helped clarify the key concepts of the training to me.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

The feedback improved my learning.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

Feedback is essential after a training session.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

The training session was focused on the relevant skills.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

The training session was flexible enough to meet my needs.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

It was a successful training session.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I learned all the key concepts of today's training session.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I developed the skills expected from this training.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

Overall, I am satisfied with the training.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

The trainers had excellent knowledge of the subject content.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

The trainers encouraged learners to ask questions.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

The trainers explained things clearly.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

The trainers made it clear right from the start what they expected from me.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

The trainers made the subject as interesting as possible.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I would recommend the training organisation to others.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

The training facilities and materials were in a good condition.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

I prefer having training session conducted in Virtual reality rather than in the classroom.

Highly Disagree Neutral
Highly Agree

1	2	3	4	5	6	7	8	9	10

It needs to be mentioned that for the VR Desktop round the same Post-training questionnaire has been used and only the term “Virtual Reality” has been substituted with the term “Desktop-Virtual reality” to capture their experience with VR Desktop.

Appendix B.3 – Technical questions:

MINES RESCUE TRAINING ROUND 2

NAME:______________________________ **DATE:**____________________

THEORY QUESTIONS

1. **Describe the method of breaching a barricade?**

____

____

____

____

____

____

2. **Name 2 items to be checked once a team has entered an irrespirable atmosphere.**

a) ____

b) ____

3. **What 3 rules must be followed when exploring or conducting a search?**

a) ____

b) ____

c) ____

4. **What information must be placed on the route marker?**

____

____

____

5. **How often should gas readings occur during deployment?**

____

____

____

6. **What equipment is required to determine an air quantity measurement?**

____

____

7. **List 4 reasons a team would return to FAB without completing a task?**

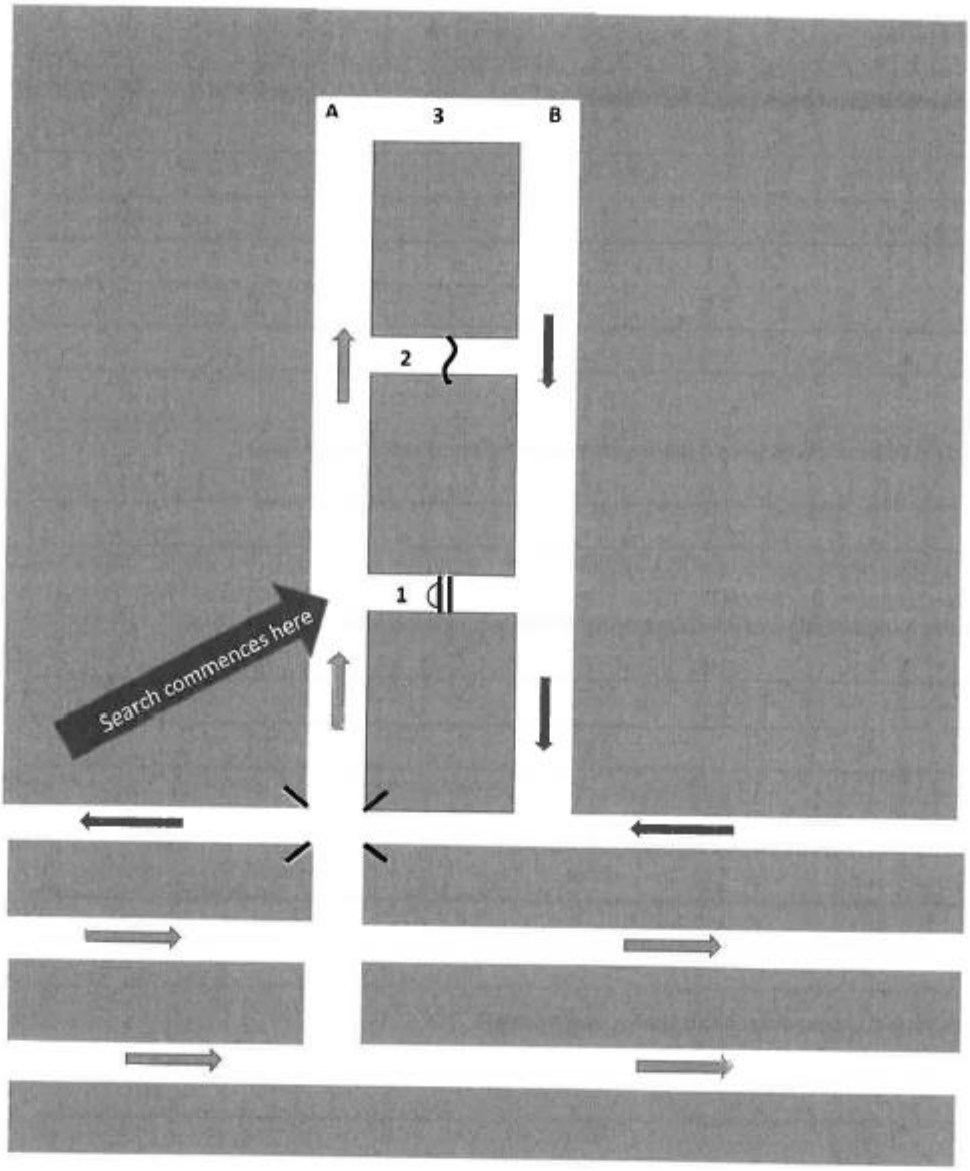
a) ____

b) ____

c) ____

d) ____

8. **From the supplied plan describe how you would search all headings inbye of the commencement point if you had a 4 man team? Pillars are 100 X30 m. Visibility is normal. You can use the diagram to assist in answering the question.**



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Appendix B.4 – Training Scenario

Overview

Round 2 Brigade training at SMRS will be undertaken in the virtual reality environment of Performance Colliery. The scenario is based on a vehicle accident and resultant fire at the bottom of the transport drift. The fire is uncontained and spreads to the coal. Whole of mine is contaminated with the subsequent gas products of the fire. The incident occurs on nightshift 3.06 am Sunday morning and there are 7 people underground at the time of the incident and 3 people on the surface.

General description

At 3.06 am a LHD loaded with a diesel pod careers into the right side rib at the bottom of the transport drift spilling its load of diesel. The diesel is ignited by the vehicles severely over heated breaking system in combination with electrical arcing from a junction box damaged in the accident. The diesel and fire has migrated across the intersection and the floor and the opposite rib is now burning.

All underground feeds from the instantaneous monitoring system have ceased secondary to the damage sustained by the junction box. The CCTV camera at the bottom of the drift has been made inoperable by the incident. At the time of the incident the Control room was unattended. The control officer had walked over to the workshop to talk to the surface electrician. They are the only personnel on the surface.

The Control Room Officer (CRO) returns at 3.17 am to the control room to find all instantaneous readings flashing red. Aware that the electrician underground is doing calibrations of the sensor heads he disregards the alarms.

At 3.11 am smoke reaches the LW 3 crib room where Brad Lee is situated. He puts CABA on immediately and calls Control repeatedly from 3.13 – 3.16 am with no answer. He receives a call from George Unger and John Laws in LW 4 panel. They are encountering smoke, have donned there CABA and are also unable to contact control. They all decide they will take their vehicles and make their way out. Heavy smoke stops both crews and they access the lifeline at the beginning of their panels. The group join up and Brad from LW 3 is the first to emerge through the stopping door at 7 C/T from C heading in the mains to see a fire raging at the bottom of the drift. They decide to go to the belt drift as per the escape plan. Visibility is down to about 50 metres. The decision to go to the belt drift is made at 3.35 am. They arrive safely at door to the belt drift and enter. They make a call to control who answers. They inform control about what they have seen. It is now 3.45 am. 12 N panel Craig Jones (Deputy) and Greg Irwin (Electrician) are already at the belt drift.

At 3.17 am in 12 N panel Craig Jones (Deputy) and Greg Irwin (Electrician) encounter smoke while at the face. They don their CSEs and make their way back the FREEK station and don CABA. At 3.20 am they call control and raise the alarm. They are donning their CABA and driving out. They do not know the source of the smoke. They are instructed to make their way to escape via the transport drift.

At 3.30 am 12 N panel Craig Jones and Greg Irwin reach the pillar inbye of the drift and are driven back by the fire and smoke. They return to the belt drift and call control and report what they have witnessed.

At 3.45 am they are joined by George Unger, John Laws, Ben Smith, Brad Lee who also provide reports of the incident

At 3.47 am they are brought to the surface via the dolly car.

Mines Rescue Task as assigned by IMT

Mines Rescue to prepare teams and undertake search and rescue for missing man.

The following competencies will be evaluated during this training scenario

Brigades Competencies:

1. Prepare for Entry to the Mine
2. Respond to Incident
3. Be Prepared for Incidents
4. Carry Out Operations in a Respirable and Irrespirable Atmosphere
5. Withdraw from Mine and Carry Out Post Operation Procedures
6. Control Fires
7. Select Breathing Apparatus Suitable for the Atmosphere and Operations Operate in Breathing Apparatus
8. Administer Oxygen to Other Persons
9. Protect Personnel From Dangerous Conditions Protect Persons from Irrespirable Atmosphere
10. Establish Limits of Irrespirable Zone
11. Establish a Fresh Air Base
12. Ensure Fresh Air Base Resources are in Place
13. Carry Out Fresh Air Base Operations
14. Check the MARS Unit Prior to Use
15. Using the MARS Unit
16. Perform Route Marking Operations
17. Received and Confirm Briefing on the Operations by Relevant Person In-Charge of Operation
18. Evaluate/Assess Capabilities of Team to Carry Out Tasks

19. Allocate Responsibilities and Standard Equipment to Rescue Team Members
20. Ensure Ancillary Equipment is Available and Fully Operational
21. Ensure Team is Briefed on Team's Role, Task and Responsibilities
22. Report to and Liaise with FAB Controllers
23. Ensure Safety and Emotional Well Being of Team in Operational Conditions
24. Inspect the SCSR Unit Prior to Fitting to Belt and Proceeding Underground
25. Run out Hoses
26. Using the Whirling Hygrometer/Sling Psychrometer
27. Breach a barricade
28. Decision making/Search pattern

Surface Coordinator Competencies:

1. Organise Personnel and Equipment Require for Team
2. Ensure Team equipment is available and tested
3. Ensure all team members are current and signed on
4. Ensure all team members are fit for deployment and not affected by drugs, alcohol, fatigue or other factors that may affect the safety of the team
5. Allocate Members into Teams
6. Update Duty Officer as required

Duty Officer Competencies

1. Analyse and prepare information for briefing
2. Brief Team captains and review Team Deployment Document
3. Update IMT and Regional / State manager

Surface Coordinator Instructions

Surface Coordinator (strike trainer) should undertake role as per real event including brigade sign on, fit for duty, breathalyser, Equipment readiness, team structure, communication with duty officer

Duty Officer Instructions

The duty officer should become familiar with the background to the scenario, brief the team and review the Team Deployment Document in preparation for team deployment