Multisensory Diorama: Enhancing Accessibility and Engagement in Museums

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Abstract. This paper describes the design and evaluation of a Multisensory Diorama (MSD) intended as a tool to provide an alternative learning environment for people with intellectual disabilities (ID) in museums. The MSD is designed to be interactive, engaging, and accessible to accommodate the specificities of participants with ID, and to help contextualize and consolidate previous knowledge. The MSD is a portable box with RFID readers, LEDs, a fan, a photoresistor, a button, an Arduino Uno, an MP3 shield, a speaker, and an external battery. The MSD offers two different ways of engagement and interaction via exploration and gamification: visitors can explore the augmented landscape and play a matching game that reinforces their knowledge of the food chain in the forest. In a formative evaluation approach focusing on the accessibility and engagement with the MSD, a study was conducted with 12 adults with ID, who provided valuable feedback to improve the design and make necessary adjustments for future implementations. The MSD proved to be a successful tool for engaging visitors and reinforcing their understanding of the food chain in an interactive and accessible way.

Keywords: Multisensory Experiences · Diorama · Accessibility · People with Intellectual Disabilities · Museum · Inclusion

1 Introduction

Museums are spaces of knowledge and cultural heritage, offering a range of experiences that aim to inform, educate, and entertain visitors. Unfortunately, many people face barriers when accessing and enjoying museums, including people with intellectual disabilities (ID). The barriers include the complexity of information and lack of inclusive interpretation. To address them, there has been growing interest in developing inclusive practices and accessible environments in museums. In particular, there has been a focus on enhancing the multisensory experience of museums by engaging multiple senses and modes of communication [11].

Multisensory experiences can facilitate learning and engagement and can enhance the accessibility of museums for people with ID. One approach to creating multisensory museum experiences is through dioramas, which are three-dimensional models or displays showing a scene or an event. Dioramas, which can provide a rich and immersive experience, allow visitors to explore different perspectives, time periods, and cultural contexts while promoting and enhancing learning and critical thinking.

This paper explores the potential of multisensory experience dioramas to enhance accessibility and engagement in museums for individuals with intellectual disabilities. Specifically, in Section 2, we will review the literature on intellectual disabilities, museum accessibility, and multisensory experiences. Further, Section 3 will present our objectives, implementation, and interaction and gamification plan. Section 4 will present the evaluation of a multisensory experience diorama designed for a museum exhibition. We will also discuss our findings in Section 5. Finally, we conclude this paper and highlight limitations and future considerations in Section 6.

2 Background and Related work

Intellectual Disabilities (ID) are neurodevelopmental disorders characterized by deficits in cognition and adaptive functioning [1]. The severity can vary widely, with some people facing minor issues and being able to live relatively independently with the right support, while others may need significant and permanent assistance [26]. Assistance is especially needed in the context of formal and informal education [20], as learning can be difficult for individuals with ID without accommodations or modifications [15]. This is due, in part, to intellectual function limits, which may include issues with abstract concepts, memory, problem-solving, planning, reasoning, and generalization [1][9][32].

In recent efforts to provide inclusive interactive technologies, the multisensory approach has received special attention [16]. Multisensoriality for people with disabilities has been employed with different applications, ranging from multisensory smart objects [24][2][13] to multisensory environments [18][5][25], and with different goals, such as relaxation [10], communication [24], and learning [2]. Indeed, multiple sensory modalities can benefit learning [29] as they present information that can be more accessible according to the preferences of the learner [21], enhancing learning opportunities for everyone [4]. Multisensory experiences can also be found in museums, where multisensory technology creates immersive experiences and empowers imagination [11]. Regarding accessibility, multisensory solutions typically focus on visual impairments [19], as visual information constitutes the majority of museums' content [11], and visitors with ID received less attention in HCI technologies.

When it comes to enhancing learning experiences, natural history museums frequently employ dioramas [12][31], which are "three-dimensional depictions of animal-landscape sceneries that include real or artificial models of animals in combination with background paintings and natural or artificial requisites" [14]. Because of their educational value [30], their potential in relation to HCI has been investigated to understand how technology could enhance dioramas. Although museums are the most common setting for digital dioramas, there are also applications set in schools to provide hands-on experience with science concepts [27][3][6]. Aside from traditional physical ones [27][3][28], there are virtual reality dioramas [22][6][23], augmented reality dioramas [7][17][23], and mixed reality dioramas [8]. Interaction is typically achieved through external controllers [27][22][6][8][28][23], with only a few opting for physical interaction [7][17][3], highlighting a lack of multimodality. Similarly, there is a lack of multisensoriality. The sensory output of digital dioramas is primarily visual, with occasional incorporation of auditory feedback [7][3][28] and even less frequent incorporation of haptic output [28]. The latter is the only one designed specifically for people with disabilities, explicitly those with visual impairment. The target users of digital dioramas are not always specified because they are appealing to a wide range of people [22][8][23], but when the design is specific to a defined population, targets are usually children [7][17][3][6].

3 Design

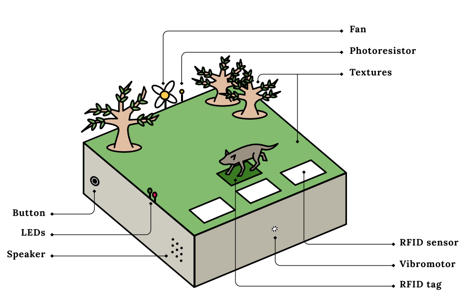
3.1 Rationale and objectives

Thanks to informal learning, museums can provide an effective informal alternative learning environment for people with ID. In particular, dioramas can provide explicit and immersive representations of information that can be more easily understood. After visiting a Natural History museum with people with ID and observing their reactions to playful interactions, we conducted a focus group session with a psychologist, educators, and the museum's researcher. Together we explored the feasibility, requirements, and features of a tangible interactive object to place inside the museum. Inspired by the literature and the museum's content, we envisioned a Multisensory Diorama (MSD) focused on the food chain. As the group of participants was going to learn content about wolves and reindeer, the educator suggested focusing on that topic and proposing an activity that could be placed inside their learning process. Following the focus group, the content of the museum, and accounting for the learning objectives of the participants, we extracted the key considerations that should have been taken into account during the design phase:

1. **Engagement:** The diorama should be designed to be interactive and engaging for the participants, to involve them in a memorable and meaningful learning experience;
2. **Accessibility:** The diorama should propose multisensory feedback to accommodate the specificities of the participant with ID. It should leave the participant the possibility to choose how to engage with it and should be easy to use;
3. **Learning:** The diorama should help contextualize and consolidate previous knowledge.

3.2 Implementation

The MSD presented in this paper is a portable box with the scenery on top and the electronics inside. To recreate the landscape, a green textured cloth miming grass covers the surface. On the front are three cards with pictures and names of mouse, moss, and reindeer. Each card has its own RFID reader housed inside the box. Red and green LEDs are on the left side of the box and next to the cards. Statuettes of wolves and reindeer occupy the middle portion of the surface, and two of them stand on a white card-shaped RFID tag. Paper trees with thin branches and leaves that can easily shake with wind serve as a backdrop for the game. The wind is generated by a small fan located directly behind the trees. It can be activated by a photoresistor placed among the trees and a button on the diorama's left side. RFID readers, LEDs, the fan, the photoresistor, and the button are all connected to an Arduino Uno, which is equipped with an MP3 shield, a speaker, and an external battery. Fig. 1a shows the components.



(a) Components available on the MSD.

(b) MSD in the Museum.

Fig. 1: MSD: Components' description and the box inside the museum.

3.3 Interaction and Gamification

The MSD offers visitors an interactive experience in a forest setting, where they can observe wolves and reindeer. The diorama is designed to provide two different ways of engagement and interaction, allowing visitors to choose their own experience and make their visit more memorable. Visitors can explore the augmented landscape, where they can touch the MSD's elements to discover their textures, activate the wind, and move the animals. This allows visitors to experience the forest environment hands-on and understand the different elements that make up the ecosystem. They can also play imaginative games set in the forest, which will make the experience more fun and creative.

In addition, visitors can play a matching game that reinforces their knowledge of the food chain in the forest. The game is based on the prompt "Who eats what?" and visitors can pick up the animals from the scenery and place them on top of the image of their food. The answers provided are mouse, moss, and reindeer. If the participant selects the wolf, the correct answers would be mouse and reindeer. However, if the participant selects the reindeer, moss is the correct answer. When the answer was wrong, a red LED lit up, and a feedback sound was played, encouraging participants to try again. On the other hand, if the answer was correct, a green LED lit up, and the speakers played a sound associated with the animal. Every time a match was made, the diorama vibrated. The game is designed to reinforce knowledge about the different animals and their role in the ecosystem in an interactive way. The simple mechanic and interaction are meant to enhance accessibility and improve understandability.

4 Evaluation

4.1 Method

To evaluate the accessibility and engagement of the MSD, we conducted a study at a Natural History museum. Participants were first given a tour of the museum room with the wolf and the reindeer and were given a brief refresher on the animals featured in the diorama. Afterward, the MSD (Fig. 1b) was placed on a table between the animal statuettes and a stool was provided for participants to sit on. The participants then entered the room individually for a one-on-one session with two researchers present. One researcher was leading the experience and was standing beside the participant to guide them through the activity, while the other researcher was standing in the corner of the room, taking notes on the participant's interactions and observations and filming the experiment for further analysis. Participants were first given the opportunity to explore the diorama freely. We then provided a brief overview of the MSD and its purpose, and later, the leading researcher presented the matching game promptly. The researcher handed the animal with the tag and asked the participant to place it on its food. At the end of the session with the MSD, the researcher showed participants any interaction that they hadn't tried at the beginning of the session. Finally, we requested that participants exercise their free will in selecting between the MSD and other familiar options, including a Museum app, an Augmented Reality app, printed easy-to-read text, and augmentative and alternative communication (AAC) pictograms. They were asked to choose their preferred option in sequence until the final alternative. After the session, participants were interviewed by an educator in a separate room, where they were asked to describe the diorama, the activity, and express their opinions about it. This approach allowed us to gather valuable feedback on the accessibility and engagement of the MSD and make any necessary adjustments for future implementations.

4.2 Participants

The study involved a sample of 12 adults with ID, 8 women and 4 men, who were chosen to participate in a museum visit by their educator from the same association. It was made possible by an ongoing agreement between the participants' association and the research organization involved and formal approval from the ethical committee of the researchers' institution. The association ensured that both legal guardians and participants knew the research purpose and that participation was voluntary. This was an important aspect of the study as it ensured that all participants were willing and able to participate in the experience. Three participants had a mild disability (P3, P5, P10), eight had a moderate disability (P1, P2, P4, P6, P8, P9, P11, P12), and one had a severe disability (P7), providing a representative sample of the population. Regarding age, 2 participants were under 40, 4 were between 40 and 50, and 6 were over 50. To ensure that all participants were comfortable during the study, frequent reminders were given that they could opt out of the activity at any time. This was an important step as it ensured that participants were not feeling pressured to continue the activity if they were uncomfortable with it. For non-verbal or minimally verbal participants, their educators were present to ensure that their needs were understood and that they felt comfortable throughout the experience.

5 Findings and Discussion

5.1 Initial observations

Participants were initially free to explore the diorama. We analyzed and clustered data based on similarities in behavior. Some participants (P1, P3, P7) focused more on physical interaction with the elements, such as touching and feeling, while (P2, P4, P5, P6, P8, P9, P10, P12) focused more on verbal expression and describing what they see or experience. P11 is initially more cautious and skeptical of the diorama and needs help to relax and understand what we are proposing.

We now look at accessibility, engagement, and learning during exploration and playing with the diorama via participant observations and feedback.

5.2 Exploration

Several similarities were observed in participants' exploration behaviors. A few participants described the elements they saw, such as in P1, P4, and P5, while others pointed at them and named them, as seen in P6 and P12. Many participants interacted with the wind, expressing enjoyment, surprise, or fascination with it, as evidenced in P2, P3, P4, P6, P8, and P12. Some participants explored the exhibit independently, as observed in P8 and P9, while others needed some prompting, such as in P6 and P10. P10 mentioned, "I am confused with the mouse" and later on highlighted when the fan was activated "as if it was the wind of nature." Ultimately, P11 expressed curiosity about the exhibit's purpose or mechanisms.

5.3 Independence and Accessibility

Most participants were able to access the diorama and complete their assigned tasks independently. Nonetheless, some participants required different levels of assistance to complete the game. Three participants (P7, P8, P12) were found to be primarily independent but required some form of guidance or assistance, such as specifying where to place a statuette or correcting the placement of a tag on the reader. One participant required scaffolding to complete the game (P9), and another needed help to start (P11).

5.4 Understanding and Learning

Participants showed a good understanding of the feedback provided in the game, either through sound or light. Some participants found the light feedback more immediate and noticeable than the sound feedback. When prompted P12 said, "It's not right because red means mistake." Several participants used the feedback to correct their following answer, while others understood that the green light meant a correct answer and moved to the next spot. P1 says when playing, "One reindeer doesn't eat another reindeer. That doesn't make sense." One participant (P11) required scaffolding to understand the game. The vibration was the least noticeable. Participants could feel it when touching the statuettes during the game's feedback.

5.5 Gaming Experience

Most participants demonstrated an understanding of right and wrong answers by saying out loud what was going to happen, before waiting for the matching game feedback. P12 is sure about her answers and proud to get them right, saying: "You see?!?" Two participants (P9 and P11) needed help playing the game. P3 explained the gaming experience "I didn't know if it was correct, but I wanted to try. The light told me it was right."

5.6 Emotions and Engagement

Participants exhibited a range of emotions during gameplay. P1, P7, and P12 were surprised and enthusiastic, with P1 expressing excitement at discovering new features "I really liked the box, did you know?" P2, P4, P6, P10, and P11 smiled during gameplay, with P6 smiling specifically at the feedback, P10 while playing with the reindeer statuette, and P11 while discovering what the box did. P5 was generally serious, while P9 was curious and spent time looking closely at the objects.

5.7 Preferences

We asked participants to freely choose which solution they would like to use to learn more about the museum content. They had five alternatives, three high-tech (Museum app, Augmented Reality app, and the MSD) and two low-tech (printed easy-to-read text and AAC pictograms). MSD was the second preference of 5 participants (P3, P6, P7, P11, P12), the third preference of 3 participants (P1, P2, P10), and the fourth (P5 and P8) and last (P4 and P9) of two. When placed as second or third place, the MSD was always chosen after a high-tech solution, proving the engagement and interest in technology by people with ID.

5.8 Interview

After each one-on-one session, the participants were asked about what they saw without any extra prompt, they were free to express what they remembered. They all described the box and various animals, the reindeer and the wolves. P3 mentioned "stickers" indicating the game alternatives glued on top of the box, while P4 and P5 provided detailed descriptions of the LEDs, fan, and wind, as well as their interactions with the box. P9 noted the presence of "fake moss," and P10 mentioned the "reindeer and wolf family."

We asked participants to describe their experience with the MSD in detail and prompted, if necessary, with the following questions: were there any noises or sounds? Did you have something to read? Were there any pictures? Were there any lights? Could you do something with the box? Many participants mentioned lights that turned green when they gave a correct answer and red when they gave an incorrect answer. Some participants also reported hearing animal sounds, such as the wolf howling or the reindeer making noise. Several participants described feeling the wind on their hands or seeing leaves move when they touched a specific box area. Participants appeared engaged and enjoyed interacting with the various elements, such as guessing which animals the wolf and reindeer should eat. However, there were also some differences in their experiences, such as one participant who reported not hearing any noises (P3) and another who did not see any lights in the box (P11).

Lastly, during the interview, the educators asked about the participants' favorite technology. A few participants said they enjoyed the tablet (with the museum or AR app) and the easy-to-read texts. P2, P6, P7, P8, P9, and P10 highlighted the box and its features. P4 answered, "I liked the pictures," which could be related to any of the alternatives they had in the hall. Additionally, one participant (P3) noted that he liked everything.

6 Conclusions

This study aimed to propose and evaluate the effectiveness of a MSD designed to enhance accessibility and interaction in the museum environment. The MSD was an innovative and inclusive way for people with ID to learn about the museum content, providing participants with multisensory experiences that allow for interactive and fun informal learning. Nevertheless, the study had limitations, such as noise inside the museum that disturbed the audio feedback experience and the museum hall with stimuli everywhere. As a result, future work should focus on evaluating new multisensory feedback and increasing speakers' volume. Overall, the results of this study suggest that the MSD successfully engaged participants and elicited a range of responses and behaviors, making it a promising approach for enhancing museum learning experiences.

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