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Transforming paramedic training with virtual reality

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Abstract

Purpose: *This study aims to evaluate the effectiveness of virtual reality (VR) training in enhancing paramedics' preparedness and response skills in mass casualty incidents (MCIs).*

Design: *This was an observational study of registered paramedics and intensive care paramedic students from NSW Ambulance. Participants completed a 30-minute VR training session simulating a car crash MCI scenario, plus pre- and post-intervention surveys measuring gaming literacy, prior simulation experience and perceived improvements in MCI skills.*

Findings: *Results indicated significant improvements in paramedics' MCI response self-efficacy. Prior to VR training, only 30.0% felt confident in managing an MCI. Post-training, over 90% reported improved skills in triage and patient management, as well as improvement in self-identified areas of weakness. Participants found the VR technology easy to use and highly immersive, with all respondents indicating the scenario mimicked real-world conditions and was transferable to their workplace.*

Research implications: *This study highlights the need for standardised protocols and comprehensive performance metrics in VR training to ensure consistent outcomes across different settings. Future research should focus on long-term skill retention and objective performance data (e.g., heat mapping, time tracking) to validate VR training effectiveness.*

Practical implications: *The findings support integrating VR training into paramedic education to bridge the gap between theoretical knowledge and practical application in MCI scenarios. Tailoring VR modules to address individual gaming literacy can enhance user engagement and training effectiveness.*

Value: *This study contributes to the growing body of literature on VR in emergency medical training by demonstrating its potential to significantly improve paramedic readiness and performance in MCIs. The use of VR provides a realistic, repeatable, and immersive training environment that traditional methods lack.*

Limitations: *Limitations include a small sample size, lack of longitudinal data on skill retention, and the absence of objective performance measurements. Future research should address these gaps to validate and enhance the effectiveness of VR training in paramedicine.*

Keywords: paramedics, mass casualty incident, simulation training, virtual reality

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INTRODUCTION

The increasing frequency and complexity of mass casualty incidents (MCIs) requires advanced and accessible training methods for paramedics and emergency responders. Traditional training often falls short when it comes to providing the realistic, immersive, and repeatable experiences required to effectively prepare responders for such high-stakes situations, and thus creates a training gap between theoretical knowledge and practical application. Virtual reality (VR) has emerged as a promising training and education tool, offering realism and interactivity to enhance both the technical and non-technical skills essential for effective disaster response.

Recent studies have revealed that VR MCI training in a prehospital emergency care clinical setting provides significant benefits, including improved decision-making, enhanced situational awareness, and greater retention of learned skills (Abbas et al. 2023). VR simulations can mimic the complex environment of MCIs by creating a perceived 3D environment including sound, spatial distance, haptic feedback and visual cues, such as colour and the simulation of obvious injuries, allowing paramedics to practice and refine response strategies in a safe, controlled setting (Berndt et al. 2018; Mills et al. 2020; Pratticò et al. 2021; Vogt et al. 2023). VR has also been shown to improve first responder performance and knowledge retention, highlighting its potential to supplement traditional training methods (Abbas et al. 2023; Heldring et al. 2024; Kman et al. 2023).

Despite these advantages, several unknowns remain. There are no standardised VR training protocols, complicating the assessment of VR's effectiveness across different settings. Furthermore, while short-term benefits are well-documented, there is limited research on the long-term retention of skills acquired through VR training. Technical challenges, including motion sickness and the high initial costs of VR systems, also pose challenges to widespread adoption. Furthermore, there is a need for comprehensive performance metrics and standardised evaluation tools to accurately assess program effectiveness (Abbas et al. 2023; Pucher et al. 2014), without which it is challenging to compare outcomes and ensure that VR training translates into real-world disaster response improvements. By acknowledging and understanding these factors, VR training modules can be tailored to relevant educational settings, enhancing user experience and training effectiveness. This integrated approach not only addresses technical and user experience challenges but also supports the development of standardised, inclusive, and scalable VR training programs.

To explore its potential to bridge the gaps between theoretical knowledge and practical application, VR was applied to paramedic MCI training and a survey designed to explore participant experiences prior to and after engaging in the VR scenario. This study aimed therefore to evaluate participant engagement with the VR experience and measure the subjective response of the participants' perceived knowledge and abilities in an MCI prior to and following the VR experience.

METHODS

STUDY SETTING AND TRAINING TOOL

The study was conducted at two NSW Ambulance educational/training facilities during 2021, and was facilitated by a paramedic educator, a VR development manager and two VR software engineers. Each participant engaged for approximately 30 minutes with VR, including education on using the VR tool, review of MCI triage and participating in the VR MCI scenario ("VR-MCI").

The VR-MCI was an incident involving a car driven into a crowd at an outdoor mall. Eight patients were spread over a large distance, requiring reconnaissance of the scene. The scenario was identical for all participants but participant performance in locating patients and skill application (i.e. life-saving interventions) affected the outcome of the patients and thus participant success. Where possible, equipment used in the VR-MCI mimicked equipment used by NSW Ambulance, as the scenario was customised for the organisation.

Skills performed during VR-MCI were: clothing removal, tourniquet application, airway clearance, pulse taking, chest auscultation, posture and triage tagging. Participants did not perform any pre-VR-MCI activities that may have improved their performance. Participants were briefed on the triage tagging labels, which were:

- **Red:** Priority 1, life threatening injuries
- **Yellow:** Priority 2, second line of treatment
- **Green:** Priority 3, walking injured patients
- **White:** Deceased

The use of a METHANE report (major incident, exact location, type of incident, hazards, access, number of casualties, emergency services) was expected (Joint Emergency Service Interoperability Program (JESIP) n.d.).

DESIGN

Data were collected via a pre- and post-intervention survey (Tables 1 and 2). This survey was based on previous experience within the organisation of introducing new training tools into the training setting, and is an adaption of previously used and accepted training evaluations. Prior to engaging in the VR-MCI, Q1 – Q3 measured participant game literacy; Q4 – Q6 measured participants' previous MCI educational simulation experience; and Q7 – Q9 evaluated participants' perceptions of their knowledge, ability to apply principals of engagement and to triage, and confidence when attending an MCI, with responses measured against a 5-point Likert scale.

Post-intervention, nine further questions measured responses against a 5-point Likert scale. Q10 – Q12 measured the virtual experience with an emphasis on ease of technology, technology affecting the learning and level of immersion; Q13 – Q15 measured the value of the scenario according to usefulness, transference to and replication of the workplace; and Q16 – Q18 measured participants' perceptions of improvements to skills, knowledge and abilities when attending an MCI and capacity to identify and improve on their weaknesses.

STATEMENT OF ETHICS

This study complied with the NSW Health Guideline GL2007_020 - Human Research Ethics Committees - Quality Improvement & Ethical Review: A Practice Guide for NSW, and was exempt from further ethical review.

RESULTS

The cohort undertaking VR training were registered paramedics employed by NSW Ambulance, with the majority (n = 17, 56.7%) being intensive care paramedic students undergoing specialist training. A further 12 (40.0%) were educators, plus one manager. Ages ranged from mid 20s to early 60s, with levels of experience from four to 35 years.

In total, 30 respondents completed the survey. Prior to undertaking the VR-MCI training, participants were asked information on general gaming literacy and prior experience with educational simulations (Table 1). Two-thirds regularly played 2D games, just over one-third played more advanced 3D games, and even fewer still (n = 3, 10.0%) played VR games. In general, most participants' prior experience with simulation training consisted of Emergo Train System® whiteboard simulations (n = 25, 83%) or human simulated patients (n = 23, 76.7%).

Table 1: Game literacy and educational simulation experience of participants

	N (%)	No	Yes
	Game Literacy		
Q1	Do you play 2-dimensional computer/mobile phone games?	10 (33.3%)	20 (66.7%)
Q2	Do you play 3-dimensional computer/mobile phone games?	19 (63.3%)	11 (36.7%)
Q3	Do you play virtual reality games involving a headset?	27 (90.0%)	3 (10.0%)
	Educational Simulation Experience		
Q4	Have you participated in an EmergoTrain whiteboard simulation?	5 (16.7%)	25 (83.3%)
Q5	Have you participated in mass casualty training using human actors?	7 (23.3%)	23 (76.7%)
Q6	Have you participated in mass casualty training using manikins?	13 (43.3%)	17 (56.7%)

Prior to undertaking the VR-MCI, participants were asked to rate their self-efficacy in MCI scenarios (Table 2, Q7 – Q9). Exactly half (*n* = 15) felt comfortable with their knowledge of MCI protocols, and nearly two-thirds (*n* = 19, 63.3%) felt confident in their ability to use the coloured triage tags. Despite this, less than a third (*n* = 9, 30%) felt confident in attending an MCI.

After undertaking the VR-MCI, participants answered questions evaluating the utility of the VR tool and its impact on their self-efficacy in MCI scenarios (Table 2, Q10 – Q18). The majority found the technology easy and not distracting from the learning (Q10 – Q11, *n* = 27, 90.0%) while all participants felt immersed in the simulated scenario (Q12). There were no notable trends according to prior gaming literacy (Q1 – Q3), and the small numbers who were unsure or did not agree with the statements in Q10 – Q12 had prior 2D gaming experience only. Agreement with the statements was also slightly higher among those with 3D gaming experience. The responses about educational experience were similarly positive, with all participants indicating that VR scenarios have a useful place in paramedic education, and that learning experiences using VR could be transferred into practice (Q13 – Q14). Only two respondents (6.7%) were unsure about the VR-MCI sufficiently mimicking the workplace (Q14).

Table 2: Reported paramedic self-efficacy in dealing with multiple patient scenarios, plus self-reported experience of the VR-MCI

		Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	% Agree/ Strongly Agree
Game Literacy							
Q7	I am very comfortable with my knowledge of protocol A11 Multiple Patient Situations		8	7	14	1	**50.0%**
Q8	I am very comfortable with my knowledge of the triage tags used in NSW Ambulance		5	6	19		**63.3%**
Q9	I feel confident in attending a multiple patient situation involving 8 – 10 patients	4	8	9	9		**30%**
The Virtual Experience							
Q10	I found the technology easy to use		1	2	16	11	**90.0%**

		Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	% Agree/ Strongly Agree
Q11	The technology did not detract from the learning		2	1	15	12	**90.0%**
Q12	I became immersed in the simulation				7	23	**100.0%**
Educational Simulation Experience							
Q13	VR scenarios have an important place in NSW Ambulance Education				4	26	**100.0%**
Q14	What I have learnt in this scenario can be transferred to the workplace				5	25	**100.0%**
Q15	The scenario mimics the workplace			2	10	18	**93.3%**
Triage & Multiple Patient Situations							
Q16	This scenario has improved my ability to respond in a multiple patient situation		1	1	11	17	**93.3%**
Q17	This scenario has improved my triaging and sorting of patients		1	1	12	16	**93.3%**
Q18	This scenario helped me to identify and improve any weaknesses I had in a multiple patient situation				11	19	**100.0%**

A large majority of respondents felt their self-efficacy improved due to the VR-MCI training; 93.3% (*n* = 28) felt that it had improved their ability to respond to MCIs, 93.3% (*n* = 28) felt the training improved their triaging skills, and all participants reported that the VR-MCI helped them identify and improve upon their personal weaknesses in MCI scenarios.

DISCUSSION

This study demonstrates the utility of purpose-built VR technologies in paramedic MCI training. MCIs are difficult to replicate in the training space, meaning VR can be utilised to fill this training gap. A large proportion of participants responded favourably to the VR-MCI, suggesting acceptability and effectiveness among this professional cohort. From an educational perspective, VR technologies provide participants the opportunity to engage in situation-based and reflective learning practices, whereby the training scenario is as close as possible to situations encountered in the field.

Comparison of responses in Q7 – Q8 (theoretical knowledge, 50.0% and 63.3%) with Q9 (self-efficacy, 30% confidence rate) identified a clear gap between theoretical knowledge and practical application in MCIs. This disparity indicates a large disconnect between theoretical knowledge and the perceived ability to practically apply this knowledge, and this disconnect is already well known (Arbon et al. 2008; Michau et al. 2009). Understandably, recreating consistent and repeatable MCIs is effectively an impossible task for educational institutions, and has limited realistic immersion possibilities for participants. However, this gap in key reconnaissance, triage tagging and life-saving intervention skills can be addressed with VR-MCI; the positive responses in Q16 – Q18 demonstrate that a single VR-MCI training event can dramatically improve participant self-efficacy in effective MCI response, pointing to the effectiveness of this technology as an appropriate solution to the theory-practice gap.

A significant portion of participants found the VR experience positive and satisfying (Q10 – Q12), and the educational simulation experience (Q1 – Q15) even more so, showing VR to be an engaging training tool for paramedics. Several factors may contribute to this, including tailored VR scenarios to address identified knowledge and training gaps, inclusion of familiar tools and procedures from the workplace into the VR experience (such as triage tags, basic airway devices, tourniquets and posturing), and simplified interactions made possible within the VR (such as removing unrealistic and distracting drop-down menus or selection options). This approach allows the MCI scenario to drive the VR experience, rather than the VR driving the scenario, reducing training scars, enhancing realism and boosting effectiveness for paramedics.

Responses to Q16 – Q18 show a substantial positive shift in self-efficacy even after a single session with VR. Although this study did not measure outcomes within the VR-MCI (for example correct application of triage tags, recorded preventable deaths) these were presented to participants at the end of the session. Participants understood that actions and interactions within the VR-MCI, which were all different depending on each participant's actions, affected the outcome. Consequently, knowledge gained by participants of patient dispositions, effectiveness of scene reconnaissance and patient outcomes allowed them to reflect on their performance and identify areas of improvement. The ability of VR to deliver personalised feedback enhances learning by linking actions to consequences.

LIMITATIONS

This study has several limitations. Firstly, no objective data, such as heat (tracking) maps, time markers, triage accuracy, and preventable deaths, were matched to self-reported improvements by participants, nor were these related to individuals' performance in the VR-MCI. This means that increases in confidence could not be related to correct decision-making (or learnings gained from incorrect decisions), and may have been simply the result of false and/or self-perceived confidence. The study also did not investigate skill retention over time, which would require a longitudinal follow up program measuring the rate at which skills deteriorated. Future studies on the effectiveness of VR training programs should utilise the metrics generated by the VR tool and compare this to each participant's skill perception and ability post-VR intervention. Gaming literacy data could also be levered to assist participants in VR training.

CONCLUSIONS

The use of a VR platform to train participants in skills for MCIs, which are difficult to create in an educational institution, can have substantial benefits, requiring minimal training to be used correctly. Targeting VR training according to participant gaming experience would assist and accelerate the uptake of the tool, removing educational barriers around gaming literacy. VR is a simulation modality that can be repeated identically on multiple occasions but result in different outcomes for the (virtual) patients depending on the performance of the participant. It can also give detailed objective data at the completion of the scenario that assist the participant in clinical improvement. The identification of the theory-practice gap around MCIs and the perceived effectiveness of the VR tool addressing this gap has demonstrated that VR for MCIs is a worthy investment for paramedic training.

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