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DinosaurVR: Using Virtual Reality to Enhance a Museum Exhibition

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Abstract

Museums featuring dinosaur fossils have always attracted the attention of the crowd. However, sustaining public interest in science becomes more challenging year after year, even for popular attractions, calling for changes in how exhibits appear in the face of new technologies. To enrich the user's experience and enhance the exhibition's attractiveness, we developed and evaluated an immersive and interactive Virtual Reality (VR) experience to integrate the Paleontology exhibition at the Câmara Cascudo Museum in Natal, Brazil. Experienced VR users were interviewed and reported, through software tests, that the system was stable and performed as intended without any noticeable issues that could affect the user experience. They also found the content adequate, except for the suggestion to include more information about Paleoichnology and the finding of fossil tracksites. The graphical quality received mixed reviews, with some participants suggesting improvements to the terrain, such as adding vegetation and enhancing lighting. They also noted that the experience would appeal to younger audiences, thanks to the novelty of VR technology and the accessibility offered by the museum. Improvements were made to the environment based on their feedback, including changes to the terrain and lighting. Additionally, we developed two alternative versions of the experience, one for multi-projection in a room and another without interactive elements. Our results indicate that the VR experience can be successfully integrated with the exhibition and has the potential to enhance museum visits. It can connect the audience with the actual fossils on display by using a dinosaur in the exhibition. It allows one to visualize how their region changed in the past million years. Finally, this experiment helped bridge the population from an unprivileged region with the science that is produced upon the fossils found in their context. Such knowledge broadens the public's imagination and triggers a whole chain of development for the community around the museum. Our VR exhibition prototype showed great potential to amplify this mission.

Keywords: *Virtual Reality, Paleontology, Museum Visit Enhancement*

1 Introduction

Since the beginning of its popularization, Virtual Reality (VR) has emerged as a powerful tool for enhancing visitor experiences in museums, providing immersive and engaging environments that extend beyond the limitations of traditional exhibits. As technology advances, VR applications offer new opportunities for the cultural heritage sector to captivate audiences and convey information innovatively. Previous studies have highlighted the potential of technology in museums (Kelly, 2014; Neuburger and Egger, 2017), emphasizing the importance of creating immersive experiences that foster meaningful connections between visitors and exhibits (Lee et al., 2020). However, there remains a need for novel VR applications that push the boundaries of storytelling and visitor engagement. Additionally, as VR is still an expensive technology to use, museums, as places of exhibition, study, and education with ease of access, can help spread the technology to a different audience that could not otherwise have access to it (Poulot, 2013).

Moreover, incorporating VR technology into exhibitions is important for museums and visitors. For museums, VR can augment traditional exhibits with immersive and interactive experiences, enhancing overall visitor engagement and educational impact (Falk and Dierking, 2016). By integrating VR into exhibitions, museums can provide visitors with unique opportunities to explore historical, cultural, and scientific subjects in ways that were previously inaccessible or difficult to comprehend. The addition of VR can breathe new life into museum displays, injecting a sense of wonder and excitement that attracts and enhances learning in diverse audiences, including younger generations who are often drawn to cutting-edge technologies (Allcoat and von Mühlenen, 2018). On the other hand, visitors are increasingly seeking more participatory and multisensory experiences when engaging with cultural institutions (Simon, 2010). VR fulfills this desire by

enabling visitors to participate actively in the exhibition, immersing themselves in simulated environments and interacting with virtual artifacts. Based on those previous studies, it is argued that this integration of VR not only fosters a deeper connection between the visitors and the subject matter but also stimulates curiosity, promotes exploration, and facilitates a deeper understanding and appreciation of the museum's collections and narratives.

As the Câmara Cascudo Museum, since one of its first permanent exhibitions in 1973, seeks to use immersive techniques and bring users closer to what is being presented, the opportunity to use this venue is very relevant to such immersive experiences. In the 1970s, the museum used dioramas to transport the users to different sites relevant to the exhibitions and the audience, such as a cavern, a paleontology site, a fishing environment, and a mine. Unlike regular dioramas, the ones used in the Câmara Cascudo Museum were not isolated from the public and allowed them to navigate the experiences and interact with them. Now, with VR technologies being the new way to immerse users in different environments, the museum has continued to pursue this path by having the MedusoZoa (Souza et al., 2022) experience in 2018, the Deynonychus experience in 2019 (de Carvalho Souza et al., 2022) and having a virtual museum set up in 2020 (Ramos and Others, 2020).

Recognizing the potential of VR to enhance visitor experiences in museums and understanding the growing demand for immersive and participatory encounters with cultural heritage, we have developed a novel VR application tailored specifically for an exhibition about Ichnology in the Câmara Cascudo Museum, in Natal, Rio Grande do Norte, Brazil. This application represents an extension of our previous work (de Carvalho Souza et al., 2022), building upon our expertise and insights gained from developing immersive experiences for that same exhibition in the past. The application aims to transport visitors into a virtual world where they can explore the fusion of futuristic aesthetics and prehistoric creatures, taking the museum experience to new heights. Using the novelty of VR technologies, our application seeks to provide an immersive experience for museum visitors to explore a small virtual world and have face-to-face encounters with a scientifically accurate dinosaur that lived in Brazil around 125 million years ago. Through this innovative use of VR, especially in the context of the Câmara Cascudo Museum, we strive to push the boundaries of visitor engagement and educational impact in the museum setting. By later integrating our application into the museum, we envision enhancing the overall museum experience by offering visitors a unique opportunity to interact with the virtual world, facing a real-sized, properly modeled abelisaur, and developing a deeper connection with the exhibit. Furthermore, by leveraging the benefits of VR technology, including its ability to transcend physical limitations and engage the senses, our application aims to unlock new dimensions of exploration and understanding, enriching the museum experience for a diverse range of visitors. The application was validated by people with a vast previous experience on the use of immersive experiences or VR games, recruited here as specialists. Lastly, by providing an easy-to-access VR experience in a free-access museum, we also aim to introduce VR to a new audience that would not otherwise be able to interact with it.

Paleontology is the study of ancient life through the analyses of fossils. It is one of the most captivating fields to raise public interest in science, especially concerning dinosaurs. Northeast Brazil presents some of the most productive fossiliferous sites worldwide, with diverse dinosaur skeletal remains and tracksites. There is a collective effort in science outreach projects to connect scientists with the local communities where such fossils come from. Previous analyses have demonstrated how much this subject appeals as a cultural identity for Brazilians and has fostered an increase in public investment in areas of social vulnerability, such as the Cariri and Sousa areas in the outback. It is our interest to use this power as a means of change.

The rest of the paper is divided as follows: the next subsection discusses works related to this one. Section 2 discusses the design decisions we made while creating the VR experience. Section 3 details the implementation of the VR experience and the necessary equipment for its installation in the museum. Section 4 summarizes our interviews with a few specialists about the experience. Finally, Section 5 discusses the results and changes based on the interviews and concludes the paper with a few ideas for future work.

1.1 Related Work

As discussed in our previous work (de Carvalho Souza et al., 2022), technology is increasingly becoming part of museum exhibitions, as highlighted by (Shehade and Stylianou-Lambert, 2020). Another common use of VR technology is to make it possible to visit virtual museums through the internet without needing to be physically present (Arts, 2019; Museum, 2016), but that works better for large exhibitions with globally relevant content. For local museums, which have content aimed at the local culture or history, as we aim to achieve with this new VR experience, bringing visitors to the physical facilities is still very important and challenging. To enhance physical exhibitions and add a sense of participation for the visitor, museums are being enhanced with augmented virtual information, such as through the use of QR-Codes (Silva, 2020; Teixeira et al., 2021).

Also, as VR is not an easily accessible technology, bringing it to the masses using the museum as a mediator is a relevant opportunity (Carrozzino and Bergamasco, 2010). As the Câmara Cascudo Museum has no admission fee, this was an excellent opportunity to do so. As also discussed in our previous work, as proposed by the Museum of Sculpture (Carrozzino et al., 2008), bringing immersive VR technology to the general audience, who is not used to having contact with such technology, can be, by itself, an attractor for a new audience. Additionally, the audience's satisfaction rates after the experience seem higher. Aiming to leverage this novelty feeling for increased amusement, the DinosaurVR experience was created.

Lastly, it is also relevant that integrating VR technology in museums has opened exciting opportunities for showcasing dinosaurs in immersive and educational ways. VR allows visitors to enter prehistoric worlds, where they can observe dinosaurs in their natural habitats, observe their behavior, and gain insights into their evolutionary history. This novel ap-

proach enhances the entertainment value of dinosaur exhibitions and offers educational benefits by engaging visitors in interactive learning experiences.

A few studies have explored the application of VR in the context of dinosaurs in museums, highlighting its potential to create compelling and informative experiences. For instance, a VR application was developed (Lugrin et al., 2018) that allowed visitors in a large empty room to visit a fully virtual dinosaur museum exhibition that contained a few animals in actual size and relevant information about them. This experience was based on a large area tracker and a VR environment that allowed for the presence of multiple users in a single experience. In an approach more related to entertainment, a fully immersive VR experience was also created inside a museum (Awadalla, 2023) to allow the overview of a Paleozoic era scenery where the users could fly using a VR device to see different beings of the time.

Furthermore, a VR experience was created (Antlej et al., 2018) based on a real dinosaur excavation site. The environment was captured in the real world, and pieces of the excavation were scanned to create a museum experience in VR that could take the visitors to a real digging site, so they could learn more about the process of finding real dinosaurs.

The use of VR in dinosaur exhibitions has demonstrated its ability to engage visitors and, in some cases, facilitate immersive learning experiences. By leveraging VR's interactive and immersive nature, museums can offer visitors an unparalleled opportunity to explore the world of dinosaurs in previously inaccessible ways. These innovative applications spark excitement and curiosity and promote scientific literacy and understanding of paleontology among visitors of all ages. As VR technology advances, there is immense potential for further exploration and refinement of dinosaur experiences in museums, contributing to the evolution of immersive and educational museum exhibits, especially considering regional objects or relevant findings that are part of the region the museum is in.

2 Design of the VR Experience

After a few months of presentation of our previous work (de Carvalho Souza et al., 2022), the space used for the multiprojection was occupied with a new section for the Ichnology exhibition. For that reason, our new goal was to develop something that would not rely on a large area but would allow users to encounter a dinosaur and learn a bit more about the subjects in the exhibition. Because of those constraints, we opted for an experience based on fully immersive VR, using VR headsets, as this would allow us to use minimal space in the exhibition while still achieving our goal of enhancing the visitor's experience.

To begin, the VR experience was developed in two versions, utilizing the Unity game engine (Unity, 2023) to maximize accessibility for museum visitors. The first version, boasting superior graphical quality and featuring positional tracking, was tailored for the Oculus Quest headset (Meta, 2023). The second version utilized the CardboardVR SDK (Google, 2023) to create an Android-compatible iteration of the experience. This iteration could be enjoyed by museum-goers on their mobile phones, utilizing inexpensive VR cardboard headsets. Ultimately, the objective of both versions remained consistent – to offer visitors an immersive VR experience that would enhance their exhibition visit while minimizing any disruption to the physical exhibition space.

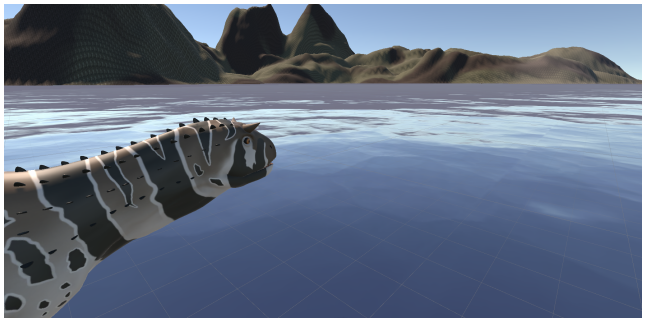

Figure 1. View of a dinosaur besides a lake that is part of the virtual environment used for the DinosaurVR experience

For the initial version utilizing the Oculus Quest, the application enabled users to navigate the virtual world by mirroring their movements in the real world. However, this approach posed a predicament. Given the confined space within the museum, having individuals physically move within an exhibition while their vision remained obscured by a VR headset proved suboptimal. To address this challenge, we eliminated the option for physical movement within the experience. This decision prompted us to explore the second version, which would employ more affordable devices lacking this functionality. This choice aligned with the evolving requirements and offered the advantage of streamlining visitor flow through the experience, given the enhanced accessibility of the new devices. Consequently, the second iteration of the application was developed, targeting VR-capable Android devices utilizing cardboard VR technology.

Also, after our last experience created for the museum (de Carvalho Souza et al., 2022), we partnered with two paleontologists to discuss how to enhance our experience for this new version. They suggested the experience was created with similar scenery but with less vegetation, as it is not trivial to specify the kind of vegetation that would be around during the time we are seeking to explore in our experience (the early Cretaceous Period). Furthermore, as a continuous enhancement for the experience, we agreed with the paleontologists to use a more scientifically accurate dinosaur model that would connect with the regional context of Northeast Brazil (da Costa et al., 2020; Ribeiro et al., 2022). The new model represented a group of dinosaurs (abelisaurid theropods) present in the fossil record from the regional Cretaceous geologic units. Some abelisaurid (and other indeterminate theropod) fossils are displayed at the museum exhibition, including body fossils and petrified footprints. The resulting experience, validated by the paleontologists throughout the development process, was considered to have improved considerably by connecting with the actual fossils on display and allowing visitors to visualize how their regional landscape and wildlife looked over 130 million years ago. A visualization of the new virtual environment with the dinosaur model can be seen in Figure 1.

To enhance the story of the experience and make it a bit more ludic and engaging to the visitor, we placed the user in-

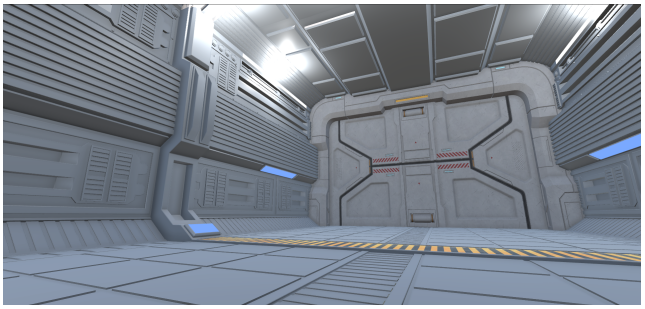

Figure 2. A view of the futuristic cage the user is placed inside. When the experience starts, the large door opens up to reveal a world with dinosaurs.

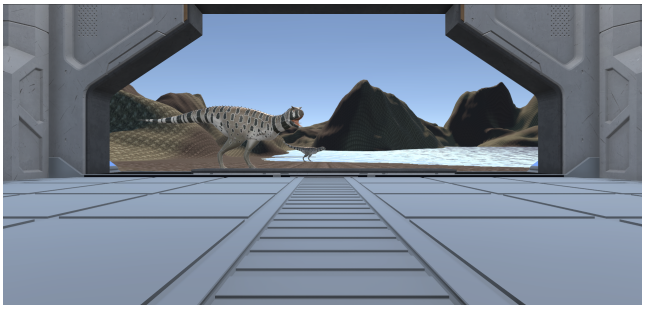

Figure 3. A view of the futuristic cage the user is placed inside. When the experience starts, the large door opens up to reveal a world with dinosaurs.

side a futuristic-looking cage from where he could then gage into the past and see the dinosaurs roaming around. This cage, seen in Figure 2, connects with the idea of having a future where dinosaurs may be recreated back to their original habitats, as seen in movies and series.

Having designed the virtual environment where the experience would take place, the next step was to plan for the content to be shown to the user. Opposed to our previous experience (de Carvalho Souza et al., 2022) that used projectors and could have a room filled with people for the same experience, using VR headsets creates a problem of throughput for the exhibition. If each visitor uses the device for 2 or 3 minutes, it could take up to two hours for a whole classroom to participate in the experience. This is not very practical, so we tried to tackle this problem in two ways. First, by having the VR experience work on mobile devices, we can scale the number of people simultaneously using the experience by the number of cardboards the museum has available. This is a lot cheaper than getting more VR headsets. The second way we approached the problem was to have a faster experience. Although not ideal, a shorter experience could lead to a steadier flow of visitors going through the device, allowing visitors to spend more time exploring a bit more after the experience.

Considering those restrictions, the experience was created to last around 45 seconds, with a few more seconds of exploration following the end of the animation. The visitors also had the option to download the application and take it home with them for extra exploration. It is left to future work to develop an extended version of the experience with more interaction to be used at home.

3 Implementation of the VR Experience

The VR experience was developed using the Unity game engine, which provided a robust platform for creating immersive virtual environments. Specific VR Software Development Kits (SDKs) were integrated to ensure compatibility with different VR devices. The Oculus SDK was employed for the Oculus version of the experience, while the Cardboard SDK was utilized for the Cardboard version.

We used the Unity Terrain editor to construct the virtual landscape, which provides a versatile toolkit for crafting terrains. Beginning with an empty VR project, we sculpted a lifelike terrain to replicate a natural setting. Our team meticulously shaped mountains and plains, molding the terrain to mirror the intended topography. A prominent aspect of this landscape was the incorporation of a lake. This addition enhanced the visual appeal of the experience and aligned with the environment's significance, as bodies of water played a crucial role in generating the footsteps integral to the exhibition. This concept is further elaborated upon in the experience's description.

After that, the central piece of the experience was added. An anatomically adequate model of an abelisaur, a dinosaur related to the fossils in the exhibition, was incorporated. The chosen dinosaur model acted as a key character within the virtual world, as it was the goal of the experience. Various animations were implemented to bring the dinosaur to life, allowing for dynamic movements and interactions with the virtual environment. For this experience, we used two dinosaurs, as seen in Figure 3.

At the start of the experience, the users found themselves inside the locked futuristic cage shown in Figure 2. After a few seconds, one of the cage doors opened, revealing the crafted world and the two dinosaurs that would be part of the experience. The first dinosaur, closer to the door, immediately noticed the participant's presence, loudly shouting to inform its partner. After that, turning to the user, the dinosaur would start smelling them while waiting for its partner to approach. The second dinosaur, found drinking water from the lake at the start of the experience, would start moving toward the user after its companion roared. The movement would increase as the dinosaur accelerated towards the user, also letting out a wild roar. At this moment, the user could look at the door and use the cursor to keep the doors from closing. This would result in both the animals approaching the observer, meaning they could take a close look at the dinosaurs before the end of the experience. The other option was to stare at the dinos with no actions to let the doors close back. The whole animation, with the simple opportunity for interaction, took part in around 40 seconds, as mentioned before. If the user let the dinosaurs get closer, the experience lasted longer as the dinosaurs approached. After the experience ended, the screen would turn black to indicate that the experience was over and to save battery and processing while changing users on the experience. A brief touch on the screen would then restart the application, with another touch starting the sequence of events.

As for installing the VR equipment, the idea was to use an office chair where the visitor could sit before wearing the cardboard headset. This can be escalated by the number of headsets available by adding additional chairs. Initially, the

idea was to have a text inside the VR experience explaining the context and why it was relevant to the user. We decided to use a printed board with the text and instructions instead to speed up placing the headset and participating in the experience. This concludes the space necessary in the museum for the installation to work.

4 Evaluation of the VR Experience

With the experience fully developed, the next step was to validate the tool with a few users before deploying it to the museum. System tests were conducted to evaluate the system's stability, content, and graphics. Five participants with previous experience in VR or gaming took part in the tests as specialists in the field to judge the quality of the experience and help develop it further through an interview. All participants took the tests voluntarily and answered the questions after seeing the experience. The participants were aged between 31 and 35 years. Four of them identified as males and one as female.

The first question they posed was regarding the system's usability and stability. It stated *"Have you noticed any nuances or instability in the system that could affect the final user experience?"*. They all reported that the experience was stable enough and that the system works as intended, with no drops in framerate or other nuances that could hinder the final user experience.

The second question was related to the content. As the story and explanation are not yet printed in their final form as of this writing, the text was presented to them digitally so they could understand the context and participate in the experience knowing what they would see. The question asked was *"Is the content adequate as an extension of a museum exhibition, following the guidelines explained in the text?"*. Four of them answered yes to this question, and one suggested that we go more in-depth on details about Ichnology and the footsteps finding. Two of them also indicated that the experience could last a bit longer.

The third question was regarding the graphic quality of the content. The posed question was *"Is the graphical content good enough to integrate the exhibition? Are the elements consistent?"* For this question, three participants said that the content was good but could be improved, especially in the terrain, and two participants said that the terrain of the experience was *"too dark and too dry, inconsistent with the dinosaur"*. The experience they took part in was shown in Figure 3.

The last question was regarding kids and younger people. We asked the specialists if they *"Would consider this a suitable experience for younger people"*. Four of them said yes, mainly regarding the tool's novelty and the awe factor still present in VR experiences, especially for those that do not have much contact with the technology. The fifth one said that the experience could scare children as the dinosaurs seem to chase the subject and roar at them.

Finally, we let them suggest anything else for the application. Two of them mentioned that we could also develop a version for projectors, even if the room is not available at the moment of this writing, as the last exhibition worked well.

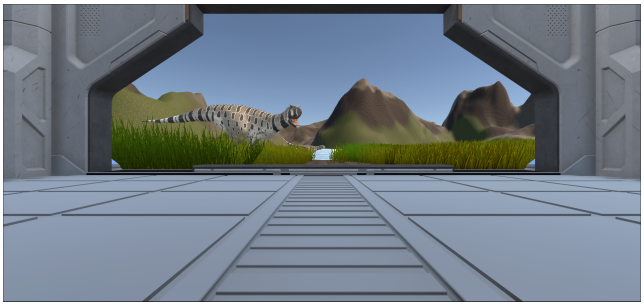

Figure 4. Screen capture of the old grass and mountains.

One mentioned that we should add vegetation to the experience as, even with changes to the terrain, as discussed in the next section, the land still looks too clear. Lastly, two participants mentioned that the water looked cool and the experience was interesting, especially to a younger audience.

5 Discussion and Conclusion

Based on the questions posed to the specialists and our own experience with the system, we concluded that the system was technically validated for deployment in the exhibition. The system works well, can run on the target devices, and has no considerable drops in FPS or stutters that may induce motion sickness in the participants. As it is a seated experience, we do not have to worry about physical space limitations, as the user will be confined to a chair. This is indicated primarily by the answers to the first posed question, which corroborated that the application is technically sound.

The second question was about the content of the experience. Four specialists indicated that the experience was good enough, and one asked us to include more about Ichnology and footsteps in the experience. We attributed that to the fact that they had not visited the exhibition before the experience and that, in the final piece, when deployed to the museum, the participants will have a bit more knowledge on the subject, as the exhibition itself explains a lot about the discipline and the pieces that are there. Regarding the details about the experience duration, that is something that will need to be tested in the museum itself during the first month or so of the experience. There needs to be a tradeoff between user throughput and experience duration so that an entire classroom of students, which is a common group of visitors to the Câmara Cascudo Museum, can participate in the experience in a timely manner. As the experience is highly customizable using the dinosaur models and the environment we proposed, it should be no problem to add a bit more interaction between the dinosaurs or even more species or specimens, but, as said before, that will need to be tested in the museum. Acquiring more headsets may also be a solution, but, as of now, it is not viable.

The third question, regarding the graphical setting of the experience, was the one where specialists were more critical. Although the model of the dinosaur was considered good enough by all of them, the environment was considered bad, and changes to it were requested. Using real-time feedback from two specialists, we changed the environment, as seen in Figure 4. We added vegetation to the terrain, as asked by

Figure 5. Screen capture of the final version of the experience. Trees and plants that are scientifically accurate to the depicted period were added to enhance the scenery.

one of the specialists, and added a bit more grassy spots to the terrain to remove the "darkness and dryness" reported by another specialist and also changed the lighting of the system a bit so the faces of the mountains that are facing the player are the ones being light up by the sun. These changes made the experience lighter and, as described by one of the specialists later, *"more interesting and attractive for a younger audience"*.

After showing the new version to the paleontologists, the grass was removed from the scene as it is not accurate to the period depicted in the simulation. To still keep the lightness of the terrain while maintaining the accuracy of the imagery, we opted to use a plant common to that time instead. As the experience is confined to a single space, we added a lot of those new plants to shorten the environment a bit and enhance the focus on the dinosaurs. The final version of the application can be seen in Figure 5.

Regarding the fourth question, which asks about our main target audience – younger people and children – the specialists agree that the application is attractive and suitable, mainly due to the awe factor the VR still brings and the accessibility the museum brings to audiences that are not used to having access to VR equipment. The concern of one of the specialists about the scare of being chased by a dinosaur is also valid and something that will be brought up to the volunteers of the museum that are accompanying the experience. They should warn the parents about the content and be ready to remove the headset if any user shows any signs of distress. Based on that feedback, we also prepared a secondary experience that features no interaction with the dinosaurs or between them, instead turning the experience into just a simple visualization of two dinosaurs minding their own business. This experience will also be made available to the museum as a backup if they want to use it.

Lastly, following the extra comments from the specialists, we also created a different version of the experience that can run on the projectors setup that was used for our previous installation in the Câmara Cascudo Museum (de Carvalho Souza et al., 2022). This version has the exact same experience as the one in the headsets but can be projected into a room using four projectors, showing a wide vision of the space the dinosaurs are in. For this version, as we did in the last exhibition, we also added dinosaurs posing at the end of the experience to allow visitors to take pictures with the dinosaurs projected on the screen. The other comments were addressed in the improvements made for the other questions, concluding the development of our VR experience.

This paper presented the development of a VR experience for an exhibition in the Câmara Cascudo Museum, in Natal, RN, Brazil. The experience was created to integrate the exhibition about Ichnology in the museum without affecting its current area or having to remodel any of its rooms. For that, the installation used a VR headset and was made for a seated VR experience. In the end, following improvements suggested by specialists that interacted with the software, two other versions of the same experience were also made available, one for a projected room and another one without interactions. The experience consisted of a short moment of interaction between the user and two virtual dinosaurs that are modeled to adequate precision and are put into the virtual world with correct proportions so that the users can feel their real size.

Because of time constraints and the low availability of VR headsets, the experience was created to be short. In future

work, we plan to extend the capabilities of the application and then make it available to be used in different environments from the museum itself. We also plan on using this model and scenery for different applications that can be also integrated into the context of museum exhibitions, even in other museums of the region, as abelisaurs were the most common predatory dinosaurs in Brazil. This is not only an important feature for a decolonial experience but also relevant to the museums, as the dinosaurs portrayed in virtual experiences and movies are usually the ones mainly found in the Global North. It is uncommon to find experiences such as the game Dino Hazard: Chronos Blackout (Collectors, 2020), which highlights lesser-known dinosaurs from less publicized regions. Experiences like this should be encouraged to connect populations from unprivileged regions with the science that is produced upon the resources found in their own territories. Such knowledge broadens the imagination of the public and triggers a whole chain of development for the community around the museum, and our VR exhibition prototype showed great potential to amplify this mission.

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