Co-designing a Museum Application with People with Intellectual Disabilities: Findings and Accessible Redesign

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In order to improve the user experience and general accessibility, inclusive apps are essential. They promote independence and engagement in individuals with impairments and may be tailored for a broad range of situations. This article outlines the different steps of the co-design process to produce ACCESS+, an accessible application for navigating museum material for people with Intellectual Disabilities (ID). We conducted three research visits with 20 participants to understand their needs and collect requirements. Our qualitative approach aims to (i) understand the overall experience with an existing museum website and application; (ii) gather the understanding of specific UI elements; and (iii) assess the overall UX provided by the new app, including the challenges with specific features and the touch-based interaction. We concentrated on customized and inclusive features, allowing users to adapt icon and text sizes, backgrounds, labels, and voices to their own requirements and preferences. Users also made sense of the content by looking at symbols using Augmentative and Alternative Communication (AAC) and listening to full-text text-to-speech with personalized tone, pitch, and highlight settings. Participants shared their thoughts, helping us to improve the accessibility of each choice. Together with technology experts, a psychologist, a museum professional, and two educators, they contributed invaluable insights, enabling this research to give helpful information for future application design.

CCS Concepts: • **Human-centered computing** → *Accessibility theory, concepts and paradigms*; **Accessibility design and evaluation methods**; • **Social and professional topics** → **People with disabilities**.

Additional Key Words and Phrases: Co-design, Application, Museum, Accessibility, People with Intellectual Disabilities

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1 INTRODUCTION

Co-designing inclusive applications that cater to the unique needs and preferences of People with Intellectual Disabilities (ID) has the potential to support their independence and engagement in a variety of contexts, including cultural heritage sites such as museums. Yet, creating inclusive applications that are genuinely accessible and usable requires a collaborative and participatory approach that involves individuals with intellectual disabilities as well as relevant stakeholders, such as museum professionals, educators, psychologists, and technology experts.

People with ID face numerous barriers to accessing and fully participating in museums [13, 15]. Regardless, there is growing recognition of the importance of their inclusion and participation in these spaces. Inclusive and accessible applications represent a promising solution to address some of the challenges this population faces in museums. Such applications can provide tailored support, promote independence and engagement, and enhance the overall museum experience.

This paper focuses on the co-design process of ACCESS+ [21], an accessible application designed with and for People with ID to navigate museum content. To iterate and make ACCESS+ more accessible, the co-design process involved multiple research visits with stakeholders (museum professionals, educators, psychologists, and technology experts) and individuals with ID to understand their needs and collect requirements.

The co-design process focused on customized and inclusive features, allowing users to adapt icon and text sizes, backgrounds, labels, and voices to their requirements and preferences. To help participants with different needs to make sense of the content, they could use Augmentative and Alternative Communication (AAC) pictograms of texts translated in plain language (Easy-to-Read) and listen to full-text text-to-speech (TTS) with a personalized tone, pitch, and highlight settings.

Through a qualitative approach, participants shared their thoughts in multiple forms, and the research aimed to gain insights into the participants' experiences with existing websites and applications, their understanding of user interface (UI) elements, and their overall user experience (UX), including challenges with specific features and touch-based interaction. This process involved multiple stages, such as brainstorming, focus groups, prototyping, and testing (hands-on and interviews), following principles of universal design, user-centered design, and participatory design.

Our qualitative approach aims to:

- **(i)** understand the overall experience with an existing museum website and application;
- **(ii)** gather the understanding of specific UI elements; and
- **(iii)** assess the overall UX provided by the new app, including the challenges with specific features and the touch-based interaction.

This paper contributes to the field of inclusive design by providing insights into the co-design process of an inclusive application for people with intellectual disabilities in museums. Additionally, it offers practical recommendations for improving accessibility and usability, which can inform the design of future inclusive applications.

2 BACKGROUND AND RELATED WORK

2.1 Intellectual Disabilities and Designing for Inclusion

Intellectual disabilities are a disorder that affects neurodevelopment and results in cognitive and adaptive functioning deficits [1]. Individuals with ID may face a variety of challenges in their lives. For example, they may have difficulty with problem-solving, memory, planning, reasoning, and generalization. They may also struggle with social and communication skills, making it challenging to interact with others [1, 7, 18]. In other words, people with ID may have difficulty learning and performing everyday tasks that are necessary for independent living.

Designing inclusive technology is crucial to promote independence for individuals with ID, as technology offers a flexible environment that can take multiple abilities into account, enabling inclusive design that benefits everyone. Additionally, in today's society, digital accessibility is essential to ensure equal participation in all aspects of life, as technology has a significant impact on our daily routines. Assistive technology, which is an umbrella term for any technology adapted or specially designed for improving the life of a person with a disability [16], can enable people with ID to live independently and actively participate in social and cultural life [17]. These accessible solutions are an important area of study that includes as well people with ID as users, both in work-related context [14] and educational context [8].

The first step to ensuring inclusion is to involve people with ID in the design process. Their participation is critical to gather valuable insights: by involving them, designers and researchers can understand their needs and consequently create solutions that can address them. Their level of participation can be viewed as a continuum based on the design stage and the abilities of the participants [10]. They can be co-researchers who consciously and directly help to design the solution; feedback givers who actively suggest improvements; testing users who are observed while trying the solutions; or they can be substituted by proxies or experts who can analyze the solution on their behalf [10]. While including people with ID as co-designers may be difficult, their participation is still valuable, even if it is limited, because they can provide feedback even if they do not fully understand the technology [3].

The second step is to make technology accessible. Accessibility refers to the measure of a solution's availability and usability regardless of a person's abilities. The Web Content Accessibility Guidelines (WCAG), developed by the World Wide Web Consortium (W3C), provides a set of requirements for designing and evaluating the accessibility of digital solutions [24]. In particular, WCAG is structured around four tenets: both content and UI of an application should be *perceivable*, *navigable*, *understandable*, and *robust.*

2.2 Accessible museums for ID

Museums are wonderful resources for people with ID, offering opportunities for learning and enrichment. Moreover, they are an essential part of the community and cultural life of a person [19, 20], and as such, it is important for museums to consider the needs of visitors with ID when designing exhibits and experiences. An inclusive museum has to provide accessibility on the *architectural, digital and sensory* aspects [4]. This can include providing clear signage, accessible seating, and alternative formats for exhibit content. For the latter, technology can play an important role in making museums more accessible and engaging for people with ID. By using technology to create inclusive experiences, museums can help ensure that visitors with ID feel welcome and included. This can encourage greater participation and engagement from visitors with ID, leading to a more enriching and rewarding experience for everyone.

To date, inclusive technology in museums has primarily targeted people with visual impairments, with a focus on navigation and auditory information solutions [2, 5, 11, 12, 23, 25]. Several studies have investigated solutions for this group, followed by solutions for people with hearing impairments [9] and wheelchair users [6]. However, while existing technologies have been adapted to cater to the needs of visitors with disabilities, these efforts have largely overlooked people with intellectual disabilities. Current approaches aim to improve the basic accessibility and overall experience in museums but fail to address the needs of this important group.

3 METHOD

This section outlines the different steps of the co-design process to develop ACCESS+. We conducted three research visits (nine days in total) with 20 adults with ID to understand their needs and collect requirements, iterating the application as needed. The research team included technology experts, a psychologist, a museum professional, and two educators.

We collaborated with Anffas, an association that supports individuals with ID, and the Natural History Museum of Trieste - Italy. This collaboration seamlessly integrated into the participants' daily learning activities and museum visits, where they delve into the fascinating world of animals and assume the role of easy-to-read experts. Their task involved simplifying texts that were connected to the museum's content, making it more accessible to everyone.

The successful execution of this study was facilitated by an enduring agreement between the participants' association, the involved research organization, and the formal approval obtained from the ethical committee of the researchers' institution. Before data collection, we ensured the informed consent of the participants and their guardians. Throughout the study, we gathered audio and video data for comprehensive analysis, taking utmost care to remove any sensitive information before securely storing it.

The authors employed various tools to analyze the collected data, including Spreadsheets, Documents, and a Miro board. By meticulously mapping the participants' actions, reactions, and voiced opinions in relation to specific subtasks, we were able to extract meaningful insights. The results were then carefully coded and clustered to identify key patterns and themes that emerged from the data.

3.1 Procedure

We used a combination of activities to trigger co-design and gathered more participant feedback. This insight implicitly and explicitly enabled us to improve the app between visits (Fig. 1). We encountered unforeseen challenges during RV1 due to the prevailing COVID-19 restrictions, which necessitated improvisation techniques [22] to adapt and overcome the obstacles.

Fig. 1. Representation of the main steps for designing and evaluating ACCESS+.

Our visits started with focus groups to get to know the participants and understand their prior knowledge about the animals we planned to introduce. The group discussed the content (animals of the Natural History Museum) through written responses or drawings according to their abilities, and we reviewed the key details about each animal with an easy-to-read text.

Following each museum visit, participants engaged with the app, giving them a preview of the captivating encounters they had at the museum. In the first Research Visit (RV1), participants learned about dinosaurs, in the second (RV2) about crocodiles, and in the third (RV3) about wolves and reindeer. We also asked questions during the study to assess their technology habits and preferences. These activities were carefully planned in collaboration with stakeholders to ensure alignment with the visit's educational objectives and participants' interests.

During RV1, we evaluated the usability of an existing museum website and tablet application. This session aimed to determine what participants liked and disliked about the current solutions. We used a task-based approach to engage them and, ultimately, asked about their preferences. Tasks included finding the museum page, the dinosaur page, the museum address, the museum opening time, and a specific room on the museum map. The qualitative research focused on their preferences between devices, solutions, and UI elements.

RV2 and RV3 focused primarily on enhancing the ACCESS+ interaction. The participants engaged in a two-step process where they initially visited the museum and later utilized the application to retrieve information related to their visits. Through a task-based usability testing approach, participants could customize various aspects such as icon and text sizes, backgrounds, labels, and voices to cater to individual preferences and requirements. Users also made sense of the museum content by looking at symbols using AAC and listening to full-text TTS with personalized tone, pitch, and highlight settings. Some participants shared their thoughts, helping us to improve the accessibility of each choice and to add new features based on what was unclear or missing. Other participants provided non-verbal feedback that their educators interpreted.

3.2 Participants

A total of 20 participants, comprising 13 women and 7 men, with ages ranging from 21 to 63, took part in this study (refer to Table 1). All participants were from Italy. For each research visit, 12 participants were available. Participants P1, P2, P3, P4, and P5 were present for all research visits, although they may not have attended every specific session. P1, P2, and P4 participated in all the task-based usability testing sessions, while P1, P2, P3, P4, P5, P15, P16, P17, and P18 attended all the ACCESS+ co-design sessions (RV II and RV III).

Table 1. Participants' demographic and diagnostic information.

PID	Gender	Age	Research Visit	Presence	Context	Diagnosis
P1	Woman	21	I, II and III	In Person	Association and Museum	Moderate Intellectual Disability
P2	Woman	44	I, II and III	In Person	Association	Moderate Intellectual Disability
P3	Woman	63	I, II and III	In Person	Association and Museum	Mild Intellectual Disability and Down Syndrome
P4	Man	32	I, II and III	In Person	Association and Museum	Moderate Intellectual Disability
P5	Man	49	I, II and III	In Person	Association and Museum	Mild Intellectual Disability
P6	Woman	51	I	Hybrid	Association	Moderate Intellectual Disability
P7	Woman	34	I	Online	Association	Mild Intellectual Disability
P8	Woman	45	I	In Person	Association	Moderate Intellectual Disability and Down Syndrome
P9	Man	63	I	In Person	Association	Mild Intellectual Disability
P10	Man	28	I	In Person	Association	Severe Intellectual Disability
P11	Woman	23	I and II	In Person	Association and Museum	Mild Intellectual Disability
P12	Woman	55	I and III	Hybrid	Association	Moderate Intellectual Disability
P13	Woman	22	II	In Person	Association	Mild Intellectual Disability
P14	Man	21	II	In Person	Association	Severe Intellectual Disability
P15	Woman	47	II and III	In Person	Association and Museum	Severe Intellectual Disability
P16	Woman	55	II and III	In Person	Association and Museum	Moderate Intellectual Disability
P17	Man	58	II and III	In Person	Association and Museum	Moderate Intellectual Disability and Low Vision
P18	Man	50	II and III	In Person	Association and Museum	Mild Intellectual Disability
P19	Woman	53	III	In Person	Association and Museum	Moderate Intellectual Disability and Down Syndrome
P20	Woman	55	III	In Person	Association and Museum	Moderate Intellectual Disability

Throughout the visits, we emphasized to the participants that they had the freedom to opt-out at any time, and we reiterated the study's objectives. Some participants were absent from certain activities during a particular research visit or from an entire research visit due to illness, being new to the group, or other pre-existing commitments outside of the study. These factors were controlled by their respective institutions, and the researchers did not exert any influence on their individual freedoms. To ensure participant comfort, the activities were designed to be concise, and regular breaks were included. Additionally, the researchers arranged for sufficient time intervals between sessions with the assistance of educators who were familiar with the participants.

4 FINDINGS

4.1 Usability of an existing museum website and application

4.1.1 Website. Most participants randomly touched the interface's elements to achieve their tasks, which suggested that the interface needed to be more explicit and intuitive for these users. The website was not designed with people with ID in mind, which could explain the cognitive overload. Additionally, some participants who needed help reading text had to rely on images and icons to navigate the website.

The study also found that the return button on the interface was difficult to find for all participants, regardless of their experience with technology. The arrow icon used for the return button was not intuitive enough for novice users, as they required verbal or gestural prompts to navigate back to the previous page successfully. This presents a semiotics engineering challenge, as modifying the icon, training participants, or adding more information may be necessary to make it more intuitive for users with different experience levels.

Despite the difficulties with navigation, the study found that certain website elements were easy for participants to find. Specifically, the address and opening hours of the museum were easy to locate, as they were familiar to the participants. Additionally, some participants associated tasks with previous experiences. For example, P6 mentioned that she had been to the museum in the morning when asked about the opening hours.

4.1.2 App. The lack of labels or any other descriptive information made it challenging for participants to understand the meaning of the icons on the landing page (Fig. 2). This finding highlights the importance of providing clear labels and additional relevant information to support people with ID in navigating digital interfaces.

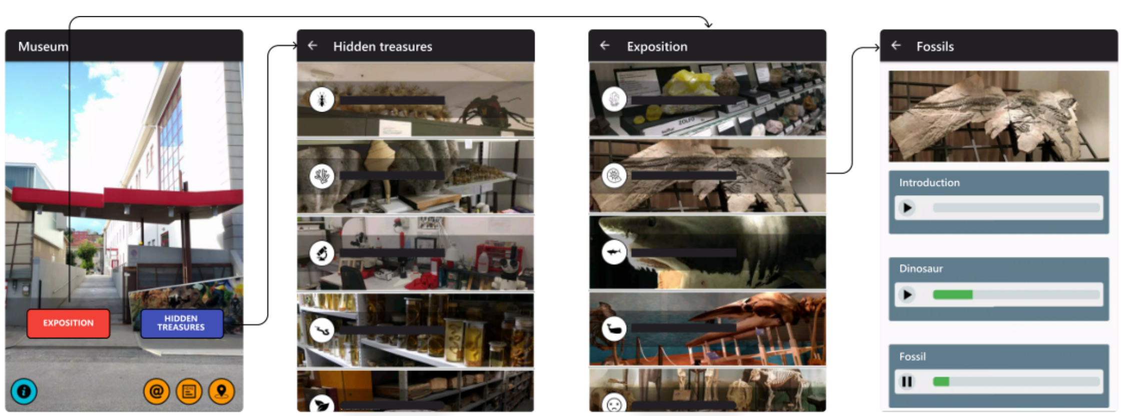


Fig. 2. Screens of the Museum application, which was tested on the first research visit.

On the other hand, participants quickly accessed the exposition area section and the fossils page thanks to icons and a background image that helped illiterate participants, highlighting the potential benefit of visual aids in supporting people with ID in navigating digital interfaces.

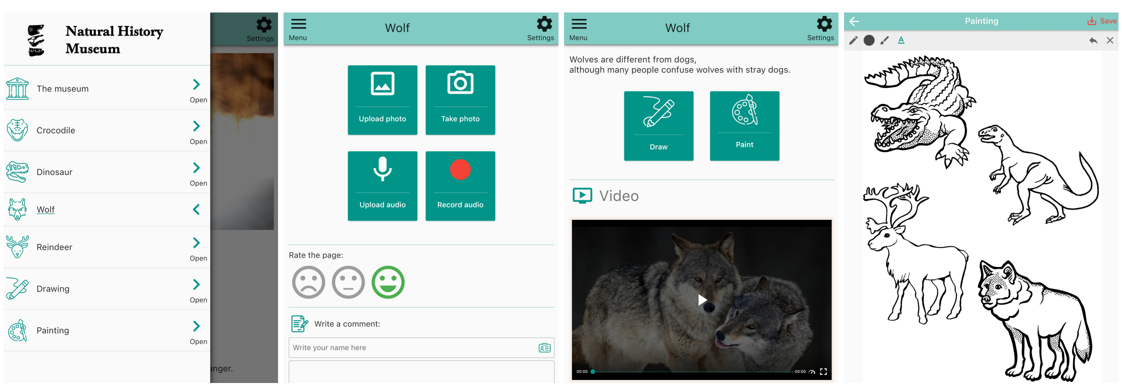
Another problem arose with Android's soft keys. Aside from the soft key of the back button present in the Android navigation bar, there was also the back button in the top bar of the application. This ambiguity made navigation confusing for participants, who accidentally tapped the soft key instead of the app back button, causing them to exit the app. These findings underscore the significance of consistency and simplicity in UI design, especially for individuals with ID who may struggle with complex visual information. Nevertheless, despite the quantity of content on the interface and the availability of icons and pictures, the app did not cause cognitive overload.

4.2 ACCESS+ app

The design of ACCESS+ incorporated researchers' experience, literature, heuristic evaluation, and feedback from RV1. We included icons, labels, AAC pictograms, and TTS to help users understanding. This first version also considered customizable icon sizes, a dark background, and different input modalities for commenting and rating. We used Flutter, an open-source UI development kit, to create a responsive cross-platform application.

We started RV2 and RV3 with exploratory testing on the ACCESS+ app in landscape mode on an iPad, allowing participants to become familiar with the touchscreen interaction modality. At this stage, we noticed challenges related to responsiveness and repetition. P3 was interacting with the app without scrolling unless prompted, which influenced the content she saw, affecting her effective search for information and, ultimately, her overall experience. In contrast, P5 was scrolling after a quick gesture prompt, demonstrating a solid understanding of the touchscreen interaction modality. In this exploratory phase, we asked participants to verbalize what they saw. Some participants answered in detail, while others needed verbal scaffolding to start this conversation.

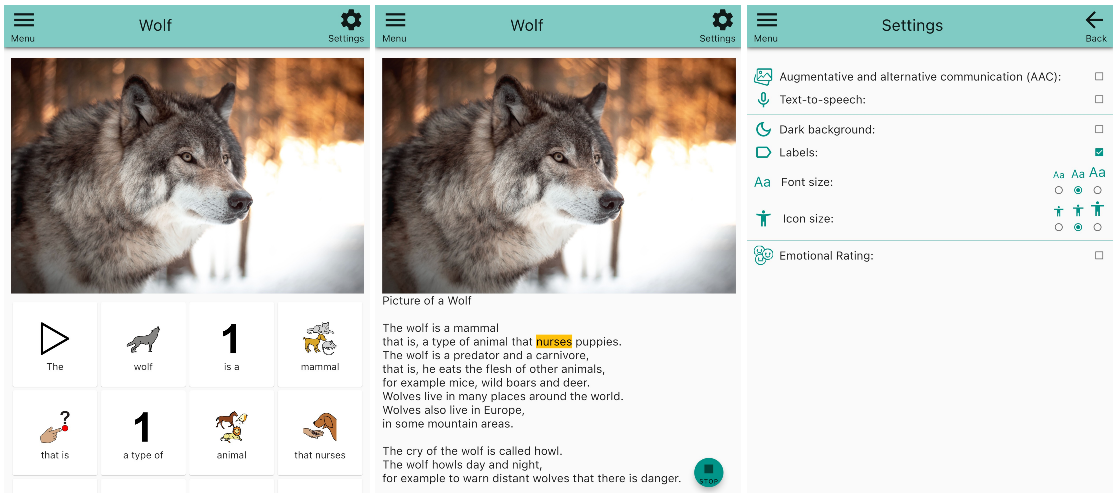
The task-based usability testing began by searching "The museum" on the menu (Fig. 3a). We designed a menu with icons, text, arrows, and labels based on 4.1.2 findings. The majority could find it quickly because they could read or understand the icon. P17 required assistance in both RVs to locate the option. P17's low vision and difficulty with reading may have contributed to the challenge of identifying the correct choice.



(a) Menu (b) Photo, audio, and input (c) Creation and video playback (d) Painting feature

Fig. 3. ACCESS+ menu, blocks, input, and video: features to spark participation and engagement.

The next task on RV2 and RV3 was to locate a specific animal on the menu. Upon accessing the right page, a picture and the first few lines of content were displayed (Fig 4b), requiring participants to scroll down to read further. While most participants could scroll independently, some needed verbal or gestural prompts as a form of scaffolding. During the task, we observed P4 experiencing distractions and frustrations, requiring a supportive mood to participate fully.



(a) AAC text (b) Easy-to-read text with text-to-speech (c) Settings

Fig. 4. ACCESS+ app with different features.

One issue we identified was that some participants needed a gestural or verbal prompt to find the app settings, indicating a need for familiarity with that icon. To address this, we adapted the version used on RV3 to provide a linkable area on the labels and nearby regions whenever possible. We also tested the understanding of the naming and icons available in each feature, and the last version is available in Fig. 4c. However, there are still icons without a design standard, such as AAC, which makes it hard to represent them efficiently.

We also proposed a dark background feature to improve readability and reduce eye strain. However, this divided opinions among participants, and some changed their preferences when we compared both RVs' answers. Due to their needs, we also increased the font and icon size on RV3. Another issue we identified that needed clarification was the fixed menu in landscape mode on RV2. Participants were looking for information on only one part of the screen, so we decided to hide it automatically after it appeared and the participants selected a page to navigate.

We tested easy-to-read text with TTS with word highlighting (Fig. 4b). P1 successfully used the TTS feature after receiving verbal instructions, but P18 experienced difficulty adjusting the voice speed. While some participants found the TTS feature helpful, others needed clarification or couldn't focus while reading and listening to the text.

P10 is a non-verbal participant that uses AAC to communicate. He communicated through his AAC notebook or provided gestures. His contribution was essential since he could tell us which were complex pictograms (Fig. 4a) as a daily user. He was happy to touch the interface and listen to each pictogram at a time with TTS. P16 said it was "Very easy! I pressed an image, and the iPad spoke."

The majority of participants preferred emotional rating scales as a way to provide feedback. However, P20 said, "I prefer stars since the smileys were a little sad". In response, we increased the size of icons and selected three emotional expressions with colors (red to sad, yellow to neutral, and green to happy). Additionally, we incorporated a 5-star Likert scale, although most participants found it challenging to understand this rating system. Participants liked to write comments, but illiterate participants would require an AAC keyboard or speech-to-text.

In the RV3 museum activity, we individually 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 (ACCESS+, Augmented Reality, and a Multisensory Diorama) and two low-tech (printed easy-to-read text and AAC). ACCESS+ was the first preference of 4 participants, the second preference of another 4, the third preference of 2 participants, and the fourth and fifth of one.

We added extra features based on the feedback we collected from RV2 and RV3. The buttons became bigger blocks to help participants find and interact with them. Fig. 3b shows an example of a block and introduces new features: taking and uploading photos and recording and uploading audio. These features were important to participants that visited museums and wanted to remember information in different media formats. The blocks provide a visible link, including familiar icons to our participants. Fig. 3c shows the Drawing and Painting features. When clicking on the painting block, users will be redirected to its page (Fig. 3d) with a black-and-white image of the content ready to be painted.

5 DISCUSSION, REFLECTIONS, LIMITATIONS & FUTURE CONSIDERATIONS

It is essential to recognize that a museum app must serve as a support to the conventional, human-led learning experience that people with ID are accustomed to in an educational environment. As P9 mentioned, "First, I prefer to learn alone, after with an educator. I feel more prepared if I read myself to explain to the educators."

This paper primarily emphasizes the iterative design process of ACCESS+ and its development in close collaboration with individuals with ID. Ensuring the UI is intuitive and simple is paramount, as people with ID may need help with complex navigation. Also, listening to users independently of their abilities is essential to design an accessible solution. Here are a few reflections on issues to consider when co-designing accessible applications with people with ID:

- **Education:** Providing education and training sessions is crucial when conducting co-design and usability testing with participants with ID. Workshops can be designed to help participants understand how to use the technology involved in the testing process, such as touch screens or computer mice. This will increase their confidence and ability to engage effectively with the testing process.
- **Support:** The role of the educator or support worker is essential in conducting co-design and usability testing with participants with ID. Educators can provide guidance and support during the testing process, helping participants navigate the application and complete tasks successfully. Additionally, participants can help one another directly or indirectly by providing feedback that can be applied to other participants.
- **Emotions:** Participants with ID may enjoy using technology but only sometimes know how to use devices effectively. It is important to consider their feelings when conducting co-design and usability testing. Participants may feel frustrated or embarrassed if they cannot complete a task, so creating a supportive environment that encourages them to ask for help and provides positive feedback is essential.
- **Complexity:** The co-design and usability testing process should be designed to be as simple as possible. Participants with ID may lose attention if the tasks are too complicated or the application is too challenging to navigate. Using simple language, clear instructions, and avoiding cluttered or confusing interfaces is important. Keeping the testing process straightforward and clear will help participants engage with the testing process.

- **Attention:** Participants with ID may struggle with concentration and focus due to the co-morbidity of intellectual disability and attention deficit hyperactivity disorder (ADHD) [1], so it is crucial to design the co-design and usability testing process with this in mind. For example, tasks should be broken down into smaller, more manageable steps. The application should be designed to minimize distractions and encourage participants to stay engaged.
- **Readability:** It is crucial to consider the readability of text used in the co-design activities, as participants with ID may need help with abstract or complex concepts.
- **Navigation:** The risk of getting lost is high, especially when navigating on very crowded pages. Interactive maps and navigational aids should be co-designed with participants as the best way to keep the focus on their needs.

One notable limitation of this paper stems from the participants' particular affinity for the museum content, which may account for the overwhelmingly positive feedback and their enthusiastic anticipation of visiting the museum. It is plausible that different groups engaged in co-designing a museum application may not exhibit the same level of enthusiasm. Additionally, our study is confined to a single-site investigation focused on a natural science museum, thereby limiting the generalizability of the findings. Furthermore, language and demographic representation were restricted, as the study was conducted exclusively in one language and within a single country.

It is crucial to acknowledge that due to the diverse and specific needs of each participant, the applicability of our solution cannot be assumed to be universally effective. Even if our solution may not cater to everyone's requirements, we believe it is a valuable contribution to the field of accessibility research. By addressing the aforementioned limitations, we aspire to enhance accessibility within the realm of museums and advance the existing body of knowledge in this area.

6 CONCLUSIONS

This study aimed to evaluate the usability of an existing museum website and application, laying the groundwork for the collaborative design of ACCESS+. The findings indicated the need for specific modifications such as enhancing visual cues, providing training for participants, and incorporating additional information to improve the overall intuitiveness of the application. To effectively support individuals with ID in navigating digital interfaces, it was emphasized that clear labels and verbal assistance play an essential role, underscoring the value of accessible co-design. The study further highlighted the significance of maintaining consistency and simplicity in UI design, as these factors greatly contribute to a positive user experience. Throughout the entire process, the involvement of stakeholders and the implementation of verbal, gestural, and physical scaffolding were identified as essential tools to assist participants in successfully accomplishing their objectives. Lastly, this paper emphasized the importance of inclusion and empowerment in the design of solutions, as these elements serve as critical catalysts for enhancing learning and overall experiences.

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