Safe Spaces for Immersive Safety Training in Virtual Reality: A Phenomenological Conceptualization

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Abstract

Immersive Virtual Reality (IVR) technology has been shown to effectively facilitate fire safety training. However, the current discourse on immersive safety training provides scarce knowledge on the quality of immersive safety training from the perspective of safe spaces. In turn, the general notion of a safe space – being an environment that is characterized by the freedom to move, share, talk, and act freely without risk for physical or mental damage – needs further elaboration in an IVR training context where the experience of safety is highly interrelated with embodiment and immersion. This study employed thus a phenomenological approach to explore and conceptualize characteristics of immersive safe spaces. This was done through phenomenological interviews with employees at Sweden's largest train operating company, which undertook fire safety training in IVR by using an IVR application known as the "Fire Trainer". The interview material was then analyzed through an Interpretative Phenomenological Analysis (IPA) that conceptualized four themes for characterizing immersive safe spaces: *Sense of Authentic Hazard Recognition*, *Sense of Behavioral Responsiveness*, *Sense of Intersubjective Risk Perception*, and *Sense of Embodied Atmosphere*. Implications of conceptualizing the themes are targeted towards understanding the quality of being/feeling safe during safety training in IVR, and how the design of future immersive fire safety environments might benefit from employing the proposed themes.

1. Introduction

Immersive Virtual Reality (IVR) technology has experienced exponential growth in attention in the past 5 years. Many see IVR technology as a novel tool for mediating a one-to-one analog of physical, face-to-face (F2F) interaction. This has given rise to various applications meant to mediate interactions that usually happen F2F in the physical space, varying from surgical and defense training to academic conferences, to business meetings, and safety training. For the latter application area, IVR technology has been shown to benefit the F2F interaction for soft-skills acquisition, increased engagement, presence, and immersion (Buttussi & Chittaro, 2017), reduced cognitive load (Sun, Chen, Tao & Liu, 2019), and acquisition of both procedural and behavioral safety skills (Radhakrishnan et al., 2021). Especially in relation to increased presence, IVR technology creates an illusory feeling of 'being-there' in the virtual reality to conduct activities in a convincing way by substituting sensory input with data that is received through simulation in a realistic three-dimensional fashion (Heim, 2000). The illusory feeling is also convincing when it comes to simulating sensations that human beings relate to in the physical world, such as the sense of being safe or safety.

The sense of safety of which IVR safety training provides in an immersive virtual environment, is governed under secure circumstances which override direct implications of traditional safety failures. This includes injuries, fatalities, near-hit incidents, and other kinds of 'what-not-to-do' examples which have been used to improve safety programs in most industries (Norris et al., 2019). Therefore, it is not surprising that there is a growing interest from industry to invest in and academia to research the implications of IVR technology for safety training. And while the general perception of IVR technology's utility is positive for facilitating safety

training under secure and sustainable circumstances (Haj-Bolouri, Katende & Rossi, 2023), the current discourse on IVR safety training does not provide a clear notion of 'safe spaces' for safety training in IVR environments (Haj-Bolouri et al., 2023). Multidisciplinary about safe-spaces provide definitions of what a safe space is and how it can be designed, and at the same time raise the issue of over-generalization of what a safe space means across different contexts (Ruiz-Bravo, 2024). There exists thus a gap for conceptualizing a notion of safe spaces that is concurrently relevant for IVR research and the immersive experience of safety training.

Hence, in this paper, I explore the gap and propose how a safe space can be characterized for immersive safety training in IVR by: (1) drawing upon insights from a specific case of evaluating immersive fire safety training in IVR, and (2) extracting and proposing generic characteristics of safe spaces for immersive safety training in IVR. The characteristics can, I suggest, be used to inform the design of safe spaces for IVR safety training in general, whereas fire safety is used as a case to contextualize the characteristics and illustrate their implications for IVR safety training. Consequently, this study employed phenomenology (Van Manen, 2016, 2017) to gain an in-depth understanding of how the immersive training environment enabled and maintained an immersive feeling of safety among the training participants in IVR. More specifically, the study applied a phenomenological approach in interviewing the IVR users of the immersive fire safety training case, for understanding their lived experiences of safety in IVR. The findings of the interviews were then analyzed based on an Interpretative Phenomenological Analysis (IPA) (Smith et al., 1999). The IPA approach helped this study to conduct the phenomenological approach and to identify emerging themes which were then used to conceptualize safe space characteristics.

2. Related Work

2.1. Immersive Virtual Reality

IVR is a peculiar form of digital technology that distinguishes itself from ordinary Information Technologies (ITs) due to the capability of simulating virtual worlds through Head-Mounted Displays (HMDs) that mediate an immersive experience that feels realistic (Fromm et al., 2021). Although the concept of Virtual Reality (VR) has been well-known for decades, its popularity has – since 2016 – and onwards been increasing due to affordable and powerful consumer-grade HMDs that produce the immersive experience (McGill, Williamson, & Brewster, 2016). In fact, the increased popularity of IVR technology led to 2.3 billion-dollar investments in IVR start-ups in 2016 (CAICT, 2017), creating a 6.1-billion-dollar market in 2020. And by the year of 2025, the IVR market is expected to reach 20.9 billion dollars (Kugler, 2021) as Big Tech is re-emphasizing IVR for consumer and business applications (Huddleston, 2021). IVR technology is thus gaining more and more popularity in organizations and at various institutions of society, allowing people to move beyond 2-dimensional virtual experiences by integrating the five traditional senses of users, including: sight, hearing, smell, taste, and touch, which together provides an immersive experience that relies on multimodal sensory cues such as visual, auditory, olfactory, haptic, and social cues (Tcha-Tokey et al., 2016).

The immersive experience is different from other non-immersive VR experiences (e.g., desktop VR) because the symbiotic world relies on 'immersion', a quality that mainly refers to the development and change of mental state from one world to another (Petersen, Petkakis, & Makransky, 2022). Another way of describing immersion is as "*[…] a form of spatio-temporal belonging in the world that is characterized by deep involvement in the present moment.*" (Hansen & Mossberg, 2013, p. 212). Another way of characterizing immersion is through the feeling of an increased sense of embodiment and presence in the virtual space (Biocca, & Levy, 2013). Additionally, through the immersive experience in the virtual space, what we experience as seeming real, and thus who we are, or choose to be, is up to us due to the possibility of exploring hypothetical scenarios that do not have an extensible cause-and-effect, making the IVR experience feel safe (Bailenson, 2018). For example, if a user's embodied avatar jumps down from a building in IVR, the user does not experience any effect of pain or death as a cause of falling to the ground. Nor does the user,

in the physical world, has the possibility to create movement via teleportation. As such, the body is safe from getting harmed and it is free for extensive possibilities of movement, whereas at the same time, the realism of immersion provides end-users a psychological care for activities that are meaningful and relevant for them, such as safety training.

2.2. Immersive Safety Training in Virtual Reality

Safety training (also referred to as 'safety education') is a special form of learning experience that integrates the development of procedural skills (e.g., how to accomplish something) through hands-on exercises that are heavily task-dependent and can expose the training participants to potential risks (Conges et al., 2020). Moreover, practical safety training exercises can also require expensive, fragile, or rare equipment, which could be difficult to secure for real-life training experiences (Zhang et al., 2019). A particular field that is affected by such issues is that of industrial training, where operators must be prepared to work with potentially hazardous systems (e.g., robotic manipulators, electrical machinery) (Çakiroğlu & Gökoğlu, 2019), or dangerous situations that might affect other people such as fire safety training (e.g., De Lorenzis et al., 2023) However, thanks to the rapid development of IVR technology, organizations can today create high-detailed simulations of real-life training scenarios that, given also the widespread availability of low-cost devices, can be easily exploited to safely facilitate immersive safety training in virtual reality (Pirker et al., 2020 ; Seo et al., 2021). Especially for procedural learning (e.g., technical skills and procedural skills), simulation with IVR systems have generally focused on feasibility, reliability or easiness of use, to assist trainees acquire safety training skills in a safe environment (Agha & Fowler, 2015; Bracq et al., 2019).

Immersive safety training that is based on IVR technology is gaining traction as innovative bundles of technology for mediating realistic and viable safety training experiences in virtual reality (Radhakrishnan et al., 2021). One of the reasons why IVR technology is prominent for safety training is because its high practicality, low risk, and low cost, as well as its capacity to ensure both safety and efficiency during learning processes (Adami et al., 2021). IVR training environments are mainly based on pedagogical design features and experiential modes of learning through simulation, visualization, and/or gamified learning scenarios (Park et al., 2020). But the environments' level of authenticity is also related to the fidelity of a learning task's psychological, physical, functional, and social aspects that needs to be taken into consideration for design of such environments (Lowell & Tagare, 2023). As such, IVR environments employed for safety training aim to allow workers to actively participate in scenarios that represent the actual conditions of real-life scenarios, enhancing and strengthening safety awareness and allowing them to experience the learning activities, under secure circumstances (Pinheiro et al., 2021). Application areas include emergency preparation (Zhu et al., 2020), fire prevention (Fromm et al., 2021), and first aid (Chryssolouris et al., 2008), and preparation for managing workplace accidents (Kim & Leem, 2020; Mavrikios et al., 2013). However, with increasing possibilities of organizing and facilitating safety training in IVR, also comes an ambiguity about how to characterize safe spaces IVR that per default eliminate unsafe practices and increase the physically safe performance of dangerous training tasks (Toyoda et al., 2022). A further exploration into the concept of safe spaces is thus needed.

2.3. The Notion of 'Safe Spaces'

Currently, there are no universal definitions of what a safe space is for immersive safety training in IVR. A general notion of a 'safe space' can be expressed as a secure environment that allows and encourages individuals to navigate freely, experiment with behaviors and actions, and iterate around training objectives through a safe trial-and-error process. Such a space can be mediated physically as well as virtually, making its material/immaterial characteristics, different depending on the format of a safe space (e.g., physical, or virtual or hybrid). However, the above-given notion of a safe space is very broad and has typically been developed in other research contexts than the area of IVR research, to depict the experience of safety features for education and learning experiences that feel safe among participants that want to experiment with their personal identities and opinions (Acena et al., 2021). This includes safe spaces for provoking new ideas for

learning that might be controversial (Freeman & Acena, 2022), and/or to provide low skilled novice workers with a safe environment to learn through experience and perform actions that might be costly or embarrassing to do in the physical space (Al Farsi et al., 2021). Additionally, others, such as Gruber et al. (2023), indicate that IVR in general provides a safe space for students and teachers interaction during students' learning because the virtual experience is secure from not injuring the body of IVR users.

Although current research on the notion of 'safe spaces' is scarce in the IVR literature, general characteristics of a safe space might be conceptualized based on inspiration from cross-disciplinary research on this topic. For instance, a recent study Haj-Bolouri et al. (2023) propose a mid-range theory for how to design 'sustainable safe spaces' for facilitating safety training in IVR, which provide this study inspiration for understanding the design characteristics of a safe space in IVR. Especially for the context of immersive safety training in IVR, traditional safety training issues regarding high consumption of natural resources, limited flexibility to various fields and areas of training, lack of adaptability for experimentation and repetition of training scenarios, and high risk for injury in safety operations, can all be reduced in an immersive virtual setting because of the 'immaterial characteristics' of virtuality (Moura et al., 2021). Moreover, because IVR is an instance of digital technologies, perhaps exploring the notion of 'digital safe spaces' might provide a deeper understanding about how a safe space is generally enabled in digital settings.

2.4. The Notion of 'Digital Safe Spaces'

Although this study narrows its scrutiny towards safe spaces for immersive safety training, the concurrent notion of safe spaces that is most relevant to this study is the notion of 'digital safe spaces'. Digital safe spaces can be understood as spaces created with digital technologies for and by vulnerable groups to connect and seek refuge (Kenney, 2001). A digital safe space incorporates generic definitions of safe spaces, including the three primary objectives of safe spaces identified by Linabary (2017): (1) offering a refuge from external threats without the watchful eye of dominant groups; (2) fostering a collective identity and solidarity; and (3) providing a platform for organizing and resistance. Such a safe space can be based on dimensions that are physical, psychological/affective, sociocultural, political, and experimental (Spaaij & Schulenkorf, 2014). However, some of the prior notions of safe spaces have led to separatist kind of safe spaces, which face internal divisions and clashes over time, challenging the notion of safety and creating a re-marginalized group within the space (Linabary, 2017; The Rosestone Collective, 2014). As a consequence, the separatist tendency of contemporary conceptualizations of safe spaces has led to a need to for re-conceptualizations of safe spaces that provide a nuanced notion for digital environments.

However, current attempts to re-conceptualize a nuanced notion of safe spaces for digital environments, is emerging, yet scarce. To this date, there is one conference paper by Ruiz-Bravo (2024) that explicitly focuses to characterize a notion of digital safe spaces for the field of IS, and a seminal journal paper published by the author of this study on the topic of space in general. As Ruiz-Bravo (2024) illustrates, there are characteristics and individual perceptions of digital safe spaces, which together, create three types of digital safe spaces: (1) *Supportive Digital Safe Spaces* – digital safe spaces that provide emotional or psychological support to its members, social support, shared experiences without judgement, and shared information (Johnson et al., 2022; Singh & Brandon, 2019); (2) *Confirmative Digital Safe Spaces* – digital safe spaces that allow individuals to freely express their identity and ideas without fear of discrimination or prejudice (Cui et al., 2022; McKenna, 2020); and (3) *Activist Digital Safe Space* – digital safe spaces that provide platforms for organization and resistance, offering opportunities for collective action and mobilization around social and political issues (McKenna & Chughtai, 2020).

As such, Ruiz-Bravo's (2024) provide a good overview on digital safe spaces in general, their characteristics, mainly situated for digital platforms, whereas the sensation of 'feeling safe' in a digital context is not only a phenomenon relevant for digital platforms. But rather, 'feeling safe' is highly related to qualia and subjectivity through the lived experiences of individuals who perceive the feeling of safety in a safe space

(e.g., the quality of how it feels to feel safe can vary across groups of individuals). The feeling of safety varies also depending on how meaningful and immersive the safe space feels for the lifeworld of the individual (e.g., the individual's concerns, beliefs, desire and will), and how realistic the safe space feels due to the capacity of the particular technology that mediates the space. Still, the question remains: what characterizes the qualitative feeling of safe spaces for immersive safety training in IVR? The question remains because, to this date, there is a need to explicate safe spaces for IVR safety training, what characterizes them, and how researchers and designers of IVR safety training can understand their implications for safety training in IVR (Haj-Bolouri et al., 2023).

3. Method

As a way of exploring what characterizes the qualitative feeling of safe spaces for immersive safety training, in IVR, this study employed a phenomenological approach. The approach was employed for a case of immersive fire safety training in IVR, which for this study, is considered as a special case of immersive safety training in general. Hence, this section, will first outline and motivate the phenomenological approach, and then present the empirical setting. Finally, this section will present focus how phenomenology was used for interviewing respondents of the immersive fire safety training and interpret their lived experiences into themes that characterize the safe space of immersive fire safety training.

3.1. A Backdrop to Phenomenology

Phenomenology is generally seen as a philosophical program and tradition that makes an effort to disclose the features or presuppositions of the world as given in the lived experience (Zahavi, 2018). In other more simpler words, phenomenology studies questions such as: what is the nature of experiencing anything? Or what does it mean to experience something? And from these more general questions, phenomenologists focus the particular lived experience by asking questions such as: what does it mean to experience fear? Or what characterizes the individually lived experience of fear? As such, the lived experience is the starting point for a phenomenological inquiry. But what does the lived experience mean for phenomenology?

The lived experience refers to the experiences and choices that a person has in a given situation, and the knowledge that the person gains from these experiences and choices (Van Manen, 2016). Hence, a phenomenological approach and inquiry starts by exploring the lived experience and looks for an a-theoretical comportment that focuses creation and sharing of meaning, rather than focusing the theoretical and objectifying where the emotions are barred and the lived experience cleansed (Sokolowski, 1999). Subsequently, phenomenology consists of different streams ranging from viewing the lived experience as a phenomenon of our consciousness (Husserl, 1962), to studying the perception of bodily lived experience (Merleau-Ponty, 1962), to the lived experience as the primordial mode of Dasein or being-in-the-world (Heidegger, 1962).

For this study, the phenomenological approach that was used to conceptualize safe spaces for immersive safety training, was the one closest to Merleau-Ponty's (1968) stream of studying topics such as perception, the bodily lived experience (which is an extension of Husserl's idea of the 'living body'), and space. The reason behind why this particular stream is more suitable for this study is because of a number of reasons. First, Merleau-Ponty's (1962) phenomenology builds upon both Husserl's and Heidegger's views on the 'living body' and embodiment, both of which also are elaborated in contemporary phenomenology around topics related to immersion and VR (e.g., (Baily, 2016); (Du Toit & Swer, 2021)).

One of the reasons phenomenology has shown interest for immersion and VR, is because of the tension between physical and virtual realism, where on the one hand, the 'realness' of immersion is materialized through the feeling of being surrounded by virtual things presented on a screen, the feeling of walking freely around in a immersive space and interacting with the virtual things, just in a similar way we would do when interacting with physical things in our physical world (Metzinger, 2018). On the other hand, if the immersive

experience is meaningful for the users, then the question of 'realness' is not crucial for phenomenology because the embodied experience is real enough for creating and sharing meaning – as has been illustrated in studies around body-perception in IVR (e.g., Paladino et al., 2010; Porciello et al., 2018). Especially, in relation Kilteni et al's (2012) Sense of Embodiment (SoE) concept, one can see that their views on sense of self-location, sense of agency, and sense of body ownership in VR, draws from Mearleau-Ponty's (1968) phenomenology. There is, in other words, a discourse on phenomenology and VR, which this study contributes to by adopting the phenomenological approach for studying a case of immersive fire safety training in order to characterize safe spaces for immersive safety training.

3.2. The Empirical Setting: A Case of Immersive Fire Safety Training in IVR

In phenomenology, the empirical setting represents the 'horizon' (or background) of the lived experiences that a phenomenological inquiry takes place (Zahavi, 2018). In this study, the horizon was set against an empirical case of immersive fire safety training in IVR together with Sweden's largest train operating company known as 'SJ'. Since late 2020, SJ provides their employees (e.g., train conductors, train drivers) immersive fire safety training in IVR. The specific purpose of exercising fire safety training in IVR, rather than doing it in a physical training space, is to provide SJ's employees an interactive safe space where they can develop procedural skills for extinguishing fire under secure circumstances. This in turn will help them increase their fire safety awareness, and through a knowledge transfer from the virtual space to the physical one, prepare them for extinguishing real fire onboard real trains. Consequently, the particular IVR training application that SJ employed for their immersive fire safety training, is called 'VR Fire Trainer 'and is built by a company called Vobling.

The application is fully immersive with and provides a real fire extinguisher that is integrated into the training environment, which means that the IVR user must use the extinguisher nozzle to aim and press the extinguisher handle to release the agent, in order to extinguish the fire in IVR. The training environment is realistic as it is based on SJ's train surroundings, where fire spreads realistically in different materials and reacts naturally to different fire agents. The application also consists of performance analytics (e.g., how much the fire spread, how much of the extinguisher was used), simulates four fire types, nine different environments, six training scenarios, provided through 9 languages. Moreover, the participants conduct the training exercises according to the **PASS** technique, which stands for ***P**ull the pin*, ***A**im the nozzle*, ***S**queeze the nozzle*, and ***S**weep the nozzle*. Figure 1 depicts the VR Fire Trainer, both the technology as well as in-app images of the IVR environment.

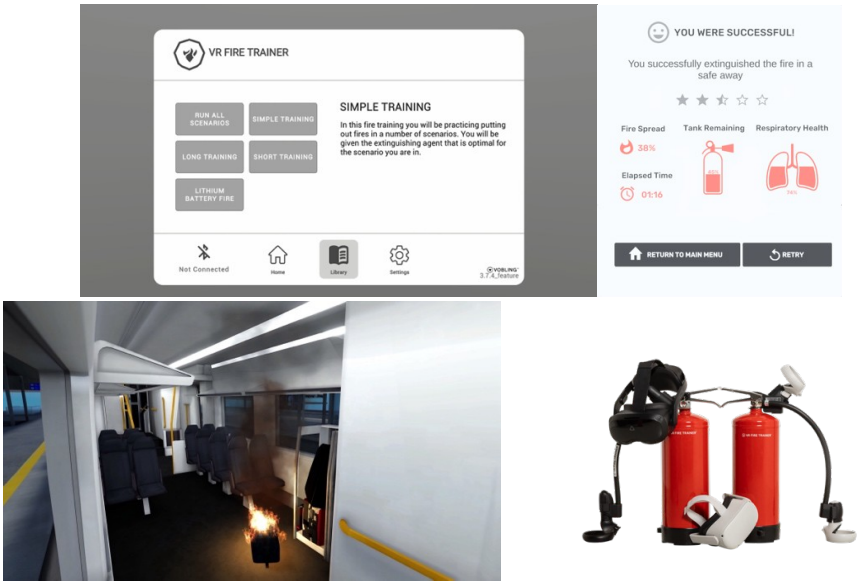

Figure 1. VR Fire Trainer: Application and In-App Snapshots

Subsequently, the immersive fire safety training episode that SJ's employees conducted was designed according to the following narrative of steps:

1. A participant is equipped with the IVR equipment shown in Figure 1 (e.g., HMD, hand control, fire extinguisher)
2. An instructor from SJ goes through the training episode and objectives verbally.
3. The participant gets 'teleported' to the IVR training space.
4. The participant undertakes a trial-and-error process exploring the training environment, familiarizing himself/herself with the setting, in order to embody the training scenario.
5. After the performance, data is saved in the application, and the participant has a reflective dialogue together with the instructor.

The participants were 10 employees (adults) at SJ aged between 28 and 50+ years old. Participants were selected based on their inclusion in SJ's fire safety training program. More specifically, the participants of the interviews had a different spectrum of roles and areas of responsibility ranging from being train operators that are responsible for working as conductors and staff onboard the train with direct interaction with the passengers, to train drivers that are in charge of driving the trains. Additionally, instructors from SJ were involved in the training sessions and interviews to nuance their role in supporting the trainees during the IVR safety training session. The instructors' role was twofold during the training session: (1) to inform the participants about the training session, the objectives, and purpose of conducting the fire safety training scenario in IVR; and (2) to conduct post-training reflection with the participants and discuss their lived experience (e.g., overall experience, performance). Finally, one manager from SJ participated in the training session. Together, the number of participants were sufficient for conducting a phenomenological interviewing because the phenomenological technique emphasizes entering the life-world of a participant to gather rich data that can create meaningful narratives, rather than clustering quantities of data (Bevan, 2014). Further participant information is listed in Table 1.

Table 1. Information about the Participants

Participants	**Gender**	**Role**	**Fire Safety Training Experience**	**Immersive Fire Safety Training Experience in VR**
P1	M	Train Operator	Yes	No
P2	M	Train Operator	Yes	No
P3	M	Train Driver	Yes	No
P4	F	Train Driver	No	No
P5	F	Train Operator	No	No
P6	F	Train Operator	Yes	No
P7	M	Manager	Yes	No
P8	M	Train Driver	No	No
P9	M	Instructor	Yes	Yes
P10	F	Instructor	Yes	Yes

3.3. Phenomenological Interviewing and Qualitative Data Analysis

It was against the horizon of the empirical case and setting that a phenomenological approach to interviewing (Bevan, 2014) was combined with an Interpretative Phenomenological Analysis (IPA) inspired by Smith et al. (1999) guidelines. The phenomenological approach to interviewing (as shown in Table 1) propounds that the identity of a lived experience has modes of appearance that the interview protocol's structure needs to take into consideration (Sokolowski, 1999). When conducing the phenomenological interviews for this study, interview questions were prompted with an underpinning awareness of the participants' domain of practice. As such, theory-laden questions (e.g., questions that are theoretically ingrained through specific concepts, words) were, according to the phenomenological interviewing guidelines of Bevan (2014), avoided to maintain a pre-reflective entry point for exploring the participants' immersive lived experiences.

Consequently, a total of 12 participants were interviewed, ranging from being train conductors to train drivers to instructors. The interviews' structure was formed by varying the quality of questions from being descriptive/narrative, to being structural and imaginative. The variation of question types enabled an in-depth contextualization and elicitation of the participants' sense of safety, sense of meaning in their lived immersive experience, and clarification of how they experience the quality of an immersive safe space.

Table 2. Structure of Phenomenological Approach for Interviewing (adapted from Bevan (2014))

Interview Structure	**Method**	**Example of Interview Questions**
Contextualization by Eliciting the Lived Immersive Experience in IVR	Descriptive/Narrative Context Questions	"Tell me about sensing danger for the fire in the IVR training environment" or "Tell me how you identified the fire onboard the train in IVR"
Comprehending Participants' Sense of Safety in IVR	Descriptive and Structural Questions of Modes of Appearing	"Tell me about your typical interaction with fire onboard a real train" or "Tell me about the qualitative difference between sensing fire onboard a real train, with sensing fire onboard the virtual train in IVR"
Clarifying the Quality of a Safe Immersive Safety Training Experience	Imaginative Variation: Varying of Structure Questions	"Describe how you felt safe during the training episode in IVR" or "Describe what it was in IVR that made you stay on your toes for not causing damage through the fire"

In addition to the interviews, the IPA approach for analysis was employed to transcribe, line-by-line openly code interview data into focused coding grouping and identifying themes through a phenomenological interpretation following Smith et al. (1999) original guidelines. As a method, the IPA approach is rooted in a consistent tradition of phenomenology and the idea that the world is understood through our lived experiences and that it is the lifeworld that needs to be explored, contextualized, and thematized into meaningful narratives (Smith et al., 1999). Consequently, the IPA approach provides key features for conducting a phenomenological analysis that emphasizes meaning creation across direct expressions that are collected via phenomenological interviews. As such, the IPA approach was chosen for this study because it is consistent with (1) the overall phenomenological framing of this research, (2) the specific technique for data collection (phenomenological interviewing), and (3) the aim of conceptualizing the characteristics of safe spaces for immersive safety training. The overall process of the IPA approach for this study is depicted in Table 3.

Table 3. Interpretative Phenomenological Analysis (adapted Smith et al. (1999))

Analysis Phase	**Outcome**	**Code Example**
Transcription	Direct Transcriptions	N/A
Line-by-Line Open Coding	812 codes formulated closely to the original wording	*feeling a sense of safety, sensing danger, becoming comfortable*
Focused Coding Grouping	17 initial themes were extracted based on the most significant codes	*being safe from real fire, feeling safe from burning, becoming comfortable for doing mistakes*
Looking for Themes	Extraction and mapping of themes of feeling safe	*feeling safe* is associated with *being in a safe environment* that is *forgiving towards doing mistakes* that in reality *would have severe consequences*
Memo-Writing	46 memos for documented insights and interpretations	*"The virtual reality reminded me about the trains from the real reality so to speak. It felt real until I saw the virtual fire, you know, if it was a real fire I would feel the heat, sense the smoke, hear people screaming 'fire', and experience the energy on train. Now, I felt more safe about the situation because the fire was not real…"*

The specific IPA features employed for this study were: *experience*, *idiography*, which supports the central feature of *interpretation*. The *experience* feature focused the meaningfulness of the whole immersive safety experience with respect to the participants' lived safety experience, whereas *idiography* was concerned with how to understand the particular quality of safety or 'being/feeling safe' in the immersive safety training setting. Finally, *interpretation* here stressed the interviews, rather than only single words or single extracts, by navigating layers of interpretation that engages with the participants' immersive safety experience. This led to construction of themes that characterize the participants' lived immersive safety experience The analysis process was subsequently supported by using the software NVivo 12 to create grouping of codes, visual representations that map the codes into clusters, in order to create themes that characterize the immersive safe space in IVR – e.g., the code "feeling safe from burning" related to the code "being safe from fire" because "being" and "feeling" safe characterize the lived experience of the safe space. Finally, it was during the stage of axial coding that specific themes for characterizing safe spaces in immersive fire safety training were unveiled. These themes represent the results of this study and will be presented in the next section.

4. Results

This section presents the findings from the empirical case of immersive fire safety training in IVR, accordingly to the outcomes of the IPA process. The analysis unveiled four overarching themes that characterize the safe space of immersive fire safety training: *Sense of Authentic Hazard Recognition*, *Sense of Behavioral Responsiveness*, *Sense of Intersubjective Risk Perception*, and *Sense of Embodied Atmosphere*. Throughout the IPA process, the quality of experiencing safety in an immersive setting, was rooted in the participants' general awareness of the immaterial characteristics of virtuality (e.g., virtual fire cannot burn the participants' physical body). The quality of safety was thus more related to developing a sensibility towards what it means to be safe during circumstances of fire onboard trains, and how the immersive feeling can help exploring that quality in a safe space. Developing a sensibility towards what it means to be safe relates to both the development of procedural skills of extinguishing fire in an immersive setting, but also to developing subtle form of soft skills that enhance the ability of 'sensing' danger in a situation onboard a train.

The latter form of skills (soft skills) is also associated with the phenomenological view on embodying sensory perceptive skills are based on a pre-reflective mode of acting, whereas representations of such form of skills are considered as an intermediate step to understanding the feeling of safety or feeling of danger (Van Manen, 2016, 2017). At the same time, the immaterial characteristics of virtuality create sensory constraints for the participant in IVR, making the quality of realism for danger/safety experienced differently – e.g., if a participant stands close to fire onboard a train in the immersive fire safety training setting, he/she cannot feel the heat nor sense the smoke through his/her senses, but still, he/she can react to the situation because it takes place within a field of meaning (e.g., participants' pre-reflective familiarity with fire as being something potentially dangerous for passengers' well-being onboard trains). As such, characterizing safe spaces for immersive fire safety training emphasizes, in this study, themes that elaborate on the phenomenological sensation (e.g., a 'sense of') of experiential qualities of 'feeling safe'. The themes are now described separately in the subsequent sections.

4.1. Theme 1 – Sense of Authentic Hazard Recognition

The first theme refers to the characteristic of a safe space that helps IVR users to develop a sense of authentic hazard recognition. "Being Authentic" is a central theme of phenomenology that stresses the phenomenological idea of staying true to the original source of the sensed phenomenon, which simply can be translated into experiencing a reliable and accurate representation of the phenomenon (Van Manen, 2016). The situation of dealing with hazard during fire situations, requires a sense of authenticity because the situations might be experienced differently depending on from who's perspective it is perceived. If the

situation is perceived from a child's perspective, a sense of authentic hazard recognition might look very different than if it is perceived from an adult's perspective. Also, their reactions might vary: a child perhaps runs to the nearest adult to inform them about the fire situation, whereas an adult perhaps might instead inform about the fire situation with a loud voice so that everyone close by gets noticed. Moreover, the same logic is also applicable to the distinction of being a more experienced train personal to being a less experienced train personal – experienced in terms of having procedural skills in how to sufficiently sense and manage fire situations onboard a train.

Hence, in order to increase participants' safety awareness in fire situations that emerge during different circumstances onboard a train, this theme proposes that multimodal features of IVR need to be employed in a safe space to train participants in developing a sense of authentic hazard recognition. Drawn on recommendations from Seo et al. (2021), this theme proposes that the multimodal features might be designed to provide signage of emerging fire (e.g., color shifting, smoke), safety indicators (e.g., proximity and distance of being safe from fire), and dynamic sound that uses the entire spectra of frequencies related to fire (e.g., animated fire with wind). Moreover, as expressed by one of the training participants when asked about the need of hazard recognition, the features might have to be adapted to different levels of hazard recognition in order to become sufficient for training:

> *Sensing danger with fire is usually connected to what we see, hear, and smell… and yeah, the heat of course. In the VR training we cannot smell the fire but we can see the smoke from distance, but the sound is the same all the time. I am not sure if this is the same in a real situation* (P1)

Another participant expressed the importance of being able to experiment with different levels of hazardous fire situations without getting injured. The participant felt that it is meaningful to approach a fire situation in a 'wrong way' repeatedly, observing its consequences in the immersive training setting, without facing any 'real consequences'. The freedom of repeating mistakes without facing real physical consequences reinforces a perceived freedom in a safe space, which typically is a characteristic that Ruiz-Bravo (2024) depicts as the freedom of comfortably sharing experiences, thoughts, and feelings, whereas in this case, the perceived freedom is coupled with acting and interacting freely to develop a sense of authentic recognition. One of the participants illustrated this accordingly:

> *I felt safe in knowing that I can learn by doing and doing it [referring to the training scenario] wrongly without injuring myself or others. I could for instance observe how fire spreads on a train by standing very close to it without extinguishing it. The system [referring to the immersive fire safety training application] simulated the consequences before the situation restarted from the beginning of the training scenario again* (P3)

In summary, developing an immersive safe space that allows participants to experiment and develop a sense of authentic hazard recognition, might benefit from explicating the consequences of embodied actions caused by others onboard a train in a visual way (Pirker et al., 2020). This includes actions that are documented about fire situations in incident reports, which might include the triggered actions caused by traumatized passengers that escalate the hazardous situation, as well as the random actions of others. Otherwise, the feeling of authenticity might be based on too simplified or narrow fire situations that create a false sense of safety – 'false' in the sense that it becomes less realistic to happen during a real fire situation.

4.2. Theme 2 – Sense of Behavioral Responsiveness

The second theme refers to the characteristic of a safe space that provides interactive feedback mechanisms to enable a sense of behavioral responsiveness during fire situations. "Being Responsive" is a phenomenological mode of entering a situation with a pre-reflective attitude/mindset that underpins layers of

thought processes without becoming fully attached to their conceptual framing of a first-hand experience (Zahavi, 2018). This includes having a sense of behavioral responsiveness towards fire situations, as they emerge under dynamic circumstances which makes it crucial for train personal to be attentive and mindfully present (Pinheiro et al., 2021). The sequence of actions before, during, and after a fire situation, requires a situational awareness that is not solely based on procedural skills (e.g., routines for fire safety), but also behavioral skills that correct the behavioral response of train personal (Gruber et al., 2023). Providing feedback mechanisms that correct the behavior of train personal during immersive safety training, is thus crucial in order to enhance the body performance of participants with respect to qualities such as correct gesture, speed, reaction, and ability to handle fire equipment under stress (Conges et al., 2020). Moreover, using IVR technology as a 'gesture-based' technology (Al Farsi et al., 2021), makes it possible for instructors of immersive fire safety training to map multimodal features of IVR with a behavioral skills training structure that incorporates the participants' responsiveness through interaction, immersion, and involvement (Fromm et al., 2021).

Hence, in order to increase participants' situational awareness during fire situations that require attention and correct behavior among the train personal, this theme proposes that interactive feedback mechanisms of IVR need to be employed in a safe space to train participants in developing a sense of behavioral responsiveness. The set of mechanisms might be designed based on different types of IVR feedback, including: haptic feedback that reinforces locomotion (e.g., physically simulating the feeling of walking, running, away/towards fire), tactile feedback that augments the feeling of realism in a fire situation (e.g., perception of sudden air flow the nozzle of the fire hose), instructor-based feedback that is provided in-situ during an immersive fire safety exercise (e.g., instructors embodied avatars that are interactive and provide feedback in the virtual training space as), personalized feedback that adapts the content depending on the role and fire safety experience of the participant (e.g., individualized performance measures to improve behavioral skills), and also, in the future, a sufficient and safe thermal feedback mechanism for bidirectional thermal stimulus on the skin (e.g., an untethered real-time thermal display glove that reacts to the virtual body's proximity and distance to fire).

Moreover, as expressed by one of the participants when asked about the current IVR experience of performance feedback, feedback in the virtual training space must be provided with care, otherwise, it might feel too overwhelming and stressful if the feedback is provided simultaneously:

> *Sometimes it felt like we got too much information from the system [referring to the IVR application] at the same time… both through text and sound but also through images and signs… perhaps they should not come at the same time while doing the training, I don't know but it made me behave more stressed than when we had this training [referring to fire safety training] in the physical world* (P2)

Another participant requested guidelines for what is a 'correct' or 'incorrect' safety behavior during a fire situation onboard. Guidelines are typically helpful for regulating participants' behaviors (e.g., actions, reactions), both collectively and individually, as they provide normative instructions – e.g., do x and y in order to achieve z. Establishing guidelines does also reinforce the feeling of being in a safe space because participants can embody the guidelines as routines for fire safety procedures:

> *Following official fire safety rules is one thing, but I think that guidelines for managing unpredictable moments in a fire situation could help us, hm, get a better grip of how to solve problems with fire in different ways, but still feel secure about doing it in a right way* (P4)

In summary, developing an immersive safe space that helps participants develop a sense of behavioral responsiveness, might benefit from feeling realistic enough to understand the consequences of one's

actions in a real fire situation. In other words, acting according to guidelines that corrects one's safety behavior is also a question for evaluating the knowledge transfer of behavioral skills from the virtual fire safety situation to a real fire situation (Moraes & Machado, 2007). Otherwise, skill acquisition that occurs in a virtual setting for an enhanced sense of behavioral responsiveness might become misaligned and cause damage (Toyoda et al., 2022).

4.3. Theme 3 – Sense of Intersubjective Risk Perception

The third theme refers to the characteristic of a safe space that shares a social virtuality among IVR users to develop a sense of intersubjective risk perception. "Intersubjectivity" is a central theme in phenomenology that stresses the importance of building a 'bridge' between the personal and shared experience, the self and the others (Sokolowski, 1999). Other phenomenologists (e.g., Malpas, 2000; Van Manen, 2017) elaborate on intersubjectivity as a "field of perception", which can be translated into a space for perceiving phenomena (such as fire). During potential fire situations, having access to a shared field of perception brings a collective feeling of safety to the ones involved in the situation, especially because there are risks involved.

Risks within a fire situation usually cause physical harm and side-effects to the surrounding and passengers of a train. Being able to identify risks also requires that one can identify the risk factors and indicators during a fire situation, because risks can be caused by certain factors that occur before the emergence of a fire situation (e.g., obstacles for preventive measures) or after fire has emerged and started to spread itself on a train (e.g., complexity of limiting the spread of fire and smoke). Virtual fire safety scenarios in IVR needs thus to be designed as a shared space with a high level of detail about the setting in order to depict the underlying processes of a fire situation. That way, a shared safe space in IVR can be used by participants to encounter the realistic setting and develop an intersubjective form of risk perception together (Moraes & Machado, 2007; Makransky et al., 2019).

Hence, in order to increase participants' shared risk perception during a fire situation, this theme proposes that immersive fire safety space might provide training scenarios that engage multiple user perspectives (e.g., concerns, fear of fire, risk perception) for multiple risk assessment. Developing general features for multiple assessment in IVR has been discussed in prior IVR research (e.g., Makransky et al., 2019; Moraes & Machado., 2007) and can partially be used to draw inspiration from. For instance, visualization of well-known risks can be done to formalize a point of view that shows the level of vulnerability one might have towards encountering a risk (e.g., how plausible the risk is for the given situation). The complexity of such a feature might vary and range from basic figures and colors (e.g., triangles, squares, red, green) that indicate the value of a potential risk (e.g., 'false', 'true' risks), to complex multimodal information (e.g., animated signs and warning sounds). It is my understanding then that a intersubjective sense-making process could present a safe space with 'triggers' (e.g., risks) and 'emergent support' (e.g., perception of the risks) (Ruiz-Bravo, 2024) through affordances for shared risk of perceptions (or point of views). This was also reflected upon by two of the participants when asked what they think about dealing with fire situations in a team:

> *For me, I feel safe when we are more than one that handle fire situation because then we can collaborate to spot risks and their consequences if we do not act together* (P5)

> *In a real fire situation, there exists the possibility of communicating with colleagues onboard the train to manage risks that are perceived in different wagons. We can signal each other via portable devices and communicate with the driver as well, which gives us a feeling of safety* (P8)

Another participant expressed the importance of being able to see/perceive the fire situation from a passenger's perspective in order to empathize with them. The participant thought that it is difficult to handle the circumstances of which a fire situation emerges unless one is aware of the surrounding, the persons

onboard, and their potential support. Developing a sense of intersubjective risk perception might thus not only emphasize a bridging of employees' awareness of the fire situation, but also the passengers:

> *Many times, the passengers are supportive during emergency situations onboard a train. I imagine that they would also be supportive during a fire situation, you know, helping us out if they can and want… that would give us [referring to the employees] a feeling of safety as well… so perhaps we should train these situations [referring to the IVR fire safety scenarios] by looking at the problem from theirs perspective as well [referring to the perspectives of the passengers]* (P6)

In summary, developing an immersive safe space that allows participants to explore and develop a sense of intersubjective risk perception, might benefit from developing a risk protocol that is treated as a 'lived source' experiences (Zahavi, 2018). A 'lived source' refers to the shared spaces of which participants' lived experiences of managing risks and sharing their insights from the lived experiences over time, come from and can be shown for each other. This includes insights from both successful/unsuccessful attempts of identifying key risks during a fire situation, to gathered knowledge from other employees' experiences to stories that can be transformed into immersive tutorials on risk perception. Otherwise, the feeling of intersubjectivity might become locked to space and time during designated training sessions, whereas using the safe space as a medium for sharing lived experiences under secure circumstances, adds an additional dimension of meaning to the participants' overall training experience. Hence, the immersive safe space might, through help of IVR technology's capacity to simulate and visualize abstract risk perceptions, show the shared risk perceptions of users through designated training exercises.

4.4. Theme 4 – Sense of Embodied Atmosphere

The fourth and final theme refers to the characteristic of a safe space that provides an immersive mood that enables a sense of embodied atmosphere in the virtual environment. Both "Mood" and "Embodiment" are central themes of phenomenology (Van Manen, 2017). Embodiment as the 'living body' is, according to Merleau-Ponty (1962), the dynamic horizon of lived experiences, and the basis for perception – rather than being conceived as a mere object among other objects in the world. As such, the mood of an immersive safe space might take the shape of depth through immersion, and configure the boundaries of the safe space through the mood rather than visual cues. And although it is, in general, difficult to establish a feeling for an 'energy' or 'atmosphere' in a virtual setting – similarly to how people do in a physical room for instance (e.g., 'the energy of that room') – it is still valuable to explore the possibilities as embodiment in a phenomenological sense, allows the user to 'grip' (encounter) the dispositions of the safe space (e.g., the boundaries, rules, and affordances). Then the question becomes: how can such a process of embodiment occur in the immersive safe space?

For example, when embodying a mood in the physical world, one's way of acting is configured, but also configures, the mood of that space to reveal changes in the atmosphere through both subtle and explicit ways. Similarly, this theme suggests that a user can embody mood in the immersive safe space; a subtle shift in the atmosphere can for instance be embodied via change of colors or low-pitched sounds that emerge to create a certain mood for the fire situation (e.g., gloomy mood, happy mood, serious mood), whereas an explicit shift might be done by changing the virtual training space completely into a new setting with new design elements that are not similar nor representations of a real train setting. The fidelity – which is a design attribute that refers to the degree of detail and quality replicated in the design of the train environment – of such shift needs to be on a high level, physical (e.g., degree to which the spatial and sensory attributes of the environment are available for users' senses – (Champney, Stanney, Milham, Carroll & Cohn, 2017) and social/psychological (e.g., allowing users to believe in the realness of the immersive situation presented to them – see (Sinatra et al., 2021)).

By embodying the mood in the above-mentioned manner, the safe space is not necessarily any longer bound to given rules that might risk fostering a separatist atmosphere which scholars warn about (e.g., Ruiz-Bravo, 2024). Instead, the atmosphere might be used to enhance embodiment on a cultural level (rather than solely on a representational level – e.g., the virtual body representing an image of the physical body) by depicting the atmosphere of safety through the immersive experience of what it feels to be safe for that particular moment of fire situation (Haj-Bolouri, 2023). However, the atmosphere of a safe space might not always need to project a feeling of safety, but also have the capability to project a dissonant atmosphere that indicates emerging danger, which is embodied through the sensations of dissonance in the living body as the core medium. At the same time, it might be questionable to what degree one can experience atmosphere in the body as virtuality is based on immaterial characteristics (Du Toit & Swer, 2021).

Hence, in order to enhance participants' lived experience of embodied atmosphere in an immersive safe space, this theme proposes that the IVR environment needs to provide different sets of mood that can trigger the participants' familiarity of the intentionality of the mood and atmosphere (e.g., what phenomena the mood and atmosphere is directing to). This can include the intentionality of the atmosphere as directing to safety, danger, emerging risks. Here, IVR features that combine motion with multimodal information can be used to enhance the sense of atmosphere. Subsequently, when asked if the participants could elaborate how they experience the mood or atmosphere of a fire situation in general (according to their prior physical fire safety training experiences), two of the participants answered the following:

> *The atmosphere in a real situation might typically be a bit chaotic or messy, but sometimes it also depends on the circumstances… I mean, the mood might depend on how I feel, how stressed I get or if I have the nerves to be calm… but yeah, in general, it is a bit chaotic* (P7)

> *I work as an instructor, so I have only instructed the participants in fire safety and heard stories from others. But regarding atmosphere… hmm, I think it is a sense of danger that people feel. Danger and urgency* (P9)

Then when asked about how much the atmosphere might affect their fire safety procedures and how the feeling of a certain mood might either help/deceive them to act consistent, the instructors answered:

> *Yes, it affects the employees, especially if they are new and don't have any experience of handling fire on a train, they might let nervosity and feeling of danger affect them… so I think this training in VR is good because they can overcome that fear and still feel the danger somehow* (P9)

> *It can be both, I mean, the energy in a room during fire can give them [referring to the employees onboard a train] an adrenalin rush and make them more focused, but it can also lead to disaster if they only act upon emotions. But I get your question, the atmosphere is difficult to capture in a virtual reality… hmm… very interesting if we can do it properly though* (P10)

In summary, developing an immersive safe space that enables a sense of embodied atmosphere might benefit the overall fire safety experience by making it dynamic and 'living' in relation to bodily sensations. In other words, embodying a sense of atmosphere makes the complexity of feeling safety more organic as if it was a real fire situation the participants experienced. Their awareness of the situation might become directed towards their bodily lived experience of both the explicit and subtle nuances in the mood that affect their bodily actions and attitude (e.g., sense of being brave) under emotional conditions. Without the possibility of experimenting with a sense of embodied atmosphere in an immersive safe space, procedural skills that are acquired during the IVR training process might risk become detached from the energy surrounding the fire situation. If the detachment is good or bad for the overall knowledge transfer, is a question for further discussion.

5. Discussion

The use of IVR for fire safety training was evaluated through a phenomenological approach to interviewing training participants at SJ and conducting an interpretative phenomenological analysis of the interview material. The participants of this study were employees at SJ who work onboard trains and/or instruct other employees in fire safety training at SJ. The results of this study were categorized into themes for characterizing safe spaces for immersive fire safety training in IVR. Together, the themes incorporated a phenomenological conceptualization of what it means to develop skills (e.g., behavioral, procedural) that can enable a sense of authentic hazard recognition, a sense of behavioral responsiveness, a sense of intersubjective risk perception, and a sense of atmosphere.

Subsequently, the participants of the study had different opinions about the qualities of an immersive fire safety training, and they showed individual differences in their emotional experience of a fire situation. They were, however, unanimous on the advantages of immersive fire safety training in IVR as it establishes a safe space for learning by doing and experimentation. As for the current state of IVR technology and its capacity to mediate the different themes of a safe space, the majority of the participants believed that it is a good idea because it might offer more than instrumental exercises that are experienced as too simplistic and non-realistic, but it still lacks the proper elements that make the knowledge acquisition reliable to a real physical fire situation. As such, this section discusses the implications IVR fire safety training in light of the experience of realism and the emotional bodily experiences one might sense in safe spaces for immersive fire safety training, because both aspects (realism and emotional bodily experiences) are intertwined in what is experienced as being more or less ‘real’ when training for fire safety.

5.1. Experience of Realism during Immersive Safety Training

If we consider realism as a similar or collective result of the fidelity in every sensory modality that IVR technology offers, then it could be considered as a feature of the immersive experience (Kilteni & Slater, 2012). It could be the extent to which immersive safety training could resemble or seem like the traditional safety training or a real safety situation such as the ones illustrated in the fire safety training scenario. Secondly, with regard to the need of creating a multimodal sense of fidelity and a sense of realism that ingrains an immersive safe space, one needs to ask to what extent it is realistic to train fire extinguishing in any setting, be it IVR or the real fire safety training setting, where everything to the smallest detail is accounted for? – including wearing full protective gear or picking an already selected fire extinguisher capsule to combat that specific type of fire situation.

It could thus be argued that none of the fire safety training methods (e.g., traditional or IVR) described as ‘realistic’, are completely realistic in the sense of training on specific fire situations that could emerge in unpredictable circumstances on a train. It could be due to different types of simulations have different limitations and strengths, whereas the advantage of IVR is that you are thrown into a scenario that you need to cope with under secure circumstances without injuring yourself. But wouldn’t then the realism of that scenario, become to generic and less unique for a realistic fire situation?

From a phenomenological perspective, the ‘real’ (representing a sense of realism) is found in the lived experiences, rather than a mere representation or mirroring of it (Van Manen, 2016). Experiencing the real is afforded by our being-in-the-world, or our modes of coping with the world as it is brought forth to our first-hand lived experiences. Thus, a sense of authentic hazard recognition and a sense of intersubjective risk perception are characteristics that we live through, rather than perceive distinctively as separate things. For example, when perceiving emerging fire onboard a train, the feeling of being in a safe space starts to slowly transit into an unsafe space mode because fire spreads and can damage the surrounding. At that particular moment, one can consider the feeling of danger as necessary enough to set boundaries for the fire situation that triggers the user to react immediately without reflecting upon the immaterial characteristics of the fire (e.g., the fire is not real, I will not get hurt because this is only happening in the virtual world).

However, tradeoffs between the complexity (e.g., size and photorealism, as well as the amount of quality of sensory information and details that are designed and incorporated into the IVR experience) with the amount of the feeling of immersion and interactivity, might reduce the feeling of what we typically think is realistic during a fire situation (Norris et al., 2019). For instance, the sense of danger is in fact not correlated with a real danger in IVR as we know in beforehand that I cannot get burned by the virtual fire, whereas in a real situation, I might get burned and thus my danger is for the detrimental consequences of becoming burned. The realism of first-hand lived experience of getting burned might thus not be warranted in an immersive fire safety experience, as it would decrease the safety of trainees, whereas there is an overarching awareness of what it means to get burned. As such, the phenomenological interpretation of what is 'real' can only be situated within the pre-conditions of a fire situation's intentionality – e.g., the discourse of an IVR fire safety training scenario, where the 'realness' of the scenario is real enough for the purpose of the training.

For the reasons discussed so far, it might be critical to determine at the design stage what would take priority and would enhance the feeling of safety during immersive fire training, rather than providing the most 'realistically' looking environment. This is of course a difficult balance to achieve because fidelity and immersion increases acceptance and perceived usability (Sun et al., 2019), but as Salas et al. (2012) and Lowell & Tagare (2023) suggest, the physical fidelity is not as essential as the psychological fidelity or a sense of presence that is fostered through the customized design of the simulation and scenarios, and the provision of instruction, multimodal feedback mechanisms, and measure of performance. This indicates that a usability evaluation of an immersive safe space should be based on a lived experience of realism within the boundaries of the given safe space. An option to this would be to derive from a pure intellectual discourse around 'realism' that stands outside of the lived experience and judges what is real or not for the ones who are doing the training (e.g., the first-hand experience of the trainees). But a categorical understanding of what is real or not can be deceiving, especially when it comes to the emotional and bodily experiences of danger and safety.

5.2. Emotional and Bodily Experiences during Immersive Safety Training

In general, the experience of simulator or motion sickness can overlap with feeling stressed and disoriented in IVR (Adami et al., 2021). Bodily presence also depends on psychological and individual factors (De Lorenzis et al., 2023). Therefore, it is important to take the differences of emotional and bodily experiences into account when implementing safe spaces for immersive fire safety training. Developing a sense of behavioral responsiveness and a sense of atmosphere for an immersive safe space, might thus overlap with both emotionally and bodily experiential themes of discomfort and sickness. Emotional experiences of a joyful atmosphere could be undermined by the feelings of bodily discomfort, resulting in feelings of disorientation and stress. For example, establishing a safe space might lead to higher engagement under circumstances that are secured from dealing with fire, but at the same time, cause other kind of unwanted emotional and bodily sensations that are negative (e.g., distress, sickness). But how does an immersive safe space affect the embodiment of safety qualities such as safety awareness, risk perception?

From a phenomenological perspective of embodiment as the 'lived body' (Zahavi, 2018), it was interesting to see how the bodily perception' of some of the training participants became more focused, while for others, the embodiment of safety felt less focused as they considered the fire training to be too safe and thus not realistic. For example, in relation to perceptions of boundaries and designed support of an immersive safe space, guidance and visual cues for indicating emerging danger of a fire situation, were factors that affected components of Kilteni et al's (2012) sense of embodiment – e.g., sense of embodied agency in relation to identifying a risk and having the designed support (e.g., guidance). But the sense of body ownership might be difficult, from a phenomenological standpoint, to distinguish from evoking a sense of embodiment to the virtual body versus the physical body. For instance, as Merleau-Ponty (1962) elaborated, embodiment is not only about how virtuality allows the individual to resemble a shape of a body in a virtual space, but it is also

about the existential condition in which the body is the subjective source or intersubjective ground of experience. As such, an embodied act in an immersive safe space cannot detach the lived experiences from the virtual and physical as the lived body grips the emotional and bodily experiences in both worlds (Saker & Frith, 2020).

Moreover, bodily experiences can be augmented through for instance heating jackets to provide thermal feedback or vibration that stems from the training atmosphere, as well as other sensory feedback such as audio and olfactory feedback, which together potentially can enhance the feeling of safety/danger and engage the user in such a way that they take the immersive training more seriously and less of a mere game. This could also enhance the lived experience of a safe space with respect to emotional arousal caused through embodied atmosphere, leading to an increased bodily lived engagement with the safety situation, whether it is about fire safety or other forms of safety, the feeling of danger and safety body might be bodily perceived similarly (Buttussi & Chittaro, 2017). Furthermore, designing a safe space during immersive fire safety training, might consider whether preparatory training for learning how to stand, walk, act and interact with virtual objects could improve participants' emotional and bodily experiences during the training, because it would enable diversity of internationalities - e.g., some participants can focus on exploring the virtual environment and the surrounding, whereas others might be more focused on the task while others merely observe their bodily movements and how it influences their performance.

6. Conclusion and Perspectives

To conclude, this article is further evidence that IVR technology is a suitable tool for facilitating immersive safety training as it provides a natural physical safe space for safety training. This article further elaborated how IVR spaces can also mediate a sense of embodiment that nuances what it means to feel safe, rather than only focusing on the bodily safety in IVR. This was done through a phenomenological conceptualization of immersive safe space characteristics, by emphasizing how employees from Sweden's largest train operating company, SJ, lived the experience of fire safety training in IVR.

In line with previous studies that employ phenomenology for inquiring and conceptualizing technology-mediated experiences, this study thus expanded the scope of prior IVR studies by conceptualizing characteristics of safe spaces for immersive safety training into four themes: *Sense of Authentic Hazard Recognition*, *Sense of Behavioral Responsiveness*, *Sense of Intersubjective Risk Perception*, and *Sense of Embodied Atmosphere*. Although the themes focus the phenomenological ideas of Merleau-Ponty (1962; 1968), the themes are also grounded in narratives constructed from the phenomenological interviewing and analysis. This article suggests thus that the themes can be used through different perspectives.

First, the themes can be seen as carriers of both descriptive knowledge and normative knowledge; descriptive because each theme interrelates safe space characteristics with the lived experiences of interviewees' as they described them, and normative because the themes provide knowledge that can inform the design of immersive safe spaces for safety training. In relation to the latter form of knowledge (normative), the themes imply that the phenomenological conceptualization provides a sense of generalizability for experiences that focus safety training in IVR, rather than only dealing with fire safety in particular. For instance, the theme regarding a sense of intersubjective risk perception introduced the phenomenological notion of intersubjectivity, a notion which has been overlooked in research about VR safety training. With intersubjectivity, this article proposes that future research on safety training in IVR can design training environments that allow users to experiment with their own notions of safety and safe space characteristics such as setting boundaries, rules.

Second, because of the empirical limitations of this article, the article suggest that the themes should be evaluated in additional contexts of IVR safety training which deal with other kinds of safety situations than fire safety. For example, the themes provide general characteristics that might help researchers to plan for an

evaluation study on risk evacuation in IVR or embodiment of procedural learning for safety skills. Subsequently, embodiment in particular, being drawn on the phenomenological notion of the 'lived body', provides IVR researchers a rather different perspective on how embodiment becomes meaningful beyond being associated with a mere representation of the physical body. The sense of embodied atmosphere for instance suggests that IVR embodiment can both be seen as a resemblance of someone/something (e.g., a physical body), but also that IVR embodiment enables an apparatus for embodying the mood/atmosphere of a safety situation (e.g., the mood of emerging danger, the atmosphere of feeling mentally safe). Future research can thus explore how the phenomenological notion of embodiment proposed by this article can be used to re-conceptualize representational views on embodiment in IVR research.

Third and finally, there are certain practical implications that this article contributes with for future research on IVR safety training. For example, both designers of IVR training environments and designers of safety training scenarios can draw inspiration from the themes by: (a) looking closer at the subtleties of how safe space characteristics (e.g., boundaries, rules, affordances) can be turned into fidelity attributes for visualizing different scales being safe (e.g., very safe, safe, not so safe, vulnerable) dynamically during immersive safety training sessions; (b) extracting design implications that build upon the different thematic aspects to inform the design process; and (c) focus on how to evaluate the transfer of embodied safety skills from a safe space in IVR to a physical space in the physical world. The latter point is critical because if the participants feel too safe in the immersive safe space, then that might become deceiving for a real safety situation. At the same time, by developing a sense of safety in IVR, the safe space might also help the participants to stay calm during real safety situations. Henceforth, further steps of work would need to explore the knowledge transfer aspect closer.

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