Comparing the Effects of Immersive Training Environments on Cognitive and Affective Variables in the Development of Situation Awareness

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Table of Contents

List of Figures

List of Tables

Abstract

In high-risk industries, scenario-based training is critical for the development of decision-making skills. Whereas real-life role-played scenarios are preferred, they can be time and resource intensive as well as expensive. Virtual reality, through immersion and interactivity, may provide an effective solution in terms of scenario-based simulations. However, it is currently unclear whether virtual reality is a more effective training option compared to more traditional methods. This study aimed to investigate the effectiveness of virtual reality in the development of situation awareness compared to an interactive video. Participants (N = 36) were randomly assigned to complete a situation awareness training scenario in either an immersive virtual reality or interactive video condition. In addition, using the Cognitive and Affective Model of Immersive Learning the subjective variables of presence, agency, situational interest, self-efficacy, cognitive load and intrinsic motivation based were also measured. Presence was significantly higher in the immersive VR condition and was found to significantly predict situational interest and intrinsic motivation. Agency also significantly predicted intrinsic motivation. Overall, immersive VR appears to offer numerous educational affordances which in turn influence cognitive load, motivation, situational interest, and self-efficacy. Understanding these relationships is critical for effective instructional design that will maximise the affordances of virtual reality technology.

Key words: virtual reality, immersion, interactivity, situation awareness

Declaration

This thesis contains no material that has been accepted for the award of any other degree or diploma in any University, and, to the best of my knowledge, this thesis contains no material previously published except where due reference is made. I give permission for the digital version of this thesis to be made available on the web search engines, unless permission has been granted by the School to restrict access for a period of time.

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September 2022

Contribution Statement

In writing my thesis, my supervisors and I collaborated to generate research questions and design the appropriate methodology.

[redacted] piloted the experiment and the recognition memory test.

I conducted the literature search and completed the ethics application.

I created the interactive video version of the scenario for the control condition and created the recognition memory quiz on Qualtrics with guidance from my supervisors.

Steve Cook assisted with setting up the VR equipment in the lab. I conducted the lab sessions and tidied the data in preparation for analysis in R.

My supervisors assisted me with the data analysis plan and R script. I conducted the analyses, interpreted the results, and wrote the thesis independently with their guidance.

Immersive technologies such as virtual reality (VR) allows the development of scenario-based simulated training in areas where real-life training may be expensive, impractical, or even unsafe. This is particularly the case in industries such as emergency response, complex medical procedures and pilot training (Makransky & Petersen, 2021). Being able to simulate the learning environment and provide an immersive experience in which to practice enables the exposure without the risk (Grassini et al., 2020). Despite the advantages, it is currently unclear whether VR is a more effective training option compared to traditional methods such as lectures and videos.

Simulated learning environments include non-immersive types such as desktop VR that need only a keyboard, mouse and/or joystick or touchscreen to navigate. At the other end of the scale, there is immersive VR. Here, users are provided with a 360-degree view of a virtual environment using a head-mounted display. In addition, a pair of hand controllers enable a user's physical actions to be mimicked in the virtual environment and thereby enabling natural movement and interaction therein. With this VR technology, simulated learning environments allow learners to explore and interact with the environment and objects in it. Their use has been shown to be superior compared to traditional methods for knowledge acquisition and skills development in subjects such as anatomy (Lee & Wong, 2014) and biology (Richards & Taylor, 2015). A recent meta-analysis indicated that students who received a combination of desktop VR and traditional teaching outperformed students who just received traditional teaching or 2D images in subsequent testing (Merchant et al., 2014).

As this technology has become more affordable and accessible, so too has its proliferation outside of the classroom in the training space (Buttussi & Chittaro, 2018; Ouverson et al., 2020). In turn, the body of research into the effects of VR on learning outcomes has grown and these results have been mixed. Immersive VR has been found to be more effective in developing problem-solving skills, motivating learners, assisting in cognitive processing and knowledge transfer compared to other methods such as tablets and board games (Araiza-Alba et al., 2021). It has also resulted in better performance in recall tests of spatial mapping, that is, memorising locations of buttons on information displays (Caluya et al., 2018) and recognition of faces (Krokos et al., 2018). A meta-analysis by McGaghie et al. (2011) showed that scenario-based medical education coupled with deliberate practice led to superior outcomes in the development of clinical skills, compared to traditional, clinical education methods. Lohre et al. (2020) found that a single session of immersive VR simulation training resulted in orthopedic residents demonstrating significant improvements in knowledge and procedural application compared to using technical video instruction. Furthermore, the immersive VR groups completed training faster and reported greater enjoyment of learning.

Similar improvements in procedural knowledge and behavioural skills were found when comparing immersive VR to video training in confined space rescue (Lu et al., 2022) and in comparing VR to video training in fire extinguisher operation (Lovreglio et al., 2020). However, Grassini et al. (2020) found no significant difference to the number of errors, time taken or proportion correct in an assembly task when trained using video compared to VR. Likewise, immersive technology has also been shown to make no significant difference to knowledge acquisition in emergency preparedness (Chittaro & Sioni, 2015), safety training (Buttussi & Chittaro, 2018; Makransky et al., 2019), mechanical maintenance (Schroeder et al., 2017) and car parking (Read & Saleem, 2017). These mixed results demonstrate that there is a need to better understand the predicted benefits of this technology in training.

Characteristics of VR

The two unique characteristics of VR that set this technology apart from traditional teaching methods and multimedia content are the level of immersion and interactivity afforded by the user interface (Makransky & Petersen, 2021). Firstly, immersion is an objective measure of the level of sensory fidelity provided by a system and the extent to which it is capable of shutting out the outside world (Petersen et al., 2022). In addition to having the advantage of providing environments that are realistic and interactive, technology such as head-mounted displays place users at the centre of the scenario and fully immerse them in the experience (Allcoat & von Mühlenen, 2018; Yoo et al., 2022). Quite often in the literature, the term immersion is used interchangeably with presence which can create a lack of coherence in the research (Lee, 2004).

Presence is an individual's subjective perception of the virtual environment (Grassini et al., 2020) as a response to the level of immersion in that environment enabled by the technology. The more real a virtual environment seems, the higher this sense of presence becomes (Ai-Lim Lee et al., 2010). Clifford et al. (2018) did include a measure of presence in their study on situation awareness. They found significant differences between all three conditions with the head-mounted display resulting in the highest sense of presence compared to HDTV and a 270 degree cylindrical projection. Pollard et al. (2020) investigated performance on recognition memory tests and orientation tasks across three different levels of immersion. Their results showed that higher immersive conditions resulted in better recognition memory performance. However, the experimental conditions themselves were a combination of low, medium and high immersive technological features which made it difficult to pinpoint what features accounted for the difference in performance results. In this study, a comparison will be made between two different levels of immersion in a scenario as afforded by a desktop VR (interactive video or IV condition) compared to immersive VR using a head-mounted display (immersive VR or IVR condition). The subjective experience of immersion will be measured by a presence rating and will be analysed to better understand the effect of increased immersion on learning outcomes.

The second defining characteristic of VR is interactivity (Makransky & Petersen, 2021). More than just a passive video that can only be watched, VR scenarios allow users to actively learn through direct interaction with the environment and the objects within it (Allcoat & von Mühlenen, 2018). Interactivity is shaped by factors such as the mechanism for interaction (i.e. hand controllers, touch screen), the fidelity of movement, the speed at which input from the user is replicated and how natural it feels (Read & Saleem, 2017). Just as presence is a subjective response to immersion, interactivity is measured by a sense of agency. Agency is the degree of control a user feels they have over their actions in the virtual environment (Makransky & Petersen, 2021). This can include where they look, where they move and how they touch or interact with objects. It is the combination of immersion and interactivity that creates the unique experience that is the defining characteristic and strength of VR. This study will include consideration of interactivity that will be measured by an agency rating, to see if there is an effect on learning outcomes.

Application of VR training

One field where the application of VR has the potential to have a significant impact is in domains where practical training may not be appropriate or affordable. Real-life role-played scenarios are generally preferred in terms of the ecological validity of skill development (Wheeler et al., 2021) but those are time and resource intensive as well as expensive. In these circumstances, virtual learning simulations provide an ideal practical and economical supplement (Makransky & Lilleholt, 2018). This is particularly the case for training in high-risk industries such as performing medical procedures (McGaghie et al., 2011), laboratory safety (Makransky et al., 2019) and emergency response procedures (Kwegyir-Afful et al., 2022). Here, VR technology has the ability to provide effective training for the development of cognitive skills such as problem-solving and decision-making under stress without exposing learners to unacceptable levels of risk (Radianti et al., 2020).

A key component of these cognitive skills such as problem-solving and decision-making is the ability to maintain a high level of situation awareness (Endsley et al., 1998). Situation awareness is an understanding of the state of the environment and provides the primary basis for subsequent decision making. About 88% of major airline accidents that have involved human error can be attributed to problems with situation awareness (Endsley, 1995). Situation awareness involves understanding how information, events and actions around us impact our current situation and how changes might impact the future (Bonasio, 2018, July 23). At the first level, a person needs to perceive relevant information in their environment. Subsequent levels involve integrating data with goals to provide meaning from which the understanding that leads to projection of future events is formed.

The difficulty in training skills such as situation awareness has to do with the fact that it requires a combination of perceptual, spatial and cognitive abilities working together (Kaber et al., 2017). Accordingly, immersive VR which provides an environment wherein users make simultaneous use of all these abilities, would seem to be the optimal training tool in this context. However, research into immersive VR and situation awareness training has yielded definitive results. Chiu (2020) investigated training situation awareness in firefighters and found that it did improve through VR training but only for the first awareness level and then only for those who were observing participants using the VR kit. Clifford et al. (2018) compared situation awareness acquisition in aerial firefighters using three different types of VR technology including, a high-definition TV, 270-degree cylindrical projection and a head-mounted display. They found that participants developed better situation awareness across all three levels in the head-mounted display and cylindrical projection compared to the high-definition TV but with no significant difference between the head-mounted display and the cylindrical projection. The findings from Chiu (2020) and Clifford et al. (2018) indicate that situation awareness and the effect that immersive VR training has on it, is not straightforward. For this reason, this study will have situation awareness as the learning outcome. Coupled with the mixed results of studies in training with immersive VR in general noted earlier, perhaps more needs to be considered than just the technology. That is, there should also be focus on the learner's experience. The subjective experiences of presence and agency afforded by immersive VR need to be considered in addition to the technology (Mount et al., 2015).

As mentioned earlier, one of the key characteristics of VR is immersion which has a subjective response of presence. In studies that have included presence as an outcome measure, the results are mixed. Even though presence was always higher in the VR condition, the relationship between presence and performance was positive in some studies (Ai-Lim Lee et al., 2010; Clifford et al., 2018) and in others, an inverse relationship was found (Eiris et al., 2020). An increased presence score was also found when there was no significant difference between conditions for performance or learning outcomes (Buttussi & Chittaro, 2018; Leder et al., 2019; Moreno & Mayer, 2002). Interestingly, Grassini et al. (2020) found higher presence ratings correlated with better completion time and quality of work, but not with number of errors.

Schroeder et al. (2017) compared VR with desktop training and found that the effect of presence on recall performance occurred through an indirect path. Specifically, it was mediated through usability, a variable similar to agency that correlated highly with presence. An additional layer to this was identified by Makransky et al. (2021) who found that while VR simulations afford higher levels of presence, they may also lead to higher levels of cognitive load which resulted in a reduction in learning. In contrast, an earlier study found that training in a high immersion virtual environment lowered the mental demand in a subsequent performance test, however the result was not statistically significant (Gisler et al., 2020). This suggests that the effect of VR technology on learning outcomes is not a direct one. Further to this, the affordances of VR seem to work through cognitive and affective factors which can be antecedents to learning outcomes. While previous studies have included measures of these factors to varying degrees, what was needed was a theoretical framework to underpin the research.

Theoretical framework of immersive learning

The development of such a theoretical framework began with the work of Ai-Lim Lee et al. (2010) who found psychological variables such as presence, motivation, usability, cognitive benefits, control, active learning and reflective thinking were strong predictors of learning outcomes. Based on this study, Makransky and Petersen (2021) refined the factors into the Cognitive Affective Model Immersive Learning Model (CAMIL).

The CAMIL framework also includes and builds on earlier theories of Cognitive Load Theory (Sweller, 2011) and the Cognitive Theory of Multimedia Learning (Mayer, 2005; Mayer, 2017). The multimedia principle embedded in the Cognitive Theory of Multimedia Learning states that information is easier to learn when presented in dual modalities because multimedia instruction enters the learner's information processing system through two pathways: auditory and visual. Each pathway has limited capacity and therefore, dual modality presentation should decrease cognitive load (Mayer, 2017). VR achieves this through its engagement of multiple senses as mentioned earlier.

The CAMIL theory also considers affective factors that have been shown to contribute to how learners process information in the virtual environment. According to the CAMIL theoretical framework, there are several cognitive and affective factors through which presence and agency lead to learning outcomes. These include self-efficacy (the sense of belief in one's own capabilities), intrinsic motivation (the level of engagement in an activity as a result of the inherent satisfaction in doing the activity itself and not some other external reward), situational interest (the degree of attention and engagement that develops because of the stimuli presented in the environment), and embodied learning (the degree to which the physical body is involved in the learning process through movements and gestures). The model also includes extraneous cognitive load (the cognitive load imposed by the way information is presented) which is further categorised into two different types: interactional (the method through which one engages with the environment) and environmental (the elements in the environment itself e.g., objects and people.)

Extraneous cognitive load is the only factor in the CAMIL framework that is theorised to have a negative effect on learning outcomes. It posits that a learner's limited cognitive resources that are required for learning may instead be taken up by the clearer representational fidelity, complex visuals and interaction methods in an immersive VR environment (Meyer et al., 2019; Moreno & Mayer, 2007). This was supported by one of the few studies that had a measure akin to cognitive load called mental effort. This study found mental effort to be significantly negatively related to performance (Schroeder et al., 2017). The remaining factors are posited to have positive effects on learning outcomes as they theoretically lead to increased levels of persistence and effort (Makransky & Petersen, 2021). This could provide an explanation for the inconsistent results of previous research as these influences are not considered.

Petersen et al. (2022) ran an experimental study to validate the pathways identified in the CAMIL theoretical model. Using a between-subjects design, they administered a virtual lesson across four different conditions of varying levels of immersion and interactivity. There was no direct effect on learning outcomes, as measured by a multiple-choice knowledge test, from immersion and interactivity. Instead, they found that both immersion and interactivity had a positive effect on agency, physical presence, and embodied learning. Furthermore, they found a positive effect of immersion on situation interest and of interactivity on environmental cognitive load.

Interestingly, they found that instead of presence being an antecedent to cognitive load as predicted by CAMIL, it was the other way around with cognitive load predicting presence. They also found that interactivity only had a significant effect on agency when immersion was low. This indicates that when a learning environment is immersive enough, interactivity no longer has a significant influence. In fact, this may be why the studies before Petersen et al. (2022) did not include a measure of agency and focused instead on immersion.

The CAMIL theoretical framework was mostly validated in the above study and provides a good grounding for further research into understanding immersive VR in training. In this study, the effectiveness of immersive VR in training situation awareness will be investigated further with consideration of the relationships predicted by CAMIL and the cognitive and affective variables as measured by Petersen et al. (2022).

This study will compare performance in a forced choice recognition memory test as the measure of learning, in a scenario across two conditions that have different immersion levels: immersive VR and interactive video. Participants will first need to complete a virtual scenario that involves investigating criminal activity. Participants will be instructed to be observant of their surroundings and the objects in it, as they make their way through the virtual environment. Upon completion of the scenario, participants complete a recognition memory test of the objects and features in the virtual environment.

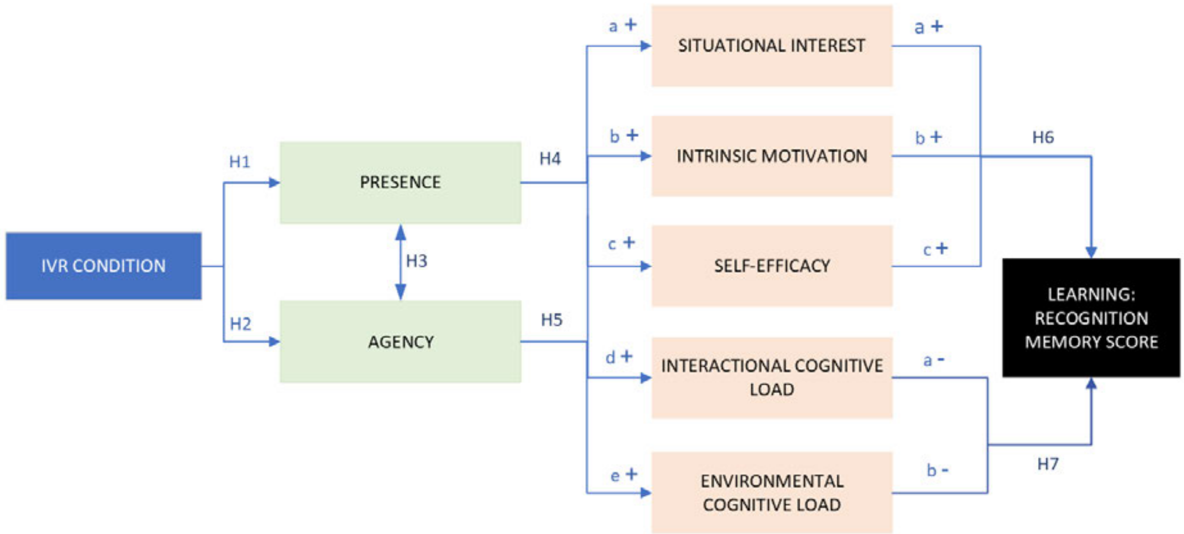
The recognition memory test is designed to measure level one situation awareness which is defined as the perception of the elements in the environment (Endsley, 1995). Recognition is also the first category of cognitive processes in learning taxonomy (Anderson et al., 2000). In terms of evaluation of learning, in conjunction with the subjective measures of situational interest and intrinsic motivation, recognition memory aligns to the reaction and learning levels of training assessment criteria as defined by Kirkpatrick and Kirkpatrick (2006). The higher levels of both situation awareness and learning taxonomy will not be included as the ability to understand what is important in a context for decision-making as well as being able to project outcomes based on that information, would require a level of expertise in the scenario that is outside the scope of this study.

The recognition memory test is then followed by a subjective measures questionnaire. The CAMIL theoretical framework posits that the immersive VR condition will result in higher ratings of presence and agency as afforded by the immersion and interactivity provided by the technology. CAMIL theorises a positive relationship between presence and agency and the subjective measures of situational interest, intrinsic motivation, self-efficacy, interactional and environmental cognitive load. Finally, CAMIL predicts positive relationships between these variables and learning outcomes, except for interactional and environmental cognitive load which will have a negative effect. Figure 1 below provides a summary of the CAMIL framework and the predicted relationships that will be analysed in this study.

Hypotheses

Figure 1

Diagram of the Hypothesised Relationships Between Variables



This study makes the following hypotheses:

1. Participants in the immersive VR condition will have higher ratings of presence than participants in the interactive video condition (H1).
2. Participants in the immersive VR condition will have higher ratings of agency than participants in the interactive condition (H2).
3. Presence and agency will be positively correlated (H3).
4. There will be a positive relationship between presence and the subjective variables such that a high presence rating will predict a high rating of situational interest (H4a), intrinsic motivation (H4b), self-efficacy (H4c), interactional cognitive load (H4d) and environmental cognitive load (H4e).
5. There will be a positive relationship between agency and the subjective variables such that a high agency rating will predict a high rating of situational interest (H5a), intrinsic motivation (H5b), self-efficacy (H5c), interactional cognitive load (H5d) and environmental cognitive load (H5e).
6. There will be a positive relationship between the subjective variables and learning such that a high recognition memory score will be predicted by high ratings of situational interest (H6a), intrinsic motivation (H6b) and self-efficacy (H6c).
7. There will be a negative relationship between the subjective variables and learning such that a low recognition memory score will be predicted by high ratings of interactional cognitive load (H7a) and environmental cognitive load (H7b).

Method

The aim of this study was to investigate the effects of immersive VR on learning outcomes as measured by performance in a recognition memory test. In addition, the process of learning is examined through the Cognitive and Affective Model of Immersive Learning (CAMIL) theoretical framework (Petersen et al., 2022). The between-subjects experimental design consisted of a first-person view scenario that was presented as either an immersive virtual reality experience, or as an interactive video with the latter being the control condition.

Participants

Ethics approval was granted by the University of Adelaide, School of Psychology's Human Research Ethics Sub-Committee (22/50). A total of 37 participants participated in the experiment. One participant was excluded from the analysis as they had completed the same scenario as part of a different study. The remaining 36 participants was comprised of 20 (55.6%) males, 15 (41.7%) females and one non-binary/third gender. Participant ages ranged from 18 to 62 (M = 36.03, SD = 15.87). Participants were randomly assigned to one of the two experimental conditions. The interactive video group was comprised of nine males and nine females with an age range of 18 to 56 (M = 36.67, DS = 16.04). Of this group, there were four participants with previous gaming experience (ranging from 1-20 hours per week) and three who had previous experience with VR technology (ranging from 5-70 hours total). The immersive VR group comprised of 11 males, six females and one non-binary/third gender with an age range of 18-62 (M = 35.39, SD = 16.14). Of this group, there were six participants with previous gaming experience (ranging from 2-20 hours per week) and three who had previous experience with VR technology (ranging from 1-4 hours total).

Participants consisted of undergraduate psychology students recruited via an online research participation system called SONA and members of the general public recruited through word of mouth and social media. Undergraduate students received course credit for their participation. Members of the general public did not receive any incentive or monetary compensation for their participation.

Materials

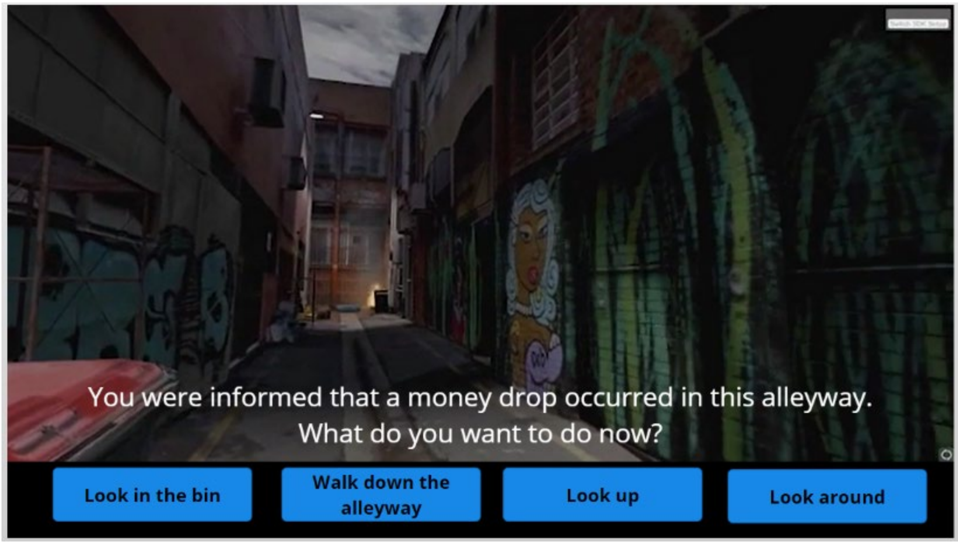
Simulated Scenario

The simulated scenario used in this study is a custom-designed immersive simulation created by Steve Cook of the University of Adelaide for a separate project and was provided for use in this study. The scenario is designed for an immersive VR set up, to be used with a head-mounted display and hand controllers. It consists of a first-person experience of a money-drop in an alley way in the first instance, followed by a hostage being held in a house. The goal of the exercise is for participants to investigate each scene, be aware of their surroundings and to make sure they do not put themselves in any danger. The scenario is designed to evaluate the development of situation awareness and is thus well-suited to this study.

For the interactive video condition, a screen recording was made as the researcher walked through the entire scenario in virtual reality. This recording was then adapted into a "choose-your-own-adventure" style interactive video wherein the playback was paused at certain decision points and participants were asked to decide what to do next by clicking the options available (see Figure 2 below). Each decision point had a maximum of four options. The options usually involved either looking around the environment, choosing a direction to go in or interacting with different objects such as opening doors. If a decision led to a disastrous consequence, participants were subsequently returned to the same decision point wherein that option was no longer available. This design enabled participants to learn from mistakes in a way that was similar to the immersive VR condition.

Figure 2

Example of a Decision Point In the Interactive Video Condition



The screen recording was completed using Open Broadcaster Software (OBS) which is a free, open-source screen recording software. The interactive video playback was created using Articulate

Storyline. The interactive video version of this scenario is available on The University of Adelaide's cloud storage software, Box to view.

Equipment

Figure 3

Room Set Up With Tripods (L) and Participant (R).

In the immersive VR condition, participants used the HTC VivePro MV equipment which included a head-mounted display, two sensors and two controllers. The sensors were set up on tripods at their maximum height, in opposing corners of the room (Figure 3). The virtual play area was marked out as a 2.6 m x 2.1 m virtual room.

The VR scenario was run from a desktop computer with AMD Ryzen 7 3700X 8-core processor, 16 GB RAM, 64-bit operating system running Windows 10 Home version, connected to an NVIDIA GeForce RTX 2080 SUPER graphics card and using Steam VR version 1.21.12. This computer was connected to a 24-inch LG monitor with a resolution of 1920 x 1080 and 60 Hz refresh rate. This monitor allowed the researcher to see the participant's view in the head-mounted display. This screen was recorded with a Samsung s20FE smart phone during sessions.

The scenario in the interactive video condition and the subsequent recognition memory test and subjective measures questionnaire was completed via Qualtrics on a Macbook with a mouse connected.

Measures

Recognition memory test

The recognition memory test was designed to measure the development of level one situation awareness as indicated by a participant's memory of objects and features from the scenario environment. It consists of an 18-item forced-choice questionnaire. It includes items about the global features of the environment such as *'What lighting was there in the alleyway?'* as well as local features such as *'Which of the following objects was NOT in the kitchen?'* (see Appendix A for full list items). The final score was a total of correct answers, with a higher score representing greater recognition memory.

Subjective measures questionnaire

The items in this questionnaire are based on the scales used by Petersen et al. (2022) that included measures of the variables identified in the CAMIL theoretical framework. This study did not include embodied learning as measure as it was not applicable in the interactive video condition and therefore not comparable. The terminology used in the scales were adapted so that the language was appropriate to the context of the scenario as well as being applicable to both the interactive video and immersive VR conditions in the study. For example, references to '*virtual environment*' and '*simulation'* were changed to *'scenario environment'* and *'scenario'* respectively.

Cronbach's alpha was used as an indicator of the internal reliability of the subjective measures. Petersen et al. (2022) reported Cronbach's alphas of above .80 for all measures. This study found acceptable Cronbach's alpha levels of .70 or above for all measures (DeVellis, 2016).

Agency

Consisting of three items measured on a five-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). This scale includes items about the experiences and actions in the scenario exercise being "*under my control*". The second item in the scale is reverse scored. The overall score is an average of all items in the scale with a higher score representing a greater sense of agency. The Cronbach's alpha for this scale is .77.

Presence

Consisting of five items measured on a five-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). This scale includes items referring to how real the scenario environment feels for the participant such as "*I had a sense of acting in the scenario, rather than operating something from outside*". The overall score is an average of all items in the scale with a higher score representing a greater sense of presence. The Cronbach's alpha for this scale is .83.

Intrinsic motivation

Consisting of five items measured on a five-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). The items in this scale refer to the level of interest participants have while in the scenario (i.e. "*the scenario was very interesting*"). Items 3 and 4 are reverse scored. The overall score is an average of all items in the scale with a higher score representing greater intrinsic motivation. The Cronbach's alpha for this scale is .74.

Self-efficacy

Consisting of four items measured on a five-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). This scale includes items about the participants' confidence in their recognition and recall of objects in the scenario (i.e. "*I'm confident that I had good recognition of objects and people*"). The overall score is an average of all items in the scale with a higher score representing greater self-efficacy. The Cronbach's alpha for this scale is .81.

Interactional cognitive load

Consisting of four items measured on a five-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). This scale includes items about the method of interaction in the scenario (i.e. "*the interaction technique used for the scenario made it hard to complete the exercise*"). The overall score is an average of all items in the scale with a higher score representing greater interactional cognitive load. The Cronbach's alpha for this scale is .70.

Environmental cognitive load

Consisting of four items measured on a five-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). This scale includes items about the scenario environment itself (i.e. "*in terms of completing the exercise, the scenario environment was full of irrelevant content*"). The overall score is an average of all items in the scale with a higher score representing greater environmental cognitive load. The Cronbach's alpha for this scale is .76.

Situational interest

Consisting of six items measured on a four-point Likert scale ranging from 1 *(not at all*) to 4 (*completely*). This scale includes items about how entertaining the exercise was (i.e. "*to what extent did the exercise capture your attention?")*. The overall score is an average of all items in the scale with a higher score representing greater situational interest. The Cronbach's alpha for this scale is .90.

See Appendix B for full details of all items in the scales.

Procedure

Using a between-subjects design, participants were randomly assigned to either the interactive video or immersive VR condition. Participants were provided with a participant information sheet and consent form to read and sign on arrival (see Appendix C). Once informed consent was given, participants were provided with a briefing about the scenario (see Appendix D for the full script). Participants were forewarned about the coarse language and the use of "jump-scares" throughout and told that they were able to stop at any time.

In the immersive VR condition, participants were asked to stand in the middle of the room and were assisted with putting on the head-mounted display and hand controllers. Once they confirmed that they were comfortable and ready to start, the scenario was launched. Preceding the scenario was a short tutorial for participants to learn how to navigate and interact with objects in the VR environment using the hand controllers. Once a participant had made their way to the end of the scenario, the immersive VR gear was removed, and they were directed to sit down in front the laptop to complete the recognition memory test and subjective measures questionnaire.

In the interactive video condition, participants were directed to sit down in front of the laptop and were provided with oral instructions on how to navigate the video. Once they were comfortable to proceed, they were informed that the computer would automatically direct them to the recognition memory test and subjective measures questionnaire on completion of the scenario.

In both conditions, interaction only occurred with participants during the scenario if they seemed distressed or asked for help. At the end of the questionnaire, participants were thanked for their participation and were provided with an opportunity to ask questions.

Data was collected at University of Adelaide and at the Metropolitan Fire Service Training Centre at Angle Park using the same equipment and room set-up.

Results

Analysis Plan

All analyses and hypothesis testing were performed in R (version 4.1.0) and the alpha level set at .05 which is the conventional standard (Field et al., 2012). The hypotheses in this study involved group differences and relationships between variables which were analysed using t-tests and correlations or the non-parametric equivalents if required.

Descriptive statistics

A summary of the means, standard deviations and ranges for recognition memory score and ratings for all subjective variables in the study are presented in Table 1.

Table 1

Summary of Descriptive Statistics

Variables	M	SD	Min	Max
Recognition memory score	9.75	3.10	2	16
Agency	3.42	0.81	1	5
Presence	3.53	0.74	1.6	5
Intrinsic motivation	4.23	0.54	3	5
Situational interest	3.46	0.57	1.83	4
Interactional cognitive load	2.31	0.56	1	4
Environmental cognitive load	2.27	0.64	1	4
Self-efficacy	2.59	0.69	1	4

Assumptions

A visual inspection of the histograms for variables in both the interactive video and immersive VR conditions, as shown in Appendix E, reveal non-normal distributions. The histograms display positive or negative skewing, leptokurtic distributions, multimodal distributions and gaps. Shapiro-Wilk tests returned significant results for self-efficacy in the interactive video condition (W = 0.87, p = .021), situational interest in the immersive VR condition (W = 0.78, p = .001) and interactional cognitive load in the immersive VR condition (W = 0.81, p = .002). All other variables returned non-significant results. However, the Shapiro-Wilk tests were likely underpowered due to the sample size. Therefore, based on the histograms, normality of distributions was not assumed.

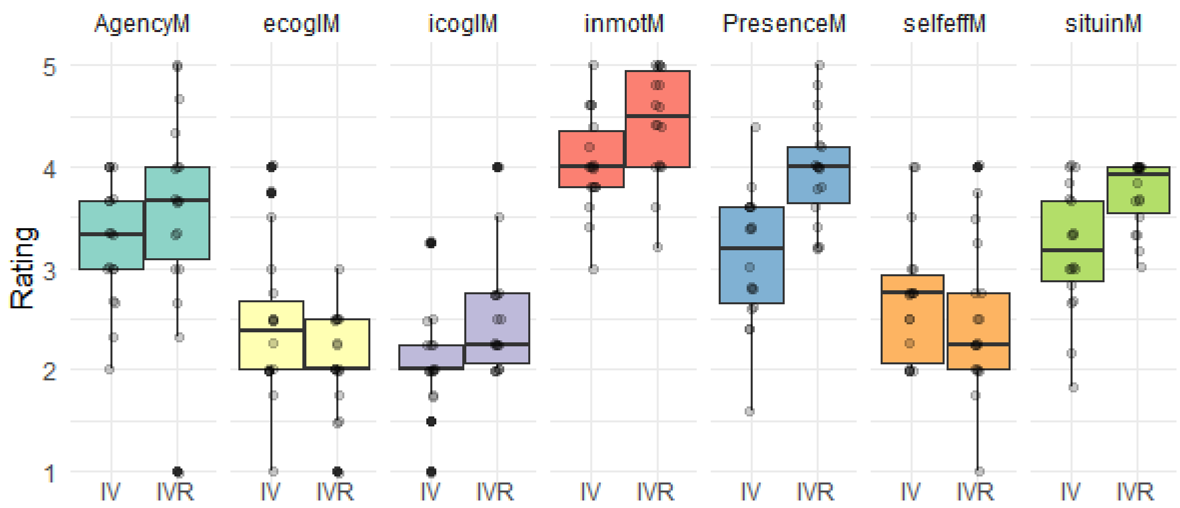
A Levene's test revealed that situational interest had unequal variances between the 2 experimental conditions, F(1, 34) = 6.47, p = .016. The assumption of equal variance was met for all other variables. Since there were violations of the assumption of normality and homogeneity of variance, the data were analysed using non-parametric tests.

Group differences

All participant ratings for the subjective variables are represented in Figure 4. It was predicted that the participants in the immersive VR condition would have higher ratings of presence and agency. A Wilcoxon sum-rank test (Table 2) showed that participants in the immersive VR condition reported significantly higher ratings of presence compared to the interactive video group, which supports hypothesis 1. There was no statistically significant difference in reported agency ratings between the two conditions thus not supporting hypothesis 2. However, this may be due to a lack of statistical power as there was a small to moderate effect in the hypothesised direction (r = .23). Reported ratings for environmental cognitive load also yielded a moderate effect size but this was not statistically significant. There was a small effect for self-efficacy that also did not reach statistical significance.

Figure 4

Summary of Participant Ratings in All Subjective Measures



Note: IV = interactive video, IVR = immersive VR, Inmot = intrinsic motivation, situin = situational interest, icogl = interactional cognitive load, ecogl = environmental cognitive load, selfeff = self-efficacy

Statistically significant differences can be seen in Table 2 for reported ratings in intrinsic motivation, situational interest and interactional cognitive load with large effect sizes.

Table 2

Mean, Median and Standard Deviation of All Variable Scores and Wilcoxon Rank-Sum Test Statistics In Both Conditions

Variables	IV			IVR			Wilcoxon rank-sum		
by group	M	Mdn	SD	M	Mdn	SD	W	P value	Effect size (r)
Rmscore	9.72	9	3.37	9.78	10	2.90	154	.811	.04
Agency	3.26	3.33	0.60	3.57	3.67	0.98	118.5	.169	.23
Presence	3.10	3.2	0.66	3.97	4	0.53	49	<.001***	.60
Inmot	4.03	4	0.48	4.43	4.5	0.54	89.5	.021*	.39
Situin	3.19	4.17	0.62	3.73	4.92	0.33	73	.004**	.48
Icogl	2.13	2.00	0.54	2.49	2.25	0.55	94	.028*	.37
Ecogl	2.44	2.38	0.76	2.10	2	0.47	203.5	.183	.22
Selfeff	2.69	2.75	0.64	2.49	2.25	0.74	193.5	.32	.17

Note: IV = interactive video, IVR = immersive VR, Rmscore = recognition memory score, Inmot = intrinsic motivation, situin = situational interest, icogl = interactional cognitive load, ecogl = environmental cognitive load, selfeff = self-efficacy.

*p< .05, ** p<.01, *** p<.001

Correlations

Table 3

Spearman's Rho Correlation Matrix of All Variables

	Rmscore	Agency	Presence	Icogl	Ecogl	Situin	selfeff
Agency	.03						
Presence	-.05	.58***					
Icogl	.04	-.10	-.10				
Ecogl	.25	-.19	-.32	.36*			
Situin	.12	.27	.50**	-.02	-.20		
Selfeff	.35*	-.21	-.14	-.38*	.10	.14	
Inmot	.16	.42*	.62***	-.17	-.44**	.69***	.12

Note: IV = interactive video, IVR = immersive VR, Rmscore = recognition memory score, Inmot = intrinsic motivation, situin = situational interest, icogl = interactional cognitive load, ecogl = environmental cognitive load, selfeff = self-efficacy.

*p< .05, ** p<.01, *** p<.001

Table 3 shows the relationship between all variables as assessed by Spearman's Rho. Agency and presence had a strong, positive correlation that was statistically significant, thereby supporting hypothesis 3. Presence also had a strong, positive, statistically significant correlation with situational interest and intrinsic motivation, confirming hypotheses H4a and H4b respectively. Presence had a moderate, negative relationship with environmental cognitive load, but this was not statistically significant thus not supporting hypothesis H4e. Hypotheses H4c and H4d were also not supported as the relationships did not reach statistical significance and were in the opposite directions to those predicted.

Agency had a moderate, positive relationship with situational interest but did not support hypothesis H5a as it was not statistically significant. Agency had a statistically significant relationship with intrinsic motivation and this correlation was large and in the positive direction, thereby supporting hypothesis 5b. Agency was shown to have small, negative correlations with self-efficacy and both interactional and environmental cognitive load that were not statistically significant and in the opposite direction predicted, thus hypotheses 5c, 5d and 5e were not confirmed.

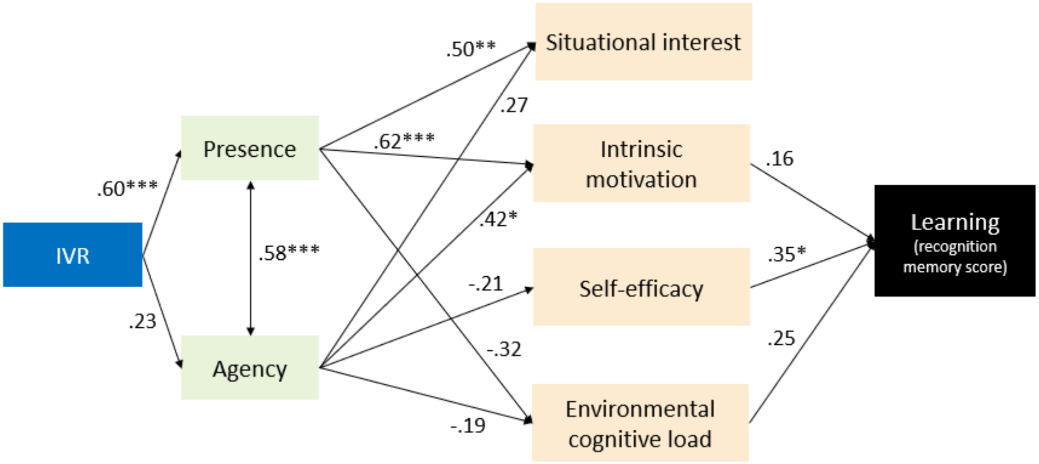
Of all the predicted relationships between the subjective variables and learning outcomes, only self-efficacy demonstrated statistical significance with a moderate, positive correlation, confirming hypothesis H6c. Hypotheses H6a and H6b were not supported with the small, positive relationships between learning and situational interest and intrinsic motivation not reaching statistical significance.

Hypothesis 7a was not confirmed with the correlation between interactional cognitive load and recognition memory score not being statistically significant. Environmental cognitive load had a moderate correlation with recognition memory score, but this was not statistically significant and was in the opposite direction of what was predicted, thus not supporting hypotheses H7b.

Figure 5 shows the final model of the effects of high immersion training on presence and agency and the associated predictor variables that lead to learning. It shows all the statistically significant relationships between the two affordances of immersive VR environments to the cognitive and affective variables in the individual and the path to learning. In addition, the model also includes along those relationships that were small to moderate in size and thus have scientific significance but did not reach statistical significance.

Figure 5

Model Showing Statistically Significant Correlations and Noteworthy Relationships Between Variables



Discussion

This study aimed to establish whether immersive training environments provide a more effective training option compared to traditional methods in the development of situation awareness. It also sought to develop a greater understanding of the cognitive and affective factors that influence learning. This was achieved by measuring the development of situation awareness in a learning scenario delivered through an immersive VR environment compared to an interactive video. Building on previous studies that had showed mixed results regarding the effectiveness of immersive technologies on learning outcomes, this study was designed to also include consideration of cognitive and affective variables experienced by participants as posited by the CAMIL theoretical framework.

The results found that participants in the immersive VR condition reported statistically significantly higher levels of presence compared to the interactive video group. This confirms similar findings in earlier studies that also found increased presence in conditions of higher immersion. However, these studies did not include a measure of interactivity in their immersive condition (Leder et al., 2019) or the degree of interactivity only extended to controlling the flow of information (Petersen et al., 2022). This study conceptualised interactivity as the ability to interact with objects or the environment in a scenario which is more aligned with the definition utilised in the CAMIL framework (Makransky & Petersen, 2021). The studies that did include both interactivity and immersion also demonstrated increased presence in the immersive VR condition. Those results were different in context to this study as they did not include an objective measure of learning as an outcome (Makransky & Lilleholt, 2018). Or their learning outcome was in a procedural task and not situation awareness (Moreno & Mayer, 2002). One study that did use situation awareness as an outcome measure, also found increased presence when using a head-mounted display compared to a TV screen (Clifford et al., 2018). In a similar vein to the studies mentioned above, presence was the only affordance measured as their performance task only included visual scanning of the environment and consequently, did not include interaction. The present study included measures of both affordances of VR technology as modeled in the CAMIL framework and did so in the context of a situation awareness scenario.

The CAMIL framework posits that the interactivity enabled by immersive VR technology should increase agency. The immersive VR condition in this study yielded a small relationship (r = .23) to agency that was not statistically significant. However, it is comparable to the effect size observed by Petersen et al (2022) who found immersion and interactivity had significantly positive effects on agency with effects of .23 and .35 respectively. What also needs to be considered though is the finding that the influence of agency was not as prevalent when immersion was high. So, the higher degree of control in the immersive VR condition of this study may have been diminished thus leading to there not being a significant group difference in agency. Only one other study reviewed included a measure of interactivity similar to agency and they found no significant difference between 2D desktop and 3D VR (Schroeder et al., 2017).

The underpinning theoretical model predicts that while immersion impacts presence, control factors influence both presence and agency (Makransky & Petersen, 2021). This indicates that the two key affordances of IVR are linked. That is, when a participant has an increased sense of presence in a scenario, then so too is their sense of agency. Schroeder et al (2017) found a high degree of correlation between presence and usability (a measure of interactivity akin to agency). This interaction was also present in the study by Petersen et al. (2022). Therefore, this study hypothesised that there would be a correlation between presence and agency, and this was confirmed by the results with a large, positive, and highly significant relationship demonstrated. This supports the findings of the two studies mentioned above in a context with a higher degree of interactivity in the immersive VR condition for situation awareness.

According to the CAMIL framework, presence and agency do not directly influence learning outcomes. Instead, they work through an indirect pathway to learning via cognitive and affective variables. Specifically, a high level of presence and agency within a learning environment will trigger situational interest and intrinsic motivation by enabling enjoyment and autonomy (Makransky & Petersen, 2021). The results of this study demonstrated that presence is a significant positive predictor of situational interest and that both presence and agency are significant predictors of intrinsic motivation. Agency also had a small to moderate positive relationship with situational interest that did not reach statistical significance. These relationships were also supported in the study by Petersen et al. (2022). Situational interest and intrinsic motivation theoretically promote learning by increasing attention, engagement and curiosity (Makransky & Petersen, 2021). According to Mount et al. (2015), the degree of success of any immersive learning activity depends partly on the learner's motivation to engage with it. So even though it did not reach statistical significance, the results of this study support this pathway with a small, positive relationship found between intrinsic motivation and learning which is an important consideration in support of the theory.

Agency is theorised in the CAMIL to have a positive relationship with self-efficacy. This is enabled in an immersive VR environment since learners can control their actions in the scenario in a naturalistic way, thereby experiencing a scenario or activity as real. Furthermore, the immediate feedback provided in immersive VR scenarios in response to actions works to increase estimates of self-efficacy (Makransky & Petersen, 2021).

This study however, demonstrated that agency was a negative predictor of self-efficacy. Although not statistically significant, this relationship still has theoretical importance for the fact that it was in the reverse direction to that theorised. Agency being a negative predictor of self-efficacy appears counter-intuitive at first glance. However, it can be rationalised when considering the factors present in the immersive VR condition of this study. Despite having full control over where to look, what to interact with and what to do in the immersive VR condition, this high level of control also meant that it was entirely up to the participant to decide what to do. The stimuli were constant and the environment dynamic. In the absence of any obvious prompts for action, participants appeared unsure of what to do next. As a result, they often spent a lot of time just looking around. This was exacerbated by the fact that wrong decisions would trigger disastrous consequences. Therefore, the increased agency meant increased complexity and higher complexity can result in lower self-efficacy.

In contrast, the interactive video condition provided a set of options from which to choose after each video played. Having predefined options at preset decision points and having the next video play immediately after a choice is made, would make it easier to gauge progress through the scenario and reinforce correct decisions, thereby instilling self-efficacy.

The CAMIL framework posits that self-efficacy is increased when presence and agency are high since accomplishments in these environments can feel like real ones. In conditions such as videos, the experience is more of a vicarious one. Lu et al. (2022) compared the use of immersive VR with an e-lecture for confined space rescue training and found that immersive VR resulted in significantly better performance in subsequent knowledge and behavioural tests. Furthermore, this was positively correlated with self-efficacy which was also better in the immersive VR condition**.** The results of the present study also demonstrated that self-efficacy was a significant, positive predictor of learning.

According to CAMIL, increased presence and agency should lead to higher environmental cognitive load. This is caused by the larger visual field of view provided by head-mounted displays increasing the amount of information available to participants. As a result, participants need to search through the content-rich environment for what is relevant to their desired outcomes. This means there is more processing required, leading to higher environmental cognitive load. In a similar way, agency is also theorised to increase environmental cognitive load since participants have more autonomy to view and interact with the environment as they please. This means that there are more distractions and irrelevant information to process.

In contrast to this theory, although not statistically significant, this study found small to moderate, negative relationships between environmental cognitive load and both presence and agency. The high-fidelity environment, rather than taking up more cognitive resources, resulted in an experience that was less mentally effortful.

On the other hand, participants in the interactive video condition did not feel immersed in the scenario which served to increase the cognitive load required to process information from the scenario environment. It may be because participants had no control over where they looked. This would serve to make the simple act of looking around to take in a scene, a more conscious one and thus increasing the effort required to do it. Being less immersed and having less control would increase environmental cognitive load since participants were instructed to observe and remember what was in their environment as they made their way through the scenario.

This study also found that environmental cognitive load had a small, positive relationship with learning outcomes. Though not statistically significant, it is worthy to note since it is in the opposite direction of what is posited in the CAMIL framework. Unlike the unexpected negative relationship between presence and environmental cognitive load, the positive relationship to learning may be harder to rationalise. The items in the environmental cognitive load scale included aspects such as the environment being irrelevant, unclear, and ineffective in terms of completing the activity. In this context, it is possible that the higher cognitive load may be an indication of more attention being paid to the environment which could result in improving performance in the recognition memory test.

Theoretical implications

The findings in this study were able to map onto some of the core components of the CAMIL theoretical framework. Firstly, higher immersion and agency lead to an increased sense of presence and agency. The effect on the cognitive and affective variables of situational interest and intrinsic motivation were also as predicted. Lastly, self-efficacy was a predictor of learning outcomes, in line with the theoretical framework. The negative relationship between self-efficacy and agency may be indicative of the complexity of the scenario and how well it mapped onto recognition memory as a learning outcome.

The original CAMIL theoretical framework was amended slightly by Petersen et al. (2022) who concluded that instead of presence and agency being positive predictors of cognitive load, it was cognitive load that negatively predicted presence and agency. Therefore, environmental cognitive load may warrant further study and reassessment.

Practical implications

As mentioned earlier, this study provided support for some key components of the CAMIL theoretical framework despite there not being a statistically significant difference in recognition memory score between conditions. More importantly, what was revealed was a complex interplay of presence and agency with the cognitive and affective variables identified in the CAMIL framework which were the pathway to learning outcomes. This enables a better insight into the process of learning within an immersive learning environment. Understanding the variables that impact on learning outcomes can inform the instructional design principles as well as the process of scenario development to ensure that environmental cognitive load is balanced and self-efficacy is not reduced.

Limitations

The final model derived in this study displayed a number of relationships that, while moderate in size, were not statistically significant. These associations are included in the discussion as they are scientifically significant effects. A retrospective power analysis revealed that power of

0.44 was achieved meaning that statistical analyses were underpowered. This indicates that with a larger sample size, it is likely these relationships would have reached statistical significance. This makes them noteworthy in understanding the mechanisms of learning in immersive VR.

Another limitation of this study is associated with the observation that numerous participants displayed difficulty using the controllers in the immersive VR condition. It is feasible that questions about degree of control in the scenario (agency scale) may be confounded with the interaction method that is measured by interactional cognitive load. This may be a result of the way items were adapted to suit the context and scenario of this study.

Lessons learned

One of the key lessons learned from this study was the importance of the scenario design itself. This study design and recognition memory test were retrofitted to an existing scenario which had flow-on effects that impacted the end results. The scenario was comprised of several jump-scares that were the result of decisions made without due consideration of safety because of poor situation awareness. This often resulted in heightened levels of anxiety that may have been compounded by the fact that requiring participants to enter a house to look for a hostage went against their natural instincts to stay safe. Heightened anxiety has been shown to result in compromised recognition memory in an animated context (Zlomuzica et al., 2022) and may explain why there is not a significant difference in recognition memory score between groups in this study.

One of the key advantages of VR is that it enables interaction with a scenario in a naturalistic way. People can move about and act much like they would in the real world. This is an important consideration when training situation awareness since it is a combination of cognitive and behavioural elements. Therefore, the flexibility to move through a scenario and scan an environment naturally, is important. While this is a strength of immersive VR learning technology, it also makes comparisons difficult in terms of replicating the same experience in a non-immersive way.

Future research

To mitigate the issue of consistency in moving through a scenario as described above, future research can allow greater experimental control by providing more explicit instructions so that participants stay on task, ensuring that scenarios are mapped out in the same way in both conditions and providing more thorough pre-training. The use of pre-training has been demonstrated to have a significant positive effect on learning by enabling participants to be able to interpret their experiences in a meaningful way (Meyer et al., 2019). In addition, development of prior knowledge also serves to reduce the entertainment or novelty factor in the scenario thereby allowing participants to better identify and process information that is relevant to the task at hand.

Future research in this area could seek to replicate the results from this study with a larger sample size to increase the power of the statistical tests. Further to this, including more than one measure of learning would be valuable in providing a better understanding of all the types of gains achieved through immersive learning. For example, including measures from the higher levels of taxonomy that look to see if there was understanding and not just recollection.

It was apparent that conducting this type of comparative study using scenarios across two different types of conditions is time consuming and as a result, large sample sizes may not always be feasible. In this case, it may be pertinent to control for individual differences that would otherwise be distributed evenly amongst large groups. For example, an individual variable such as spatial ability has been shown to significantly impact performance after training in VR (Lee & Wong, 2014).

To increase the generalisability of the results, having a second scenario that participants could complete would provide a second data point for comparison and ensure that any performance issues were not an artefact of the scenario itself.

The complex relationships between variables may be better understood through a mediation or moderation analysis. This would provide a more thorough understanding of the pathways through to learning. In addition, this would allow for consideration of the intercorrelations between variables that were more complex and outside the scope of this study.

Conclusion

This study aimed to establish whether immersive training environments provide a more effective training option compared to traditional methods in the development of situation awareness. It demonstrated that immersive VR does offer numerous educational affordances, such as increased presence, which in turn influenced situational interest, intrinsic motivation, self-efficacy, and cognitive load and in turn, learning outcomes. Understanding these relationships are critical in effective instructional design so that the affordances of immersive learning environments can be maximised for better learning in those industries that would most benefit from scenario-based training.

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Appendix A – Qualtrics Recognition Memory Test

Recognition - The following questions are designed to evaluate your level of observation and awareness in the scenario you just completed.

RM1 How thick was the smoke from the fire in the alley?

o Light smoke

o Thick, white smoke

o Thick, black smoke

o There was no visible smoke

RM2 How many bins were visible in the alley?

o 1

o 2

o 3

o 4

RM3 What lighting was there in the alleyway?

o It wasn't dark enough for street lights to be on

o There were street lamps

o There was only my torchlight

o There was only light from the fire

RM4 Which of these did NOT appear in the alleyway

RM5 Which of these objects was present in the alleyway?

RM6 What colour were the bins in the alley next to the suitcase?




RM7 Which of the following objects was NOT in the kitchen of the house?




RM8 Was the kitchen window:

o Open

o Closed

o Open and cracked/damaged

o Closed and cracked/damaged

RM9 What was next to the knife on the kitchen sink?

o Detergent

o Bleach

o Alcohol

o Can of spray paint

RM10 How many gas bottles were there at the house?

o Just 1 in the foyer

o At least 2

o 1 in the foyer and 1 in the house

o Just 1 in the house

RM11 What could be seen from the kitchen window looking into the foyer?

o The backyard

o A toilet

o Just the foyer

o Nothing - it was too dark

RM12 When the suspect ran out of the kitchen to the next room, what direction did they take?

o Left

o Right

o Straight

o Upstairs

RM13 Which of the following objects was on the bathroom floor?

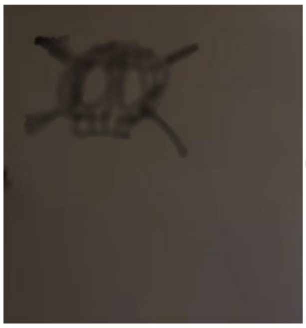
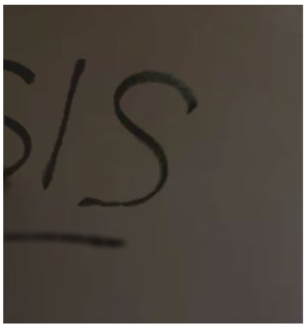



RM14 Which direction was the arrow pointing on the wall in the foyer?




RM15 Which of the following graffiti was on the wall in the room with the mannequin?



RM16 Which of the following objects was inside the house?




RM17 Which of the following elements was in the living room of the house (the living room is the one leading out from the kitchen)?

RM18 Which of the following elements was NOT in the bathroom in the house?

Appendix B - Subjective Measures Questionnaire

Agency The following statements are about your sense of control over your actions while completing the scenario exercise. Select the response that best suits your experience against each statement.

During the scenario exercise, I felt that my experiences and actions were:

	Strongly disagree (1)	Disagree (2)	Neither disagree nor agree (3)	Agree (4)	Strongly agree (5)
Under my control	○	○	○	○	○
Not caused by me	○	○	○	○	○
Self-generated	○	○	○	○	○

Presence The following statements are about how immersed and present you felt in the scenario. Select the response that best suits your experience against each statement.

	Strongly disagree (1)	Disagree (2)	Neither disagree nor agree (3)	Agree (4)	Strongly agree (5)
The scenario environment seemed real to me	○	○	○	○	○
I had a sense of acting in the scenario, rather than operating something from outside	○	○	○	○	○
I expect this scenario in the real world would be consistent with this scenario	○	○	○	○	○
I had a sense of being there in the scenario.	○	○	○	○	○
I was completely captivated by the scenario	○	○	○	○	○

Intrinsic motivation The following statements are about how motivated you felt while completing the scenario exercise. Select the response that best suits your experience against each statement.

	Strongly disagree (1)	Disagree (2)	Neither disagree nor agree (3)	Agree (4)	Strongly agree (5)
I enjoyed the scenario	○	○	○	○	○
It was fun to complete the scenario	○	○	○	○	○
The scenario was boring	○	○	○	○	○
The scenario did not hold my attention at all	○	○	○	○	○
The scenario was very interesting	○	○	○	○	○

Self-efficacy The following statements are about your level confidence in your observation and awareness while completing the scenario. Select the response that best suits your experience against each statement.

I'm confident that I:

	Strongly disagree (1)	Disagree (2)	Neither disagree nor agree (3)	Agree (4)	Strongly agree (5)
Had good awareness of my surroundings	○	○	○	○	○
Had good recall of objects and people	○	○	○	○	○
Had good recognition of objects and people	○	○	○	○	○
Could do well if tested on my awareness of the surroundings	○	○	○	○	○

Interactional Cognitive Load The following statements are about the way you interacted with the scenario. Select the response that best suits your experience against each statement.

The interaction technique used for the scenario:

	Strongly disagree (1)	Disagree (2)	Neither disagree nor agree (3)	Agree (4)	Strongly agree (5)
Was very unclear	○	○	○	○	○
Was very ineffective in terms of completing the exercise	○	○	○	○	○
Made it hard to complete the exercise	○	○	○	○	○
Was difficult to master	○	○	○	○	○

Environmental Cognitive Load The following statements are about the environment within the scenario itself. Select the response that best suits your experience against each statement.

In terms of completing the exercise, the scenario environment:

	Strongly disagree (1)	Disagree (2)	Neither disagree nor agree (3)	Agree (4)	Strongly agree (5)
Contained elements that made the exercise unclear	○	○	○	○	○
Was very ineffective	○	○	○	○	○
Was full of irrelevant content	○	○	○	○	○
Made it difficult to find relevant learning information	○	○	○	○	○

Situational Interest The following questions refer to your level on interest while completing the scenario exercise. Select the response that best suits your experience against each statement.

To what extent:

	Not at all (1)	Slightly (2)	Mostly (3)	Completely (4)
Did the exercise spark your curiosity?	○	○	○	○
Did the exercise capture your attention?	○	○	○	○
Were you concentrated on the exercise?	○	○	○	○
Was the exercise entertaining for you?	○	○	○	○
Did you have fun during the exercise?	○	○	○	○
Was the exercise exciting for you?	○	○	○	○

Gaming experience-1 Approximately how many hours a week do you spend playing video games?

▼ 0 (1) ... 168 (169)

Gaming experience-2 Approximately how many hours have you spent playing games using virtual reality or a similar immersive technology?

▼ 0 (1) ... 168 (169)

Age What is your age (in years)?

▼ 17 (2) ... Prefer not to say (68)

Gender What is your gender?

○ Male (1)

○ Female (2)

○ Non-binary / third gender (3)

○ Prefer not to say (4)

Appendix C - Participant Information Sheet and Consent Form

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Participant information sheet

PROJECT TITLE: Comparing the effects of traditional and immersive training environments on presence and learning in scenario-based training

HUMAN RESEARCH ETHICS COMMITTEE APPROVAL NUMBER: H-2022-50

PRINCIPAL INVESTIGATOR: [redacted]

STUDENT RESEARCHER: [redacted]

STUDENT'S DEGREE: Bachelor of Psychological Science (Honours)

Dear Participant,

You are invited to participate in the research project described below.

What is the project about?

This research project is about evaluating how effective immersive technology is in developing a learner's observation and situation awareness levels. We are focusing on the concept of "presence" and particularly how technology can optimise a learner's feeling of being immersed in a learning scenario. We hope to develop a clearer understanding of that relationship and how cognitive and affective factors can mediate learning outcomes.

Who is undertaking the project?

[redacted]

Why am I being invited to participate?

This study aims to generate results that have a wide application and therefore is open to any participants who are proficient in English and have normal or corrected-to-normal vision.

What am I being invited to do?

The study will require participants to undertake a computer-based scenario involving decision-making at different points. The exercise will be followed by a series of questions about the scenarios and the user experience. Screens may be recorded during the exercise and may be viewed by the researcher to assist with data analysis. This recording is only of the screen itself and not of the participant.

The study will take place at The University of Adelaide, City Campus in Room 253 of the Hughes Building.

How much time will my involvement in the project take?

Participants only need to attend one session which will take approximately 45-60 minutes to complete.

Are there any risks associated with participating in this project?

The computer-based scenario will play out on a screen so there is a small risk of dizziness. In addition, the scenario includes coarse language and mild themes so there is a small risk of participants feeling anxious or offended. The researcher will be present during the sessions therefore participants can opt out at any time during the session if they wish.

What are the potential benefits of the research project?

This study will contribute to the body of knowledge about use of technology in optimising learning outcomes. Participants will provide valuable insight into the mechanisms behind its effectiveness and hopefully also have fun in a choose-your-own-adventure scenario!

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Can I withdraw from the project?

Participation in this project is completely voluntary. As stated above participants can withdraw from the study at any time during their session.

What will happen to my information?

Confidentiality and privacy: participants will be assigned a random number once the session commences and thus all data collected in the session will be deidentified and cannot be traced back to individuals on reporting. However, the utmost care will be taken to ensure that no personally identifying details are revealed.

Storage: The data from this experiment will be identified by a random number upon completion. You will not be identified by this random number, so your performance in this experiment will be recorded, but not associated with you personally. The data may be stored in an online open access repository such as the Open Science Framework, for future meta-analyses and so that other researchers can easily reproduce our work. In any publication, presentation, or online record, you cannot be identified.

Publishing: The results of this study will be reported in an Honours thesis and the results discussed in workshops.

Sharing: De-identified data will be stored in a publicly accessible online repository such as The Open Science Framework. Additionally, the results of the project will be published in journal articles, academic and industry presentations, and workshops. If the resulting publications are not openly accessible, pre-prints of the work will be stored in a public online archive such as ArXiv.

Your information will only be used as described in this participant information sheet and it will only be disclosed according to the consent provided, except as required by law.

Who do I contact if I have questions about the project?

[redacted]

What if I have a complaint or any concerns?

The study has been approved by the Human Research Ethics Committee at the University of Adelaide (approval number H-2022-50). This research project will be conducted according to the NHMRC National Statement on Ethical Conduct in Human Research 2007 (Updated 2018). If you have questions or problems associated with the practical aspects of your participation in the project or wish to raise a concern or complaint about the project, then you should consult the Principal Investigator. If you wish to speak with an independent person regarding concerns or a complaint or your rights as a participant, please contact the Convenor of the School of Psychology Human Research Ethics Sub-Committee at: paul.delfabbro@adelaide.edu.au

Any complaint or concern will be treated in confidence and fully investigated. You will be informed of the outcome.

If I want to participate, what do I do?

Undergraduate psychology students can book in a session time through SONAR. All other participants can send an email to the student researcher [redacted]

Yours sincerely,

[redacted]

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Human Research Ethics Committee (HREC)

CONSENT FORM

1. I have read the attached Information Sheet and agree to take part in the following research project:

Title:	**Comparing the effects of traditional and immersive training environments on presence and learning in scenario-based training**
Ethics Approval Number:	**H-2022-50**

2. I have had the project, so far as it affects me, and the potential risks and burdens fully explained to my satisfaction by the research worker. I have had the opportunity to ask any questions I may have about the project and my participation. My consent is given freely.
3. Although I understand the purpose of the research project, it has also been explained that my involvement may not be of any benefit to me.
4. I agree to participate in the activities outlined in the participant information sheet.
5. I agree to for my screen to be recorded.
6. I have been informed that my involvement is voluntary and that I am free to withdraw from the project at any time without explanation or prejudice and to withdraw any unprocessed data previously supplied.
7. I have been informed that the information gained in the project may be published in a thesis, journal articles and presented at academic and industry presentations.
8. I have been informed that in the published materials I will not be identified and my personal results will not be divulged.
9. I agree to my information being used for future research purposes as follows:
   Research undertaken by these same researcher(s) Yes ☐ No ☐
   Research undertaken by any researcher(s) Yes ☐ No ☐
10. I hereby provide 'extended' consent for the use of my data in future research projects that are:
    a. an extension of, or closely related to, the original project: Yes ☐ No ☐
    b. in the same general area of research (for example, genealogical, ethnographical, epidemiological, or chronic illness research): Yes ☐ No ☐
11. I understand my information will only be disclosed according to the consent provided, except where disclosure is required by law.

Participant to complete:

Name: ________________________Signature: ___________________________ Date:_____________

For Adelaide University psychology undergraduates, so that we can credit you for participation:

Student ID no.: ________________________ SONA RPS number: _______________________________

Researcher/Witness to complete:

I have described the nature of the research to ____

(print name of participant)

and in my opinion she/he understood the explanation.

Signature: _____________________Position: ____________________________ Date:_____________

Appendix D - Scenario Briefing Script

First, have you had any cold or flu-like symptoms?

So what you'll be doing today is completing a simulated scenario using the <computer> <Virtual Reality>.

I just need to prewarn you that there is extremely coarse language used in the scenario and it is designed with a couple of jump scares. Will that be ok?

Just know if you get too uncomfortable or anxious you can stop at any time.

Here is the participant information sheet and consent form. If you could have a read through and then sign it for me then we can start.

Today you will be completing a scenario that is about developing your observation and what's called situation awareness. That means your awareness of objects and people in your environment. The scenario will play out in 2 consecutive parts. The context is that you are a police officer investigating some criminal activity involving a money drop in the first instance and then a hostage in the second. You need to be observant and aware of your surroundings as you make your way through the scenario.

Once you finish it, you will then complete a recognition memory test and some user experience questions.

It's important to remember that this is not a video game although it might feel like it. It is a training exercise for developing situation awareness. Your goal is not just to complete the investigation and get to the hostage, but to do it safely so that means being aware of your surroundings and what it means for your decisions about what to do next. So look around, look up, look down, take everything in.

Any questions?

For VR condition:

Stand in the middle of the room here, facing the wall. I'll get you to put the headset on first. Adjust it so it's comfortable and in focus. Which is your non-dominant hand, I'll put the torch in that one.

Okay, so when the scenario launches, you will go through a tutorial first so you can get used to the controls and how to move around. You won't need to walk, you will be using the teleporting. Make sure you use that time to really familiarise yourself with how to use the controls. So don’t limit yourself to do just what the instructions are telling you but play around. The more comfortable you are with the controls the easier it will be to move through the scenario.

See the blue grid – that marks out the physical barriers of the space so it represents the table and walls in this room so if you see the blue grid, you are getting close to walking into something.

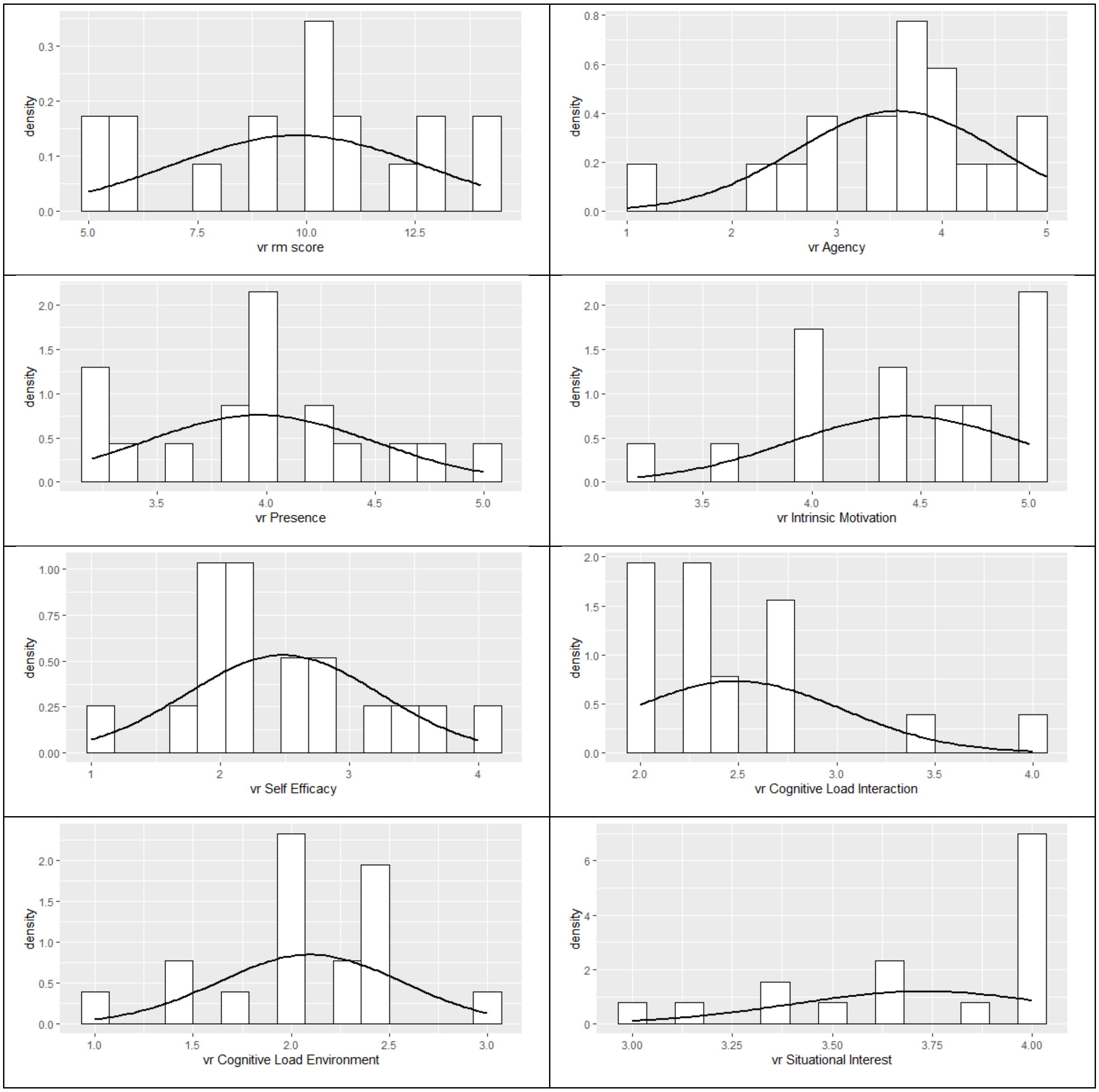
Any questions?

For video condition:

Sit down here. There are videos that will play on the computer. You can pause and restart them at anytime just by clicking on the screen. You can also replay a video as many times as you need before making a choice. When you are ready to start, just click proceed.

Appendix E - Histograms

IVR Condition



IV Condition