http://jates.org

Journal of Applied Technical and Educational Sciences jATES

ISSN 2560-5429

jATES Journal of Applied Technical and Educational Sciences

Introducing Virtual Reality for Firefighter Skills Training

Opinions from Sweden and Brazil

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Abstract: The emergence of immersive virtual reality (IVR) technologies has raised interest in the use of fire and rescue services (FRS) as a supplement to the established practice-based hot fire-live simulation (HF-LS) training. This is due to features such as time efficiency, portable technologies, and training in scenarios not possible in HF-LS. However, whether IVR provides realistic firefighter training situations has been called into question. Previous studies have revealed differences regarding perceived presence in, and attitudes toward IVR training between novice firefighters (who can only relate to HF-LS training) and experienced firefighters (who can relate to both HF-LS and real fires). In the present study, two groups of experienced full-time employed firefighters, 53 from Brazil and 18 from Sweden tested the same IVR technology. The hypothesis was that differences in national education and training programs and real fire experiences might influence experiences in IVR technology. This study examines the differences and similarities in experienced presence, opinions on whether the graphical representations and tasks performed convey realism, and attitudes toward the IVR-supported training format. Data were collected via systematic post-training presence questionnaires and observations. The results revealed a highly experienced presence and perceived realism of the representations by the participants from both countries. However, attitudes toward using IVR technologies differed. The motivation to utilize currently available IVR training tools was higher in Brazil than in Sweden. This may be partly explained by less frequent HF-LS training opportunities in Brazil. Nevertheless, further research is needed to investigate the training transfer of IVR technologies and how these can better support skills training.

Keywords: *virtual reality; firefighter; training; comparison; immersion*

1. Introduction

Practice-based training is crucial for fire and rescue service (FRS) emergency personnel, as it prepares them to respond efficiently and effectively to a wide variety of civil contingencies. Live mimulation (LS) training on a training ground is a powerful training format that requires the trainee to act in realistic situations in which they can transform knowledge into skills (Blyth, Bloom, & Krathwohl, 1966), collaborate with others and use different equipment. Using real fire and smoke, hot fire-live simulation (HF-LS) is considered the most realistic format for training in both incident management and the practical skills required for real fire situations.

During the past decade, virtual simulation (VS) has become mature enough to facilitate incident management training that supports decision-making competences (Lamb, Davies, Bowley & Williams, 2014; Reis & Neves, 2019; Wijkmark, Metallinou & Heldal, 2021). Several studies have highlighted the benefits of training supported by VS technologies compared with other training formats such as lower cost, the possibility of using a broader range of scenarios, reduced risks, support for higher cognitive processes, and easily accessible training situations (Engelbrecht, Lindeman & Hoermann, 2019; Hsu et al., 2013; Wijkmark & Heldal, 2020; Wijkmark, Heldal & Metallinou, 2022). In such realistic and dynamic scenarios, VS can simulate how the fire can develop and spread, supporting trainees in experiencing the possible consequences of actions and non-actions taken (Riedl et al., 2008, Heldal, 2016). By providing concrete experiences, reflections, and the possibility to train again in the same or similar scenario, VS applications can contribute to experiential learning (Kolb, 1984). Additionally, VS scenarios can be developed to meet specific learning objectives, and their use can be adjusted to the training requirements (Wijkmark & Heldal, 2020).

Various immersive virtual reality (IVR) tools for firefighter skills training have been developed in recent years, including caves (Backlund, Engström, Hammar, Johannesson & Lebram, 2007), head-mounted displays, or other physical elements such as heat vests, hoses, and nozzles with haptic feedback (Levin, 2019). Despite increasing interest in novel IVR technologies from the FRS organizations responsible for training firefighters, end-users are reluctant to regard IVR training as being equally beneficial as HF-LS. Such hesitation has been shown to be higher among students and novices than among experienced firefighters (Wijkmark, Heldal & Metallinou, 2021) and is often substantiated by questions as to whether the training experience is realistic enough in comparison with real fires or to the accepted HF-LS format. Therefore, further investigation is needed to determine how previous real fire and training experiences influence the user experience in IVR, and how IVR and HF-LS supplement and contribute to learning objectives. This would increase our understanding of how IVR technology and training formats may be adjusted for different user groups, and thus benefit future training.

In the current field study, 53 experienced full-time employed firefighters from Firefighter Corps training in Paraná, Brazil (in 2022) performed training in IVR. Data were collected and compared with data collected in a previous field study (Wijkmark et al., 2022) which involved 18 experienced firefighters from an association of three FRSs in west Sweden: Fire and Rescue Service Östra Skaraborg, Samhällsskydd Mellersta Skaraborg, and Räddningstjänsten Västra Skaraborg) (Sweden) (in 2020), who performed training using the same IVR tool. The aim was to investigate the user experiences of two diverse groups of firefighters and their requirements for scenarios and representations, thereby providing increased knowledge of context-specific needs. The main research question investigated was: *What are the similarities and differences between Brazilian and Swedish firefighters in experiencing presence, and their attitudes toward utilizing IVR in firefighter skills training?*

The focus of this study was on firefighters' sense of presence in the virtual environment, the perceived realism of the applied representations in the different scenarios they performed, and the attitudes of the management responsible for utilizing IVR training as a replacement or a supplement to HF-LS training.

The results may contribute to a better understanding of which general and essential contextual requirements must be considered when designing and adjusting IVR training for different user groups, contexts, or countries.

First, there are several limitations of this study that need to be addressed. Because the two countries have different climates, infrastructures, and building requirements this will influence firefighters' real fire experiences and education planning and curriculum, issues that are investigated in depth in this paper. The illustrative calculations in this paper are based on the available statistics on fires in buildings (defined by the respective statistics sources); therefore, the investigation excludes other types of fires, such as fires in vehicles, to allow discussions in relation to the HF-LS concepts to be included. A major difference that may impact this study is firefighters' earlier experiences in HF-LS training due to their access to training facilities and plans for their training sessions. Both countries use training facilities according to a common base, the internationally and widely used concept of Compartment Fire Behavior Training (CFBT) (Mackay, Barber & Yeoh, 2010). However, they use this to different extents. CFBT includes three main steps: demonstration container (DC) for demonstration purposes, attack container (AC) for basic training, and multi-container (MC) for more complex team training in fire scenarios. In Brazil, only the first two steps are utilized, whilst in Sweden all three are followed. Using training scenarios supported by IVR technologies cannot be considered a direct digital corollary of CBT training. Because there is more than one year between the two field studies, there has been one update in the software that may affect their experience in IVR. This has not been investigated in this study.

2. Background

The hypothesis in this study was that participating firefighters from two diverse countries, Brazil and Sweden, may experience IVR training differently due to variations in previous experiences of real fires and training. The arctic circle runs through Sweden, while the equator runs through Brazil, implying large differences in geography and climate. The temperature in Sweden may vary between -30ºC in the winter in the north to +30ºC in the summer. This makes building requirements regarding insulation and construction for a large amount of snow different from the situation in the humid tropical and subtropical climate of the larger parts of Brazil. Family houses in Sweden are often built of wood, with wooden structures for roofs, whereas windows and doors are built to insulate against the cold. The interior of the typical Swedish home has wooden floors or plastic carpets, wallpaper, or paint on the walls, producing combustible gases when heated. In Brazil, the typical home has brick walls and tile floors, while the ceiling is often made of wood or PVC. These differences influence fire development and behavior, resulting in notably different fire scenarios when comparing an ordinary apartment or house fire in the two countries.

In Brazil, the FRS is organized within the military and all firefighters are employed full-time. In Sweden, every municipality is responsible for their FRS, and only one-third of the total number of firefighters are employed full-time, with the remaining two-thirds employed part-time. The difference in organizational preconditions and the continuous training and development provided for firefighters may induce differences in IVR training experience and corresponding attitudes. To ensure the results are comparable, only full-time personnel from Sweden were included in the study. In the following sections, the FRS organization, education, and continuous training are presented in more detail, together with the relevant theoretical background.

2.1. Educating firefighters in Sweden: The municipal FRS

All 290 municipalities in Sweden are responsible for having an FRS ("Government Office of Sweden", 2022) ("Sveriges Riksdag", 2022). Approximately 33% of Swedish firefighters are employed full-time by an FRS and 67% are employed part-time ("MSB:s statistik och analysverktyg IDA") meaning that they have an ordinary job that allows them to be scheduled on call. The governmental agency Myndigheten för Samhällsskydd och Beredskap (MSB) provides two study programs: the two-year study program Skydd mot Olyckor (SMO) which prepares students (after graduation) to apply for a full-time firefighter position at a FRS, and a six-week basic course, *Grib*, for part-time firefighters who are already employed. For SMO, students are admitted based on their high-school grades, provided they perform satisfactorily in the mandatory physical fitness tests. The SMO and *Grib* diplomas are not mandatory and the FRS may choose to hire persons without these and provide its own training program. Most firefighters in Sweden, full-time and part-time, have attended the education at MSB.

In general, firefighters in Sweden work in teams of five, comprising one team leader and four firefighters, two of whom are prepared for breathing apparatus (BA) entry or smoke diving inside a burning building, one is the BA leader responsible for safety and communication with the BA team and one operates the engine and pump. The Swedish Work Environment Authority's Statute Book regarding BA entry requires a minimum of four firefighters to perform BA entry ("The Swedish Work Environment Authority's Statute Book", 2022). The same statute book defines the education needed for BA entry and the mandatory yearly training.

In Sweden, there are approximately 16000 FRS operational personnel with at least 50% operational duties. According to the national statistics tool IDA ("MSB:s statistik och analysverktyg IDA") provided by MSB, around 6500 fires in buildings per year result in an FRS response (2021) which corresponds to an average of 0.62 fires per 1000 inhabitants.

2.2. Educating firefighters in Brazil: The Military Firefighters Corps

The Brazilian Constitution states that the National Military Firefighters Corps is a military reserve and auxiliary force of the Brazilian Army. Most districts only employ firefighters full-time, the number of which in 2022 totaled 55072. In addition to this, 12633 firefighters are in the reserve or are retired firefighters who have attributions in public security and civil defense (Pública, 2022). There are also volunteer fire departments in the southern states (Santa Catarina and Rio Grande do Sul), with a total of 6295 firefighters in addition to civilian firefighters who work in the area of health and safety. Regarding fire incidents, there are no national statistics available.

The fire departments provide the education and training for their personnel, for which a high-school diploma and a pass in a national exam is a necessary qualification for admission. Within the military fire department, there are two education programs: one for soldiers (firefighters) which is a 10-month program, and one for officers which is a three-year program that includes a university degree.

In Brazil, no statute defines the number of yearly HF-LS training sessions required for firefighters to perform BA entry. In general, firefighters work in teams of four, consisting of one team leader and three firefighters. The focus of this article is on the district of Paraná which employed 3020 firefighters in 2020. There were 4603 fires in 2019, a ratio of 0.4 fires per 1000 inhabitants.

2.3. Practice-based training: HF-LS

Practice-based training in situations which are as realistic as possible is important in firefighter training. To create these situations, cold smoke produced by smoke generators can be used, while for some training situations, real fire and smoke are used to provide the realistic heat and visuals, here referred to as hot fire-live simulation (HF-LS). HF-LS training is often based on the concept of compartment fire behavior training (CFBT) which originated from Sweden in 1984 and has since been internationally adopted (Mackay et al., 2010). The training is conducted in facilities consisting of steel ship containers, sometimes referred to as: demonstration container (DC), attack container (AC), and multi container (MC) training, several of which are connected to each other to represent a building. In the DC, a fire is set to allow trainees to observe fire development with no interactions (see Fig. 1). Specific types of DCs are used to trigger dangerous phenomena and illustrate signs and symptoms, as well as to explain the differences between backdraft, flashover, and smoke gas explosions (Bengtsson, 1999). (Backdraft is the burning of heated gaseous products of combustion when oxygen is introduced into an environment that has a depleted supply of oxygen due to fire such as when the BA team opens a door. This burning often occurs with explosive force). ACs are used to practice skills in handling the nozzle, cool gases and advance in thick smoke to find the fire. In MC facilities with a more complex layout, the fire compartment must be localized in the thick smoke, providing more complex BA entry training.

HF-LS training is traditionally appreciated, especially by instructors, as the only practice-based method that can resemble actual incidents. However, HF-LS is associated with limitations regarding the resemblance to real buildings, and the amount and type of fuel permitted for training purposes (Narciso, Melo, Raposo, Cunha & Bessa, 2019; Wijkmark et al., 2022). Safety measures and environmental regulations limit the amount and type of fuel that can be used. Depending on the training facility, wood, soft board, hardboard, particle boards, or LPG gas, are used to simulate fires. The pyrolysis and burning of standard modern building material and furniture, including plastic materials, is excluded. Additionally, the safe setting of these fires ensures that they cannot spread, which limits the illustration of fire and smoke behavior. After practicing individual skills, more complex HF-LS scenario training is conducted in MC, simulating the whole process from the initial call, when students are at the training ground fire station, to the end of the incident, involving a team of firefighters. The MC used, or concrete buildings represent apartment blocks, ships, and industries, even though they do not actually resemble any of these (see Fig. 2). These buildings will never burn down, even if the firefighters do not intervene. However, the simulation is performed in a physical space involving real equipment and interaction between people who are firefighters and role-playing bystanders, allowing for realistic collaboration and use of tools.

Fig. 1: Fire development observation in DC (Sweden)

Fig. 2: A concrete construction representing an apartment building in HF-LS scenario training (Sweden)

2.4. Practice-based training: (I)VR

VR supporting skills training is utilized in several domains, such as education in medicine (Ruthenbeck & Reynolds, 2013), biomedicine (Frøland et al., 2022), architecture, managing emergency cases (Ren, Chen & Luo, 2008), or in the construction industry (Xiao, Wen, Hung-Lin, Xiangyu & Albert, 2018). Several European countries have introduced virtual reality in the training and/or assessment of incident commanders (IC), including in the United Kingdom (Butler, Honey & Cohen-Hatton, 2019; Lamb et al., 2014), Estonia (*Training Incident Commander's Situational Awareness---A Discussion of How Simulation Software Facilitate Learning*, 2019), Portugal (Reis & Neves, 2019), and Sweden (Heldal, 2016) in the fire academies or rescue services. In the IC role, the focus is on the whole incident scenario or one sector. It involves situational awareness, an overview that is required for risk assessments, anticipation, and decision-making (Wijkmark & Heldal, 2020). The IC does not enter a burning building or approach flames and smoke. This training is usually performed using non-immersive VR, with the virtual environment projected on screens so that the IC can move as they wish using a game control or keyboard (Wijkmark, Metallinou, et al., 2021). The firefighters' perspective on the incident scene differs. When holding the nozzle, approaching flames and smoke, extinguishing, or entering the building on fire (BA entry) to search for victims, and so on, the focus is much narrower; for example, on the fire and smoke and its behavior, the compartment or the building layout, and associated risks. The physical parts, the heat, the heavy equipment, and the limited field of view in the BA mask are all aspects related to the firefighters' experience of the real fire situation and HF-LS and may also be required in IVR-supported training to provide valuable training experiences.

In a study by Grabowski (2022), a comparison of IVR and CAVE-based simulator training was conducted involving 67 cadets and seven instructors who were also active firefighters. The results revealed differences in the perceived spatial presence, with lower levels reported by the experienced participants and higher levels among the cadets. These results were explained by the fact that VR technology is usually perceived better among younger people, the tool was designed for cadets, and experienced participants may perceive lower levels of realism in the representations.

Although there has been an interest in VR for skills training in Sweden, demonstrated by MSB when initiating the first study on user experience and acceptance of IVR training in 2019 (Wijkmark, Heldal & Metallinou, 2019), there has been a reluctance to implement this in the firefighter training program. Such hesitation was shown by instructors participating in the study and explained by referring to the HF-LS as the most realistic training format, arguing against replacing any HF-LS training, and questioning the realistic experience in IVR settings compared with real fire situations. MSB purchased (in 2019) an IVR set identical to the one used in this study (FLAIM trainer) as the first public FRS in Europe, but did not implement any IVR training in firefighter education until 2022. It has previously only been used for demonstration and testing/research purposes. To the best of our knowledge, no FRS in Sweden has implemented IVR training for firefighter skill training. In Brazil, the Military Firefighters Corps purchased the IVR technology in 2021 and was the first organization in South America to do so.

2.5. Presence and immersion influencing practice-based training

Immersion is an objective feature of the technology (Slater & Wilbur, 1997) and denotes the extent to which the technology immerses (surrounds the senses of) the user. Presence, on the other hand, is defined as the subjective experience of "being there" in the virtual environment. Salas, Wildman, and Piccolo (2009) and Slater and Sanchez-Vives (2016) argue that two components: place illusion (the illusion of "being there" in the virtual environment) and plausibility (the scenario is really occurring) are important in shaping the user's experience of presence in VR. The consequence of place illusion and plausibility is that the user behaves in the VR as s/he would do so in the corresponding real situation. Additionally, the experience of presence in a virtual environment is affected by two types of realism; social realism (reflects events as they would occur in real life) and perceptual realism (objects and people look and sound like they do in real life).

Flach and Holden (1998) argue that "the reality of experience is defined relative to functionality, rather than to appearances" (p. 94), meaning that the experience of *being there* (a.k.a. presence) depends on the ability *to act there*. Slater argues that the real power of VR is "being there", the perceptual illusion that makes a person perceive and react to the situation as if it were real, even though they know it is not (Slater, 2018).

Earlier, a common assumption was made that experiencing high presence in VS would result in better performance in real life (transfer) (Youngblut & Huie, 2003). Although the literature is not conclusive as to whether there is a causal relationship between presence and positive training transfer (to real-life performance), it is believed that a sufficient level of fidelity, that is the extent to which the simulation recreates the real world system, is required for effective training (Jonathan & Kincaid, 2015; Salas, Bowers & Rhodenizer, 1998; Salas et al., 2009).

Software for firefighter skills training is less mature than tools developed for other domains, such as navigation and aviation, which poses challenges for proof of transfer. The visual and sensory fidelity associated with firefighter practice is described as immaturity of technology by Engelbrecht et al. (2019), as well as a lack of multi-user fidelity (Engelbrecht, Lindeman & Hoermann, 2019). Simulation developers need better understanding of the variables contributing to higher experiences and how these can be refined to influence learning and performance. Thus, further research is necessary to achieve and assess the adequate level of fidelity in firefighter training.

3. Methodology

The aim of this study was to compare results from two field studies, one from Sweden and one from Brazil. The technology, study design, and data collection procedure used in the Swedish study (Wijkmark et al., 2022) were also applied in Brazil. The motivation for designing the Brazilian study and comparing the results was to generate more generalizable knowledge about the way in which contextual factors influence firefighters' experiences using IVR training.

3.1. The study set-up and data collection

Two field studies were conducted during IVR training at 1) the FRS Östra Skaraborg training ground facilities Hasslum, in Skøvde, Sweden in October 2020, and at 2) the Firefighter Corps training center in Paraná, Brazil in April 2022. Data were collected systematically by designing similar situations, using similar technologies and applications, and collecting data in similar ways. Two questionnaires were used, a background questionnaire covering users' individual and professional background in the FRS, such as their experience of HF-LS and real fires, which was completed before the IVR training, and another questionnaire covering the IVR experience with items asking participants to relate the IVR experience to their previous experience of HF-LS training and fighting real fires. The development of the questionnaires for the firefighters was based on the battery defined by Slater, Usoh, and Steed (1994) and complemented with questions for firefighter skills training inspired by Schroeder and his colleagues (Schroeder, Heldal & Tromp, 2006; Schroeder et al., 2001). The additional questions concerned necessary actions for learning and practicing firefighter training. Responses were made on a five-point Likert scale (1= very low, 2 = low, 3 = medium/acceptable, 4 = high, 5 = very high) or by "yes" or "no", with the option to explain this in text.

Each participant followed three steps: 1) answer the background questionnaire; 2) dress in personal protective clothing (suit and gloves) and conduct the training; and 3) answer the post-exposure questionnaire. The management of the training section selected the IVR scenarios to reflect two common fire scenarios and one uncommon scenario (Slater et al., 1994). The Swedish study scenarios were: 1) fire in a kitchen, 2) fire in a bedroom on the second floor of a family home, and 3) fire in a car involved in a traffic accident in a tunnel. For the Brazilian study, the scenarios were: 1) fire in a bedroom, 2) car accident on a highway, and 3) an airplane engine on fire. The IVR training was performed for 15-20 minutes and observed by one researcher. In addition, the head of training at both organizations answered 25 questions, in writing, describing the real fire context, fire and FRS statistics, the education and training background, and the HF-LS training utilized in their organizations, as well as their main objectives for using IVR training and plans for implementation.

3.2. Participants and their experiences

The Swedish group included 18 experienced firefighters, 17 men and one woman. Information on age was not collected in this questionnaire. All participants were employed full-time with an average of 14 years in the occupation, spanning from two to 30 years.

In the Brazilian group, 53 firefighters participated, of whom 4% (n= 2) were women. The average age was 43, with the span ranging from 30 to 55 years of age. All Brazilian participants were employed full-time with an average of 19 years (6-32 years) of employment.

3.3. The technology used

The participating organizations chose the IVR tool (see Fig. 3) based on its promised higher experiences, high-fidelity simulations, and rich sensory inputs. The participants wore a head-mounted display (HMD), a self-contained breathing apparatus (SCBA) with an air bottle and harness (includes a half-face mask that was not used in this study as a COVID-19 safety measure), a vest including responsive heat elements (responding to the distance and direction of the fire), and the protective clothing and gloves for the ordinary firefighter. The only exception in terms of the standard equipment was the helmet, as this did not fit under the HMD. This simulated the experience of weight, heat, and clumsiness in the movement and handling of the nozzle. A proper nozzle for applying water providing a sense of the recoil of water flowing through it was included. The instructor was able to watch the users' field of view on a screen (in Fig. 4). For more information on the IVR, see Wijkmark et al. (2022).

Fig. 3: The IVR used in this study

4. Results

4.1. The participants' earlier experiences of real fire situations

There is no exact data on how many real fire situations every firefighter has been involved in. Using the available fire statistics at national and regional levels, the number of firefighters and the size of ordinary teams, an estimate can be calculated as follows. In Sweden, 16000 operational FRS personnel make up 3200 teams. The 6500 fires in buildings in Sweden each year, divided by the number of teams, would result in two fires per team and year. In the region of the participating Swedish FRS's, there were 149 (30%) full-time employed firefighters (14 women) and 346 (70%) part-time firefighters (10 women) in 2021 which corresponds to the Swedish distribution. In this region, the FRS were called to 358 fire incidents in buildings (2021) corresponding to 0.92 fires per 1000 inhabitants, of which 110 fires were not causing any damage, while 248 fire were considered real fire experiences. We then calculated the number of fires per team and year corresponding to the national level: 495 firefighters, divided into teams of five which gives 99 teams, resulting in 2.5 (248/99) fires per team per year. This reveals that an average of 14 years in the occupation gives an experience of 35 fires (14*2.5) for the participating group. However, it is important to bear in mind that 70% of the FRS's firefighters are part-time employees, on call in specific weeks which means that there are fewer real fire experiences for the majority than the illustrative calculation suggests, and correspondingly more for the experienced firefighters in the participating group. Details of the number of fires per person was not available.

In total, 73% (n = 11) of the participants in the Swedish group stated that they have experienced more than 20 real fires during their career. Specifically, 22.2% (n = 4) have experienced over 50 fires, 33.3% (n = 6) 21-50 fires, 22.2% (n = 4) six to 20 fires, and 22.2% (n = 4) one to five fires. However, no national statistics on fires in Brazil are available which makes it difficult to compare the FRS responses on a national scale. The corresponding illustrative calculation was undertaken for the Paraná context: usually, the firefighters work in teams of four. Dividing the total number of 3020 firefighters by four firefighters per team, 755 teams are formed. Dividing the total of 4603 fires among the 755 teams would result in six fires per team and year. This calculation indicates that an average of 19 years in the occupation means an experience of 114 fires (19* 6) for the participating group. When asked to approximate their experience of real fires, 70% (n = 37) stated that they have experience of more than 20 fires, 52.8% (n = 28) over

50 fires, 17% (n = 9) 21-50 fires, 24.5% (n = 13) six to 20 fires, and 5.7% (n = 3) one to five fires.

Comparison between the two groups indicates that the Brazilian group in general have experienced more than double the number of real fire incidents experienced by the Swedish group.

4.2. Participants' earlier experiences of HF-LS training

All Swedish participants had attended the SMO education provided by MSB which includes approximately (there are some variations between the two MSB colleges and time periods) 12 HF-LS training sessions distributed among the three general types of HF-LS training environments;: DC, AC, and MC training, as described in Section 2.3 where the firefighter student performs BA entry. Every training session is planned for 3.5 hours and includes two BA entries of approximately 15 minutes for each firefighter. Following the SMO education, the employer (the FRS) is responsible for continuous training and development. According to the statute book, four yearly training sessions are mandatory, of which two must involve heat, that is HF-LS of some sort (not further specified). For the Swedish group, this is conducted in ACs in addition to a number of scenario-based training sessions involving HF-LS. The participants in the Swedish group have been firefighters for an average of 14 years. Given that they have all passed the SMO program and participated in all mandatory HF-LS training yearly, they have earlier experience amounting to an average 40 (12 + 14*2) HF-LS training sessions.

Within the Brazilian Firefighter Corps education program (Paraná), the students perform five to six HF-LS sessions for four hours, where each individual acts in BA for approximately 15 minutes twice. For development and continuous training, one HF-LS training session per year is performed, although no statute book or law regulates this. The participants in the Brazilian group have, on average, spent 19 years in their occupation as firefighters which encompasses experience of 25 (6 + 19*1) HF-LS training sessions.

These calculations illustrate the differences in HF-LS experience in that the Swedish participants have undertaken considerably more HF-LS training sessions than their Brazilian counterparts. Another important difference concerns the HF-LS training facilities at the training grounds. The Hasslum (Sweden) training ground, used by the participating FRS, includes DC, AC, and MC buildings, providing access to more extensive training in terms of the number of training sessions and complexity, while the Parana (Brazil) training ground provides only the first two facilities. Regarding time effectiveness, at both sites each firefighter participated in a 3.5- 4-hour HF-LS session for approximately 2*15 minutes.

4.3. Experiencing presence in IVR compared to HF-LS training

The participants were asked to relate their experienced presence in IVR to a previous HF-LS training situation. In the Brazilian group, 92% of the participants rated their presence as acceptable to very high (Likert > = 3) (17% Likert 5, 45% Likert 4, 30% Likert 3, 8% Likert 2, 0% Likert 1), with an average of 3.72. In the Swedish group, 89% of the participants rated the presence as acceptable to very high (Likert > = 3) (27.8% Likert 5, 33.3% Likert 4, 27.8 Likert 3, 11.1% Likert 2, 0% Likert 1) with an average of 3.78.

When asked to rate the extent to which the tasks performed in IVR correspond to the tasks that can be performed in HF-LS, 89% of the Brazilian participants stated that it corresponds to a medium to very high extent (Likert > = 3) (9.4% Likert 5, 54.7% Likert 4, 24.5% Likert 3, 7.5 % Likert 2, 3.8 Likert 1). By contrast, only 56% of Swedish participants stated that it corresponds to a medium to very high extent (0% Likert 5, 27.7% Likert 4, 27.7% Likert 3, 38.9% Likert 2, 5.6% Likert 1).

Summarized in Table 1, the results reveal a similarly high presence in both groups compared with HF-LS, although the Brazilian group rated the task similarity higher than the Swedish group. This difference may be related to the earlier, more extensive, HF-LS experiences that were highly appreciated by the Swedish group. It may also indicate that the tasks performed in IVR settings represent more closely the two HF-LS training types available in Brazil, while the Swedish group have additional, more complex HF-LS training facilities.

Table 1: IVR experience compared with previously experienced HF-LS

IVR experience compared to HF-LS	**Sweden**	**Brazil**
Experienced HF-LS training sessions on average (n)	40	24
Acceptable presence in IVR compared to HF-LS (Likert > = 3)	89%	92%
Acceptable correspondence of task performed in IVR to HF-LS (Likert > = 3)	56%	89%

4.4. IVR experience of presence compared to real fire experiences

The participants were asked to compare their experienced presence in IVR to the feeling of being in a real fire situation. Overall, 72% of the Brazilian participants rated their presence as acceptable to very high (Likert > = 3) (5.7% Likert 5, 28.3% Likert 4, 37.7% Likert 3, 20.8%, 7.5% Likert 1) with an average of 3.04. Of the Swedish participants, 94% rated this as acceptable to very high, (16.7% Likert 5, 44.4% Likert 4, 33.3% Likert 3, 5.6% Likert2, 0% Likert 1), with an average of 3.72.

Regarding the question "To what extent does the feeling of stress in IVR correspond to the feeling of stress in a real fire situation?", 64% of the Brazilian participants scored this as acceptable to very high (Likert > = 3) (5.7% Likert 5, 17.0% Likert 4, 41.5% Likert 3, 26.4% Likert 2, 9.4% Likert 1) with an average of 2.83. In comparison, 89% of the Swedish participants scored this as acceptable to very high (Likert > = 3) (11.1% Likert 5, 38.9% Likert 4, 38.8% Likert 3, 5.6% Likert 2, 5.6% Likert 2) with an average of 3.44. The lower score of the Brazilian group may be because they have had greater real fire experience than the Swedish group.

Regarding the realistic representation in the IVR settings, 73.6% of Brazilian participants rated the extent to which the visual appearance of the fire in IVR is realistic as high/very high (6% Likert 5, 21% Likert 4, 34% Likert 3, 30% Likert 2, 9% Likert 1) with an average of 3.17. In the Swedish group, 94.4% rated the realism of the fire as medium to very high (11.1% Likert 5, 50.0% Likert 4, 33.3% Likert 3, 5.6% Likert 2, 0% Likert 1) with an average of 3.67.

Regarding the smoke, 84.9% of the Brazilian participants rated the realism of this as medium to very high (9% Likert 5, 30% Likert 4, 34% Likert 3, 21% Likert 2, 6% Likert 1) with an average of 3.51. In the Swedish group, 88.9% rated the smoke as realistic from medium to very high (Likert 4 or 5) (5.6% Likert 5, 50.0% Likert 4, 33.3% Likert 3, 11.1% Likert 2, 0% Likert 1) with an average of 3.50.

The group reported similar scores regarding the realistic representations of fire and smoke. This may be because the participants found the representations of fire and smoke to be satisfactory and related to the scenarios (Likert > = 3), although there is room for improvement.

Table 2: IVR experiences compared with previously experienced real fires.

IVR experience compared with real fires	**Sweden**	**Brazil**
Real fires experienced on average (n)	35	114
Acceptable presence in IVR compared with real fires (Likert >=3)	94%	72%
Acceptable correspondence of stress experienced in IVR to HF-LS (Likert >=3)	89%	64%

4.5. Objectives and organizational attitudes toward introducing IVR training

The interest and motivation to explore and implement IVR training differed in the participating organizations. The head of training and other management personnel at the participating Swedish FRS have previously used non-immersive virtual reality for incident commander training, and therefore using IVR for firefighter skills training was a natural further step. Funding for the test session was provided through a project. There was no plan to purchase or implement IVR training in their own FRS introductory courses or for the annual training sessions. The study was performed to explore added value and for discussion on future utilization. Since then, there has been no purchase of this or similar technology. The main objective for exploring IVR training was expressed by the head of training as follows: "IVR gives a possibility to develop training, include new environments that are not familiar to the firefighters, as the HF-LS facilities are, and to train standard operational procedures with the same preconditions in exactly the same scenarios for all firefighters which is not possible in HF-LS". The IVR was also expected to reduce costs and provide more training in less time compared with HF-LS, although the initial cost of purchasing the technology is considered high, and thus a challenge or barrier for purchase and adoption.

In the Paraná case, the management decided to implement IVR training in the organization and the technology was purchased in 2021. The main motivation for this decision was expressed as "It's useful to evaluate firefighter's adherence to protocols". Another added value expressed by the management is the portability that enables training in locations other than the training ground.

The difference in management attitudes and decisions regarding IVR training may be explained by the value of such training being more urgent in the Brazilian case where HF-LS training is less widely available.

5. Discussion

Fires occur when there is the right mix of combustible material, oxygen, and heat. This is often referred to as the fire triangle, and fires start in these same preconditions everywhere on earth. However, after ignition, fires in buildings are never the same, even if they occur in the same neighborhood. Fire development and smoke behavior depend on the layout of the building, the building material, the furniture, and the climate. An apartment fire in a Nordic country, with the building constructed out of wood and insulation material, with plastic floors and wallpaper would generally exhibit more material pyrolyzing when heated than an apartment in a subtropical country with tile floors and plastered walls. The experience of real fires may differ for firefighters from various regions and countries which may differentially affect which aspects are perceived as “typical” between the Swedish and the Brazilian group.

Differences in the format and meaning of standard operational procedures and compliance with these can also affect how training in IVR is received and experienced. For example, in Sweden, the Work Environment Authority's Statute Book (2022) will only allow BA entry if there are lives to save; if not, external methods for cooling and extinguishing are to be used. BA entry is always performed in pairs. In the IVR scenarios employed in this study, there were no external extinguishing alternatives. It was not possible to work in pairs and there were not always persons to be rescued inside. This required the instructor to roleplay the BA leader, informing the trainee that there may be people inside to be rescued, and also to play the second BA firefighter to add to the realism of the task. When there was a person (avatar) to rescue, this was only marked as “rescued” and not undertaken. The trainee was then supposed to continue extinguishing the fire inside the building. This may be perceived as not realistic in relation to the task and procedures. Compliance with procedures is not explicitly measured by the technology, but can be observed and assessed by the instructor in closer detail compared with HF-LS which was appreciated by the managers for both groups and was a key motivation for implementing IVR in the Brazil FRS.

The scenarios employed in this study were general and not adjusted to represent the context of the country which would allow investigation of how differences in previous real fire experience influence the IVR experience.

The general experience of real fires was higher in the Brazilian group, while the HF-LS training experience was higher in the Swedish group. The differences in the experience of real fires (high) and the amount of HF-LS training (low) indicate that the Brazilian participants can relate their experiences in IVR to real fire situations to a higher degree than their Swedish counterparts. Conversely, the Swedish participants can relate their experience in IVR to HF-LS to a higher degree.

Both groups report a similarly high presence in IVR compared with HF-LS. However, the similarity of the stress level experienced in IVR compared to real fire situations was rated higher by the Swedish group who have less experience of real fires. Regarding the realistic representation of fire and smoke, this was rated similarly in both groups.

To summarize, the IVR used reveals high presence and acceptance, albeit not adjusted to the different contexts of countries. Further work could investigate whether context-specific, country-adjusted scenarios (e.g., a typical Swedish apartment and a typical Brazilian apartment) would enhance the sense of presence and the perception of realism. Furthermore, the participants in these studies were all first-time users of the IVR and the results should be viewed from this perspective. When training in IVR on a regular basis, experienced presence may increase as it becomes a familiar training format. Alternatively, users may start focusing on details that disturb presence and make higher demands in terms of graphical representations. As demonstrated in previous studies, the difference in IVR experience between novices and experienced firefighters may need to be considered in the design of training tools intended for different groups.

IVR training allows a new supplementary training format which may not be instantly motivated by the organizational goals and learning objectives. The well-established and accepted practice-based training format (HF-LS), viewed as the most realistic training format possible, involves real fire and smoke, but also imposes limitations; for example, the fire cannot spread and the building does not resemble what it represents which limits fidelity. The realistic representation of objects and the realistic feeling of being and acting in the situation has been questioned regarding IVR training. Yet a sufficient level of fidelity is believed to contribute to training transfer. Further investigation is required to increase knowledge regarding the training transfer of IVR, as well as the traditional and accepted HF-LS which will enhance our understanding of how these two formats effectively supplement each other.

6. Conclusion

The primary aim of this paper is to investigate the similarities and differences in experienced firefighters` perceived presence and attitudes toward IVR training in Brazil and Sweden. The initial hypothesis, that both the experience of presence and attitudes toward IVR training would differ considerably among the two groups, was only partially confirmed. The experienced presence in IVR training was high in both countries, as was the perceived realism of representations. The results indicate that differences in previous experience of HF-LS training and real fires may influence the realistic experience of the task performed compared with HF-LS, and the stress levels in comparison real fire situations. The group with less previous HF-LS experience rated the task as more similar to HF-LS, while the group with less real fire experience rated the IVR stress level as more similar to real fire situations. Furthermore, the results corroborate earlier findings in that experienced firefighters rate perceived presence in IVR training from high to very high.

The authors acknowledge that in both countries the organizational objective and motivation to introduce IVR training and instructors' attitudes toward this technology and the new training format may influence the individual acceptance of IVR training which, in turn, requires the acceptance of instructors and organizational support.

Acknowledgment

The contribution of all participants and their organizations in Sweden and Brazil is highly appreciated. Two of the authors were partly funded by the Research Council of Norway, through the project DYNAMIC, nr. 298993.

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