

Virtual Reality Training for Multi-Agency Traffic Incident Management

Abstract

Live training exercises aim to improve trainee confidence in performing correct procedures through simulation, although conducting live training can present several practical challenges. In the context of multi-agency Traffic Incident Management (TIM), live training requires significant resources such as access to roads, vehicles and actors. There are also several logistical challenges associated with having multiple trainees from different agencies attend a suitable training site. The recent introduction of affordable, reliable, and portable Virtual Reality (VR) headsets provides an alternative training method to live training that mitigate the cost and challenges associated with live training. This research explores the use of VR technology by developing and evaluating a multi-agency TIM VR training application. Results suggest that VR training requires similar levels of cognitive effort when compared with live training while also producing similar levels of self-efficacy and mental engagement.

Social media post

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Introduction

Traffic incident management (TIM) is important to ensure safe and efficient management of road network systems in response to traffic incidents. First responders, road authorities and other related agencies employ a wide range of techniques in a coordinated approach to control and manage traffic at incident sites to keep motorists and incident responders safe while efficiently managing traffic flows. Typically, TIM training is provided in real-world or simulated incident sites, which has some significant challenges, including the costs associated with training resources (e.g. roads, vehicles and actors) and trainee logistics (e.g. travel and accommodation costs to attend), as well as scheduling difficulties of multiple agencies. Such live trainings could also expose motorists and incident responders to unsafe traffic/road environments. Therefore, it is important to identify and validate alternative training methods.

Recent advancements in VR technologies have led to a rapid increase in the availability of consumer-grade, low-cost, easy to use, and portable VR headsets. Research suggests VR provides several benefits as a training tool, particularly where access to training environments are costly, difficult or impossible. VR has also been suggested to enhance scenarios that can already be replicated in the real-world, or those that are otherwise unsafe or ethically unjustified. For example, VR has been used for incident response training to teach firefighters how to respond to fire-related emergencies (Clifford et al., 2018; Tao et al., 2017; Xu et al., 2014), teach police officers how to perform collaborative searching tasks (Bertram et al., 2015) and decision-making (Zechner et al., 2023), and emergency medical technicians to perform tourniquet placement (Arif et al., 2023). While research has shown promising signs for the use of VR to deliver incident response training, few have focused on its use for training of response to traffic incidents. Where traffic incidents have been the focus of research, such as Czarnek et al. (2020) who explored VR training on standard rescue procedure to assist injured victims involved in a vehicle accident, or Lochmannová et al. (2022) and Berndt et al. (2018) who developed VR training for paramedics in accident reporting and triaging, they have had a single agency focus. This research aims to understand and evaluate the potentials of VR technology in multi-agency TIM training as a safer and more practical alternative to the traditional live training exercises.

Method

The research evaluates the effectiveness of two methods of multi-agency TIM training: live training and VR training. A mixed design was employed, which combined quantitative analysis of survey responses and qualitative analysis of interviews. A similar data collection process was followed for both training methods, with participants completing a pre- and post-training survey, followed by a semi-structured, group-based interview. The pre-training survey captured both demographic information as well as self-efficacy (baseline) and motivation scores of participants with respect to TIM. The post-training survey measured key constructs including self-efficacy, motivation (intrinsic, identified regulation, external regulation, and amotivation), situational interest (catch and hold), engagement, trainees' subjective reaction to the training, cognitive load, and training duration preference. The interview grouped participants based on their agencies and captured their perception of the training, including its benefits, limitations, potential, and suggested improvements. A total of 25 participants undertook the live training and 19 participants undertook the VR training, among whom 14 participants undertook both training methods. Participants of live training were predominantly male

(19 out of 25), while VR training was more balanced (10 out of 18 were male). The average age of participants is similar between the two groups (mean of 45 years for live training vs. 43 years for VR training).

Live training was conducted over two days and involved participants from emergency services and transport organisations. Live training simulated two TIM exercises; the first involved a two-vehicle crash in a regional area (Figure 1.) which required occupant extrication, while the second exercise simulated a passenger bus and guard rail collision, causing a chemical spill, due to an evasive action in response to an insecure load. Both exercises were recorded using two 360-degree video cameras, which provided content to develop the VR training application. During both exercises, a pop-up tent was used as a communication hub for the exercise commander and call centre operators, with CB radio communication between agencies, and ambient sounds recorded for VR training. The VR training application was developed using the Unity3D game engine for the Meta Quest 2 Headset. VR training included several key design elements: 360-degree video and digital annotations, VR user interfaces, audio and synthesised narration, point-and-click interactions and assessment questions.



Figure 1. Overview of 360-degree video recording during live exercise (left) and participant perspective of VR training (right)

Results

Figure 2 provides an overview of survey results, comparable results can be observed between live and VR training methods, with only slight observable advantages for VR training. Statistical analyses confirmed this observation, with no significant differences found between the two training methods besides Situational Interest—Catch, where VR training captured significantly higher initial interest of trainees compared to live training using the Mann-Whitney U test ($Z = -2.362, p = 0.018$).

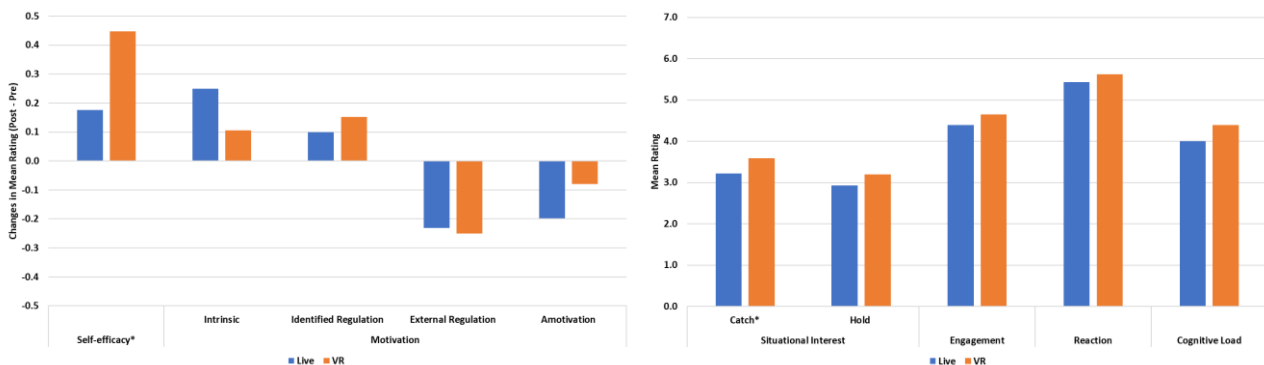


Figure 2. Mean ratings of survey measures with an Asterisk (*) denoting statistically significant results

A 2x2 mixed-design ANOVA was conducted to examine the effect of time (pre and post) and training method (live and VR) on self-efficacy. A significant main effect of time was found ($F(1,42): 8.345, p = 0.006$, partial $\eta^2 = 0.166$), indicating self-efficacy improves significantly after either training. While the mean increase is higher for VR, the effect of training (i.e., both the main and interaction effect) on self-efficacy did not reach significance. A 2x2 mixed-design ANOVA was also conducted on categories of motivation, no significant main and interaction effects of time and training were observed. Despite this, a consistent mean pattern of self-determination improvement was observed for both live and VR training. As seen in Figure 2, higher self-determination categories (i.e., intrinsic and identified regulation) increased from pre- to post-training for both training methods, while the lower self-determination categories (i.e., external regulation and amotivation) decreased.

While no significant differences were found between live and VR training with respect to Situational Interest–Hold, Reaction, and Engagement, VR training consistently showed higher mean ratings. Finally, no significant difference was found in cognitive load, suggesting comparable mental demand required. Regarding training duration, participants had varied views. Participants generally reported that duration for VR training (approximately 25 minutes) was ‘ideal’, while some suggested it was ‘slightly’ to ‘moderately’ too long. Interestingly, live training duration (approximately 45 minutes) was considered too short by most participants.

Several recurring themes were reported by participants during interviews. Firstly, VR training was suggested to benefit participants who had little to no practical experience in TIM. Participants also highlighted the value of inter-agency training in general, and the inclusion of CB radio communication in particular, as these help improve understanding with respect to roles, responsibilities and actions, especially for those who don’t attend the incident site (e.g., call centre). Further improvements were also suggested, such as tailoring content towards specific agencies, adding more detailed information to improve authenticity and including features such as time-lapse, progress clock, top-down view, subtitles, and the ability to pause and rewind exercises.

Conclusions

Live training exercises provide valuable practice of TIM in response to varied simulated traffic incidents although can be costly and logistically difficult to run. This research investigated the use of VR technology to evolve existing TIM training by providing an alternative training method for live training exercises. VR training is developed using digitally annotated 360-degree videos, audio and text narration, assessment questions and VR point and click interactions that is then compared against live training. Results shows that VR training provided similar levels of self-efficacy and mental demand as live training exercise. VR training was also more time efficient than live training taking approximately 25 minutes for each exercise compared to approximately 45 minutes for live exercises. Interviews reported that VR training would benefit those with limited experience (e.g., novices) with several features suggested to improve engagement and understanding such as the ability to pause and rewind exercises.

Relevance to conference theme and road safety

VR training has practical implications on existing TIM training programs by providing a cost-effective, portable and repeatable training method that increases accessibility to simulated multi-agency training exercises. It would also contribute to improved training outcomes and measurable road safety benefits, such as faster incident response times, improved inter-agency coordination, or reduced secondary crashes, resulting in enhanced safety at incident response sites. This research contributes to the evolution of a safe system in incident management training.

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