Experiencing Immersive VR Simulation for Firefighter Skills Training

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ABSTRACT

Virtual Reality (VR) technology for training has gained interest in many domains, including firefighter education. However, there is hesitation to accept immersive VR technology, especially for skills training. This study investigates the experiences of nineteen firefighter-students, eight instructors, and seven experienced firefighters, all first-time users of an immersive VR tool, used for simulated fire extinguishing. The technology provided simulated fire and smoke, heat elements in the suit, and pressure experience via a haptic feedback hose. User experiences were studied through questionnaires, and observations. The experience of immersive VR extinguishing was compared to previous Hot-Fire Live-Simulation (HF-LS), usually performed in a container in the training field. The results indicate that experienced firefighters valued the training more highly than students. Findings illustrate a difference between user groups regarding expectations of realism in simulated representations. For example, the visual realism of the smoke and the fire was more satisfactory for experienced firefighters than students and instructors.

Keywords

Virtual reality, training, firefighter, skills, user experiences.

INTRODUCTION

Immersive VR for training has gained interest for use in different domains, such as medicine, industry, and military, where skills training is necessary, costly, and sometimes impossible to conduct by other methods (Checa & Bustillo, 2020; Heldal, 2004). In the Fire and Rescue Service (FRS) domain, Virtual Simulation and VR have shown their potential as risk-free and cost-effective training formats, complementing live training. However, the technology barrier and the hesitancy regarding the new ways of training remain high (Heldal, Fomin, & Wijkmark, 2018). Critics question whether systems` inability to provide photorealistic scenarios with naturally interactive and dynamically correct fire and smoke representation may induce faulty learning outcomes (Engelbrecht et al., 2019a; Heldal & Hammar, 2017; Tate et al., 1997).

To become a competent firefighter, practice-based skills training is necessary. It is evident that it is impossible to learn how to connect hoses, use a nozzle, perceive risk-signs, and extinguish fires efficiently just by reading books, listening to instructors, or watching videos. One needs to be in a convincing and realistic situation, learn how to act, use equipment and methods, and repeat necessary activities several times, to be prepared for real fire incidents. The usual practice-based training is HF-LS, a training often performed in containers at the training field of fire academies or FRSs, using real fire, smoke, equipment, vehicles, and people.

Practical skills training, and particularly HF-LS training, should be practiced many times, a known issue in training emergency professionals. Setting up HF-LS training is resource-demanding and, though real-life simulation fidelity is essential, safety and environmental regulations partly limit the challenge students face during training, compared to possible real-life incidents. Additionally, buildings in a fire training field are constructed to withstand several fires per day and therefore have uncharacteristic looks. The cars used have also suffered numerous fires already. However, they are physical, tangible objects and in this way considered realistic.

The motivation for this study is to examine how new immersive technology, embracing most of the new capabilities virtual reality offers, can support training practical skills. If VR technology can complement HF-LS training, it may provide more training sessions for the students, as well as an alternative for further (and more frequent) training after the firefighter qualification has been acquired (Hartin, 2009), and provide more convincing and realistic situations.

The main research question is: To what extent are virtual immersive technologies accepted, for complementing firefighter skills training? We chose to decompose the main research question and seek to answer the following four sub-questions:

RQ1 Do the participants (firefighter students, instructors, and experienced firefighters) experience presence in VR in relation to HF-LS training?

RQ2 What are the participants' opinions on the current VR training?

RQ3 How do firefighters' earlier experiences influence their attitudes to immersive VR training?

RQ4 What are the main challenges of VR, and HF-LS, for better training from the user's perspective?

The answers to these questions are essential for user organizations interested in the potential of immersive VR for skills training. The pedagogical use of the tool, including competence to develop actual and possible training objectives in these technologies, is often a major concern for user organizations. The results may also inform researchers investigating current problems regarding the implementation and usage of VR training. Developers would gain from the results by better understanding specific needs and the situations that require further development via possible tools supporting firefighter skills training.

The data behind this paper come from a field study. The Swedish Civil Contingencies Agency (MSB[1]), responsible for the two-year firefighter study program in Sweden, has been utilizing Virtual Simulation in incident commander training, but not for skills training. In March 2019, MSB initiated a test of an immersive VR training system, with the objective of exploring the possibilities of this technology for firefighter skills training. This paper reports the results from the field study examining the experiences of firefighters with different backgrounds; nineteen firefighter students, eight instructors, and seven experienced firefighters from different FRSs in the area. The focus was on examining the realism of experiences, objects, and situations in the VR environments compared to familiar training methods (HF-LS). To our knowledge, this is the first study of its kind investigating user experiences of immersive VR employed for skills training in the field.

While this paper examines the use of a commercially available product, the intention is not to market the product or compare it with other products. It has been chosen for its currently unique ability, to our present knowledge, to stimulate different senses for immersion (visual, audio, haptic, and heat) and to fulfill our intention to learn more about how immersion influences skills training in the domain of the fire service.

BACKGROUND

Firefighter Training and Learning

Firefighter education and training programs differ in different countries. In Sweden, the FRSs usually require a MSB Fire College diploma when hiring professional firefighters. This diploma is obtained upon successful completion of the two-year study program. The training program covers several learning objectives, and students should reach the third level in Bloom's Taxonomy (Bloom et al., 1984), thus acquiring the ability to apply materials and methods to prevent or mitigate further damage to people, property, and the environment. In this context, this translates to being able to extinguish fires in various incidents by using the correct techniques and equipment.

Firefighter students need to experience the real heat, flames, smoke, and the whole situation, while handling the physical equipment, performing the necessary tasks, following procedures, and making quick risk assessments. They need to be prepared for unexpected events in potentially dangerous environments and to control the air supply, radio communication, surroundings, and extinguishing agents. They must also use appropriate methods and techniques to perform a systematic search in buildings, even in near-zero visibility, and assess and manage risks, while performing smoke-diving. It is not only a matter of extinguishing a fire; all actions must be defined, coordinated, and performed systematically. For a novice firefighter student, the learning starts with performing decomposed tasks, following instructions and rules. Since students do not have previous experiences to relate the initial training to, continuous feedback from their instructors is necessary. Extinguishing is one of the components

[1] See www.msb.se/en/ (Accessed 02.02.2021)

of incident handling, and repeated practical training is performed in HF-LS facilities, until the task is understood and embodied.

As the firefighter student learns more, their new experiences can be built on previous ones. As described by Kolb`s experiential learning cycle (Kolb, 1984), the learning process involves: *experiencing*, *reflecting*, *conceptualizing,* and *acting*. From the firefighter students' perspective, the *experience* would include using the protective gear and extinguishing a fire using the equipment. *Reflecting* upon the experience (often upon repeated experiences) leads to *conceptualization*, which triggers new (and better) ways of *acting*. Thus, "knowledge is created through the transformation of experience" (Kolb 1984).

For skills acquisition, (Dreyfus & Dreyfus, 1980) propose five stages, i.e., from novice, through beginners, competent, proficient, to expert. Professionals increase their competence, undergoing new loops of Kolb`s learning cycle, refining both practices and understanding. Proficient and expert firefighters master all six levels of Bloom's Taxonomy and are often innovative regarding using techniques and inventing new equipment. Though learning through real-incident-handling is an option for professional firefighters, successful preventive campaigns targeting the inhabitants have reduced the number of "ordinary" fires in many countries. At the same time, the rapid development of new types of buildings, materials, chemicals, vehicles, or batteries, etc. implies that new situations need to be trained for. Therefore, to become and remain skillful, both firefighter students and qualified firefighters need varied and sufficient training.

HF-LS training is resource-demanding, expensive, causes negative environmental impact (Conges et al., 2019; Narciso et al., 2020) and exposes firefighter students to carcinogenic smoke (Wingfors et al., 2018). This results in the setting of strict requirements for planning the training, as well as limiting the amount and quality of training experiences (Narciso et al., 2020): hence, the motivation for exploring alternative training formats.

Virtual Reality (VR) for Firefighter Training

A SWOT Analysis of using VR for firefighter training (Engelbrecht et al., 2019a) points out the main benefits of being cost- and environmentally friendly, combined with safe training in varied high-fidelity environments. While the use of VR for training in decision-making is more accepted, and training has many common aspects for all professions within emergency management, the skill training of firefighters involves a variety of specialized tools. Therefore, valuable VR skills training involves complex hardware and software, as it needs to be specialized to be useful. User studies, involving professionals, and the use of hardware as close to natural inputs as possible, are necessary, as acceptance or dismissal of the technology is a critical factor. Realistic input tools (natural user interfaces) and sensational stimuli beyond vision and audition may be the keys to acceptance.

While VR can create high levels (Lebram et al., 2009) of spatial presence (Narciso et al., 2020), it still lacks the necessary realism to avoid disturbing user experiences while performing activities (Conges et al., 2019). Presence refers to the user's ability to focus on the virtual representations and actions rather than on the surrounding physical environment (Slater et al., 1994). Presence can be disturbed by strange representations or when computer devices' clumsiness comes between users and their interaction (Slater et al., 2003). The lack of stimuli fidelity in adequately mapping the physical to the virtual (Narciso et al., 2020) or the lack of haptic feelings, e.g., weight and hose pressure (Engelbrecht et al., 2019; Monteiro et al., 2020), can disturb the presence and experiences during skill training.

Only few VR products for firefighter skills training that stimulate several senses (beyond vision and audition), thereby creating more realistic experiences, are available (Lebram et al., 2009; Piazzolla et al., 2017). VR technologies are constructed in academic environments and developed by companies, e.g., the Ludus[2], ADMS[3], XVR[4] or the technology examined here, the Flaim Trainer[5]. Flaim Trainer allows realistic visual and audio through a head-mounted display (HMD), realistic breathing through a self-contained breathing apparatus (SBCA), a real nozzle as an input device, and a hose with force feedback, which lets the firefighter feel the weight of the water in the hose and the pressure of the water when opening the nozzle to extinguish the virtual fires.

Williams-Bell et al. (Williams-Bell et al., 2015) discuss the possibilities of higher fidelity/realism in the virtual environment, as well as the interaction techniques and the possibilities of using sensors and game-based assessment for improving virtual training tools. They also discuss the impact of thermal stress on cognitive functions, as one of the most important factors for firefighter health and safety, citing Barr and his colleagues (Barr et al., 2010), who suggest firefighter training in virtual simulation in climatic chambers.

[2] https://ludusglobal.com/ (Accessed 20.02.2021)
[3] https://www.etcsimulation.com/ (Accessed 20.02.2021)
[4] https://www.infinityxvr.com/services/ (Accessed 20.02.2021)
[5] https://flaimsystems.com/products/trainer (Accessed 02.02.2021)

Albich and his colleagues (Abich et al., 2021) discuss the value of the increased interactivity in VR (compared to PowerPoints and videos), which may enhance training effectiveness and motivation to learn. They also discuss enhanced facilitation of the cognitive processes to learn provided by the visual, auditory, and contextual cues possible in immersive VR training.

Narciso and his colleagues (Narciso et al., 2020) presented an experimental study on VR for firefighter training, with the primary goal of evaluating the effectiveness of virtual environment training (using Oculus Rift DK2 HDM and a gamepad), compared to HF-LS training in a shipping container. The virtual environment included a replica of the LS container training session commonly used in a firefighter training program in Portugal, with "*its main goal to make trainees adapt to high temperatures, smoke and fire conditions inside a closed compartment*". The study was limited to seven (and in some conditions, four) participants, and data were collected by questionnaires and heart rate measurements during LS and VR. They concluded that a high degree of spatial presence was shown in the virtual environment, but since it did not provoke a similar psychological stress response (measured by heart rate) as the LS, it was not considered useful as a training environment. In this study, the participant was sitting on a chair, moving in the virtual environment using a gamepad. The authors suggest that adding the possibility for the firefighter to move more naturally could result in a response closer to HF-LS training.

HF-LS performed in a fire and rescue training field provides correct physical fidelity, since it uses real buildings and vehicles, fire, and smoke. But the buildings seldom look like any other buildings in a city, and the burning cars are often already burnt-out cars or steel replicas of cars, with a wood-fire inside, although they may represent modern electric cars. These limitations impose significant differences between LS-training and the real incidents. Nevertheless, HF-LS is appreciated, and students wish for more such training in their education. Virtual environments can provide visually high fidelity, i.e., the buildings can look more like real buildings, the neighborhood can look like a real neighborhood, and a car can look like a Tesla of the latest model if needed. This may affect the user's experience of realism, which may also influence their presence, i.e., feeling of "being in the situation". Current limitations are to be overcome, technologies are developing, and the need to train more and for situations that cannot be trained in HF-LS is increasing.

METHODOLOGY

The research project was conducted as a field study at the MSB College in Sweden in March 2019. The participants were: a class of firefighter students (19 students) at the end of their two-year education, instructors (8), and experienced firefighters (7 professionals). From the class invited, all students accepted the invitation. The firefighter instructors were chosen by the MSB College management, based on their experience as instructors. The experienced firefighters were appointed by the management from four nearby FRSs after an open invitation to send (maximum) two experienced firefighters per FRS. Table 1 presents the number of participants in each group, their average age (avg. age), the span of years as a firefighter/firefighter instructor (in years), their gender (M-males/F-females), the proportion of participants that believe that VR can be used for firefighter skills training (percent), and the number of participants with any other previous experience of VR technologies.

Table 1. Firefighters and characteristics

	N	avg. age	avg. exp.	Span	M/F	VR positive (%)	VR exp.
Firefighter students (FFstud)	19	26	0	N/A	14/5	100	1
Instructors (Inst)	8	45	6	1-20	6/2	100	1
Experienced firefighters (ExpFF)	7	40	18	1.5-37	7/0	100	0

Technology Used

The immersive VR tool used in this study includes high-fidelity virtual environments for common fire scenarios. The participant uses an HMD, an SCBA, including a half-face mask, responsive heating elements over the chest and back and a real hose and nozzle, thus experiencing weight and pressure feedback from the apparatus (see Figure 1). In this study, the participants also wore their protective clothing, gloves, and hood, to achieve as close to real feeling as possible. The system includes a heat jacket to simulate heat radiation, which alternates heat input from front to back when the user turns their back to the fire.

Figure 1. A student ready for the VR training scenario.

The scenarios developed use algorithmic models that deliver realistic fire behavior for the virtual environment, including fire progress and response to fire suppressants, as in the corresponding real-life scenario. Figure 2 shows the observer`s perspective and the user's perspective.

Figure 2. A car fire scenario. The observer's perspective (left) and the student's perspective (right).

The fire scenarios included in this study were: 1) a fire in a family house kitchen stove, spreading over the kitchen cabinets, 2) a car fire outdoors, and 3) an airplane engine fire. For scenarios 1 and 2, the participants used water for extinguishing, and for scenario 3 they used foam as a suppressant. The three scenarios were conducted for a total of 15 minutes.

The Evaluation

The data collection in this study is influenced by the battery of questionnaires developed by Schroeder and his colleagues (Schroeder et al., 2001), based on Slater et al.'s presence questionnaire (Slater et al., 2000). The questions were adjusted to the current setting and the user groups, with added questions regarding the current fire scenarios and to relate the experiences in the simulated VR technologies to the previous HF-LS. These added questions concerned, e.g., the required interaction, tasks, and realism of scenarios. The benefit of being inspired by the Slater/Schroeder questionnaires lies in differentiating presence from immersiveness. Presence relates to the users' experience of being and acting in the virtual environment, while immersiveness relates to the technology. For example, the technology used in this study, including the HMD and additional equipment, is an immersive technology, while a laptop is not.

Two questionnaires were used; the first one covered the participants' background information (six questions) and their understanding and expectation of VR settings (in open-ended questions), while the second one focused on the experienced presence in the VR setting (23 questions). Most of the questions (13 of 23) are based on answers in the Likert scale, the rest require answers in "yes" or "no" form or are open-ended. We used a five-point Likert scale, pointing from the worst alternative to the best, e.g., regarding experiencing presence, possibilities to mark an option were: 1=very low, 2=low, 3=medium, 4=high, 5=very high degree of experience. Several questions have sub-questions, and all questions invited the participants to comment on their answers.

Since none of the participants had any prior knowledge of the VR tool used here, all were briefly informed about the tool and went through the following three steps: 1) answered the background questions and dressed in the gear, 2) entered the next room and performed the three VR fire scenarios (approximately 15 minutes' total time), and 3) entered the next room to fill in the second questionnaire.

Firefighting, and especially breathing apparatus entry (BA), is not a one-person job. BA entry is always done in pairs and should be trained in pairs. Nevertheless, every firefighter needs to train his own skills in handling the nozzle, assessing risks, and searching a smoke-filled building. In this study, the focus is on the individual experience of VR for this training. If VR is accepted for this, further studies should investigate how it can include team training.

RESULTS

Results Based on Open-Ended Questions Regarding Experiencing VR Technologies

In the background questionnaire, all participants (FFstud, Inst, ExpFF) state that they believe that VR can be used for skills training within firefighter education, to some extent. All instructors and experienced firefighters believe that VR can also be used for the recurrent training of experienced firefighters. From these questionnaires, it was clear that all participants, except one instructor, believe that VR can complement HF-LS but not replace it.

The Role of VR-based Training

One instructor (who had previous VR experience) argued that VR could replace most hot fire training for experienced firefighters but not for novices. The argument was that "*professional firefighters gain experiences from real fire incidents and could benefit from training in various environments, complex and dangerous environments and situations, in VR*".

Six of the instructors, all (7) experienced firefighters, and 12 students answered "YES", to some extent, to the question, "*Do you believe VR can be used for other kinds of firefighter skills training?"* The answers point to using VR for training in dangerous situations that cannot be trained for in HF-LS, like hazmat incidents and complicated road traffic incidents. Four students explain why they do not believe that VR could be used for other kinds of firefighter skills training. Their motivations are *"*[they need] *more practical training* [as in HF-LS]*"; "I think you need to train for real* [HF-LS is the real situation]*, to learn";* the VR technology seems to be *"not* [enough] *for practical training"*, and "*No, no; to practice in the best way, it is necessary to physically hold the equipment".* Five students, who answered this question "to some extent", stated that they would not like VR in the training program, giving reasons like *"I really believe in the practical* [HF-LS] *training"* and expressing, instead, the need for *"more practical training* [HF-LS]*"*.

The presence questionnaire's main questions and answers (delivered in Likert scale) are listed in Table 2. The experienced firefighters give questions regarding presence higher scores, than the instructors and firefighter students do. The results for the visual realism questions also show the same picture, i.e., the professional firefighters rate the visual realism experience more highly than the other groups.

Regarding experiencing presence, most of the participants reacted positively to the feeling of the force feedback in the hose and nozzle, giving spontaneous comments like *"…cool that they can build this in, so you feel the recoil when you open the nozzle*". The experience of the use of the physical nozzle and the corresponding virtual representation of it, e.g., the water and seeing the interaction of the virtual water and fire/smoke, was appreciated. Three experienced firefighters commented, "*VR was more real* [than HF-LS]. *To fight a fire in VR was harder* [than HF-LS]"; "*I felt like I was using a real nozzle*"; "*it was a real feeling*". Firefighter students commented, "*I had a good response on how I used the nozzle*"; "*I could use the same* [firefighting] *technique I have used in the real training* [meaning HF-LS]"; "*the water looked like and behaved as it does for real*"; "*there was no Splash effect when the water hits a surface*"; and "*the length of the water jet was too short*".

On the question regarding how positive the participants are towards increased use of VR in education, all groups are predominantly positive, with the experienced firefighters being the most positive group. The two students who did not give an answer above Likert 3 gave the rating 1, commenting *"Computers cannot replace practical training [HF-LS]"* and *"I insist that actual training [HF-LS] is better"*.

To one open question in the questionnaire for the instructors and the experienced firefighters, "*Do you think VR can complement firefighter training in containers* [HF-LS]*?*", all instructors answered positively, for example, "*the student can understand what happens if you don't do it right*" and "*firefighting in a container* [HF-LS] *has* *very little similarity to a real indoor fire*". All but two experienced firefighters answered positively, while two left the question blank. This question was present in both "before-test" and "after-test" questionnaires, and no clear change in opinion/attitude between before and after the test was detected.

Table 2 Questions regarding the experienced presence, the visual realism of representations, and some overall questions and answers

	Firefighter students (n=19)			Instructors (n=8)			Experienced (n=7)		
Summary	**Likert >=3**	**Avg.**	**SD**	**Likert >=3**	**Avg.**	**SD**	**Likert >=3**	**Avg.**	**SD**
Presence									
Think of some previous hot fire training session when you experienced a high presence. Compared to that, to what extent did you experience presence in the VR simulation today?	58%	2.6	0.96	38 %	2.6	1.3	71 %	3.4	1.13
Think of the experience. To what extent did you experience a feeling of this incident happening for real?	32%	2.3	0.95	50 %	2.8	1.28	86 %	4.0	1.15
Compared to the feeling of extinguishing a fire in hot fire training, how similar would you say the feeling of extinguishing in VR was?	63%	2.9	0.81	50 %	2.5	0.53	86 %	3.3	0.76
Visual realism									
To what extent did you find the virtual representation of the FIRE realistic enough?	37%	2.4	0,96	63 %	2.9	0.83	100 %	3.9	0.9
To what extent did you find the virtual representation of the SMOKE realistic enough?	21 %	2.3	1.05	25 %	2.3	0.46	71 %	3.3	1.11
To what extent did you find the virtual representation of the WATER realistic enough?	79%	3.3	0.95	63 %	2.9	0,83	71 %	3.6	1.27
To what extent did you find the task realistic enough?	68%	2.9	1.03	38 %	2.6	1.06	86 %	4.0	1.00
Overall									
In general, how positive are you about increased use of VR / virtual simulation and serious games in your education?	89%	3.6	1.26	100 %	4.1	0.99	100 %	4.9	0.38

The correlation between the results and the demographics, age and gender, are not considered, since the firefighter students in general are younger than the experienced firefighters and the instructors, and the number of female participants was too low (Table 1).

DISCUSSION

This field study shows the attitudes in three user groups – firefighter students, instructors, and experienced professional firefighters – to the use of a specialized and domain-adapted VR tool for firefighter skills training.

The tool stimulates more sensational processes, in addition to vision and audition, since elements of tactility (heat, pressure, and weight) are represented. The natural input method is a real nozzle that is used and reacts normally, and heating elements are included in the protective gear. The haptics, the feeling of the weight of water in the hose and the pressure of water when opening the nozzle, is clearly an aspect that increases presence. The lack of haptics and realistic input has been discussed in previous studies (Conges et al., 2019; Engelbrecht et al., 2019b). In this study, we observed the reactions and the value of these aspects for increasing the experienced presence. As described by Slater, "presence" is the perceptual illusion which makes the user react automatically to the environment, as if it were for real (Slater et al., 1994). The keyword is *reaction*, i.e., that the firefighters automatically react to certain events in the VR fire scenario, go through the experiential learning cycle described by Kolb (Kolb, 1984) and applied for firefighter by Reis and Neves (Reis & Neves, 2019) and thereby are trained.

However, the evaluation differs between novices and experts (Dreyfus & Dreyfus, 1980) and also between experts with different backgrounds, i.e., from education (instructors) or from practice (expert firefighters). Therefore, while recognizing the importance of quantitative measurements, their results should be carefully interpreted, as they are based on limited data, from not significantly distributed participants (Narciso et al., 2020). If the indicated results persist when larger groups of participants have been studied during future work, this may indicate that the VR tools of this character are better suited for recurrent training of professional firefighters than for beginners, as one of the instructors suggested. Very few real-world fires occur in steel ship containers, involving a limited amount of wood – as the current HF-LS training is today. Besides that, experienced firefighters have been through the same HF-LS training so many times that it may no longer appeals to them. The tested VR tool shows the potential to prepare firefighters for realistic scenarios, in a space that may represent any building structure, and include heat simulation.

To develop an effective training program which can utilize the added value of VR, one would need more user experience tests and learning outcomes/transfer of skills studies. Another issue is better anchoring the use of VR in the education (Heldal et al., 2018) and build trust to overcome the technology acceptance barriers during introduction for students and instructors (Engelbrecht et al., 2019; Williams-Bell et al., 2015).

The correlation between age and the appreciation of visual realism (smoke and fire) was not analyzed in this study. Age may be of relevance, since younger persons are more used to commercial computer games graphics, which may enhance their expectation regarding visual (photo) realism.

The participants of this study performed three scenarios for 15 minutes. This time can be considered short, although all participants were able to finish their task to extinguish the fire. Future studies investigating user experiences and attitudes, should include larger participant groups in each category and possibly more time, to reach higher representativeness. Although this study shows some insight into the student perspective, future studies should focus on experienced firefighters, to more closely investigate what gaps VR can fill between the required skills of firefighter prepared for real incidents and the training possible in HF-LS. As Albich and his colleagues conclude (Abich et al., 2021), the task type and instructional strategies should also be considered, to maximize the benefits of VR for training. Training outcome studies are needed to investigate whether VR training fills a competence gap in today's education by complementing HF-LS training – but also how.

CONCLUSION AND FUTURE WORK

The study illustrated the opinions of firefighter students, instructors, and experienced firefighters on the application of immersive VR for extinguishing skills training. Overall, the responses regarding immersive VR complementing skills training were positive.

Regarding user experiences and presence (RQ1), results from all participants show medium to very-high presence. The experienced firefighters estimated their presence in the VR training as higher than did the firefighter students and instructors. They also found the visual realism of smoke, fire, water, and the scenarios more convincing than the firefighter students and instructors did. All appreciated the force feedback experience of VR, while they barely sensed the heat generated by the heat jacket. Their views on the use of VR technologies in everyday HF-LS training were positive (RQ2) but differed in the different user groups. Experienced firefighters found VR usage more interesting than students and instructors did. The influence of previous dominant experience can explain the difference in this interpretation. The instructors and students explain their opinions by arguing for the importance of HF-LS (RQ3). From their point of view, HF-LS is considered the *real training*. When relating this result to the opinions on realism, this study concludes that the main challenge of VR for firefighter skills training lies in anchoring it in the education (RQ4). This study shows the potential of VR to complement skills training in firefighter education. Since LS cannot be developed at the same pace as many changes in society, we need to use opportunities that computer simulations offer. Still, how exactly this should take place requires further studies. One of the main issues regarding future work is examining the natural, physical realism necessary for skills training. We plan to investigate immersive versus other training situations, not only for firefighters from emergency management but also for different professional groups, e.g., for firefighters at airports or in the oil industry, and examine the possibilities for collaborative exercises. It is essential to set up LS and VR-based training scenarios and determine how these complement each other regarding training for the "real". Today, none of them are "realistic" enough to simulate real life incidents accurately, and the best effect would be if combined, since their benefits and limitations are not the same. Consequently, a first following study may determine the cost and benefit of complementary training.

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