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# Influence of age and industry experience on learning experiences and outcomes in virtual reality mines rescue training

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This study examined the effects of age and industry expertise on trainees' state of mind before, learning experiences during, and outcomes following virtual reality (VR) mines rescue training. The trainees were 284 mine rescue brigadesmen attending group VR training sessions run by Coal Services NSW. They were aged between 24 and 64 years and had up to 40 years of mines rescue experience. Questionnaire data and learning outcome measures showed that these miners were able to effectively engage with, and learn from, this VR training regardless of their age or mining experience. While the older trainees initially reported higher levels of stress and had less gaming experience, their experiences during VR training were very similar (although reports that the VR technology sometimes did not meet the task requirements did increase with age). Crucially, the perceived learning outcomes of this VR training were unaffected by age or field experience.

KEYWORDS

**virtual reality, training, sociodemographic, vocational training, adult learning, high risk industry**

## Introduction

Two trends are currently impacting today's work environment: the rapid growth of technology and the increase in the number of older workers (Berkowsky et al., 2017) (Figure 1). These workplace changes are creating both opportunities and challenges. Individuals in the workforce often belong to groups based on their age and/or experience. Belonging to such groups is likely to affect worker perceptions/attitudes of, and performance using, training technologies (Morris et al., 2005). Therefore, this highlights the importance of choosing training technologies that can support a broad range of users (both young and old, as well as inexperienced and highly experienced).

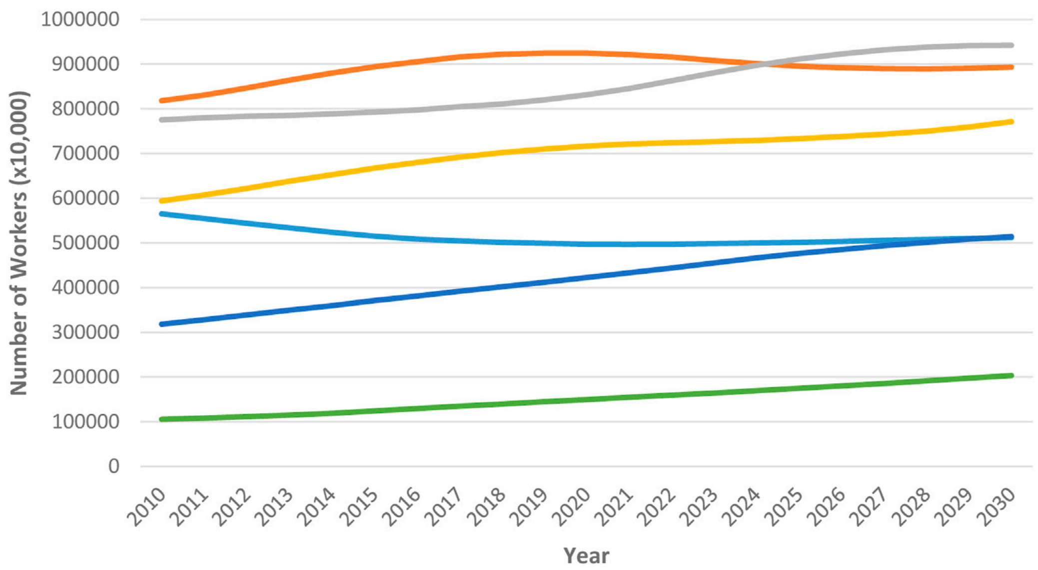


FIGURE 1
Workforce trends (thousands-annual) against different age groups (https://www.statista.com/).

Of the new training technologies currently available, virtual reality (VR) has the most potential to dramatically reshape the delivery of worker/industrial training, (Pedram et al., 2021a; Pedram et al., 2021b). In VR training, trainees typically operate simulated systems by exercising their motor, decision, or communication skills (Knerr, 2007). Such training simulations can be delivered in either fully immersive or semi-immersive virtual environments. According to Slater (1999), immersion is an objective characteristic of the VR system. Thus, interactive VR systems which provide a full field of view (e.g., head-mounted displays, CAVEs, or 360 VR theatres) are referred to as fully immersive VR, whereas those with limited fields of view (such as desktop VR) are categorized as semi-immersive VR. However, both types of VR systems are currently used to train workers/personnel, particularly in operations that are too dangerous, impractical, or costly to achieve *via* real-world/field training (Tichon and Burgess-Limerick, 2011; Bielsa, 2021; Mehrotra and Markus, 2021). For example, VR technology has long been used to train military and civilian pilots for high-risk scenarios in a safe physical environment (Honey et al., 2009; Schmitt et al., 2012). This VR technology is now also commonly used in medicine to provide surgical residency training (Barteit et al., 2021; Bielsa, 2021). The mining industry has also incorporated a variety of different virtual equipment simulators (e.g., dozer, dragline, haul truck, shovel, continuous miner, longwall, and roof bolter) to train their workers (Tichon and Burgess-Limerick, 2011; Pedram et al., 2020). As head-mounted display (HMD)–based VR technology has become increasingly affordable and available, it is also expected to play an increased role in such training.

Despite the enormous potential of VR for industrial training, technology adaptation and usage is known to depend greatly on the users' attitudes toward technology (Holden and Karsh, 2010). Thus, a lack of understanding of the end user (e.g., their attitudes and expectations about VR training) is likely to result in suboptimal outcomes. Previous research has shown that 1) computer interest is associated with the user's age, education, and computer knowledge (Ellis et al., 1999) and 2) technology usage depends on the user's age and attitudes about technology and is mediated by their computer anxiety and intelligence levels (Czaja et al., 2006; Holden and Karsh, 2010). Pedram et al. (2020) and Makransky and Petersen (2019) have both reported that positive attitudes toward the VR learning material and VR technology can significantly improve trainees' learning outcomes. The learning outcomes depending on the task might range from perceptual skills (Williams and Grant, 1999), decisional skills (Patterson and Shappell, 2010), to moto skill (Peters et al., 2010)]. These findings are compatible with the technology acceptance model (or TAM; see Davis et al., 1989), which is often used to explain utilization and user behavior in the information technology literature. TAM focuses on the person's attitudes toward using a particular technology, based on its perceived ease of use and its perceived usefulness. According to TAM, positive attitudes toward the use of technology should significantly improve VR training outcomes. More recently, Broady et al. (2010) have also proposed a unified theory of acceptance and usage of technology (UTAUT) model, which defines the usefulness of a piece of technology in terms of performance expectancy and its perceived ease of use as effort expectancy. When they are combined, performance and effort expectancy are referred to as user attitude. Thus, positive user attitudes toward VR according to this definition would also be expected to improve training outcomes.

Over the past two decades, there have been conflicting reports about the relationships between age, expertise, prior technology experience, and attitude toward technology use (Parnell and Carraher, 2003; Hawthorn, 2007; Broady et al., 2010). However, research has tended to find that 1) older adults have more negative attitude toward new technology (Broady et al., 2010; Hauk et al., 2018) and 2) attitude toward technology tend to be negatively correlated with computer anxiety (Igbaria and Chakrabarti, 1990). Taken together, this suggests that older adults might be (on average) more anxious about VR technology and therefore more negative in their attitude toward using VR for training. Older adults often report that they do not have adequate technology experience and knowledge; therefore, they have to spend more effort performing tasks involving technology (Hawthorn, 2007; Fozard and Wahl, 2012). While these older adults will not necessarily avoid technology, they may be more likely to try to limit their use of it (Hawthorn, 2007). However, while they appear to be slower than younger adults to adopt/develop positive attitude toward a new technology (Czaja et al., 2006), older adults will do so if it is perceived to have value (Heinz et al., 2013). For instance, one recent study by Huygelier et al. (2019) investigated the attitudes of older adults toward using head-mounted display (HMD)–based VR technology (with a focus on the health treatment). They examined the attitude of 76 volunteers (aged between 57 and 94 years) toward immersive VR, which changed from neutral to positive after their first exposure to immersive HMD VR. Interestingly, the oldest participants were found to show the greatest improvements in attitude with increased exposure to HMD VR.

In addition to age, adult learning and attitude toward technology are also known to be influenced by prior knowledge and technology experience (Demirbilek, 2010). For example, Arbaugh and Duray, (2002) found that MBA students with prior technology experience were more satisfied with training using computer assisted platforms. However, Pedram et al. (2020) appeared to find that prior technology/gaming experience had little impact on the outcomes of their VR mines rescue training (conducted in immersive VR)—perhaps because all of their participants were miners. According to Mayer (2014), trainees should learn best from multimedia platforms (such as immersive VR) when they are already familiar with the content and the main concepts of the training, as this familiarity should lessen their cognitive load when presented with novel concepts (Mayer, 2014). Another study by Park et al. (2009) analyzed the influence of prior science knowledge on learning in a highly immersive and interactive VR environment compared learning *via* a more traditional approach. They found that participants with more prior knowledge of the topic had better outcomes with the VR (compared to the traditional) training. It should also be noted that Makransky et al. (2019) suggested that immersive VR may not be the best medium for learning complex concepts. However, they proposed that traditional pre-training and knowledge provision could assist VR learning outcomes by decreasing the trainee's cognitive load during these simulations.

Currently, research is scarce on the impacts of age and expertise on learning experiences/outcomes during VR training. Pedram et al. (2020) has however recently identified a number of other factors that influence trainee learning experiences and outcomes during immersive VR mines rescue training. He found that the trainees' actual and perceived learning were both enhanced by their engagement with the scenario, its representational fidelity, and their feelings of presence (the sense of being in an underground mine in this study) and social presence (the experience of being with fellow miners and engaging with them), as well as high levels of immersion (being embraced by the training scenario). In that study, participants' experiences of presence and immersion reportedly created near real-life experiences during the simulated rescue, which also had a positive impact on learning experiences and outcomes.

The current study extends on this research by investigating the possible impacts of trainee age and expertise on learning experiences and outcomes during the same immersive VR mines rescue training. Trainees were provided with a pre-training questionnaire, which assessed their state of mind prior the training (Pedram et al., 2020). In addition to obtaining their demographic details (i.e., their age and years of experience as a mine worker), this questionnaire also measured 1) their levels of self-efficacy, motivation, enthusiasm, and distress just prior to the VR training; 2) their gaming experience; and 3) how they felt in general. After the VR training, the trainees also completed a post-training questionnaire that was focused on their experiences of the VR training, as well as on their learning outcomes. In the second questionnaire, the trainees rated 1) the perceived level of the realism, representational fidelity, and immersion afforded by VR; 2) their feelings of presence (including co-presence and social presence), flow, distress, pressure, and attitude toward the technology; 3) their opinions about the technology's ease of use, usefulness and plausibility; 4) the impact of the trainer and their feedback on their VR training; and 5) the amount of perceived learning that occurred during their VR training. This data therefore should shed light on the impact that age and expertise have on learning experiences and outcomes when using VR as a training platform.

## Materials and methods

The method and results presented here are part of a larger research project conducted by the Pedram et al. (2020). This paper reports a subset of reporting a subset of the results since the whole study was too large to report in a single study. The primary objective of the whole research project was to evaluate the effectiveness of a VR

TABLE 1 Participant information.

| | Number | Minimum | Maximum | Mean | Standard Deviation |
|---|---|---|---|---|---|
| Age | 284 | 24.00 | 64.00 | 40.2042 | 9.257 |
| Mining experience | 284 | 1.00 | 40.00 | 9.02 | 7.745 |

simulation for training professionals in the mining industry. As the literature review was conducted, it became apparent that we could not evaluate a VR training platform as a training tool in isolation. There is a need to develop a comprehensive research design to better understand the roles that trainees, technology, and trainers can play in technology-mediated learning environments and how each factor can impact the learning processes and outcomes. As a first step, the constructs impacting the learning process and outcome in the VR training environment were extracted from the body of knowledge, a comprehensive framework was developed, and the relationship between the constructs were presented and extensively discussed in Pedram et al. (2020). Following that, in the current study, we are presenting and discussing the possible impacts of trainee age and expertise on learning experiences and outcomes during the same immersive VR mines rescue training. Although the study is focused on training for mining industry, similar evaluation approaches could be adopted for other VR training applications in other domains because many of the factors and requirements identified are transferable across any domain.

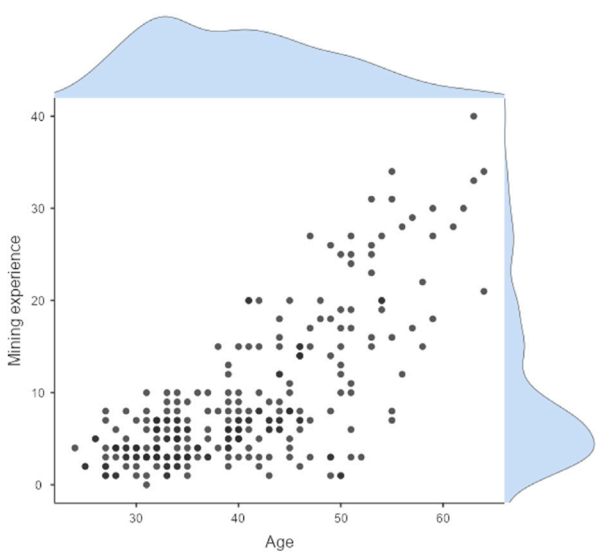


FIGURE 2
Distributions and the relationship between age and expertise.

## Scenario

The VR training scenario was developed by Mines Rescue Pty Ltd. (https://www.coalservices.com.au/mining/mines-rescue/virtual-reality-technologies-vrt/) using Unity3D, a multi-platform game engine. In the simulated scenario, an accident involving an underground vehicle starts a fire at the bottom of the transport drift. The fire is uncontained and spreads to the coal, contaminating several tunnels and roadways with toxic gases. The mine rescue team is deployed to the site, where they are informed that one of the miners is missing and the others are safe. The task assigned to the mines rescue brigade is therefore to undertake a search and rescue the missing miner. The trainer is responsible for guiding the group of 5–7 trainees through each stage of this scenario, prompting them, when required, for appropriate actions or responses.

## Participants

A total of 284 trainees took part in the study with a mean age of 40.2 (SD = 9.2) and on average 9 years of experience in the field (SD = 7.75) (see Table 1). All of the participants in this study were male, aged between 24 and 64 years, with their time spent mining ranging between 1 and 40 + years (Figure 2).

## Technology in use

This research focused on a VR training program developed specifically for a 360° immersive theatre (360 VR). This theatre consisted of a 10-m diameter and 4-m high cylindrical screen that displayed a stereo 3D 360° virtual environment, which provided a fully immersive experience to the trainees (Figure 3). The large area within the theatre allowed for a mixed reality experience, where groups of (5–7) trainees interacted with props (e.g., virtual gas detectors) and each other. This meant that appropriate physical responses, activities, and reflexes could also be included as part of the overall VR training experience.

## Research design

Pre- and post-training questionnaires were used to collect main data for this study (note: these questionnaires have been previously published in full in Pedram et al., 2020). These questionnaires measured the demographics of our trainees, as well as factors related to their state of mind before VR, their attitude, and impressions of the VR technology/training simulation, as well as their learning experiences while in VR and the outcomes of that VR

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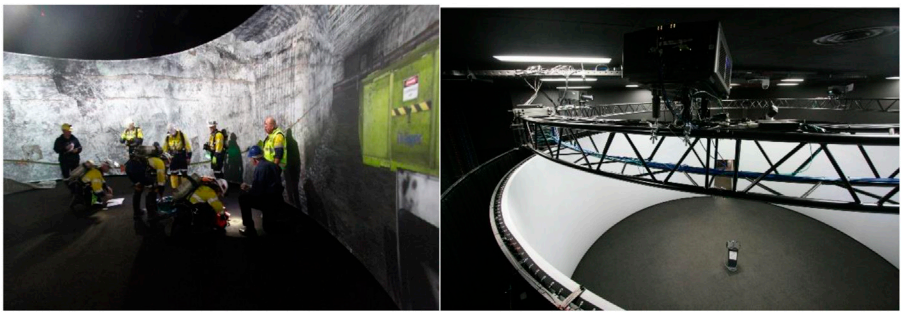

FIGURE 3
360° immersive theatre (360 VR) in Woonona, NSW (credits: Mines Rescue Pty Ltd.).

training. Each of these trainees participated in one of the 45 group VR training sessions that were available. Each participant spent 10 min prior to training to complete pre-training questionnaires, 45 min going through the training in VR, and 15 min post-training to complete post-training questionnaires.

## Data analysis

A data analysis was performed using jamovi (v. 1.6.23.0). An orthogonal principal component analysis (PCA) with varimax rotation was used to assess the factor loadings of the questionnaire items. The three components with Eigenvalues larger than 2 were retained. Cronbach alpha was used to determine the internal reliability of items relating to each of these three components. A generalized linear model (GLM) approach was then employed to investigate the relationships of age and expertise on 1) the learners' state of mind prior attending VR training, 2) their learning experiences during immersive VR, and 3) their perceived degree of learning of the training.

# Results

## State of mind prior to virtual reality training

Table 2 summarizes the state of mind of our participants prior attending the experiment (all ages and levels of field experience). Each item was measured using a 10-point Likert scale, where 0 was highly disagree, 5 was neutral, and 10 was highly agree. In general, the 284 trainees were highly motivated (M = 8.21, SD = 1.250) and excited about the experience (M = 8.22, SD = 1.309). Even though they reported low levels of gaming experience on average (M = 2.21, SD = 1.659), they did not report high feelings of distress (M = 7.49, SD = 1.659). They also reported feeling moderately competitive (M = 6.22, SD = 1.508) and (on average) reported high levels of self-efficacy (M = 8.18, SD = 1.259). On average, trainees generally felt good prior to participating in the VR training (M = 7.81, SD = 1.808).

## Virtual reality training experiences and learning outcomes

Table 3 summarizes the learning experiences and outcomes of all participants (see Table 2). In general, our trainees tended to report positive experiences while they were in VR. During this training, they reported moderate perceptions of the realism/representational fidelity (M = 5.98, SD = 1.527), immersion (M = 5.36, SD = 1.320), and co-presence (M = 6.67, SD = 1.604). They reported higher levels of presence (M = 6.67, SD = 1.915), social presence (M = 6.23, SD = 1.587), flow (M = 6.87, SD = 1.897), not being distressed/pressured (M = 6.04, SD = 1.486), ease of use (M = 6.73, SD = 1.782), usefulness (M = 6.58, SD = 1.794), and plausibility (M = 7.07, SD = 1.798). Trainees also reported highly positive attitude toward the technology (M = 7.15, SD = 1.865) and ranked both impact of the trainer (M = 8.66, SD = 1.380) and their feedback high (M = 7.54, SD = 1.584) as well. Importantly, they ranked their perceived learning as high (M = 8.03, SD = 1.411) following the VR training. Contrary to our concerns, they reported very low levels of sickness and tiredness directly after the VR training session (M = 2.63, SD = 1.489).

## Principle component analysis (PCA) on all variables

The three components extracted by the PCA (the learner's characteristics, their state of mind prior to training, and VR training experiences and outcomes) (Table 4) explain 55.5% of the overall variance. All the pre- and post-training factors returned Cronbach's alpha values of greater than 0.7, indicating acceptable levels of internal reliability. The factor structure revealed by this PCA is compatible with the structure reported in Pedram et al. (2020) (an

TABLE 2 Measures of state of mind prior to VR training.

| Factor | Mean | Std. Deviation | Skewness | Std. Error | Kurtosis |
|---|---|---|---|---|---|
| Gaming experience | 2.21 | 1.659 | 0.980 | 0.145 | 0.304 |
| Enthusiasm | 8.22 | 1.309 | −0.424 | 0.145 | −0.687 |
| Not distressed | 7.49 | 1.659 | −0.779 | 0.145 | −0.644 |
| Motivation | 8.21 | 1.250 | −0.365 | 0.145 | −0.534 |
| Competition | 6.22 | 1.508 | −0.009 | 0.145 | −0.318 |
| Self-efficacy | 8.18 | 1.259 | −0.495 | 0.145 | 0.592 |
| Well-being | 7.81 | 1.808 | −1.142 | 0.145 | 1.393 |

TABLE 3 Measures of VR training experiences and learning outcomes.

| Factor | Mean | Std. Deviation | Skewness | Std. Error | Kurtosis |
|---|---|---|---|---|---|
| Sickness | 2.63 | 1.489 | 1.299 | 0.145 | 2.211 |
| Realism | 5.98 | 1.527 | −0.162 | 0.145 | −0.044 |
| Immersion | 5.36 | 1.320 | −0.515 | 0.145 | 0.423 |
| Co-presence | 6.67 | 1.604 | −0.484 | 0.145 | 1.122 |
| Ease of use | 6.73 | 1.782 | −0.496 | 0.145 | 0.457 |
| Usefulness | 6.58 | 1.794 | −0.370 | 0.145 | 0.306 |
| Plausibility | 6.92 | 2.019 | −0.625 | 0.145 | 0.242 |
| Attitude | 7.15 | 1.865 | −0.763 | 0.145 | 0.312 |
| Presence | 6.67 | 1.915 | −0.415 | 0.145 | −0.014 |
| Social presence | 6.23 | 1.587 | −0.414 | 0.145 | 0.742 |
| Flow | 6.87 | 1.897 | −0.198 | 0.145 | −0.225 |
| Not stressed/pressured | 6.04 | 1.486 | −0.326 | 0.145 | 0.493 |
| Feedback | 7.54 | 1.584 | −0.670 | 0.145 | 0.511 |
| Trainer | 8.66 | 1.380 | −1.338 | 0.145 | 2.127 |
| Learning | 8.03 | 1.411 | −0.680 | 0.145 | 0.316 |

earlier VR mines rescue training study). In the current study, we also investigated possible relationships between the trainee's age/expertise and their learning experiences/outcomes during VR training.

The correlation matrix (see Supplementary Appendix SA1 for the correlation matrix) shows a very strong correlation between trainee age and mining experience (level of field expertise). As the current study data does not offer the opportunity to disentangle the relative contributions of age *vs*. experience, we will therefore examine the influence of these two variables together (i.e., age/experience = age and experience combined). Consistent with predictions based on past research (Heinz et al., 2013; Hauk et al., 2018), we observed the negative relationship between gaming experience and age/experience. The trainees' state of mind before training (i.e., their motivation, enthusiasm, competition, self-efficacy, and well-being) generally had positive relationships with their learning experiences in VR—with the exceptions of simulator sickness (which was negatively associated with their learning experiences) and perceived stress (which did not load on any of the components).

## Relationships between the learner's age/experience and state of mind prior to VR training

We used a generalized linear model (GLM) to examine possible relationships between age/experience and the participants' state of mind before the VR-based training (see Table 5). Age/experience was modeled as a linear combination of stress, motivation, enthusiasm, competition, self-efficacy, gaming experience, and well-being[1]. We found that age/experience was positively associated with stress and

1 Age ~1 + "Stress" + "Motivation" + "Enthusiasm" + "Competition" + "Self efficacy" + "Gaming Experience" + "Wellbeing."

TABLE 4 Component loadings for the PCA.

| Factor | Learning Experience | State of mind before training | Age, mining, and gaming experience | Uniqueness |
|---|---|---|---|---|
| Age | | | 0.856 | 0.233 |
| Brigades | | | 0.859 | 0.251 |
| Mining | | | 0.766 | 0.408 |
| Gaming experience | | | −0.522 | 0.717 |
| Motivation | | 0.724 | | 0.422 |
| Enthusiasm | | 0.841 | | 0.281 |
| Competition | | 0.534 | | 0.709 |
| Self-efficacy | | 0.774 | | 0.393 |
| Well-being | | 0.715 | | 0.484 |
| Pre-stress | | −0.463 | | 0.774 |
| Realism | 0.693 | | | 0.508 |
| Immersion | 0.663 | | | 0.534 |
| Social presence | 0.851 | | | 0.256 |
| Ease of use | 0.853 | | | 0.265 |
| Usefulness | 0.870 | | | 0.231 |
| Tool functionality | 0.871 | | | 0.235 |
| Task-technology fit | 0.909 | | | 0.169 |
| Attitude towards use | 0.871 | | | 0.208 |
| Presence | 0.862 | | | 0.244 |
| Social presence | 0.838 | | | 0.277 |
| Enjoyment/flow | 0.772 | | | 0.354 |
| Feedback | 0.582 | | | 0.655 |
| Plausibility | 0.721 | | | 0.474 |
| Perceived learning | 0.765 | | | 0.404 |
| Trainer | 0.531 | | | 0.698 |
| Simulator sickness | −0.330 | | | 0.865 |
| Perceived stress | | | | 0.958 |

TABLE 5 Estimates of the relationships between age/experience and the learner's state of mind.

| Variables | Estimate | SE | Lower | Upper | df | t | p |
|---|---|---|---|---|---|---|---|
| (Intercept) | 40.154 | 0.539 | 39.0931 | 41.214 | 259 | 74.56 | < 0.001 |
| Stress | 0.721 | 0.359 | 0.0147 | 1.428 | 259 | 2.01 | 0.045 |
| Motivation | −0.871 | 0.592 | −2.0367 | 0.294 | 259 | −1.47 | 0.142 |
| Enthusiasm | 0.691 | 0.673 | −0.6341 | 2.017 | 259 | 1.03 | 0.305 |
| Competition | −0.510 | 0.400 | −1.2979 | 0.278 | 259 | −1.28 | 0.203 |
| Self-efficacy | 0.557 | 0.548 | −0.5216 | 1.635 | 259 | 1.02 | 0.310 |
| Gaming experience | −2.192 | 0.437 | −3.0520 | −1.332 | 259 | −5.02 | <0.001 |
| Pre-well-being | −0.429 | 0.408 | −1.2317 | 0.374 | 259 | −1.05 | 0.294 |

negatively associated with prior gaming experience. This is in line with previous findings that 1) younger people generally have more exposure to technology than older people (Renaud and Ramsay, 2007) and 2) as person gets older, their levels of computer-related anxiety appear to increase (Laguna and Babcock, 1997).

## Relationships between the learner's age/experience and VR training experiences and learning outcomes

We then used the generalized linear model (GLM) to examine possible relationships between age/experience and learning

TABLE 6 Estimates of the relationships between age/experience and VR training experiences and outcomes.

| | | | 95% Confidence interval | | | | |
|---|---|---|---|---|---|---|---|
| **Variables** | **Estimate** | **SE** | **Lower** | **Upper** | **df** | **t** | **p** |
| (Intercept) | 40.1155 | 0.579 | 38.974 | 41.257 | 234 | 69.252 | <0.001 |
| Simulator sickness | 0.1050 | 0.437 | −0.756 | 0.966 | 234 | 0.240 | 0.810 |
| Perceived realism | −0.1538 | 0.577 | −1.291 | 0.983 | 234 | −0.267 | 0.790 |
| Perceived immersion | 1.0455 | 0.691 | −0.316 | 2.407 | 234 | 1.513 | 0.132 |
| Perceived social presence | −0.1512 | 0.722 | −1.574 | 1.272 | 234 | −0.209 | 0.834 |
| Perceived ease of use | 0.9016 | 0.738 | −0.553 | 2.356 | 234 | 1.221 | 0.223 |
| Perceived usefulness | −0.7859 | 0.729 | −2.222 | 0.651 | 234 | −1.078 | 0.282 |
| Perceived tool functionality | −1.6714 | 0.788 | −3.224 | −0.119 | 234 | −2.121 | 0.035 |
| Perceived task-technology fit | 0.1804 | 0.868 | −1.530 | 1.891 | 234 | 0.208 | 0.836 |
| Atittude toward use | 1.1133 | 0.775 | −0.413 | 2.640 | 234 | 1.437 | 0.152 |
| Perceived presence | −0.2015 | 0.617 | −1.416 | 1.013 | 234 | −0.327 | 0.744 |
| Perceived enjoyment/flow | 0.7313 | 0.509 | −0.272 | 1.734 | 234 | 1.436 | 0.152 |
| Perceived stress | −0.0625 | 0.473 | −0.995 | 0.870 | 234 | −0.132 | 0.895 |
| Feedback | 0.5503 | 0.535 | −0.505 | 1.605 | 234 | 1.028 | 0.305 |
| Plausibility | 0.1100 | 0.669 | −1.207 | 1.427 | 234 | 0.165 | 0.869 |
| Trainer | −0.2778 | 0.578 | −1.416 | 0.860 | 234 | −0.481 | 0.631 |
| Perceived learning | −0.5133 | 0.821 | −2.130 | 1.103 | 234 | −0.626 | 0.532 |

experience and outcome. Age/experience was modeled as a linear combination of simulator sickness, perceived realism, perceived immersion, perceived social presence, perceived ease of use, perceived usefulness, perceived tool functionality, perceived task-technology fit, attitude toward use, perceived presence, perceived enjoyment/flow, perceived stress, feedback, plausibility, trainer, and perceived learning[2]. As can be seen in Table 6, age/experience was only found to significantly affect perceived tool functionality, with older/more experienced trainees being more likely to rate this item lower than younger/less experienced trainees. Age/experience did not appear to significantly alter any other aspect of their VR training experience. Crucially, the trainees' age and level of field expertise had no impact on their perceived learning outcomes.

## Influence of age/rescue experience, learner's state of mind and learning experiences on perceived learning

We also used the generalized linear model (GLM) to examine how the perceived degree of learning as a result of the training was related to 1) the trainee's age/experience, 2) their state of mind prior attending VR training, and 3) their learning experiences during immersive VR[3] (see Table 7). This model explained 76.3% of variance in perceived learning. Importantly, there was no significant relationship between age/experience and perceived learning (beta = −8.87e−4, t (209) = −0.146, $p$ =0 .884), which is corroborated by the Bayes factor ($BF_{01}$ = 3.89). However, significant positive relationships were found between perceived learning and 1) perceived realism, 2) task-technology fit, 3) plausibility, 4) trainer, and 5) their feedback, as well as a trend involving perceived enjoyment. These findings suggest that the more the trainees' perceived their VR training to be realistic, enjoyable, fit for purpose, and plausible, the more they perceived that they had learnt during the session. This also confirms that the trainer and their feedback had a strong positive impact on the trainee's perceived learning. Interestingly, none of the trainee state-of-mind variables (obtained before the VR training) had a significant effect on their perceived learning.

## Discussion

Given the rising popularity of VR for industrial training and our aging workforce, it is important to understand the factors responsible for delivering successful VR-based training to a broad range of users. In this study, we had planned to investigate the influence of trainee's age and

2 Age ~1 + "Simulator Sickness" + "Perceived Realism" + "Perceived Immersion" + "Perceived Social Presence" + "Perceived Ease Of Use" + "Perceived Usefulness" + "Perceived Tool Functionality" + "Perceived Task-Technology Fit" + "Attitude Toward Use" + "Perceived Presence" + "Perceived Enjoyment/flow" + "Perceived Stress" + "Feedback" + "Plausibility" + "Trainer" + "Perceived Learning."

TABLE 7 Influence of age/rescue experience, learner state of mind, and learning experiences on perceived learning.

| Variables | Estimate | SE | 95% Confidence interval Lower | Upper | df | t | p |
|---|---|---|---|---|---|---|---|
| (Intercept) | 8.00863 | 0.04884 | 7.91235 | 8.1049 | 209 | 163.969 | <0.001 |
| Age | −8.87e−4 | 0.00608 | −0.01288 | 0.0111 | 209 | −0.146 | 0.884 |
| Simulator sickness | 0.02168 | 0.03753 | −0.05231 | 0.0957 | 209 | 0.578 | 0.564 |
| Perceived realism | 0.09934 | 0.05039 | 8.93e−6 | 0.1987 | 209 | 1.972 | 0.050 |
| Perceived immersion | −0.04544 | 0.06270 | −0.16904 | 0.0782 | 209 | −0.725 | 0.469 |
| Perceived social presence | 0.09156 | 0.06305 | −0.03273 | 0.2159 | 209 | 1.452 | 0.148 |
| Perceived ease of use | −0.02928 | 0.06342 | −0.15430 | 0.0957 | 209 | −0.462 | 0.645 |
| Perceived usefulness | −0.04876 | 0.06418 | −0.17528 | 0.0778 | 209 | −0.760 | 0.448 |
| Perceived tool functionality | −0.00792 | 0.06892 | −0.14379 | 0.1279 | 209 | −0.115 | 0.909 |
| Perceived task-technology fit | 0.27072 | 0.07512 | 0.12262 | 0.4188 | 209 | 3.604 | <0.001 |
| Atittude towards use | −0.00899 | 0.06903 | −0.14507 | 0.1271 | 209 | −0.130 | 0.897 |
| Perceived presence | −0.06527 | 0.05458 | −0.17287 | 0.0423 | 209 | −1.196 | 0.233 |
| Perceived social presence (2) | −0.04472 | 0.06573 | −0.17429 | 0.0848 | 209 | −0.680 | 0.497 |
| Perceived enjoyment/flow | 0.08816 | 0.04548 | −0.00151 | 0.1778 | 209 | 1.938 | 0.054 |
| Perceived stress | −0.02786 | 0.04048 | −0.10767 | 0.0519 | 209 | −0.688 | 0.492 |
| Feedback | 0.12507 | 0.04438 | 0.03758 | 0.2126 | 209 | 2.818 | 0.005 |
| Plausibility | 0.34185 | 0.05292 | 0.23753 | 0.4462 | 209 | 6.460 | <0.001 |
| Trainer | 0.18722 | 0.05022 | 0.08822 | 0.2862 | 209 | 3.728 | <0.001 |
| Pre-stress | −0.02896 | 0.03370 | −0.09540 | 0.0375 | 209 | −0.859 | 0.391 |
| Pre-motivation | −0.03120 | 0.05448 | −0.13860 | 0.0762 | 209 | −0.573 | 0.567 |
| Pre-enthusiasm | 0.08236 | 0.06303 | −0.04189 | 0.2066 | 209 | 1.307 | 0.193 |
| Pre-competition | −0.02387 | 0.03832 | −0.09941 | 0.0517 | 209 | −0.623 | 0.534 |
| Pre-self-efficacy | −0.07207 | 0.05107 | −0.17275 | 0.0286 | 209 | −1.411 | 0.160 |
| Pre-gaming experience | 0.01758 | 0.04361 | −0.06840 | 0.1036 | 209 | 0.403 | 0.687 |
| Pre-well-being | 0.01834 | 0.03777 | −0.05613 | 0.0928 | 209 | 0.486 | 0.628 |

field expertise on 1) their state of mind before VR training, 2) their experiences during the VR training, and 3) their perceived learning directly after VR training. However, due to the high correlation between age and field experience, we were forced to look at their combined influence instead. We were also interested in identifying which pre- and during-training factors have the greatest impact on our trainees' learning outcomes.

Based on past research, we had expected that the older trainees to be more anxious about VR, have less experience using this technology, have more negative in their attitudes toward using it for training, and also be less likely to use computer-based technology in general (Laguna and Babcock, 1997; Renaud and Ramsay, 2007). Consistent with these expectations, our analysis of the pre-training questionnaire data revealed tha: 1) younger participants had (on average) higher levels of gaming experience and 2) older trainees reported (on average) higher level of stress before the VR training session. However, surprisingly, these were only two pre-training variables that displayed statistically significant differences based on age/experience.

In terms of trainee experiences during their actual VR training, these were generally found to be quite positive—regardless of their age. Younger and older trainees' experiences during VR training were similarly positive, despite the older trainees' limited prior experience with technology and their reportedly higher levels of stress before the VR training. Conducting the VR mines rescue training scenario in the 360° theatre was found to generate very little simulator sickness or distress in the trainees. This VR training was generally 1) perceived to be realistic and plausible, 2) reported to promote strong feelings of presence (as well as co-presence and social presence) and flow, 3) found to generate positive attitudes toward it use, and 4) reported to be easy to use and useful. Both younger and older trainees found that their trainer played an important role in this VR training (the quality of the feedback that they provided was also highlighted). In general, our findings appear to be consistent with Broady et al. (2010)—who found that younger and older adults had similar attitude and experiences using computers and technology when they both perceived the technology to be useful.

We only found one significant effect of age/expertise on these training experiences: our older trainees tended to rate the functionality of VR as a tool lower than their younger colleagues. This negative relationship between age/experience and perceived tool functionality was due to the older (i.e., more experienced) trainees being more aware of the limitations of this technology (as they had more prior experience with this sort of rescue training and exposure to these rescue scenarios, prior to the training session). For VR training to be successful, it is crucial for training tasks to be supported by appropriate technology affordances (Zhang et al., 2017). For example, while this exercise would normally involve splitting the trainees into multiple search teams (each consisting of two rescuers), the 360 VR theatre did not support this. So, the trainees had to stay as part of one larger group the entire time. Trainee responses indicated that 1) this particular limitation did not negatively impact their learning experiences and 2) the older (more experienced) trainees still found the VR-based training useful (as it created both a realistic and enjoyable experience). However, this limitation could have been avoided by delivering the training scenario *via* multiple user HMD VR. If this is attempted in the future, it would be interesting to see whether this age/experience effect on perceived tool functionality persists.

While our older/more experienced trainees generally reported being more stressed prior to the VR training, had less general experience with technology (including VR), and had some issues with the functionality of the platform, we found no significant relationship between trainee age/experience and their perceived learning. Thus, at least in this study, neither the trainee's age nor their level of field expertise appeared to be critical factors in determining success of VR as a training platform. As we had hoped, this finding provides evidence that VR training can support a broad range of users (with perceived benefits reported for both young and old workers, with field experience ranging from 1 to 40 years).

While age and experience did not appear to influence training success, ratings of perceived learning were found to increase significantly when the VR training was reported to be more realistic, enjoyable, fit for purpose, and plausible. These findings emphasize the importance of using well-designed simulations and appropriate VR training platforms. Ideally, such VR solutions should 1) offer the optimal amount of information and task challenge to the trainee while still being realistic and enjoyable (Sweller, 1994) and 2) emphasize the core training concepts, support the training tasks and minimize the trainee's cognitive load. The current immersive VR training allowed our trainees to experience the rescue scenario "first hand". Compared to traditional teaching methods, this is known to increase the plausibility (i.e., "believing what you are seeing" (Skarbez et al., 2018 p.96:6); or thinking that the events are happening for real) and the perceived realism of the training—previously shown to also contribute to more positive attitudes toward the training (Pedram et al., 2020). These increase in plausibility and realism are especially important when training for extreme/high-risk situations, where the purpose is to create opportunities for trainees to be exposed to, and "present" in, these dangerous situations (while remaining safe). This will allow the trainees to make decisions without suffering from the potentially disastrous consequences of any mistakes. Trainees can therefore learn from their mistakes in ways might not be possible with other forms of training.

In addition to the simulation/technology factors described before, we also found that perceived learning increased with the trainee's ratings of both the trainer and the quality of their feedback became more positive, indicating that factors other than the technology and the quality of the simulation are important in producing optimal/successful learning outcomes.

## Limitations and future directions

This study is a starting point for investigating the impact of trainee' characteristics on their VR training experiences and learning outcomes. While the current findings are expected to generalize to other contexts (e.g., VR training in other industries), the study does however have some limitations, which will need to be addressed in future studies. These limitations are as follows:

- We found a strong correlation between age and mining experience (level of expertise). Therefore, our study data did not offer the opportunity to disentangle the relative contributions of age vs. experience. Future studies are needed to examine these effects separately in participant populations where age and experience are not so strongly correlated.
- We have not yet had a chance to validate these findings on other data sets. Future studies are encouraged to use the pre- and post-VR learning questionnaires developed and presented in this study (see also Pedram et al., 2020) to collect the relevant data and measure the impact of age and expertise on learning experience and outcome.
- Our evidence-based findings rely on a statistically significant group of 284 trainees; however, this group was rather specific (all of the participants were mine rescuers and they all were male; there were no female rescuers in NSW, Australia at the time of conducting this research). It would therefore be beneficial to extend this study to other industries and add gender diversity to investigate to impact of age and expertise on learning experiences and outcomes.
- Our study relied on one (search and rescue) training scenario only and utilized a 360 VR platform. It would be useful to replicate/validate these findings with different training scenarios and using different VR platforms (such as HMDs) to confirm whether age

and/or expertise still have impacts on learning experiences and outcomes.
- Perceived learning was used as a proxy for actual learning outcomes in this study. While we have previously found a high correlation between perceived and actual learning outcomes (Pedram et al., 2020), future studies would benefit from a more objective measure of learning.

## Conclusion

In this study, we found that prior to their VR mines rescue training, older trainees tended to have significantly less gaming experience and felt more stressed than younger trainees. However, all of our trainees tended to report positive VR training experiences—irrespective of their age. Neither age nor experience was found to significantly alter the outcomes of this VR training. The only effect of age/experience appears to be on perceived tool functionality (which we attributed to the limitations of our particular platform in supporting the certain task requirements involved in the training scenario). Previous research by Huygelier et al. (2019) and Syed-Abdul et al. (2019) found that older adults tended to change their perceptions of technology/VR and develop more positive attitudes toward them, after perceiving their benefits. Our results extend this knowledge by identifying other factors contributing to positive perceptions of VR technology and determining which of them have greatest impacts on perceived learning. Our findings suggest that, regardless of age/expertise, all trainees can potentially benefit from the VR mines rescue training. These findings should be very encouraging for other industries planning to use immersive VR as a training tool—as it appears that a well-designed VR training solution can produce successful learning outcomes for a wide range of workers.

## Data availability statement

The original contributions presented in the study are included in the article/Supplementary Materials; further inquiries can be directed to the corresponding author.

## Ethics statement

The studies involving human participants were reviewed and approved by Human Research Ethics Committee, University of Wollongong. The patients/participants provided their written informed consent to participate in this study.

## Author contributions

SP was the lead author, conducted literature review, performed data collection, and wrote the manuscript. SM performed data analysis and wrote the manuscript. SP performed data collection and wrote the manuscript. MF was the technical advisor on the manuscript. PP wrote and edited the manuscript.

## Conflict of interest

Author MF was employed by the company Coal Services Pty Ltd.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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## Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frvir.2022.941225/full#supplementary-material

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