Final Report

Prepared by

For

Coal Services – Health and Safety Trust

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Executive Summary

This study, supported by Coal Services' Health and Safety Trust, aimed at evaluating the ability of Virtual Reality (VR) environments to (1) address specific training needs of the(underground) mining industry, (2) overcome current limitations of real world training (pit training) and (3) deliver a good and effective training experience to trainees. To address these questions we have developed a mixed method approach, blending qualitative and quantitative research.

284 trainees were interviewed before and after 360 VR-based training sessions; then 222 trainees were interviewed before and after Desktop VR-based training sessions (using GEN 4 technology). Amongst the 222 trainees, 150 had participated in the first round of interviews, allowing for longitudinal analysis. These interviews were conducted in all training stations (Woonona, Lithgow, Singleton and Newcastle) and followed the training schedule of **Rescue Brigades**.

Our **Need Analysis** has 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

Traditional on-site training (pit training) presents several **constraints** and **challenges**:

- 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

In contrast, our SWOT analysis showed that VR-based training 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

But some **weaknesses** have also been 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 have shown that pre-training individual characteristics had a limited impact on trainee's experience during the 360 VR session and on their perceived learning at the end of the session. Conversely, experience during the session has a significant impact on perceived learning. **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.**

Overall 88% of interviewees (284 in total) 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. **Henceforth, 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 GEN 4 technology and it will be interesting to assess its effectiveness at providing a better experience to trainees in coming years.

As perceived learning is inherently subjective, we used a short competency test (designed by trainers) to assess actual learning, at least from a theoretical viewpoint. This questionnaire was filled by trainees before the 360 VR session and then a month later. Results show that 52% of trainees have improved their scores during the second round of testing. **We need further research to better understand causality links between the training session (environment and content) and actual knowledge improvement beyond simple correlation.**

Finally, a second round of training sessions using GEN 4 technology (Desktop VR environment) included 222 trainees, amongst which 150 had been through a 360 VR session in the last 6-month period (treatment group) and 72 hadn't been involved (control group). This experiment allowed us to address two questions:

Q1: Did the training experience or perceived learning of trainees belonging to the treatment group change from one technological environment to the other?
Q2: Did the treatment group perform better compared with the control group?

In response to question 1, a significant number of trainees mentioned that Desktop VR had improved their experience in terms of better engagement and immersion, as well as lesser level of stress. 46% stated a higher level of perceived learning with Desktop VR environment. Age and professional experience seem also to have an influence on these results with older and more experienced trainees tending to score higher their experience with the Desktop VR environment. However, we need to remember that Desktop VR sessions came after the 360 VR ones and we need to acknowledge the fact that reinforcing mechanisms were at play.

This argument is weakened by our response to Question 2: there wasn't any significant difference between control and treatment groups in terms of training experience or perceived learning. **Henceforth, trainees without prior (recent) exposure to VR environments performed as well as their colleagues. This outcome partially demonstrates the benefits of GEN 4 technology and Desktop VR environments.**

1 Background

The design of our conceptual and experimental framework was based on a thorough literature review. This conceptual framework aims to display the benefit(s) of VR-based training in achieving the highest level of individual competency and safety, as well as contributing to effective management and productivity in the coal mining industry. The introduction of VR-based training in the mining industry cannot be only justified through technological innovation; it also needs to demonstrate a clear and positive impact on training transfer through more competent workers, improved workplace safety conditions and a well-established culture of safety through effective communication. These three factors lead to more effective management of human resources and capital investment, ultimately leading to more sustainable production, more profitable industry and social responsibility (Pedram et al., 2013).

The aim of the research as outlined in the project proposal was: (i) to evaluate the quality of the training conducted in VR and also (ii) to measure the impact of VR on the competency of rescue brigade's members. Therefore all factors which might conceivably affect training were identified from the available literature and subsequently measured in this research.

2 Methodology

The methodological framework is outlined in Pedram and colleagues (2013) and uses a mixed method approach (qualitative and quantitative instruments) in order to evaluate complementary aspects of the VR training environment (Figure 1).

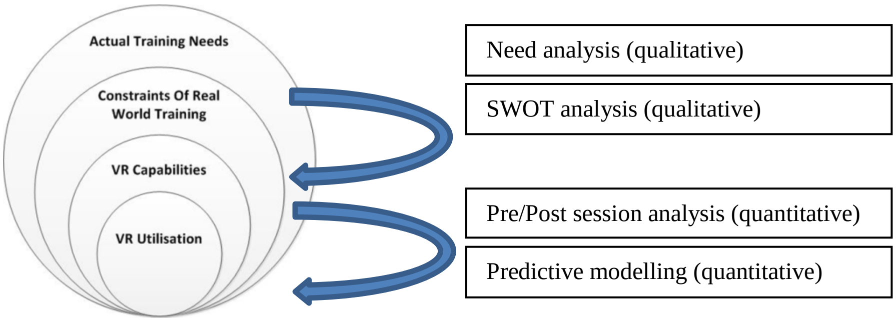


Figure 1: Methodological framework

In 2014, Mrs Shiva Pedram, PhD student at UOW, started implementing her evaluation framework at the Southern Mine Rescue station (Woonona), attending all the VR training sessions and collecting preliminary data on VR. The same year, a Health & Safety Trust grant allowed her to expand her research to all Mine Rescue stations in NSW.

Our initial intention was to use rescue competition results to measure training transfer from VR-related sessions. Unfortunately, although competitions provided interesting results, all scores obtained were group-based without the possibility to ascertain individual performance. With the introduction and testing of GEN 4 (Desktop-based and multi-player Virtual Reality environment) in late 2014, we modified our approach and decided to use GEN4 sessions as an individual assessment phase - testing trainees' competence a month after the usual group-based VR training session.

The new testing regime which commenced in March 2015 at Southern Mine Rescue station (Woonona) included two rounds of training: (1) the first round, 360 VR, used a specially designed scenario (search pattern) with the traditional VR environment and software as a training medium; (2) the second round (GEN4 round), which commenced in May 2015, used an adapted version of this proposed scenario tailored for the newly deployed Desktop-based VR environment and software as an assessment stage. The aims were to evaluate the trainee's level of learning during the VR round and the extent of training transfer to the GEN4 training environment. Therefore, the scenario had to include a broad range of training components, such as procedural (safety rules and communication protocols) or substantive (mine environment and equipment) knowledge.

Before the first round (VR), six technical questions were submitted to trainees (developed by Dale Davis) with respect to the developed scenario. The aim of these questions was to draw a learning/performance baseline (which would allow us to compare the trainee's knowledge before and after the VR training session). These questions were repeated before GEN4 round.

Then, our pre-training questionnaires were distributed among trainees, focusing on trainee's characteristics and factors thought to affect their learning experience. The researcher and/or the trainer observed the group dynamics and body language during the sessions. After each training session the post-training questionnaire was distributed in order to obtain subjective data on the trainees' perceived learning outcomes and learning experience. Then trainees were debriefed, focusing on positive and negative aspects of the training session.

During the GEN4 round, each trainee was equipped with a laptop and joystick. The scenario used in the earlier VR was specially adapted to GEN4 so as to trigger the same concepts. However the simulated accident occurred under either different circumstances or in a different location. It was essential to have a detailed record of each training session to be able to monitor and analyse the session. GEN4 enabled the trainers to monitor all of the trainees' activities (both individual and group) from a central computer. It was also important to observe the degree to which the trainees have developed non-technical skills such as group work, conflict handling, teamwork and leadership skills.

Due to logistical issues, the completion of both testing regimes in all Mine Rescue stations (Woonona, Lithgow, Singleton and Newcastle) took far more time than expected and ended in December 2015 only. Shiva Pedram had to rely on the availability and kind collaboration of trainers and training coordinators to deploy the framework across the four facilities, including the training of local personnel to implement the evaluation protocol without UOW researchers being present. The amount of data generated across 4 stations and two rounds of training (VR and GEN4) has been overwhelming and the analysis was completed in March 2016 only. **As a consequence, this final report could not be completed and submitted to the Health & Safety Trust before end of May 2016. We sincerely apologise for this delay.**

3 Results from 360 VR Training Sessions

3.1 Need Analysis

According to the methodological framework (figure 1) the need analysis is based on two source materials: (1) pre-training interviews with trainees (sections 3.1.1 and 3.1.2 below) and (2) interviews with VR developers (section 3.1.3 below).

3.1.1 Actual Training Needs from Trainee's Viewpoint

Our questionnaire allowed us to identify 8 essential needs expressed by trainees (table 1). This is an essential aspect of a gap analysis aiming at identifying training features that need to be added or modified.

	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

Table 1: Training Needs from Trainees Point of View

Recreate the Real Conditions - Trainees mentioned that training environment must "recreate real condition" such as "uneven ground, water, heat humidity" and "uneven ground affect whilst walking".

Physical Activities can be done - 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 in order for to allow trainees to experience physical exertion while undertaking usual underground activities.

Accessible at any time training is needed – 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 for the training to 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 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 training to be safe (“not exposed to hazards”) and to allow for trainees to “make mistakes with no [harmful] consequences”.

3.1.2 Real-World’s Training Constraints

Trainees were asked to identify the constraints they thought were associated with conducting training at actual mine sites. They indicated that training in the pit felt more realistic however, they mentioned that there were some challenges which would affect training and ultimately learning outcomes. Table 2 summarises the reported constraints of real-world training (statistical results in Appendix 1).

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)

Table 2: Real-World’s Training Constraints from Trainees point of view

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 scenarios in the pit”, “cannot simulate fires [in pit]” and “[not easy] to focus on correct technique and improve it”. One trainee summarises it all: “pit training is normal life for us where as 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 summarises the potentially hazardous pit training environment: “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".

3.1.3 VR-based Training Capabilities from VR-Developer's Viewpoint

Table 4 summarises the VR training capabilities as a result of interviewing VR-developers. The original list is rather large, henceforth we provided below a shortlist of the most relevant capabilities to this study.

	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.

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

3.2 SWOT Analysis of 360 VR Training Environment

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

1. What were the strengths of Virtual reality as a training environment?
2. What were the weaknesses of Virtual reality as a training environment?
3. What opportunities does Virtual reality provide as a training environment/tool?
4. 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 VR developers, Trainers using VR as a training tool during separate semi-structured interviews. We will successively present results from trainees, VR developers and trainers.

3.2.1 SWOT - Trainee's viewpoint

Table 5 summarises feedback from trainees regarding the strengths, weaknesses, opportunities and threats associated with 360 VR environments for training purposes. While strength and weakness relate to personal experiences during training sessions, opportunity and threat relate to broader consequences, generalisations or assumptions mentioned by interviewees.

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)

Table 4: SWOT from Trainee's viewpoint

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

Strength - High 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 "somewhat expose 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".

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

Weakness - 360 VR produces Simulator Sickness
Interviewees mentioned that 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 by trainers to practice 'stationary walking' during the simulation seems to help: "[having] to move as if you are walking helps the sickness". Overall, getting slightly sick doesn't deter trainees from the benefits of 360 VR environment: "[I am] getting slight motion sickness but it is worth it".

Weakness – 360 VR does not fit the task
This weakness is highly related to the specific scenario trainees have been immersed into, 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 are 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
Several interviewees insisted on 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 strong 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 several 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".

360 VR's opportunities listed by trainees (see Appendix 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 (eg. 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 pointed at 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 at 360 VR's accessibility and safety as opportunities for better 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 perceived 360 VR as 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".

360 VR's threats listed by trainees (see Appendix 5 for statistical results)

Threat - Resistance to using the technology
Resistance to the use of 360 VR for training is a risk perceived by several trainees, despite the overwhelming 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 environment were 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
Although simulator sickness was perceived as an actual weakness with limited impact on the training capacity itself, several trainees mentioned it could 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 perceived 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".

3.2.2 SWOT - Trainer's viewpoint

Table 6 summarises feedback from trainers regarding the strengths, weaknesses, opportunities and threats associated with 360 VR environments for training purposes. While strength and weakness relate to their assessment of actual training sessions, opportunity and threat relate to broader consequences, generalisations or assumptions mentioned by trainers.

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. Side Effects and Simulator Sickness 2. Not realistic enough to replace underground training 3. Technology Compatibility 4. 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. Side Effects 3. Technology Constraints 4. Limited facilities equipped with this technology

Table6: SWOT from Trainer's viewpoint

Results from interviews with trainers show a significant level of alignment with the ones elicited from trainees. However, two differences are noticeable:

(1) Trainers articulate more clearly the fact that 360 VR provides high fidelity scenarios (strength) that are probably realistic enough to replace theory-based classes (opportunity) but probably not enough (yet) to entirely replace traditional underground training despite all its logistical constraints.
(2) Trainees insist more on the relative passivity of the current 360 VR environment and scenarios compared with a real situation while they praise the given ability to better concentrate on the requested tasks or to engage with the trainers.

3.2.3 SWOT – VR Developer's viewpoint

Table 7 summarises feedback from 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 results from trainees and trainers as the design and implementation of the 360 VR technology follows its own internal SWOT pathway.

SWOT from VR-Developers 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

Table 7: SWOT from VR-Developer's viewpoint

3.3 Cross tabulations

In the following section we analyse correlations between real world training challenges (as identified by trainees in section 3.1.2) and results from 360 VR's SWOT analysis (as identified by trainees in section 3.2.1).

3.3.1 Real world challenges x 360 VR's strengths (statistical results in Appendix 6)

Appendix 6 and Figure 2 show that a majority of interviewed trainees (124 out of 226) identified real world 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, 26% consider that 360 VR help them focusing better on the tasks to be performed and another 14% consider that its controlled environment provides safe conditions to perform high-risk activities.

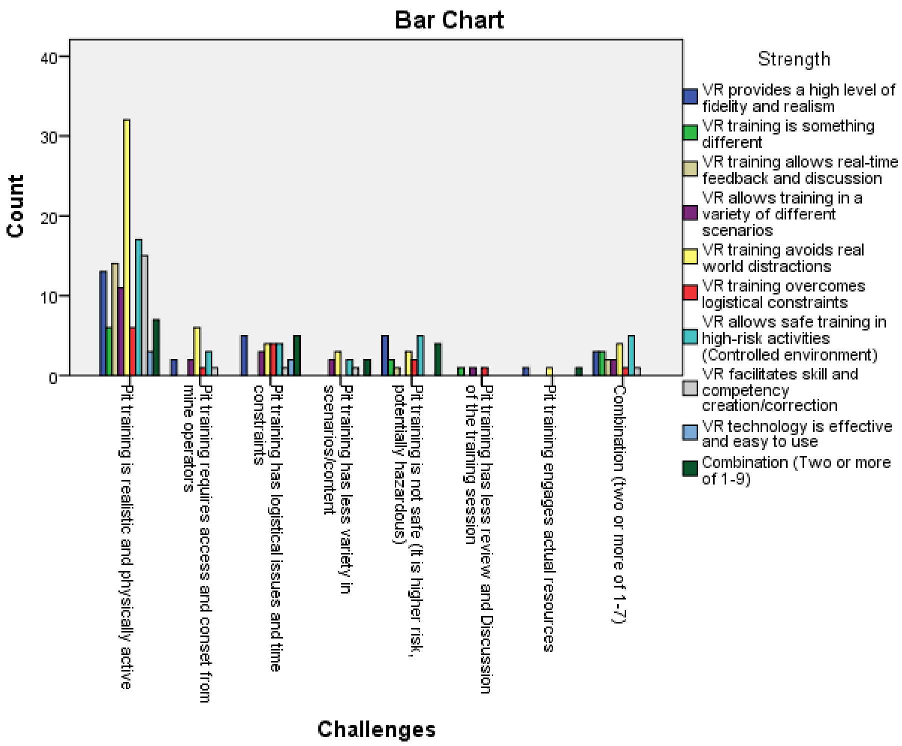


Figure 2: cross tabulation between real world training challenges and 360 VR's strengths

3.3.2 Real world challenges x 360 VR's weaknesses (statistical results in Appendix 7)

Appendix 7 and Figure 3 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% consider that 360 VR cannot entirely replace real life training and 25% that the current VR environment doesn't include enough physical activities. This apparent contradiction aligns relatively well with trainer's viewpoint that 360 VR is probably mature enough to replace most of classroom training but still lacks a degree of realism in order to entirely replace pit training. How much needs to be added without falling into current challenges presented by real world training is an issue that suggestions from trainees have touched upon (see below).

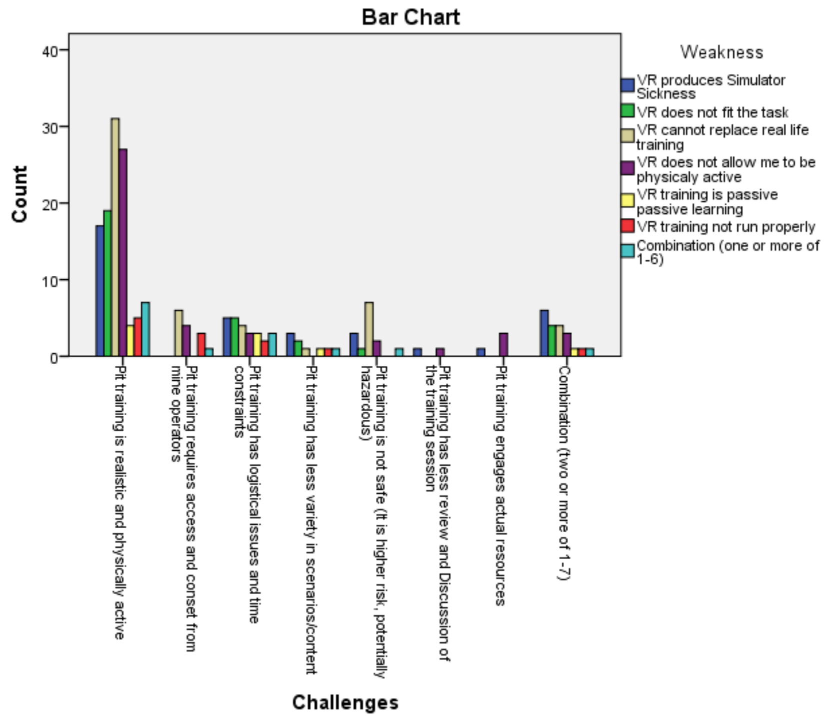


Figure 3: cross tabulation between real world training challenges and 360 VR's weaknesses

3.3.3 360 VR's strengths x 360 VR's weaknesses (statistical results in Appendix 8)

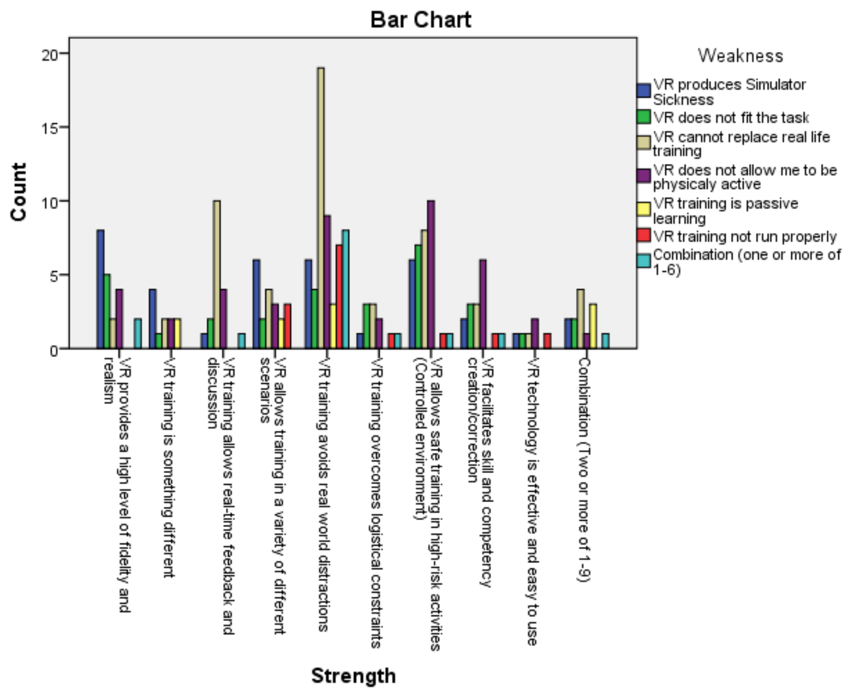


Figure 4: cross tabulation between 360 VR's strengths and 360 VR's weaknesses

Appendix 8 and Figure 4 show that the same number of trainees (56 out of 205) think that (1) a strength of 360 VR is to avoid real world distractions or (2) a weakness of 360 VR is its inability to fully replace pit training; 19 out of 56 trainees (34%) mentioned both statements confirming the apparent contradiction identified in previous section.

3.3.4 360 VR's threats x 360 VR's opportunities (statistical results in Appendix 9)

Appendix 9 and Figure 5 show that 52 out of 174 trainees consider that 360 VR presents a good opportunity to simulate various scenarios (including dangerous situations). However, several of them also mention simulation 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.

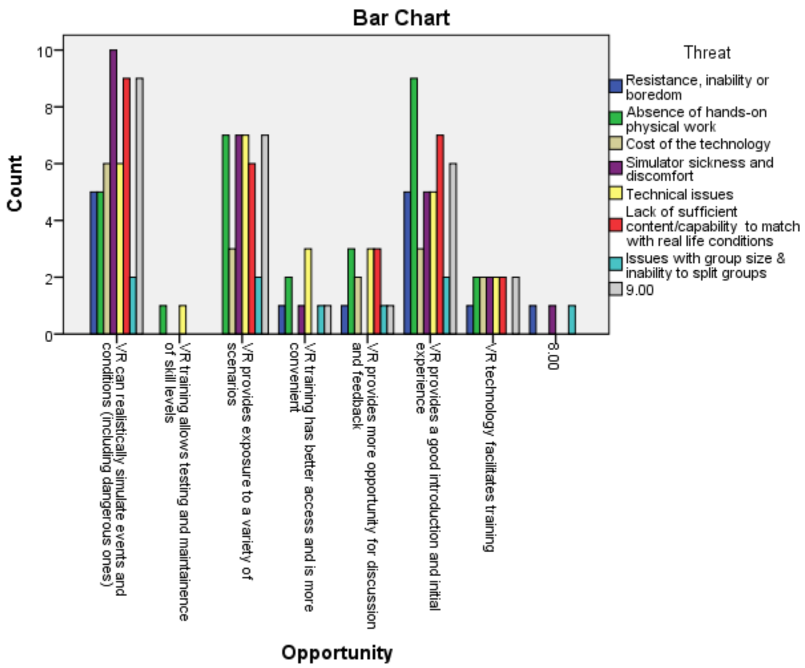


Figure 5: cross tabulation between 360 VR's opportunities and 360 VR's threats

3.4 Pre/Post Quantitative Analysis

3.4.1 Reliability Test for pre-training factors

The pre-training questionnaire focuses on nine individual perceptions, adapted from literature, as important response factors to training conditions: sense of stress, sense of motivation, sense of alert, sense of worry, sense of competition, sense of confidence, sense of digital involvement, digital environment engagement, gaming experience and well-being.

Since these factors have been adapted to create a customised questionnaire for this study, it is necessary to conduct a reliability test to ensure that questions are statistically reliable. Cronbach's Alpha test is used to assess reliability; a value above 0.7 means the questions passed the reliability test.

All variables return a Cronbach's Alpha value superior to 0.750, except for 'gaming experience' (0.720). We can conclude that all variables are statistically reliable.

3.4.2 Pre-training factors at a glance

Table 7 summarises statistical results for the nine pre-training factors. Overall, trainees are highly motivated, confident and alert, as well as feeling generally well. In average it has been reported low level of stress, worry and gaming experience.

Descriptive Statistics

	N	Minimum	Maximum	Mean
Sense of Stress	283	1.00	6.67	2.5289
Sense of Motivation	283	5.00	10.00	8.2099
Sense of Alert	282	4.75	10.00	8.1135
Sense of Worry	284	1.00	9.33	3.5634
Sense of Competition	281	2.00	10.00	6.2349
Sense of Confidence	282	3.25	10.00	8.0603
Digital World Involvement	281	1.00	9.00	3.5203
Gaming Experience	277	1.00	7.00	2.0975
Wellbeing	282	1.00	10.00	7.8121
Valid N (listwise)	265			

Table 7: Statistical results of pre-training factors

3.4.3 Reliability Test for post-training factors

The post-training questionnaire focuses on seventeen individual perceptions, adapted from literature, as important response factors to training conditions: sense of sickness, sense of realism, sense of immersion, sense of interaction, sense of presence, sense of engagement, sense of enjoyment, sense of stress, worry and pressure, sense of ease to use, sense of technology usefulness, sense of tool functionality, sense of task-functionality fit, sense of attitude towards use, sense of feedback, sense of task characteristics, sense of trainer's attitude and sense of perceived learning.

Since these factors have been adapted to create a customised questionnaire for this study, it is necessary to conduct a reliability test to ensure that questions are statistically reliable. Cronbach's Alpha test is used to assess reliability; a value above 0.7 means the questions passed the reliability test.

All variables return a Cronbach's Alpha value superior to 0.750, except for 'sense of sickness' (0.744), 'sense of enjoyment' (0.701), 'sense of stress, worry and pressure' (0.700), 'sense of task-functionality fit' (0.708), 'sense of feedback' (0.710) . We can conclude that all variables are statistically reliable.

3.4.4 Post-training factors at a glance

Table 8 summarises statistical results for the seventeen post-training factors. Overall, trainees have a highly positive sense of perceived learning, trainer's attitude, task characteristics and feedback. On average, trainees also report positive experiences with the 360-VR environment as showed by the scores reached by factors such as interaction, engagement, enjoyment, presence, ease of use, usefulness, tool functionality or task-technology fit. Additionally, participants reported very low level of simulator sickness and stress, worry and pressure.

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				

Table 8: Statistical results of post-training factors

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

Pre-training factors

The correlation matrix below (Table 9) shows that ‘perceived learning’ (last column) is only significantly (and positively) correlated with ‘sense of motivation’ and ‘sense of alert’. This is an important outcome as it demonstrates that pre-training individual factors have a limited effect on perceived learning after a training session in a 360 VR environment. Henceforth, it can be concluded that reported individual circumstances (‘sense of competition’ or ‘sense of worry’) or experiences (‘digital world involvement’ or ‘gaming experience’) don’t significantly influence the way trainees engage with the training scenario and report on their learning experience.

		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).

Table 9: Correlation matrix between pre-training factors and perceived learning

Post-training factors

The correlation matrix below (Table 10) shows that all post-training factors have a statistically significant relationship with perceived learning. Excluding ‘simulator sickness’ and ‘stress worry and pressure’ that display a negative relationship, all the other factors are positively correlated with perceived learning. These results demonstrate that the selected post-training factors were highly relevant to this study and that many factors contribute to or prevent a positive training experience in a 360 VR environment.

Correlations

		Simulator Sickness	Realism	Immersion	Interaction	Ease Of Use	Usefulness	Tool Functionality	Attitude 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
AttitudeTowardsUse	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).

Table 10: Correlation matrix between post-training factors and perceived learning

3.4.6 Influence of socio-demographic factors

Although reported pre-training factors didn't show significant effect on perceived learning, we decided to test the influence of three socio-demographic factors based on additional questions to trainees:

i) **Age** - we divided our survey sample into two groups: 24 to 40 year-old and 41 to 64 year-old.

ii) **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.

iii) **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 didn't follow a normal distribution, we used a non-parametric test: a Mann-Whitney test for two independent samples.

Influence of Age on reported pre-training factors

Group 1 corresponds to 24-40 year-old trainees and group 2 to 41-64 year-old ones. The nil hypothesis (H0) being tested assumes that there is no difference between the two groups. Table 11 provides results of the Mann Whitney U test for the 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

Table 11: influence of Age on reported pre-training factors

Results show that only two factors display a significant statistical difference between the two groups: gaming experience (Z=-4.745; p=.000<.05) and sense of stress (Z=-2.543; p=.011<.05). Trainees belonging to group1 (24-40) display a statistically higher level of gaming experience than group 2 (41-64). Conversely, trainees from group 2 display a statistically higher level of reported stress before training compared with group1.

Influence of Age on reported post-training factors

Group 1 corresponds to 24-40 year-old trainees and group 2 to 41-64 year-old ones. The nil hypothesis (H0) being tested assumes that there is no difference between the two groups. Table 12 provides results of the Mann Whitney U test for the 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]

	Atittude Towards Use	Presence	Engagement	Enjoyment	Stress Worry Pressure	Feedback	Task Characteristic s	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

Table 12: influence of Age on reported post-training factors

Results show no statistically significant differences between the two groups across all reported post-training factors. The nil hypothesis is confirmed.

Influence of Rescue Experience on reported pre-training factors

Group 1 corresponds to trainees with less than 10-year experience and group 2 to trainees with 10-year experience or more. The nil hypothesis (H0) being tested assumes that there is no difference between the two groups. Table 13 provides results of the Mann Whitney U test for the 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

Table 13: influence of Rescue Experience on reported pre-training factors

Results show that only following factors display a significant statistical difference between the two groups: sense of motivation (Z=-3.025; p=.002<.05), sense of stress (Z=-2.272; p=.023<.05), sense of alert (Z=-2.092; p=.036>.05) and gaming experience (Z=-4.383; p=.000<.05). Trainees belonging to group1 (<10-year experience) display a statistically higher level of gaming experience, sense of motivation and sense of alert while group 2 (>10-year experience) record higher level of stress before training.

Influence of Rescue Experience on reported post-training factors

Group 1 corresponds to trainees with less than 10-year experience and group 2 to trainees with 10-year experience or more. The nil hypothesis (H0) being tested assumes that there is no difference between the two groups. Table 14 provides results of the Mann Whitney U test for the 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]

	Atittude Towards Use	Presence	Engagement	Enjoyment	Stress Worry Pressure	Feedback	Task Characteristic s	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

Table 14: influence of Rescue Experience on reported post-training factors

Results show no statistically significant differences between the two groups across all reported post-training factors. The nil hypothesis is confirmed.

Influence of Mining Experience on reported pre-training factors

Group 1 corresponds to trainees with less than 10-year mining experience and group 2 to trainees with 10-year experience or more. The nil hypothesis (H0) being tested assumes that there is no difference between the two groups. Table 15 provides results of the Mann Whitney U test for the 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

Table 15: influence of Mining Experience on reported pre-training factors

Results show that only two factors display a significant statistical difference between the two groups: gaming experience (Z=-3.966; p=.000<.05) and sense of stress (Z=-1.990; p=.047<.05). Trainees belonging to group1 (less experienced) display a statistically higher level of gaming experience than group 2 (more experienced). Conversely, trainees from group 2 display a statistically higher level of reported stress before training compared with group1. We can safely assume here that there is a significant level of correlation between Age and Mining Experience.

Influence of Mining Experience on reported post-training factors

Group 1 corresponds to trainees with less than 10-year mining experience and group 2 to trainees with 10-year experience or more. The nil hypothesis (H0) being tested assumes that there is no difference between the two groups. Table 14 provides results of the Mann Whitney U test for the 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

Table 16: influence of Mining Experience on reported post-training factors

Results show no statistically significant differences between the two groups across all reported post-training factors. The nil hypothesis is confirmed.

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.

3.5 Reported Training Outcomes

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

- "How successful was the training in VR?"
- "How useful do you think this training was?"
- "How consistent was your experience with real life conditions?"

Each question used a Likert's scale between 1 ('very low opinion') to 10 ('very high opinion') to rank trainee's responses. Table 17 shows that 360-VR training was considered as highly successful, reasonably useful and fairly realistic by trainees.

		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 5: 360-VR training's perceived level of realism, usefulness and success.

Usefulness x Realism (statistical results in Appendix 11)
Appendix 11 and Figure 10 show that many trainees tend to consider 360-VR as a very useful training environment despite some reservations about its level of realism.

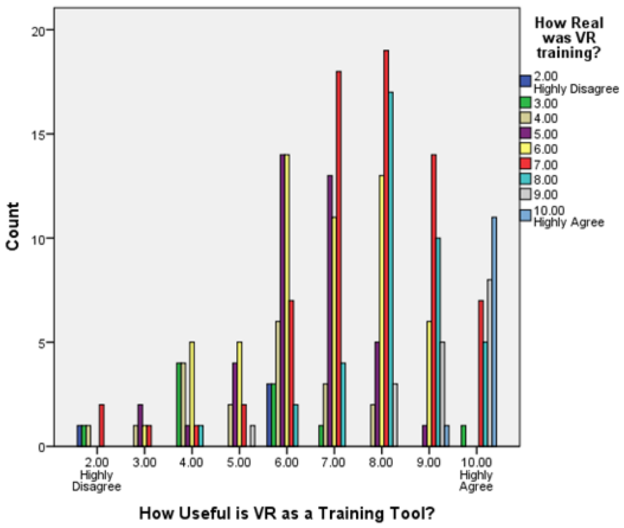


Figure 10: cross-tabulation between perceived levels of realism and usefulness.

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.

Success x Realism (statistical results in Appendix 12)
Appendix 12 and Figure 11 show that a large majority of trainees tends to consider 360-VR as a very successful training environment despite some reservations about its level of realism.

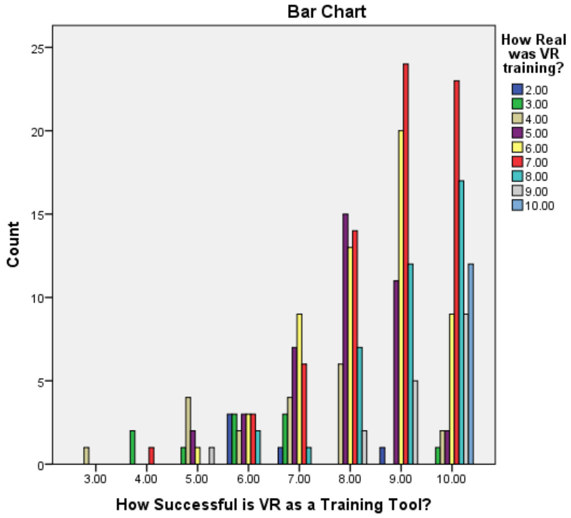


Figure 11: cross-tabulation between perceived levels of realism and success.

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 find 360-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.

Success x Usefulness (statistical results in Appendix 13)
Appendix 13 and Figure 12 show that 88% of trainees indicated that the VR training was successful, from which 70% indicated that it was also a useful tool.

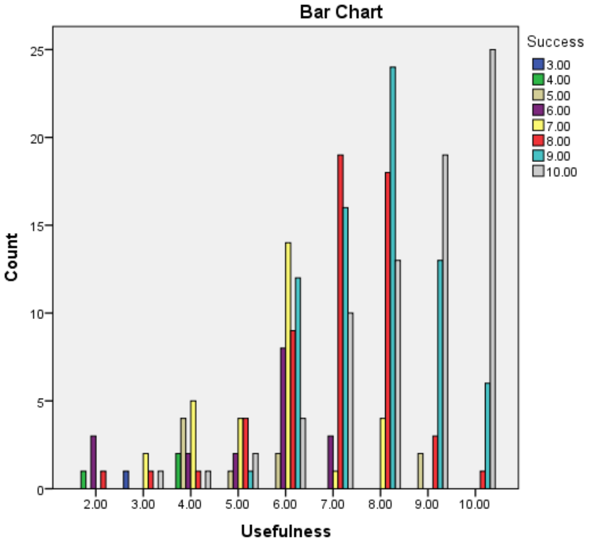


Figure 12: cross-tabulation between perceived usefulness and success.

236 trainees (88%) indicated that they found 360-VR training successful to highly successful (categories 7 to 10). Amongst these 236 trainees, only 62 considered 360-VR as 'not useful' or 'fairly useful' (categories 2 to 6). Therefore, these results confirm that a majority of trainees (65%) find 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.

3.6 Modelling of Perceived Learning (360 VR)

The next stage of this research is to estimate how much of trainee's perceived learning can be explained by our pre-training (9 in total) and post-training (16 in total) variables. The relatively small size of the sample (231 observations for 17 predictors) and the high level of correlation between variables (see section 3.4) 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.

3.6.1 Principle Component Analysis (PCA) on pre-training variables

Appendix 14 and Table 18 show that the first Component, explaining 34% of the variance, is characterised by 5 variables: Alert, Motivation, Confidence, Wellbeing and Competition. The second Component, explaining 17% of the variance, is characterised by 2 strongly correlated variables: Worry and Stress. The third Component, explaining 13% of the variance, is characterised by 2 strongly correlated variables: Gaming Experience and Digital World Involvement. These 3 Components explain 64% of the total variance.

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.

Table 18: Structure Matrix – PCA on pre-training variables

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 State of Mind (Component 1), Negative State of Mind (Component 2) and Technology Experience (Component 3).

3.6.2 Principle Component Analysis (PCA) on post-training variables

Appendix 15 and Table 19 show that the first Component, explaining 56% of the variance, is characterised by 11 correlated variables: Task-Technology Fit (TTF), Functionality, Usefulness, User-friendliness, 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.

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.

Table 19: Structure Matrix – PCA on post-training variables

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).

3.6.3 Linear regression based on aggregated variables

A linear regression model was fitted to the 6 aggregated variables (3 pre-training ones and 3 post-training ones) to estimate the impact on perceived learning. Appendix 16 and Figure 14 show that Learning Context, Positive Learning Experience and Negative Learning Experience are variables that mostly affect perceived learning. None of the pre-training aggregated variables (Positive State of Mind, Negative State of Mind and Technology Experience) have a significant impact on perceived learning.
The linear regression model can explain 71% of the variance

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

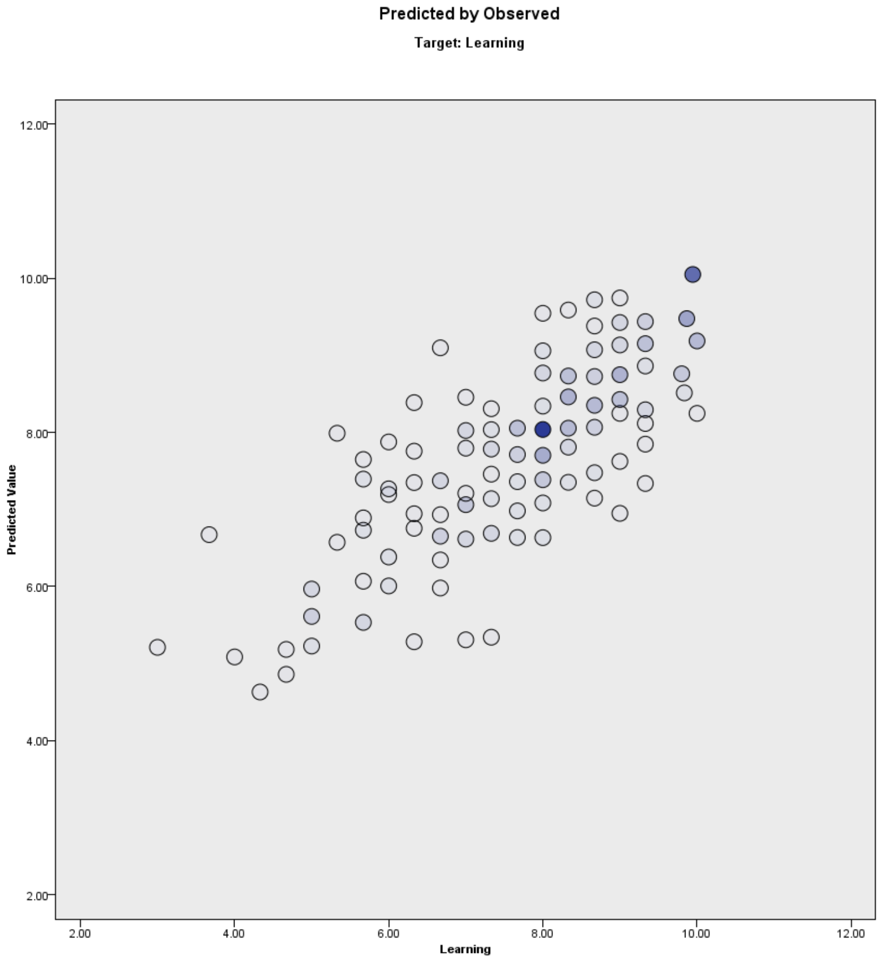


Figure 14: Observed Vs predicted values of Learning (Linear regression model)

These results confirm that pre-training individual characteristics don’t have a significant influence on perceived learning expressed by trainees after the training session. Conversely, the context of a training session and (positive or negative) individual experiences during the session will have a significant impact on perceived learning. Although the linear regression model explains only 71% of the observed variance, the overall fit between observed and predicted values for the Learning variable seems reasonably accurate (Figure 14).

Further work is needed to move from a correlation model (linear regression) to a causality-driven one through which we can explore more detailed relationships between individual characteristics, training experience and perceived learning.

4 Competency Evaluation

4.1 Competency Test

Perceived Learning can be interpreted as a stated outcome of the training transfer process that has happened during 360 VR sessions. A stated outcome is inherently subjective; henceforth, we designed a short competency test (technical quiz) to evaluate the objective impact of 360 VR sessions on trainee's learning capacity. This test was filled by each trainee prior to the 360 VR session and one month later. Figure 15 shows that 52% of the trainees have improved their score during the second test, confirming that individual Perceived Learning corresponds to an actual gain of competency. 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.

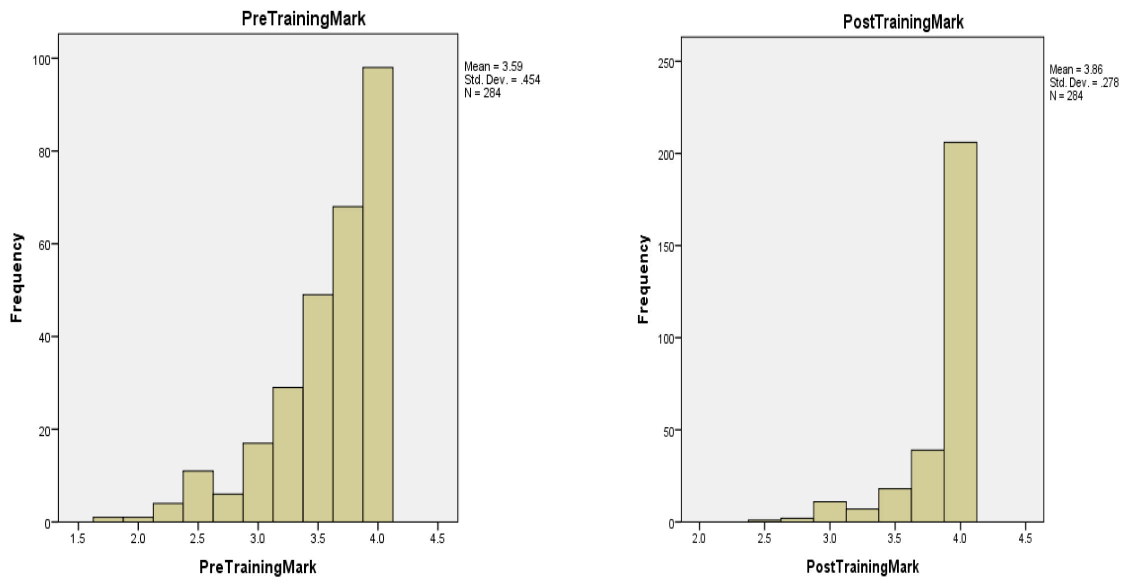


Figure 15: Results of the competency test (left: before 360 VR session; right: a month later)

4.2 GEN4-based Training Sessions

Out of the 284 trainees who were submitted to the 360 VR environment, 150 of them undertook a Desktop VR-based training session, using GEN4 technology, later on. They were joined by 72 trainees who had not been exposed to a 360 VR environment before. Henceforth 222 trainees were submitted to a Desktop VR training environment. The same ex-post questionnaire used for the 360 VR sessions was given to trainees at the end of the Desktop VR sessions. This second series of training sessions can help us to:

(1) Compare trainee's responses between the two training sessions (150 observations).

(2) Benchmark responses from trainees who undertook both sessions (150 observations) with the control group (72 observations) who only undertook a Desktop VR session.

4.2.1 Comparing responses from 360 VR and Desktop VR sessions

Appendix 17 and Table 20 show that 86% of trainees stated that they experienced less simulator sickness with Desktop-VR and 65% less stress; 63% felt more engaged with Desktop-VR; 63% also felt it was easier to use; 71% felt more immersed in the Desktop-VR environment. The other post-training variables display no significant preferences. Ultimately, only 46% of trainees believed they better learned with the Desktop-VR environment.

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

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 level of experience groups (< 10 year experience and > 10 year experience).

Influence of experience

Table 21 shows that more experienced trainees (>10 year) found the VR Desktop environment to provide more interaction, to be more useful and to be more fit to the task compared with less experienced trainees. However, the former group found that trainer's input with less effective with VR Desktop compared with the latter group. There isn't any significant impact of experience on the perceived learning.

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	-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 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	-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 21: Comparison of 360 VR and Desktop VR for post-training variables
(top: trainees with less than 10 year experience; bottom: trainees with more than 10 year experience)

Influence of age

Table 22 shows that more experienced trainees (>40 year old) found the VR Desktop environment to provide more presence and more engagement compared with younger trainees. However, the former group found that trainer's input with less effective with VR Desktop compared with the latter group. There isn't any significant impact of experience on the perceived learning.

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]	-3.911[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 22: Comparison of 360 VR and Desktop VR for post-training variables (top: trainees less than 40 year old; bottom: trainees more than 40 year old)

4.2.2 Benchmarking with control group

Table 23 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 isn't any significant difference between Desktop-VR experiences and perceived learning between the two groups.

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 Attitude 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

Table 23: Comparison of post-training variables between treatment group (150 trainees) and control group (72 trainees)

This might lead us to the realisation that Desktop-VR has been designed and implemented in a way that previous VR exposure is not necessary prerequisite. Even though the control group was not exposed to any VR environment for at least 6 months prior to the Desktop VR session, result show that their training experience and perceived learning weren't affected.

5 Conclusion

Our Need Analysis has 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

Traditional on-site training (pit training) presents several constraints and challenges:

- 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

In contrast, our SWOT analysis showed that VR-based training 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

But some weaknesses have also been 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 have shown that pre-training individual characteristics had a limited impact on trainee's experience during the 360 VR session and on their perceived learning at the end of the session. Conversely, experience during the session has a significant impact on perceived learning. 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.

Overall 88% of interviewees (284 in total) 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. Henceforth, 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 GEN 4 technology and it will be interesting to assess its effectiveness at providing a better experience to trainees in coming years.

As perceived learning is inherently subjective, we used a short competency test (designed by trainers) to assess actual learning, at least from a theoretical viewpoint. This questionnaire was filled by trainees before the 360 VR session and then a month later. Results show that 52% of trainees have improved their scores during the second round of testing. We need further research to better understand causality links between the training session (environment and content) and actual knowledge improvement beyond simple correlation. A tentative conceptual model has been designed by Shiva Pedram as part of her broader PhD research (Figure 16). This model could be validated against further monitoring of trainees.

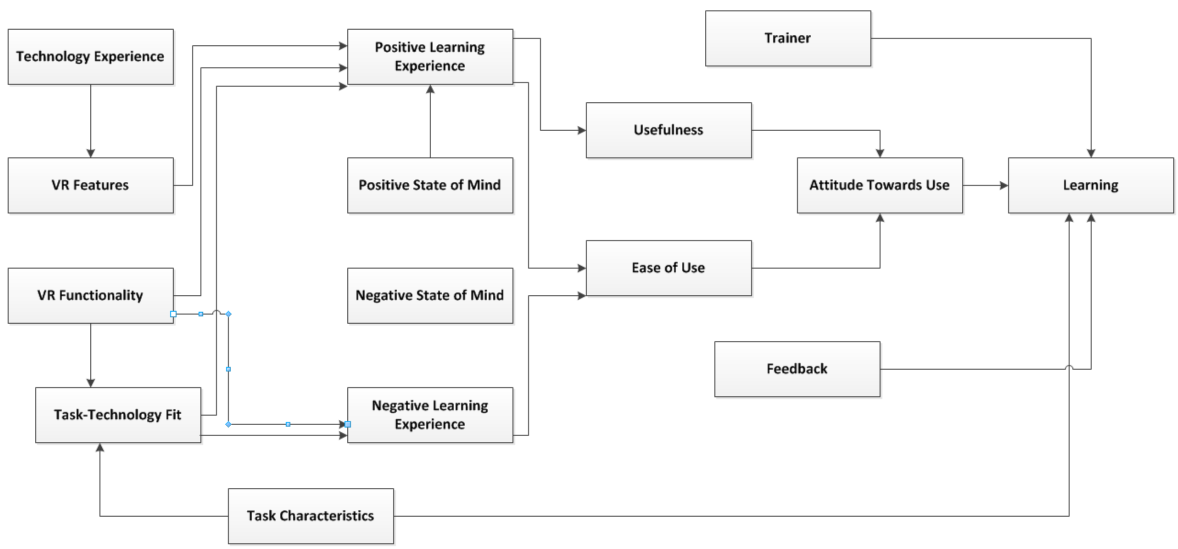


Figure 16: Conceptual model of learning process during VR-based training sessions

Finally, a second round of training sessions using GEN 4 technology (Desktop VR environment) included 222 trainees, amongst which 150 had been through a 360 VR session in the last 6-month period (treatment group) and 72 hadn't been involved (control group). This experiment allowed us to address two questions:

Q1: Did the training experience or perceived learning of trainees belonging to the treatment group change from one technological environment to the other?
Q2: Did the treatment group perform better compared with the control group?

In response to question 1, a significant number of trainees mentioned that Desktop VR had improved their experience in terms of better engagement and immersion, as well as lesser level of stress. 46% stated a higher level of perceived learning with Desktop VR environment. Age and professional experience seem also to have an influence on these results with older and more experienced trainees tending to score higher their experience with the Desktop VR environment. However, we need to remember that Desktop VR sessions came after the 360 VR ones and we need to acknowledge the fact that reinforcing mechanisms were at play.

This argument is weakened by our response to Question 2: there wasn't any significant difference between control and treatment groups in terms of training experience or perceived learning. Henceforth, trainees without prior (recent) exposure to VR environments performed as well as their colleagues. This outcome partially demonstrates the benefits of GEN 4 technology and Desktop VR environments.

Appendix 1: 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		

Appendix 2: 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		

Appendix 3: 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		

Appendix 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		

Appendix 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		

Appendix 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%

Appendix 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%

Appendix 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%

Appendix 8: 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%

Appendix 9: 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

Appendix 10: 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

Appendix 11: 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%

Appendix 12: 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%

Appendix 13: 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%

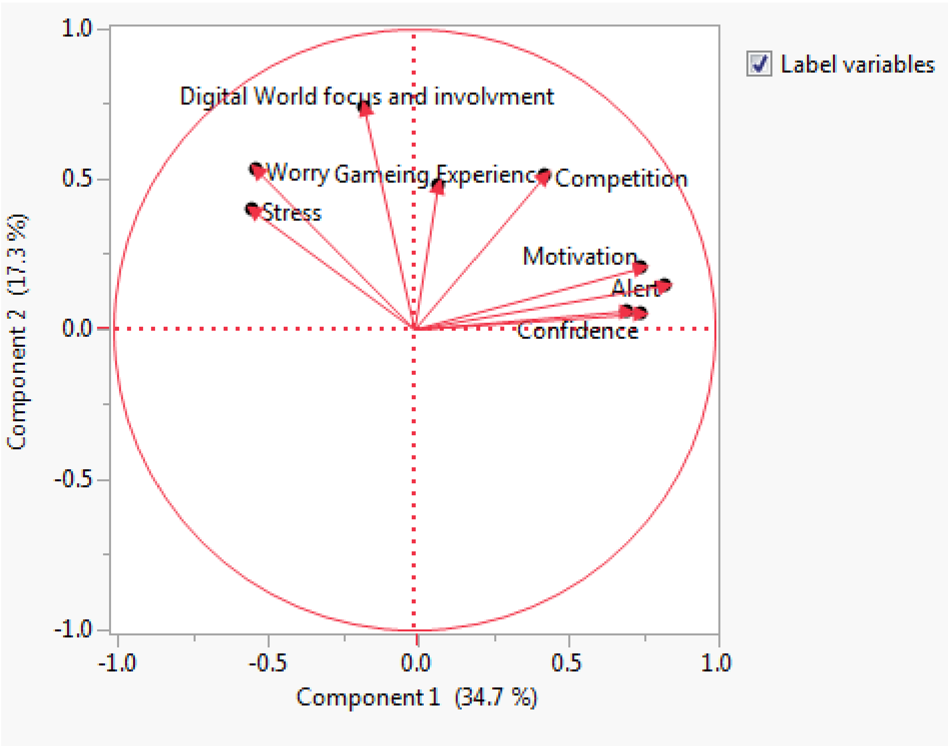
Appendix 14: Principal Component Analysis on pre-training variables (360 VR)

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.



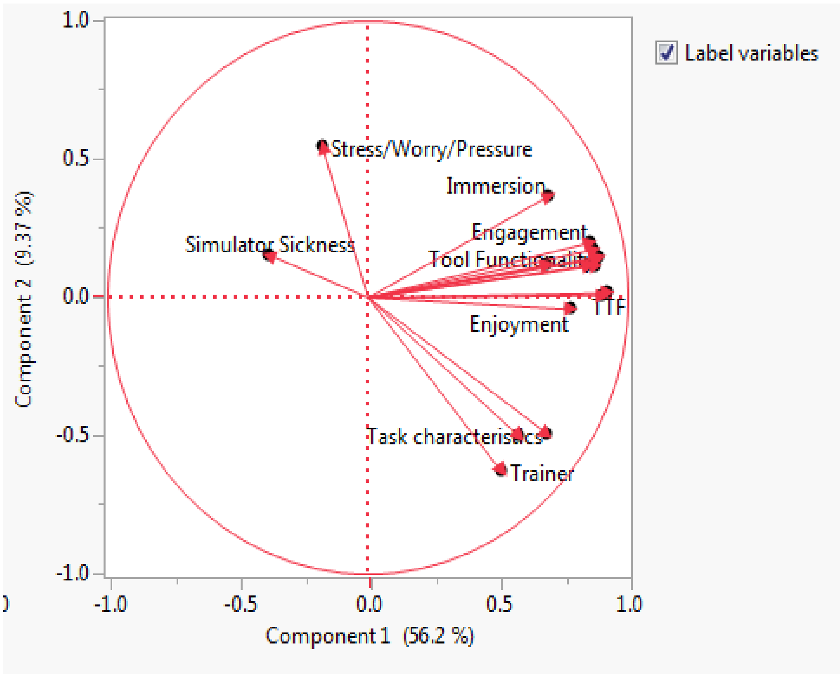
Appendix 15: Principal Component Analysis on post-training variables (360 VR)

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.



Appendix 16: 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

Appendix 17: 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 Attitude Towards Use - 360-VR Attitude 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
	Ties	20[ad]		
	Total	143		
Desktop-VR Engagement - 360-VR Engagement	Negative Ranks	37[ae]	56.03	2073.00
	Positive Ranks	87[af]	65.25	5677.00
	Ties	15[ag]		
	Total	139		
Desktop-VR Enjoyment - 360-VR Enjoyment	Negative Ranks	38[ah]	53.87	2047.00
	Positive Ranks	79[ai]	61.47	4856.00
	Ties	25[aj]		
	Total	142		
Desktop-VR Stress/Worry/Pressure - 360-VR Stress/Worry/Pressure	Negative Ranks	92[ak]	68.71	6321.50
	Positive Ranks	39[al]	59.60	2324.50
	Ties	11[am]		
	Total	142		
Desktop-VR Feedback - 360-VR Feedback	Negative Ranks	59[an]	60.53	3571.00
	Positive Ranks	64[ao]	63.36	4055.00
	Ties	22[ap]		
	Total	145		
Desktop-VR Task Characteristics - 360-VR Task Characteristics	Negative Ranks	55[aq]	61.34	3373.50
	Positive Ranks	57[ar]	51.83	2954.50
	Ties	31[as]		
	Total	143		
Desktop-VR Trainer - 360-VR Trainer	Negative Ranks	69[at]	70.17	4841.50
	Positive Ranks	54[au]	51.56	2784.50
	Ties	19[av]		
	Total	142		
Desktop-VR Perceived Learning - 360-VR Perceived Learning	Negative Ranks	52[aw]	63.24	3288.50
	Positive Ranks	66[ax]	56.55	3732.50
	Ties	27[ay]		
	Total	145		