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The experience of adults with visual disabilities in two Brazilian science museums: An exploratory and qualitative study

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In this exploratory and qualitative study, we investigate the experience of two groups of adults with visual disabilities in two science museums in Rio de Janeiro (Brazil). Data collection was performed by recording their visits through a subjective camera placed on the head of one of the visitors. The analysis used three accessibility indicators and barriers as codes. The data reveals that: (a) physical accessibility—related to the internal architectural aspects—was well developed; although other elements of this indicator need improvement; (b) attitudinal accessibility was present, mostly due to the work and guidance of the museums' educators; (c) communicational accessibility was rare in the museums, either due to a lack of diversified equipment, media or resources both for internal and external communication; (d) barriers do exist, mainly because one or more element is missing from the accessibility indicators. This study indicates that the two science museums offer accessibility strategies from the perspective of people with visual disabilities and can provide interactions, learning and science communication for this audience in different levels. However, some barriers in both institutions still need to be improved. Based on our data, results and discussions, museums and their professionals can be inspired, learn and plan an organizational change toward accessibility. Lastly, museums need to be able to learn from people with disabilities.

KEYWORDS
non-formal education, science communication, accessibility, inclusion, disability

Introduction

Access to quality education and accurate scientific information, to be part of cultural life, enjoy the arts and participate in any community social activity are the rights of every person, according to the Universal Declaration of Human Rights (UN, 1948). For people with disabilities, these rights are reinforced by a set of laws and international conventions—such as the Convention on the Rights of Persons with Disabilities (CRPD) (UN, 2006)—which is aligned with the human rights (Ollerton and Horsfall, 2013). Argyropoulos and Kanari (2019, p. 125) explain that "educational policies and initiatives toward an inclusive society have become more and more intensive in the last decades" and that the focus on the right to participate in different sectors of social life, education and culture are based on the adoption of the social model of disability.

The idea that it is possible to learn science outside of school also grew and was incentivized both in theory and practice throughout the years, as seen in the editorial organized by Longnecker et al. (2022). Science museums are considered non-formal learning environments (Bell et al., 2009) and significant places for leisure, engagement and science communication (Falk and Dierking, 2002; Schiele, 2014). Through their exhibitions and activities, museums can facilitate learning (Marandino et al., 2018) in a multidimensional way (Hooper-Greenhill, 1994, 2006). As Hooper-Greenhill (2006) states, learning in museums is based on experience, because they provide opportunities for people to perform, touch, interact through their different senses, and feel engaged and immersed.

In this way, in science museums, people can explore their interest in subjects related to science and practice skills related to science learning as logical reasoning, observation, and hypotheses construction (Norberto Rocha, 2018; Massarani et al., 2022a). Thus, people can "build upon, reinforce and strengthen their own preferred, pre-existing science understandings" (Falk and Dierking, 2019, p. 3). Visitors can choose when and how they want to learn, driven by their emotions, personal stories, and motivations—what is called "free-choice" learning (Falk and Dierking, 2002). These institutions are, thus, platforms for scientific citizenship (Bandelli, 2014) which can provide educational opportunities for all people to learn and engage at any age (O'Brien and Candlin, 2001).

As such, they need to be capable of facilitating social inclusion and the democratization of knowledge and of catering to a broad and diverse audience (Sandell, 2002; Bevan and Ramos, 2021). On this subject, during the last decades, worldwide, museums have worked on establishing relationships with people with disabilities, primarily by providing more accessible and barrier-free physical spaces (Sandell et al., 2010). Studies also indicate that museums try to promote "organizational change" and make institutional learning increasingly inclusive (Reich et al., 2011; Reich, 2014); they are developing programs and strategies and launching specific initiatives to target different audiences (Norberto Rocha et al., 2020a; Norberto Rocha, 2021).

In the specific context of Latin America, the *Guia de Museus e Centros de Ciências Acessíveis da América Latina e do Caribe* (Norberto Rocha et al., 2017) shows that accessibility is being practiced by at least 110 science museums in various forms. However, the study based on the data collected for this document reveals challenges faced by these institutions. Norberto Rocha et al. (2020b) exposed that the museums tend to emphasize physical accessibility and provide only a limited number of activities related to the attitudinal and communicational aspects of inclusion—which are essential to learning and engagement. This means that museums have already progressed in promoting access to their physical spaces, but devote insufficient attention to the resources and strategies that can facilitate learning in a non-formal environment.

Argyropoulos and Kanari (2019) mention that different types of disabilities require corresponding strategies and, what's more, that within a group of people with disabilities, there is heterogeneity and specific needs and ways of promoting inclusion. Related to individuals with visual disabilities, the authors acknowledge they still face many barriers to visiting, such as misunderstandings regarding the heterogeneity of people with visual disabilities, limited or temporary options offered for blind visitors, attitudinal barriers, and a lack of accessible web sites and publicity. Moreover, they state that "it seems that due to lack of permanent access facilitations in many museums people with visual disability face many difficulties if they want to visit them spontaneously" (Argyropoulos and Kanari, 2019, p. 131–132). The ability to visit museums spontaneously is part of what people with disabilities might consider autonomy and independent living, which are a central demand on the agenda of people with disabilities' rights (Oliver, 2013).

The study of Norberto Rocha et al. (2020a,b) on the Latin American science museums and centers explicates these institutions' point of view on accessibility. However, studies on how people with disabilities experience museum visits are still needed, from their own perspectives, as protagonists of the inclusion agenda (Levent et al., 2013). Given that experience is a central part of museums' learning (Falk and Dierking, 2002, Hooper-Greenhill, 2006; Argyropoulos and Kanari, 2019), it is essential to understand how visitors with disabilities interact with the exhibits and the museum professionals—mainly the educators—and how they face barriers. Along the same lines, Levent and Reich (2013) state that learning from the visitor experience is essential to improving museums' interactions with visitors, their services, and their educational environment.

Under these circumstances, in this study, we aimed to investigate the experience of two groups of adults with visual disabilities in two science museums in Rio de Janeiro (Brazil), focusing on aspects of physical, attitudinal and communicational accessibility and barriers. We examine how they use accessibility resources, interact with the exhibitions and professionals, overcome barriers, and potentially learn in these non-formal education places. Finally, we provide some discussion based on the evidence collected and the study's limitations.

Materials and methods

The methods of this exploratory and qualitative study were grounded in previous research involvement developed for investigating the experience of different audiences in science museums, e.g., teenagers (Massarani et al., 2019a,b,c, 2022a; Norberto Rocha et al., 2021b, 2022; Coelho et al., 2022), families (Massarani et al., 2021, 2022b; Scalfi et al., 2022) and people with disabilities (Do Carmo, 2021).

In these prior studies, professionals from Brazil, Argentina, Colombia, Uruguay, Mexico and the USA developed protocols for collecting data with a "subjective camera" method by which an audio and video recording of visitors' interactions and conversations in a museum is taken by a camera placed on the head of one of the visitors. After collecting this audiovisual material, software is used to code the gathered data in order to examine which elements of the experience can influence visitors' participation in museums. The codes are based on pre-defined categories retrieved from analysis frameworks.

This data collection protocol and analysis was reliable when applied to different types of audiences and, in the current study, we apply it to another group of visitors—adults with visual disabilities, who have not been extensively studied in the academic field of visitor studies (Fernandes, 2020).

Participants with visual disabilities

Participants were invited by the non-probability sampling technique known as snowball sampling (Biernacki and Waldorf, 1981; Bernard, 2005). This method is suitable for finding study participants who may be difficult to identify through other recruitment methods (Hennink et al., 2011). This technique relies on discovering a "strategically important contact" who can help find additional contacts that fit the characteristics of the desired target population (Henn et al., 2013) and has been used in several previous studies on museum visitors' experience.

The participants of this study were a heterogeneous group of volunteers with visual disabilities: three men and two women, aged between 23 and 60 years (**Table 1**). Their educational level varied from elementary to graduate school. The visual disability of each participant varied between total blindness and low vision. These terms are based on the International Classification of Functionality, Disability and Health and the World Health Organization, which define parameters for each degree of visual impairment. We can classify blindness and low vision according to the visual acuity of each individual. We consider people blind if they have a visual field of less than 10° and having low vision if they have 20° in the best eye (Cieza et al., 2021). We also chose to work with people who were both engaged and not engaged with museums' culture to reflect different levels of interest and participation in cultural life.

The first group of visitors was composed of three people, identified by us as "engaged visitors" (EVs). The group was characterized by significant personal involvement with museums: either through a professional relationship or interest and previous social life experiences. Also, they demonstrated expertise and knowledge regarding accessibility strategies in these spaces. They had secondary and higher education degrees and were either totally blind, with white blindness (a lack of light and figure perception) since childhood, or had experienced low vision for more than 5 years.

The second group of visitors comprises two people identified as "low-engaged visitors" (LEVs). The group members' connection with museums' activities was low, since they declared they had not regularly participated in these activities or even had never been to a museum. They had become totally blind in adulthood and completed middle and high school. We therefore consider the group as little engaged in this type of social activity.

The two groups visited the two museums in August and September of 2019, but at different times to avoid any interplay between them. Both museums offered the visits entirely guided by museum educators.

The museums: A natural history museum and a science center

The two Brazilian science museums studied are in Rio de Janeiro and consist of a natural history museum and a hands-on science center. Both have free admission and state that they provide accessibility for people with disabilities. The museums were chosen after their presentation on their accessibility strategies at the 3rd National Meeting of the Brazilian Association of Science Centers and Museums (ABCMC), which demonstrated they were working toward the same aim, but in different stages of development.

The natural history museum, the Museu da Geodiversidade (MGeo) at Universidade Federal do Rio de Janeiro, addresses the history of Planet Earth and its evolution over the years. Its extensive exhibitions contain eleven rooms with interconnected themes, displaying rocks, fossils, and specimens—the majority of which are original, in glass cases, or prepared for viewing only. Some exhibits can be touched, e.g., the representation of the Planet Earth, rocks, minerals, the reproduction of the jaw of the largest Brazilian alligator, shells, etc. In part of the exhibition, there are a few braille labels, tactile mini dioramas of specimens, other tactile representations, and audio recordings.

The Casa da Descoberta (CD) at Universidade Federal Fluminense is a hands-on science center consisting of one large exhibition hall with exhibits spread throughout the space. The central theme of the hands-on exhibits is physics, but they also explore some chemistry, astronomy, mathematics, and biology. Many exhibits are those traditionally presented in hands-on

TABLE 1 Research participants' profiles.

Group	Age	Gender	Visual disability	Education	Profession
Engaged visitor 1	41	Male	Low vision	Graduated	Audio descriptor
Engaged visitor 2	33	Male	Blind	Completed high school	Accessibility consultant
Engaged visitor 3	23	Female	Blind	Undergraduate student	Museum intern
Low-engaged visitor 1	60	Male	Blind	Completed middle school	Retired
Low-engaged visitor 2	49	Female	Low vision	Completed high school	Retired

science centers, such as the Van Der Graaff generator, pulley association, bed of nails, Newton's pendulum, human stack, power-generating bicycle, and power-generating crank. All visitors can touch them, and none provide braille or multimedia strategies. The only exhibition that presents accessible resources is about optics and was specially made for audiences with visual disabilities.

Data collection and analysis

Data was collected by recording the visits of the two groups to the two museums in total, using the "subjective camera" method (Burris, 2017). As in the previous studies using the same method, a GoPro® camera was placed on a participant's head for each group.

Five hours of recording were collected and the software Dedoose was used to code audiovisual excerpts through qualitative analysis. As in previous studies, the data were analyzed and coded from a qualitative perspective—the excerpts were coded according to the duration of the experience that naturally occurred. This means that a specific excerpt started when we interpreted that one or a set of actions, conversations, and interactions that fit in one of the codes began until the end of these actions.

For coding the excerpts, we applied the framework "Accessibility Indicators of Science Museums" (**Table 2**) proposed by the Accessible Science Museums and Centers (MCCAC) research group (Inacio, 2017; Norberto Rocha et al., 2020b). This framework was constructed based on a literature review and the study of practical norms of accessibility. Since its development, it has been applied to several studies. For instance, Norberto Rocha et al. (2020b) presented a panorama of the provision of accessibility of Latin-American institutions, Do Carmo (2021) used it to study the experience of deaf people in three different exhibitions in the city of Tomaz Silva (2022) applied it to investigate how the Museum of Tomorrow provides accessibility for visitors with Down's Syndrome. Different researchers used indicators to create analysis frameworks, especially in science education and communication, museology, accessibility, and their interconnections (Marandino et al., 2018).

Physical accessibility: the two attributes of this indicator are related to the physical and architectural aspects of the museum, its infrastructure and surroundings, and the design of the exhibition and its displays. With this indicator, we can identify the characteristics that respect and value the different abilities and physical bodies of the visitors when interacting with the exhibitions, activities, objects and the museums' physical space.

Attitudinal accessibility: the first attribute of this indicator is aimed at attitudes and actions to eliminate prejudices, stereotypes, and stigmas toward people with disabilities. The second examines political aspects, such as the institution's mission to promote accessibility, the qualification of human resources [such as museum educators], and the incentives, programs, and actions that facilitate accessibility.

Communicational accessibility: this indicator highlights the characteristics of equipment and resources that allow overcoming interpersonal, written, and/or informative communication barriers. The first attribute of communicational accessibility refers to the internal and external communication, which provides information about the functioning of the space (days and times, location, ticket price, etc.) and the contents of the exhibitions and objects of the museum itself. The second attribute refers to diversified media that facilitates content communication with visitors.

Lastly, *barriers* include obstacles, non-inclusive practices, missed opportunities and untapped adaptations, whether identified by the visitor, researcher or reported by the museum team (museum educator, coordinator, etc.).

In the coding process, each attribute of each indicator was considered a "code." It is worth mentioning that the codes are not mutually exclusive, meaning that more than one code may be applied to a given excerpt, with overlapping durations.

Results

A total of 5 h and 31 min were analyzed in the software, in which a total of 449 codes were applied. Attitudinal accessibility was highly coded in the two museums: a total of 93 codes were used, comprising 1 h and 20 min of duration. Following, there was a large number of codes for Physical accessibility: 80 codes and 2 h and 53 min of duration. The Communicational Accessibility coding had a total of 24 and 52 min of total duration. Regarding the barriers, there were 47 codes and 43 min of duration.

TABLE 2 Framework "Accessibility Indicators of Science Museums".

Indicators	Physical	Attitudinal	Communicational
Attributes	1a. Architecture, physical access, accommodations and use of space	2a. Inclusive practices, welcome and engagement	3a. Communication (onsite and external) and signage
	1b. Design and use of objects and facilities	2b. Institutional policy/mission	3b. Media, equipment, resources, etc.
Barriers: obstacles, non-inclusive practices, missed opportunities and untapped potential of adaptations, whether identified by the visitor, researcher, or reported by the museum team.			

Adapted from Norberto Rocha et al. (2020b).

As it is an exploratory and qualitative study, the numbers (which means the frequency and duration of codes) helped to provide an introductory panorama of the data. Exploring the coded excerpts in depth was able to provide a better understanding of each category and interpretation of the visitors' interactions, potential learning moments, and the nature of the barriers confronted. In the following sections, we present the analysis by each accessibility indicator using examples of transcribed excerpts of the audiovisual recorded data to illustrate our arguments.

Physical accessibility

From the point of view of the architecture and infrastructure, both museums were considered physically accessible in their interiors. At MGeo, visitors did not experience difficulty going through the exhibition rooms, mainly because the museum educators guided them throughout the visit. Some ramps had been placed over stairs when these connected rooms, and all visitors used them to move from one room to another. At CD, as the exhibition is placed in a large exhibition hall, no steps or walls separated the exhibits. Visitors did not face barriers getting around or accessing the exhibitions displayed and all exhibits' displays had the same height and shape and were arranged in a spacious way. The LEV's visitors did not make specific comments regarding the physical accessibility of the place, while EV2 commented: "It's good that everything is close by." EV1, on his turn, commented on accessibility for a broad spectrum of people who could benefit: "I liked the height of the cube because a person in a wheelchair is at a good height." EV3 added that the height was appropriate "for those who have dwarfism, too."

In relation to the second attribute, the design of objects and exhibitions were considered partially accessible in both museums, with both groups of visitors emphasizing their positive experiences. In MGeo, for example, the first exhibition hall displayed a giant globe of the Earth at the beginning of its formation. The museum educator asked both groups to touch and explore the piece before giving information about the object and what it represented. The strategy of touching the globe was a potent activity because visitors were able to raise hypotheses and try to interpret and extract information from the object—skills relevant to science learning and museum visitation. EV1 said, "It's a globe... it looks like the Moon, maybe a meteor. Very big." EV3 said: "This is Planet Earth." LEV1 asked, "Are these holes volcanoes? [...] It's a meteor? Its craters are here, right?." From the thoughts and what was raised by the visitors during the tactile exploration, the museum educator was able to develop a dialogue about the object, bringing up scientific information and relating it to daily life and previous experiences narrated by the people with visual disabilities.

In CD, most exhibitions are considered hands-on, such as the Van Der Graaff generator, association of pulleys, bed of nails, and Newton's pendulum. Other exhibitions, such as the human battery, power-generating bicycle, and power-generating crankare visual-based and require accessibility strategies to provide an understanding of their scientific concepts for people with visual disabilities.

One vision-centered exhibit (about optical concepts) gives the option of being entirely dismantled and touched. The equipment was designed to be disassembled, allowing visitors to explore its structure and the materials as part of the experiment. This allowed visitors to understand the information, to make assumptions based on prior knowledge and to combine these with the guidance of the museum educator. EV3 commented: "I should have seen this in my optics classes." EV2 said, "I think there are two mirrors, so it doesn't get inverted. If it were a mirror, it would be inverted." EV3 responded, "Yes, it is inverted and slightly bigger." EV3 said, "The tail is facing my direction, leaving the focus and going to the center of curvature to the left and the right there is a snout." EV1 ultimately said, "Very nice, this experience. That's really cool."

Another display in the science center also made visitors from both groups curious and excited: the Van Der Graaff generator. The exhibit allowed the entire structure to be touched, which helped them understand how it works. Visitors could hear and feel the effects of the concept of electrification by friction. Educators explained how the generator works, exploring the characteristic sounds. Both groups commented about their emotions and everyday experiences—elements that favor learning. EV1 asked, "Is there light? What color is it? Is her hair standing up?." EV3, touching her hair, said, "It's flying!." LEV1, touching the metal part of the stick, said "Wood doesn't give shocks. It's shocking here, right? [...] It's because it is making friction."

Attitudinal accessibility

The Attitudinal accessibility indicator was the most existent in the two groups of visitors, in special the "inclusive practices, reception and reception" attribute—demonstrating that the educators' guidance and practice during the visits acted as an essential strategy for accessibility and for reducing of some barriers encountered. Some attitudes and actions to welcome people with disabilities were noticed by visitors in both museums but in different forms and to different extents.

During both visits to the MGeo, the museum educator described all rooms and their exhibitions, as in the examples: "This is a very bright room, the walls are painted blue, and in front of you there is a plot representing the ocean. [...] This rock [that you are touching] has darker bands and lighter bands"; "In this room, our highlight is, above us, the reconstruction of the skeleton of one of the largest amphibians that ever existed in the world. We cannot touch it, but it looks like an alligator or crocodile." We can see that this is a usual practice, since it was repeated in the visitation of both groups. In addition to being an alternative to eliminate barriers, this description practice favored contextualization and encouraged visitors to seek more information. For instance, one of the EVs asked the educator about the rock she was touching. EV3: "What is the color?" Educator: "It's a black color."

In the CD, the museum educator, in her opening speech, made the presentation combined with the practice of self-description, as in the excerpt: "Educator: Good afternoon! [...] I'm 1.66 m tall, my hair is black with blonde highlights, wavy, and it's tied in a ponytail. I'm wearing a gray t-shirt, wide-flowered pants, and black sneakers. I'ma white person, full of tattoos!." This attitude of self-description for both groups generated a connection and awareness and created a relationship of trust with visitors. This made them feel more welcomed and comfortable with the educator's guidance, which opened space for asking about scientific topics during the visit, as can be seen in EV2's words: "I think the issue of receptivity made a lot of difference for us to feel comfortable. For example, I feel comfortable talking and asking questions. Because this content is also a little intimidating, you feel embarrassed to say something wrong or ask silly, nonsense questions."

Regarding the political and organizational aspects of social inclusion, there was evidence that the museums take actions to support them, although challenges and struggles also came up. During the CD visit, one of the EVs asked about the accessibility team that makes up the museum. He was informed that the museum had three educators who were fluent in sign language. According to the museum educator guiding the group, "we selected a student from the history course who is blind and will be our great mentor in this adaptation process for you." This is an example of how the institution is organizing itself to be more inclusive and brings up the issue of representation, i.e., having people with visual disabilities working in these spaces is essential for at least three reasons: (a) consultancy, meaning that this professional can give input from his own experience when the museum preparing exhibitions and changing spaces and objects to be more accessible (Monteiro, 2021); (b) political presence and representativeness, which is historically important and central in the fight for the rights of people with disabilities (Shakespeare, 2006); (c) representativeness, for the visitor to feel included and to recognize that the museum is also his place.

Communicational accessibility

Nowadays, the museum website is one of the most important means for any museum to communicate with its audience. Regarding the content and accessibility on the MGeo website, one of the EVs asks the museum educator about it: "We don't have images of the collection; we have photos of the exhibition halls. The website does not have an audio description tool." For both groups, there was no mention of daily activities, opening hours, or even MGeo's social media—information that would be essential if they wanted to return. We emphasize that people with visual disabilities, especially those engaged and interested in cultural activities, have access to and consume internet content, as EV1 highlighted: "In my free time I like to access the internet, watch series [and] movies."

The museum educator tells the EVs group the accessibility days schedule on the CD, but she does not mention the opening hours or other relevant information. For the LEVs, at the end of the visit, information about the museum's operation was provided. The educator said: "You can bring family members, our museum is free, it is open from Monday to Friday from 9 am to 12 pm and from 2 pm to 5 pm. Show up, [you] are all our guests!." By sharing this information, the interest and curiosity of the visitors were aroused about other activities available in the space, as seen in the comments. A visitor asked, "What time is the telescope open?" and the educator responded, "On Tuesdays, from 6 pm to 9 pm."

Regarding the communication accessibility strategies presented to the two groups of visitors at MGeo, we can highlight three different moments. The first was a mammal footprint exhibit that offered a label in braille. When this resource was provided, the visitors explored the exhibits without depending on the guidance of the museum educator. EV3 reported: "I love this braille here." The second moment was a tactile mini diorama of the exhibition scenario with captioning. A tactile mini diorama is a valuable tool that, when explained by the museum educator, can add rich scientific information to a scene that would possibly only be verbally described to visitors. The third was an interactive dashboard with audio recording. The dashboard provided information about various objects of daily life (e.g., plastic bottles, lipstick, cell phone, tire, etc.) which contained petroleum in their composition. To activate the audio recording, the visitor had to choose one of the objects and place it in the dashboard's center. This auditory resource made the visitors surprised and curious about the objects, combined with the joy and fun of being able to interact with the dashboard freely. LEV2 said, "The rest I already know have petroleum; the lipstick, I didn't know." LEV1 said, "That petroleum dashboard, I thought it was entertaining, you can put [a product in it and] it has information about the product."

Barriers

In general, barriers were encountered by both groups in both museums, but the EVs emphasized them more. Several MGeo exhibits, which are in glass cases, are not signaled and obstruct the tactile exploration of specimens. Visitors from both groups were uncomfortable with the experience because they could not touch or did not feel safe going through the exhibition circuit. EV1 commented: "There are many things in a glass dome, which is very frustrating. A lot of things we can't touch, they didn't present us with any audio description." EV3 said, "This makes us very dependent" and "the part I was most uncomfortable with was the window display." LEV2 said that it was only possible "for [a visually disability] person to walk being moved. You can't walk alone here if you can't see, because it doesn't have a tactile floor; there is nothing. The person will directly collide with the glass because it is not signaled."

From examples like these, visitors stated their fear of exploring the exhibition by themselves and the discomfort caused by being dependent on the museum educators' guidance—which directly influenced their learning experience and feeling of autonomy. Also, at the CD, the hugest barrier was access to its building: it had elevators and stairs, with very poor signage. This made physical guidance necessary. EV1 said: "Here, it is inaccessible. The problem is not the ladder, the problem is getting to the ladder! [A visually disability person] is in no condition to come alone."

Another barrier that negatively influenced the visit of the EVs group at MGeo was the museum educator's self-introduction to the group. Right after starting his interaction with the visitors, he stated that he was not going to describe himself: "I'm not going to describe myself because I don't like it. My self-esteem gets a little... I'm a Latin American guy, that's all you need to know." The group felt the educator was insecure and not prepared to guide people with disabilities—particularly with visual disabilities—which generated discomfort and caused a feeling of awkwardness in the museum. The group commented on this. EV3 said, "[At the] beginning, mainly, I was a little uncomfortable," and EV2 said that this "already created a barrier."

Another barrier was the material used in the natural history museum as a resource for representing the dinosaur fossils exhibited—plastic dinosaur toys. The EVs group realized that the material presented for touch did not faithfully represent the dinosaur fossils in the exhibit, which resulted in unfulfilled expectations. EV1 said, "Actually, what they showed us is not quite a replica. Because from what I understand, what is there is just the skeleton and what they gave us was not the skeleton." EV3 said, "I felt a little frustrated there [...] I also thought it was going to be fun there, but it was pretty frustrating." A suggestion the visitors gave to make the room more attractive to them would be to provide sounds and present more realistic replicas.

Finally, regarding the few braille labels in MGeo, the EV group questioned why only a part of the exhibition contained this accessibility strategy. EV1 said: "I don't know what the purpose was because there were several exhibits and only a few have braille." In addition to being only present in a small part of the exhibition, it is relevant to note that although helpful for some people, this strategy does not serve all visitors with visual disabilities. Some people are not literate in braille, as one of the LEVs pointed out: "I still don't know. I would like to learn this here." At CD, this communicational strategy was not even used, since there were no braille labels or audio descriptions in the entire exhibit, which indicated that the science center still needed to develop this communication tool.

In summary, based on the accessibility indicators, we can conclude that:

a) Physical accessibility, related to the internal architectural aspects of the museums, was well developed. However, there is still room for improvement, mainly related to the outside environment of the museums and the design of objects and some exhibitions inside the museums.
b) Attitudinal accessibility was very present, mainly due to the guidance and work of the museums' educators. At different times, visitors found objects, rooms, or exhibits that presented barriers and the museum staff could carry out attitudinal practices to overcome or minimize them.
c) Communicational accessibility was rare in the museums, either due to a lack of diversified equipment or resources to overcome interpersonal, written, and/or informative communication barriers, internal and external communication.
d) Barriers were present in both visits for both groups. They demonstrated one or more missing elements for accessibility, either physical, attitudinal, communicational, or several of them. Several barriers were encountered by both—which proved to be issues that the institutions needed to face. Other barriers were encountered only by one of the groups, given their diverse profile.

Discussion, limitations, and contributions of the study

In general, after the framework analysis and also the interviews with participants, we can see that visitors demonstrated curiosity and willingness to explore the exhibitions and that they had positive experiences concerning accessibility (primarily with regard to the physical and attitudinal indicators). From the tactile exploration of objects and interaction with the exhibits, hands-on activities and educators, they were able to think up hypotheses and connect them with previous knowledge and experiences, leading to potential learning and engagement with scientific content. In addition, there is evidence that both groups experienced appreciation, surprise, discovery, leisure, and emotion—all of which are crucial to free-choice learning in non-formal education environments (Falk and Dierking, 2002). The visitors reported their life experiences several times, which was a fruitful way to establish a bridge between the exhibition and the visitor, encourage debate, and favor learning in non-formal learning environments (Coelho et al., 2022).

From the experiences of the two heterogeneous groups of visitors with visual disabilities, we can see that both the natural history museum and the science center offer accessibility strategies that can potentially provide learning and science communication. Nonetheless, some gaps, barriers, and vulnerabilities still need to be improved—which is in line with the results of the accessibility panorama of science museums in Latin America obtained by Norberto Rocha et al. (2020b). We hope that the results obtained here will be able to guide and encourage more accessible practices.

These results were due to the nature of the visits and the formats adopted by the museums. First, the visits were fully guided by educators of each museum, which may have favored the strong presence of attitudinal accessibility, but, at the same time, do not offer the option of having an autonomous visit. Second, the elimination of some physical barriers, improvements in the signage and design of objects would make visitors with visual disabilities feel safer and more comfortable when walking through the halls. Third, both museums provided a tactile exploration of some exhibits and hands-on activities, favoring learning and interaction; however, other senses, such as smell or hearing—which could have been helpful for the participation of these visitors—were barely explored. Fourth, the museums did not offer diversified communication resources, such as texts and audio texts, multimedia, support resources, etc.; this led to low of communicational accessibility.

From the experiences of the visitors, we noted that, on the one hand, some changes to extant objects and exhibits in the two museums and how they worked could make them more accessible and participatory to adults with disabilities. Although on the other hand, providing such facilities to make possible autonomous visits by people with disabilities still seems to be a distant prospect for these institutions. This represents a critical barrier to be solved, since independent living is central for people with disabilities.

Additionally, the heterogeneity of the visual disabilities of the study participants, their different backgrounds, and their personal stories stood out during the museum visits and demonstrated that not all accessibility strategies entirely meet the needs of every person of this audience—as Argyropoulos and Kanari (2019) anticipated. Some of the accessibility strategies were considered positive by and for both groups. Conversely, other strategies were successful only for one group—e.g., the braille labels for those who were literate in them. Therefore, exhibitions and activities need to offer wide-ranging accessibility strategies with options to explore through multisensory stimuli, as well as complementary and redundant actions, diversifying the ways to access information, mainly by providing apparatus, equipment, and media.

It is worth mentioning that considering the exploratory and qualitative nature of this study, the results cannot be extrapolated to all the adults with visual disabilities visiting museums, since the study was focused on two Brazilian science museums and the sample was neither statistically representative of blind and low vision population, nor geographically distributed.

Although there are these limitations, the study still provides qualitative data that deepens the experiences and the potential learning of two heterogeneous groups of visitors with visual disabilities. It can contribute, in practice and theory, to the fields of non-formal education, special education, science communication, museology, visitor studies, and others with intersections and points of tension that coexist. Based on our data, results and discussions, museums and their professionals can be inspired, learn and plan an organizational change toward inclusion and accessibility.

Science museums are places of non-formal education and science communication; they can contribute to free-choice learning throughout the lives of people with visual disabilities if their accessibility strategies (physical, attitudinal, and communicational) are continuously improving. It is thus necessary to keep elaborating strategies, planning and encouraging social interaction for and with different audiences. Recalling Levent and Reich (2013), museums need to be able to learn from the visitors because they are the ones who can explain their needs and what they are looking for in these educational and cultural experiences. Therefore, our primary expectation in performing this type of study was to highlight their voices, perspectives, and opinions, as the protagonists of accessibility and inclusion in science museums.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Comitê de Ética da Fundação Oswaldo Cruz, sob o número CAAE: 10663419.0.0000.5241. The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

MF: data collection and analysis, and development of original research. JN: responsible for the guidance and development of original research. Both authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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