Training Interorganizational Risk Management of Emergency Service First Responders with Virtual Simulation

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ABSTRACT

Emergency service first responders are increasingly confronted with hazardous work environments due to extreme weather conditions, new technologies such as solar panels, or antagonistic events. Consequently, police officers, firefighters, and prehospital care paramedics need to manage risks and ensure their own safety when working collaboratively. Virtual simulation enables regular training across a wide variety of scenarios, where high-risk situations and the consequences of faulty decisions can be experienced without endangering trainees. An extensive literature review reveals a lack of studies explicitly addressing virtual training of interorganizational risk management for emergency service first responders. It is argued how this phenomenon can be better understood by mapping types of scenarios and types of risks, by exploring how these risks can be conveyed in virtual simulations, and by a stronger focus on long-term learning retention and learning transfer to the workplace when evaluating studies.

Keywords

Risk management, Emergency Service First Responders, Virtual Simulation, Safety, Training.

INTRODUCTION

Training of emergency service first responders (ESFR) could become more effective with virtual simulation (VS). When incident response officers are trained in a VS, they can practice more often with a greater diversity and number of scenarios. That enables skill development, such as making adequate risk assessments during ongoing operations. Training joint risk assessment for complex events and new threat scenarios has been identified as an important research need in workshops and interviews with practitioners. ESFR are increasingly expected to be confronted with completely new risks such as new technologies (electric cars or solar panels), threatening situations (riots, terrorist attacks), extreme weather (floods, landslides and rockfalls), which require entirely different types of risk assessments than ordinary apartment fires or the care of injured people at a traffic accident. No single professional group has the complete picture for good risk analysis when ESFR work together in a shared dangerous environment. Hence, training joint risk assessment and collaborative risk management is needed.

Simulating large, complex, and hazardous events in a field simulation exercise is challenging. Such scenarios might be costly in terms of the number of figurants, or they might be impossible to realistically ensure the trainees' safety in the face of landslides, explosives, or hazardous chemicals. VS creates opportunities to convey risks in a more realistic manner and to create consequences if safety is not addressed, e.g., by having the (avatars of the) first responders get hurt or die in the VS.

As the long-term objective of our research endeavor is to develop a method for virtual training in IORAM and risk management of ESFR, a first important step is to identify previous research on this topic. Consequently, this article reports on an extensive literature review that aimed to identify opportunities and research gaps with regard to training interorganizational risk assessment and management (IORAM) of ESFR with VS. The literature review reveals that research on this topic is lacking. Concrete examples from the analyzed articles show how future research could build on lessons learned in related fields like interorganizational risk management (IORM) training through traditional role-playing simulations and VS training of safety procedures within individual organizations.

BACKGROUND

Our society is increasingly exposed to extreme events due to heightened tensions among ecology, climate, and social and economic development (Ansell et al., 2010). ESFR are often the ones who have to work in the center of the extreme event, which also entails risks. These types of events require cross-organizational collaboration across legal, geographic, and functional boundaries, which society is not sufficiently equipped to provide (Ansell et al., 2010; House et al., 2013). Response leaders are responsible for their personnel safety in the difficult work environments created by extreme events (Granter et al., 2019; Smith & Dyal, 2016). Cross-organizational collaboration presents challenges, including diverse mandates, separate management structures, and distinct professional cultures (Charman, 2018; McAleavy, 2021; Power, 2018). Extreme events involve uncertainty, which means that ESFR on the scene cannot fully rely on previous experience or standard procedures and must synchronize their efforts through improvisation (McAleavy, 2021; Power, 2018).

Simulation-based training is often recommended as a suitable approach for developing skills in cross-organizational collaboration during extreme events (Berlin & Carlström, 2015; Power, 2018). Simulation based training is based on the theory of experiential learning (Kolb and Kolb, 2009) and enables situated learning (Charman, 2018) where new shared practices can be developed in a setting where it is safe top experiment and fail (van Laere & Lindblom, 2019). Practitioners use simulation-based training extensively, but there is a lack of research on how simulation-based training should be designed, and on its effectiveness (Berlin & Carlström, 2015; van Laere & Lindblom, 2019; Solinska-Nowak et al, 2018). Digital simulations are more motivating that traditional training environments, lead to a higher self-efficacy and to higher learning-transfer (Gegenfurtner et al, 2014). In addition, training with VS can offer a cost-effective and safe learning environment, enable repetition in a way which is not possible with live simulation, and provide the possibility to record and review scenarios (Heldring et al, 2024). Especially with respect to training risk assessment in extremely hazardous environments, VS can provide risk-free immersive learning (Rey-Becerra et al, 2021).

RESEARCH METHOD

To build an understanding of the current state of research on training IORM for ESFR with VS, a systematic literature review was conducted. The aim of the literature review was to identify existing studies on this topic to inform the design of the virtual training method and VS scenarios. A search string was applied, including the structure *"(simulation/game AND virtual/digital AND train/educate) AND (interorganizational/collaboration/cooperation/interprofessional OR risk/hazard) AND first responder/incident*". The search string was applied to the databases Scopus, Web of Science, Medline EBSCO, Pubmed, CINAHL EBSCO, and ERIC EBSCO in June 2025 and returned 1667 articles between 2013 and 2025. After removing duplicates, 978 hits remained. A total of 126 of them were tables of contents of proceedings (not including the individual research papers). After omitting those, the set of papers to be analyzed was 852.

The title and abstracts of these 852 articles were reviewed by the first author, and by at least one of the other authors, and rated on the following inclusion criteria: (1) applies VS training; (2) regards training of professionals in one or multiple emergency services; (3) applies collaborative training or addresses interorganizational collaboration; (4) addresses risk management or safety management. All four authors met in two meetings to discuss and solve inter-rater agreement. Initially, an article was eligible for inclusion if three of four of these criteria were met. As only a few articles met all these requirements, some that fulfilled two criteria and were judged particularly interesting were also included. A total of fifteen articles were identified. During full-text analysis, nine of these fifteen articles were excluded for several reasons. Four articles were excluded because they focused solely on virtual reality (VR) training for one task (e.g. extinguishing a fire, triaging casualties) with no focus on risk management, first responder safety issues, risk- or situation assessment. Next, three additional articles were excluded because they only tested a VR training module on students, not the training of professional first responders. Finally, two articles were excluded because they discussed or evaluated the impact of VR training for emergency services or industry training in general and were un-specific with regard to the research questions of this literature review.

As only six studies remained, additional snowball sampling was done in order to identify more candidates. This was done in several ways. One strategy was to look for other papers from the same authors. Sharma and Moses (2025) is an example of an article identified that way. Another article of these authors did not pass full text review, but this article, which was not included in the initial dataset, was judged interesting. Likewise, articles were screened to which articles from the initial full text screened papers referred to, or which were referring to articles from the full text review phase. Eide et al (2026) is an example of an article which referred to Heldring et al (2024). Whereas Heldring et al 2024 was excluded after full text review, Eide et al (2026) was included. A total of 11 articles were identified through such snowball sampling. Seven of those articles were excluded after full text review, which resulted in four extra publications included in the dataset through snowball sampling.

The ten selected articles were full-text analyzed with the following research questions in mind: What kinds of risk scenarios were trained? What kind of risk management practices were trained? How were risks visualized/portrayed in the (virtual) scenarios? What are the common challenges in training IORM of ESFR? What research gaps have been identified for training IORM of ESFR with VS? The results section of this article provides an overview of the identified studies and their main findings with respect to the above questions. In the discussion section, an analysis of some recurring themes is presented.

Table 1 summarizes the literature review process according to a Prisma format.

Table 1. Prisma Flow Diagram for the literature review

Database search	
Records identified (n=1667)	**Records removed before screening**
Scopus (n=748) Web of science (n=391) Medline ebsco (n=193) Pubmed (n=204) CINAHL ebsco (n=65) ERIC ebsco (n=66)	Removal of Duplicates (n=689) Removal of records which were Table of Contents of proceedings (n=126)
Records screened (title/abstract)	**Records excluded**
n=852	n=837
Articles assessed for eligibility	**Articles excluded in full text review**
n=15	Focus on one limited task (n=4) Students as trainees (n=2) Too general and unspecific (n =2)
Articles included	
n = 6 (see table 2)	
Snow ball search	
Records identified	**Records removed before screening**
n=11	n=0
Articles assessed for eligibility	**Articles excluded in full text review**
n=11	Focus on one limited task (n=4) Students as trainees (n=2) Too general and unspecific (n =1)
Articles included	
n = 4 (see table 2)	

RESULTS OF THE LITERATURE REVIEW

The literature search identified 10 studies: 6 from the initial database search and 4 from additional snowball sampling. The selected articles are listed in Table 2, including their categorization based on the 4 inclusion criteria.

Table 2. Categorization of research articles identified and included in the literature review

Authors (year)	Training with virtual simulation	Emergency Services	Inter-organizational	Risk or Safety Management
Articles from database search				
Carrozzino et al (2023)	x			x
Hewagarusinghe & Sridarran (2024)	x			x
Berthiaume et al (2024)	x	x		x
Lavender et al (2019)	x			x
Gürer et al (2023)	x			x
Rey-Becerra et al (2023)	x			x
Articles from snowballing and additional literature search				
Dubois et al (2022)		x	x	x
Eide et al (2026)	x	x	x	
van Ruijven et al (2015)	x	x	x	
Sharma & Moses (2025)	x			x

Training Interorganizational Risk Management of ESFR with VS

Table 2 shows that none of the identified studies met all four inclusion criteria. The ten studies that partially met the inclusion criteria are discussed groupwise in the next subsections, following the structure of Table 3.

Table 3. Grouping of selected articles

Group	Articles included	Number of articles
Training Interorganizational Risk Management of ESFR (with other forms of simulation)	Dubois et al (2022)	1
Interorganizational Training of ESFR with VS (not focusing on risk management)	Eide et al (2026) van Ruijven et al (2015)	2
Training Risk Management of ESFR with VS (where only one single organization is trained)	Berthiaume et al (2024)	1
Training Risk/Safety Management with VS (for other professionals, i.e. not ESFR)	Carrozzino et al (2023) Gürer et al (2023) Hewagarusinghe & Sridarran (2024) Lavender et al (2019) Rey-Becerra et al (2023) Sharma & Moses (2025)	6

Training IORAM of ESFR (with other forms of simulation)

Dubois et al (2022) report on role-playing exercises of Casualty Extraction Teams. These are specialized teams of seven firefighters who operate in dangerous areas (a post-attack environment) to save as many casualties as possible, while they are protected by police officers. This enables them to reach casualties more quickly than other rescue services, thereby increasing their chances of survival. Training is conducted through 11 role-playing scenarios, each approximately 20 minutes, preceded by a briefing and concluded with a debriefing. The training pedagogy is to start with simple scenarios and progress to increasingly complex ones. Consequently, early scenarios are trained only with firefighters while co-training with police is performed in later scenarios. Evaluation of performance is done by giving feedback on the number and character of unfulfilled or partially fulfilled prescriptions. Prescriptions are safety rules for managing risks to casualties and to first responders. Examples of

such rules are: wearing safety equipment, never turning your back on the threat, prioritizing one's own safety over the safety of casualties, and not staying too long in the dangerous area. Not following safety rules can sometimes be motivated by multiple issues to be addressed in the scenario. Avoidable deviations are discussed in the debriefings as learning points. For instance, when firefighters endanger their own safety by giving more care than necessary in the dangerous zone, rather than leaving the zone earlier with the casualty. Dubois et al (2022) reflect that the trainings mostly deal with expected risks and strongly focus on "following protocol", not so much on "exceptional unexpected risks" which would require managing risk by re-inventing protocol. Secondly, that interorganizational training was underdeveloped because only a few of the simulations involved police officers, whereas collective risk management across organizations can be adequately trained only when both are present. Finally, Dubois et al (2022) stress the importance of the quality of debriefing for learning impact, and argue for more self-reflection of trainees, rather than only feedback from the trainers. They argue that participants in the debriefing can go beyond experiences in the training when they also share experiences from real-world incidents.

Interorganizational Training of ESFR with VS

Eide et al (2026) give an example of a VS training in which 6 pre-hospital care paramedics, 4 police officers, 4 firefighters, and 2 volunteers (N=16) evaluated a VR training exercise where they had to perform triage of a total of 26 casualties as the first responders arriving at the scene. The training was conducted in single-user mode, followed by a 45-minute interview. Researchers observed the training and documented technical issues and deviations from the triage protocol. Although this study did not address safety procedures, and although the participants from different agencies did not interact during training, this study was included in our analysis as the discussion included a lot of comments on interagency training. Participants explained that they are rarely trained for complex major disaster scenarios (as this is very resource-intensive) and that there is also a lack of interagency training. Even in large drills, the police focus on security, the fire brigade on rescue activities, and the paramedics on triage, resulting in each agency following its own agenda, poor coordination, and speaking different languages. Hence, there is a strong need for collaborative multi-agency training to develop common procedures, which was expressed as follows (Eide, 2026, page 6): "*Several suggested that joint multi-user simulations, even when conducted remotely, could help standardize triage procedures and improve communication across police, fire, and emergency medical services. By engaging with the same virtual scenarios, different agencies could develop a shared understanding of roles, terminology, and expectations during mass-casualty incidents.*" Furthermore, participants highlighted the resource effectiveness of the VR application. They were able to triage 26 virtual patients in a relatively short time (far more than possible in a live field exercise), could perform this scenario at their own workplace, and could repeat training regularly, which would contribute to learning retention. On the other hand, in VR there is no physical effort (running, carrying) and less stress, which means that VR can complement, but never completely replace, live trainings. Participants suggested adding stress-inducing elements, such as increased noise, time limits, and background distractions, to better simulate the chaos and pressure of mass-casualty situations. Participants recommended using VR to build initial competence, followed by live scenarios with increasing levels of realism and challenge.

In van Ruijven et al. (2015) it is evaluated how 20 multidisciplinary on-scene command teams consisting of police, fire and medical services personnel, municipal officers and infrastructure operators coordinate their tasks in four scenarios involving: (i) hazardous material spill in a tunnel; (ii) evacuation of victims from a tunnel; (iii) hazardous material spill in an urban area; and (iv) carbon monoxide release in a port. Contra-indicative results are that teams that coordinate less perform better. This study only counts coordination frequency through network analysis, not coordination content or quality. The article does not provide any details on the kinds of safety risks and hazards included in the scenarios, or on how they become recognizable to the teams. Performance is measured by the number of tasks successfully completed, but no details are given about which tasks are involved in each scenario.

Training Risk Management of ESFR with VS

The study by Berthiaume et al. (2024) is an example of VR training for firefighters that focuses on recognizing, identifying, and communicating hazards during a dangerous goods accident while adhering to existing safety protocols. The tool was tested by 24 professional firefighters, who each completed two scenarios and provided feedback on cybersickness, perceived workload, and usability. The VR tool recorded the task completion duration and participants' navigation and use of tools events. Hazards needed to be identified by locating and reading the dangerous goods signs, while at the same time respecting the prescribed safety distance. With regard to technological constraints, participants requested additional realism (e.g., sounds, improved landscape details for judging distances, additional features such as a driver, visible wind direction and unexpected complications) or better interaction (e.g., making the binoculars easier to use). In general, the participants were enthusiastic about the potential, but requested more complex tasks and scenarios. Some participants reported on cybersickness, which may mean that this kind of training may not be suited for everybody.

Training Risk/Safety Management with VS

Carrozzino et al. (2023) present a VR training application that enables trainees to practice triage of buildings. After an earthquake, first responders need to mark each building with a triage marker indicating whether victims are confirmed or suspected, whether there are small or large voids, and the recommended intervention. Although this study does not explicitly focus on risk management for first responders, it is included because a part of the initial response involves assessing the building's condition to inform later-arriving teams about safety risks. Unlike other studies, this one provides a detailed account of the design and training process. The training begins with a short tutorial to familiarize the user with the environment and controls. The trainee wears a VR visor, while the trainer observes the same experience on a screen. The trainee selects equipment (placing relevant items in a bag) and explores the environment further. Trainees can inspect buildings, gather information from virtual humans, and must ultimately complete the building triage form for each structure. After the immersive session, a debriefing follows, supported by a text file summarizing the trainee's actions and timestamps. The application includes seven types of sites, from residential houses to supermarkets, schools, and healthcare clinics, each with different witness types providing information. Significant effort has been made to create realistic earthquake damage visuals. Scenarios were developed in close collaboration with urban search-and-rescue trainers. The tool was rated as easy to use, with realism highlighted as a key strength. Users appreciated the option to select whether the scenario occurred at night or during the day, which required using a torch at night. Suggested improvements included adding more scenario variety, such as atmospheric conditions (rain, fog, snow) and environmental agents (dust, debris, smoke), along with more environmental sounds (screams, voices, crying). They also requested a collaborative mode allowing two trainees to share the same virtual scenario and work together on assessments.

Gürer et al. (2023) assessed the usability of a virtual reality training program where users could explore an underground coal mine and identify hazards. Hazardous situations were created across various risk categories. When a hazard is detected, a multiple-choice question appears asking how to handle it. If the user chooses the correct answer, feedback is given, and performance is recorded (e.g. this hazard was solved correctly). Two separate focus groups, consisting of mining engineers and game developers, rated the usability positively.

Hewagarusinghe & Sridarran (2024) compared traditional and VR training methods to enhance occupational health and safety training and to prevent fatal and non-fatal accidents in Sri Lanka's construction industry. These accidents are largely due to inadequate safety knowledge among workers and weaknesses in the health and safety system. A total of 60 construction workers participated in this study: 30 in VR training and 30 in a conventional PowerPoint lecture. No specific details are provided about the content of the trainings, aside from their focus on "working on heights". Based on post-training questionnaires and interviews, it was concluded that VR training is significantly more effective than PP training in raising safety knowledge and awareness. Participants expressed a desire for a wider variety of scenarios. The limited availability and high cost of VR tools hinder the feasibility and scalability of this training in Sri Lanka.

Lavender et al. (2019) assessed a home healthcare VS training system where 49 home healthcare workers identified hazards that could pose injury risks. These hazards are broadly categorized as "electric, fire and burn", "environmental", or "slip, trip, and lift" hazards. The study examined the ability of these 49 users to detect hazards within each of these categories. Throughout all modules, participants identified the most obvious hazards (e.g., clutter on stairs, unattended candles, biohazard stains) but found it difficult to identify some of the less noticeable hazards. These included pet food bowls in the path of travel, a frayed electrical cord, an oxygen tube leaking into a mattress, water that was too hot, and elevated room temperatures. Some of the most difficult hazards to recognize were those created by the absence of certain items, such as the lack of grab bars in the bathroom and shower (which might lead patients to use towel rods for support), the absence of a handrail on the basement stairs, or a nonfunctional smoke detector. Future research challenges include finding ways to make lesser-known or hard-to-find hazards more noticeable and determining whether good performance in training actually influences behavior in real-world settings, i.e. hazard identification during home visits to care recipients.

Rey-Becerra et al. (2023) demonstrate how VR training is applied to safety training with a particular focus on working at heights in construction work. With VR technology, trainees can experience real-life situations cost-effectively without risking injury during training. Effective training is characterized by learning transfer, i.e. that acquired skills are applied in the work environment. An important prerequisite for that is immersion, fidelity, and control, which implies that the trainee experiences being present in an environment that resembles their actual work environment. To evaluate learning transfer, a video game was designed in the Unity game engine, with the mission to safely perform different tasks at heights in the shortest time possible. Participants had to explore the construction site and perform three tasks: paint a façade using scaffolding, transport two boxes across a platform, and install a camera on a roof corner. For each one, they had to choose the appropriate personal protective equipment and to report unsafe conditions and hazards. At the end, general feedback was displayed, showing the safety actions taken and those missed. The game was played with a video headset, which caused temporary dizziness in 5 of 39 participants at one site, where the training room was only 2 square meters, and participants

could not move enough. In other sites, such problems did not arise. There were 102 participants in the study, and the 53 participants in the VR-based training achieved significantly higher knowledge scores and reported higher attitudes (commitment and motivation) than the 49 participants in the lecture-based training.

Sharma & Moses (2025) introduce a multi-user VR platform designed for conducting experiments on active shooter responses, utilizing both computer-controlled agents and user-controlled agents. Such applications can prepare civilians and first responders to act appropriately during hostile attacks in public spaces. A user study involving 195 participants was carried out to evaluate the immersive VR training environment. The experiment assessed how the proposed tool affected participants' understanding of the safest actions to take in an active shooter situation (i.e., run, hide, or fight). Post-training surveys showed that most users felt a stronger sense of presence when using the immersive emergency response training environment and experienced significant increases in their knowledge, intrinsic motivation, and self-efficacy immediately after training. In an earlier publication, Sharma et al. (2023) outlined the experimental setup of a Security Personnel Training module where multiple first responders can train together to locate and stop threats, administer trauma care, and evacuate victims. While that application could potentially meet all four inclusion criteria, the paper only describes the technical design of the VR tool, offers no details on how actual training can be conducted or evaluated, and, as far as we know, has not yet been used or assessed by professional first responders. Therefore, that paper was excluded.

DISCUSSION

The literature review identified several research gaps.

A Lack of Research Considering Training IORM with VS

No identified studies fulfilled all four inclusion criteria. Although many research studies explore the opportunities and challenges of VS training for ESFR, whether as individual organizations or in multi-agency settings, most focus on the primary tasks to be executed, i.e., triage and rescue of casualties, firefighting, incident command, and so on. It could be that safety awareness or risk management is included as one of many issues to address in general situation assessment or incident command, but in that case, academic studies on VS training do not report on the specific concerns about safety awareness or risk management of ESFR.

In contrast, training safety awareness and risk management using VS is a more developed research area in industry and construction. Hence, ESFR researchers and practitioners could benefit from experience with how risks can be conveyed and managed in VS for industry and construction. Likewise, researchers and practitioners could take stock on studies of other types of simulation trainings where IORAM is in focus, such as the role-playing simulations described by Dubois et al (2022).

Types of safety and risk scenarios included in trainings

The literature review reveals a wide range of potential scenarios where risks and hazards can occur, including shooter situations (Dubois et al., 2022; Sharma & Moses, 2025), dangerous goods (van Ruijven et al., 2015; Berthiaume et al., 2024), working at heights (Hewagarusinghe & Sridarran, 2024; Rey-Becerra et al., 2023), home environments (Lavender et al., 2019), underground mines (Gürer et al., 2023), post-earthquake scenarios (Carrozzino et al., 2023), and mass casualty events (Eide et al., 2026). All these scenarios and risks could be relevant for ESFR, as they might arrive at the scene after accidents in such situations. On the other hand, many additional scenarios could be imagined that are not yet covered in the current literature review, such as fires involving electric cars, houses with solar panels on fire, landslides, extreme snowfall or avalanches, aggressive crowds, or panic among crowds.

Almost all studies provide very limited details about what kinds of risks are involved and what risk management or safety procedures are tested. Most studies briefly mention types of risks and mainly focus on data collection and analysis methods from a research perspective, regarding general evaluation of learning and tool usability. As a result, reading these papers offers little guidance for actually designing scenarios or modeling risks in VR environments. It might be that the format of academic papers does not allow for detailed descriptions of design. In that case, it would be worthwhile to develop other ways to share design information within the academic community. Researchers should pay more attention to the craft and challenges of designing risk scenarios in VR applications, instead of only assessing usability and learning in general without exploring how different design choices could affect usability, training effectiveness, or learning.

How Risks are Portrayed in VS

In the reviewed articles, hazards and risks are conveyed in many different ways. Primarily, VR is used to visually present risks, but sound is often considered a positive cue or requested by professionals as an important indicator for risk detection. Additionally, other people (facilitators or automated avatars) can provide information that reveal risks, or they can indicate risks through their behavior. Some studies, like Lavender et al (2019) and Carrozzino et al (2023), provide detailed descriptions of the types of risks included in the simulation and how they are conveyed, while many other studies are very limited in describing what risks are included and how they can be recognized. Stressful environments with many distractions (Carrozzino et al, 2023; Eide et al, 2026) and weather conditions (Carrozzino et al, 2023) are identified as factors that may hinder risk identification, which could be used to create a more complex level of risk recognition in a training program that progresses from simple exercises to more advanced ones (Dubois et al, 2022). How risks are presented remains a promising area for future research.

How Learning Retention and Learning Transfer is addressed

Rey-Becerra et al. (2023) is the only study which measures learning transfer, providing evidence that what was learned in training actually influenced behavior at work. Future studies should aim to measure the impact of learning transfer beyond immediate post-training evaluation. Multiple studies emphasize the importance of proper briefings and debriefings to support reflection and learning (Carrozzino et al, 2023; Dubois et al, 2022; Eide et al, 2026; Rey-Becerra et al, 2023; van Ruijven et al, 2015), aligning with established debriefing and facilitation practices in simulation training (Kriz, 2010; van Laere et al, 2021). While VS studies most often concentrate on assessing the usability of the tool and learning effectiveness, other design elements—such as learning goals, briefing structure, and debriefing strategies—can either enhance or hinder learning. Therefore, it would be valuable to expand the evaluation beyond the VR tool itself and to examine the effects of onboarding, briefing, debriefing, and facilitator performance.

CONCLUSION

There is a lack of research explicitly focusing on how to carry out training of interorganizational risk management for emergency service first responders with virtual simulation. This literature review shows how researchers and practitioners could integrate lessons learned from related fields, like collaborative ESFR risk management training in role playing simulations (Dubois et al, 2022), or risk management training of individuals in construction/industry (Rey-Becerra et al, 2023). Future research challenges to address are: (1) developing a typology and deeper understanding of types of scenarios, types of risks, and appropriate risk management procedures; (2) exploring different ways of conveying risks in a VS; and finally (3) for the evaluation of studies, establishing a stronger focus on long-term learning retention and learning transfer to the workplace, instead of only VR tool usability.

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