Exploring Evidence of Presence in Gamified Virtual Reality Training to Empower Construction Professionals

Regina Maria Cunha Leite[1*], Yasmim T. Santos Ferreira[2], André M. Cordeiro[3], Lucas Gregory G. Almeida[4], Matheus A. Souza dos Santos[5], Luiz C. Machado[5], Marcio F. Catapan[4], Ingrid Winkler[2]

[1] *Federal Institute of Education, Science and Technology of Bahia, Construction Department, Salvador, Bahia, Brazil*
[2] *Institute for Science, Innovation and Technology in Industry 4.0*
INCITE INDUSTRIA 4.0, SENAI CIMATEC University - Salvador, BA, Brazil
[3] *Oswaldo Cruz Foundation - FIOCRUZ, Rio de Janeiro, Brazil*
[4] *Federal University of Paraná - UFPR, Curitiba, Brazil*
[5] *Federal Institute of Education, Science and Technology of Bahia - Lauro de Freitas, Brazil.*
**Corresponding author: IFBA;* regina.leite@ifba.edu.br,

The construction sector is inherently complex, dynamic, and hazardous, ranking among the industries with the highest rates of occupational accidents. Even experienced professionals, despite prior training, often struggle to effectively recognize and manage risks. The construction industry is one of the sectors that employs the most people in the country, and has a high rate of accidents and deaths, with working at heights being one of the main causes of this. The lack of training and awareness among workers so that they can recognize risk situations is one of the factors that appear to cause this situation. To obtain positive rates regarding the minimization of accidents, responsibilities must be met, through Regulatory Standards NR18 and NR35. This study aims to evaluate the effectiveness of virtual reality training for work at heights by analyzing users' sense of presence through both subjective and physiological measures. The study presents findings from a VR simulation conducted in a laboratory setting with 14 participants, all with no prior experience in such activities. Data was collected during and after the experiment to assess signs of presence. The results indicate that the practical application of VR generates a strong sense of presence among participants, suggesting that virtual reality may be a promising solution for training professionals in high-risk construction tasks. The contribution of this study is, in addition to advancing research on the practical use of virtual reality for training construction professionals, to prove the effectiveness of VR for training the target audience without risk to life.

Keywords: **Virtual reality. Gamification. Construction. Working at height. Safety training.**

1. Introduction

The construction industry is considered complex, dynamic, and dangerous [1]. Worldwide, it is one of the leading sectors for accidents at work, causing substantial economic losses, according to the International Labor Organization. Despite regulations and ongoing efforts, the incidence of accidents remains unacceptably high, indicating a persistent gap in current training approaches. Human factors, such as inattention and negligence, are responsible for many of the disasters that occur on construction sites. The interactions between human beings, the working environment, and working conditions mean that errors are a consequence when minimum safety standards are not applied. In Brazil, working at heights in construction has explicit requirements in Regulatory Norms NR18 [2] and NR35 [3].

Estremote and Oliveira [4] analyzed accident prevention measures in activities at height and noted that they occur mainly due to three factors: poor training, which in itself has an impact on workers' lack of awareness so that they can recognize risk situations and on the incorrect use of protective equipment; lack of inspection and monitoring by professionals in the relevant area, which has an impact on the degree of pre-existing risk; and negligence, especially in the safekeeping and conservation of equipment. Few studies combine physiological and experiential data to evaluate training realism and user engagement. Thus, the need for more effective training is evident.

In this context, virtual reality (VR) and gamification have emerged as allies in training for more conscious work at height. VR immerses users in a realistic, computer-generated simulation [5], while gamification applies game-design elements to non-gaming contexts to enhance motivation and engagement. When combined, these approaches can create highly effective and safe learning experiences [6]. Slater et al. [7] state that immersion and presence are distinct concepts and clarify that high technological immersion is necessary but not sufficient for effective participant presence; it also requires appropriate experiential design.

The results of a VR simulation with 14 participants with no experience of working at height are presented to verify the level of presence evidence of these individuals by analyzing the data collected during and after the experiment.

Therefore, this study aims to evaluate the effectiveness of virtual reality training for work at heights by analyzing users' sense of presence through both subjective and physiological measures.

This article is organized as follows: Section 2 describes the methods used; Section 3 presents the experiment; Section 4 analyzes the results and discussions; and Section 5 provides our final considerations.

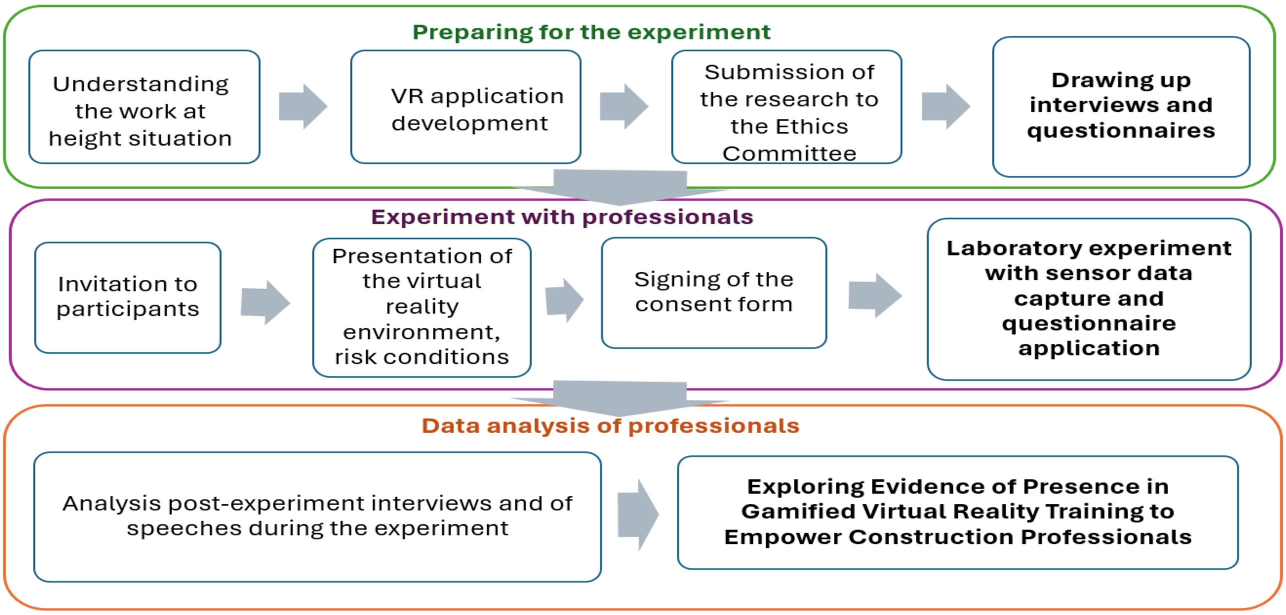
2. Methods

The methodological approach adopted is experimental, conducted in a laboratory without a control group. The aim is to refine the device for evaluation by experienced workers at heights. Figure 1 details the protocol for this experiment.

After understanding the situation, the experiment was prepared in detail, consisting of analyzing the reactions and perceptions of participants using headsets programmed for working at height in construction. The experiment used a Meta Quest 3 headset and a Samsung Galaxy Watch 7 to measure heart rate, which will be evaluated later. This article focuses on the analysis of the speeches collected during and after the experiment.

The research was submitted to the ethics committee for working with human beings in accordance with current legislation, Resolutions No. 466/12 and 510/16, and approved under opinion number 7.247.106. To carry out the research, the Terms of Free Consent for the participating public were used.

Figure 1: Research flowchart.



The target audience was made up of 8 building technician students over the age of 18 and 6 civil construction teachers, who are therefore professionals without prior knowledge of working at height but who are aware of the requirements imposed by the regulatory realism of environmental elements [8].

standards. The sources of evidence were the researchers' observations, audio data, and semi-structured questionnaires applied after the experiment.

All participants particularly enjoyed the weather changes and visual effects, which contributed to the authenticity of the experience. However, two mentioned that the lack of platform movement and the simulated wind detracted from the potential for immersion. Both wanted to feel, in addition to the visual and audio effects, the platform moving underfoot and the sensation of the wind against their skin.

This article presents and discusses the evidence of presence collected during the experiment. To this end, the following constructs will be observed:

(a) Adaptation/Immersion refers to the extent to which participants naturally feel integrated into the virtual environment, considering factors such as ease of adaptation and the perceived (b) Engagement measures the cognitive and emotional involvement of participants, with a focus on their attention to the tasks and emotional responses during the simulation [8].

(c) Interface quality assesses the usability and responsiveness of the tools and controls within the virtual environment, influencing user interaction and comfort [8].

(d) Sensory fidelity refers to the perceived accuracy and realism of sensory stimuli, including visual, auditory, and tactile feedback provided by the virtual system [8].

3. The Experiment.

The experiment used virtual reality to simulate the task of painting a 33-meter building facade from a suspended platform, aiming to assess user responses in a high-risk, immersive scenario.

The simulation goes through 4 stages that reflect real-world tasks: Application of Personal Protective Equipment (PPE), Workplace Assessment, Platform Operation, and Surface Preparation and Painting. Figures 2 and 3 show scenarios from this simulation.

Figure 2. Platform on the ground

To increase realism, dynamic environmental factors, such as changes in weather from clear skies to thunderstorms, were simulated using a specialized Unreal Engine 5 plugin. Realistic sound signals, including thunder and rain, accompanied these situations.

Figure 3. Platform at a height of 33 meters

The session began with a narrative approach to working at height, highlighting the importance of the tasks to be carried out and the time constraints.

The four phases of the simulation were explained: the choice of PPE, how to operate the ascent and descent of the platform, the need to observe the weather conditions, and the washing, sanding, and painting work to be carried out.

The participant was then taken to the location to put on the Meta Quest 3 headset, and the simulation began with audio recording during the experiment and heartbeat capture (Figure 4).

Gamification elements were introduced by creating decision-making scenarios under pressure, requiring participants to choose between adhering to safety protocols or maximizing task efficiency in adverse weather conditions.

Figure 4. The experiment VR

For example, they could stop working and lower the platform if the weather conditions became unfavorable, generating different simulated results. After the simulation, Meta Quest 3 and watches were collected, and questionnaires were administered.

4. Results and discussions

Evidence of immersion was collected during the experiment. We selected the feedback from some of the participants. Table 1 presents the participants' statements during the simulation and responses to interviews.

Table 1- Participants' statements during the simulation and responses to interviews.

	Speeches during the experiment	**Interview responses**
Adaptation/Immersion	*"Wow! It's high." (P11)* *"It's going up. That's crazy."* *"I'm not even going to look down there. Okay. Oh, okay. Now I get it." (P10)* *What a scare. I think so. Mercy! (P10)*	*"At first, I was very scared, because I'm afraid of heights, but I also found it difficult when I thought about the worker who actually does this every day, how dangerous it is" (P11).* *Walking on the platform. Because it swayed. Even though I knew it was secured by the steel bars, right? It still swayed and was a little scary, especially when turning to pick up the equipment. (P11).*

Involvement	*"I started sanding. ... It's halfway done. ... It's almost finished. ... It's finished. Now I'll apply the paint. ... It's started." (P1)* *"Oh no, man. Oh no. I don't believe it. How slow of me. The weather is starting to get dark, and I'm working there." (P10)*	*"It involves that challenge where you have to face the altitude and you have to, yeah… simulate the work, which is you sanding, cleaning, and, yeah, managing to do your job properly." (P9)* *You forget about the environment around you. You, you're there on the construction site" (P6)*
Interface quality	*"What is this button for?' (P10)* *"It's not loading. I'm fully inside the paint bucket and the red bar is… It keeps saying 'preparing painting material,' and it stays red the whole time. I can't make any progress with this… And here on the wall, it doesn't do anything either. I know I don't know how to paint, but this is too much. I should at least be able to splatter something here." (P4)*	*'I noticed some difficulty with certain mechanics, for example, the painting one, which I think is more about fine details to help improve the experience, you know? Like when it was time to prepare the paint, I wasn't really sure what to do. You had to put the brush in and pull…" (P3)*
Sensory fidelity	*"Everything is black, a simulated serious accident, you were the victim of a serious accident. Thank you... Did I die? I didn't die, right? "(P1)* *"Wow! What happened?" (P2)* *"Osh, did I fall?" (P5)* *"Guys, did I die then?" (P12)* *"Simulated serious accident. You were the victim of a serious accident because you continued working in conditions... Oh, no. I didn't notice." (P4)* *"Wow! It's all dark in here, you, see? (P7)* *It's cloudy! "(P11)* *"Man, man, it's going to rain. It can't be. Man, the weather here looks like it's going to be a downpour. "(P10)* *"Oh no, man. Oh no. I don't believe it. How slow of me. The weather was starting to get dark, and I was working." (P10)* *"..just when I started painting there was a thunderstorm... "(P4)*	*"It's a new experience, because I've never done anything like that. And it gave me a little adrenaline rush, like, it was a bit nerve-wracking and stuff." (P12)* *"And I believe that it is also important to pay more attention to the weather, right? Because at first it was just cloudy and then it started raining out of nowhere…. And then there was this accident." (P11)*

All the participants found the simulation immersive or realistic. Many were unfamiliar with virtual reality, which made them very focused on carrying out the tasks. After a short learning period, the participants were able to use the interface. Nonetheless, all participants reported initial difficulties with understanding the controls. Many felt confused by unclear progress indicators and suggested improvements to enhance guidance during the simulation.

All the participants particularly enjoyed the weather changes and the visual effects, which contributed to the authenticity of the experience. However, two of them mentioned that the absence of platform movement and wind simulation hindered the full potential of immersion. The introduction of these elements could make the environment even more dynamic and realistic.

This analysis is conducted through the lens of existing literature:

1. Immersion and realism

Phrases like *“Wow! It’s high.”* and *“I’m not even going to look down there”* reflect a strong spatial and emotional response, which aligns with Slater’s definition of place illusion, the sensation of “being there” in a virtual environment. According to Slater, presence emerges when users respond to virtual stimuli as if they were real, regardless of knowing they are not [9]. Slater [10] highlights that presence intensifies when users emotionally respond to the virtual environment as though it were real.

2. Engagement with the task

The sequence: *“I started sanding... It’s almost finished... Now I’ll apply the paint”* illustrates how users internalize the virtual task flow. Slater [10] suggests that presence is reinforced when the environment allows coherent, goal-oriented behavior that mirrors real-world logic.

Lamas [11] suggests that engaging in specific tasks within VR strengthens the sense of being “in” the experience.

3. Interface and interaction

Although technical issues like *“I know I don’t know how to paint, but this is too much”* may seem outside the scope of presence, Slater argues that sensorimotor consistency and plausibility are essential for maintaining presence. When system responses break expected patterns, the illusion of presence can be disrupted.

McMahan [12] argues that interface glitches can interrupt presence, while smooth, intuitive interactions help sustain it.

4. Sensory and emotional reactions

Heightened Emotions and Disorientation: Reactions such as *“Guys, did I die then?”* and *“Osh, did I fall?”* demonstrate behavioral realism, a key indicator of presence. Slater emphasizes that presence is not merely engagement, but a psychological state where users behave in VR as they would in real life situations.

Curiosity and Exploration Attempts: The question *"What is this button for?"* reflects active engagement with the environment. Slater notes that presence is enhanced when the virtual world responds appropriately to user actions, reinforcing the illusion that their behavior has meaningful consequences.

Spontaneous narratives and environmental integration: Weather-related remarks such as *"Man, it's going to rain."* or *"...just when I started painting there was a thunderstorm..."* illustrate how participants assign narrative meaning to their experience. This reflects the concept of contextualized comprehension, which is aligned with situated learning theory.

Strong emotional reactions have been recognized as core indicators of presence in virtual environments, especially in high-risk simulations where users respond to the virtual context as if it were real, an idea supported by both Maples-Keller et al. [13] and Slater [14], who emphasizes that authentic emotional engagement reflects the plausibility and immersive quality of the scenario.

5. Final considerations

This article presents the first results of a larger experiment involving professionals with no experience of working at height. In this research, it is believed that immersive technologies, when combined with elements such as gamification, physical objects, and storytelling, can improve the quality of the height training usually provided to construction workers. The aim is to further evaluate this technology to improve the model used.

The analysis reveals multiple types of presence that go beyond visual perception, including emotional immersion and task engagement. Key considerations include the importance of intuitive interfaces and environments enriched with realistic stimuli.

It is suggested that future VR experiences optimize sensory and narrative elements to enhance their formative and emotional impact.

As a limitation, the study involved 14 participants with no experience working at heights and no experience with VR.

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