Reflecting on interaction spaces in public immersive installations

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Abstract. Immersive experiences within public spaces offer significant educational and recreational potential, yet they remain unexplored in developing optimal experiences. The aim of this work is to pinpoint pertinent user experience elements crucial for user engagement in such interactions. Furthermore, this investigation establishes correlations between identified UX elements from two public installations in Brazil and strategies derived from the literature review for overcoming potential interaction obstacles encountered. The work analysis consists of codifying data from events attendees and staff teams performing 138 citations categorized into eleven UX aspects. Ultimately, the findings of this research point out strategies for empowering designers of immersive experiences to craft more enriching public journeys for all stakeholders involved in immersive public installations.

Keywords: interaction spaces · public installations · immersive installations · virtual reality

1 Introduction

Virtual Reality (VR) emerges to allow individuals or groups to engage in sensory, motor, and cognitive activities while immersed in a digitally created environment, which can either be entirely fictional or a simulation of the real world [9]. Initially confined to laboratories, VR has undergone technological evolution and consequent cost reduction, leading to increased interest in developing VR-based content for the general public [5]. Given the various types of interactions that VR systems offer users, and the ongoing development of new interaction types, continual studies into user experience are essential [8]. Furthermore, research suggests that understanding the factors contributing to user experience is crucial for designing more effective virtual environments [3].

However, although the numbers are growing, there is still a small amount of research on how users experience the spaces created using this technology in public spaces. Recent research [6, 10, 11] have focused on the practices, experiences, and perspectives of professionals working in museums using VR. As for challenges, the main point raised was that immersion is typically designed for one person to use at a time, which isolates the user from the rest of the environment and limits their ability to engage in social interactions. Additionally, we can mention the large number of people circulating the installations, as well as the frequent queues that form quickly and often discourage experimentation.

In this direction, identifying which user experience (UX) aspects are emerging as barriers from this public and immersive scenario is becoming challenging. Therefore, this work aims to compile and analyze data collected from both literature and the experience of mediators of immersive installations. According to the lessons learned from this study we expect to inform researchers and designers of immersive public installations to be aware of the main challenges and potential strategies that can positively influence audience engagement and experience.

2 Background

The theme of this study consists of experiments in VR in the context of public spaces. Because of this, we rely on both directly related VR research and those that do not address the mentioned technology but make use of various interactive installations and bring relevant elements to the problem raised in this study.

Brignull and Rogers [2] discuss people's resistance to engaging in public interactions. To this end, they developed a system called "Opinionizer" in which people add their views and opinions through a keyboard, and the added content is projected on a wall. In this case, the motivation to interact starts with an attractive image and a phrase or question. Thus, the authors define that it is indispensable for public interaction to have a purpose, be easy to understand, execute, and have its transmission highly visible.

In Wouter et al. [12], based on the public installation "Encounter", which translates body movements into video and audio, the description of the honeypot effect is presented as a spatiotemporal model. The triggers for the experience, in addition to its powerful audiovisual feedback, included online advertisements, spokespersons circulating near the installation, and contracted dancers performing group choreographies to demonstrate its functionality. The authors delineated the various roles that users adopt, as well as the trajectories they pursue. The transition between roles is heavily influenced by social interaction with other individuals.

Gentile et al.'s study [4] demonstrates how passive audiences affect engagement in experiments conducted in public spaces. The experiment consists of an avatar that appears on the screen when a person approaches the display and interacts with other on-screen elements through gestures in the air and provides various information. The analysis revealed that users may discontinue interaction and return when there are no other individuals present.

In Alallah et al. [1], the study showed that inputs that require less noticeable gestures to operate are more accepted by both observers and performers. However, it was noted that different perspectives impacted the perception of the social acceptability of input types.

In Mai and Khamis [7], the authors focused in modeling user behavior, and used the audience funnel, which describes the stages of interaction.Regarding attention capture, two phenomena are mentioned: the Honeypot effect, where a user's interaction with the setup serves as a stimulus to attract the attention of other people, and the landing effect, in which a person passes by the display, stops, and returns to the location.

In addition to the headset, a poster encouraging its use, its controls, and a screen displaying the user's view, a 2-square-meter area for movement was marked.

The experiment conductors observed the interactions remotely and measured the duration of HMD usage.

When someone showed signs of leaving the space, the experimenter appeared and recruited them for a semi-structured interview. Another finding was that there is no subtle interaction phase for VR devices, hence the suggested name change does make sense. Furthermore, it was observed that people need to understand the purpose of this type of interaction and what to expect from immersion, so designing self-explanatory systems is necessary to avoid experiencing interruption.

Finally, Greuter et al. [5] draw upon their experience with designing immersive Virtual Reality installations in public spaces to outline the segmentation of interaction spaces into different frames. They also identify various user roles within each frame and propose eight tactics to aid designers in facilitating user's transitions between these roles. These tactics are as follows:

- T1. Use physical props: This refers to the incorporation of physical embellishments aimed at expanding the virtual environment, thereby rendering it more tangible and consequently heightening user engagement.
- T2. Increase propensity for immersion: Offer intricately designed virtual settings crafted to captivate participants throughout the experience and distract them from the audience.
- T3. Share the VR content: Present the immersion content to other individuals in the interaction space who are not using the HMD.
- T4. Use the queue time to train VR Skills: Even individuals with prior VR experience can benefit from this, as certain experiences may necessitate specific movements or actions. it is important to emphasize that this training usually takes place outside the immersive environment.
- T5. Immerse users before the VR experience begins: Incorporating users who are not wearing the HMD into the immersion has the potential to benefit all participants. It helps those waiting to understand the mechanics of the experience while adjusting to the virtual environment. Moreover, it kepng them engaged, preventing any disruptions to the immersion of other participants.
- T6. Employ other users: Non-HMD wearers can play a role in relieving facilitators by acting as protective barriers against physical space risks or by assuming roles within the immersion experience.
- T7. Accessible VR equipment: offering touch interaction stations with the equipment has the potential to draw more people to the immersion area and encourage them to become potential participants.

– T8. Customize exit and return strategies for different user roles: Enabling users with various roles to exit the immersion area effortlessly can enhance their experience by offering a sense of freedom in movement, while also preventing certain individuals from hindering the transition of others to roles closer to the participant.

Lastly, we observe that tactic T2 exclusively addresses aspects of game design, whereas all other tactics focus on strategies aimed at maximizing user experience during the public immersive interactions. Table 1 summarizes the main contributions of each mentioned work for this study.

Table 1. Summary of interactive experiences in public installations.

Work	Public interaction	Triggers to engage	Artifacts used for the experience
[2]	Non-immersive	An image and a phrase or question that are legible from about 5 meters away	A keyboard and a projection screen approximately 6' wide by 4.5' tall
[12]	Non-immersive	Online advertisements, spokespersons circulating near the installation, and dancers performing group choreographies	A large LED screen, archways with sensors and three 5x5 meters dance zones
[4]	Non-immersive	A screen that displays an avatar when a person approaches	A 32-inch LCD monitor with a Microsoft Kinect sensor
[1]	Immersive	Input modalities less noticeable are better	Head worm displays (AR and VR displays) with head movements, hand gestures, ring, voice and touchpad
[7]	Immersive	Honeypot effect, landing effect, posters, sharing the user's view interaction	Head mounted displays
[5]	Immersive	1 tactic (during game design) and 7 tactics (during interaction)	Head mounted displays

3 Immersive installations of the Discovery House

Discovery House is an interactive museum that receives visitors mainly from public schools as well as performs itinerant events.

"WindyVR", as shown in Fig. 1, simulates the real scenario of windsurfing in a sector of the Marine Extractive Reserve (RESEX) of Itaipu[1], in Niteroi, Rio

[1] https://storymaps.arcgis.com/stories/f99afb816cb541ebb0b6c7ded88edd5b

de Janeiro, Brazil. There are two interaction options available. One that involves real equipment connected to the controls (Fig. 4 (A) and (B)) and another that only requires the virtual interface and the controls (Fig. 1). Within the region, several points of interest are established and marked by buoys. In this way, the installation encourages exploration and examination while strengthening basic sensory skills such as direction sense, balance, vision, endurance, and strength. Tutorials are provided in text and audio formats. The gameplay involves collecting floating residues in the sea or visiting the areas of interest within a maximum time limit of 2 minutes.

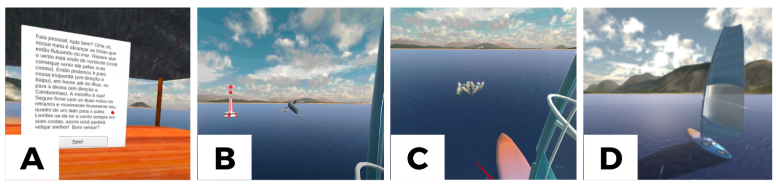

Fig. 1. Screenshots of the immersive environment of WindyVR: (A) Instruction screen; (B) View of a dolphin jumping in front of the windsurfer; (C) View of plastic bottles to be collected during the surfing; (D) View of the sail with mountains in the background.

"Stones in Space" game, shown in Fig.2, simulates the surface of planets and natural satellites. The interaction is done using a VR headset and two controllers to manipulate the rocks. The experience can be described as a journey across the surface of various celestial bodies, where to move from one body to another, the player needs to hit rocks at dynamic targets a predetermined number of times. The player can experience the different forces of gravity. This experience ends when all planets where visited.

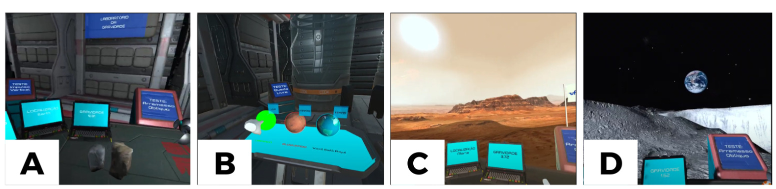

Fig. 2. Screenshots of the immersive environment of Stones in Space: (A) Gravity Laboratory environment (Earth); (B) View of the planet/satellite selection; (C) Mars environment view; (D) Lunar environment view.

4 Public immersive events

Digital Connections: The exhibition took place on June 28, 2022, as part of an itinerant event as can be seen in Fig. 3. The visit consisted of the following phases:(a) A queue was formed near the area where the installations were set up. (b) Each person was directed to the game installation they were most interested in. (c) The responsible mediator provided more specific instructions regarding the chosen game. (d) At the end of the experience, individuals who were interested in participating in the research were redirected to a table where Consent Forms and printed questionnaires were available for them to complete.

Fig. 3. Immersive installations at the Digital Connection event: (A) Overview of the space; (B) User interacting with one of the immersive installations; (C) User being assisted by a mediator while interacting with immersive installations.

MACBit: The event was held at the Museum of Contemporary Art (MAC) in Niteroi,Rio de Janeiro, Brazil, where immersive installations were experienced over a 3-day event in August 2022. Some immersive games were set up in the entrance hall of the MAC (see Fig. 4 (A) and (B)) and also within a container (see Fig. 4 (C) and (D)). Considering both public events they got around 150 persons who have experienced at least one immersive installation.

Fig. 4. Immersive Installations at MACBit (A) Entrance hall focusing on the WindyVR installation; (B) User interacting with the WindyVR immersive installation; (C) External view of the container installation space and (D) Internal view of the space.

5 Method

Eight individuals (2 female and 6 male), who served as mediators at Discovery House, responded to the evaluation. All are aged between 18 and 24 years old. The online survey form included 5 open-ended questions. These questions can be seen in the right-hand column of Fig. 5. In addition to the survey, a brainstorming session with the team that designed and monitored the immersions was also analyzed, containing lessons learned during the events.

To analyze the data, the selected methodology was the content analysis[2], with the unit of study being the theme of the analyzed excerpts. Initially, an inductive coding of the excerpts was performed to understand the aspects of interaction mentioned in each of the responses. Then, a co-occurrence analysis of the codes with each of the questions was conducted. The coding of 138 citations was carried out by two researchers (one senior and one student) in the field of HCI. As a result of this analysis, the Sankey diagram in Fig. 5 was obtained, describing the main UX aspects found in the mediators' reports.

On the other hand, deductive coding was conducted, starting from the design tactics proposed by Greuter et al [5] (described in Section 2) and linking them to the UX aspects mentioned in the mediators' responses. This analysis aims to determine how these UX aspects could be effectively addressed by the proposed tactics and identify any additional approaches that may be needed.

6 Results

According to Fig. 5, it is evident that aspects like Educational Potential, Discovery, and Immersion only appeared in excerpts from responses to questions aimed at collecting positive interaction aspects. Conversely, aspects such as Cybersickness and Fun were mentioned in responses to both positively and negatively phrased questions. Finally, aspects like Potential bugs, External environment, audience suitability, and game understanding were mentioned in all three types of questions. This recurrence of various aspects in more than one type of response occurs because these aspects can be cited in different contexts. For instance, the understanding of one experience may be described as easy, while that of another game is perceived as difficult.

One observation related to the potential discomfort experienced by adult participants when being observed by others while interacting with the installation, as follows:

> **M3:** *"Some adults struggled to engage in the game immersion due to feeling embarrassed about being watched."*

This UX aspect, shame, could be addressed by implementing tactics T2, enabling participants to become so engrossed in the interaction that they disconnect from the outside world, and T5, where the queue could serve as a preparation and icebreaker for the immersion experience itself. Tactic T2 also pertains

[2] Quantitative analysis was done using the ATLAS.TI software version 2024.

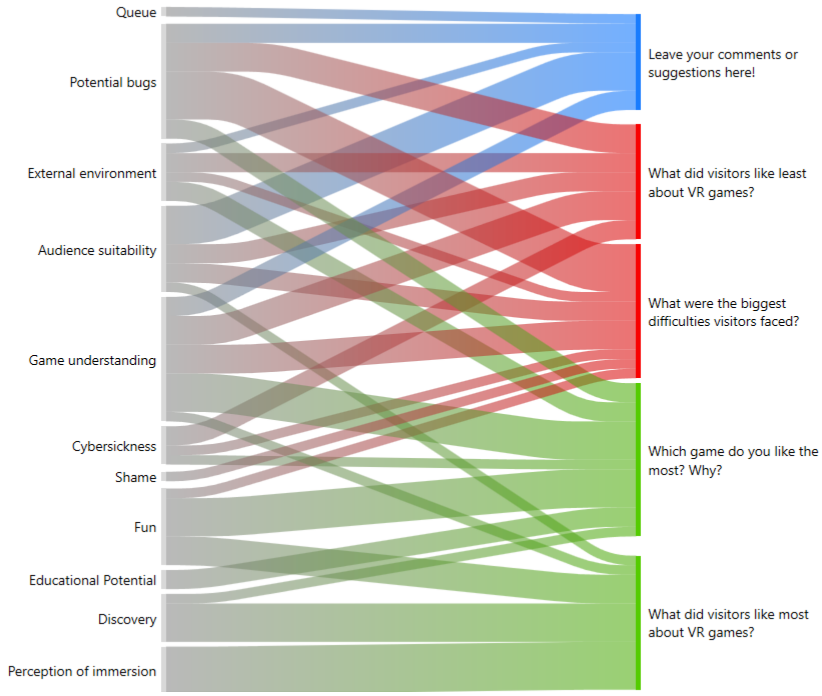

Fig. 5. Relationships between the main aspects mentioned by mediators (on the left side) while answering the form questions (on the right side). Blue color is related to the comments question, red color is related to negative questions, and, green color is related to the positive questions.

to the aspect of Potential Bugs, as glitches can lead to crashes, thereby disrupting immersion, as illustrated by one of the mediator's comments below:

> **M7:** *"The bug I encountered personally was in Cagarras, where the bird, depending on its path, could end up in a position that made it appear as though it was trapped inside one of the islands."*

Additionally, concerning the aspect of Potential Bugs, this can also be related to Tactic T4, as in the training on how to interact with the immersion, we can mitigate the risk of participants encountering flaws, as follows:

> **M2:** *"Some participants were unable to progress in the immersion because they said that, upon descending from the level of the rings, they couldn't return to the higher part. [...]."*

On the other hand, intending to reduce queues, this mediator proposed adjusting the interaction time with each installation, as described below:

> **M1:** *"I recommend adjusting the duration of all games to prevent the visitor queue from becoming long."*

Another aspect that can lead to an increase in waiting queues or even disrupt the immersion is the lack of battery for the proper functioning of the installation's equipment, as reported by the staff team:

> **Team:** *"We need to have extra HMDs to replace the equipment that needs to be recharged."*

The insufficient space for interaction was also noted in the collected responses.

> **M8:** *"The interaction space was a limiting factor [...]. Playing without hitting the wall added extra stress for the mediators, who had to remain extra vigilant to prevent participants from hitting the wall or anything else nearby."*

This matter could be tackled through the implementation of tactic T6. However, for this approach to work effectively, the available space must be of appropriate size. Otherwise, the team must ensure that the immersion area is sufficiently large for participants to explore the virtual environment.

Half of the respondents in the questionnaire highlighted the aspect of fun as a positive aspect of immersion, as evidenced by the following excerpt:

> **M3:** *"I prefer Stones in Space because I enjoy the change it offers with the scenarios, and I find it fun to try to hit the target."*

Because it is intrinsically linked to the creation of captivating scenarios for participants, the aspect of enjoyment can be significantly enhanced by the implementation of Tactic T2. Further related to Tactic T2, the aspect of Perception of immersion arises, reflecting how deeply participants can become engaged with the possibilities offered by the virtual environment they interact with. This is exemplified by one of the mediators' comments:

> **M7:** *"Visitors enjoyed it more simply because they could put on a headset and experience something completely new."*

Comprehending the immersion is crucial for a satisfying experience. The following excerpts from the respondents' remarks support this statement:

> **M3:** *"I prefer Stones in Space because I feel like I have a clear challenge[...]."*
> **M5:** *"In regular situations, participants typically dislike the lack of intuitiveness in the immersions."*

Understanding is a critical aspect that can significantly improve through participant training during queue time (T4). This training can implement strategies to more clearly articulate the objectives of each immersion. Additionally, implementing tactic T2 can enhance comprehension by focusing on practices that keep participants more engaged with the virtual environment, thereby increasing their inclination to understand the immersion. Sharing the immersion content with participants who are not wearing the HMD, as well as enabling early immersion (described by T3 and T5, respectively), also contributes to enhancing comprehension. These tactics provide opportunities to keep participants engaged with the immersion for extended periods, ultimately leading to a better understanding.

The need to adjust the immersion to the event's audience was mentioned by 7 out of the 8 respondents as an aspect to be considered:

> **M7:** *"It was noticeable that with very young children, the immersions don't work very well, so it is necessary to have them only watch what happens in the virtual environment."*

In the case of the Stones in Space, the virtual environment showcases a countertop with interactive objects (see Fig. 2). However, the height of this countertop often wasn't adjusted to match the participants' height, resulting in difficulties for them to manipulate the interactive objects effectively. Another issue identified was with interacting with the sail of the WindyVR board, which was designed for a minimum height of 4'11". Participants shorter than this struggled to operate the controls of the installation correctly (see Fig. 4). Tactic T3 could be employed, where the experience is conducted by observing another participant's immersion. Additionally, tactic T7, as used, can also minimize this effect of inadequacy of the installation to the audience, thereby enabling them to self-assess their suitability for that interaction. However, it was not enough to avoid participants' frustration in not being part of the target public. The tactic of using queue time to train VR skills (T4) can also assist in adapting the immersion to the audience, as sometimes the issue may be a lack of understanding of what needs to be done, as reported below:

> **M5:** *"Especially children often became quite impatient due to not understanding what was supposed to be done."*

Another aspect raised in the thematic analysis is related to potential issues of Cybersickness. Regarding this aspect, it was possible to observe that the mediators themselves may experience cybersickness effects. In this case, implementation of T3 would help, as by sharing the view of the immersed person on another display, the mediator does not need to wear the HMD to intervene in the immersion, thus reducing their immersion time in the virtual environment. Reducing the immersion time can also help decrease the likelihood of a participant experiencing cybersickness, in addition to adapting the immersion for individuals who are already prone to this type of symptom, by reducing movement acceleration and the amplitude of the field of view, as the following statement:

> **M7:** *"Only people with a history of labyrinthitis or associated illnesses experienced some discomfort during the games."*

The outcome of this coding is depicted in the graph in Fig. 6, where connections in yellow represent the tactics described in the study by Greuter et al [5], while connections in pink correspond to new tactics identified to better tackle the raised UX issues. The new tatics are described in the next section.

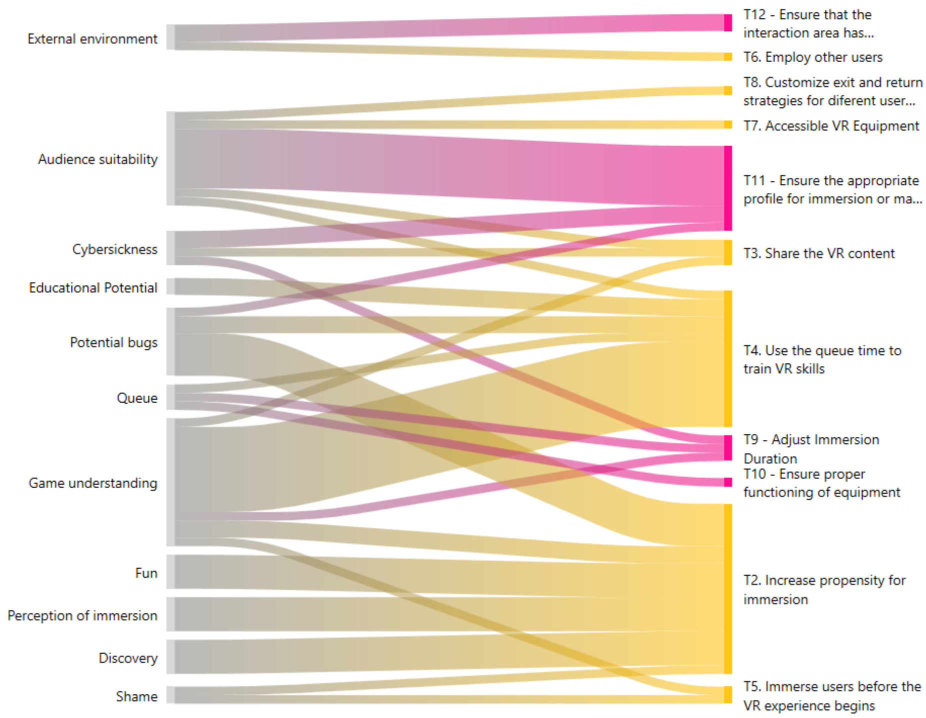

Fig. 6. Sankey Diagram describing relationships between the main UX aspects (on the left side) mentioned by the mediators and the tatics repertoire (on the right side).

6.1 Overcoming barriers while interacting with immersive public installations

Analyzing the highlighted passages in the thematic analysis of the responses from the team working with immersive experiences, we describe here four new tactics to be considered into the suggested repertoire aiming to guide all stakeholders involved with the public installation:

- T9 - Adjust Immersion Duration: Adjusting the immersion time according to the event and user profile aims to reduce queues and also provide greater predictability of the time from entering the queue to the end of the experience. This may also assist in implementing practices related to T8, such as a ticketing system providing an estimated time for when individuals need to return to participate in the immersion. It is important to emphasize that this adjustment must accommodate the increase or decrease in the queue. Therefore, it is highly recommended that designers preemptively develop various configurations for immersion duration.
- T10 - Ensure proper functioning of equipment: Given that VR devices rely on battery power, the team must organize themselves to ensure devices are

fully charged and configured for prompt replacement of those in use. This approach aims to minimize interruptions in immersion caused by the need to switch equipment.

- T11 - Ensure the appropriate profile for immersion or make it adjustable to different audiences: For instance, prominently displaying signage near the installation specifying the minimum and maximum height requirements ensures that participants can fully and satisfactorily engage with the experience. This proactive approach helps mitigate potential frustration arising from exclusion due to incompatible profiles. Furthermore, it is crucial to ensure that both physical installations and virtual environments accommodate individuals of varying ages, weights, heights, and needs.
- T12 - Ensure that the interaction area has an appropriate delimited place: In an immersive setting, participants must engage in mechanics and interact with the virtual environment. Therefore, designers must ensure that the physical space provides a sufficient perimeter for such interactions to occur seamlessly.

7 Conclusion

In this study, we analyzed how to link UX aspects with corresponding tactics aimed at addressing them promoting better immersion to users and attendants. To ensure our findings are valuable for other designers as well as all stakeholders of immersive installations in public spaces, we also propose additional tactics to enhance the overall experience. The UX aspects were delineated based on data gathered from user experiences in immersive installations within public settings, as highlighted by the mediators facilitating such interactions. The study explored tactics to be implemented during the technical development of the immersion, as well as strategies for organizing the spatial context in which the immersion occurs. As a future work, we intend to provide an instrument to guide designers of immersive installations. This instrument should be able to identify user's roles and journeys performed before, during, and after the experience. As a final contribution, we hope to allow designers to identify and prevent potential problems and maximize the user's experience.

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[3] https://casadadescoberta.uff.br/
[4] https://chatgpt.com/

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