Ux in Immersive Reality: The Power of the Users

Janaina Ferreira Cavalcanti(✉)

Universitat Politècnica de València, 46022 Valencia, Spain
jaferca@doctor.upv.es

Abstract. Repeated exposure to a sign can generate habits with it and, consequently, less attention to it. In order to prevent this, it is possible to make use of new accessories that make the signage more dynamic. On the other hand, the individual's behavior tends to change when he/she is in a dangerous situation, which makes the same individual behave differently in terms of a warning when there is a stressor load or not. For this purpose, an immersive virtual environment was generated, in which different warning variables can be set, as well as different types of hazard presence to evaluate the user's actions. This paper presents the evaluation of the users of the immersive environment. The results show that most users have different feedback to the signage depending on the degree of risk exposure. This study is of great importance for the prevention of occupational hazards, as well as for the creators and developers of games and extended realities.

Keywords: Virtual Reality · User experience · User-centered methodologies · Signage

1 Introduction

Accidents can generate big financial and social losses with serious, hard, and, sometimes, even irreparable consequences for people and companies. Studies show that every three-and-a-half second an European worker is forced to stay at home for at least three working days due to a labor accident. Due to the magnitude of the problem, any initiative to improve the current situation will be of great interest. In this context, current technological developments such as Internet, "smart" environments, virtual reality (VR), and others affect not only the work, bringing new challenges to the safety of workers [1] and opportunities to improve safety training.

The behaviour of a person is determined by the context in which he/she develops an activity. So, when thinking about behaviour and performance is necessary to consider the interaction between the person and her working environment. In order to investigate human behaviour and its relation to accidents and human errors is important to observe individuals working during critical situations, taking account of performance, emotional and physiological levels [2].

For the other side, over the past decades, there has been a movement in the industry to improve work safety practices based on previous experiences. This happens based on the premise that personal experiences and memories strongly influence the perception of

A. Marcus et al. (Eds.): HCII 2023, LNCS 14031, pp. 47–56, 2023.
https://doi.org/10.1007/978-3-031-35696-4_4

risk. A challenge faced today is to transfer the knowledge gained from past experience to citizens who may not have witnessed serious works incidents and as a result may fail to recognise the potential injury associated with the job.

In this sense, Virtual Reality (VR) can offer us experiences with no limits, but if VR environments and interactions are not designed and implemented properly, users have the risk of feel frustrated and or even sick [3]. For obtaining good results is mandatory provide a Human – Centered design. Immersive virtual reality also offers an environment without distractors. In this context, we conceive safety as a promising domain for virtual reality because we will be able to develop more engaging learning experiences in immersive environments without exposing trainees to risky situations. VR hardware and software can be used to enhance learning processes, being able to activate human senses and feelings and to improve memory performance.

User experience (Ux) and usability are widely used tools for quality testing [4]. They allow obtaining valuable information from the interaction with the user, for a better adjustment, redesign, and/or improvement of the system based on the opinion and typology of the end user [5]. Usability is related to the ease of use of a product by an individual [6] and its measurement should be based on the quality of manipulation, the degree to which a product can be used by specific individuals to achieve specific objectives effectively, efficiently, and satisfactory manner [7]. Usability problems lead to reduced utilization, lower rates of retention, and increase frustration [8]. On the other hand, the term user experience, popularized by Don Norman, includes the feelings and meaningful aspects of user interaction with machines and services. It is related to the product handling experience ("How did I feel using this?"). Usability directly influences the user experience [9].

Following these aspects, this paper presents a gamified immersive virtual environment developed to evaluate human behaviour in risk environments, and to improve safety. It is organized in the following manner: Sect. 2, describes information's about gamification and Usability, the main topics of this project; Sect. 3 presents Game for Safety (GfS); the material and methods are presented in Sect. 4; Sect. 5 presents the results and discussion; and in Sect. 6 conclusions and outline of future works are presented.

2 Gamification and Ux Research

Researchers have recently paid attention to the playability and appeal of gamification techniques for human behavior assessments. Coming from the video games and games, but differing of them by their non-entertainment purpose, these techniques are also becoming an important tool for training because they can be closely aligned with the design of good educational experiences. In addition, they allow players to naturally produce rich sequences of actions while performing complex tasks by drawing on their competencies [10].

A game environment is full of stimuli. Gamification techniques are interactive, which is a key for motivation [11].We could say that features of games are directly associated with human desires: reward, status, success, self-expression, competition and others, but for an appropriate result is necessary to pay attention to the challenges. They couldn't be so easy or so difficult to keep players/learners engaged. In this way, the safety training could be supported with progressive levels and scores [12].

Another strong point of the serious games is that they could help users to build richer cognitive maps. This feature, highlighted by Chittaro [13] allows different types of special knowledge acquisition.

Based on this, VR games could provide a comprehensive training environment.

Ux Research

Ux Research is a process that aims at the optimization of a product or system. Thus, Ux research aims to prevent usability problems. Since usability problems lead to reduce utilization, decrease user retention, and increased user frustration, this is an important and essential tool for product success [14].

When we think of usability, we must consider interactions that are usable, safe, effective, and comfortable interactions, easy to learn and with a low level of error occurrence. To this end, it is necessary to take into account the performance of users while interacting with the product (e.g., measuring the time to perform a task, the level of perception, and others) [15]. It is also necessary to take account the affective responses elicited by a product, which are classified according to the user´s emotional state, which are dynamic and time-dependent.

Thus, taking into account the usability objectives mentioned above, it is important to proceed to key questions to address each objective. That is, when we think about:

- effectiveness - which says how good a system or product is at doing what it is supposed to do;
- efficiency - which refers to the way a system helps users to perform their tasks;
- safety – intended to protect the individual against dangerous conditions and undesirable situations;
- usability - which refers to the extent to which the system provides the right kind of functionality so that users can do what they need or want to do; V. learning - which deals with the extent to which the system provides the right kind of functionality so that users can do what they need or want to do;
- learning - which deals with how easy it is to learn to use a system or product;
- recall - which is related to how easy it is to remember how to use a system once it is learned.

Consequently, we must think about key questions such as, for example:

- Is the system capable of enabling people do their work efficiently, access the information they need, buy the goods they want? When we think of efficiency, for example.
- After they learn to use the system, are they able to sustain high performance in their tasks, if we think about efficiency?
- Is the system or product able to prevent users from making serious errors, and, if they make any errors, is it possible to heal them easily? if thinking about the security objective
- Does the system provide an appropriate set of functions so that users can do what they want? In terms of usability;
- How easy is it and how long does it take for the user to start performing their activities? If we think about learning;

- What help interface does the user have to remember how to perform the tasks they don't have to do often? When thinking about memory

This approach allows us to evaluate the performance of the products.

3 Game for Safety

Game for safety is an immersive environmental virtual game simulating an office setting in which a recent incident occurs, with a single, seamless collection and no choice of routes. This allows decision-making in the environment to focus only on hazard-related tasks, reducing the excess of items and abundance of information that can generate noise in information processing. On the other hand, in relation to cognitive load, the tasks generated in response to the hazard are mandatory.

The environment is adopted by two zones: a training hallway and a main room. These are detailed below.

Training Hallway
The training corridor is located at the beginning of the stage and continues its dual function: to convey a background story and to familiarize the subjects with the environment and its functionalities (controls and keyboards, for example). It has the same floor, ceiling, and walls as in the main room. On it, there are signs informing about an incident that occurred in the office, the necessary commands for navigation, the subject's task to act in connection with the obvious dangers (eliminate fire, dry the floor). In the end of this hallway, a signal offer the possibility to follow and begging the experience or go back and train once more.

The Fig. 1 shows a view of the training hallway.

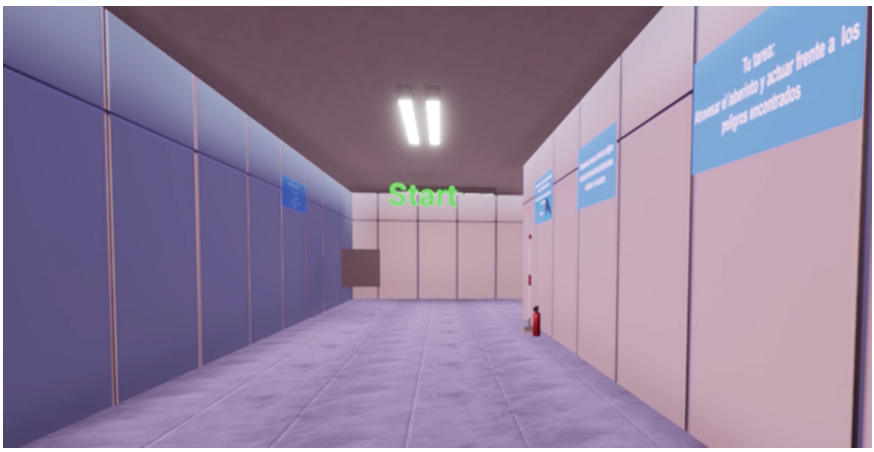

Fig. 1. Training hallway

Main Room

The main room is a linear path with curves where as the player advances, he is confronted with dangers and elements found in an office as can be seen in the diagram below (Fig. 2). The participant does not know which hazard he will encounter, he only becomes aware of it as he makes the curve and visualizes it in the section where he is. Such a factor serves to maintain engagement with the narrative and increase the element of surprise.

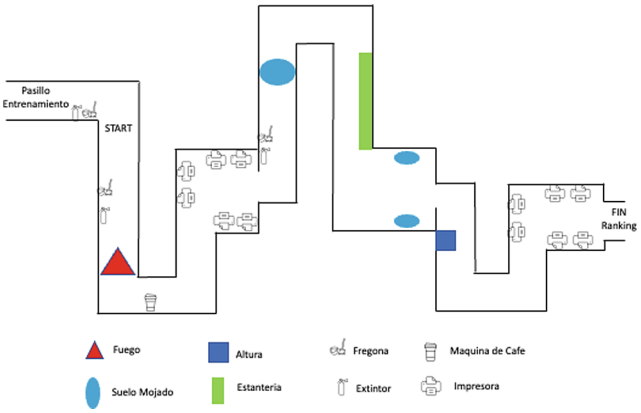

Fig. 2. Diagram with office hazards and equipament

Some hazards occupied the entire width, so that in order to pass through them, users would have to resolve them (extinguish the fire and dry the floor). On the other hand, for decision making, there was in the height hazard a wooden plate (board). The user should choose to pass through the fixed floor (diverting his path a little) or through the board (following the direct path).

Near the hazards that require a task (to cure the problem) there are two tools (one correct for the action and one incorrect), and a sign indicating which tool option requires the hazard that is nearby. In addition to these signs, others are distributed identifying the visible hazards, the risks that may occur (falling objects), and informing of equipment failures.

With the aim of stimulating stress (more proximity to the real scenario of use of the posters) but without general discomfort or harm to the user, we made use of some artifices such as:

- Signs: the blurring of the signs remained, but with less intensity.
- Fire extinguisher: when dropped to the ground, the user could not pick it up again. There were only 3 fire extinguishers in the environment, but only 2 could be used to remove the fire, since the last one was located after the fire flame, and the player would not be allowed to advance the fire without extinguishing it.
- When approaching the wall the user would see everything in the color of the wall, as information that it had collided. This action was given to add a sense of uncertainty.

If that happened, the participant should then look to the opposite side and press the button to advance.

The gamification strategy adopted is the competition between users. In this way we added a leaderboard/ranking among the users was created. The ranking was only presented at the end of the game, but at the beginning of the game the player was aware of it. In addition, as the experience was to be applied within a coexistence network, the ranking table allowed to promote interaction between users, even if they were not all together at the same time.

In terms of interaction, to better fit the user's technological profile, the game allowed the player to choose the speed of movement within the environment. In addition, the user was free to change it when he/she felt necessary, even after being immersed in the environment, choosing to use the left controller (faster and more sensitive, so that if you put your finger up, it moves) or the right one (slower and you need to press).

4 Materials and Methods

Taking into account the principle of subjectivity [17] that comments on the necessary user participation, but with the care that this is guided to avoid deviations from the learning objective, the sample was warned to pay attention to the signal along the way.

From a methodological point of view, we adopted a user-centered design. This study privileged measures of behavior (attention, performance, errors and learnability) and satisfaction (subjective responses after game interaction). The experimental session was divided into 3 stages: (1) pretest survey; (2) immersive simulation session; and (3) per-test survey, in English or Spanish (user's choice).

The pretest survey was designed with some points in mind.

– the questions had to be clear and organized in a cohesive way so that the individual could answer them alone;
– they should be designed in a homogeneous way. Thus, when using a scale, they should all start, for example, from the most assiduous to the least assiduous.

The experimental passes took place in the laboratory with a free area of 2.40 m x 2.0 m for free movement and locomotion of the user and happened from 2022, April until 2022, July (one academic term). Participation was voluntary and participants were free to leave the task whenever they wished. The immersive experience took place seated, in first person and without sound to maintain the user's freedom to express their doubts and opinions at any time. It had an average duration of 15 min. The character movement adopted is lineal character movement. It consists of making the character move forward immediately when the user pushes the forward button.

Components

Regarding the components required for this proposal, we took into account two premises: (a) implementing a device system that allows easy use anywhere and is easily recognized, familiar and affordable; (b) technological devices, tracking and mobile systems with a high degree of accuracy in stimuli reproduction to create a sense of presencea.

Based on this, was used sensor-type HDMs for VR headsets, HTC Vive headset. It consists of a headset with two controllers and two base stations that emit infrared pulses at 60 Hz, providing submillimeter tracking precision to the headset and controllers. The headset has the following characteristics: two OLED panels, each with a display resolution of 1080 × 1200 pixels per eye update at 90 Hz cover a send out horizontal and vertical infrared laser sweeps spanning 120° in each direction, a mass of 470 g, G-sensor, gyroscope, proximity, remote control with a battery with a range of 6 h of play, and SteamVR tracking sensorsb. The differences in time at which the laser hits the various photodiodes allows recovery of the position and orientation of headset a.

HTC Vive has development compatibility with the Unity and Unreal Engine 4 game engines. For this work, we chose Unreal because of its more straightforward coding method (C++ coding allows the possibility of coding through blueprints and Visual Studio). Unreal is developed by Epic Games and is free for use for academic purposes.

5 Results and Discussion

Responses were labeled with all respondents and questionnaire identification numbers. The sample was composed by 50 individuals (30 males and 20 females). The age range was between 41 and 50 years old (36%); 18 to 30 years old and 31 to 40 years old (22% each) and the remaining 20% between 51 and 65 years old.

In terms of education, the level of study ranged from a high school diploma to a completed doctorate.

For the evaluation and analysis of the data we made use of the Welch t-test (also known as "t-test for unequal variances" or "Welch's t-test for unequal variances"), thus, of the difference in the valid sample of the quantity of men (x = 30) and women (y = 20). In this way we were able to maintain the assumption of normality of the population sample with unequal variances.

The characteristics of the users that can influence the results obtained in the experience are:

- all are smartphone or tablet users, but 54% of the sample never play games on the devices;
- in relation to the use of technology our sample is classified as digitally literate (x = 100%), making daily use of Tablet, computer or Smartphone, but mostly not a user of video games (x = 78%), and not a user of VR technology (x = 48%);
- of gamer profile, although most of our sample is classified as explorers (60%), we have present the 4 types of profiles of the Bartle classification as can be seen in Fig. 3.

Considering the presence, we used the subjective measure through the evaluation of the ITC- SOPI questionnaire. The mean (MD) and standard deviation (SD) of each dimension were calculated, resulting in the following results:

– spatial presence: MD = 3.79 and SD = 0.53;
– engagement: MD = 3.99 and SD = 0.5;
– ecological validity: MD = 3.26 and SD = 0.75;

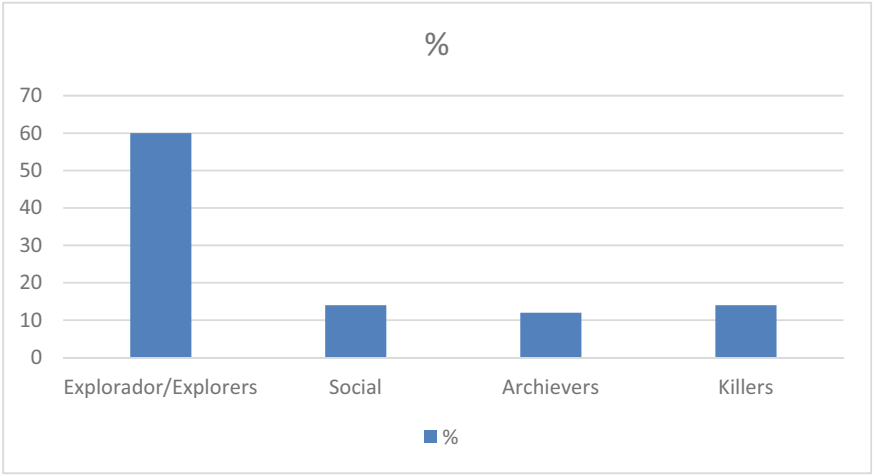

Fig. 3. Perfil Gamer

– negative effects: MD = 2.36 and SD = 0.87.

We also proceed to conduct presence using the count of user response. A total of 218 counts were considered valid. It stands out the fact of a higher perceptual count in actions near the hazards considered perceptible and of higher degree: fire (58%) and height (21.6%).

As for the negative effects, it is worth noting that, at times, the environment had a blurring effect, to encourage the idea of accident. This fact generated a bias in the answers to the question "difficulty to focus", in which a little more than half of the respondents (55.1%) affirmed to have it in a slight way.

The analysis results in the identification of experiences that illustrate satisfaction.

The data obtained showed that learning and memorization of the system was considered by 43% of the sample as sufficiently intuitive and easy to use.

Efficiency was considered good by 57% of the participants, but to improve performance, it is necessary to fix insignificant problems. The game was also considered safe and effective.

In addition, when evaluating the dates it was possible to realize that the Game for safety was considered "Moderately interesting" for most of the participants, and overall rated as 8–10 recommendable.

In relation to the signs In general, the signs with LEDs (technological variable) were more interesting to the users. In terms of the color of the turn signal used, there was no difference between white, red or yellow light. However, the LED position on the sign was of great relevance to the users. According to the data, users find the sign more interesting with the presence of the LED around the pictogram.

Based on these dates and the opinion expressed by the subjects it was possible to conclude that the Game fos Safety achieves its objective. The environment, in addition to motivating users to participate in the activity, allowed for a good evaluation of the different signage and danger levels.

6 Conclusion and Future Works

VR system enables users to physically walk around objects and touch them as if they were real. The possibility of designing first-person, fully immersive experiences with high-quality visualizations, the advanced interactive capabilities, connectivity and flexibility offered by modern VR solutions can impact in a very positive way in safety education.

The results suggest that the possibility of evaluating cause and effect constitutes a powerful argument for the use of an immersive virtual environment. Additionally, the engagement produced by gamification stimulates training tools. Motivators in a virtual environment consist of better adjusting objectives to user profiles rather than enhancing elements. This happens, for example, because the system requirements of a person with game familiarity differ from those of a person without game familiarity. Game mechanics and the virtual environment therefore provide a level of engagement and interactivity that makes it a promising tool in any phase of the design process.

Immersive virtual reality, in our opinion, is a very adequate and important tool, since makes possible immersive learning, contextualized content, living a more realistic experience, without risks, flexible, at reduced cost if compared to being reproduced in reality. It makes possible build optimized, first person virtual safety training, engaging, personal, and believable.

This work should empower authorities to start pilot projects to introduce this methodology/technology to prevent accidents and safety.

References

1. Smith-Jackson, T., Wolgater, M.S.: Potential uses of technology to communicate risk in manufacturing. Hum. Factors Ergon. Manufact. **14**(1), 1–14 (2004)
2. Olander, J., Ronchi, E., Lovreglio, R., Nilsson, D.: Dissuasive Exit Signage for Building Fire Evacuation. Appl. Ergon. **59**, 84–93 (2017)
3. Cavalcanti, J.F., Duarte, F.C.A., Ayabe, R.C.F., da Silva, A.G.B.: Virtual Reality and Ergonomics: Making the Immersive Experience. In: Soares, M.M., Rosenzweig, E., Marcus, A. (eds.) HCII 2021. LNCS, vol. 12781, pp. 158–170. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-78227-6_12
4. Organización Internacional de Normalización: Ergonomía de la inetracción hombre-sistema. Parte 11:Usabilidad, Definiciones y conceptos (ISO 9241–11:2018) (2018)
5. McNamara, N., Kirakowski, J.: Functionality, usability, and user experience: three areas of concern. Interactions **13**(6), 26–28 (2006)
6. Thies, K., Anderson, D., Cramer, B.: Lack of adoption of a mobile app to support patient self-management of diabetes and hypertension in a federally qualified health center: interview analysis of staff and patients in a failed randomized trial. JMIR Hum. Factors **4**(4), e24 (2017)
7. Norman, D., Miller, J., Henderson, A.: What You See, Some of What's in the Future, And How We Go About Doing It: HI at Apple Computer; Association for Computing Machinery: New York, NY, USA, (1995)
8. Fonseca, D., Redondo, E., Villagrasa, S.: Mixed-methods research: a new approach to evaluating the motivation and satisfaction of university students using advanced visual technologies. In: Stephanidis, C. (ed). Universal Access in the Information Society, vol. 14(3), pp. 311–332, (2015)

9. Quitana, Y., Fahy, D., Abdelfattah, A.M., Henao, J., Safran, C.: The design and methodology of a usability protocol for the management of medications by families for aging older adults. BMC Med. Inform. Decis. Mak. **19**, 181 (2019)
10. Villegas, E., Fonseca, D., Peña, E., Bonet, P., Fernández-guinea, S.: Qualitative assessment of effective gamification design processes using motivators to identify game mechanics. Sensors **21**, 2556 (2021)
11. Connolly, T.M., Boyle, E.A., MacArthur, E., Hainey, T., Boyle, J.M.: A systematic literature review of empirical evidence on computer games and serious games. Comput. Educ. **59**, 661–686 (2012)
12. Lavoué, É., Monterrat, B., Desmarais, M., George, S.: Adaptive gamification for learning environments. IEEE Trans. Learn. Technol. **12**, 16–28 (2019)
13. Chittaro, L., Rannon, R.: Serious games for training occupants of a building in personal fire safety skills. In: Proceedings of the 2009 Conference in Games and Virtual Worlds for Serious Applications, VS-GAMES, pp. 76–83 (2009)
14. Cavalcanti, J., Valls, V., Contero, M., Fonseca, D.: Gamification and hazard communication in virtual reality: a qualitative study. Sensors **21**(14), 4663 (2021)
15. Rebelo, F., Noriega, P., Duarte, E., Soares, M.: Using virtual reality to assess user experience. Hum. Factors **54**(6), 964–982 (2012)
16. Cavalcanti, J.F., Soler, J.L., Alcañiz, M., Contero. M.: Educational application of virtual reality in safety training. In: Inted2017 Proceedings, pp. 9261–9266 (2017)
17. Belikova, N.Y., Vaskov,M.A., Zritneva, E.I., Afanaseva, O.O., Litvinova, E.Y., Azhiba, M.A.: Formation of a developing educational environment as a condition for socio-psychological interaction of subjects in educational and pedagogical space. In: Dilemas contemporáneos: educación, política y valore, 6 (2019)